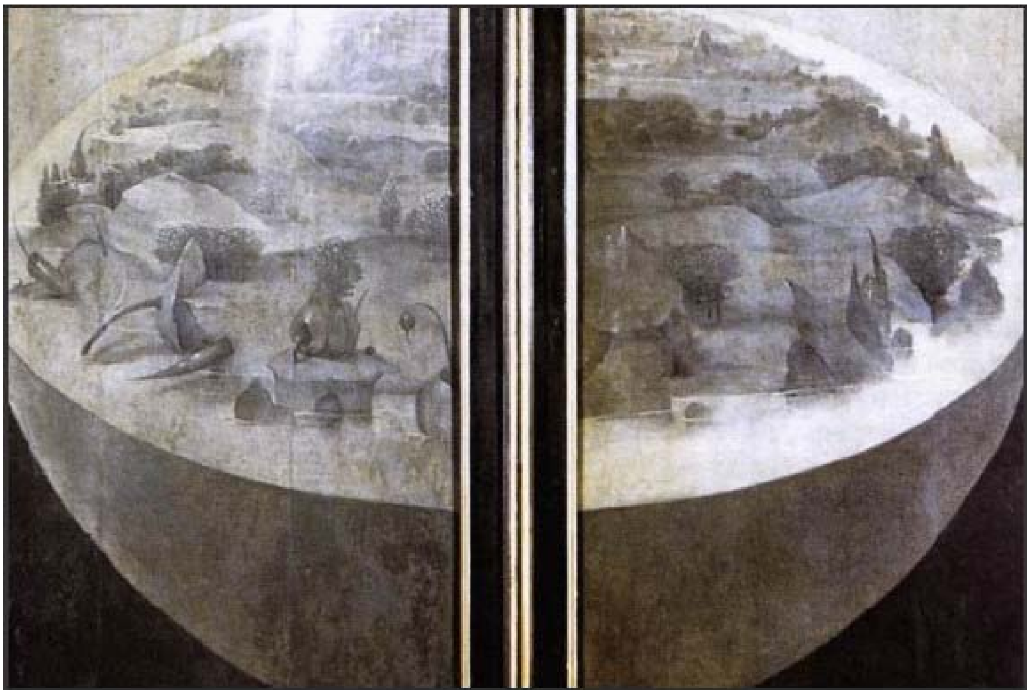

THEORY OF THE EARTH

JAMES HUTTON

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THEORY OF THE EARTH

BY
JAMES HUTTON

COMPRISING HIS 1788 PAPER *THEORY OF THE EARTH*, READ BEFORE THE ROYAL SOCIETY OF EDINBURGH, AND THE TWO EXTANT VOLUMES OF HIS 1795 BOOK OF THE SAME NAME

Theory of the Earth by James Hutton.

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OR

AN INVESTIGATION OF THE LAWS OBSERVABLE IN THE COMPOSITION, DISSOLUTION, AND RESTORATION OF LAND UPON THE GLOBE

BY

JAMES HUTTON

TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, VOL. I, PART II, PP.209-304

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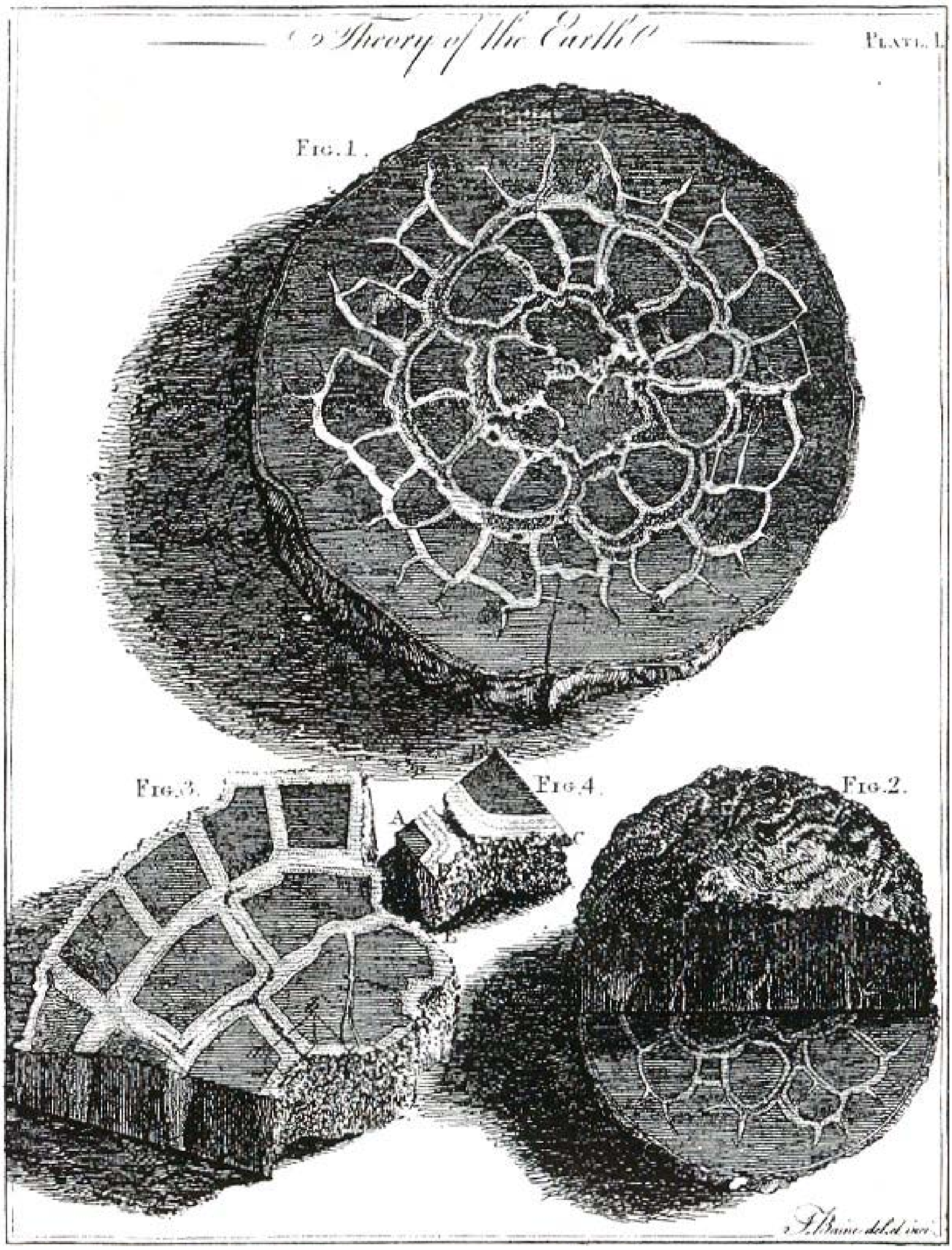

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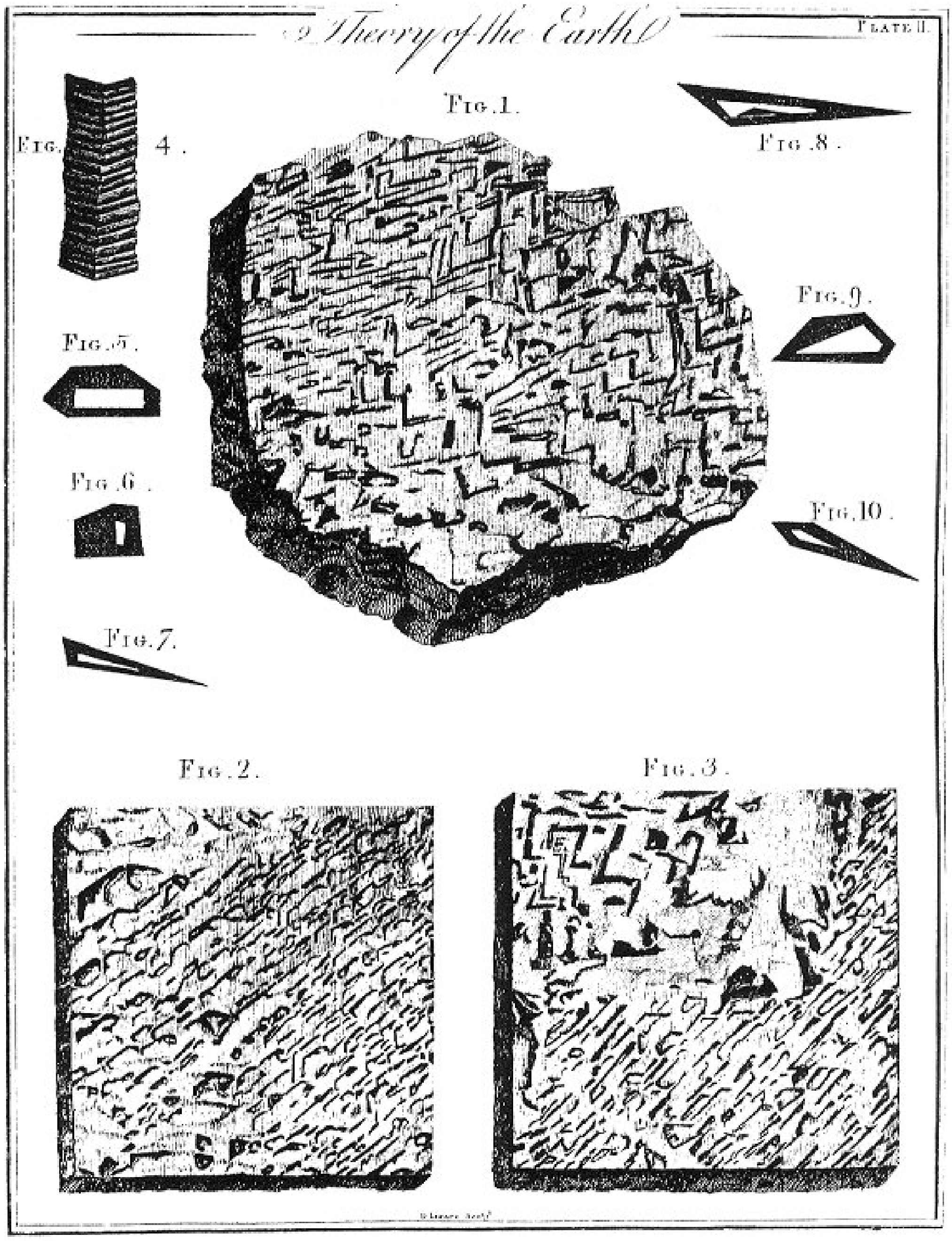
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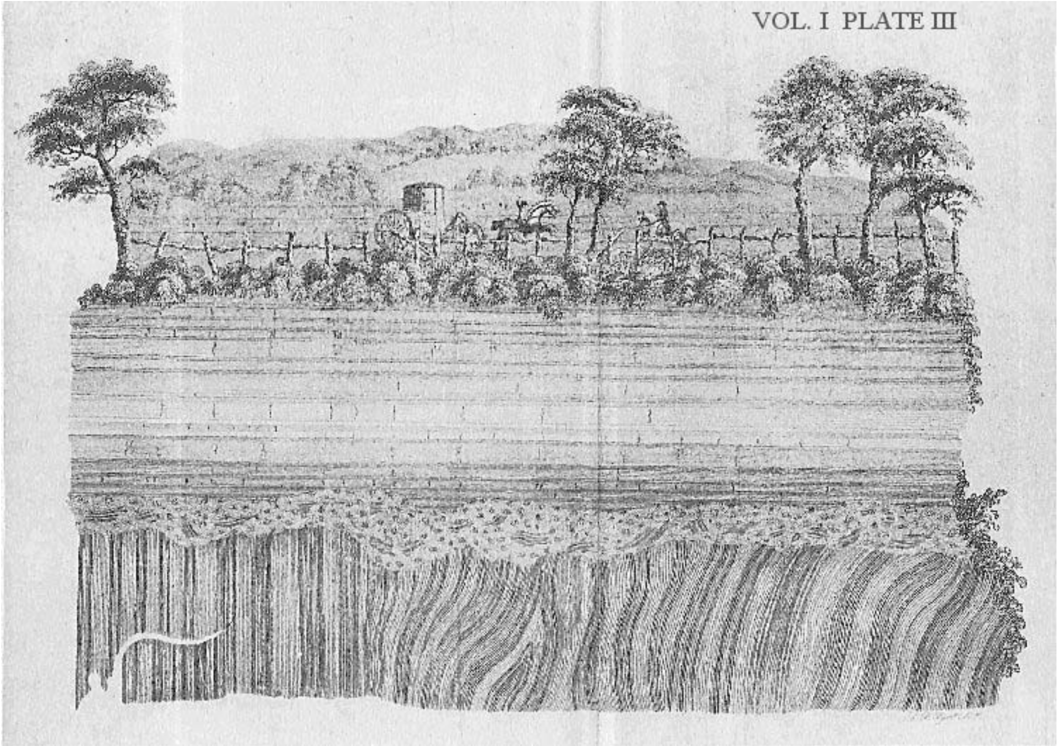

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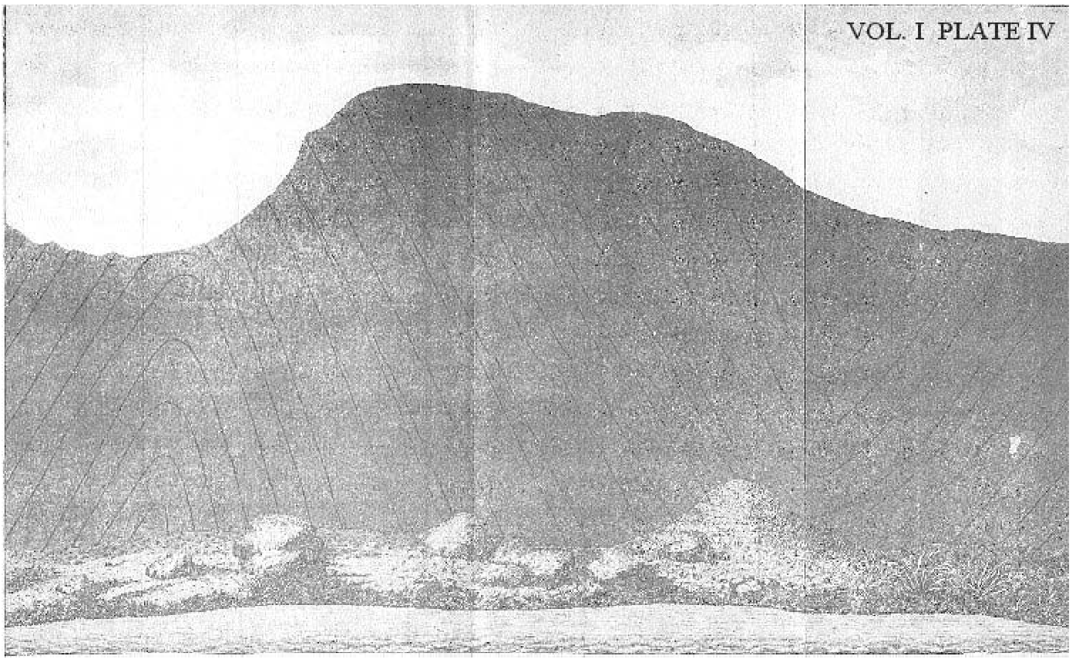

Plate IV

Part 1. Prospect Of The Subject To Be Treated Of

WHEN we trace the parts of which this terrestrial system is composed, and when we view the general connection of those several parts, the whole presents a machine of a peculiar construction by which it is adapted to a certain end. We perceive a fabric, erected in wisdom, to obtain a purpose worthy of the power that is apparent in the production of it.

WE know little of the earth's internal parts, or of the materials which compose it at any considerable depth below the surface. But upon the surface of this globe, the more inert matter is replenished with plants, and with animals and intellectual beings.

WHERE so many living creatures are to ply their respective powers, in pursuing the end for which they were intended, we are not to look for nature in a quiescent state; matter itself must be in motion, and the scenes of life a continued or repeated series of agitations and events.

THIS globe of the earth is a habitable world; and on its fitness for this purpose, our sense of wisdom in its formation must depend. To judge of this point, we must keep in view, not only the end, but the means also by which that end is obtained. These are, the form of the whole, the materials of which it is composed, and the several powers which concur, counter-act, or balance one another, in procuring the general result.

THE form and constitution of the mass are not more evidently calculated for the purpose of this earth as a habitable world, than are the various substances of which that complicated body is composed. Soft and hard parts variously combine, to form a medium consistence adapted to the use of plants and animals; wet and dry are properly mixed for nutrition, or the support of those growing bodies; and hot and cold produce a temperature or climate no less required that a soil. Insomuch, that there is not any particular, respecting either the qualities of the materials, or the construction of the machine, more obvious to our perception, than are the presence and efficacy of design and intelligence in the power that conducts the work.

IN taking this view of things, where ends and means are made the object of attention, we may hope to find a principle upon which the comparative importance of parts in the system of nature may be estimated, and also a rule for selecting the objet of our enquiries. Under this direction, science may find a fit subject of investigation in every particular, whether of *form*, *quality*, or *active power*, that presents itself in this system of motion and of life; and which, without a proper attention to this character of the system, might appear anomalous and incomprehensible.

IT is not only by seeing those general operations of the globe which depend upon its peculiar construction as a machine, but also by perceiving how far the particulars, in the construction of that machine, depend upon the general operations of the globe, that we are enabled to understand the constitution of this earth as a thing formed by design. We shall thus also be led to acknowledge an order, not unworthy of Divine wisdom, in a subject which, in another view, has appeared as the work of chance, or as absolute disorder and confusion.

TO acquire a general or comprehensible view of this mechanism of the globe, by which it is adapted to the purpose of forming a habitable world, it is necessary to distinguish three different bodies which compose the whole. These are, a solid body of earth, an aqueous body of sea, and an elastic fluid of air.

IT is the proper shape and disposition of these three bodies that form this globe into a habitable world; and it is the manner in which these constituent bodies are adjusted to each other and the laws of action by which they are maintained in their proper qualities and respective departments, that form the Theory of the machine which we are now to examine.

LET us begin with some general sketch of the particulars now mentioned.

1*st*, THERE is a central body in the globe. This body supports those parts which come to be more immediately exposed to our view, or which may be examined by our sense and observation. This first part is commonly supposed to be solid and inert; but such a conclusion is only mere conjecture; and we shall afterwards find occasion, perhaps, to form another judgment in relation to this subject, after we have examined strictly, upon scientific principles, what appears upon the surface, and have formed conclusions concerning that which must have been transacted in some more central part.

2*dly*, WE find a fluid body of water. This, by gravitation, is reduced to a spherical form, and by the centrifugal force of the earth's rotation, is become oblate. The purpose of this fluid body is essential in the constitution of the world; for, besides affording the means of life and motion to a multifarious race of animals, it is the source of growth and circulation to the organized bodies of this earth, in being the receptacle of the rivers, and the fountain of our vapours.

3*dly*, WE have an irregular body of land, raised above the level of the ocean. This, no doubt, is the smallest portion of the globe; but it is the part to us by far most interesting. It is upon the surface of this part that plants are made to grow; consequently, it is by virtue of this land that animal life, as well as vegetation, is sustained in this world.

Lastly, WE have a surrounding body of atmosphere, which completes the globe. This vital fluid is no less necessary in the constitution of the world than are the other parts; for there is hardly an operation upon the surface of the earth, that is not conducted or promoted by its means. It is a necessary condition for the sustenance of fire; it is the breath of life to animals; it is at least an instrument in vegetation; and while it contributes to give fertility and health to things that grow, it is employed in preventing noxious effects from such as go into corruption. In short, it is the proper means of circulation for the matter of the world by raising up the water of the ocean, and pouring it forth upon the surface of the earth.

SUCH is the mechanism of the globe; let us now mention some of those powers by which motion is produced, and activity procured to the mere machine.

FIRST, There is the progressive force, or moving power, by which this planetary body, if solely actuated, would depart continually from the path which it now pursues, and thus be for ever removed from its end, whether as a planetary body, or as a globe sustaining plants and animals, which may be termed a living world.

BUT this moving body is also actuated by gravitation, which inclines it directly to the central body of the sun. Thus it is made to revolve about that luminary, and to preserve its path.

IT is also upon the same principles, that each particular part upon the surface of the globe, is alternately exposed to the influence of light and darkness, in the diurnal rotation of the earth, as well as in its annual revolution. In this manner are produced the vicissitudes of night and day, so variable in the different latitudes from the equator to the pole, and so beautifully calculated to equalize the benefits of light, so variously distributed in the different regions of the globe.

GRAVITATION and the *vis incita* of matter thus form the first two powers distinguishable in the operations of our system, and wisely adapted to the purpose for which they are employed.

WE next observe the influence of light and heat, of cold and condensation. It is by means of these two powers that the various operations of this living world are more immediately transacted; although the other powers are no less required, in order to produce or modify these great agents in the oeconomy of life, and system of our changing things.

WE do not now enquire into the nature of those powers, or investigate the laws of light and heat, of cold and condensation, by which the various purposes of this world are accomplished; we are only to mention those effects which are made sensible to the common understanding of mankind, and which necessarily imply a power that is employed. Thus, it is by the operation of those powers that the varieties of season in spring and autumn are obtained, that we are blessed with the vicissitudes of summer's heat and winter's cold, and that we possess the benefit of artificial light and culinary fire.

WE are thus bountifully provided with the necessaries of life; we are supplied with things conducive to the growth and preservation of our animal nature, and with fit subjects to employ and to nourish our intellectual powers.

THERE are other actuating powers employed in the operations of this globe, which we are little more than able to enumerate; such are those of electricity and magnetism.

POWERS of such magnitude or force, are not to be supposed useless in a machine contrived surely not without wisdom; but they are mentioned here chiefly on account of their general effect; and it is sufficient to have named powers, of which the actual existence in well known, but of which the proper use in the constitution of the world is still obscure.

WE have thus surveyed the machine in general, with those moving powers, by which its operations, diversified almost *ad infinitum*, are performed. Let us now confine our view, more particularly, to that part of the machine on which we dwell, that so we may consider the natural consequences of those operations which, being within our view, we are better qualified to examine.

THIS subject is important to the human race, to the possessor of this world, to the intelligent being Man, who foresees events to come, and who, in contemplating his future interest, is led to enquire concerning causes, in order that he may judge of events which otherwise he could not know.

IF, in pursuing this object, we employ our skill in research, not in forming vain conjectures; and if *data* are to be found, on which Science may form just conclusions, we should not long remain in ignorance with respect to the natural history of this earth, a subject on which hitherto opinion only, and not evidence, has decided: For in no subject is there naturally less defect of evidence, although philosophers, led by prejudice, or misguided by false theory, have neglected to employ that light by which they should have seen the system of the world.

BUT to proceed in pursuing a little farther our general or preparatory ideas. A solid body of land could not have answered the purpose of a habitable world; for a soil is necessary to the growth of plants; and a soil is nothing but the materials collected from the destruction of the solid land. Therefore, the surface of this land, inhabited by man, and covered with plants and animals, is made by nature to decay, in dissolving from that hard and compact state in which it is found below the soil; and this soil is necessarily washed away, by the continual circulation of the water, running from the summits of the mountains towards the general receptacle of that fluid.

THE heights of our land are thus levelled with the shores; our fertile plains are formed from the ruins of the mountains; and those travelling materials are still pursued by the moving water, and propelled along the inclined surface of the earth. These moveable materials, delivered into the sea, cannot, for a long continuance, rest upon the shore; for, by the agitation of the winds, the tides and currents, every moveable thing is carried farther and farther along the shelving bottom of the sea, towards the unfathomable regions of the ocean.

IF the vegetable soil is thus constantly removed from the surface of the land, and if its place is thus to be supplied from the dissolution of the solid earth, as here represented, we may perceive an end to this beautiful machine; an end, arising from no error in its constitution as a world, but from that destructibility of its land which is so necessary in the system of the globe, in the oeconomy of life and vegetation.

THE immense time necessarily required for this total destruction of the land, must not be opposed to that view of future events, which is indicated by the surest facts and most approved principles. Time, which measures every thing in our idea, and is often deficient to our schemes, is to nature endless and as nothing; it cannot limit that by which alone it had existence; and as the natural course of time, which to us seems infinite, cannot be bounded by any operation that may have an end, the progress of things upon this globe, that is, the course of nature, cannot be limited by time, which must proceed in a continual succession. We are, therefore, to consider as inevitable the destruction of our land, so far as effected by those operations which are necessary in the purpose of the globe, considered as a habitable world; and so far as we have not examined any other part of the oeconomy of nature, in which other operations and a different intention might appear.

WE have now considered the globe of this earth as a machine, constructed upon chemical as well as mechanical principles, by which its different parts are all adapted, in form, in quality, and in quantity, to a certain end; an end attained with certainty or success; and an end from which we may perceive wisdom, in contemplating the means employed.

BUT is this world to be considered thus merely as a machine, to last no longer than its parts retain their present position, their proper forms and qualities? Or may it not be also considered as an organized body? Such as has a constitution in which the necessary decay of the machine is naturally repaired, in the exertion of those productive powers by which it had been formed.

THIS is the view in which we are now to examine the globe; to see if there be, in the constitution of this world, a reproductive operation, by which a ruined constitution may be again repaired, and a duration or stability thus procured to the machine, considered as a world sustaining plants and animals.

IF no such reproductive power, or reforming operation, after due enquiry, is to be found in the constitution of this world, we should have reason to conclude, that the system of this earth has either been intentionally made imperfect, or has not been the work of infinite power and wisdom.

HERE is an important question, therefore, with regard to the constitution of this globe; a question which, perhaps, it is in the power of man's sagacity to resolve; and a question which, if satisfactorily resolved, might add some lustre to science and the human intellect.

ANIMATED with this great, this interesting view, let us strictly examine our principles, in order to avoid fallacy in our reasoning; and let us endeavour to support our attention, in developing and subject that is vast in its extent, as well as intricate in the relation of parts to be stated.

THE globe of this earth is evidently made for man. He alone, of all the beings which have life upon this body, enjoys the whole and every part; he alone is capable of knowing the nature of this world, which he thus possesses in virtue of his proper right; and he alone can make the knowledge of this system a source of pleasure and the means of happiness.

MAN alone, of all the animated beings which enjoy the benefits of this earth, employs the knowledge which he there receives, in leading him to judge of the intention of things, as well as of the means by which they are brought about; and he alone is thus made to enjoy, in contemplation as well as sensual pleasure, all the good that may be observed in the constitution of this world; he, therefore, should be made the first subject of enquiry.

NOW, if we are to take the written history of man for the rule by which we should judge of the time when the species first began, that period would be but little removed from the present state of things. The Mosaic history places this beginning of man at no great distance; and there has not been found, in natural history, any document by which a high antiquity might be attributed to the human race. But this is not the case with regard to the inferior species of animals, particularly those which inhabit the ocean and its shores. We find in natural history monuments which prove that those animals had long existed; and we thus procure a measure for the computation of a period of time extremely remote, though far from being precisely ascertained.

IN examining things present, we have data from which to reason with regard to what has been; and, from what has actually been, we have data for concluding with regard to that which is to happen hereafter. Therefore, upon the supposition that the operations of nature are equable and steady, we find, in natural appearances, means for concluding a certain portion of time to have necessarily elapsed, in the production of those events of which we see the effects.

IT is thus that, in finding the relics of sea-animals of every kind in the solid body of our earth, a natural history of those animals is formed, which includes a certain portion of time; and for ascertaining this portion of time, we must again have recourse to the regular operations of the world. We shall thus arrive at facts which indicate a period to which no other species of chronology is able to remount.

IN what follows, therefore, we are to examine the construction of the present earth, in order to understand the natural operations of time past; to acquire principles, by which we may conclude with regard to the future course of things, or judge of those operations, by which a world, so wisely ordered, goes into decay; and to learn, by what means such a decayed world may be renovated, or the waste of habitable land upon the globe repaired.

THIS, therefore, is the object which we are to have in view during this physical investigation; this is the end to which are to be directed all the steps in our cosmological pursuit.

THE solid parts of the globe are, in general, composed of sand, of gravel, of argillaceous and calcareous strata, or of the various compositions of these with some other substances, which it is not necessary now to mention. Sand is separated and sized by streams and currents; gravel is formed by the mutual attrition of stones agitated in water; and marly, or argillaceous strata, have been collected by subsiding in water with which those earthy substances had been floated. Thus, so far as the earth is formed of these materials, that solid body would appear to have been the production of water, winds, and tides.

BUT that which renders the original of our land clear and evident, is the immense quantities of calcareous bodies which had belonged to animals, and the intimate connection of these masses of animal production with the other strata of the land. For it is to be proved, that all these calcareous bodies, from the collection of which the strata were formed, have belonged to the sea, and were produced in it.

WE find the marks of marine animals in the most solid parts of the earth, consequently, those solid parts have been formed after the ocean was inhabited by those animals, which are proper to that fluid medium. If, therefore, we knew the natural history of those solid parts, and could trace the operations of the globe, by which they had been formed, we would have some means for computing the time through which those species of animals have continued to live. But how shall we describe a process which nobody has seen performed, and of which no written history gives any account? This is only to be investigated, *first*, in examining the nature of those solid bodies, the history of which we want to know; and, 2*ndly*, In examining the natural operations of the globe, in order to see if there now actually exist such operations, as, from the nature of the solid bodies, appear to have been necessary to their formation.

BUT, before entering more particularly into those points of discussion, by which the question is to be resolved, let us take a general view of the subject, in order to see what it is which science and observation must decide.

IN all the regions of the globe, immense masses are found, which, though at present in the most solid state, appear to have been formed by the collection of the calcareous *exuviae* of marine animals. The question at present is not, in what manner those collections of calcareous relics have become a perfect solid body, and have been changed from an animal to a mineral substance; for this is a subject that will be afterwards considered; we are now only enquiring, if such is truly the origin of those mineral masses.

THAT all the masses of marble or limestone are composed of the calcareous matter of marine bodies, may be concluded from the following facts:

1*st*, THERE are few beds of marble or limestone, in which may not be found some of those objects which indicate the marine origin of the mass. If, for example, in a mass of marble, taken from a quarry upon the top of the Alps or

Andes[1] , there shall be found once cockle-shell , or piece of coral, it must be concluded, that this bed of stone had been originally formed at the bottom of the sea, as much as another bed which is evidently composed almost altogether of cockle-shells and coral. If one bed of limestone is thus found to have been of a marine origin, every concomitant bed of the same kind must be also concluded to have been formed in the same manner.

[1] "Cette sommité élevée de 984 toises au dessus de notre lac, et par consequent de 1172 au dessus de la mer, est remarquable en ce que l'on y voit des fragmens d'huîtres pétrifiés.----Cette montagne est dominée par un rocher excarpé, qui s'sil n'est pas inaccessible, est du moins d'un bien difficile accès; il paroît presqu'entierement composé de coquillages pétrifés, renfermés dans un roc calcaire, ou marbre grossier noirâtre. Les fragmens qui s'en detachent, et que l'on rencontre en montant à la Croix de fer, sont remplis de *turbinites* de différentes especes." M. DE SAUSSURE, *Voyage dans les Alpes*, p. 394.

WE thus shall find the greatest part of the calcareous masses upon this globe to have originated from marine calcareous bodies; for whether we examine marbles, limestones, or such solid masses as are perfectly changed from the state of earth, and are become compact and hard, or whether we examine the soft, earthy, chalky or marly strata, of which so much of this earth is composed, we still find evident proofs, that those beds had their origin from materials deposited at the bottom of the sea; and that they have the calcareous substance which they contain, from the same source as the marbles or the limestones.

2*dly*, IN those calcareous strata, which are evidently of marine origin, there are many parts that are of a sparry structure, that is to say, the original texture of those beds, in such places, has been dissolved, and new structure has been assumed, which is peculiar to a certain state of the calcareous earth. This change is produced by crystallization, in consequence of a previous state of fluidity, which has so disposed the concreting arts, as to allow them to assume a regular shape and structure proper to that substance. A body, whose external form has been modified by this process, is called a *crystal*; one whose internal arrangement of parts is determined by it, is said to be of a *sparry structure*; and this is known from its fracture.

3*dly*, THERE are, in all the regions of the earth, huge masses of calcareous matter, in that crystalline form or sparry state, in which perhaps no vestige can be found of any organized body, nor any indication that such calcareous matter had belonged to animals; but as, in other masses, this sparry structure, or crystalline state, is evidently assumed by the marine calcareous substances, in operations which are natural to the globe, and which are necessary to the consolidation of the strata, it does not appear, that the sparry masses, in which no figured body is formed, have been originally different from other masses, which, being only crystallized in part, and in part still retaining their original form, leave ample evidence of their marine origin.

WE are led, in this manner, to conclude, that all the strata of the earth, not only those consisting of such calcareous masses, but others superincumbent upon these, have had their origin at the bottom of the sea, by the collection of sand and gravel, of shells, of coralline and crustaceous bodies, and of earths and clays, variously mixed, or separated and accumulated. Here is a general conclusion, well authenticated in the appearance of nature, and highly important in the natural history of the earth.

THE general account of our reasoning is this, that nine tenths, perhaps, or ninety-nine hundredths of this earth, so far as we see, have been formed by natural operations of the globe, in collecting loose materials, and depositing them at the bottom of the sea; consolidating those collections in various degrees, and either elevating those consolidated masses above the level on which they were formed, or lowering the level of the sea.

THERE is a part of the solid earth which we may at present neglect, not, as being persuaded that this part may not also be found to come under the general rule of formation with the rest, but as considering this part to be of no consequence in forming a general rule, which shall comprehend almost the whole, without doing it absolutely. This excluded part consists of certain mountains and masses of granite. These are thought to be still older in their formation, and are very rarely, at least found superincumbent on strata which must be acknowledged as the productions of the sea.

HAVING thus found the greater part, if not the whole, of the solid land to have been originally composed at the bottom of the sea, we may now, in order to form a proper idea of these operations, suppose the whole of this sea-born land to be again dispersed along the bottom of the ocean, the surface of which would rise proportionally over the globe. We would thus have a spheroid of water, with granite rocks and islands scattered here and there. But this would not be the world which we inhabit; therefore, the question now is, how such continents, as we actually have upon the globe, could be erected above the level of the sea.

IT must be evident, that no motion of the sea, caused by this earth revolving in the solar system, could bring about that end; for let us suppose the axis of the earth to be changed from the present poles, and placed in the equinoctial line, the consequence of this might, indeed, be the formation of a continent of land about each new pole, from whence the sea would run towards the new equator; but all the rest of the globe would remain an ocean. Some new points might be discovered, and others, which before appeared above the surface of the sea, would be sunk by the rising of the water; but, on the whole, land could only be gained substantially at the poles. Such a supposition as this, if applied to the present state of things, would be destitute of every support, as being incapable of explaining what appears.

BUT even allowing that, by the changed axis of the earth, or any other operation of the globe, as a planetary body revolving in the solar system, great continents of land could have been erected from the place of their formation, the bottom of the sea, and placed in a higher elevation, compared with the surface of that water, yet such a continent as this could not have continued stationary for many thousand years; nor could a continent of this kind have presented to us, every where within its body, masses of consolidated marble and other mineral substances, in a state as different as possible from that in which they were, when originally collected together in the sea.

CONSEQUENTLY, besides an operation, by which the earth at the bottom of the sea should be converted into an elevated land, or placed high above the level of the ocean, there is required, in the operations of the globe, a consolidating power by which the loose materials that had subsided from water should be formed into masses of the most perfect solidity, having neither water nor vacuity between their various constituent parts, nor in the pores of those constituent parts themselves.

HERE is an operation of the globe, whether chemical or mechanical, which is necessarily connected with the formation of our present continents: Therefore, had we a proper understanding of this secret operation, we might thereby be enabled to form an opinion, with regard to the nature of that unknown power, by which the continents have been placed above the surface of that water wherein they had their birth.

IF this consolidating operation be performed at the bottom of the ocean, or under great depths of the earth, of which our continents are composed, we cannot be witnesses to this mineral process, or acquire the knowledge of natural causes, but immediately observing the changes which they produce; but though we have not this immediate observation of those changes of bodies, we have, in science, the means of reasoning from distant events; consequently, of discovering, in the general powers of nature, causes for those events of which we see the effects.

THAT the consolidating operation, in general, lies out of the reach of our immediate observation, will appear from the following truth: All the consolidated masses, of which we now enquire into the cause, are, upon the surface of the earth in a state of general decay, although the various natures of those bodies admit of that dissolution in very different degrees[2].

FROM every view of the subject, therefore, we are directed to look into those consolidated masses themselves, in order to find principles from whence to judge of those operations by which they had attained their hardness or consolidated state.

IT must be evident, that nothing but the most general acquaintance with the laws of acting substances, and with those of bodies changing by the powers of nature, can enable us to set about this undertaking with any reasonable prospect of success; and here the science of Chemistry must be brought particularly to our aid; for this science, having for its object the changes produced upon the sensible qualities, as they are called, of bodies, by its means we may be enabled to judge of that which is possible according to the laws of nature, and of that which, in like manner, we must consider as impossible.

WHATEVER conclusions, therefore, by means of this science, shall be attained, in just reasoning from natural appearances, this must be held as evidence, where more immediate proof cannot be obtained; and, in a physical subject, where things actual are concerned, and not the imaginations of the human mind, this proof will be considered as amounting to a demonstration.

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[2] Stalactical and certain ferruginous concretions may seem to form an exception to the generality of this proposition. But an objection of this kind could only arise from a partial view of things; for the concretion here is only temporary, it is in consequence of a solution, and it is to be followed by a dissolution, which will be treated of in its proper place.

Part 2. An Investigation Of The Natural Operations Employed In Consolidating The Strata Of The Globe

THERE are just two ways in which porous or spongy bodies can be consolidated, and by which substances may be formed into masses of a natural shape and regular structure; the one of these is simple *congelation* from a fluid state, by means of cold; the other is *accretion*; and this includes a separatory operation, as well as that by which the solid body is to be produced. But, in whichever of these ways solidity is to be procured, it must be brought about by first inducing fluidity, either immediately by the action of heat, or mediately with the assistance of a solvent, that is, but the operation of solution.

THUS, fire and water may be considered as the general agents in this operation which we would explore. We are, therefore, to consider well, what may be the consequences of consolidation by the one or other of those agents; and what may be their several powers with respect to this operation.

IF we are not informed in this branch of science, we may gaze without instruction upon the most convincing proofs of what we want to attain. If our knowledge is imperfect, we may form erroneous principles, and deceive ourselves in reasoning with regard to those works of nature, which are wisely calculated for our instruction.

THE strata, formed at the bottom of the sea, are to be considered as having been consolidated, either by aqueous solution and crystallization, or by the effect of heat and fusion. If it is in the first of these two ways that the solid strata of the globe have attained to their present state, there will be a certain uniformity observable in the effects; and there will be general laws, by which this operation must have been conducted. Therefore, knowing those general laws, and making just observations with regard to the natural appearances of those consolidated masses, a philosopher, in his closet, should be able to determine, what may, and what may not have been transacted in the bowels of the earth , or below the bottom of the ocean.

LET us now endeavour to ascertain what may have been the power of water, acting under fixed circumstances, operating upon known substances, and conducting to a certain end.

THE action of water upon all different substances is an operation with which we are familiar. We have it in our power to apply water in different degrees of heat for the solution of bodies, and under various degrees of compression; consequently, there is no reason to conclude any thing mysterious in the operations of the globe, which are to be performed by means of water, unless an immense compressing power should alter the nature of those operations. But compression alters the relation of evaporation only with regard to heat, or it changes the degree of heat which water may be made to contain; consequently, we are to look for no occult quality in water acting upon bodies at the bottom of the deepest ocean, more than what can be observed in experiments which we have it in our power to try.

WITH regard again to the effect of time. Though the continuance of time may do much in those operations which are extremely slow, where no changes, to our observation, had appeared to take place; yet, where it is not in the nature of things to produce the change in question, the unlimited course of time would be no more effectual, than the moment by which we measure events in our observations.

WATER being the general medium in which bodies collected at the bottom of the sea are always contained, if those masses of collected matter are to be consolidated by solution, it must be by the dissolution of those bodies in that water as a menstruum, and by the concretion or crystallization of this dissolved matter, that the spaces, first occupied by water in those masses, are afterwards to be filled with a hard and solid substance; but without some other power, by which the water contained in those cavities and endless labyrinths of the strata, should be separated in proportion as it had performed its task, it is inconceivable how those masses, however changed from the state of their first subsidence, should be absolutely consolidated, without a particle of fluid water in their composition.

BESIDES this difficulty of having the water separated from the porous masses which are to be consolidated, there is another with which, upon this supposition, we have to struggle. This is, From whence should come the matter with which the numberless cavities in those masses are to be filled?

THE water in the cavities and interstices of those bodies composing strata, must be in a stagnating state; consequently, it can only act upon the surfaces of those cavities which are to be filled up. But with what are they to be filled? Not with water; they are full of this already: Not with the substance of the bodies which contain that water; this would be only to make one cavity in order to fill up another. If, therefore, the cavities of the strata are to be filled with solid matter, but means of water, there must be made to pass through those porous masses, water impregnated with some other substances in a dissolved state; and the aqueous menstruum must be made to separate from the dissolved substance, and to deposit the same in those cavities through which the solution moves.

BY such a supposition as this, we might perhaps explain a partial consolidation of those strata; but this is a supposition, of which the case under consideration does not admit; for in the present case, which is that of materials accumulated at the bottom of the ocean, there is not proper means for separating the dissolved matter from the water included in those enormous masses; nor are there any means by which a circulation in those masses may be formed. In this case, therefore, where the means are not naturally in the supposition, a philosopher, who is to explain the phænomenon by the natural operation of water in this situation, must not have recourse to another agent, still more powerful, to assist his supposition, which cannot be admitted.

THUS, it will appear, that, to consolidate strata formed at the bottom of the sea, in the manner now considered, operations are required unnatural to this place; consequently , not to be supposed in order to support a hypothesis.

BUT now, instead of enquiring how far water may be supposed instrumental in the consolidation of the strata which were originally of loose texture, we are to consider how far there may be appearances in those consolidated bodies, by which it might be concluded, whether or not the present state of their consolidation has been actually brought about by means of that agent.

IF water had been the menstruum by which the consolidating matter was introduced into the interstices of strata, masses of those bodies could only be found consolidated with such substances as water is capable of dissolving; and these substances would be found only in such a state as the simple separation of the dissolving water might produce.

IN this case, the consolidation of strata would be extremely limited; for we cannot allow more power to water than we find it has in nature; nor are we to imagine to ourselves unlimited powers in bodies, on purpose to explain those appearances, by which we should be made to know the powers of nature. Let us, therefore, attend, with every possible circumspection, to the appearances of those bodies, by means of which we are to investigate the principles of mineralogy, and know the laws of nature.

THE question now before us concerns the consolidating substances of strata. Are these such as will correspond to the dissolving power of water, and to the state in which those substances might be left by the separation of their menstruum? No; far, far from this supposition is the conclusion that necessarily follows from natural appearances.

WE have strata consolidated by calcareous spar, a thing perfectly distinguishable from the stalactical concretion of calcareous earth, in consequence of aqueous solution. We have strata made solid by the formation of fluor, a substance not soluble, so far as we know, by water. We have strata consolidated with sulphureous and bituminous substances, which do not correspond to the solution of water. We have strata consolidated with siliceous matter, in a state totally different from that under which it has been observed, on certain occasions, to be deposited by water. We have strata consolidated by feldspar, a substance insoluble in water. We have strata consolidated by almost all the various metallic substances, with their almost endless mixtures and sulphureous compositions; that is to say, we find, perhaps, every different substance introduced into the interstices of strata which had been formed by subsidence at the bottom of the sea.

IF it is by means of water that those interstices have been filled with those materials, water must be, like fire, an universal solvent, or cause of fluidity, and we must change entirely our opinion of water in relation to its chemical character. But there is no necessity thus to violate our chemical principles, in order to explain certain natural appearances; more especially if those appearances may be explained in another manner, consistently with the known laws of nature.

IF, again, it is by means of heat and fusion that the loose and porous structure of strata shall be supposed to have been consolidated, then every difficulty which had occurred in reasoning upon the power or agency of water is at once removed. The loose and discontinuous body of a stratum may be closed by means of softness and compression; the porous structure of the materials may be consolidated, in a similar manner, by the fusion of their substance; and foreign matter may be introduced into the open structure of strata, in form of steam or exhalation, as well as in the fluid state of fusion; consequently, heat is an agent competent for the consolidation of strata, which water alone is not. If, therefore, such an agent could be found acting in the natural place of strata, we must pronounce it proper to bring about that end.

THE examination of nature gives countenance to this supposition, so far as strata are found consolidated by every species of substance, and almost every possible mixture of those different substances; consequently, however difficulty it may appear to have this application of heat, for the purpose of consolidating strata formed at the bottom of the ocean, we cannot, from natural appearances, suppose any other cause, as having actually produced the effects which are now examined.

THIS question, with regard to the means of consolidating the strata of the globe, is, to natural history, of the greatest importance; and it is essential in the theory now proposed to be given of the mineral system. It would, therefore, require to be discussed with some degree of precision, in examining the particulars; but of these, there is so great a field, and the subject is so complicated in its nature, that volumes might be written upon particular branches only, without exhausting what might be said upon the subject; because the evidence, though strong in many particulars, is chiefly to be enforced by a multitude of facts, conspiring, in a diversity of ways, to point out one truth, and by the impossibility of reconciling all these facts, except by means of one supposition.

BUT, as it is necessary to give some proof of that which is to be a principle in our reasoning afterwards, I shall now endeavour to generalize the subject as much as possible, in order to answer that end, and, at the same time, to point out the particular method of enquiry.

THERE are to be found, among the various strata of the globe, bodies formed of two different kinds of substances, *siliceous* bodies, and those which may be termed *sulphureous.*With one or other, or both of those two substances, every different consolidated stratum of the globe will be found so intimately mixed, or closely connected, that it must be concluded, by whatever cause those bodies of siliceous and sulphureous matter had been changed from a fluid to a concreted state, the strata must have been similarly affected by the same cause.

THESE two species of bodies, therefore, the siliceous and the sulphureous, may now be examined, in relation to the causes of their concretion, with a view to determine, what has been the general concreting or consolidating power, which has operated universally in the globe; and particularly to shew, it has not been by means of any fluid solution, that strata in general have been consolidated, or that those particular substances have been crystallized and concreted.

SILICEOUS matter, physically speaking, is not soluble in water; that is to say, in no manner of way have we been enabled to learn, that water has the power of dissolving this matter.

MANY other substances, which are so little soluble in water, that their solubility could not be otherwise detected of themselves, are made to appear soluble by means of siliceous matter; such is fel-spar, one of the component parts of rock-granite.

FELD-SPAR is a compound of siliceous, argillaceous, and calcareous earth, intimately united together. This compound siliceous body being, for ages, exposed to the weather, the calcareous part of it is dissolved, and the siliceous part is left in form of a soft white earth. But whether this dissolution is performed by pure water, or by means also of an acid, may perhaps be questioned. This, however, is certain, that we must consider siliceous substances as insoluble in water.

THE water of Giezer in Iceland undoubtedly contains this substance in solution; but there is no reason to believe, that it is here dissolved by any other than natural means; that is, an alkaline substance, by which siliceous bodies may be rendered soluble in water.

IT may be, therefore, asserted, that no siliceous body having the hardness of flint, nor any crystallization of that substance, has ever been formed, except by fusion. If, by any art, this substance shall be dissolved in simple water, or made to crystallize from any solution, in that case, the assertion which has been here made may be denied. But where there is not the vestige of any proof, to authorise the supposition of flinty matter being dissolved by water, or crystallized from that solution, such an hypothesis cannot be admitted, in opposition to general and evident appearances.

BESIDES this proof for the fusion of siliceous bodies, which is indirect, arising from the indissolubility of that substance in water, there is another, which is more direct, being founded upon appearances which are plainly inconsistent with any other supposition, except that of simple fluidity induced by heat. The proof I mean is, the penetration of many bodies with a flinty substance, which, according to every collateral circumstance, must have been performed by the flinty matter in a simply fluid state, and not in a state of dissolution by a solvent.

THESE are flinty bodies perfectly insulated in strata both of chalk and sand. It requires but inspection to be convinced. It is not possible that flinty matter could be conveyed into the middle of those strata, by a menstruum in which it was dissolved, and thus deposited in that place, without the smallest trace of deposition in the surrounding parts.

BUT, besides this argument taken from what does not appear, the actual form in which those flinty masses are found, demonstrates, *first*, That they have been introduced among those strata in a fluid state, by injection from some other place. 2*dly*, That they have been dispersed in a variety of ways among those strata, then deeply immersed at the bottom of the sea; and, *lastly*, That they have been there congealed from the state of fusion, and have remained in that situation, while those strata have been removed from the bottom of the ocean to the surface of the present land.

TO describe those particular appearances would draw this paper beyond the bounds of an essay. We must, therefore, refer those who would enquire more minutely into the subject, to examine the chalk-countries of France and England, in which the flint is found variously formed; the sand-hills interspersed among those chalk-countries, which have been also injected by melted flint; and the pudding-stone of England, which I have not seen in its natural situation. More particularly, I would recommend an examination of the insulated masses of stone, found in the sand-hills by the city of Brussels; a stone which is formed by an injection of flint among sand, similar to that which, in a body of gravel, had formed the pudding-stone of England[3].

ALL these examples would require to be examined upon the spot, as a great part of the proof for the fusion of the flinty substances, arises, in my opinion, from the form in which those bodies are found, and the state of the surrounding parts. But there are specimens brought from many different places, which contain, in themselves, the most evident marks of this injection of the flinty substance in a fluid state. These are pieces of fossil wood, penetrated with a siliceous substance, which are brought from England, Germany, and Lochneagh in Ireland.

IT appears from these specimens, that there has sometimes been a prior penetration of the body of wood, either with irony matter, or calcareous substance. Sometimes, again, which is the case with that of Lochneagh, there does not seem to have been any penetration of those two substances. The injected flint appears to have penetrated the body of this wood, immersed at the bottom of the sea, under an immense compression of

[3] ACCURATE descriptions of those appearances, with drawings, would be, to natural history, a valuable acquisition.

water. This appears from the wood being penetrated partially, some parts not being penetrated at all.

NOW, in the limits between those two parts, we have the most convincing proof, that it had been flint in a simple fluid state which had penetrated the wood, and not in a state of solution.

First, BECAUSE, however little of the wood is left unpenetrated, the division is always distinct between the injected part of that which is not penetrated by the fluid flint. In this case, the flinty matter has proceeded a certain length, which is marked, and no farther; and, beyond this boundary, there is no partial impregnation, nor a gradation of the flintifying operation, as must have been the case if siliceous matter had been deposited from a solution. 2*dly*, The termination of the flinty impregnation has assumed such a form, precisely, as would naturally happen from a fluid flint penetrating that body.

IN other specimens of this mineralizing operation, fossil wood, penetrated, more of less, with ferruginous and calcareous substances, has been afterwards penetrated with a flinty substance. In this case, with whatever different substances the woody body shall be supposed to have been penetrated in a state of solution by water, the regular structure of the plant would still have remained, with its vacuities variously filled with the petrifying substances, separated from the aqueous menstruum, and deposited in the vascular structure of the wood.

THERE cannot be a doubt with regard to the truth of this proposition; for as it is, we frequently find parts of the consolidated wood, with the vascular structure remaining perfectly in the natural shape and situation; but if it had been by aqueous solution that the wood had been penetrated and consolidated, all the parts of that body would be found in the same natural shape and situation.

THIS, however, is far from being the case; for while, in some parts, the vascular structure is preserved entire, it is also evident, that, in general, the woody structure is variously broken and dissolved by the fusion and crystallization of the flint. There are so many and such various convincing examples of this, that, to attempt to describe them, would be to exceed the bounds prescribed for this dissertation; but such specimens are in my possession, ready for the inspection of any person who may desire to study the subject.

WE may now proceed to consider sulphureous substances, with regard to their solubility in water, and to the part which these bodies have acted in consolidating the strata of the globe.

THE sulphureous substances here meant to be considered, are substances not soluble in water, so far as we know, but fusible by heat, and inflammable by means of heat and vital air. These substances are of two kinds; the one more simple, the other more compound.

THE most simple kind is composed of two different substances, *viz.* phlogiston, with acid or metallic substances; from which result, on the one hand, sulphur, and, on the other, metals, both properly so called. The more compound sort, again, is oily matter, produced by vegetables, and forming bituminous bodies.

THE *first* of these is found naturally combined with almost all metallic substances, which are then said to be mineralized with sulphur. Now, it is well known, that this mineralizing operation is performed by means of heat or fusion; and there is no person skilled in chemistry that will pretend to say, this may be done by aqueous solution. The combination of iron and sulphur, for example, may easily be performed by fusion; but, by aqueous solution, this particular combination is again resolved, and forms an acido-metallic, that is, a vitriolic substance, after the phlogiston (which refuses aqueous solution) has been separated from the composition, by means of the joint operation of vital air.

THE variety of these sulphureo-metallic substances, in point of composition, is almost indefinite; but, unless they were all soluble in water, this could not have happened by the action of that solvent. If we shall allow any one of those bodies to have been formed by the fluidity of heat, they must all have been formed in the same manner; for there is such a chain of connection among those bodies in the mineral regions, that they must all have been composed, either, on the one hand, by aqueous solution, or, on the other, by means of heat and fusion.

HERE, for example, are crystallized together in one mass, *first, Pyrites*, containing sulphur, iron copper; 2*dly, Blend*, a composition of iron, sulphur, and calamine; 3*rdly, Galena*, consisting of lead and sulphur; 4*thly, Marmor metallicum*, being the terra ponderosa, saturated with the vitriolic acid; a substance insoluble in water; 5*thly*, *Fluor*, a saturation of calcareous earth, with a peculiar acid, called the acid of spar, also insoluble in water; 6*thly, Calcareous spar*, of different kinds, being calcareous earth saturated with fixed air, and something besides, which forms a variety in this substance; *lastly, Siliceous substances*, or *Quartz crystals*. All these bodies, each possessing its proper shape, are mixed in such a manner as it would be endless to describe, but which may be expressed in general by saying, that they are mutually contained in, and contain each other.

UNLESS, therefore, every one of these different substances may be dissolved in water, and crystallized from it, it is in vain to look for the explanation of these appearances in the operations of nature, by the means of aqueous solution.

ON the other hand, heat being capable of rendering all these substances liquid, they may be, with the greatest simplicity, transported from one place to another; and they may be made to concrete altogether, at the same time, and distinctly separate in any place. Hence, for the explanation of those natural appearances, which are so general, no further conditions are required, than the supposition of a sufficient intensity of subterraneous fire or heat, and a sufficient degree of compression upon those bodies, which are to be subjected to that violent heat, without calcination or change. But, so far as this supposition is not gratuitous, the appearances of nature will be thus explained.

I SHALL only mention one specimen, which must appear most decisive of the question. It is, I believe, from an Hungarian mine. In this specimen, petro-silex, pyrites, and cinnabar, are so mixed together, and crystallized upon each other, that it is impossible to conceive any one of those bodies to have had its fluidity and concretion from a cause which had not affected the other two. Now, let those who would deny the fusion of this siliceous body explain how water could dissolved these three different bodies, and deposit them in their present shape. If, on the contrary, they have not the least shadow of reason for such gratuitous supposition, the present argument must be admitted in its full force.

SULPHUR and metals are commonly found combined in the mineral regions. But this rule is not universal; for they are also frequently in a separate state. There is not, perhaps, a metal, among the great number which are now discovered, that may not be found native, as they are called, or in their metallic state.

METALLIC substances are also thus found in some proportion to the disposition of the particular metals, to resist the mineralizing operations, and to their facility of being metallized by fire and fusion. Gold, which refuses to be mineralized with sulphur, is found generally in its native state. Iron, again, which is so easily mineralized and scorified, is seldom found its malleable state. The other metals are all found more of less mineralized, though some of them but rarely in the native state.

BESIDES being found with circumstances thus corresponding to the natural facility, or to the impediments attending the metallization of those different calces, the native metals are also found in such a shape, and with such marks, as can only agree with the fusion of those bodies; that is to say, those appearances are perfectly irreconcileable with any manner of solution and precipitation.

FOR the truth of this assertion, among a thousand other examples, I appeal to that famous mass of native iron, discovered by Mr PALLAS, in Siberia. This mass being so well known to all the mineralists of Europe, any comment upon its shape and structure will be unnecessary [4].

[4] Since this Dissertation was written, M. DE LA PEYROUSE has discovered a native manganese. The circumstances of this mineral are so well adapted for illustrating the present doctrine, and so well related by M. DE LA PEYROUSE, that I should be wanting to the interest of mineral knowledge, were I not to give here that part of his Memoir.
"LORSQUE je fis insérer dans the journal de physique de l'anneée 1780, au mois de Janvier, une Dissertation contenant la classification des mines de manganèse, je ne connoissois point, à cette epoque, la mine de manganèse native. Elle a la couleur de son régule: elle salit les doigts de la même teinte. Son tissu paroit aussi lamelleux, et les lames semblent affecter une sorte de divergence. Elle a ainsi que lui, l'éclat métalllique; comme lui elle se laisse applatir sous le marteau, et s'exfolie si l'on redouble les coups; mais une circonstance qui est trop frappante pour que je l'omette, c'est la figure de la manganèse native, si prodigieusement conforme à celle du régule, qu'on s'y laisseroit tromper, si la mine n'étoit encore dans sa gangue: figure très-essentielle à observer ici, parce qu'elle est due à la nature même de la manganèse. En effect, pour réduire toutes les mines en général, il faut employer divers flux appropriés. Pour la reduction

WE come now to the *second* species of inflammable bodies called oily or bituminous. These substances are also found variously mixed with mineral bodies, as well as forming strata of themselves; they are, therefore, a proper subject for a particular examination.

IN the process of vegetation, there are produced oily and resinous substances; and from the collection of these substances at the bottom of the ocean, there are formed strata, which have been variously changed, in consequence of the effects of that heat, according as the distillation of the more volatile parts of those bodies has been suffered to proceed.

IN order to understand this, it must be considered that, while immersed in water, and under insuperable compression, the vegetable, oily, and resinous substances, would appear to be unalterable by heat; and it is only in proportion as certain chemical separations take place, that these inflammable bodies are changed in their substance by the application of heat. Now, the most general change of this kind is in consequence of evaporation, or the distillation of their more volatile parts, by which oily substances become bituminous, and bituminous substances become coaly.

THERE is here a gradation which may best understood by comparing the extremes.

ON the one hand, we know by experiment, that oily and bituminous substances can be melted and partly changed into vapour by heat, and that they become harder and denser, in proportion as the more volatile parts have evaporated from them. On the other hand, coaly substances are destitute of fusibility and volatility, in proportion as they have been exposed

de la manganèse, bien loin d'user de ce moyen, il faut, au contraire, éloigner tout flux, produire la fusion, par la seule violence et la promptetude du feu. Et telle est la propension naturelle et prodigieuse de la manganèse à la vitrification, qu'on n'a pu parvenir encore à réduire son régule en un seul culot; on trouve dans le creuset plusieurs petits boutons, qui forment autant de culots séparés. Dans la mine de manganèse native, elle n'est point en une seule masse; elle est disposée également en plusieurs culots séparés, et un peu applatis, comme ceux que l'art produit; beaucoup plus gros, à la vérité, parce que les agens de la nature doivent avoir une autre énergie, que ceux de nos laboratoires; et cette ressemblance si exacte, semble devoir vous faire penser que la mine native a été produite par le feu, tout comme son régule. La presence de la chaux argentée de la manganèse, me permettroit de croire que la nature n'a fait que réduire cette chaux. Du reste, cette mine native est très-pure, et ne contient aucune partie attirable à l'aimant. Cette mine, unique jusqu'à ce moment, vient, tout comme les autres manganèse que j'ai décrites, des mines de fer de*Sem*, dans la vallée de *Viedersos*, en Comté de Foix." *Journal de Physique, Janvier 1786*.

to greater degrees of heat, and to other circumstances favourable to the dissipation of their more volatile and fluid parts.

IF, therefore, in mineral bodies, we find the two extreme states of this combustible substance, and also the intermediate states, we must either conclude, that this particular operation of heat has been thus actually employed in nature, or we must explain those appearances by some other means, in as satisfactory a manner, and so as shall be consistent with other appearances.

IN this case, it will avail nothing to have recourse to the false analogy of water dissolving and crystallizing salts, which has been so much employed for the explanation of other mineral appearances. The operation here in question is of a different nature, and necessarily requires both the powers of heat and proper conditions for evaporation.

THEREFORE, in order to decide the point, with regard to what is the power in nature by which mineral bodies have become solid, we have but to find bituminous substance in the most complete state of coal, intimately connected with some other substance, which is more generally found consolidating the strata, and assisting in the concretion of mineral substances. But I have in my possession the most undoubted proof of this kind. It is a mineral vein, or cavity, in which are blended together coal of the most fixed kind, quartz and marmor metallicum. Nor is this all; for the specimen now referred to is contained in a rock of this kind, which every naturalist now-a-days will allow to have congealed from a fluid state of fusion. I have also similar specimens from the same place, in which the coal is not of that fixed and infusible kind, which burns without flame or smoak, but is bituminous or inflammable coal.

WE have hitherto been resting the argument upon a single point, for the sake of simplicity or clearness, not for want of those circumstances which shall be found to corroborate the theory. The strata of fossil coal are found in almost every intermediate state, as well as in those of bitumen and charcoal. Of the one kind is that fossil coal which melts or becomes fluid upon receiving heat; of the other, is that species of coal, found both in Wales and Scotland, which is perfectly infusible in the fire, and burns like coaks, without flame or smoak. The one species abounds in oily matter, the other has been distilled by heat, until it has become a *caput mortuum*, or perfect coal.

THE more volatile parts of these bituminous bodies are found in their separate state on some occasions. There is a stratum of limestone in Fifeshire near Raith, which, though but slightly tinged with a black colour, contains bituminous matter, like pitch, in many cavities, which are lined with calcareous spar crystallized. I have a specimen of such a cavity, in which the bitumen is in sphericles, or rounded drops, immersed in the calcareous spar.

NOW, it is to be observed, that, if the cavity in the solid limestone or marble, which is lined with calcareous crystals containing pyrites, had been thus encrusted by means of the filtration of water, this water must have dissolved calcareous spar, pyrites and bitumen. But these natural appearances would not even be explained by this dissolution and supposed filtration of those substances. There is also required, *first*, a cause for the separation of those different substances, form the aqueous menstruum in which they had been dissolved: 2*dly*, An explanation of the way in which a dissolved bitumen should be formed into round hard bodies of the most solid structure; and, *lastly*, Some probable means for this complicated operation being performed, below the bottom of the ocean, in the close cavity of a marble stratum.

THUS, the additional proof, from the facts relating to the bituminous substances, conspiring with that from the phaenomena of other bodies, affords the strongest corroboration of this opinion, that the various concretions found in the internal parts of strata have not been occasioned by means of aqueous solution, but by the power of heat and operation of simple fusion, preparing those different substances to concrete and crystallize in cooling.

THE arguments which have been now employed for proving that strata have been consolidated by the power of heat, or by the means of fusion, have been drawn chiefly from the insoluble nature of those consolidating substances in relation to water, which is the only general menstruum that can be allowed for the mineral regions. But there are found in the mineral kingdom, many solid masses of sal gem, which is a soluble substance. It may be now enquired, how far these masses, which are not unfrequent in the earth, tend either to confirm the present theory, or, on the contrary, to give countenance to that which supposes water the chief instrument in consolidating strata.

THE formation of salt at the bottom of the sea, without the assistance of subterranean fire, is not a thing unsupposable, as at first sight it might be. Let us but suppose a rock place across the gut of Gibraltar, (a case nowise unnatural), and the bottom of the Mediterranean would be certainly filled with salt, because the evaporation from the surface of that sea exceeds the measure of its supply.

BUT strata of salt, formed in this manner at the bottom of the sea, are as far from being consolidated by means of aqueous solution, as a bed of sand in the same situation; and we cannot explain the consolidation of such a stratum of salt by means of water, without supposing subterranean heat employed, to evaporate the brine which would successively occupy the interstices of the saline crystals. But this, it may be observed, is equally departing from the natural operation of water, as the means for consolidating the sediment of the ocean, as if we were to suppose the same thing done by heat and fusion. For the question is not, if subterranean heat be of sufficient intensity for the purpose of consolidating strata by the fusion of their substances; the question, is whether it be by means of this agent, subterranean heat, or by water alone, without the operation of a melting heat, that those materials have been variously consolidated.

THE example now under consideration, consolidated mineral salt, will serve to throw some light upon the subject; for as it is to be shewn, that this body of salt had been consolidated by perfect fusion, and not by means of aqueous solution, the consolidation of strata of dissoluble substances, by the operation of a melting heat, will meet with all that confirmation which the consistency of natural appearances can give.

THE rock salt in Cheshire lies in strata of red marl. It is horizontal in its direction. I do not know its thickness, but it is dug thirty or forty feet deep. The body of this rock is perfectly solid, and the salt, in many places, pure, colourless and transparent, breaking with a sparry cubical structure. But the greatest part is tinged by the admixture of the marl, and that in various degrees, from the slightest tinge of red, to the most perfect opacity. Thus, the rock appears as if it had been a mass of fluid salt, in which had been floating a quantity of marly substance, not uniformly mixed, but every where separating and subsiding from the pure saline substance.

THERE is also to be observed a certain regularity in this separation of the tinging from the colourless substance, which, at a proper distance, gives to the perpendicular section of the rock a distinguishable figure in its structure. When looking at this appearance near the bottom of the rock, it, at first, presented me with the figure of regular stratification; but, upon examining the whole mass of rock, I found, that it was only towards the bottom that this stratified appearance took place; and that, at the top of the rock, the most beautiful and regular figure was to be observed; but a figure the most opposite to that of stratification. It was all composed of concentric circles; and these appeared to be the section of a mass, composed altogether of concentric spheres, like those beautiful systems of configuration which agates so frequently present us with in miniature. In about eight or ten feet from the top, the circles growing large, were blended together, and gradually lost their regular appearance, until, at a greater depth, they again appeared in resemblance of a stratification.

THIS regular arrangement of the floating marly substance in the body of salt, which is that of the structure of a coated pebble, or that of concentric spheres, is altogether inexplicable upon any other supposition, than the perfect fluidity or fusion of the salt, and the attractions and repulsions of the contained substances. It is in vain to look, in the operations of solution and evaporation, for that which nothing but perfect fluidity or fusion can explain.

THIS example of a mineral salt congealed from a melted state, may be confirmed from another which I have from Dr BLACK, who suggested it to me. It is an alkaline salt, found in a mineral state, and described in the Philosophical Transactions, *anno* 1771. But to understand this specimen, something must be premised with regard to the nature of fossil alkali.

THE fossil alkali crystallizes from a dissolved state, in combining itself with a large portion of the water, in the manner of alum; and, in this case, the water is essential to the constitution of that transparent crystalline body; for, upon the evaporation of the water, the transparent salt loses its solidity, and becomes a white powder. If, instead of being gently dried, the crystalline salt is suddenly exposed to a sufficient degree of heat, that is, somewhat more than boiling water, it enters into the state of aqueous fusion, and it boils, in emitting the water by means of which it had been crystallized in the cold, and rendered fluid in that heated state. It is not possible to crystallize this alkaline salt from a dissolved state, without the combination of that quantity of water, nor to separate that water without destroying its crystalline state.

BUT in this mineral specimen, we have a solid crystalline salt, with a structure which, upon fracture, appears to be sparry and radiated, something resembling that of zeolite. It contains no water in its crystallization, but melts in a sufficient heat, without any aqueous fusion. Therefore, this salt must have been in a fluid state of fusion, immediately before its congelation and crystallization.

IT would be endless to give examples of particular facts, so many are the different natural appearances that occur, attended with a variety of different circumstances.

THERE is one, however, which is peculiarly distinct, admits of sufficiently accurate description, and contains circumstances from which conclusions may be drawn with clearness. This is the iron-stone, which is commonly found among the argillaceous strata, attendant upon fossil coal, both in Scotland and in England.

THIS stone is generally found among the bituminous schistus, or black argillaceous strata, either in separate masses of various shapes and sizes, or forming of itself strata with are more or less continuous in their direction among the schistus or argillaceous beds.

THIS mineral contains in general from 40 to 50 *per cent.* of iron, and it loses near one third of its weight in calcination. Before calcination it is of a gray colour, is not penetrable by water, and takes a polish. In this state, therefore, it is perfectly solid; but being calcined, it becomes red, porous, and tender.

THE fact to be proved with regard to these iron-stones is this, That they have acquired their solid state from fusion, and not in concreting from any aqueous solution.

TO abridge this disquisition, no argument is to be taken from contingent circumstances, (which, however, are often found here as well as in the case of marbles); such only are to be employed as are general to the subject, and arise necessarily from the nature of the operation.

IT will be proper to describe a species of these stones, which is remarkably regular in its form. It is that found at Aberlady in East Lothian.

THE form of these iron-stones is that of an oblate or much compressed sphere, and the size from two or three inches diameter to more than a foot. In the circular or horizontal section, they present the most elegant septarium (Plate 1); and, from the examination of this particular structure, the following conclusions may be drawn.

First, THAT the septa have been formed by the uniform contraction of the internal parts of the stone, the volume of the central parts diminishing more than that of the circumference; by this means, the separations of the stone diminish, in a progression from the centre towards the circumference.

2*d*, THAT there are only two ways in which the septa must have received the spar with which they are filled, more or less, either, *first*, By insinuation into the cavity of the septa after these were formed; or, 2*dly*, By separation from the substance of the stone, at the same time that the septa were forming.

WERE the first supposition true, appearances would be observable, shewing that the sparry substance had been admitted, either through the porous structure of the stone, or through proper apertures communicating from without. Now, if either one or other of these had been the case, and that the stone had been consolidated from no other cause than concretion from a dissolved state, that particular structure of the stone, by means of which the spar had been admitted, must appear at present upon an accurate examination.

THIS, however, is not the case, and we may rest the argument here. The septa reach not the circumference; the surface of the stone is solid and uniform in every part; and there is not any appearance of the spar in the argillaceous bed around the stone.

IT, therefore, necessarily follows, that the contraction of the iron-stone, in order to form septa, and the filling of these cavities with spar, had proceeded *pari passu*; and that this operation must have been brought about by means of fusion, or by congelation from a state of simple fluidity and expansion.

IT is only further to be observed, that all the arguments which have been already employed, concerning mineral concretions from a simply fluid state, or that of fusion, here take place. I have septaria of this kind, in which, besides pyrites, iron-ore, calcareous spar, and another that is ferruginous and compound, there is contained siliceous crystals; a case which is not so common. I have them also attended with circumstances of concretion and crystallization, which, besides being extremely rare, are equally curious and interesting.

THERE is one fact more which is well worth our attention, being one of those which are so general in the mineral regions. It is the crystallizations which are found in the close cavities of the most solid bodies.

NOTHING is more common than this appearance. Cavities are everywhere found closely lined with crystallization, of every different substance which may be supposed in those places. These concretions are well known to naturalists, and form part of the beautiful specimens which are preserved in the cabinets of collectors, and which the German mineralists have termed *Drusen*. I shall only particularize one species, which may be described upon principle, and therefore may be a proper subject on which to reason, for ascertaining the order of production in certain bodies. This body, which we are now to examine, is of the agate species.

WE have now been considering the means employed by nature in consolidating strata which were originally of an open structure; but in perfectly solid strata, we find bodies of agate, which have evidently been formed in that place where they now are found. This fact, however, is not still that of which we are now particularly to enquire; for this, of which we are to treat, concerns only a cavity within this agate; now, whatever may have been the origin of the agate itself, we are to shew, from what appears within its cavity, that the crystallizations which are found in this place had arisen from a simply fluid state, and not from that of any manner of solution.

THE agates now in question are those of the coated kind, so frequent in this country, called pebbles. Many of these are filled with a siliceous crystallization, which evidently proceeds from the circumferences towards the centre. Many of them, again, are hollow. Those cavities are variously lined with crystallized substances; and these are the object of the present examination.

BUT before describing what is found within, it is necessary to attend to this particular circumstance, that the cavity is perfectly inclosed with many solid coats, impervious to air or water, but particularly with the external cortical part, which is extremely hard, takes the highest polish, and is of the most perfect solidity, admitting the passage of nothing but light and heat.

WITHIN these cavities, we find, *first*, The coat of crystals with which this cavity is always lines; and this is general to all substances concreting, in similar circumstances, from a state of fusion; for when thus at liberty they naturally crystallize. 2*dly*, We have frequently a subsequent crystallization, set upon the first, and more or less immersed in it. 3*dly*, There is also sometimes a third crystallization, superincumbent on the second, and in like manner as the second is on the first. I shall mention some particulars.

I HAVE one specimen, in which the primary crystals are siliceous, the secondary thin foliaceous crystals of deep red but transparent iron-ore, forming elegant figures, that have the form of roses. The tertiary crystallization is a frosting of small siliceous crystals upon the edges of the foliaceous crystals.

IN other specimens, there is first a lining of colourless siliceous crystals, then another lining of amethystine crystals, and sometimes within that, fuliginous crystals. Upon these fuliginous and amethystine crystals are many sphericles or hemispheres of red compact iron-ore, like haematites.

IN others, again, the primary crystals are siliceous, and the secondary calcareous. Of this kind, I have one which has, upon the calcareous crystals, beautiful transparent siliceous crystals, and iron-sphericles upon these.

Lastly, I HAVE an agate formed of various red and white coats, and beautifully figured. The cavity within the coated part of the pebble is filled up without vacuity, first, with colourless siliceous crystals; secondly, with fuliginous crystals; and, lastly, with white or colourless calcareous spar. But between the spar and crystals there are many sphericles, seemingly of iron, half sunk into each of these two different substances.

FROM these facts, I may now be allowed to draw the following conclusions:

First, THAT concretion had proceeded from the surface of the agate body inwards. This necessarily follows from the nature of those figured bodies, the figures of the external coats always determining the shape of those within, and never, contrarily, those within affecting those without.

2*dly*, THAT when the agate was formed, the cavity then contained everything which now is found within it, and nothing more.

3*dly*, THAT the contained substances must have been in a fluid state, in order to their crystallizing.

Lastly, THAT as this fluid state had not been the effect of solution in a menstruum, it must have been fluidity from heat and fusion.

THERE are in jaspers and agates many other appearances, from whence this last conclusion may be formed with great certainty and precision; but it is hoped, that what has been now given may suffice for establishing that proposition without any doubt.

IT must not here be objected, that there are frequently found siliceous crystals and amethysts containing water; and that it is impossible to confine water even in melted glass. It is true, that here, at the surface of the earth, melted glass cannot, in ordinary circumstances, be made to receive and inclose condensed water; but let us only suppose a sufficient degree of compression in the body of melted glass, and we can easily imagine it to receive and confine water, as well as any other substance. But if, even in our operations, water, by means of compression, may be made to endure the heat of red hot iron without being converted into vapour, what may not the power of nature be able to perform? The place of mineral operations is not on the surface of the earth; and we are not to limit nature with our imbecility, or estimate the powers of nature by the measure of our own.

TO conclude this long chemico-mineral disquisition, I have specimens in which the mixture of calcareous, siliceous and metallic substances, in almost every species of concretion which is to be found in mineral bodies, may be observed, and in which there is exhibited, in miniature, almost every species of mineral transaction, which, in nature, is found upon a scale of grandeur and magnificence. They are nodules contained in the whinstone, porphyry, or basaltes of the Calton-hill, by Edinburgh; a body which is to be afterwards examined, when it will be found to have flowed, and to have been in fusion, by the operation of subterranean heat.

THIS evidence, though most conclusive with regard to the application of subterranean heat, as the means employed in bringing into fusion all the different substances with which strata may be found consolidated, is not directly a proof that strata had been consolidated by the fusion of their proper substance. It was necessary to see the general nature of the evidence, for the universal application of subterranean heat, in the fusion of every kind of mineral body. Now, that this has been done, we may give examples of strata consolidated without the introduction of foreign matter, merely by the softening or fusion of their own materials.

FOR this purpose, we may consider two different species of strata, such as are perfectly simple in their nature, of the most distinct substances, and whose origin is perfectly understood, consequently, whose subsequent changes may be reasoned upon with certainty and clearness. These are the siliceous and calcareous strata; and these are the two prevailing substances of the globe, all the rest being, in comparison of these, as nothing; for unless it be the bituminous or coal strata, there is hardly any other which does not necessarily contain more or less of one of other of these two substances. If, therefore, it can be shewn, that both of those two general strata have been consolidated by the simple fusion of their substance, no *desideratum* or doubt will remain, with regard to the nature of that operation which has been transacted at great depths of the earth, places to which all access is denied to mortal eyes.

WE are now to prove, *first*, That those strata have been consolidated by simple fusion; and, 2*dly*, That this operation is universal, in relation to the strata of the earth, as having produced all various degrees of solidity or hardness in these bodies.

I SHALL first remark, that a fortuitous collection of hard bodies, such as gravel and sand, can only touch in points and cannot, while in that hard state, be made to correspond so precisely to each other's shape as to consolidate the mass. But if these hard bodies should be softened in their substance, or brought into a certain degree of fusion, they might be adapted mutually to each other, and thus consolidate the open structure of the mass. Therefore, to prove the present point, we have but to exhibit specimens of siliceous and calcareous strata which have been evidently consolidated in this manner.

OF the first kind, great varieties occur in this country. It is, therefore, needless to describe these particularly. They are the consolidated strata of gravel and sand, often containing abundance of feld-spar, and thus graduating into granite; a body, in this respect, perfectly similar to the more regular strata which we now examine.

THE second kind, again, are not so common in this country, unless we consider the shells and coralline bodies in our limestones, as exhibiting the same example, which indeed they do. But I have a specimen of marble from Spain, which may be described, and which will afford the most satisfactory evidence of the fact in question.

THIS Spanish marble may be considered as a species of pudding-stone, being formed of calcareous gravel; a species of marble which, from Mr BOWLES'S Natural History, appears to be very common in Spain. The gravel of which this marble is composed, consists of fragments of other marbles of different kinds. Among these, are different species of *oolites* marble, some shell marbles, and some composed of a chalky substance, or of undistinguishable parts. But it appears, that all these different marbles had been consolidated or made hard, then broken into fragments, rolled and worn by attrition, and thus collected together, along with some sand or small siliceous bodies, into one mass. *Lastly*, This compound body is consolidated in such a manner as to give the most distinct evidence, that this had been executed by the operation of heat or simple fusion.

THE proof I have is this, That besides the general conformation of those hard bodies, so as to be perfectly adapted to each other's shape, there is, in some places, a mutual indentation of the different pieces of gravel into each other; an indentation which resembles perfectly that junction of the different bones of the *cranium*, called sutures, and which must have necessarily required a mixture of those bodies while in a soft or fluid state.

THIS appearance of indentation is, by no means, singular or limited to one particular specimen. I have several specimens of different marbles, in which fine examples of this species of mixture may be perceived. But in this particular case of the Spanish pudding-stone, where the mutual indentation is made between two pieces of hard stone, worn round by attrition, the softening or fusion of these two bodies is not simply rendered probable, but demonstrated.

HAVING thus proved, that those strata had been consolidated by simple fusion, as proposed, we now proceed to shew, that this mineral operation had been not only general, as being found in all regions of the globe, but universal, in consolidating our earth in all the various degrees, from loose and incoherent shells and sand, to the most solid bodies of the siliceous and calcareous substances.

TO exemplify this in the various collections and mixtures of sands, gravels, shells and corals, were endless and superfluous. I shall only take, for an example, one simple homogeneous body, in order to exhibit it in the various degrees of consolidation, from the state of simple incoherent earth to that of the most solid marble. It must be evident that this is chalk; naturally a soft calcareous earth, but which may be also found consolidated in every different degree.

THROUGH the middle of the isle of Wight, there runs a ridge of hills of indurated chalk. This ridge runs from the isle of Wight directly west into Dorsetshire, and goes by Corf-castle towards Dorchester, perhaps beyond that place. The sea has broke through this ridge at the west end of the isle of Wight, where columns of the indurated chalk remain, called the needles; the same appearance being found upon the opposite shore in Dorsetshire.

IN this field of chalk, we find every gradation of that soft earthy substance to the most consolidated body of this indurated ridge, which is not solid marble, but which has lost its chalky property, and has acquired a kind of stony hardness.

WE want only further to see this cretaceous substance in its most indurated and consolidated state; and this we have in the north of Ireland, not far from the Giants Causeway. I have examined cargoes of this limestone brought to the west of Scotland, and find the most perfect evidence of this body having been once a mass of chalk, which is now a solid marble.

THUS, if it is by means of fusion that the strata of the earth have been, in many places, consolidated, we must conclude, that all the degrees of consolidation, which are indefinite, have been brought about by the same means.

NOW, that all the strata of the mineral regions, which are those only now examined, have been consolidated in some degree, is a fact for which no proof can be offered here, but must be submitted to experience and enquiry; so far, however, as they shall be considered as consolidated in any degree, which they certainly are in general, we have investigated the means which had been employed in that mineral operation.

WE have now considered the concretions of particular bodies, and the general consolidation of strata; but it may be alleged, that there is a great part of the solid mass of this earth not properly comprehended among those bodies which have been thus proved to be consolidated by means of fusion. The body here alluded to is granite; a mass which is not generally stratified, and which, being a body perfectly solid, and forming some part in the structure of this earth, deserves to be considered.

THE nature of granite, as a part of the structure of the earth, is too intricate a subject to be here considered, where we only seek to prove the fusion of a substance from the evident marks which are to be observed in a body. We shall, therefore, only now consider one particular species of granite; and if this shall appear to have been in a fluid state of fusion, we may be allowed to extend this property to all the kind.

THE species now to be examined comes from the north country, about four or five miles west from Portsoy, on the road to Huntly. I have not been upon the spot, but am informed that this rock is immediately connected or continuous with the common granite of the country. This indeed appears in the specimens which I have got; for, in some of these, there is to be perceived a gradation from the regular to the irregular sort.

THIS rock may indeed be considered, in some respects, as a porphyry; for it has an evident ground, which is feld-spar, in its sparry state; and it is, in one view, distinctly maculated with quartz, which is transparent, but somewhat dark-coloured (Plate 1, fig 1,2,3).

CONSIDERED as a porphyry, this specimen is no less singular than as a granite. For, instead of a siliceous ground, maculated with the rhombic feld-spar, which is the common state of porphyry, the ground is uniformly crystallized, or a homogeneous regular fel-spar, maculated with the transparent siliceous substance. But as, besides the fel-spar and quartz, which are the constituent parts of the stone, there is also mica, in some places, it may, with propriety, be termed a granite.

THE singularity of this specimen consists, not in the nature or proportions of its constituent parts, but in the uniformity of the sparry ground, and the regular shape of the quartz mixture. This siliceous substance, viewed in one direction, or longitudinally, may be considered as columnar, prismatical, or continued in lines running nearly parallel. These columnar bodies of quartz are beautifully impressed with a figure on the sides, where they are in contact with the spar. This figure is that of furrows or channels, which are perfectly parallel, and run across the longitudinal direction of the quartz. This is represented in fig. 4. This striated figure is only seen when, by fracture, the quartz is separated from the contiguous spar.

BUT what I would here more particularly represent is, the transverse section of those longitudinal siliceous bodies. These are seen in fig. 1. 2. and 3. They have not only separately the forms of certain typographic characters, but collectively give the regular lineal appearance of types set in writing.

IT is evident from the inspection of this fossil, that the sparry and siliceous substances had been mixed together in a fluid state; and that the crystallization of the sparry substance, which is rhombic, had determined the regular structure of the quartz, at least in some directions.

THUS, the siliceous substance is to be considered as included in the spar, and as figured according to the laws of crystallization proper to the sparry ground; but the spar is also to be found included in the quartz. IT is not, indeed, always perfectly included or inclosed on all sides; but this is sometimes the case, or it appears so in the section. Fig. 5. 6. 7. 8. 9. and 10. are those cases magnified, and represent the different figured quartz inclosing the feld-spar. In one of them, the feld-spar, which is contained within the quartz, contains also a small triangle of quartz, which it incloses. Now, it is not possible to conceive any other way in which those two substances, quartz and feld-spar, could be thus concreted, except by congelation from a fluid state, in which they have been mixed.

THERE is one thing more to be observed with regard to this curious species of granite. It is the different order or arrangement of the crystallization or internal structure of the feld-spar ground, in two contiguous parts of the same mass. This to be perceived in the polished surface of the stone, by means of the reflection of light.

THERE is a certain direction in which, viewing the stone, when the light falls with a proper obliquity, we see a luminous reflection from the internal parts of the stone. This arises from the reflecting surfaces of the sparry structure or minute cracks, all turned in one direction, consequently, giving that luminous appearance only in one point of view.

NOW, all the parts of the stone in which the figured quartz is directed in the same manner, or regularly placed in relation to each other, present that shining appearance to the eye at one time, or in the same point of direction. But there are parts of the mass, which, though immediately contiguous and properly continuous, have a different disposition of the figured quartz; and these two distinguished masses, in the same surface of the polished stone, give to the eye their shining appearance in very different directions. Fig. 3 shows two of those figured and shining masses, in the same plane or polished surface.

IT must be evident, that, as the crystallization of the sparry structure is the figuring cause of the quartz bodies, there must be observed a certain correspondency between those two things, the alinement (if I may be allowed the expression) of the quartz, and the shining of the sparry ground. It must also appear, that, at the time of congelation of the fluid spar, those two contiguous portions had been differently disposed in the crystallization of their substance. This is an observation which I have had frequent opportunities of making, with respect to masses of calcareous spar.

UPON the whole, therefore, whether we shall consider granite as a stratum or as an irregular mass, whether as a collection of several material, or as the separation of substances which had been mixed, there is sufficient evidence of this body having been consolidated by means of fusion, and in no other manner.

WE are thus led to suppose, that the power of heat and operation of fusion must have been employed in consolidating strata of loose materials, which had been collected together and amassed at the bottom of the ocean. It will, therefore, be proper to consider, what are the appearances in consolidated strata that naturally should follow, on the one hand, from fluidity having been, in this manner, introduced by means of heat, and, on the other, from the interstices being filled by means of solution; that so we may compare appearances with the one and other of those two suppositions, in order to know that with which they may be only found consistent.

THE consolidation of strata with every different kind of substance was found to be inconsistent with the supposition, that aqueous solution had been the means employed for this purpose. This appearance, on the contrary, is perfectly consistent with the idea, that the fluidity of these bodies had been the effect of heat; for, whether we suppose the introduction of foreign matter into the porous mass of a stratum for its consolidation, or whether we shall suppose the materials of the mass acquiring a degree of softness, by means of which, together with an immense compression, the porous body might be rendered solid; the power of heat, as the cause of fluidity and vapour, is equally proper and perfectly competent. Here, therefore, appearances are as decidedly in favour of the last supposition, as they had been inconsistent with the first.

BUT if strata have been consolidated by means of aqueous solution, these masses should be found precisely in the same state as when they were originally deposited from the water. The perpendicular section of those masses might shew the compression of the bodies included in them, or of which they are composed; but the horizontal section could not contain any separation of the parts of the stratum from one another.

IF, again, strata have been consolidated by means of heat, acting in such a manner as to soften their substance, then, in cooling, they must have formed rents or separations of their substance, by the unequal degrees of contraction which the contiguous strata may have suffered. Here is a most decisive mark by which the present question must be determined.

THERE is not in nature any appearance more distinct than this of the perpendicular fissures and separations in strata. These are generally known to workmen by the terms of veins or backs and cutters; and there is no consolidated stratum that wants these appearances. Here is, therefore, a clear decision of the question, whether it has been by means of heat, or by means of aqueous solution, that collections of loose bodies at the bottom of the sea have been consolidated into the hardest rocks and most perfect marbles.

ERROR never can be consistent, nor can truth fail of having support from the accurate examination of every circumstance. It is not enough to have found appearances decisive of the question, with regard to the two suppositions which have been now considered. we may farther seek confirmation of that supposition which has been found alone consistent with appearances.

IF it be by means of heat and fusion that strata have been consolidated, then, in proportion to the degree of consolidation they have undergone from their original state, they should, *caeteris paribus*, abound more with separations in their mass. But this conclusion is found consistent with appearances. A stratum of porous sand-stone does not abound so much with veins and cutters as a similar stratum of marble, or even a similar stratum of stand-stone that is more consolidated. In proportion, therefore, as strata have been consolidated, they are in general intersected with veins and cutters; and in proportion as strata are deep in their perpendicular section, the veins are wide, and placed at greater distances. In like manner, when strata are thin, the veins are many, but proportionally narrow.

IT is thus, upon chemical principles, to be demonstrated, that all the solid strata of the globe have been condensed by means of heat, and hardened from a state of fusion. But this proposition is equally to be maintained from principles which are mechanical. The strata of the globe, besides being formed of earths, are composed of sand, of gravel, and fragments of hard bodies, all which may be considered as, in their nature, simple; but these strata are also found composed of bodies which are not simple, but are fragments of former strata, which had been consolidated, and afterwards were broken and worn by attrition, so as to be made gravel. Strata composed in this manner have been again consolidated; and now the question is, by what means?

IF strata composed of such various bodies had been consolidated, by any manner of concretion, from the fluidity of a dissolution, the hard and solid bodies must be found in their entire state, while the interstices between those constituent parts of the stratum are filled up. No partial fracture can be conceived as introduced into the middle of a solid mass of hard matter, without having been communicated from the surrounding parts. But such partial separations are found in the middle of those hard and solid masses; therefore, this compound body must have been consolidated by other means than that of concretion from a state of solution.

THE Spanish marble already described, as well as many consolidated strata of siliceous gravel, of which I have specimens, afford the clearest evidence of this fact. These hard bodies are perfectly united together, in forming the most solid mass; the contiguous parts of some of the rounded fragments are interlaced together, as has already been observed; and there are partial shrinkings of the mass forming veins, traversing several fragments, but perfectly filled with the sparry substance of the mass, and sometimes with parts of the stone distinctly floating in the transparent body of spar. Now, there is not, besides heat or fusion, any known power in nature by which these effects might be produced. But such effects are general to all consolidated masses, although not always so well illustrated in a cabinet specimen.

THUS we have discovered a truth that is confirmed by every appearance, so far as the nature of the subject now examined admits. We now return to the general operation, of forming continents of those materials which had been deposited at the bottom of the sea.

Part 3. Investigation Of The Natural Operations Employed In The Production Of Land Above The Surface Of The Sea

WE seek to know that operation by means of which masses of loose materials, collected at the bottom of the sea, were raised above its surface, and transformed into solid land.

WE have found, that there is not in this globe (as a planet revolving in the solar system) any power or motion adapted to the purpose now in view; nor, were there such a power, could a mass of simply collected materials have continued any considerable time to resist the waves and currents natural to the sea, but must have been quickly carried away, and again deposited at the bottom of the ocean. But we have found, that there had been operations, natural to the bowels of this earth, by which those loose and unconnected materials have been cemented together, and consolidated into masses of great strength and hardness; those bodies are thus enabled to resist the force of waves and currents, and to preserve themselves, for a sufficient time, in their proper shape and place, as land above the general surface of the ocean.

We now desire to know, how far those internal operations of the globe, by which solidity and stability are procured to the beds of loose materials, may have been also employed in raising up a continent of land, to remain above the surface of the sea.

THERE is nothing so proper for the erection of land above the level of the ocean, as an expansive power of sufficient force, applied directly under materials in the bottom of the sea, under a mass that is proper for the formation of land when thus erected. The question is not, how such a power may be procured; such a power has probably been employed. If, therefore, such a power should be consistent with that which we found had actually been employed in preparing the erected mass; or, if such a power is to be reasonable concluded as accompanying those operations which we have found natural to the globe, and situated in the very place where this expansive power appears to be required, we should thus be led to perceive, in the natural operations of the globe, a power as efficacious for the elevation of what had been at the bottom of the sea into the place of land, as it is perfect for the preparation of those materials to serve the purpose of their elevation.

IN opposition to this conclusion, it will not be allowed to allege, that we are ignorant how such a power might be exerted under the bottom of the ocean; for the present question is not, what had been the cause of heat, which has appeared to have been produced in that place; but, if this power of heat, which has certainly been exerted at the bottom of the ocean for consolidating strata, had been employed also for another purpose, that is, for raising those strata into the place of land.

WE may, perhaps, account for the elevation of land, by the same cause with that of the consolidation of strata, already investigated, without explaining the means employed by nature in procuring the power of heat, or shewing from what general source of action this particular power had been derived; but, by finding in subterranean heat a cause for any other change, besides the consolidation of porous or incoherent bodies, we shall generalize a fact, or extend our knowledge in the explanation of natural appearances.

THE power of heat for the expansion of bodies, is, so far as we know, unlimited; but by the expansion of bodies placed under the strata at the bottom of the sea, the elevation of those strata may be affected; and the question now to be resolved regards the actual exertion of this power of expansion, how far it is to be concluded as having been employed in the production of this earth above the level of the sea.

BEFORE attempting to resolve that question, it may be proper to observe, there has been exerted an extreme degree of heat below the strata formed at the bottom of the sea; and this is precisely the action of a power required for the elevation of those heated bodies into a higher place. Therefore, if there is no other way in which we may conceive this event to have been brought about, consistent with the present state of things, or what actually appears, we shall have a right to conclude, that such had been the order of procedure in natural things, and that the strata formed at the bottom of the sea had been elevated, as well as consolidated, by means of subterraneous heat.

THE consolidation of strata by means of fusion or the power of heat, has been concluded from the examination of nature, and from finding, that the present state of things is inconsistent with any other supposition. Now, again, we are considering the only power that may be conceived as capable of elevating strata from the bottom of the sea, and placing such a mass above the surface of the water. It is a truth unquestionable, that what had been originally at the bottom of the sea, is at present the highest of our land. In explaining this appearance, therefore, no other alternative is left, but either to suppose strata elevated by the power of heat above the level of the present sea, or the surface of the ocean reduced many miles below the height at which it had subsisted during the collection and induration of the land which we inhabit.

NOW, if, on the one hand, we are to suppose no general power of subterraneous fire or heat, we leave to our theory no means for the retreat of the sea, or the lowering of its surface; if, on the other hand, we are to allow the general power of subterraneous heat, we cannot have much difficulty in supposing, either the surface of the sea to have subsided, or the bottom of the ocean, in certain parts, to have been raised by a subterranean power above the level of the surface, according as appearances shall be found to require the one or other of those conclusions. Here, therefore, we are again remitted to the history of nature, in order to find matter of fact by which this question may be properly decided.

IF the present land had been discovered by the subsiding of the waters, there has not been a former land, from whence materials had been procured for the construction of the present, when at the bottom of the sea; for there is no vestige remaining of that land, the whole land of the present earth having been formed evidently at the bottom of the sea. Neither could the natural productions of the sea have been accumulated, in the shape in which we now find them, on the surface of this earth; for how should the Alps and Andes have been formed within the sea from the natural productions of the water? Consequently, this is a supposition inconsistent with every natural appearance.

THE supposition, therefore, of the subsidence of the former ocean, for the purpose of discovering the present land, is beset with more difficulty than the simple erection of the bottom of the former ocean; for, *first*, There is a place to provide for the retirement of the waters of the ocean; and, 2*dly*, There is required a work of equal magnitude; that is, the swallowing up of that former continent, which had procured the materials of the present land.

ON the one hand, the subsiding of the surface of the ocean would but make the former land appear the higher; and, on the other, the sinking the body of the former land into the solid globe, so as swallow up the greater art of the ocean after it, if not a natural impossibility, would be a least a superfluous exertion of the powers of nature. Such an operation as this would discover as little wisdom in the end elected, as in the means appropriated to that end; for , if the land be not wafted and worn away in the natural operations of the globe, why make such a convulsion in the world in order to renew the land? If, again, the land naturally decays, why employ so extraordinary a power, in order to hide a former continent of land, and puzzle man?

LET us now consider how far the other proposition, of strata being elevated by the power of heat above the level of the sea, may be confirmed from the examination of natural appearances.

THE strata formed at the bottom of the ocean are necessarily horizontal in their position, or nearly so, and continuous in their horizontal direction or extent. They may change, and gradually assume the nature of each other, so far as concerns the materials of which they are formed; but there cannot be any sudden change, fracture or displacement naturally in the body of a stratum. But, if these strata are cemented by the heat of fusion, and erected with an expansive power acting below, we may expect to find every species of fracture, dislocation and contortion, in those bodies, and every degree of departure from a horizontal towards a vertical position.

THE strata of the globe are actually found in every possible position: For from horizontal, they are frequently found vertical; from continuous, they are broken and separated in every possible direction; and, from a plane, they are bent and doubled. It is impossible that they could have originally been formed, by the known laws of nature, in their present state and position; and the power that has been necessarily required for their change, has not been inferior to that which might have been required for their elevation from the place in which they had been formed.

IN this case, natural appearances are not anomalous. They are, indeed, infinitely various, as they ought to be, according to the rule; but all those varieties in appearances conspire to prove one general truth, *viz*. That all which we see had been originally composed according to certain principles, established in the constitution of the terraqueous globe; and that those regular compositions had been afterwards greatly changed by the operations of another power, which had introduced apparent confusion among things first formed in order and by rule.

IT is concerning the operation of this second power that we are now enquiring; and here the apparent irregularity and disorder of the mineral regions are as instructive, with regard to what had been transacted in a former period of time, as the order and regularity of those same regions are conclusive, in relation to the place in which a former state of things had produced that which, in its changed state, we now perceive.

WE are now to conclude, that the land on which we dwell had been elevated from a lower situation by the same agent which had been employed in consolidating the strata, in giving them stability, and preparing them for the purpose of the living world. This agent is matter actuated by extreme heat, and expanded with amazing force.

IF this has been the case, it will reasonable to expect, that some of the expanded matter might be found condensed in the bodies which have been heated by that igneous vapour; and that matter, foreign to the strata, may have been thus introduced into the fractures and separations of those indurated masses.

WE have but to open our eyes to be convinced of this truth. Look into the sources of our mineral treasures; ask the miner from whence has come the metal into his veins? Not from the earth or air above, not from the strata which the vein traverses; these do not contain one atom of the minerals now considered: There is but one place from whence these minerals may have come; this is, the bowels of the earth, the place of power and expansion, the place from whence must have proceeded that intense heat by which loose materials have been consolidated into rocks, as well as that enormous force by which the regular strata have been broken and displaced.

OUR attention is here peculiarly called upon, where we have the opportunity of examining those mineral bodies, which have immediately proceeded from the unknown region, that place of power and energy which we want to explore; for, if such is the system of the earth, that materials are first deposited at the bottom of the ocean, there to be prepared in a certain manner, in order to acquire solidity, and then to be elevated into the proper place of land, these mineral veins, which contain matter absolutely foreign to the surface of the earth, afford the most authentic information with regard to the operations which we want to understand. It is these veins which we are to consider as, in some measure, the continuation of that mineral region, which lies necessarily out of all possible reach of our examination. It is, therefore, peculiarly interesting to know the state in which things are to be found in this place, which may be considered as intermediate between the solid land, upon the one hand, and the unknown regions of the earth, upon the other.

WE are now to examine those mineral veins; and these may be considered, first, in relation to their form, independent of their substance or particular contents; and, secondly, in relation to the contained bodies, independent of their form.

IN examining consolidated strata, we remarked veins and cutters as a proof of the means by which those bodies had been consolidated. In that case, the formation of these veins is a regulated process, determined by the degree of fusion, and the circumstances of condensation or refrigeration. In respect of these, the mineral veins now to be examined are anomalous. They are;

but we know not why or how. We see the effect; but, in that effect, we do not see the cause. We can say, negatively, that the cause of mineral veins is not that by which the veins and fissures of consolidated strata have been formed; consequently, that is not the measured contraction and regulated condensation of the consolidated land which has formed those general mineral veins; however, veins, similar in many respects, have been formed by the co-operation of this cause.

HAVING thus taken a view of the evident distinction between the veins or contractions that are particular to the consolidated body in which they are found, and those more general veins which are not limited to that cause, we may now consider what is general in the subject, or what is universal in these effects of which we wish to investigate the cause.

THE event of highest generalization or universality, in the form of those mineral veins, is fracture and dislocation. It is not, like that of the veins of strata, simple separation and measured contraction; it is violent fracture and unlimited dislocation. In the one case, the forming cause is in the body which is separated; for, after the body had been actuated by heat, it is by the reaction of the proper matter of the body, that the chasm which constitutes the vein is formed. In the other case, again, the cause is extrinsic in relation to the body in which the chasm is formed. There has been the most violent fracture and divulsion; but the cause is still to seek; and it appears not in the vein; for it is not every fracture and dislocation of the solid body of our earth, in which minerals, or the proper substances of mineral veins, are found.

WE are now examining matter of fact, real effects, from whence we would investigate the nature of certain events which do not now appear. Of these, two kinds occur; one which has acted in relation to the hardness and solidity, or the natural constitution of the body; the other, to its shape or local situation. The first has been already considered; the last is now the subject of enquiry.

BUT, in examining those natural appearances, we find two different kinds of veins; the one necessarily connected with the consolidating causes; the other with that cause of which we now particularly enquire. For, in those great mineral veins, violent fracture and dislocation is the principle; but there is no other principle upon which strata, or masses formed at the bottom of the sea, can be placed at a height above its surface. Hence, in those two different operations, for forming mineral veins, and erecting strata form a lower to a higher place, the principle is the same; for neither can be done without violent fracture and dislocation.

WE now only want to know, how far it is by the same power, as well as upon the same principle, that those two operations have been made. An expansive force, acting from below, is the power most proper for erecting masses; but whether it is a power of the same nature with that which has been employed in forming mineral veins, will best appear in knowing the nature of their contents. These, therefore, may be now considered.

EVERY species of fracture, and every degree of dislocation and contortion, may be received in the form of mineral veins; and there is no other general principle to be observed in examining their form. But, in examining their contents, some other principle may appear, so far as, to the dislocating power or force, there may be superadded matter, by which something in relation to the nature of the power may be known. If, for example, a tree or a rock shall be found simply split asunder, although there be no doubt with regard to some power having been applied in order to produce the effect, yet we are left merely to conjecture at the power. But when wedges of wood or iron, or frozen water, should be found lodged in the cleft, we might be enabled, from this appearance, to form a certain judgment with regard to the nature of the power which had been applied. This is the case with mineral veins. We find them containing matter, which indicates a cause; and every information in this case is interesting to the theory.

THE substances contained in mineral veins are precisely the same with those which, in the former part of this paper, we have considered as being made instrumental in the consolidation of strata; and they are found in every species of mixture and concretion.

BUT, besides this evidence for the exertion of extreme heat, in that process by which those veins were filled, there is another important observation to be gathered from the inspection of this subject. There appears to have been a great mechanical power employed in the filling of these veins, as well as that necessarily required in making the first fracture and divulsion.

THIS appears from the order of the contents, or filling of these veins, which is a thing often observed to be various and successive. But what it is chiefly now in view to illustrate, is that immense force which is manifested in the fracture and dispersion of the solid contents which had formerly filled those veins. Here we find fragments of rock and spar floating in the body of a vein filled with metallic substances; there, again, we see the various fragments of metallic masses floating in the sparry and siliceous contents.

ONE thing is demonstrable from the inspection of the veins and their contents; this is, the successive irruptions of those fluid substances breaking the solid bodies which they meet, and floating those fragments of the broken bodies in the vein. It is very common to see three successive series of those operations; and all this may be perceived in a small fragment of stone, which a man of science may examine in his closet, often better than descending to the mine, where all the examples are found on an enlarged scale.

LET us now consider what power would be required to force up, from the most unfathomable depth of the ocean, to the Andes or the Alps, a column for fluid metal and of stone. This power cannot be much less than that required to elevate the highest land upon the globe. Whether, therefore, we shall consider the general veins as having been filled by mineral steams, or by fluid minerals, an elevating power of immense force is still required, in order to form as well as fill those veins. But such a power acting under the consolidated masses at the bottom of the sea, is the only natural means for making those masses land.

IF such have been the operations that are necessary for the production of this land; and if these operations are natural to the globe of this earth, as being the effect of wisdom in its contrivance, we shall have reason to look for the actual manifestation of this truth in the phaenomena of nature, or those appearances which more immediately discover the actual cause in the perceived effect.

TO see the evidence of marble, a body that is solid, having been formed of loose materials collected at the bottom of the sea, is not always easy, although it may be made abundantly plain; and to be convinced that this calcareous stone, which calcines so easily in our fires, should have been brought into fusion by subterraneous heat, without suffering calcination, must require a chain of reasoning which ever one is not able to attain. But when fire bursts forth from the bottom of the sea, and when the land is heaved up and down, so as to demolish cities in an instant, and split asunder rocks and solid mountains, there is nobody but must see in this a power, which may be sufficient to accomplish every view of nature in erecting land, as it is situated in the place most advantageous for that purpose.

THE only question, therefore, which it concerns us to decide at present, is, whether those operations of extreme heat, and violent mechanic force, be only in the system as a matter of accident; or if, on the contrary, they are operations natural to the globe, and necessary in the production of such land as this which we inhabit. The answer to this is plain: these operations of the globe, remain at present with undiminished activity, or in the fulness of their power.

A stream of melted lava flows from the sides of Mount Ætna. Here a column of weighty matter raised an immense height above the level of the sea, and rocks of an enormous size are projected from its orifice some miles into the air. Every one acknowledges that here is the liquefying power and expansive force of subterranean fire, or violent heat. But that Sicily itself had been raised from the bottom of the ocean, and that the marble called Sicilian Jasper, had its solidity upon the same principle with the lava, would stumble many a naturalist to acknowledge. Nevertheless, I have in my possession a table of this marble, from which it is demonstrable, that this calcareous stone had flowed, and been in such a state of fusion and fluidity as lava.

HERE is a comparison formed of two mineral substances, to which it is of the highest importance to attend. The solidity and present state of the one of these is commonly thought to be that of water. This, however, is not the case. The immediate state and condition of both these bodies is now to be considered as equally the effect of fire or heat. The reason of our forming such a different judgment with regard to these two subjects is this; we see, in the one case, the more immediate connection of the cause and the effect, while, in the other, we have only the effects from whence we are in science to investigate the cause.

BUT, if it were necessary always to see this immediate connection, in order to acknowledge the operation of a power which, at present, is extinguished in the effect, we should lose the benefit of science, or general principles, from whence particulars may be deduced, and we should be able to reason no better that the brute. Man is made for science; he reasons from effects to causes, and from causes to effects; but he does not always reason without error. In reasoning, therefore, from appearances which are particular, care must be taken how we generalize; we should be cautious not to attribute to nature, laws which may perhaps be only of our own invention.

THE immediate question now before us is not, if the subterraneous fire, or elevating power, which we perceive sometimes as operating with such energy, be the consolidating cause of strata formed at the bottom of the sea; nor, if that power be the means of making land appear above the general surface of the water; for, though this be the end we want to arrive at ultimately, the question at present in agitation respects the laws of nature, or the generality of particular appearances.

HAS the globe within it such an active power as fits it for the renovation of that part of its constitution which may be subject to decay? Are those powerful operations of fire, or subterraneous heat, which so often have filled us with terror and astonishment, to be considered as having always been? Are they to be concluded as proper to every part upon the globe, and as continual in the system of this earth? If these points in question shall be decided in the affirmative, we can be at no loss in ascertaining the power which has consolidated strata, nor in explaining the present situation of those bodies, which had their origin at the bottom of the sea. This, therefore, should be the object of our pursuit; and, in order to have demonstration in a case of physical enquiry, we must again have recourse to the book of nature.

THE general tendency of heat is to produce fluidity and softness; as that of cold is, on the contrary, to harden soft and fluid bodies. But this softening power of heat is not uniform in its nature; it is made to act with very different effect, according to the nature of the substance to which it is applied. We are but limited in the art of increasing the heat or the cold of bodies; we find, however, extreme difference in their substances with respect to fusibility.

A FUSIBLE substance, or mineral composition in a fluid state, is emitted from those places of the earth at which subterraneous fire and expansive force are manifested in those eruptive operations. In examining these emitted bodies, men of science find a character for such productions, in generalizing the substance, and understanding the natural constitution of those bodies. It is in this manner, that such a person, finding a piece of lava in any place of the earth, says with certainty, Here is a stone which had congealed from a melted state.

HAVING thus found a distinguishing character for those fused substances called, in general, lavas, and having the most visible marks for that which had been actually a volcano, naturalists, in examining different countries, have discovered the most undoubted proofs of many ancient volcanos, which had not been before suspected. Thus, volcanos will appear to be not a matter of accident, or as only happening in an particular place, they are general to the globe, so far as there is no place upon the earth that may not have an eruption of this kind; although it is by no means necessary for every place to have had those eruptions.

VOLCANOS are natural to the globe, as general operations; but we are not to consider nature as having a burning mountain for an end in her intention, or as a principal purpose in the general system of this world. The end of nature in placing an internal fire or power of heat, and a force of irresistible expansion, in the body of this earth, is to consolidate the sediment collected at the bottom of the sea, and to form thereof a mass of permanent land above the level of the ocean, for the purpose of maintaining plants and animals. The power appointed for this purpose is, as on all other occasions, where the operation is important, and where there is any danger of a shortcoming, wisely provided in abundance; and there are contrived means for disposing of the redundancy. These, in the present case, are our volcanos.

A VOLCANO is not made on purpose to frighten superstitious people into fits of piety and devotion, nor to overwhelm devoted cities with destruction; a volcano should be considered as a spiracle to the subterranean furnace, in order to prevent the unnecessary elevation of land, and fatal effects of earthquakes; and we may rest assured, that they, in general, wisely answer the end of their intention, without being in themselves an end, for which nature had exerted such amazing power and excellent contrivance.

LET us take a view of the most elevated places of the earth; if the present theory is just, it is there that we should find volcanos. But is not this the case? There are volcanos in the Andes; and round the Alps we find many volcanos, which are in France upon the one side, and in Germany upon the other, as well as upon the Italian side, where Vesuvius still continues to exhibit violent eruptions.

IT is not meant to allege, that it is only upon the summit of a continent volcanos should appear. Subterraneous fire has sometimes made its appearance in bursting from the bottom of the sea. But, even in this last case, land was raised from the bottom of the sea, before the eruption made its exit into the atmosphere. It must also be evident, that, in this case of the new island near Santorini, had the expansive power been retained, instead of being discharged. much more land might have been raised above the level of the ocean.

NOW, the eruption of that elastic force through the bottom of the sea, may be considered as a waste of power in the operations of the globe, where the elevation of the indurated strata is an object in the exertion of that power; whereas, in the centre of a continent sufficiently elevated above the level of the sea, the eruption of that fiery vapour calculated to elevate the land, while it may occasionally destroy the habitations of a few, provides for the security and quiet possession of the many.

IN order to see the wisdom of this contrivance, let us consider the two extreme places at which this eruption of ignited matter may be performed. These are, on the one hand, within a continent of land, and, on the other, at the bottom of the ocean. In the one case, the free eruption of the expanding power should be permitted; because the purpose for which it had been calculated to exist, has been accomplished. In the other, again, the free eruption of that powerful matter should be repressed; because there is reserved for that power much of another operation in that place. But, according to the wise constitution of things, this must necessarily happen. The eruption of the fiery vapour from volcanos on the continent or land, is interrupted only occasionally, by the melted bodies flowing in the subterraneous chimney; whereas, at the bottom of the ocean, the contact of the water necessarily tends to close the orifice, by accumulating condensed matter upon the weakest place.

IF this be a just theory of the natural operations of the globe, we shall have reason to expect, that great quantities of this melted matter or fusible substance may be found in form of lava, among the strata of the earth, where there are no visible marks of any volcano, or burning mountain, having existed. Here, therefore, is an important point to be determined; for, if it shall appear, that much of this melted matter, analogous to lave, has been forced to flow among the strata which had been formed at the bottom of the sea, and now are found forming dry land above its surface, it will be allowed, that we have discovered the secret operations of nature concocting future land, as well as those by which the present habitable earth had been produced from the bottom of the abyss. Here, therefore, we shall at present rest the argument, with endeavouring to shew that such is actually the case.

IT appears from CRONSTEDT's Mineralogy, that the rockstone, called trap by the Swedes, the amygdaloides and the schwarts-stein of the Germans, are the same with the whinstone of this country. This is also confirmed by specimens from Sweden, sent me by my friend Dr GAHN. Whatever, therefore, shall be ascertained with regard to our whinstone, may be so far generalised or extended to the countries of Norway, Sweden, and Germany.

THE whinstone of Scotland is also the same with the toadstone of Derbyshire, which is of the amygdaloides species; it is also the same with the ragstone of the south of Staffordshire, which is a simple whinstone, or perfect trap. England, therefore, must be included in this great space of land, the mineral operations of which we explore; and also Ireland, of which the Giants Causeway, and many others, are sufficient proof.

IN the south of Scotland, there is a ridge of hills, which extends from the west side of the island in Galloway to the east side in Berwickshire, composed of granite, of schistus, and of siliceous strata. The Grampians on the north, again, form another range of mountains of the same kind; and between these two great fields of broken, tumbled and distorted strata, there lies a field of lesser hardness and consolidation, in general; but a filed in which there is a great manifestation of subterraneous fire, and of exerted force.

THE strata in this space consist, in general, of sandstone, coal, limestone or marble, ironstone, and marl or argillaceous strata, with strata of analogous bodies, and the various compositions of these. But what is to the present purpose is this, that, through all this space, there are interspersed immense quantities of whinstone; a body which is to be distinguished as very different from lava; and now the disposition of this whinstone is to be considered.

SOMETIMES it is found in an irregular mass or mountain, as Mr CRONSTEDT has properly observed; but he has also said, that this is not the case in general. His words are: "It is oftener found in form of veins in mountains or another kind, running commonly in a serpentine manner, contrary or across to the direction of the rock itself."

THE origin of this form, in which the trap or whinstone appears, is most evident to inspection, when we consider that this solid body has been in a fluid state, and introduced, in that state, among strata which preserved their proper form. The strata appear to have been broken, and the two correspondent parts of those strata are separated to admit the flowing mass of whinstone.

A FINE example of this kind may be seen upon the south side of the Earn, on the road to Crief. It is twenty-four yards wide, stands perpendicular, and appears many feet above the surface of the ground. It runs from that eastward, and would seem to be the same with that which crosses the river Tay, in forming Campsy-lin above Stanley, as a lesser one of the same kind does below it. If have seen it at Lednoc upon the Ammon, where it forms a cascade in that river, about five or six miles west of Campsy-lin. It appears to run from the Tay east through Strathmore, so that it may be considered as having been traced for twenty or thirty miles, and westwards to Drummond castle, perhaps much farther.

TWO small veins of the same kind, only two or three feet wide, may be seen in the bed of the Water of Leith, traversing the horizontal strata, the one is above St BERNARD's well, the other immediately below it. But, more particularly, in the shire of Ayr, to the north of Irvine, there are to be seen upon the coast, between that and Scarmorly, in the space of about twenty miles, more than twenty or thirty such dykes (as they are called) of whinstone. Some of them are of a great thickness; and, in some places, there is perceived a short one, running at right angles, and communicating with the other two that run parallel.

THERE is in this country, and in Derbyshire[5] , another regular appearance of this stone, which CRONSTEDT has not mentioned. In this case, the strata are not broken in order to have the whinstone introduced, they are separated, and the whinstone is interjected in form of strata, having various degrees of regularity, and being of different thickness. On the south side of Edinburgh, I have seen, in little more than the space of a mile from east to west, nine or ten masses of whinstone interjected among the strata. These masses of whinstone are from three or four to an hundred feet thick, running parallel in planes inclined to the horizon, and forming with it an angle of about twenty or thirty degrees, as may be seen at all times in the hill of Salisbury Craggs.

HAVING thus described these masses, which have flowed by means of heat among the strata of the globe, strata which had been formed by subsidence at the bottom of the sea, it will now be proper to examine the difference that subsists between these subterraneous lavas, as they may be termed,

[5] See Mr WHITEHURST'S Theory of the Earth.

and the analogous bodies, which are proper lavas, in having issued out of a volcano[6].

THERE can be no doubt that these two different species of bodies have had the same origin, and that they are composed of the same materials nearly; but from the different circumstances of their production, there is formed a character to these bodies, by which they may be perfectly distinguished. The difference of those circumstances, consists in this; the one has been emitted to the atmosphere in its fluid state, the other only came to be exposed to the light in a long course of time, after it had congealed under the compression of an immense load of earth, and after certain operations, proper to the mineral regions, had been exercised upon the indurated mass. This is the cause of the difference between those erupted lavas, and our whinstone, toadstone, and the Swedish trap, which may be termed subterraneous lava. The visible effects of those different operations may now be mentioned.

IN the erupted lavas, those substances which are subject to calcine and vitrify in our fires, suffer similar changes, when delivered from a compression which has rendered them fixed, though in an extremely heated state. Thus, a lava in which there is much calcareous spar, when it comes to be exposed to the atmosphere, or delivered from the compressing force of

[6] The Chevalier de Dolomieu, in his accurate examination of Ætna and the Lipari islands, has very well observed the distinction of these two different species of lavas; but without seeming to know the principle upon which this essential difference depends. No bias of system, therefore, can here be supposed as perverting the Chevalier's view, in taking those observations; and these are interesting to the present theory, as corresponding perfectly with the facts from whence it has been formed. It will be proper to give the account of these in his own words. La zeolite est tres-commune dans certains laves de l'Ethna; il feroit peut être possible d'y en recontrer des morceaux aussi gros que ceux que fournit l'isle de Ferroé. Quoique cette substance semble ici appartenir aux laves, je ne dirai cependant point que toutes les zeolites soient volcaniques, ou unies à des matieres volcaniques; celles que l'on trouve en Allemagne sont, dit-on, dans des circonstances differentes; mais je doit annoncer que je n'ai trouvé cette substance en Sicile, que dans les seules laves qui evidemment ont coulé dans la mer, et qui ont été recouvertes par ses eaux. La zeolite des laves n'est point une dejection volcanique, ni une production du feu, ni même un matiere que les laves aient enveloppée lorsequ'elles etoient fluides; elle est le resultat d'une operation et d'une combinaison posterieure, auxquelles les eaux de la mer ont concouru. Les laves qui n'ont pas été submergées, n'en contiennent jamais. J'ai trouvé ces observation si constantes, que par-tout où je rencontrois de la zeolite, j'étois sûr de trouver d'autres preuves de submersion, et partout où je voyois des laves recouvertes des dépôts de l'eau, j'étois sûr de trouver de la zeolite, et un de ces faits m'a toujours indiqué l'autre. Je me suis servi avec succes de cette observation pour diriger mes recherches, et pour connoitre l'antiquité des laves. *Mineralogie de Volcans, par M. Faujas de Saint-Fond*. Here would appear to be the distinction of subterraneous lava, in which zeolite and calcareous spar may be found, and that which has flowed from a volcano, in which neither of these are ever observed.

its confinement, effervesces by the explosion of its fixed air; the calcareous earth, at the same time, vitrifies with the other substances: hence such violent ebullition in volcanos, and hence the emission of so much pumice-stone and ashes, which are of the same nature.

IN the body of our whinstone, on the contrary, there is now mark of calcination or vitrification. We frequently find in it much calcareous spar, or the *terra calcarea aerata*, which had been in a melted state by heat, and had been crystallized by congelation into a sparry form. Such is the *lapis amygdaloides*, and many of our whinstone rocks, which contain pebbles crystallized and variously figured, both calcareous, siliceous, and of a mixture in which both these substances form distinct parts. The specimens of this kind, which I have from the whinstone or porphyry rock of the Calton-hill, exhibit every species of mineral operation, in forming jasper, figured agate, and marble; and they demonstrate, that this had been performed by heat or fusion.

I DO not mean to say, that this demonstration is direct; it is conditional, and proceeds upon the supposition, that the basaltic or porphyry rock, in which those specimens are found, is a body which had been in a melted state. Now, this is a supposition for which I have abundance of evidence, were it required; but naturalists are now sufficiently disposed to admit that proposition; they even draw conclusions from this fact, which, I think, they are not sufficiently warranted in doing; that is, from this appearance, they infer the former existence of volcanos in those places. For my part, though I have made those most strict examination, I never saw and vestige of such an event. That there are, in other countries, evident marks of volcanos which have been long extinguished, is unquestionably true; but naturalists, imagining that there are no other marks of subterraneous fire and fusion, except in the production of a lava, attribute to a volcano, as a cause, these effects, which only indicate the exertion of that power which might have been the cause of a volcano.

IF the theory now given be just, a rock of marble is no less a mark of subterraneous fire and fusion, than that of the basaltes; and the flowing of basaltic streams among strata broken and displaced, affords the most satisfactory evidence of those operations by which the body of our land had been elevated above the surface of the sea; but it gives no proof that the eruptive force of mineral vapours had been discharged in a burning mountain. Now, this discharge is essential in the proper idea of a volcano.

BESIDES this internal mark of an unerupted lava in the substance of the stone or body of the flowing mass, there are others which belong to it in common with all other mineral strata, consolidated by subterraneous fire, and changed from the place of their original formation; this is, the being broken and dislocated, and having veins of foreign matter formed in their separations and contractions.

IF these are mineral operations, proper to the lower regions of the earth, and exerted upon bodies under immense compression, such things will be sometimes found in the unerupted lavas, as well as in the contiguous bodies with which they are associated. If, on the contrary, these are operations proper to the surface of the earth, where the dissolving power of water and air take place, and where certain stalactical and ferruginous concretions are produced by these means; then, in erupted lavas, we should find mineral concretions, which concretions should be denied to bodies which had been consolidated at the bottom of the sea; that is to say, where, without the operation of subterraneous fire, no changes of that kind could have taken place, as has already been observed. But in the unerupted species of lava, that is to say, in our whinstone, every species of mineral appearance is occasionally to be found. Let those who have the opportunity to examine, say, what are to be found in proper lavas, that is, those of the erupted kind. Sir WILLIAM HAMILTON informed me, when I shewed him those mineral veins and spars in our whinstone, that he had never observed the like in lavas.

WE have now formed some conclusions with regard to the nature and production of those parts of the land of this globe which we have had the means of examining perfectly; but form the accounts of travellers, and from the specimens which are brought to us from distant parts, we have reason to believe, that all the rest of the earth is of the same nature with that which has been now considered. The great masses of the earth are the same every where; and all the different species of earths, of rocks or stone, which have as yet appeared, are to be found in the little space of this our island.

IT is true, that there are peculiar productions in the mineral kingdom which are rare, as being found only in few places; but these things are merely accidental in relation to the land, for they belong in property to those parts of the mineral region which we never see. Such are, the diamond of the east, the platina of the west, and the tin of Cornwall, Germany, and Sumatra. Gold and silver, though found in many countries, do not appear to be immediately necessary in the production of a habitable country. Iron, again, is universal in the operations of the globe, and is found often in that profusion which equals its utility. Between these two extremes, we find all other minerals, that is to say, here and there in moderate quantity, and apparently in some proportion to their use. But all these substances are to be considered as the vapours of the mineral regions, condensed occasionally in the crevices of the land; and it is only the rocks and strata (in which those mineral veins are found) that are now examined with regard to their original composition at the bottom of the sea, as well as to that operation by which those bodies had been indurated in their substance, and elevated from the place in which they had been formed.

THUS, we have sufficient reason to believe, that, in knowing the construction of the land in Europe, we know the constitution of the land in every part of the globe. Therefore, we may proceed to form general conclusions, from the knowledge of the mineral region, thus acquired in studying those parts which are seen.

HAVING thus found, *first*, That the consolidated and indurated masses of our strata had suffered the effects of violent heat and fusion; 2*dly*, That those strata, which had been formed in a regular manner at the bottom of the sea, have been violently bended, broken and removed from their original place and situation; and, *lastly*, Having now found the most indubitable proof, that the melting, breaking, and removing power of subterraneous fire, has been actually exerted upon this land which we examine, we cannot hesitate in ascribing these operations as a cause to those effects which are exposed to our view. Now, these may be considered as consisting the solid state and present situation of those stratified bodies, originally formed by subsidence in the ocean; appearances which cannot, in reason, be ascribed to any other cause, and which, upon this principle, are perfectly explained.

IT is not meant to specify every particular in the means employed by nature for the elevation of our land. It is sufficient to have shewn, that there is, in nature, means employed for the consolidation of strata, formed originally of loose and incoherent materials; and that those same means have also been employed in changing the place and situation of those strata. But how describe an operation which man cannot have any opportunity of perceiving? Or how imagine that, for which, perhaps, there are not proper data to be found? We only know, that the land is raised by a power which has for principle subterraneous heat; but how that land is preserved in its elevated station, is a subject in which we have not even the means to form conjecture; at least, we ought to be cautious how we indulge conjecture in a subject where no means occur for trying that which is but supposition.

WE now proceed, from the facts which have been properly established, to reason with regard to the duration of this globe, or the general view of its operations, as a living world, maintaining plants and animals.

Part 4. System Of Decay And Renovation Observed In The Earth

PHILOSOPHERS observing an apparent disorder and confusion in the solid parts of this globe, have been led to conclude, that there formerly existed a more regular and uniform state, in the constitution of this earth; that there had happened some destructive change; and that the original structure of the earth had been broken and disturbed by some violent operation, whether natural, or from a supernatural cause. Now, all these appearances, from which conclusions of this kind have been formed, find the most perfect explanation in the theory which we have been endeavouring to establish; for they are the facts from whence we have reasoned, in discovering the nature and constitution of this earth: therefore, there is no occasion for having recourse to any unnatural supposition of evil, to any destructive accident in nature, or to the agency of any preternatural cause, in explaining that which actually exists.

IT is necessary for a living or inhabited world, that this should consist of land and water. It is also necessary, that the land should be solid and stable, resisting, with great power, the violent efforts of the ocean; and, at the same time, that this solid land should be resolved by the influence of the sun and atmosphere, so as to decay, and thus become a soil for vegetation. But these general intentions are perfectly fulfilled in the constitution of our earth, which has been now investigated. This great body being formed of different mixed masses, having various degrees of hardness and solubility, proper soil for plants is supplied from the gradual resolution of the solid parts; fertility in those soils arises from the mixture of different elementary substances; and stability is procured to that vegetable world, by the induration of certain bodies, those rocks and stones, which protect the softer masses of clay and soil.

IN this manner, also, will easily be explained those natural appearances which diversify the surface of the earth for the use of plants and animals, and those objects which beautify the face of nature for the contemplation of mankind. Such are, the distinctions of mountains and valleys, of lakes and river, of dry barren desarts and rich watered plains, of rocks which stand apparently unimpaired by the lapse of time, and sands with fluctuate with winds and tides. All these are the effects of steady causes; each of these has its proper purpose in the system of the earth; and in that system is contained another, which is that of living growing bodies, and of animated beings.

BUT, besides this, man, the intellectual being, has, in this subject of the mineral kingdom, the means of gratifying the desire of knowledge, a faculty by which he is distinguished from the animal, and by which he improves his mind in knowing causes. Man is not satisfied, like the brute, in seeing things which are; he seeks to know how things have been, and what they are to be. It is with pleasure that he observes order and regularity in the works of nature, instead of being disgusted with disorder and confusion; and he is made happy from the appearance of wisdom and benevolence in the design, instead of being left to suspect in the Author of nature, any of that imperfection which he finds in himself.

LET us now take a view of that system of mineral oecomony, in which may be perceived every mark of order and design, of provident wisdom and benevolence.

WE have been endeavouring to prove, that all the continents and island of this globe had been raised above the surface of the ocean; we have also aimed at pointing out the cause of this translation of matter, as well as of the general solidity of that which is raised to our view; but however this theory shall be received, no person of observation can entertain a doubt, that all, or almost all we see of this earth, had been originally formed at the bottom of the sea. We have now another object in our view; this is to investigate the operations of the globe, at the time that the foundation of this land was laying in the waters of the ocean, and to trace the existence and the nature of things, before the present land appeared above the surface of the waters. We should thus acquire some knowledge of the system according to which this world is ruled, both in its preservation and production; and we might be thus enabled to judge, how far the mineral system of the world shall appear to be contrived with all the wisdom, which is so manifest in what are termed the animal and vegetable kingdoms.

IT must not be imagined that this undertaking is a thing unreasonable in its nature; or that it is a work necessarily beset with any unsurmountable difficulty; for, however imperfectly we may fulfil this end proposed, yet, so far as it is to natural causes that are to be ascribed the operations of former time, and so far as, from the present state of things, or knowledge of natural history, we have it in our power to reason from effect to cause, there are, in the constitution of the world, which we now examine, certain means to read the annals of a former earth.

THE object of enquiry being the operations of the globe, during the time when the present earth was forming at the bottom of the sea, we are now to take a very general view of nature, without descending into those particulars which so often occupy the speculations of naturalists, about the present state of things. We are not at present to enter into any discussion with regard to what are the primary and secondary mountains of the earth; we are not to consider what is the first, and what the last, in those things which now are seen; whatever is most ancient in the strata which we now examine, is supposed to be collecting at the bottom of the sea, during the period concerning which we are now to enquire.

WE have already considered those operations which had been necessary informing our solid land, a body consisting of materials originally deposited at the bottom of the ocean; we are now to investigate the source from whence had come all those materials, from the collection of which the present land is formed; and from knowing the state in which those materials had existed, previously to their entering the composition of our strata, we shall learn something concerning the natural history of this world, while the present earth was forming in the sea.

WE have already observed, that all the strata of the earth are composed either from the calcareous relics of sea animals, or from the collection of such materials as we find upon our shores. at a gross computation, there may perhaps be a fourth part of our solid land, which is composed from the matter that had belonged to those animals. Now, what a multitude of living creatures, what a quantity of animal oeconomy must have been required for producing a body of calcareous matter which is interspersed throughout all the land of the globe, and which certainly forms a very considerable part of that mass! Therefore, in knowing how these animals had lived, or with what they had been fed, we shall have learned a most interesting part of the natural history of this earth; a part which it is necessary to have ascertained, in order to see the former operations of the globe, while preparing the materials of the present land. But, before entering upon this subject, let us examine the other materials of which our land is formed.

GRAVEL forms a part of those materials which compose our solid land; but gravel is no other than a collection of the fragments of solid stones worn round, or having their angular form destroyed by agitation in water, and the attrition upon each other, or upon similar hard bodies. Consequently, in finding masses of gravel in the composition of our land, we must conclude, that there had existed a former land, on which there had been transacted certain operations of wind and water, similar to those which are natural to the globe at present, and by which new gravel is continually prepared, as well as old gravel consumed or diminished by attrition upon our shores.

SAND is the material which enters, perhaps in greatest quantity, the composition of our land. But sand is no other than small fragments of hard and solid bodies, worn or rounded more or less by attrition; consequently, the same natural history of the earth, which is investigated from the masses of gravel, is also applicable to those masses of sand which we find forming so large a portion of our present land throughout all the earth.

CLAY is now to be considered as the last of those materials of which our strata re composed; but, in order to understand the nature of this ingredient, something must be premised.

CLAY is a mixture of different earths or hard substances, in an impalpable state. Those substances are chiefly the siliceous and aluminous earths. Other earths are occasionally mixed in clays, or perhaps always to be found in some small portion. But this does not affect the general character of clay; it only forms a special variety in the subject. A sensible or considerable portion of calcareous earth, in the composition of clay, constitutes a marl, and s sufficient admixture of sand, a loam.

AN indefinite variety of those compositions of clay form a large portion of the present strata, all indurated and consolidated in various degrees; but this great quantity of siliceous, argillaceous, and other compound substances, in form of earth or impalpable sediment, corresponds perfectly with that quantity of those same substances which must have been prepared in the formation of so much gravel and sand, by the attrition of those bodies in the moving waters.

THEREFORE, from the consideration of those materials which compose the present land, we have reason to conclude, that, during the time this land was forming, by the collection of its materials at the bottom of the sea, there had been a former land containing materials similar to those which we find at present in examining the earth. We may also conclude, that there had been operations similar to those which we now find natural to the globe, and necessarily exerted in the actual formation of gravel, sand and clay. But what we have now chiefly to view to illustrate is this, that there had then been in the ocean a system of animated beings, which propagated their species, and which have thus continued their several races to this day.

IN order to be convinced of that truth, we have but to examine the strata of our earth, in which we find the remains of animals. In this examination, we not only discover every genus of animal which at present exists in the sea, but probably every species, and perhaps some species with which at present we are not acquainted. There are, indeed, varieties in those species, compared with the present animals which we examine, but no greater varieties than may perhaps be found among the same species in the different quarters of the globe. Therefore, the system of animal life, which had been maintained in the ancient sea, had not been different from that which now subsists, and of which it belongs to naturalists to know the history.

IT is the nature of animal life to be ultimately supported from matter of vegetable production. Inflammable matter may be considered as the *pabulum* of life. This is prepared in the bodies of living plants, particularly in their leaves exposed to the sun and light. This inflammable matter, on the contrary, is consumed in animal bodies, where it produces heat or light, or both. Therefore, however animal matter, or the pabulum of life, may circulate through a series of digesting powers, it is constantly impaired or diminishing in the course of this oeconomy, and, without the productive power of plants, it would finally be extinguished.

THE animals of the former world must have been sustained during indefinite successions of ages. The mean quantity of animal matter, therefore, must have been preserved by vegetable production, and the natural waste of inflammable substance repaired with continual addition; that is to say, the quantity of inflammable matter necessary to the animal consumption, must have been provided by means of vegetation. Hence we must conclude, that there had been a world of plants, as well an ocean replenished with living animals.

WE are now, in reasoning from principles, come to a point decisive of the question, and which will either confirm the theory, if it be just, or confute our reasoning, if we have erred. Let us, therefore, open the book of Nature, and read in her records, if there had been a world bearing plants, at the time when this present world was forming at the bottom of the sea.

HERE the cabinets of the curious are to be examined; but here some caution is required, in order to distinguish things perfectly different, which sometimes are confounded.

FOSSIL WOOD, to naturalists in general, is wood dug up from under ground, without enquiring whether this had been the production of the present earth, or that which had preceded it in the circulation of land and water. The question is important, and the solution of it is, in general, easy. The vegetable productions of the present earth, however deep they may be found buried beneath the surface, and however ancient they may appear, compared with the records of our known times, are new, compared with the solid land on which they grew; and they are only covered with the produce of a vegetable soil, or the alluvion of the present land on which we dwell, and on which they had grown. But the fossil bodes which from the present subject of enquiry, belonged to former land, and are found only in the sea-born strata of our present earth. It is to these alone that we appeal, in order to prove the certainty of former events.

MINERALIZED wood, therefore, is the object now enquired after; that wood which had been lodged in the bottom of the sea, and there composed part of a stratum, which hitherto we have considered as only formed of the materials proper to the ocean. Now, what a profusion of this species of fossil wood is to be found in the cabinets of collectors, and even in the hands of lapidaries, and such artificers of polished stones! In some places, it would seem to be as common as the agate.

I SHALL only mention a specimen in my own collection. It is wood petrified with calcareous earth, and mineralized with pyrites. This specimen of wood contains in itself, even without the stratum of stone in which it is embedded, the most perfect record of its genealogy. It had been eaten or perforated by those sea-worms which destroy the bottoms of our ships. There is the clearest evidence of this truth. Therefore, this wood had grown upon land which stood above the level of the sea, while the present land was only forming at the bottom of the ocean.

WOOD is the most substantial part of plants, as shells are the more permanent part of marine animals. It is not, however, the woody part alone of the ancient vegetable world that is transmitted to us in the record of our mineral pages. We have the type of many species of foliage, and even of the most delicate flower; for, in this way, naturalists have determined, according to the Linnaean system, the species, or at least the genus, of the plant. Thus, the existence of a vegetable system at the period now in contemplation, so far from being doubtful, is a matter of physical demonstration.

THE profusion of this vegetable matter, delivered into the ocean, which then generated land, is also evidenced in the amazing quantities of mineral coal, which is to be found in perhaps every region of the earth.

NOTHING can be more certain, than that all the coaly or bituminous strata have had their origin from the substance of vegetable bodies that grew upon the land. Those strata, though, in general, perfectly consolidated, often separate horizontally in certain places; and there we find the fibrous or vascular structure of the vegetable bodies. Consequently, there is no doubt of fossil coal being a substance of vegetable production, however animal substances also may have contributed in forming this collection of oleaginous or inflammable matter.

HAVING thus ascertained the state of a former earth, in which plants and animals had lived, as well as the gradual production of the present earth, composed from the materials of a former world, it must be evident, that here are two operations which are necessarily consecutive. The formation of the present earth necessarily involves the destruction of the continents in the ancient world; and, by pursuing in our minds the natural operations of a former earth, we clearly see the origin of that land, by the fertility of which, we, and all the animated bodies of the sea, are fed. It is in like manner, that, contemplating the present operations of the globe, we may perceive the actual existence of those productive causes, which are now laying the foundation of land in the unfathomable regions of the sea, and which will, in time, give birth to future continents.

BUT though, in generalizing the operations of nature, we have arrived at those great events, which, at first sight, may fill the mind with wonder and with doubt, we are not to suppose, that there is any violent exertion of power, such as is required in order to produce a great event in little time; in nature, we find no deficiency in respect of time, nor any limitation with regard to power. But time is not made to flow in vain; nor does there ever appear the exertion of superfluous power, or the manifestation of design, not calculated in wisdom to effect some general end.

THE events now under consideration may be examined with a view to see this truth; for it may be enquired, why destroy one continent in order to erect another? The answer is plain; Nature does not destroy a continent from having wearied of a subject which had given pleasure, or changed her purpose, whether for a better or a worse; neither does she erect a continent of land among the clouds, to shew her power, or to amaze the vulgar man: Nature has contrived to productions of vegetable bodies, and the sustenance of animal life, to depend upon the gradual but sure destruction of a continent; that is to say, these two operations necessarily go hand in hand. But with such wisdom has nature ordered things in the oeconomy of this world, that the destruction of one continent is not brought about without the renovation of the earth in the production of another; and the animal and vegetable bodies, for which the world above the surface of the sea is levelled with its bottom, are among the means employed in those operations, as well as the sustenance of those living beings is the proper end in view.

THUS, in understanding the proper constitution of the present earth, we are led to know the source from whence had come all the materials which nature had employed in the construction of the world which appears; a world contrived in consummate wisdom for the growth and habitation of a great diversity of plants and animals; and a world peculiarly adapted to the purposes of man, who inhabits all its climates, who measures its extent, and determines its productions at his pleasure.

THE whole of a great object or event fills us with wonder and astonishment, when all the particulars, in the succession of which the whole had been produced, may be considered without the least emotion. When, for example, we behold the pyramids of Egypt, our mind is agitated with a crowd of ideas that highly entertains the person who understands the subject; but the carrying a heavy stone up to the top of a hill or mountain would give that person little pleasure or concern. We wonder at the whole operation of the pyramid, but not at any one particular part.

THE raising up of a continent of land from the bottom of the sea, is an idea that is too great to be conceived easily in all the parts of its operation, many of which are perhaps unknown to us; and without being properly understood, so great an idea may appear like a thing that is imaginary. In like manner, the co-relative, or corresponding operation, the destruction of the land, is an idea that does not easily enter into the mind of man in its totality, although he is daily witness to part of the operation. We never see a river in a flood, but we must acknowledge the carrying away of part of our land, to be sunk at the bottom of the sea; we never see a storm upon the coast, but we are informed of a hostile attack of the sea upon our country; attacks which must, in time, wear away the bulwarks of our soil, and sap the foundations of our dwellings. Thus, great things are not understood without the analyzing of many operations, and the combination of time with many events happening in succession.

LET us now consider what is to be the subject of examination, and where it is that we are to observe those operations which must determine either the stability or the instability of this land on which we live.

OUR land has two extremities; the tops of mountains, on the one hand, and the sea-shores, on the other: it is the intermediate space between these two, that forms the habitation of plants and animals. While there is a sea-shore and a higher ground, there is that which is required in the system of the world: Take these away, and there would remain an aqueous globe, in which the world would perish. But, in the natural operations of the world, the land is perishing continually; and this is that which now we want to understand.

UPON the one extremity of our land, there is no increase, or there is no accession of any mineral substance. That place is the mountain top, on which nothing is observed but continual decay. The fragments of the mountain are removed in a gradual succession from the highest station to the lowest. Being arrived at the shore, and having entered the dominion of the waves, in which they find perpetual agitation, these hard fragments, which had eluded the resolving powers natural to the surface of the earth, are incapable of resisting the powers here employed for the destruction of the land. By the attrition of one hard body upon another, the moving stones and rocky shore, are mutually impaired. And that solid mass, which of itself had potential stability against the violence of the waves, affords the instruments of its own destruction, and thus gives occasion to its actual instability.

IN order to understand the system of the heavens, it is necessary to connect together periods of measured time, and the distinguished places of revolving bodies. It is thus that system may be observed, or wisdom, in the proper adapting of powers to an intention. In like manner, we cannot understand the system of the globe, without seeing that progress of things which is brought about in time, thus measuring the natural operations of the earth with those of the heavens. This is properly the business of the present undertaking.

OUR object is to know the time which had elapsed since the foundation of the present continent had been laid at the bottom of the ocean, to the present moment in which we speculate on these operations. The space is long; the data for the calculations are, perhaps, deficient: no matter; so far as we know our error, or the deficiency in our operation, we proceed in science, and shall conclude in reason. It is not given to man to know what things are truly in themselves, but only what those things are in his thought. We seek not to know the precise measure of any thing; we only understand the limits of a thing, in knowing what it is not, either on the one side or the other.

WE are investigating the age of the present earth, from the beginning of that body which was in the bottom of the sea, to the perfection of its nature, which we consider as in the moment of our existence; and we have necessarily another area, which is collateral, or correspondent, in the progress of those natural events. This is the time required, in the natural operations of this globe, for the destruction of a former earth; and earth equally perfect with the present, and an earth equally productive of growing plants and living animals. Now, it must appear, that, if we had a measure for the one of those corresponding operations, we would have an equal knowledge of the other.

THE formation of a future earth being in the bottom of the ocean, at depths unfathomable to man, and in regions far beyond the reach of his observation, here is apart of the process which cannot be taken as a principle in forming an estimate of the whole. But, in the destruction of the present earth, we have a process that is performed within the limits of our observation; therefore, in knowing the measure of this operation, we shall find the means of calculating what had passed on a former occasion, as well as what will happen in the composition of a future earth. Let us, therefore, now attempt to make this estimate of time and labour.

THE highest mountain may be levelled with the plain from when it springs, without the loss of real territory in the land; but when the ocean makes encroachment on the basis of our earth, the mountain, unsupported, tumbles with its weight; and with the accession of hard bodies, moveable with the agitation of the waves, gives to the sea the power of undermining farther and farther into the solid basis of our land. This is the operation which is to be measured; this is the mean proportional by which we are to estimate the age of worlds that have terminated, and the duration of those that are but beginning.

BUT how shall we measure the decrease of our land? Every revolution of the globe wears away some part of some rock upon some coast; but the quantity of that decrease, in that measured time, is not a measurable thing. Instead of a revolution of the globe, let us take an age. The age of man does no more in this estimate than a single year. He sees, that the natural course of things is to wear away the coast, with the attrition of the sand and stones upon the shore; but he cannot find a measure for this quantity which shall correspond to time, in order to form an estimate of the rate of this decrease.

BUT man is not confined to what he sees; he has the experience of former men. Let us then go to the Romans and the Greeks in search of a measure of our coasts, which we may compare with the present state of things. Here, again, we are disappointed; their descriptions of the shores of Greece and of Italy, and their works upon the coast, either give no measure of a decrease, or are not accurate enough for such a purpose.

IT is in vain to attempt to measure a quantity which escapes our notice, and which history cannot ascertain; and we might just as well attempt to measure the distance of the stars without a parallax, as to calculate the destruction of the solid land without a measure corresponding to the whole.

THE description which POLYBIUS has given of the Pontus Euxinus, with the two opposite Bosphori, the Meotis, the Propontis, and the Port of Byzantium, are as applicable to the present state of things, as they were at the writing of that history. The filling up of the bed of the Meotis, an event which, to POLYBIUS, appeared not far off, must also be considered as removed to a very distant period, though the causes still continue to operate as before.

BUT there is a thing in which history and the present sate of things do not agree. It is upon the coast of Spain, where POLYBIUS says there was an island in the mouth of the harbour of New Carthage. At present, in place of the island, there is only a rock under the surface of the water. It must be evident, however, that the loss of this small island affords no proper ground of calculation for the measure or rate of wasting which could correspond to the coast in general; as neither the quantity of what is now lost had been measured, nor its quality ascertained.

LET us examine places much more exposed to the fury of the waves and currents than the coast of Carthagena, the narrow fretum, for example, between Italy and Sicily. It does not appear, that this passage is sensibly wider than when the Romans first had known it. The Isthmus of Corinth is also apparently the same at present as it had been two or three thousand years ago. Scilla and Charibdis remain now, as they had been in ancient times, rocks hazardous for coasting vessels which had to pass that strait.

IT is not meant by this to say, these rocks have not been wasted by the sea, and worn by the attrition of moving bodies, during that space of time; were this true, and that those rocks, the bulwarks of the land upon those coasts, had not been at all impaired from that period, they might remain for ever, and thus the system of interchanging the place of sea and land upon this globe might be frustrated. It is only meant to affirm, that the quantity which those rocks, or that coast, have diminished from the period of our history, has either been too small a thing for human observation, or, which is more probable, that no accurate measurement of the subject, by which this quantity of decrease might have been ascertained, had been taken and recorded. It must be also evident, that a very small operation of an earthquake would be sufficient to render every means of information, in this manner of mensuration, unsatisfactory or precarious.

PLINY says Italy was distant from Sicily a mile and a half; but we cannot suppose that this measure was taken any otherwise than by computation, and such a measure is but little calculated to afford us the just means of a comparison with the present distance. He also says, indeed, that Sicily had been once joined with Italy. His words are: " Quondam BRUTIO agro cohaerens, mox interfuso mari avulsa *." But all that we can conclude from this history of PLINY is, that, in all times, to people considering the appearances of those two approached coasts, it had seemed probably, that the sea formed a passage between the two countries which had been once united; in like manner as is still more immediately perceived, in that smaller disjunction which is made between the island of Anglesey and the continent of Wales.

THE port of Syracuse, with the island which forms the greater and lesser, and the fountain of Arethusa, the water of which the ancients divided from the sea with a wall, do not seem to be altered. From Sicily to the coast of Egypt, there is an uninterrupted course of sea for a thousand miles; consequently, the wind, in such a stretch of sea, should bring powerful waves against those coasts. But, on the coast of Egypt, we find the rock on which was formerly built the famous tower of Pharos; and also, at the eastern extremity of the port Eunoste, the sea-bath, cut in the solid rock upon the shore. Both those rocks, buffeted immediately with the waves of the Mediterranean sea, are, to all appearance, the same at this day as they were in ancient times *.

MANY other such proofs will certainly occur, where the different parts of those coasts are examined by people of observation and intelligence. But is enough for our present purpose, that this decrease of the coasts in general has not been observed; and that it is as generally thought, that the land is gaining upon the sea, as that the sea is gaining upon the land.

TO sum up the argument, we are certain, that all the coasts of the present continents are wasted by the sea, and constantly wearing away upon the whole; but this operation is so extremely slow, that we cannot find a measure of the quantity in order to form an estimate. Therefore, the present continents of the earth, which we consider as in a state of perfection, would, in the natural operations of the globe, require a time indefinite for their destruction.

BUT, in order to produce the present continents, the destruction of a former vegetable world was necessary; consequently, the production of our present continents must have required a time which is indefinite. In like manner, if the former continents were of the same nature as the present, it must have required another space of time, which also is indefinite, before they had come to their perfection as a vegetable world.

WE have been representing the system of this earth as proceeding with a certain regularity, which is not perhaps in nature, but which is necessary for our clear conception of the system of nature. The system of nature is certainly in rule, although we may now know every circumstance of its regulation. We are under a necessity, therefore, of making regular suppositions, in order to come at certain conclusions which may be compared with the present state of things.

IT is not necessary that the present land should be worn away and wasted, exactly in proportion as new land shall appear; or, conversely, that an equal proportion of new land should always be produced as the old is made to disappear. It is only required, that, at all times, there should be a just proportion of land and water upon the surface of the globe, for the purpose of a habitable world.

NEITHER is it required in the actual system of this earth, that every part of the land should be dissolved in its structure, and worn away by attrition, so as to be floated in the sea. Parts of the land may often sink in a body below the level of the sea, and parts again may be restored, without waiting for the general circulation of land and water, which proceeds with all the certainty of nature, but which advances with an imperceptible progression. Many of such apparent irregularities may appear, without the least infringement on the general system. That system is comprehended in the preparation of future land at the bottom of the ocean, from those materials which the dissolution and attrition of the present land may have provided, and from those which the natural operations of the sea afford.

IN thus accomplishing a certain end, we are not to limit nature with the uniformity of an equable progression, although it be necessary in our computations to proceed upon equalities. Thus also, in the use of means, we are not to prescribe to nature those alone which we think suitable for the purpose, in our narrow view. It is our business to learn of nature (that is by observation) the ways and means, which in her wisdom are adopted; and we are to imagine these only in order to find means for further information, and to increase our knowledge from the examination of things which actually have been. It is in this manner, that intention may be found in nature; but this intention is not to be supposed, or vainly imagined, from what we may conceive to be.

WE have been now supposing that the beginning of our present earth had been laid in the bottom of the ocean, at the completion of the former land; but this was only for the sake of distinctness. The just view is this, that when the former land of the globe had been complete, so as to begin to waste and be impaired by the encroachment of the sea, the present land began to appear above the surface of the ocean. In this manner we suppose a due proportion to be always preserved of land and water upon the surface of the globe, for the purpose of a habitable world, such as this which we possess. We thus, also, allow time an opportunity for the translation of animals and plants to occupy the earth.

BUT, if the earth on which we live, began to appear in the ocean at the time when the last began to be resolved, it could not be from the materials of the continent immediately preceding this which we examine, that the present earth had been constructed ; for the bottom of the ocean must have been filled with materials before land could be made to appear above its surface.

LET us suppose that the continent, which is to succeed our land, is at present beginning to appear above the water in the middle of the Pacific Ocean, it must be evident, that the materials of this great body, which is formed and ready to be brought forth, must have been collected from the destruction of an earth which does not now appear. Consequently, in this true statement of the case, there is necessarily required the destruction of an animal and vegetable earth prior to the former land; and the materials of that earth which is first in our account, must have been collected at the bottom of the ocean, and begun to be concocted for the production of the present earth, when the land immediately preceding the present had arrived at its full extent.

THIS, however, alters nothing with regard to the nature of those operations of the globe. The system is still the same. It only protracts the indefinite space of time in its existence, while it gives us a view of another distinct period of the living world; that is to say, the world which we inhabit is composed of the materials, not of the earth which was the immediate predecessor of the present, but of the earth which, in ascending from the present, we consider as the third, and which had preceded the land that was above the surface of the sea, while our present land was yet beneath the water of the ocean. Here are three distinct successive periods of existence, and each of these is, in our measurement of time, a thing of indefinite duration.

WE have now got to the end of our reasoning; we have no data further to conclude immediately from that which actually is: But we have got enough; we have the satisfaction to find, that in nature there is wisdom, system, and consistency. For having, in the natural history of this earth, seen a succession of worlds, we may from this conclude that there is a system in nature; in like manner as, from seeing revolutions of the planets, it is concluded, that there is a system by which they are intended to continue those revolutions. But if the succession of worlds is established in the system of nature, it is in vain to look for any thing higher in the origin of the earth. The result, therefore, of our present enquiry is, that we find no vestige of a beginning,--no prospect of an end.

THEORY OF THE EARTH

WITH PROOFS AND ILLUSTRATIONS

BY

JAMES HUTTON

IN FOUR PARTS.

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VOL. I

CHAPTER 1

Section 1. Prospect Of The Subject To Be Treated Of

When we trace the parts of which this terrestrial system is composed, and when we view the general connection of those several parts, the whole presents a machine of a peculiar construction by which it is adapted to a certain end. We perceive a fabric, erected in wisdom, to obtain a purpose worthy of the power that is apparent in the production of it.

We know little of the earth's internal parts, or of the materials which compose it at any considerable depth below the surface. But upon the surface of this globe, the more inert matter is replenished with plants, and with animal and intellectual beings.

Where so many living creatures are to ply their respective powers, in pursuing the end for which they were intended, we are not to look for nature in a quiescent state; matter itself must be in motion, and the scenes of life a continued or repeated series of agitations and events.

This globe of the earth is a habitable world; and on its fitness for this purpose, our sense of wisdom in its formation must depend. To judge of this point, we must keep in view, not only the end, but the means also by which that end is obtained. These are, the form of the whole, the materials of which it is composed, and the several powers which concur, counteract, or balance one another, in procuring the general result.

The form and constitution of the mass are not more evidently calculated for the purpose of this earth as a habitable world, than are the various substances of which that complicated body is composed. Soft and hard parts variously combine to form a medium consistence, adapted to the use of plants and animals; wet and dry are properly mixed for nutrition, or the support of those growing bodies; and hot and cold produce a temperature or climate no less required than a soil: Insomuch, that there is not any particular, respecting either the qualities of the materials, or the construction of the machine, more obvious to our perception, than are the presence and efficacy of design and intelligence in the power that conducts the work.

In taking this view of things, where ends and means are made the object of attention, we may hope to find a principle upon which the comparative importance of parts in the system of nature may be estimated, and also a rule for selecting the object of our inquiries. Under this direction, science may find a fit subject of investigation in every particular, whether of *form*, *quality*, or *active power*, that presents itself in this system of motion and of life; and which, without a proper attention to this character of the system, might appear anomalous and incomprehensible.

It is not only by seeing those general operations of the globe which depend upon its peculiar construction as a machine, but also by perceiving how far the particulars, in the construction of that machine, depend upon the general operations of the globe, that we are enabled to understand the constitution of this earth as a thing formed by design. We shall thus also be led to acknowledge an order, not unworthy of Divine wisdom, in a subject which, in another view, has appeared as the work of chance, or as absolute disorder and confusion.

To acquire a general or comprehensive view of this mechanism of the globe, by which it is adapted to the purpose of being a habitable world, it is necessary to distinguish three different bodies which compose the whole. These are, a solid body of earth, an aqueous body of sea, and an elastic fluid of air.

It is the proper shape and disposition of these three bodies that form this globe into a habitable world; and it is the manner in which these constituent bodies are adjusted to each other, and the laws of action by which they are maintained in their proper qualities and respective departments, that form the Theory of the machine which we are now to examine.

Let us begin with some general sketch of the particulars now mentioned.

1st, There is a central body in the globe. This body supports those parts which come to be more immediately exposed to our view, or which may be examined by our sense and observation. This first part is commonly supposed to be solid and inert; but such a conclusion is only mere conjecture; and we shall afterwards find occasion, perhaps, to form another judgment in relation to this subject, after we have examined strictly, upon scientific principles, what appears upon the surface, and have formed conclusions concerning that which must have been transacted in some more central part.

2dly, We find a fluid body of water. This, by gravitation, is reduced to a spherical form, and by the centrifugal force of the earth's rotation, is become oblate. The purpose of this fluid body is essential in the constitution of the world; for, besides affording the means of life and motion to a multifarious race of animals, it is the source of growth and circulation to the organized bodies of this earth, in being the receptacle of the rivers, and the fountain of our vapours.

3dly, We have an irregular body of land raised above the level of the ocean. This, no doubt, is the smallest portion of the globe; but it is the part to us by far most interesting. It is upon the surface of this part that plants are made to grow; consequently, it is by virtue of this land that animal life, as well as vegetation, is sustained in this world.

Lastly, We have a surrounding body of atmosphere, which completes the globe. This vital fluid is no less necessary, in the constitution of the world, than are the other parts; for there is hardly an operation upon the surface of the earth, that is not conducted or promoted by its means. It is a necessary condition for the sustenance of fire; it is the breath of life to animals; it is at least an instrument in vegetation; and, while it contributes to give fertility and health to things that grow, it is employed in preventing noxious effects from such as go into corruption. In short, it is the proper means of circulation for the matter of this world, by raising up the water of the ocean, and pouring it forth upon the surface of the earth.

Such is the mechanism of the globe: Let us now mention some of those powers by which motion is produced, and activity procured to the mere machine.

First, There is the progressive force, or moving power, by which this planetary body, if solely actuated, would depart continually from the path which it now pursues, and thus be for ever removed from its end, whether as a planetary body, or as a globe sustaining plants and animals, which may be termed a living world.

But this moving body is also actuated by gravitation, which inclines it directly to the central body of the sun. Thus it is made to revolve about that luminary, and to preserve its path.

It is also upon the same principles, that each particular part upon the surface of this globe, is alternately exposed to the influence of light and darkness, in the diurnal rotation of the earth, as well as in its annual revolution. In this manner are produced the vicissitudes of night and day, so variable in the different latitudes from the equator to the pole, and so beautifully calculated to equalise the benefits of light, so variously distributed in the different regions of the globe.

Gravitation, and the *vis infita* of matter, thus form the first two powers distinguishable in the operations of our system, and wisely adapted to the purpose for which they are employed.

We next observe the influence of light and heat, of cold and condensation. It is by means of these two powers that the various operations of this living world are more immediately transacted; although the other powers are no less required, in order to produce or modify these great agents in the economy of life, and system of our changing things.

We do not now inquire into the nature of those powers, or investigate the laws of light and heat, of cold and condemnation, by which the various purposes of this world are accomplished; we are only to mention those effects which are made sensible to the common understanding of mankind, and which necessarily imply a power that is employed. Thus, it is by the operation of those powers that the varieties of season in spring and autumn are obtained, that we are blessed with the vicissitudes of summer's heat and winter's cold, and that we possess the benefit of artificial light and culinary fire.

We are thus bountifully provided with the necessaries of life; we are supplied with things conducive to the growth and preservation of our animal nature, and with fit subjects to employ and to nourish our intellectual powers.

There are other actuating powers employed in the operations of this globe, which we are little more than able to enumerate; such are those of electricity, magnetism, and subterraneous heat or mineral fire.

Powers of such magnitude or force, are not to be supposed useless in a machine contrived surely not without wisdom; but they are mentioned here chiefly on account of their general effect; and it is sufficient to have named powers, of which the actual existence is well known, but of which the proper use in the constitution of the world is still obscure. The laws of electricity and magnetism have been well examined by philosophers; but the purposes of those powers in the economy of the globe have not been discovered. Subterraneous fire, again, although the most conspicuous in the operations of this world, and often examined by philosophers, is a power which has been still less understood, whether with regard to its efficient or final cause. It has hitherto appeared more like the accident of natural things, than the inherent property of the mineral region. It is in this last light, however, that I wish to exhibit it, as a great power acting a material part in the operations of the globe, and as an essential part in the constitution of this world.

We have thus surveyed the machine in general, with those moving powers, by which its operations, diversified almost *ad infinitum*, are performed. Let us now confine our view, more particularly, to that part of the machine on which we dwell, that so we may consider the natural consequences of those operations which, being within our view, we are better qualified to examine.

This subject is important to the human race, to the possessor of this world, to the intelligent being Man, who foresees events to come, and who, in contemplating his future interest, is led to inquire concerning causes, in order that he may judge of events which otherwise he could not know.

If, in pursuing this object, we employ our skill in research, not in forming vain conjectures; and if *data* are to be found, on which Science may form just conclusions, we should not long remain in ignorance with respect to the natural history of this earth, a subject on which hitherto opinion only, and not evidence, has decided: For in no subject, perhaps, is there naturally less defect of evidence, although philosophers, led by prejudice, or misguided by false theory, may have neglected to employ that light by which they should have seen the system of this world.

But to proceed in pursuing a little farther our general or preparatory ideas. A solid body of land could not have answered the purpose of a habitable world; for, a soil is necessary to the growth of plants; and a soil is nothing but the materials collected from the destruction of the solid land. Therefore, the surface of this land, inhabited by man, and covered with plants and animals, is made by nature to decay, in dissolving from that hard and, compact state in which it is found below the soil; and this soil is necessarily washed away, by the continual circulation of the water, running from the summits of the mountains towards the general receptacle of that fluid. The heights of our land are thus levelled with the shores; our fertile plains are formed from the ruins of the mountains; and those travelling materials are still pursued by the moving water, and propelled along the inclined surface of the earth[7] These moveable materials, delivered into the sea, cannot, for a long continuance, rest upon the shore; for, by the agitation of the winds, the tides and currents, every moveable thing is carried farther and farther along the shelving bottom of the sea, towards the unfathomable regions of the ocean.

If the vegetable soil is thus constantly removed from the surface of the land, and if its place is thus to be supplied from the dissolution of the solid earth, as here represented, we may perceive an end to this beautiful machine; an end, arising from no error in its constitution as a world, but from that destructibility of its land which is so necessary in the system of the globe, in the economy of life and vegetation.

[7] M. de Luc, in his second letter to me, published in the Monthly Review for 1790, says, "You ought to have proved that both gravel and sand are carried from our continents to the sea; which, on the contrary, I shall prove not to be the case." He then endeavours to prove his assertion, by observing, that, in certain places where there is not either sufficient declivity in the surface, or force in the running water, gravel and sand are made to rest, and do not travel to the sea. This surely is a fact to which I most readily assent; but, on the other hand, I hope he will acknowledge, that, where there is sufficient declivity in the surface, or force in the running water, sand, gravel, and stones, are travelled upon the land, and are thus carried into the sea—at last. This is all that my theory requires, and this is what I believe will be admitted, without any farther proof on my part.

The immense time necessarily required for this total destruction of the land, must not be opposed to that view of future events, which is indicated by the surest facts, and most approved principles. Time, which measures every thing in our idea, and is often deficient to our schemes, is to nature endless and as nothing; it cannot limit that by which alone it had existence; and, as the natural course of time, which to us seems infinite, cannot be bounded by any operation that may have an end, the progress of things upon this globe, that is, the course of nature, cannot be limited by time, which must proceed in a continual succession. We are, therefore, to consider as inevitable the deduction of our land, so far as effected by those operations which are necessary in the purpose of the globe, considered as a habitable world; and, so far as we have not examined any other part of the economy of nature, in which other operations and a different intention might appear.

We have now considered the globe of this earth as a machine, constructed upon chemical as well as mechanical principles, by which its different parts are all adapted, in form, in quality, and in quantity, to a certain end; an end attained with certainty or success; and an end from which we may perceive wisdom, in contemplating the means employed.

But is this world to be considered thus merely as a machine, to last no longer than its parts retain their present position, their proper forms and qualities? Or may it not be also considered as an organized body? such as has a constitution in which the necessary decay of the machine is naturally repaired, in the exertion of those productive powers by which it had been formed.

This is the view in which we are now to examine the globe; to see if there be, in the constitution of this world, a reproductive operation, by which a ruined constitution may be again repaired, and a duration or stability thus procured to the machine, considered as a world sustaining plants and animals.

If no such reproductive power, or reforming operation, after due inquiry, is to be found in the constitution of this world, we should have reason to conclude, that the system of this earth has either been intentionally made imperfect, or has not been the work of infinite power and wisdom.

Here is an important question, therefore, with regard to the constitution of this globe; a question which, perhaps, it is in the power of man's sagacity to resolve; and a question which, if satisfactorily resolved, might add some lustre to science and the human intellect.

Animated with this great, this interesting view, let us strictly examine our principles, in order to avoid fallacy in our reasoning; and let us endeavour to support our attention, in developing a subject that is vast in its extent, as well as intricate in the relation of parts to be stated.

The globe of this earth is evidently made for man. He alone, of all the beings which have life upon this body, enjoys the whole and every part; he alone is capable of knowing the nature of this world, which he thus possesses in virtue of his proper right; and he alone can make the knowledge of this system a source of pleasure, and the means of happiness.

Man alone, of all the animated beings which enjoy the benefits of this earth, employs the knowledge which he there receives, in leading him to judge of the intention of things, as well as of the means by which they are brought about; and he alone is thus made to enjoy, in contemplation as well as sensual pleasure, all the good that may be observed in the constitution of this world; he, therefore, should be made the first subject of inquiry.

Now, if we are to take the written history of man for the rule by which we should judge of the time when the species first began, that period would be but little removed from the present state of things. The Mosaic history places this beginning of man at no great distance; and there has not been found, in natural history, any document by which a high antiquity might be attributed to the human race. But this is not the case with regard to the inferior species of animals, particularly those which inhabit the ocean and its shores. We find, in natural history, monuments which prove that those animals had long existed; and we thus procure a measure for the computation of a period of time extremely remote, though far from being precisely ascertained.

In examining things present, we have data from which to reason with regard to what has been; and, from what has actually been, we have data for concluding with regard to that which is to happen hereafter. Therefore, upon the supposition that the operations of nature are equable and steady, we find, in natural appearances, means for concluding a certain portion of time to have necessarily elapsed, in the production of those events of which we see the effects.

It is thus that, in finding the relics of sea-animals of every kind in the solid body of our earth, a natural history of those animals is formed, which includes a certain portion of time; and, for the ascertaining this portion of time, we must again have recourse to the regular operations of this world. We shall thus arrive at facts which indicate a period to which no other species of chronology is able to remount.

In what follows, therefore, we are to examine the construction of the present earth, in order to understand the natural operations of time past; to acquire principles, by which we may conclude with regard to the future course of things, or judge of those operations, by which a world, so wisely ordered, goes into decay; and to learn, by what means such a decayed world may be renovated, or the waste of habitable land upon the globe repaired.

This, therefore, is the object which we are to have in view during this physical investigation; this is the end to which are to be directed all the steps in our cosmological pursuit.

The solid parts of the globe are, in general, composed of sand, of gravel, of argillaceous and calcareous strata, or of the various compositions of these with some other substances, which it is not necessary now to mention. Sand is separated and sized by streams and currents; gravel is formed by the mutual attrition of stones agitated in water; and marly, or argillaceous strata, have been collected, by subsiding in water with which those earthy substances had been floated. Thus, so far as the earth is formed of these materials, that solid body would appear to have been the production of water, winds, and tides.

But that which renders the original of our land clear and evident, is the immense quantities of calcareous bodies which had belonged to animals, and the intimate connection of these masses of animal production with the other strata of the land. For it is to be proved, that all these calcareous bodies, from the collection of which the strata were formed, have belonged to the sea, and were produced in it.

We find the marks of marine animals in the most solid parts of the earth; consequently, those solid parts have been formed after the ocean was inhabited by those animals which are proper to that fluid medium. If, therefore, we knew the natural history of those solid parts, and could trace the operations of the globe, by which they had been formed, we would have some means for computing the time through which those species of animals have continued to live. But how shall we describe a process which nobody has seen performed, and of which no written history gives any account? This is only to be investigated, *first*, in examining the nature of those solid bodies, the history of which we want to know; and, 2*dly*, In examining the natural operations of the globe, in order to see if there now actually exist such operations, as, from the nature of the solid bodies, appear to have been necessary to their formation.

But, before entering more particularly into those points of discussion, by which the question is to be resolved, let us take a general view of the subject, in order to see what it is which science and observation must decide.

In all the regions of the globe, immense masses are found, which, though at present in the most solid state, appear to have been formed by the collection of the calcareous *exuviae* of marine animals. The question at present is not, in what manner those collections of calcareous relics have become a perfect solid body, and have been changed from an animal to a mineral substance; for this is a subject that will be afterwards considered; we are now only inquiring, if such is truly the origin of those mineral masses.

That all the masses of marble or limestone are composed of the calcareous matter of marine bodies, may be concluded from the following facts:

1*st*, There are few beds of marble or limestone, in which may not be found some of those objects which indicate the marine origin of the mass. If, for example, in a mass of marble, taken from a quarry upon the top of the Alps or Andes[8] , there shall be found one cockle-shell, or piece of coral, it must be concluded, that this bed of stone had been originally formed at the bottom of the sea, as much as another bed which is evidently composed almost altogether of cockle-shells and coral. If one bed of limestone is thus found to have been of a marine origin, every concomitant bed of the same kind must be also concluded to have been formed in the same Manner.

We thus shall find the greatest part of the calcareous masses upon this globe to have originated from marine calcareous bodies; for whether we examine marbles, limestones, or such solid masses as are perfectly changed from the state of earth, and are become compact and hard, or whether we examine the soft, earthy, chalky or marly strata, of which so much of this earth is composed, we still find evident proofs, that those beds had their origin from materials deposited at the bottom of the sea; and that they have the calcareous substance which they contain, from the same source as the marbles or the limestones.

2*dly*, In those calcareous strata, which are evidently of marine origin, there are many parts that are of a sparry structure, that is to say, the original texture of those beds, in such places, has been dissolved, and a new structure has been assumed, which is peculiar to a certain state of the calcareous earth. This change is produced by crystallisation, in consequence of a previous state of fluidity, which has so disposed the concreting parts, as to allow them to assume a regular shape and structure proper to that substance. A body, whose external form has been modified by this process, is called a *crystal*; one whose internal arrangement of parts is determined by it, is said to be of a *sparry structure*; and this is known from its fracture.

3*dly*, There are, in all the regions of the earth, huge masses of calcareous matter, in that crystalline form of sparry state, in which perhaps no vestige can be found of any organised body, nor any indication that such calcareous matter had belonged to animals; but as, in other masses, this sparry

[8] "Cette sommité élevée de 984 toises au dessus de notre lac, et par conséquent de 1172 au dessus de la mer, est remarquable en ce que l'on y voit des fragmens d'huîtres pétrifiés.—Cette montagne est dominée par un rocher escarpé, qui s'il n'est pas inaccessible, est du moins d'un bien difficile accès; il paroît presqu'entièrement composé de coquillages pétrifiés, renfermés dans un roc calcaire, ou marbre grossier noirâtre. Les fragmens qui s'en détachent, et que l'on rencontre en montant à la Croix de fer, sont remplis de *turbinites* de différentes espèces." M. DE SAUSSURE, *Voyage dans les Alpes*, p. 394.

structure, or crystalline state, is evidently assumed by the marine calcareous substances, in operations which are natural to the globe, and which are necessary to the consolidation of the strata, it does not appear, that the sparry masses, in which no figured body is formed, have been originally different from other masses, which, being only crystallised in part, and in part still retaining their original form, leave ample evidence of their marine origin [9].

We are led, in this manner, to conclude, that all the strata of the earth, not only those consisting of such calcareous masses, but others superincumbent upon these, have had their origin at the bottom of the sea, by the collection of sand and gravel, of shells, of coralline and crustaceous bodies, and of earths and clays, variously mixed, or separated and accumulated. Here is a general conclusion, well authenticated in the appearances of nature, and highly important in the natural history of the earth.

The general amount of our reasoning is this, that nine-tenths, perhaps, or ninety-nine hundredths of this earth, so far as we see, have been formed by natural operations of the globe, in collecting loose materials, and depositing them at the bottom of the sea; consolidating those collections in various degrees, and either elevating those consolidated masses above the level on which they were formed, or lowering the level of that sea.

There is a part of the solid earth which we may at present neglect, not as being persuaded that this part may not also be found to come under the general rule of formation with the rest, but as considering this part to be of no consequence in forming a general rule, which shall comprehend almost the whole, without doing it absolutely. This excluded part consists of certain mountains and masses of granite. These are thought to be still older in their formation, and are said never to be found superincumbent on strata which must be acknowledged as the productions of the sea.

Having thus found the greater part, if not the whole, of the solid land to have been originally composed at the bottom of the sea, we may now, in

[9] M. de Saussure, describing the marble of Aigle, says, "Les tables polies de ce marbre présentent fréquemment des coquillages, dont la plupart sont des peignes striés, et de très-beaux madrépores. Tous ces corps marins on pris entierement la nature et le grain même du marbre, on n'y voit presque jamais la coquille sous sa forme originaire."

order to form a proper idea of these operations, suppose the whole of this seaborn land to be again dispersed along the bottom of the ocean, the surface of which would rise proportionally over the globe. We would thus have a spheroid of water, with granite rocks and islands scattered here and there. But this would not be the world which we inhabit; therefore, the question now is, how such continents, as we actually have upon the globe, could be erected above the level of the sea.

It must be evident, that no motion of the sea, caused by this earth revolving in the solar system, could bring about that end; for let us suppose the axis of the earth to be changed from the present poles, and placed in the equinoctial line, the consequence of this might, indeed, be the formation of a continent of land about each new pole, from whence the sea would run towards the new equator; but all the rest of the globe would remain an ocean. Some new points might be discovered, and others, which before appeared above the surface of the sea, would be sunk by the rising of the water; but, on the whole, land could only be gained substantially at the poles. Such a supposition, as this, if applied to the present state of things, would be destitute of every support, as being incapable of explaining what appears.

But even allowing that, by the changed axis of the earth, or any other operation of the globe, as a planetary body revolving in the solar system, great continents of land could have been erected from the place of their formation, the bottom of the sea, and placed in a higher elevation, compared with the surface of that water, yet such a continent as this could not have continued stationary for many thousand years; nor could a continent of this kind have presented to us, every where within its body, masses of consolidated marble, and other mineral substances, in a state as different as possible from that in which they were, when originally collected together in the sea.

Consequently, besides an operation, by which the earth at the bottom of the sea should be converted into an elevated land, or placed high above the level of the ocean, there is required, in the operations of the globe, a consolidating power, by which the loose materials that had subsided from water, should be formed into masses of the most perfect solidity, having neither water nor vacuity between their various constituent parts, nor in the pores of those constituent parts themselves.

Here is an operation of the globe, whether chemical or mechanical, which is necessarily connected with the formation of our present continents: Therefore, had we a proper understanding of this secret operation, we might thereby be enabled to form an opinion, with regard to the nature of that unknown power, by which the continents have been placed above the surface of that water wherein they had their birth.

If this consolidating operation be performed at the bottom of the ocean, or under great depths of the earth, of which our continents are composed, we cannot be witnesses to this mineral process, or acquire the knowledge of natural causes, by immediately observing the changes which they produce; but though we have not this immediate observation of those changes of bodies, we have, in science, the means of reasoning from distant events; consequently, of discovering, in the general powers of nature, causes for those events of which we see the effects.

That the consolidating operation, in general, lies out of the reach of our immediate observation, will appear from the following truth: All the consolidated masses, of which we now inquire into the cause, are, upon the surface of the earth, in a state of general decay, although the various natures of those bodies admit of that dissolution in very different degrees.[10]

From every view of the subject, therefore, we are directed to look into those consolidated masses themselves, in order to find principles from whence to judge of those operations by which they had attained their hardness or consolidated state.

It must be evident, that nothing but the most general acquaintance with the laws of acting substances, and with those of bodies changing by the powers of nature, can enable us to set about this undertaking with any reasonable prospect of success; and here the science of Chemistry must be brought

[10] Stalactical and certain ferruginous concretions may seem to form an exception to the generality of this proposition. But an objection of this kind could only arise from a partial view of things; for the concretion here is only temporary; it is in consequence of a solution, and it is to be followed by a dissolution, which will be treated of in its proper place.

particularly to our aid; for this science, having for its object the changes produced upon the sensible qualities, as they are called, of bodies, by its means we may be enabled to judge of that which is possible according to the laws of nature, and of that which, in like manner, we must consider as impossible.

Whatever conclusions, therefore, by means of this science, shall be attained, in just reasoning from natural appearances, this must be held as evidence, where more immediate proof cannot be obtained; and, in a physical subject, where things actual are concerned, and not the imaginations of the human mind, this proof will be considered as amounting to a demonstration.

Section 2. An Investigation Of The Natural Operations Employed In Consolidating The Strata Of The Globe.

We are now about to investigate those mineral operations of the globe by which the qualities of hardness and solidity, consequently of strength and durability, are procured to great bodies of this earth.

That those qualities are not original to such bodies, but actually superinduced in the natural operations of the earth, will appear from the examination of some of the hardest and most solid of those mineral bodies. In such masses, (for example of flint and agate,) we find included shells and coralline bodies. Consequently, there must be a natural operation in the globe for consolidating and hardening its soft and loose materials. It is concerning the nature of this consolidating operation that we are now to inquire.

There are just two ways in which porous or spongy bodies can be consolidated, and by which substances may be formed into masses of a natural shape and regular structure; the one of these is simple *congelation* from a fluid state, by means of cold; the other is *accretion*; and this includes a separatory operation, as well as that by which the solid body is to be produced. But in whichever of these ways solidity shall be procured, it must be brought about by first inducing fluidity, either immediately by the action of heat, or mediately with the assistance of a solvent, that is, by the operation of solution. Therefore, fire and water may be considered as the general agents in this operation, which we would explore.

Heat has been already mentioned as a general power, and as acting in all the different parts of the globe; I would now wish more particularly to call the attention of the reader to subterraneous fire, or heat, as a powerful agent in the mineral regions, and as a cause necessarily belonging to the internal constitution of this earth.

It is not our purpose at present to inquire into the particular nature of this power of subterraneous heat, or to trace the proper connection and analogy of the internal fire with that which is so necessary to our life, and which acts so great a part upon the surface of the earth, this being reserved for the last part. Our intention in here mentioning it, is only to dispose the mind to look for active powers or efficient causes, in that part of the earth which has been commonly considered as passive and inert, but which will be found extremely active, and the source of mighty revolutions in the fate of land.

There may, indeed, be some difficulty in conceiving all the modifications of this mineral power; but as, on the one hand, we are not arbitrarily to assume an agent, for the purpose of explaining events, or certain appearances which are not understood; so, on the other, we must not refuse to admit the action of a known power, when this is properly suggested in the appearances of things; and, though we may not understand all the modifications, or the whole capacity and regulation of this power in bodies, we are not to neglect the appropriating to it, as a cause, those effects which are natural to it, and which, so far as we know, cannot belong to any other. On all occasions, we are to judge from what we know; and, we are only to avoid concluding from our suppositions, in cases where evidence or real information is necessarily required. The subject now considered, subterraneous fire, will afford an example of that truth; and, a general view of this great natural power will here find a proper place, before the application of it for the explanation of natural appearances.

No event is more the object of our notice, or more interesting as a subject for our study, than is the burning of a fire: But, the more that philosophers have studied this subject, the more they seem to differ as to the manner in which that conspicuous event is to be explained. Therefore, being so ignorant with regard to that fire of which we see the origin as well as the more immediate effects, how cautious should we be in judging the nature of subterraneous fire from the burning of bodies, a subject which we so little understand.

But, though the cause of fire in general, or the operations of that power in its extreme degrees, be for us a subject involved in much obscurity, this is not the case with regard to the more common effects of heat; and, tho' the actual existence of subterraneous fire, as the cause of light and heat, might be a thing altogether problematical in our opinion; yet, as to other effects, there are some of these from which the action of that liquefying power may be certainly concluded as having taken place within the mineral region, although the cause should be in every other respect a thing to us unknown. In that case, where the operation or effect is evident, and cannot be disputed, to refuse to admit the power in question, merely because we had not seen it act, or because we know not every rule which it may observe in acting, would be only to found an argument upon our ignorance; it would be to misunderstand the nature of investigating physical truths, which must proceed by reasoning from effect to cause.

Our knowledge is extremely limited with regard to the effects of heat in bodies, while acting under different conditions, and in various degrees. But though our knowledge in these respects is limited, our judgment with regard to the efficacy of this power of heat is in its nature positive, and contains not any thing that is doubtful or uncertain. All mankind, who have the opportunity, know that the hard substance of ice is by heat converted into water, wherein no hardness remains; and the profound philosophy of Dr Black, in relation to the subject of *latent heat*, as that of Sir Isaac Newton, in relation to the weight of bodies, is not necessary to convince the world that in the one case ice will melt, and in the other, that heavy bodies will move when unsupported.

But though, in the abstract doctrine of *latent heat*, the ingenuity of man has discovered a certain measure for the quantity of those commutable effects which are perceived; and though this be a progress of science far above the apprehension of the vulgar, yet still, that solid bodies are changed into fluids, by the power of heat, is the same unalterable judgment, which the savage forms as well as the philosopher. Here, therefore, are evident effects, which mankind in general attribute to the power of heat; and it is from those known effects that we are to investigate subterraneous fire, or to generalise the power of heat, as acting in the interior parts, as well as on the surface of this earth.

If, indeed, there were any other cause for fluidity besides the operation of fire or the power of heat, in that case the most evident proof, with regard to the flowing, or former fluidity, of mineral bodies, would draw to no conclusion in proving the existence of mineral fire; but when we have not the smallest reason for conjecturing any other cause, or the least doubt with regard to that which, in the doctrine of latent heat, has been properly investigated, the proofs which we shall bring, of fusion in all the minerals of this earth, must be held as proofs of mineral fire, in like manner as the proof of subterraneous fire would necessarily imply mineral fusion as its natural effect.

Thus we have, in our physical investigation, several points in view. First, from the present state of things, to infer a former state of fusion among mineral bodies. Secondly, from that former fusion, to infer the actual existence of mineral fire in the system of the earth. And, lastly, from the acknowledged fact of subterraneous fire as a cause, to reason with regard to the effects of that power in mineral bodies.

But besides the power or effect of subterraneous heat in bodies which are unorganised, and without system, in the construction of their different parts, we have to investigate the proper purpose of this great agent in the system of this world, which may be considered as a species of organised body. Here, therefore, final causes are to be brought into view, as well as those which are efficient. Now, in a subject involved with so much obscurity, as must be for us the internal regions of the globe, the consideration of efficient and final causes may contribute mutually to each others evidence, when separately the investigation of either might be thought unsatisfactory or insufficient.

So far it seemed necessary to premise with regard to the great mineral power which we are to employ as an agent in the system of this earth; and it may be now observed, that it is in the proper relation of this power of heat and the fluidity or softness of bodies, as cause and effect, that we are to find a physical principle or argument for detecting those false theories of the earth that have been only imagined, and not properly founded on fact or observation. It is also by means of this principle, that we shall be enabled to form a true theory of the mineral region, in generalising particular effects to a common cause.

Let us now proceed in endeavouring to decide this important question, viz. By what active principle is it, that the present state of things, which we observe in the strata of the earth, a state so very different from that in which those bodies had been formed originally, has been brought about?

Two causes have been now proposed for the consolidating of loose materials which had been in an incoherent state; these are, on the one hand, fire; or, on the other, water, as the means of bringing about that event. We are, therefore, to consider well, what may be the consequences of consolidation by the one or other of those agents; and what may be the respective powers of those agents with respect to this operation.

If we are not informed in this branch of science, we may gaze without instruction upon the most convincing proofs of what we want to attain. If our knowledge is imperfect, we may form erroneous principles, and deceive ourselves in reasoning with regard to those works of nature, which are wisely calculated for our instruction.

The strata, formed at the bottom of the sea, are to be considered as having been consolidated, either by aqueous solution and crystallization, or by the effect of heat and fusion. If it is in the first of these two ways that the solid strata of the globe have attained to their present state, there will be a certain uniformity observable in the effects; and there will be general laws, by which this operation must have been conducted. Therefore, knowing those general laws, and making just observations with regard to the natural appearances of those consolidated masses, a philosopher, in his closet, should be able to determine, what may, and what may not have been transacted in the bowels of the earth, or below the bottom of the ocean.

Let us now endeavour to ascertain what may have been the power of water, acting under fixed circumstances, operating upon known substances, and conducting to a certain end.

The action of water upon all different substances is an operation with which we are familiar. We have it in our power to apply water in different degrees of heat for the solution of bodies, and under various degrees of compression; consequently, there is no reason to conclude any thing mysterious in the operations of the globe, which are to be performed by means of water, unless an immense compressing power should alter the nature of those operations. But compression alters the relation of evaporation only with regard to heat, or it changes the degree of heat which water may be made to sustain; consequently, we are to look for no occult quality in water acting upon bodies at the bottom of the deepest ocean, more than what can be observed in experiments which we have it in our power to try.

With regard again to the effect of time: Though the continuance of time may do much in those operations which are extremely slow, where no change, to our observation, had appeared to take place, yet, where it is not in the nature of things to produce the change in question, the unlimited course of time would be no more effectual, than the moment by which we measure events in our observations.

Water being the general medium in which bodies collected at the bottom of the sea are always contained, if those masses of collected matter are to be consolidated by solution, it must be by the dissolution of those bodies in that water as a menstruum, and by the concretion or crystallization of this dissolved matter, that the spaces, first occupied by water in those masses, are afterwards to be filled with a hard and solid substance; but without some other power, by which the water contained in those cavities and endless labyrinths of the strata, should be separated in proportion as it had performed its task, it is inconceivable how those masses, however changed from the state of their first subsidence, should be absolutely consolidated, without any visible or fluid water in their composition.

Besides this difficulty of having the water separated from the porous masses which are to be consolidated, there is another with which, upon this supposition, we have to struggle. This is, From whence should come the matter with which the numberless cavities in those masses are to be filled?

The water in the cavities and interstices of those bodies composing strata, must be in a stagnating state; consequently, it can only act upon the surfaces of those cavities which are to be filled up. But with what are they to be filled? Not with water; they are full of that already: Not with the substance of the bodies which contain that water; this would be only to make one cavity in order to fill up another. If, therefore, the cavities of the strata are to be filled with solid matter, by means of water, there must be made to pass through those porous masses, water impregnated with some other substances in a dissolved state; and the aqueous menstruum must be made to separate from the dissolved substance, and to deposit the same in those cavities through which the solution moves.

By such a supposition as this, we might perhaps explain a partial consolidation of those strata; but this is a supposition, of which the case under consideration does not admit; for in the present case, which is that of materials accumulated at the bottom of the ocean, there is not proper means for separating the dissolved matter from the water included in those enormous masses; nor are there any means by which a circulation in those masses may be formed. In this case, therefore, where the means are not naturally in the supposition, a philosopher, who is to explain the phenomenon by the natural operation of water in this situation, must not have recourse to another agent, still more powerful, to assist his supposition which cannot be admitted.

Thus, it will appear, that, to consolidate strata formed at the bottom of the sea, in the manner now considered, operations are required unnatural to this place; consequently, not to be supposed, in order to support a hypothesis.

But now, instead of inquiring how far water may be supposed instrumental in the consolidation of strata which were originally of a loose texture, we are to consider how far there may be appearances in those consolidated bodies, by which it might be concluded, whether or not the present state of their consolidation has been actually brought about by means of that agent.

If water had been the menstruum by which the consolidating matter was introduced into the interstices of strata, masses of those bodies could only be found consolidated with such substances as water is capable of dissolving; and these substances would be found only in such a state as the simple separation of the solvent water might produce.

In this case, the consolidation of strata would be extremely limited; for we cannot allow more power to water than we find it has in nature; nor are we to imagine to ourselves unlimited powers in bodies, on purpose to explain those appearances by which we should be made to know the powers of nature. Let us, therefore, attend, with every possible circumspection, to the appearances of those bodies, by means of which we are to investigate the principles of mineralogy, and know the laws of nature.

The question now before us concerns the consolidating substances of strata. Are these such as will correspond to the dissolving power of water, and to the state in which these substances might be left by the separation of their menstruum? No; far, far from this supposition is the conclusion that necessarily follows from natural appearances.

We have strata consolidated by calcareous spar, a thing perfectly distinguishable from the stalactical concretion of calcareous earth, in consequence of aqueous solution. We have strata made solid by the formation of fluor, a substance not soluble, so far as we know, by water. We have strata consolidated with sulphureous and bituminous substances, which do not correspond to the solution of water. We have strata consolidated with siliceous matter, in a state different from that under which it has been observed, on certain occasions, to be deposited by water. We have strata consolidated by feld-spar, a substance insoluble in water. We have strata consolidated by almost all the various metallic substances, with their almost endless mixtures and sulphureous compositions; that is to say, we find, perhaps, every different substance introduced into the interstices of strata which had been formed by subsidence at the bottom of the sea.

If it is by means of water that those interstices have been filled with those materials, water must be, like fire, an universal solvent, or cause of fluidity, and we must change entirely our opinion of water in relation to its chemical character. But there is no necessity thus to violate our chemical principles, in order to explain certain natural appearances; more especially if those appearances may be explained in another manner, consistently with the known laws of nature.

If, again, it is by means of heat and fusion that the loose and porous structure of strata shall be supposed to have been consolidated, then every difficulty which had occurred in reasoning upon the power or agency of water is at once removed. The loose and discontinuous body of a stratum may be closed by means of softness and compression; the porous structure of the materials may be consolidated, in a similar manner, by the fusion of their substance; and foreign matter may be introduced into the open structure of strata, in form of steam or exhalation, as well as in the fluid state of fusion; consequently, heat is an agent competent for the consolidation of strata, which water alone is not. If, therefore, such an agent could be found acting in the natural place of strata, we must pronounce it proper to bring about that end.

The examination of nature gives countenance to this supposition, so far as strata are found consolidated by every species of substance, and almost every possible mixture of those different substances; consequently, however difficult it may appear to have this application of heat, for the purpose of consolidating strata formed at the bottom of the ocean, we cannot, from natural appearances, suppose any other cause, as having actually produced the effects which are now examined.

This question, with regard to the means of consolidating the strata of the globe, is, to natural history, of the greatest importance; and it is essential in the theory now proposed to be given of the mineral system. It would, therefore, require to be discussed with some degree of precision in examining the particulars; but of these, there is so great a field, and the subject is so complicated in its nature, that volumes might be written upon particular branches only, without exhausting what might be laid upon the subject; because the evidence, though strong in many particulars, is chiefly to be enforced by a multitude of facts, conspiring, in a diversity of ways, to point out one truth, and by the impossibility of reconciling all these facts, except by means of one supposition.

But, as it is necessary to give some proof of that which is to be a principle in our reasoning afterwards, I shall now endeavour to generalise the subject as much as possible, in order to answer that end, and, at the same time, to point out the particular method of inquiry.

There are to be found, among the various strata of the globe, bodies formed of two different kinds of substances, *siliceous* bodies, and those which may be termed *sulphureous* or*phlogistic*. With one or other, or both of those we substances, every different consolidated stratum of the globe will be found so intimately mixed, or closely connected, that it must be concluded, by whatever cause those bodies of siliceous and sulphureous matter had been changed from a fluid to a concreted state, the strata must have been similarly affected by the same cause.

These two species of bodies, therefore, the siliceous and the sulphureous, may now be examined, in relation to the causes of their concretion, with a view to determine, what has been the general concreting or consolidating power, which has operated universally in the globe; and particularly to show, it has not been by means of any fluid solution, that strata in general have been consolidated, or that those particular substances have been crystallized and concreted.

Siliceous matter, physically speaking, is not soluble in water; that is to say, in no manner of way have we been enabled to learn, that water has the power of dissolving this matter.

Many other substances, which are so little soluble in water, that their solubility could not be otherwise detected of themselves, are made to appear soluble by means of siliceous matter; such is feld-spar, one of the component parts of rock-granite.

Feld-spar is a compound of siliceous, argillaceous, and calcareous earth, intimately united together. This compound siliceous body being, for ages, exposed to the weather, the calcareous part of it is dissolved, and the siliceous part is left in form of a soft white earth. But whether this dissolution is performed by pure water, or by means also of an acid, may perhaps be questioned. This, however, is certain, that we must consider siliceous substances as insoluble in water.

The water of Glezer in Iceland undoubtedly contains this substance in solution; but there is no reason to believe, that it is here dissolved by any other than the natural means; that is, an alkaline substance, by which siliceous bodies may be rendered soluble in water[11].

It may be, therefore, asserted, that no siliceous body having the hardness of flint, nor any crystallization of that substance, has ever been formed, except by fusion. If, by any art, this substance shall be dissolved in simple water, or made to crystallise from any solution, in that case, the assertion which has been here made may be denied. But where there is not the vestige of any proof, to authorise the supposition of flinty matter being dissolved by water, or crystallized from that solution, such an hypothesis cannot be admitted, in opposition to general and evident appearances[12].

[11] This conjecture, which I had thus formed, has been fully confirmed by the accurate analysis of those waters. See vol. 3d. of the Phil. Trans. of Edin.

[12] The Chevalier de Dolomieu has imagined an ingenious theory for the solution of siliceous substances in water (Journal de Physique, Mai 1792.). This theory has not been taken up merely at a venture, but is founded upon very accurate and interesting chemical experiments. Hitherto, however, the nature of the siliceous substance is not sufficiently known, to enable us to found, upon chemical principles, the mineral operations of nature. That siliceous substance may be dissolved, or rendered soluble in water, by means of alkaline salt, and that it may be also volatilised by means of the fluor acid, is almost all that we know upon the subject. But this is saying no more in relation to the mineral operations employed upon the siliceous substance, than it would be, in relation to those upon gold, to say that this metal is dissolved by aqua regia. It is to be admitted, that every simple substance may have its menstruum, by means of which it may be retained with water in a dissolved state; but from this it does not follow, that it is by the means of aqueous solutions of all those mineral bodies, that nature operates the consolidation of bodies, which we find actually accomplished with all those different substances. It is the business of this work to show, that from all appearances in the mineral regions, as well as those upon the surface in the atmosphere, the supposition, of that manner of consolidating bodies by solution, is inconsistent both with natural appearances, and also with chemical principles.
Our ingenious author, who has, with, great diligence as well as an enlightened mind, observed the operations of nature upon the surface of the earth, here says, "ce n'est pas sans étonnement que je remarque depuis long-temps que jamais aucune eau qui coule à la surface de la terre n'attaque le quartz, aucune n'en tient en dissolution, pendant que celles qui circulent intérieurement le corrodent aussi souvent qu'elles le déposent."—How dangerous it is in science for ingenious men to allow themselves to

Besides this proof for the fusion of siliceous bodies, which is indirect, arising from the in dissolubility of that substance in water, there is another, which is more direct, being founded upon appearances which are plainly inconsistent with any other supposition, except that of simple fluidity induced by heat. The proof I mean is, the penetration of many bodies with a flinty substance, which, according to every collateral circumstance, must have been performed by the flinty matter in a simply fluid state, and not in a state of dissolution by a solvent.

These are flinty bodies perfectly insulated in strata both of chalk and sand. It requires but inspection to be convinced. It is not possible that flinty matter could be conveyed into the middle of those strata, by a menstruum in which it was dissolved, and thus deposited in that place, without the smallest trace of deposition in the surrounding parts.

form conclusions, which the principles on which they reason do not strictly warrant, we have a remarkable example in the present case.

M. de Dolomieu sees no corrosion of quartz, or solution of that substance, upon the surface of the earth; from this, then, he concludes, that siliceous substance is not dissolved in that situation of things. On the other hand, he finds siliceous bodies variously concreted among the solid strata of the earth; and, from this he concludes, that siliceous substance has been both dissolved by water in the strata, and also there again concreted and crystallised in having been separated from the water. This is certainly what we all perceive; but we do not all allow ourselves to draw such inconclusive inferences from our premises. Notwithstanding the greatest accuracy of our observations, quartz may be dissolvable in a minute degree by water, upon the surface of this earth; and, all the appearances of siliceous bodies, in the mineral regions, where we cannot immediately see the operation, may be better explained by fusion than by aqueous solution.

But, from his chemical experiments, our author has conjectured that there may be a phlogistic substance, by means of which the siliceous earth is dissolved when in darkness; and that this solvent loses its power, if exposed to the light of day. I have one observation to oppose to this ingenious theory. Under deep black mosses, through which no ray of light can penetrate, every condition for dissolving siliceous bodies should be found, according to the supposition in question; neither will sufficient time be found wanting, in those deep mosses, upon the summits of our mountains; yet, examine the matter of fact? not the smallest solution is to be perceived in the siliceous parts of the stones which are found under those mosses, but every particle of iron is dissolved, so that the surface of every stone is white, and nothing but the siliceous earth of the feld-spar, and perhaps the argillaceous, is left.

Here we have in this author an instructive example: No person, in my opinion, has made such enlightened or scientific experiments, or such judicious observations with regard to the nature of siliceous substance, as a compound thing; no person reasons more distinctly in general, or sees more clearly the importance of his principles; yet, with regard to mineral concretions, how often has he been drawn thus inadvertently into improper generalization! I appeal to the analogy which, in this treatise, he has formed, between the stalactical concretions upon the surface of the earth, and the mineral concretions of siliceous substance. As an example of the great lights, and penetrating genius, of this assiduous studier of nature, I refer to the judicious observations which he has made upon the subject of aluminous earth, in this dissertation.

I am surprised to find this enlightened naturalist seeking, in the origin of this globe of our earth, a general principle of fluidity or solution in water, like the alkahest of the alchymists, by means of which the different substances in the chemical constitution of precious stones might have been united as well as crystallised. One would have thought, that a philosopher, so conversant in the operations of subterraneous fire, would have perceived, that there is but one general principle of fluidity or dissolution, and that this is heat.

But, besides this argument taken from what does not appear, the actual form in which those flinty masses are found, demonstrates, *first*, That they have been introduced among those strata in a fluid state, by injection from some other place. 2*dly*, That they have been dispersed in a variety of ways among those strata, then deeply immersed at the bottom of the sea; and, *lastly*, That they have been there congealed from the state of fusion, and have remained in that situation, while those strata have been removed from the bottom of the ocean to the surface of the present land.

To describe those particular appearances would draw this paper beyond the bounds of an essay. We must, therefore, refer those who would inquire more minutely into the subject, to examine the chalk-countries of France and England, in which the flint is found variously formed; the land-hills interspersed among those chalk-countries, which have been also injected by melted flint; and the pudding-stone of England, which I have not seen in its natural situation. More particularly, I would recommend an examination of the insulated masses of stone, found in the sand-hills by the city of Brussels; a stone which is formed by an injection of flint among sand, similar to that which, in a body of gravel, had formed the pudding-stone of England[13].

All these examples would require to be examined upon the spot, as a great part of the proof for the fusion of the flinty substance, arises, in my opinion, from the form in which those bodies are found, and the state of the surrounding parts. But there are specimens brought from many different places, which contain, in themselves, the most evident marks of this injection of the flinty substance in a fluid state. These are pieces of fossil wood, penetrated with a siliceous substance, which are brought from England, Germany, and Lochneagh in Ireland.

It appears from these specimens, that there has sometimes been a prior penetration of the body of wood, either with irony matter, or calcareous substance. Sometimes, again, which is the case with that of Lochneagh, there does not seem to have been any penetration of those two substances. The injected flint appears to have penetrated the body of this wood, immersed at the bottom of the sea, under an immense compression of

[13] Accurate descriptions of those appearances, with drawings, would be, to natural history, a valuable acquisition.

water. This appears from the wood being penetrated partially, some parts not being penetrated at all.

Now, in the limits between those two parts, we have the most convincing proofs, that it had been flint in a simple fluid state which had penetrated the wood, and not in a state of solution.

First, Because, however little of the wood is left unpenetrated, the division is always distinct between the injected part and that which is not penetrated by the fluid flint. In this case, the flinty matter has proceeded a certain length, which is marked, and no farther; and, beyond this boundary, there is no partial impregnation, nor a gradation of the flintifying operation, as must have been the case if siliceous matter had been deposited from a solution. 2*dly*, The termination of the flinty impregnation has assumed such a form, precisely, as would naturally happen from a fluid flint penetrating that body.

In other specimens of this mineralising operation, fossil wood, penetrated, more or less, with ferruginous and calcareous substances, has been afterwards penetrated with a flinty substance. In this case, with whatever different substances the woody body shall be supposed to have been penetrated in a state of solution by water, the regular structure of the plant would still have remained, with its vacuities, variously filled with the petrifying substances, separated from the aqueous menstruum, and deposited in the vascular structure of the wood. There cannot be a doubt with regard to the truth of this proposition; for, as it is, we frequently find parts of the consolidated wood, with the vascular structure remaining perfectly in its natural shape and situation; but if it had been by aqueous solution that the wood had been penetrated and consolidated, all the parts of that body would be found in the same natural shape and situation.

This, however, is far from being the case; for while, in some parts, the vascular structure is preserved entire, it is also evident, that, in general, the woody structure is variously broken and dissolved by the fusion and crystallization of the flint. There are so many and such various convincing examples of this, that, to attempt to describe them, would be to exceed the bounds prescribed for this dissertation; but such specimens are in my possession, ready for the inspection of any person who may desire to study the subject.

We may now proceed to consider sulphureous substances, with regard to their solubility in water, and to the part which these bodies have acted in consolidating the strata of the globe.

The sulphureous substances here meant to be considered, are substances not soluble in, water, so far as we know, but fusible by heat, and inflammable or combustible by means of heat and vital air. These substances are of two kinds; the one more simple, the other more compound.

The most simple kind is composed of two different substances, viz. phlogiston, with certain specific substances; from which result, on the one hand, sulphur, and, on the other, proper coal and metals. The more compound sort, again, is oily matter, produced by vegetables, and forming bituminous bodies.

The *first* of these is found naturally combined with almost all metallic substances, which are then said to be mineralised with sulphur. Now, it is well known, that this mineralising operation is performed by means of heat or fusion; and there is no person skilled in chemistry that will pretend to say, this may be done by aqueous solution. The combination of iron and sulphur, for example, may easily be performed by fusion; but, by aqueous solution, this particular combination is again resolved, and forms an acido-metallic, that is, a vitriolic substance, after the phlogiston (by means of which it is insoluble in water) has been separated from the composition, by the assistance of vital air.

The variety of these sulphureo-metallic substances, in point of composition, is almost indefinite; but, unless they were all soluble in water, this could not have happened by the action of that solvent. If we shall allow any one of those bodies to have been formed by the fluidity of heat, they must all have been formed in the same manner; for there is such a chain of connection among those bodies in the mineral regions, that they must all have been composed, either, on the one hand, by aqueous solution, or, on the other, by means of heat and fusion.

Here, for example, are crystallised together in one mass, 1*st, Pyrites*, containing sulphur, iron, copper; 2*dly, Blend*, a composition of iron, sulphur, and calamine; 3*dly, Galena*, consisting of lead and sulphur; 4*thly, Marmor metallicum*, being the terra ponderosa, saturated with the vitriolic acid; a substance insoluble in water; 5*thly, Fluor*, a saturation of calcareous earth, with a peculiar acid, called the *acid of spar*, also insoluble in water; 6*thly, Calcareous spar*, of different kinds, being calcareous earth saturated with fixed air, and something besides, which forms a variety in this substance; *lastly, Siliceous substance*, or *Quartz crystals*. All these bodies, each possessing its proper shape, are mixed in such a manner as it would be endless to describe, but which may be expressed in general by saying, that they are mutually contained in, and contain each other.

Unless, therefore; every one of these different substances may be dissolved in water, and crystallised from it, it is in vain to look for the explanation of these appearances in the operations of nature, by the means of aqueous solution.

On the other hand, heat being capable of rendering all these substances fluid, they may be, with the greatest simplicity, transported from one place to another; and they may be made to concrete altogether at the same time, and distinctly separate in any place. Hence, for the explanation of those natural appearances, which are so general, no further conditions are required, than the supposition of a sufficient intensity of subterraneous fire or heat, and a sufficient degree of compression upon those bodies, which are to be subjected to that violent heat, without calcination or change. But, so far as this supposition is not gratuitous, the appearances of nature will be thus explained.

I shall only mention one specimen, which must appear most decisive of the question. It is, I believe, from an Hungarian mine. In this specimen, petro-silex, pyrites, and cinnabar, are so mixed together, and crystallised upon each other, that it is impossible to conceive any one of those bodies to have had its fluidity and concretion from a cause which had not affected the other two. Now, let those who would deny the fusion of this siliceous body explain how water could dissolve these three different bodies, and deposit them in their present shape. If, on the contrary, they have not the least shadow of reason for such a gratuitous supposition, the present argument must be admitted in its full force.

Sulphur and metals are commonly found combined in the mineral regions. But this rule is not universal; for they are also frequently in a separate state. There is not, perhaps, a metal, among the great number which are now discovered, that may not be found native, as they are called, or in their metallic state.

Metallic substances are also thus found in some proportion to the disposition of the particular metals, to resist the mineralising operations, and to their facility of being metallised by fire and fusion. Gold, which refuses to be mineralised with sulphur, is found generally in its native state. Iron, again, which is so easily mineralised and scorified, is seldom found in its malleable state. The other metals are all found more or less mineralised, though some of them but rarely in the native state.

Besides being found with circumstances thus corresponding to the natural facility, or to the impediments attending the metallization of those different calces, the native metals are also found in such a shape, and with such marks, as can only agree with the fusion of those bodies; that is to say, those appearances are perfectly irreconcilable with any manner of solution and precipitation.

For the truth of this assertion, among a thousand other examples, I appeal to that famous mass of native iron discovered by Mr Pallas in Siberia. This mass being so well known to all the mineralists of Europe, any comment upon its shape and structure will be unnecessary[14].

[14] Since this Dissertation was written, M. de la Peyrouse has discovered a native manganese. The circumstances of this mineral are so well adapted for illustrating the present doctrine, and so well related by M. de la Peyrouse, that I should be wanting to the interest of mineral knowledge, were I not to give here that part of his Memoir.

"Lorsque je fis insérer dans le journal de physique de l'année 1780, au mois de Janvier, une Dissertation contenant la classification des mines de manganèse, je ne connoissois point, à cette époque, la mine de manganèse native. Elle a la couleur de son régule: Elle salit les doigts de la même teinte. Son tissu parait aussi lamelleux, et les lames semblent affecter une sorte de divergence. Elle a ainsi que lui, l'éclat métallique; comme lui elle se laisse aplatir sous le marteau, et s'exfolie si l'on redouble les coups; mais une circonstance qui est trop frappante pour que je l'omette, c'est la figure de la manganèse native, si prodigieusement conforme à celle du régule, qu'on s'y laisseroit tromper, si la mine n'étoit encore dans sa gangue: figure très-essentielle à observer ici, parce qu'elle est due à la nature même de la manganèse. En effet, pour réduire toutes les mines en général, il faut employer divers flux appropriés. Pour la réduction de

We come now to the *second* species of inflammable bodies called oily or bituminous. These substances are also found variously mixed with mineral bodies, as well as forming strata of themselves; they are, therefore, a proper subject for a particular examination.

In the process of vegetation, there are produced oily and resinous substances; and, from the collection of these substances at the bottom of the ocean, there are formed strata, which have afterwards undergone various degrees of beat, and have been variously changed, in consequence of the effects of that heat, according as the distillation of the more volatile parts of those bodies has been suffered to proceed.

In order to understand this, it must be considered, that, while immersed in water, and under insuperable compression, the vegetable, oily, and resinous substances, would appear to be unalterable by heat; and it is only in proportion as certain chemical separations take place, that these inflammable bodies are changed in their substance by the application of heat. Now, the most general change of this kind is in consequence of evaporation, or the distillation of their more volatile parts, by which oily substances become bituminous, and bituminous substances become coaly.

There is here a gradation which may be best understood, by comparing the extremes.

On the one hand, we know by experiment, that oily and bituminous substances can be melted and partly changed into vapour by heat, and that they become harder and denser, in proportion as the more volatile parts have evaporated from them. On the other hand, coaly substances are destitute of fusibility and volatility, in proportion as they have been exposed

la manganèse, bien loin d'user de ce moyen, il faut, au contraire, éloigner tout flux, produire la fusion, par la seule violence et la promptitude du feu. Et telle est la propension naturelle et prodigieuse de la manganèse à la vitrification, qu'on n'a pu parvenir encore à réduire son régule en un seul culot; on trouve dans le creuset plusieurs petits boutons, qui forment autant de culots séparés. Dans la mine de manganèse native, elle n'est point en une seule masse; elle est disposée également en plusieurs culots séparés, et un peu aplatis, comme ceux que l'art produit; beaucoup plus gros, à la vérité, parce que les agens de la nature doivent avoir une autre énergie, que ceux de nos laboratoires; et cette ressemblance si exacte, semble devoir vous faire penser que la mine native à été produite par le feu, tout comme son régule. La présence de la chaux argentée de la manganèse, me permettroit de croire que la nature n'a fait que réduire cette chaux. Du reste, cette mine native est très-pure, et ne contient aucune partie attirable à l'aimant. Cette mine, unique jusqu'à ce moment, vient, tout comme les autres manganèse que j'ai décrites, des mines de fer de *Sem*, dans la vallée de *Viedersos*, en Comté de Foix."—*Journal de Physique, Janvier 1786*.

to greater degrees of heat, and to other circumstances favourable to the dissipation of their more volatile and fluid parts.

If, therefore, in mineral bodies, we find the two extreme states of this combustible substance, and also the intermediate states, we must either conclude, that this particular operation of heat has been thus actually employed in nature, or we must explain those appearances by some other means, in as satisfactory a manner, and so as shall be consistent with other appearances.

In this case, it will avail nothing to have recourse to the false analogy of water dissolving and crystallising salts, which has been so much employed for the explanation of other mineral appearances. The operation here in question is of a different nature, and necessarily requires both the powers of heat and proper conditions for evaporation.

Therefore, in order to decide the point, with regard to what is the power in nature by which mineral bodies have become solid, we have but to find bituminous substance in the most complete state of coal, intimately connected with some other substance, which is more generally found consolidating the strata, and assisting in the concretion of mineral substances. But I have in my possession the most undoubted proof of this kind. It is a mineral vein, or cavity, in which are blended together coal of the most fixed kind, quartz and marmor metallicum. Nor is this all; for the specimen now referred to is contained in a rock of this kind, which every naturalist now-a-days will allow to have congealed from a fluid state of fusion. I have also similar specimens from the same place, in which the coal is not of that fixed and infusible kind which burns without flame or smoke, but is bituminous or inflammable coal.

We have hitherto been resting the argument upon a single point, for the sake of simplicity or clearness, not for want of those circumstances which shall be found to corroborate the theory. The strata of fossil coal are found in almost every intermediate state, as well as in those of bitumen and charcoal. Of the one kind is that fossil coal which melts or becomes fluid upon receiving heat; of the other, is that species of coal, found both in Wales and Scotland, which is perfectly infusible in the fire, and burns like coals, without flame or smoke. The one species abounds in oily matter, the other has been distilled by heat, until it has become a *caput mortuum*, or perfect coal.

The more volatile parts of these bituminous bodies are found in their separate state on some occasions. There is a stratum of limestone in Fifeshire, near Raith, which, though but slightly tinged with a black colour, contains bituminous matter, like pitch, in many cavities, which are lined with calcareous spar crystallised. I have a specimen of such a cavity, in which the bitumen is in sphericles, or rounded drops, immersed in the calcareous spar.

Now, it is to be observed, that, if the cavity in the solid limestone or marble, which is lined with calcareous crystals containing pyrites, had been thus encrusted by means of the filtration of water, this water must have dissolved calcareous spar, pyrites, and bitumen. But these natural appearances would not even be explained by this dissolution and supposed filtration of those substances. There is also required, *first*, A cause for the separation of those different substances from the aqueous menstruum in which they had been dissolved; *2dly*, An explanation of the way in which a dissolved bitumen should be formed into round hard bodies of the most solid structure; and, *lastly*, Some probable means for this complicated operation being performed, below the bottom of the ocean, in the close cavity of a marble stratum.

Thus, the additional proof, from the facts relating to the bituminous substances, conspiring with that from the phenomena of other bodies, affords the strongest corroboration of this opinion, that the various concretions found in the internal parts of strata have not been occasioned by means of aqueous solution, but by the power of heat and operation of simple fusion, preparing those different substances to concrete and crystallise in cooling.

The arguments which have been now employed for proving that strata have been consolidated by the power of heat, or by the means of fusion, have been drawn chiefly from the insoluble nature of those consolidating substances in relation to water, which is the only general menstruum that can be allowed for the mineral regions. But there are found, in the mineral kingdom, many solid masses of saltgem, which is a soluble substance. It may be now inquired, How far these masses, which are not infrequent in the earth, tend either to confirm the present theory, or, on the contrary, to give countenance to that which supposes water the chief instrument in consolidating strata.

The formation of salt at the bottom of the sea, without the assistance of subterranean fire, is not a thing unsupposable, as at first sight it might appear. Let us but suppose a rock placed across the gut of Gibraltar, (a case nowise unnatural), and the bottom of the Mediterranean would be certainly filled with salt, because the evaporation from the surface of that sea exceeds the measure of its supply.

But strata of salt, formed in this manner at the bottom of the sea, are as far from being consolidated by means of aqueous solution, as a bed of sand in the same situation; and we cannot explain the consolidation of such a stratum of salt by means of water, without supposing subterranean heat employed, to evaporate the brine which would successively occupy the interstices of the saline crystals. But this, it may be observed, is equally departing from the natural operation of water, as the means for consolidating the sediment of the ocean, as if we were to suppose the same thing done by heat and fusion. For the question is not, If subterranean heat be of sufficient intensity for the purpose of consolidating strata by the fusion of their substances; the question is, Whether it be by means of this agent, subterranean heat, or by water alone, without the operation of a melting heat, that those materials have been variously consolidated.

The example now under consideration, consolidated mineral salt, will serve to throw some light upon the subject; for, as it is to be shown, that this body of salt had been consolidated by perfect fusion, and not by means of aqueous solution, the consolidation of strata of indissoluble substances, by the operation of a melting heat, will meet with all that confirmation which the consistency of natural appearances can give.

The salt rock in Cheshire lies in strata of red marl. It is horizontal in its direction. I do not know its thickness, but it is dug thirty or forty feet deep. The body of this rock is perfectly solid, and the salt, in many places, pure, colourless, and transparent, breaking with a sparry cubical structure. But the greatest part is tinged by the admixture of the marl, and that in various degrees, from the slightest tinge of red, to the most perfect opacity. Thus, the rock appears as if it had been a mass of fluid salt, in which had been floating a quantity of marly substance, not uniformly mixed, but every where separating and subsiding from the pure saline substance.

There is also to be observed a certain regularity in this separation of the tinging from the colourless substance, which, at a proper distance, gives to the perpendicular section of the rock a distinguishable figure in its structure. When looking at this appearance near the bottom of the rock, it, at first, presented me with the figure of regular stratification; but, upon examining the whole mass of rock, I found, that it was only towards the bottom that this stratified appearance took place; and that, at the top of the rock, the most beautiful and regular figure was to be observed; but a figure the most opposite to that of stratification. It was all composed of concentric circles; and these appeared to be the section of a mass, composed altogether of concentric spheres, like those beautiful systems of configuration which agates so frequently present us with in miniature. In about eight or ten feet from the top, the circles growing large, were blended together, and gradually lost their regular appearance, until, at a greater depth, they again appeared in resemblance of a stratification.

This regular arrangement of the floating marly substance in the body of salt, which is that of the structure of a coated pebble, or that of concentric spheres, is altogether inexplicable upon any other supposition, than the perfect fluidity or fusion of the salt, and the attractions and repulsions of the contained substances. It is in vain to look, in the operations of solution and evaporation, for that which nothing but perfect fluidity or fusion can explain.

This example of a mineral salt congealed from a melted state, may be confirmed from another which I have from Dr Black, who suggested it to me. It is an alkaline salt, found in a mineral state, and described in the Philosophical Transactions, *anno* 1771. But to understand this specimen, something must be premised with regard to the nature of fossil alkali.

The fossil alkali crystallises from a dissolved state, in combining itself with a large portion of the water, in the manner of alum; and, in this case, the water is essential to the constitution of that transparent crystalline body; for, upon the evaporation of the water, the transparent salt loses its solidity, and becomes a white powder. If, instead of being gently dried, the crystalline salt is suddenly exposed to a sufficient degree of heat, that is, somewhat more than boiling water, it enters into the state of aqueous fusion, and it boils, in emitting the water by means of which it had been crystallised in the cold, and rendered fluid in that heated state. It is not possible to crystallise this alkaline salt from a dissolved state, without the combination of that quantity of water, nor to separate that water without destroying its crystalline state.

But in this mineral specimen, we have a solid crystalline salt, with a structure which, upon fracture, appears to be sparry and radiated, something resembling that of zeolite. It contains no water in its crystallization, but melts in a sufficient heat, without any aqueous fusion. Therefore, this salt must have been in a fluid state of fusion, immediately before its congelation and crystallization.

It would be endless to give examples of particular facts, so many are the different natural appearances that occur, attended with a variety of different circumstances.

There is one, however, which is peculiarly distinct, admits of sufficiently accurate description, and contains circumstances from which conclusions may be drawn with clearness. This is the ironstone, which is commonly found among the argillaceous strata, attendant upon fossil coal, both in Scotland and in England.

This stone is generally found among the bituminous schistus, or black argillaceous strata, either in separate masses of various shapes and sizes, or forming of itself strata which are more or less continuous in their direction among the schistus or argillaceous beds.

This mineral contains, in general, from 40 to 50 *per cent.* of iron, and it loses near one third of its weight in calcination. Before calcination it is of a grey colour, is not penetrable by water, and takes a polish. In this state, therefore, it is perfectly solid; but being calcined, it becomes red, porous, and tender.

The fact to be proved with regard to these iron-stones is this, That they have acquired their solid state from fusion, and not in concreting from any aqueous solution.

To abridge this disquisition, no argument is to be taken from contingent circumstances, (which, however, are often found here as well as in the case of marbles); such only are to be employed as are general to the subject, and arise necessarily from the nature of the operation.

It will be proper to describe a species of these stones, which is remarkably regular in its form. It is that found at Aberlady, in East Lothian.

The form of these iron-stones is that of an oblate or much compressed sphere, and the size from two or three inches diameter to more than a foot. In the circular or horizontal section, they present the most elegant septarium (Plates 1 and 2); and, from the examination of this particular structure, the following conclusions may be drawn.

First, That, the septa have been formed by the uniform contraction of the internal parts of the stone, the volume of the central parts diminishing more than that of the circumference; by this means, the separations of the stone diminish, in a progression from the center towards the circumference.

2d, That there are only two ways in which the septa must have received the spar or spatthose ore with which they are filled, more or less, either, *first* By insinuation into the cavity of the septa after these were formed; or, *2dly*, By separation from the substance of the stone, at the same time that the septa were forming.

Were the first supposition true, appearances would be observable, showing that the sparry substance had been admitted, either through the porous structure of the stone, or through proper apertures communicating from without. Now, if either one or other of these had been the case, and that the stone had been consolidated from no other cause than concretion from a dissolved state, that particular structure of the stone, by means of which the spar had been admitted, must appear at present upon an accurate examination.

This, however, is not the case, and we may rest the argument here. The septa reach not the circumference; the surface of the stone is solid and uniform in every part; and there is not any appearance of the spar in the argillaceous bed around the stone.

It, therefore, necessarily follows, that the contraction of the iron-stone, in order to form septa, and the filling of these cavities with spar, had proceeded*pari passu*; and that this operation must have been brought about by means of fusion, or by congelation from a state of simple fluidity and expansion.

It is only further to be observed, that all the arguments which have been already employed, concerning mineral concretions from a simply fluid state, or that of fusion, here take place. I have septaria of this kind, in which, besides pyrites, iron-ore, calcareous spar, and another that is ferruginous and compound, there is contained siliceous crystals; a case which is not so common. I have them also attended with circumstances of concretion and crystallization, which, besides being extremely rare, are equally curious and interesting.

There is one fact more which is well worth our attention, being one of those which are so general in the mineral regions. It is the crystallizations which are found in close cavities of the most solid bodies.

Nothing is more common than this appearance. Cavities are every where found closely lined with crystallizations, of every different substance which may be supposed in those places. These concretions are well known to naturalists, and form part of the beautiful specimens which are preserved in the cabinets of collectors, and which the German mineralists have termed *Drusen*. I shall only particularise one species, which may be described upon principle, and therefore may be a proper subject on which to reason, for ascertaining the order of production in certain bodies. This body, which we are now to examine, is of the agate species.

We have now been considering the means employed by nature in consolidating strata which were originally of an open structure; but in perfectly solid strata we find bodies of agate, which have evidently been formed in that place where they now are found. This fact, however, is not still that of which we are now particularly to inquire; for this, of which we are to treat, concerns only a cavity within this agate; now, whatever may have been the origin of the agate itself, we are to show, from what appears within its cavity, that the crystallizations which are found in this place had arisen from a simply fluid state, and not from that of any manner of solution.

The agates now in question are those of the coated kind, so frequent in this country, called pebbles. Many of these are filled with a siliceous crystallization, which evidently proceeds from the circumference towards the centre. Many of them, again, are hollow. Those cavities are variously lined with crystallized substances; and these are the object of the present examination.

But before describing what is found within, it is necessary to attend to this particular circumstance, that the cavity is perfectly inclosed with many solid coats, impervious to air or water, but particularly with the external cortical part, which is extremely hard, takes the highest polish, and is of the most perfect solidity, admitting the passage of nothing but light and heat.

Within these cavities, we find, *1st*, The coat of crystals with which this cavity is always lined; and this is general to all substances concreting, in similar circumstances, from a state of fusion; for when thus at liberty they naturally crystallise. *2dly*, We have frequently a subsequent crystallization, resting on the first, and more or less immersed in it. *3dly*, There is also sometimes a third crystallization, superincumbent on the second, in like manner as the second was on the first. I shall mention some particulars.

I have one specimen, in which the primary crystals are siliceous, the secondary thin foliaceous crystals of deep red but transparent iron-ore, forming elegant figures, that have the form of roses. The tertiary crystallization is a frosting of small siliceous crystals upon the edges of the foliaceous crystals.

In other specimens, there is first a lining of colourless siliceous crystals, then another lining of amethystine crystals, and sometimes within that, fuliginous crystals. Upon these fuliginous and amethystine crystals are many sphericles or hemispheres of red compact iron-ore, like haematites.

In others, again, the primary crystals are siliceous, and the secondary calcareous. Of this kind, I have one which has, upon the calcareous crystals, beautiful transparent siliceous crystals, and iron sphericles both upon all these crystals, and within them.

Lastly, I have an agate formed of various red and white coats, and beautifully figured. The cavity within the coated part of the pebble is filled up without vacuity, first, with colourless siliceous crystals; secondly, with fuliginous crystals; and, lastly, with white or colourless calcareous spar. But between the spar and crystals there are many sphericles, seemingly of iron, half sunk into each of these two different substances.

From these facts, I may now be allowed to draw the following conclusions:

1*st*, That concretion had proceeded from the surface of the agate body inwards. This necessarily follows from the nature of those figured bodies, the figures of the external coats always determining the shape of those within, and never, contrarily, those within affecting those without.

2*dly*, That when the agate was formed, the cavity then contained every thing which now is found within it, and nothing more.

3*dly*, That the contained substances must have been in a fluid state, in order to their crystallizing.

Lastly, That as this fluid state had not been the effect of solution in a menstruum, it must have been fluidity from heat and fusion.

Let us now make one general observation and argument with regard to the formation of those various coated, concreted, crystallized, and configured bodies. Were the crystallization and configuration found to proceed from a central body, and to be directed from that centre outwards, then, without inquiring into collateral appearances, and other proofs with regard to the natural concretion of those substances, we might suppose that these concretions might have proceeded from that central body gradually by accretion, and that the concreting and crystallizing substances might have been supplied from a fluid which had before retained the concreting substance in solution; in like manner as the crystallizations of sugar, which are formed in the solution of that saccharine substance, and are termed candies, are formed upon the threads which are extended in the crystallizing vessel for that purpose. But if, on the contrary, we are to consider those mineral bodies as spheres of alternate coats, composed of agate, crystal, spars, etc.; and if all those crystallizations have their *bases* upon the uncrystallized coat which is immediately external to it, and their *apices* turned inwards into the next internal solid coat, it is not possible to conceive that a structure of this kind could have been formed in any manner from a solution. But this last manner is the way without exception in which those mineral bodies are found; therefore we are to conclude, that the concretion of those bodies had proceeded immediately from a state of fusion or simple fluidity.

In granite these cavities are commonly lined with the crystal corresponding to the constituent substances of the stone, viz. quartz, feld-spar, and mica or talk. M. de Saussure, (Voyages dans les Alpes, tom. ii. §722.), says, "On trouve fréquemment des amas considérables de spath calcaire, crystallisé dans les grottes ou se forme le crystal de roche; quoique ces grottes soient renfermées dans le coeur des montagnes d'un granit vif, & qu'on ne voie aucun roc calcaire au dessus de ces montagnes."

So accurate an observer, and so complete a naturalist, must have observed how the extraneous substance had been introduced into this cavity, had they not been formed together the cavity and the calcareous crystals. That M. de Saussure perceived no means for that introduction, will appear from what immediately follows in that paragraph. "Ces rocs auroient-ils été détruits, ou bien ce spath n'est il que le produit d'une sécrétion des parties calcaires que l'on fait êtres dispersées entre les divers élémens du granit?"

Had M. de Saussure allowed himself to suppose all those substances in fusion, of which there cannot be a doubt, he would soon have resolved both this difficulty, and also that of finding molybdena crystallized along with feld-spar, in a cavity of this kind. §718.

To this argument, taken from the close cavities in our agates, I am now to add another demonstration. It is the case of the calcedony agate, containing a body of calcareous spar; here it is to be shown, that, while the calcareous body was altogether inclosed within the calcedony nodular body, these two substances had been perfectly soft, and had mutually affected each others shape, in concreting from a fluid state. In order to see this, we are to consider that both those substances have specific shapes in which they concrete from the third state; the sparry structure of the one is well known; the spherical or mammelated crystallization of the calcedony, is no less conspicuous; this last is, in the present case, spherical figures, which are some of them hemispheres, or even more. The figures which we have now in contemplation are so distinctly different as cannot be mistaken; the one is a rhombic figure bounded by planes; the other is a most perfect spherical form; and both these are specific figures, belonging respectively to the crystallization of those two substances.

The argument now to be employed for proving that those two bodies had concreted from the fluid state of fusion, and not from any manner of solution, is this: That, were the one of those bodies to be found impressing the other with its specific figure, we must conclude that the impressing body had concreted or crystallized while the impressed body was in a soft or fluid state; and that, if they are both found mutually impressing and impressed by each other, they must have both been in the fluid and concreting state together. Now the fact is, that the calcareous body is perfectly inclosed within the solid calcedony, and that they are mutually impressed by each others specific figure, the sparry structure of the calcareous body impressing the calcedony with its type of planes and angles, at the same time that, in other parts, the spherical figures of the calcedony enter the solid body of the spar, and thus impress their mammelated figures into that part which is contiguous. It is therefore inconceivable, that these appearances could have been produced in any other manner than by those two bodies concreting from a simply fluid state.

There are in jaspers and agates many other appearances, from whence the fusion of those substances may be concluded with great certainty and precision; but it is hoped, that what has been now given may suffice for establishing that proposition without any doubt.

It must not be here objected, That there are frequently found siliceous crystals and amethysts containing water; and that it is impossible to confine water even in melted glass. It is true, that here, at the surface of the earth, melted glass cannot, in ordinary circumstances, be made to receive and inclose condensed water; but let us only suppose a sufficient degree of compression in the body of melted glass, and we can easily imagine it to receive and confine water as well as any other substance. But if, even in our operations, water, by means of compression, may be made to endure the heat of red hot iron without being converted into vapour, what may not the power of nature be able to perform? The place of mineral operations is not on the surface of the earth; and we are not to limit nature with our imbecility, or estimate the powers of nature by the measure of our own.[15]

[15] This is so material a principle in the theory of consolidating the strata of the earth by the fusion of mineral substances, that I beg the particular attention of the reader to that subject. The effect of compression upon compound substances, submitted to increased degrees of heat, is not a matter of supposition, it is an established principle in natural philosophy. This, like every other physical principle, is founded upon matter of fact or experience; we find, that many compound substances may with heat be easily changed, by having their more volatile parts separated when under a small compression; but these substances are preserved without change when sufficiently compressed. Our experiments of this kind are necessarily extremely limited; they are not, however, for that reason, the less conclusive. The effects of increasing degrees of heat are certainly prevented by increasing degrees of compression; but the rate at which the different effects of those powers proceed, or the measure of those different degrees of increase that may be made without changing the constitution of the compound substance, are not known; nor is there any limit to be set to that operation, so far as we know. Consequently, it is a physical principle, That the evaporation of volatile substances by heat, or the reparation of them from a compound substance, consequently the effect of fire in changing that compound substance, may be absolutely prevented by means of compression.

It now remains to be considered, how far there is reason to conclude that there had been sufficient degrees of compression in the mineral regions, for the purpose of melting the various substances with which we find strata consolidated, without changing the chemical constitution of those compound substances.

Had I, in reasoning *a priori*, asserted, That all mineral bodies might have been melted without change, when under sufficient compression, there might have arisen, in the minds of reasoning men, some doubt with regard to the certainty of that proposition, however probable it were to be esteemed: But when, in reasoning *a posteriori*, it is found that all mineral bodies have been actually melted, then, all that is required to establish the proposition on which I have founded my theory, is to see that there must have been immense degrees of compression upon the subjects in question; for we neither know the degree of heat which had been employed, nor that of compression by which the effect of the heat must have been modified.

Now, in order to see that there had been immense compression, we have but to consider that the formation of the strata, which are to be consolidated, was at the bottom of the ocean, and that this place is to us unfathomable. If it be farther necessary to show that it had been at such unfathomable depth strata were consolidated, it will be sufficient to observe, it is not upon the surface of the earth, or above

To conclude this long chemico-mineral disquisition, I have specimens in which the mixture of calcareous, siliceous, and metallic substances, in almost every species of concretion which is to be found in mineral bodies, may be observed, and in which there is exhibited, in miniature, almost every species of mineral transaction, which, in nature, is found upon a scale of grandeur and magnificence. They are nodules contained in the whin-stone, porphyry, or basaltes of the Calton-hill, by Edinburgh; a body which is to be afterwards examined, when it will be found to have flowed, and to have been in fusion, by the operation of subterraneous heat.

This evidence, though most conclusive with regard to the application of subterraneous heat, as the means employed in bringing into fusion all the different substances with which strata may be found consolidated, is not directly a proof that strata had been consolidated by the fusion of their proper substance. It was necessary to see the general nature of the evidence, for the universal application of subterraneous heat, in the fusion of every kind of mineral body. Now, that this has been done, we may give examples of strata consolidated without the introduction of foreign matter, merely by the softening or fusion of their own materials.

For this purpose, we may consider two different species of strata, such as are perfectly simple in their nature, of the most distinct substances, and whose origin is perfectly understood, consequently, whose subsequent changes may be reasoned upon with certainty and clearness. These are the siliceous and calcareous strata; and these are the two prevailing substances of the globe, all the rest being, in comparison of these, as nothing; for unless it be the bituminous or coal strata, there is hardly any other which does not necessarily contain more or less of one or other of these two substances. If, therefore, it can be shown, that both of those two general strata have been consolidated by the simple fusion of their substance, no *desideratum* or doubt will remain, with regard to the nature of that operation which has

the level of the sea, that this mineral operation can take place; for, it is there that those consolidated bodies are redissolved, or necessarily going into decay, which is the opposite to that operation which we are now inquiring after; therefore, if they were consolidated in any other place than at the bottom of the sea, it must have been between that place of their formation and the surface of the sea; but that is a supposition which we have not any reason to make; therefore, we must conclude that it was at the bottom of the ocean those stratified bodies had been consolidated.

been transacted at great depths of the earth, places to which all access is denied to mortal eyes.

We are now to prove, *first*, That those strata have been consolidated by simple fusion; and, *2dly*, That this operation is universal, in relation to the strata of the earth, as having produced the various degrees of solidity or hardness in these bodies.

I shall first remark, that a fortuitous collection of hard bodies, such as gravel and sand, can only touch in points, and cannot, while in that hard state, be made to correspond so precisely to each others shape as to consolidate the mass. But if these hard bodies should be softened in their substance, or brought into a certain degree of fusion, they might be adapted mutually to each other, and thus consolidate the open structure of the mass. Therefore, to prove the present point, we have but to exhibit specimens of siliceous and calcareous strata which have been evidently consolidated in this manner.

Of the first kind, great varieties occur in this country. It is, therefore, needless to describe these particularly. They are the consolidated strata of gravel and sand, often containing abundance of feld-spar, and thus graduating into granite; a body, in this respect, perfectly similar to the more regular strata which we now examine.

The second kind, again, are not so common in this country, unless we consider the shells and coralline bodies in our lime-stones, as exhibiting the same example, which indeed they do. But I have a specimen of marble from Spain, which may be described, and which will afford the most satisfactory evidence of the fact in question.

This Spanish marble may be considered as a species of pudding-stone, being formed of calcareous gravel; a species of marble which, from Mr Bowles' Natural History, appears to be very common in Spain. The gravel of which this marble is composed, consists of fragments of other marbles of different kinds. Among these, are different species of *oolites* marble, some shell marbles, and some composed of a chalky substance, or of undistinguishable parts. But it appears, that all these different marbles had been consolidated or made hard, then broken into fragments, rolled and worn by attrition, and thus collected together, along with some sand or small siliceous bodies, into one mass. Lastly, This compound body is consolidated in such a manner as to give the most distinct evidence, that this had been executed by the operation of heat or simple fusion.

The proof I give is this, That besides the general conformation of those hard bodies, so as to be perfectly adapted to each other's shape, there is, in some places, a mutual indentation of the different pieces of gravel into each other; an indentation which resembles perfectly that junction of the different bones of the *cranium*, called sutures, and which must have necessarily required a mixture of those bodies while in a soft or fluid state.

This appearance of indentation is by no means singular, or limited to one particular specimen. I have several specimens of different marbles, in which fine examples of this species of mixture may be perceived. But in this particular case of the Spanish pudding-stone, where the mutual indentation is made between two pieces of hard stone, worn round by attrition, the softening or fusion of these two bodies is not simply rendered probable, but demonstrated.

Having thus proved, that those strata had been consolidated by simple fusion, as proposed, we now proceed to show, that this mineral operation had been not only general, as being found in all the regions of the globe, but universal, in consolidating our earth in all the various degrees, from loose and incoherent shells and sand, to the most solid bodies of the siliceous and calcareous substances.

To exemplify this in the various collections and mixtures of sands, gravels, shells, and corals, were endless and superfluous. I shall only take, for an example, one simple homogeneous body, in order to exhibit it in the various degrees of consolidation, from the state of simple incoherent earth to that of the most solid marble. It must be evident that this is chalk; naturally a soft calcareous earth, but which may be also found consolidated in every different degree.

Through the middle of the Isle of Wight, there runs a ridge of hills of indurated chalk. This ridge runs from the Isle of Wight directly west into Dorsetshire, and goes by Corscastle towards Dorchester, perhaps beyond that place. The sea has broke through this ridge at the west end of the Isle of Wight, where columns of the indurated chalk remain, called the Needles; the same appearance being found upon the opposite shore in Dorsetshire.

In this field of chalk, we find every gradation of that soft earthy substance to the most consolidated body of this indurated ridge, which is not solid marble, but which has lost its chalky property, and has acquired a kind of stony hardness.

We want only further to see this cretaceous substance in its most indurated and consolidated state; and this we have in the north of Ireland, not far from the Giants Causeway. I have examined cargoes of this lime-stone brought to the west of Scotland, and find the most perfect evidence of this body having been once a mass of chalk, which is now a solid marble.

Thus, if it is by means of fusion that the strata of the earth have been, in many places, consolidated, we must conclude, that all the degrees of consolidation, which are indefinite, have been brought about by the same means.

Now, that all the strata of the mineral regions, which are those only now examined, have been consolidated in some degree, is a fact for which no proof can be offered here, but must be submitted to experience and inquiry; so far, however, as they shall be considered as consolidated in any degree, which they certainly are in general, we have investigated the means which had been employed in that mineral operation.

We have now considered the concretions of particular bodies, and the general consolidation of strata; but it may be alleged, that there is a great part of the solid mass of this earth not properly comprehended among those bodies which have been thus proved to be consolidated by means of fusion. The body here alluded to is granite; a mass which is not generally stratified, and which, being a body perfectly solid, and forming some part in the structure of this earth, deserves to be considered.

The nature of granite, as a part of the structure of the earth, is too intricate a subject to be here considered, where we only seek to prove the fusion of a substance from the evident marks which are to be observed in a body. We shall, therefore, only now consider one particular species of granite; and if this shall appear to have been in a fluid state of fusion, we may be allowed to extend this property to all the kind.

The species now to be examined comes from the north country, about four or five miles west from Portfoy, on the road to Huntly. I have not been upon the spot, but am informed that this rock is immediately connected or continuous with the common granite of the country. This indeed appears in the specimens which I have got; for, in some of these, there is to be perceived a gradation from the regular to the irregular sort.

This rock may indeed be considered, in some respects, as a porphyry; for it has an evident ground, which is feld-spar, in its sparry state; and it is, in one view, distinctly maculated with quartz, which is transparent, but somewhat dark-coloured (Plate II, fig 1,2,3).

Considered as a porphyry, this specimen is no less singular than as a granite. For, instead of a siliceous ground, maculated with the rhombic feld-spar, which is the common state of porphyry, the ground is uniformly crystallised, or a homogeneous regular feld-spar, maculated with the transparent siliceous substance. But as, besides the feld-spar and quartz, which are the constituent parts of the stone, there is also mica, in some places, it may, with propriety, be termed a granite.

The singularity of this specimen consists, not in the nature or proportions of its constituent parts, but in the uniformity of the sparry ground, and the regular shape of the quartz mixture. This siliceous substance, viewed in one direction, or longitudinally, may be considered as columnar, prismatical, or continued in lines running nearly parallel. These columnar bodies of quartz are beautifully impressed with a figure on the sides, where they are in contact with the spar. This figure is that of furrows or channels, which are perfectly parallel, and run across the longitudinal direction of the quartz. This is represented in fig. 4. This striated figure is only seen when, by fracture, the quartz is separated from the contiguous spar.

But what I would here more particularly represent is, the transverse section of those longitudinal siliceous bodies These are seen in fig. 1. 2. and 3. They have not only separately the forms of certain typographic characters, but collectively give the regular lineal appearance of types set in writing.

It is evident from the inspection of this fossil, that the sparry and siliceous substances had been mixed together in a fluid state; and that the crystallization of the sparry substance, which is rhombic, had determined the regular structure of the quartz, at least in some directions.

Thus, the siliceous substance is to be considered as included in the spar, and as figured, according to the laws of crystallization proper to the sparry ground; but the spar is also to be found included in the quartz. It is not, indeed, always perfectly included or inclosed on all sides; but this is sometimes the case, or it appears so in the section. Fig. 5. 6. 7. 8. 9. and 10. are those cases magnified, and represent the different figured quartz inclosing the feld-spar. In one of them, the feld-spar, which is contained within the quartz, contains also a small triangle of quartz, which it incloses. Now, it is not possible to conceive any other way in which those two substances, quartz and feld-spar, could be thus concreted, except by congelation from a fluid state, in which they had been mixed.

There is one thing more to be observed with regard to this curious species of granite. It is the different order or arrangement of the crystallization or internal structure of the feld-spar ground, in two contiguous parts of the same mass. This is to be perceived in the polished surface of the stone, by means of the reflection of light.

There is a certain direction in which, viewing the stone, when the light falls with a proper obliquity, we see a luminous reflection from the internal parts of the stone. This arises from the reflecting surfaces of the sparry structure or minute cracks, all turned in one direction, consequently, giving that luminous appearance only in one point of view.

Now, all the parts of the stone in which the figured quartz is directed in the same manner, or regularly placed in relation to each other, present that shining appearance to the eye at one time, or in the same point of direction. But there are parts of the mass, which, though immediately contiguous and properly continuous, have a different disposition of the figured quartz; and these two distinguished masses, in the same surface of the polished stone, give to the eye their shining appearance in very different directions. Fig. 3. shows two of those figured and shining masses, in the same plane or polished surface.

It must be evident, that, as the crystallization of the sparry structure is the figuring cause of the quartz bodies, there must be observed a certain correspondency between those two things, the alinement (if I may be allowed the expression) of the quartz, and the shining of the sparry ground. It must also appear, that at the time of congelation of the fluid spar, those two contiguous portions had been differently disposed in the crystallization of their substance. This is an observation which I have had frequent opportunities of making, with respect to masses of calcareous spar.

Upon the whole, therefore, whether we shall consider granite as a stratum or as an irregular mass, whether as a collection of several materials, or as the separation of substances which had been mixed, there is sufficient evidence of this body having been consolidated by means of fusion, and in no other manner.

We are thus led to suppose, that the power of heat and operation of fusion must have been employed in consolidating strata of loose materials, which had been collected together and amassed at the bottom of the ocean. It will, therefore, be proper to consider, what are the appearances in consolidated strata that naturally should follow, on the one hand, from fluidity having been, in this manner, introduced by means of heat, and, on the other, from the interstices being filled by means of solution; that so we may compare appearances with the one and other of those two suppositions, in order to know that with which they may be only found consistent.

The consolidation of strata with every different kind of substance was found to be inconsistent with the supposition, that aqueous solution had been the means employed for this purpose. This appearance, on the contrary, is perfectly consistent with the idea, that the fluidity of these bodies had been the effect of heat; for, whether we suppose the introduction of foreign matter into the porous mass of a stratum for its consolidation, or whether we shall suppose the materials of the mass acquiring a degree of softness, by means of which, together with an immense compression, the porous body might be rendered solid; the power of heat, as the cause of fluidity and vapour, is equally proper and perfectly competent. Here, therefore, appearances are as decidedly in favour of the last supposition, as they had been inconsistent with the first.

But if strata have been consolidated by means of aqueous solution, these masses should be found precisely in the same state as when they were originally deposited from the water. The perpendicular section of those masses might show the compression of the bodies included in them, or of which they are composed; but the horizontal section could not contain any separation of the parts of the stratum from one another.

If, again, strata have been consolidated by means of heat, acting in such a manner as to soften their substance, then, in cooling, they must have formed rents or separations of their substance, by the unequal degrees of contraction which the contiguous strata may have suffered. Here is a most decisive mark by which the present question must be determined.

There is not in nature any appearance more distinct than this of the perpendicular fissures and separations in strata. These are generally known to workmen by the terms of veins or backs and cutters; and there is no consolidated stratum that wants these appearances. Here is, therefore, a clear decision of the question, Whether it has been by means of heat, or by means of aqueous solution, that collections of loose bodies at the bottom of the sea have been consolidated into the hardest rocks and most perfect marbles[16].

[16] This subject is extremely interesting, both to the theory of the earth, and to the science cf the mining art; I will now illustrate that theory, with an authority which I received after giving this dissertation to the Royal Society. It is in the second volume of M. de Saussure's *voyages dans les Alpes*. Here I find proper examples for illustrating that subject of mineralogy; and I am happy to have this opportunity of giving the reasoning of a man of science upon the subject, and the opinion of a person who is in every respect so well qualified to judge upon a point of this kind.
The first example is of a marble in the Alps, (*voyages dans les Alpes.*) tom. 2. page 271.
"La pâte de ces brèches est tantôt blanche, tantôt grise, et les fragmens qui y font renfermés font, les uns blancs, les autres gris, d'autres roux, et presque toujours d'une couleur différente de celle de la pâte qui les lit. Ils sont tous de nature calcaire; tels étaient au moins tous ceux que j'ai pus observer; et ce qu'il-y-a de remarquable, c'est qu'ils sont tous posés dans le sens des feuillets de la pierre; on diroit en les voyant, qu'ils ont tous été comprimés et écrasés dans le même sens. Cette même pierre est mêlée de mica, sur-tout dans les interstices des couches et entre les fragmens et la pâte qui les réunit; mais on ne voit point de

mica dans les fragmens eux-mêmes. On trouve aussi dans ces brèches des infiltrations de quartz. Cette pierre est coupée par des fréquentes fissures perpendiculaires aux plans des couches. On voit clairement que ces fentes out été formées par l'inégal affaissement des couches, et non par une retraite spontanée: car les morceaux ou fragmens étrangers sont tous partagés et coupés net par ces fissures au lieu que dans les divisions naturelles des couches, ces mêmes fragmens sont entiers et saillans au dehors de la surface. Les noeuds de quartz et les divers crystaux, que renferment les roches feuilletées, présentent le même phénomène, et l'on peut en tirer la même conséquence; ils font partagés dans les fentes, et entiers dans les séparations des couches."

He finds those particular strata in the other side of the mountain *col de la Seigne*, and gives us the following observations:

"Plus bas on passe entre deux bancs de ces mêmes brèches, entre lesquels sont interposées des couches d'ardoises noires et de grès feuilletés micacés, dont la situation est la même.

"On retrouve encore ces brèches vers le has de la descente, au pied de pyramides calcaires dont j'ai parlé plus haut. Je trouvai en 1774 de très-jolis crystaux de roche qui s'étaient formés dans les fentes de cette brèche. Il y avoit même un mélange de quartz et de mica qui s'étoit moulé dans quelques-une de ces fentes. C'étoit donc une roche semblable aux primitives, et pourtant d'une formation postérieure à celle de la pierre calcaire. Et quel système pourroit nous persuader que la nature ne puisse encore produire ce qu'elle a produit autrefois!"

M. de Saussure has here given us an example of a calcareous Braccia, as he calls it, but which is rather a pudding stone, with veins or contractions of the mass. He does not seem to understand these as consequences of the consolidation of those strata; this, however, is the only light in which these appearances may be explained, when those bodies are thus divided without any other separation in the mass.

The second example is found in the vertical strata of those mountains through which the Rhône has made its way in running from the great valley of the *Vallais* towards the lake of Geneva. (Chapitre xlviii.)

"C'est une espèce de pétrosilex gris, dur, sonore, un peu transparent, qui se débite en feuillets minces parfaitement plans et réguliers. Ces feuillets, ou plutôt ces couches, courent à 35 degrés du nord par est, en montant du coté de l'ouest sous un angle de 80 degrés. Ces couches sont coupées par des fentes qui leur sont à-peu-près perpendiculaires et qui le sont aussi à l'horizon. Cette pierre s'emploie aux mêmes usage que l'ardoise, mais elle est beaucoup plus forte et plus durable, parce qu'elle est plus dure et moins accessible aux impressions de l'eau et de l'air.

§ 1047. "Ces pétrosilex feuilletés changent peu-à-peu de nature, en admettant dans les interstices de leurs feuillets des parties de feldspath. Ils out alors l'apparence d'une roche feuilletée, quartzeuse et micacée, (*quartzum fornacum W.*). Mais cette apparence est trompeuse; car on n'y trouve pas un atome de quartz: toutes les parties blanches qui donnent du feu contre l'acier, font du feldspath; et les parties grise écailleuses ne font point du mica, ce sont de lames minces du pétrosilex dont j'ai déjà parlé."

Here is evidently what I would call petuntze strata, or porcelane stone, that is, strata formed by the deposits of such materials as might come from the *detritus* of granite, arranged at the bottom of the sea, and consolidated by heat in the mineral regions. We have precisely such stratified masses in the Pentland hills near Edinburgh. I have also a specimen of the same kind, brought from the East Indies, in which there is the print of an organized body. I believe it to be of some coralline or zoophite.

§ 1048. "Cette roche mélangée continue jusqu'à ce que le rocher s'éloigne un peu du grand chemin. Là, ce rocher se présente coupé à pic dans une grande étendue, et divisé par de grandes fentes obliques, à-peu-près parallèles entr'elles. Ces fentes partagent la montagne en grandes tranches de 50 à 60 pieds d'épaisseur, que de loin semblent être des couches. Mais lorsqu'on s'en approche, on voit, par le tissu même de la pierre feuilletée, que ses vraies couches font avec l'horizon des angles de 70 à 75 degré, et que ces grandes divisions sont de vraies fentes par lesquelles un grand nombre de couches consécutives sont coupées presque perpendiculairement à leurs plans. Les masses de rocher, comprises entre ces grandes fentes, sont encore divisées par d'autres fentes plus petites, dont la plupart sont paralleles aux grandes, d'autres leur sont obliques; mais toutes sont à très-peu-près perpendiculaires aux plans des couchés dont la montagne est composée."

Here is a distinct view of that which may be found to take place in all consolidated strata, whatever be the composition of the stratum; and it is this appearance which is here maintained to be a physical demonstration, that those strata had been consolidated by means of heat softening their materials. In that case, those stratified bodies, contracting in cooling, form veins and fissures traversing perpendicularly their

Error never can be consistent, nor can truth fail of having support from the accurate examination of every circumstance. It is not enough to have found appearances decisive of the question, with regard to the two suppositions which have been now considered, we may farther seek confirmation of that supposition which has been found alone consistent with appearances.

If it be by means of heat and fusion that strata have been consolidated, then, in proportion to the degree of consolidation they have undergone from their original state, they should, *caeteris paribus*, abound more with separations in their mass. But this conclusion is found consistent with appearances. A stratum of porous sand-stone does not abound so much with veins and cutters as a similar stratum of marble, or even a similar stratum of sand-stone that is more consolidated. In proportion, therefore, as strata have been consolidated, they are in general intersected with veins and cutters; and in proportion as strata are deep in their perpendicular section, the veins are wide, and placed at greater distances. In like manner, when strata are thin, the veins are many, but proportionally narrow.

It is thus, upon chemical principles, to be demonstrated, That all the solid strata of the globe have been condensed by means of heat, and hardened from a state of fusion. But this proposition is equally to be maintained from principles which are mechanical. The strata of the globe, besides being formed of earths, are composed of sand, of gravel, and fragments of hard bodies, all which may be considered as, in their nature, simple; but these strata are also found composed of bodies which are not simple, but are fragments of former strata, which had been consolidated, and afterwards were broken and worn by attrition, so as to be made gravel. Strata composed in this manner have been again consolidated; and now the question is, By what means?

planes; and these veins are afterwards filled with mineral substances. These are what I have here distinguished as the *particular* veins of mineral masses; things perfectly different from proper mineral or metallic veins, which are more general, as belonging to immense masses of those strata; and which had been formed, not from the contraction, but from the disrupture of those masses, and by the forcible injection of fluid mineral substances from below. Now these two species of veins, the particular and the general, although occasionally connected, must be in science carefully distinguished; in the one, we see the means which had been employed for the consolidation of the strata; in the other, we see that power by which the strata have been raised from the bottom of the sea and placed in the atmosphere.

If strata composed of such various bodies had been consolidated, by any manner of concretion, from the fluidity of a dissolution, the hard and solid bodies must be found in their entire state, while the interstices between those constituent parts of the stratum are filled up. No partial fracture can be conceived as introduced into the middle of a solid mass of hard matter, without having been communicated from the surrounding parts. But such partial separations are found in the middle of those hard and solid masses; therefore, this compound body must have been consolidated by other means than that of concretion from a state of a solution.

The Spanish marble already described, as well as many consolidated strata of siliceous gravel, of which I have specimens, afford the clearest evidence of this fact. These hard bodies are perfectly united together, in forming the most solid mass; the contiguous parts of some of the rounded fragments are interlaced together, as has already been observed; and there are partial shrinkings of the mass forming veins, traversing several fragments, but perfectly filled with the sparry substance of the mass, and sometimes with parts of the stone distinctly floating in the transparent body of spar. Now, there is not, besides heat or fusion, any known power in nature by which these effects might be produced. But such effects are general to all consolidated masses, although not always so well illustrated in a cabinet specimen.

Thus we have discovered a truth that is confirmed by every appearance, so far as the nature of the subject now examined admits. We now return to the general operation, of forming continents of those materials which had been deposited at the bottom of the sea.

Section 3. Investigation Of The Natural Operations Employed In The Production Of Land Above The Surface Of The Sea

We seek to know that operation by means of which masses of loose materials, collected at the bottom of the sea, were raised above its surface, and transformed into solid land.

We have found, that there is not in this globe (as a planet revolving in the solar system) any power or motion adapted to the purpose now in view; nor, were there such a power, could a mass of simply collected materials have continued any considerable time to resist the waves and currents natural to the sea, but must have been quickly carried away, and again deposited at the bottom of the ocean. But we have found, that there had been operations, natural to the bowels of this earth; by which those loose and unconnected materials have been cemented together, and consolidated into masses of great strength and hardness; those bodies are thus enabled to resist the force of waves and currents, and to preserve themselves, for a sufficient time, in their proper shape and place, as land above the general surface of the ocean.

We now desire to know, how far those internal operations of the globe, by which solidity and stability are procured to the beds of loose materials, may have been also employed in raising up a continent of land, to remain above the surface of the sea.

There is nothing so proper for the erection of land above the level of the ocean, as an expansive power of sufficient force, applied directly under materials in the bottom of the sea, under a mass that is proper for the formation of land when thus erected. The question is not, how such a power may be procured; such a power has probably been employed. If, therefore, such a power should be consistent with that which we found had actually been employed in preparing the erected mass; or, if such a power is to be reasonably concluded as accompanying those operations which we have found natural to the globe, and situated in the very place where this expansive power appears to be required, we should thus be led to perceive, in the natural operations of the globe, a power as efficacious for the elevation of what had been at the bottom of the sea into the place of land, as it is perfect for the preparation of those materials to serve the purpose of their elevation.

In opposition to this conclusion, it will not be allowed to allege; that we are ignorant how such a power might be exerted under the bottom of the ocean; for, the present question is not, what had been the cause of heat, which has appeared to have been produced in that place, but if this power of heat, which has certainly been exerted at the bottom of the ocean for consolidating strata, had been employed also for another purpose, that is, for raising those strata into the place of land.

We may, perhaps, account for the elevation of land, by the same cause with that of the consolidation of strata, already investigated, without explaining the means employed by nature in procuring the power of heat, or showing from what general source of action this particular power had been derived; but, by finding in subterranean heat a cause for any other change, besides the consolidation of porous or incoherent bodies, we shall generalise a fact, or extend our knowledge in the explanation of natural appearances.

The power of heat for the expansion of bodies, is, so far as we know, unlimited; but, by the expansion of bodies placed under the strata at the bottom of the sea, the elevation of those strata may be effected; and the question now to be resolved regards the actual exertion of this power of expansion. How far it is to be concluded as having been employed in the production of this earth above the level of the sea.

Before attempting to resolve that question, it may be proper to observe, there has been exerted an extreme degree of heat below the strata formed at the bottom of the sea; and this is precisely the action of a power required for the elevation of those heated bodies into a higher place. Therefore, if there is no other way in which we may conceive this event to have been brought about, consistent with the present state of things, or what actually appears, we shall have a right to conclude, that such had been the order of procedure in natural things, and that the strata formed at the bottom of the sea had been elevated, as well as consolidated, by means of subterraneous heat.

The consolidation of strata by means of fusion or the power of heat, has been concluded from the examination of nature, and from finding, that the present state of things is inconsistent with any other supposition. Now, again, we are considering the only power that may be conceived as capable of elevating strata from the bottom of the sea, and placing such a mass above the surface of the water. It is a truth unquestionable, that what had been originally at the bottom of the sea, is at present the highest of our land. In explaining this appearance, therefore, no other alternative is left, but either to suppose strata elevated by the power of heat above the level of the present sea, or the surface of the ocean reduced many miles below the height at which it had subsisted during the collection and induration of the land which we inhabit.

Now, if, on the one hand, we are to suppose no general power of subterraneous fire or heat, we leave to our theory no means for the retreat of the sea, or the lowering of its surface; if, on the other hand, we are to allow the general power of subterraneous heat, we cannot have much difficulty in supposing, either the surface of the sea to have subsided, or the bottom of the ocean, in certain parts, to have been raised by a subterranean power above the level of its surface, according as appearances shall be found to require the one or other of those conclusions. Here, therefore, we are again remitted to the history of nature, in order to find matter of fact by which this question may be properly decided.

If the present land had been discovered by the subsiding of the waters, there has not been a former land, from whence materials had been procured for the construction of the present, when at the bottom of the sea; for, there is no vestige remaining of that land, the whole land of the present earth having been formed evidently at the bottom of the sea. Neither could the natural productions of the sea have been accumulated, in the shape in which we now find them, on the surface of this earth; for, How should the Alps and Andes have been formed within the sea from the natural productions of the water? Consequently, this is a supposition inconsistent with every natural appearance.

The supposition, therefore, of the subsidence of the former ocean, for the purpose of discovering the present land, is beset with more difficulty than the simple erection of the bottom of the former ocean; for, *first*, There is a place to provide for the retirement of the waters of the ocean; and, *2dly*, There is required a work of equal magnitude; this is, the swallowing up of that former continent, which had procured the materials of the present land.

On the one hand, the subsiding of the surface of the ocean would but make the former land appear the higher; and, on the other, the sinking the body of the former land into the solid globe, so as to swallow up the greater part of the ocean after it, if not a natural impossibility, would be at least a superfluous exertion of the power of nature. Such an operation as this would discover as little wisdom in the end elected, as in the means appropriated to that end; for, if the land be not wasted and worn away in the natural operations of the globe, Why make such a convulsion in the world in order to renew the land? If, again, the land naturally decays, Why employ so extraordinary a power, in order to hide a former continent of land, and puzzle man?

Let us now consider how far the other proposition, of strata being elevated by the power of heat above the level of the sea, may be confirmed from the examination of natural appearances.

The strata formed at the bottom of the ocean are necessarily horizontal in their position, or nearly so, and continuous in their horizontal direction or extent. They may change, and gradually assume the nature of each other, so far as concerns the materials of which they are formed; but there cannot be any sudden change, fracture, or displacement, naturally in the body of a stratum. But, if these strata are cemented by the heat of fusion, and erected with an expansive power acting below, we may expect to find every species of fracture, dislocation, and contortion, in those bodies, and every degree of departure from a horizontal towards a vertical position.

The strata of the globe are actually found in every possible position: For, from horizontal, they are frequently found vertical; from continuous, they are broken and separated in every possible direction; and, from a plane, they are bent and doubled. It is impossible that they could have originally been formed, by the known laws of nature, in their present state and position; and the power that has been necessarily required for their change, has not been inferior to that which might have been required for their elevation from the place in which they had been formed.

In this cafe, natural appearances are not anomalous. They are, indeed, infinitely various, as they ought to be, according to the rule; but all those varieties in appearances conspire to prove one general truth, viz. That all which we see had been originally composed according to certain principles, established in the constitution of the terraqueous globe; and that those regular compositions had been afterwards greatly changed by the operations of another power, which had introduced apparent confusion among things first formed in order and by rule.

It is concerning the operation of this second power that we are now inquiring; and here the apparent irregularity and disorder of the mineral regions are as instructive, with regard to what had been transacted in a former period of time, as the order and regularity of those same regions are conclusive, in relation to the place in which a former state of things had produced that which, in its changed state, we now perceive.

We are now to conclude, that the land on which we dwell had been elevated from a lower situation by the same agent which had been employed in consolidating the strata, in giving them stability, and preparing them for the purpose of the living world. This agent is matter actuated by extreme heat, and expanded with amazing force.

If this has been the case, it will be reasonable to expect, that some of the expanded matter might be found condensed in the bodies which have been heated by that igneous vapour; and that matter, foreign to the strata, may have been thus introduced into the fractures and separations of those indurated masses.

We have but to open our eyes to be convinced of this truth. Look into the sources of our mineral treasures; ask the miner, from whence has come the metal into his vein? Not from the earth or air above,—not from the strata which the vein traverses; these do not contain one atom of the minerals now considered. There is but one place from whence these minerals may have come; this is the bowels of the earth, the place of power and expansion, the place from whence must have proceeded that intense heat by which loose materials have been consolidated into rocks, as well as that enormous force by which the regular strata have been broken and displaced.

Our attention is here peculiarly called upon, where we have the opportunity of examining those mineral bodies, which have immediately proceeded from the unknown region, that place of power and energy which we want to explore; for, if such is the system of the earth, that materials are first deposited at the bottom of the ocean, there to be prepared in a certain manner, in order to acquire solidity, and then to be elevated into the proper place of land, these mineral veins, which contain matter absolutely foreign to the surface of the earth, afford the most authentic information with regard to the operations which we want to understand. It is these veins which we are to consider as, in some measure, the continuation of that mineral region, which lies necessarily out of all possible reach of our examination. It is, therefore, peculiarly interesting to know the state in which things are to be found in this place, which may be considered as intermediate between the solid land, upon the one hand, and the unknown regions of the earth, upon the other.

We are now to examine those mineral veins; and these may be considered, first, in relation to their form, independent of their substance or particular contents; and, secondly, in relation to the contained bodies, independent of their form.

In examining consolidated strata, we remarked veins and cutters as a proof of the means by which those bodies had been consolidated. In that case, the formation of these veins is a regulated process, determined by the degree of fusion, and the circumstances of condensation or refrigeration. In respect of these, the mineral veins now to be examined are anomalous. They are; but we know not why or how. We see the effect; but, in that effect, we do not see the cause. We can say, negatively, that the cause of mineral veins is not that by which the veins and fissures of consolidated strata have been formed; consequently, that it is not the measured contraction and regulated condensation of the consolidated land which has formed those general mineral veins; however, veins, similar in many respects, have been formed by the cooperation of this cause.

Having thus taken a view of the evident distinction between the veins or contractions that are particular to the consolidated body in which they are found, and those more general veins which are not limited to that cause, we may now consider what is general in the subject, or what is universal in these effects of which we wish to investigate the cause.

The event of highest generalization or universality, in the form of those mineral veins, is fracture and dislocation. It is not, like that of the veins of strata, simple separation and measured contraction; it is violent fracture and unlimited dislocation. In the one case, the forming cause is in the body which is separated; for, after the body had been actuated by heat, it is by the reaction of the proper matter of the body, that the chasm which constitutes the vein is formed. In the other case, again, the cause is extrinsic in relation to the body in which the chasm is formed. There has been the most violent fracture and divulsion; but the cause is still to seek; and it appears not in the vein; for it is not every fracture and dislocation of the solid body of our earth, in which minerals, or the proper substances of mineral veins, are found.

We are now examining matter of fact, real effects, from whence we would investigate the nature of certain events which do not now appear. Of these, two kinds occur; one which has relation to the hardness and solidity, or the natural constitution of the body; the other, to its shape or local situation. The first has been already considered; the last is now the subject of inquiry.

But, in examining those natural appearances, we find two different kinds of veins; the one necessarily connected with the consolidating cause; the other with that cause of which we now particularly inquire. For, in those great mineral veins, violent fracture and dislocation is the principle; but there is no other principle upon which strata, or masses formed at the bottom of the sea, can be placed at a height above its surface. Hence, in those two different operations, of forming mineral veins, and erecting strata from a lower to a higher place, the principle is the same; for, neither can be done without violent fracture and dislocation.

We now only want to know, how far it is by the same power, as well as upon the same principle, that these two operations have been made. An expansive force, acting from below, is the power most proper for erecting masses; but whether it is a power of the same nature with that which has been employed in forming mineral veins, will best appear in knowing the nature of their contents. These, therefore, may be now considered.

Every species of fracture, and every degree of dislocation and contortion, may be perceived in the form of mineral veins; and there is no other general principle to be observed in examining their form. But, in examining their contents, some other principle may appear, so far as, to the dislocating power or force, there may be superadded matter, by which something in relation to the nature of the power may be known. If, for example, a tree or a rock shall be found simply split asunder, although there be no doubt with regard to some power having been applied in order to produce the effect, yet we are left merely to conjecture at the power. But when wedges of wood or iron, or frozen water, should be found lodged in the cleft, we might be enabled, from this appearance, to form a certain judgment with regard to the nature of the power which had been applied. This is the case with mineral veins. We find them containing matter, which indicates a cause; and every information in this case is interesting to the theory.

The substances contained in mineral veins are precisely the same with those which, in the former section, we have considered as being made instrumental in the consolidation of strata; and they are found mixed and concreted in every manner possible.

But, besides this evidence for the exertion of extreme heat, in that process by which those veins were filled, there is another important observation to be gathered from the inspection of this subject. There appears to have been a great mechanical power employed in the filling of these veins, as well as that necessarily required in making the first fracture and divulsion.

This appears from the order of the contents, or filling of these veins, which is a thing often observed to be various and successive. But what it is chiefly now in view to illustrate, is that immense force which is manifested in the fracture and dispersion of the solid contents which had formerly filled those veins. Here we find fragments of rock and spar floating in the body of a vein filled with metallic substances; there, again, we see the various fragments of metallic masses floating in the sparry and siliceous contents.

One thing is demonstrable from the inspection of the veins and their contents; this is, the successive irruptions of those fluid substances breaking the solid bodies which they meet, and floating those fragments of the broken bodies in the vein. It is very common to see three successive series of those operations; and all this may be perceived in a small fragment of stone, which a man of science may examine in his closet, often better than descending to the mine, where all the examples are found on an enlarged scale.

Let us now consider what power would be required to force up, from the most unfathomable depth of the ocean, to the Andes or the Alps, a column of fluid metal and of stone. This power cannot be much less than that required to elevate the highest land upon the globe. Whether, therefore, we shall consider the general veins as having been filled by mineral steams, or by fluid minerals, an elevating power of immense force is still required, in order to form as well as fill those veins. But such a power acting under the consolidated masses at the bottom of the sea, is the only natural means for making those masses land.

If such have been the operations that are necessary for the production of this land; and if these operations are natural to the globe of this earth, as being the effect of wisdom in its contrivance, we shall have reason to look for the actual manifestation of this truth in the phaenomena of nature, or those appearances which more immediately discover the actual cause in the perceived effect.

To see the evidence of marble, a body that is solid, having been formed of loose materials collected at the bottom of the sea, is not always easy, although it may be made abundantly plain; and to be convinced that this calcareous stone, which calcines so easily in our fires, should have been brought into fusion by subterraneous heat, without suffering calcination, must require a chain of reasoning which every one is not able to attain[17] .

[17] Mr le Chevalier de Dolomieu, in considering the different effects of heat, has made the following observation; Journal de Physique, Mai 1792.
"Je dis *le feu tel que nous l'employons* pour distinguer le feu naturel des volcans, du feu de nos fourneaux et de celui de nos chalumeaux. Nous sommes obligés de donner une grande activité à son action pour suppléer et au volume qui ne seroit pas à notre disposition et au tems que nous sommes forcés de ménager, et cette manière d'appliquer une chaleur très-active, communique le mouvement et le désordre

But when fire bursts forth from the bottom of the sea, and when the land is heaved up and down, so as to demolish cities in an instant, and split asunder rocks and solid mountains, there is nobody but must see in this a power, which may be sufficient to accomplish every view of nature in erecting land, as it is situated in the place most advantageous for that purpose.

The only question, therefore, which it concerns us to decide at present, is, Whether those operations of extreme heat, and violent mechanic force, be only in the system as a matter of accident; or if, on the contrary, they are operations natural to the globe, and necessary in the production of such land as this which we inhabit? The answer to this is plain: These operations of the globe remain at present with undiminished activity, or in the fullness of their power.

A stream of melted lava flows from the sides of Mount Aetna. Here is a column of weighty matter raised from a great depth below, to an immense height above, the level of the sea, and rocks of an enormous size are projected from its orifice some miles into the air. Every one acknowledges that here is the liquefying power and expansive force of subterranean fire, or violent heat. But, that Sicily itself had been raised from the bottom of the ocean, and that the marble called Sicilian Jasper, had its solidity upon the same principle with the lava, would stumble many a naturalist to

jusques dans les molécules constituantes. Agrégation et composition, tout est troublé. Dans les volcans la grand masse du feu supplée à son intensité, le tems remplace son activité, de manière qu'il tourmente moins les corps fournis à son action; il ménage leur composition en relâchant leur agrégation, et les pierres qui eut été rendues fluides par l'embrasement volcanique peuvent reprendre leur état primitif; la plupart des substances qu'un feu plus actif auroit expulsées y restent encore. Voilà pourquoi les laves ressemblent tellement aux pierres naturelles des espèces analogues, qu'elles ne peuvent en être distinguées; voilà également pourquoi les verres volcaniques eux-même renferment encore des substances élastiques qui les font boursoufler lorsque nous les fondons de nouveau, et pourquoi ces verres blanchissent aussi, pour lors, par la dissipation, d'une substance grasse qui a résisté à la chaleur des volcans, et que volatilise la chaleur par laquelle nous obtenons leur second fusion."

No doubt, the long application of heat may produce changes in bodies very different from those which are occasioned by the sudden application of a more intense heat; but still there must be sufficient intensity in that power, so as to cause fluidity, without which no chemical change can be produced in bodies. The essential difference, however, between the natural heat of the mineral regions, and that which we excite upon the surface of the earth, consists in this; that nature applies heat under circumstances which we are not able to imitate, that is, under such compression as shall prevent the decomposition of the constituent substances, by the separation of the more volatile from the more fixed parts. This is a circumstance which, so far as I know, no chemist or naturalist has hitherto considered; and it is that by which the operations of the mineral regions must certainly be explained. Without attending to this great principle in the mineralizing operations of subterraneous fire, it is impossible to conceive the fusion and concretion of those various bodies, which we examine when brought up to the surface of the earth.

acknowledge. Nevertheless, I have in my possession a table of this marble, from which it is demonstrable, that this calcareous stone had flowed, and been in such a state of fusion and fluidity as lava.

Here is a comparison formed of two mineral substances, to which it is of the highest importance to attend. The solidity and present state of the one of these is commonly thought to be the operation of fire; of the other, again, it is thought to be that of water. This, however, is not the case. The immediate state and condition of both these bodies is now to be considered as equally the effect of fire or heat. The reason of our forming such a different judgment with regard to these two subjects is this; we see, in the one case, the more immediate connection of the cause and the effect, while, in the other, we have only the effects from whence we are in science to investigate the cause.

But, if it were necessary always to see this immediate connection, in order to acknowledge the operation of a power which, at present, is extinguished in the effect, we should lose the benefit of science, or general principles, from whence particulars may be deduced, and we should be able to reason no better than the brute. Man is made for science; he reasons from effects to causes, and from causes to effects; but he does not always reason without error. In reasoning, therefore, from appearances which are particular, care must be taken how we generalise; we should be cautious not to attribute to nature, laws which may perhaps be only of our own invention.

The immediate question now before us is not, If the subterraneous fire, or elevating power, which we perceive sometimes as operating with such energy, be the consolidating cause of strata formed at the bottom of the sea; nor, if that power be the means of making land appear above the general surface of the water? for, though this be the end we want to arrive at ultimately, the question at present in agitation respects the laws of nature, or the generality of particular appearances.

Has the globe within it such an active power as fits it for the renovation of that part of its constitution which may be subject to decay? Are those powerful operations of fire, or subterraneous heat, which so often have filled us with terror and astonishment, to be considered as having always been? Are they to be concluded as proper to every part upon the globe, and as continual in the system of this earth? If these points in question shall be decided in the affirmative, we can be at no loss in ascertaining the power which has consolidated strata, nor in explaining the present situation of those bodies, which had their origin at the bottom of the sea. This, therefore, should be the object of our pursuit; and in order to have demonstration in a case of physical inquiry, we must again have recourse to the book of nature.

The general tendency of heat is to produce fluidity and softness; as that of cold is, on the contrary, to harden soft and fluid bodies. But this softening power of heat is not uniform in its nature; it is made to act with very different effect, according to the nature of the substance to which it is applied. We are but limited in the art of increasing the heat or the cold of bodies; we find, however, extreme difference in their substances with respect to fusibility.

A fusible substance, or mineral composition in a fluid state, is emitted from those places of the earth at which subterraneous fire and expansive force are manifested in those eruptive operations. In examining these emitted bodies, men of science find a character for such productions, in generalising the substance, and understanding the natural constitution of those bodies. It is in this manner that such a person, finding a piece of lava in any place of the earth, says with certainty, Here is a stone which had congealed from a melted state.

Having thus found a distinguishing character for those fused substances called, in general, Lavas, and having the most visible marks for that which had been actually a volcano, naturalists, in examining different countries, have discovered the most undoubted proofs of many ancient volcanos, which had not been before suspected. Thus, volcanos will appear to be not a matter of accident, or as only happening in a particular place, they are general to the globe, so far as there is no place upon the earth that may not have an eruption of this kind; although it is by no means necessary for every place to have had those eruptions.

Volcanos are natural to the globe, as general operations; but we are not to consider nature as having a burning mountain for an end in her intention, or as a principal purpose in the general system of this world. The end of nature in placing an internal fire or power of heat, and a force of irresistible expansion, in the body of this earth, is to consolidate the sediment collected at the bottom of the sea, and to form thereof a mass of permanent land above the level of the ocean, for the purpose of maintaining plants and animals. The power appointed for this purpose is, as on all other occasions, where the operation is important, and where there is any danger of a shortcoming, wisely provided in abundance; and there are contrived means for disposing of the redundancy. These, in the present case, are our volcanos.

A volcano is not made on purpose to frighten superstitious people into fits of piety and devotion, nor to overwhelm devoted cities with destruction; a volcano should be considered as a spiracle to the subterranean furnace, in order to prevent the unnecessary elevation of land, and fatal effects of earthquakes; and we may rest assured, that they, in general, wisely answer the end of their intention, without being in themselves an end, for which nature had exerted such amazing power and excellent contrivance.

Let us take a view of the most elevated places of the earth; if the present theory is just, it is there that we should find volcanos. But is not this the case? There are volcanos in the Andes; and round the Alps we find many volcanos, which are in France upon the one side, and in Germany upon the other, as well as upon the Italian side, where Vesuvius still continues to exhibit violent eruptions.

It is not meant to allege, that it is only upon the summit of a continent volcanos should appear. Subterraneous fire has sometimes made its appearance in bursting from the bottom of the sea. But, even in this last case, land was raised from the bottom of the sea, before the eruption made its exit into the atmosphere. It must also be evident, that, in this case of the new island near Santorini, had the expansive power been retained, instead of being discharged, much more land might have been raised above the level of the ocean.

Now, the eruption of that elastic force through the bottom of the sea, may be considered as a waste of power in the operations of the globe, where the elevation of indurated strata is an object in the exertion of that power; whereas, in the centre of a continent sufficiently elevated above the level of the sea, the eruption of that fiery vapour calculated to elevate the land, while it may occasionally destroy the habitations of a few, provides for the security and quiet possession of the many.

In order to see the wisdom of this contrivance, let us consider the two extreme places at which this eruption of ignited matter may be performed. These are, on the one hand, within a continent of land, and, on the other, at the bottom of the ocean. In the one case, the free eruption of the expanding power should be permitted; because the purpose for which it had been calculated to exist has been accomplished. In the other, again, the free eruption of that powerful matter should be repressed; because there is reserved for that power much of another operation in that place. But, according to the wise constitution of things, this must necessarily happen. The eruption of the fiery vapour from volcanos on the continent or land, is interrupted only occasionally, by the melted bodies flowing in the subterraneous chimney; whereas, at the bottom of the ocean, the contact of the water necessarily tends to close the orifice, by accumulating condensed matter upon the weakest place.

If this be a just theory of the natural operations of the globe, we shall have reason to expect, that great quantities of this melted matter, or fusible substance, may be found in form of lava, among the strata of the earth, where there are no visible marks of any volcano, or burning mountain, having existed. Here, therefore, is an important point to be determined; for, if it shall appear that much of this melted matter, analogous to lava, has been forced to flow among the strata which had been formed at the bottom of the sea, and now are found forming dry land above its surface, it will be allowed, that we have discovered the secret operations of nature concocting future land, as well as those by which the present habitable earth had been produced from the bottom of the abyss. Here, therefore, we shall at present rest the argument, with endeavouring to show that such is actually the case.

It appears from Cronstedt's Mineralogy, that the rock-stone, called trap by the Swedes, the amygdaloides and the schwarts-stein of the Germans, are the same with the whin-stone of this country. This is also fully confirmed by specimens from Sweden, sent me by my friend Dr Gahn. Whatever, therefore, shall be ascertained with regard to our whin-stone, may be so far generalized or extended to the countries of Norway, Sweden, and Germany.

The whin-stone of Scotland is also the same with the toad-stone of Derbyshire, which is of the amygdaloides species; it is also the same with the flagstone of the south of Staffordshire, which is a simple whin-stone, or perfect trap. England, therefore, must be included in this great space of land, the mineral operations of which we explore; and also Ireland, of which the Giant's Causeway, and many others, are sufficient proof.

In the south of Scotland, there is a ridge of hills, which extends from the west side of the island in Galloway to the east side in Berwickshire, composed of granite, of schistus, and of siliceous strata. The Grampians on the north, again, form another range of mountains of the same kind; and between these two great fields of broken, tumbled, and distorted strata, there lies a field of lesser hardness and consolidation, in general; but a field in which there is a great manifestation of subterraneous fire, and of exerted force.

The strata in this space consist, in general, of sand-stone, coal, lime-stone or marble, iron-stone, and marl or argillaceous strata, with strata of analogous bodies, and the various compositions of these. But what is to the present purpose is this, that, through all this space, there are interspersed immense quantities of whinstone; a body which is to be distinguished as very different from lava; and now the disposition of this whin-stone is to be considered.

Sometimes it is found in an irregular mass or mountain, as Mr Cronstedt has properly observed; but he has also said, that this is not the case in general. His words are: "It is oftener found in form of veins in mountains of another kind, running commonly in a serpentine manner, contrary or across to the direction of the rock itself."

The origin of this form, in which the trap or whin-stone appears, is most evident to inspection, when we consider that this solid body had been in a fluid state, and introduced, in that state, among strata, which preserved their proper form. The strata appear to have been broken, and the two correspondent parts of those strata are separated to admit the flowing mass of whin-stone.

A fine example of this kind may be seen upon the south side of the Earn, on the road to Crief. It is twenty-four yards wide, stands perpendicular, and appears many feet above the surface of the ground. It runs from that eastward, and would seem to be the same with that which crosses the river Tay, in forming Campsy-lin above Stanley, as a lesser one of the same kind does below it. I have seen it at Lednoc upon the Ammon, where it forms a cascade in that river, about five or six miles west of Campsy-lin. It appears to run from the Tay east through Strathmore, so that it may be considered as having been traced for twenty or thirty miles, and westwards to Drummond castle, perhaps much farther.

Two small veins of the same kind, only two or three feet wide, may be seen in the bed of the Water of Leith, traversing the horizontal strata, the one is above St Bernard's well, the other immediately below it. But, more particularly, in the shire of Ayr, to the north of Irvine, there are to be seen upon the coast, between that and Scarmorly, in the space of about twenty miles, more than twenty or thirty such dykes (as they are called) of whin-stone. Some of them are of a great thickness; and, in some places, there is perceived a short one, running at right angles, and communicating with other two that run parallel.

There is in this country, and in Derbyshire[18] , another regular appearance of this stone, which Cronstedt has not mentioned. In this case, the strata are not broken in order to have the whin-stone introduced, they are separated, and the whin-stone is interjected in form of strata, having various degrees of regularity, and being of different thickness. On the south side of Edinburgh, I have seen, in little more than the space of a mile from east to west, nine or ten masses of whin-stone interjected among the strata. These masses of

[18] See Mr Whitehurst's Theory of the Earth.

whin-stone are from three or four to an hundred feet thick, running parallel in planes inclined to the horizon, and forming with it an angle of about twenty or thirty degrees, as may be seen at all times in the hill of Salisbury Craggs.

Having thus described these masses, which have flowed by means of heat among the strata of the globe, strata which had been formed by subsidence at the bottom of the sea, it will now be proper to examine the difference that subsists between these subterraneous lavas, as they may be termed, and the analogous bodies which are proper lavas, in having issued out of a volcano.[19]

There can be no doubt that these two different species of bodies have had the same origin, and that they are composed of the same materials nearly; but from the different circumstances Of their production, there is formed a character to these bodies, by which, they may be perfectly distinguished. The difference of those circumstances consists in this; the one has been emitted to the atmosphere in its fluid state the other only came to be exposed to the light in a long course of time, after it had congealed under the compression of an immense load of earth, and after certain operations, proper to the mineral regions, had been exercised upon the indurated mass. This is the cause of the difference between those erupted lavas, and our

[19] The Chevalier de Dolomieu, in his accurate examination of Aetna and the Lipari islands, has very well observed the distinction of these two different species of lavas; but without seeming to know the principle upon which this essential difference depends. No bias of system, therefore, can here be supposed as perverting the Chevalier's view, in taking those observations; and these are interesting to the present theory, as corresponding perfectly with the facts from whence it has been formed. It will be proper to give the account of these in his own words.
La zéolite est très-commune dans certains laves de l'Ethna; il seroit peut-être possible d'y en rencontrer des morceaux aussi gros que ceux que fournit l'isle de Ferroé. Quoique cette substance semble ici appartenir aux laves, je ne dirai cependant point que toutes les zéolites soient volcaniques, ou unies à des matières volcaniques; celles que l'on trouve en Allemagne sont, dit-on, dans des circonstances différentes; mais je doit annoncer que je n'ai trouvé cette substance en Sicile, que dans les seules laves qui évidemment ont coulé dans la mer, et qui out été recouvertes par ses eaux. La zéolite des laves n'est point une déjection volcanique, ni une production du feu, ni même un matière que les laves aient enveloppée lorsqu'elles étoient fluides; elle est le résultat d'une opération et d'une combinaison postérieure, auxquelles les eaux de la mer ont concouru. Les laves qui n'ont pas été submergées, n'en contiennent jamais. J'ai trouvé ces observations si constantes, que par-tout où je rencontrois de la zéolite, j'étois sûr de trouver d'autres preuves de submersion, et partout où je voyois des laves recouvertes des dépôts de l'eau, j'étois sûr de trouver de la zéolite, et un de ces faits m'a toujours indiqué l'autre. Je me suis servi avec succès de cette observation pour diriger mes recherches, et pour connoître l'antiquité des laves. *Minéralogie de Volcans, par M. Faujas de Saint-Fond*. Here would appear to be the distinction of subterraneous lava, in which zeolite and calcareous spar may be found, and that which has flowed from a volcano, in which neither of these are ever observed.

whin-stone, toad-stone, and the Swedish trap, which may be termed subterraneous lava. The visible effects of those different operations may now be mentioned.

In the erupted lavas, those substances which are subject to calcine and vitrify in our fires, suffer similar changes, when delivered from a compression which had rendered them fixed, though in an extremely heated state. Thus, a lava in which there is much calcareous spar, when it comes to be exposed to the atmosphere, or delivered from the compressing force of its confinement, effervesces by the explosion of its fixed air; the calcareous earth, at the same time, vitrifies with the other substances. Hence such violent ebullition in volcanos, and hence the emission of so much pumice-stone and ashes, which are of the same nature.

In the body of our whin-stone, on the contrary, there is no mark of calcination or vitrification. We frequently find in it much calcareous spar, or the *terra calcarea aerata*, which had been in a melted state by heat, and had been crystallized by congelation into a sparry form. Such is the *lapis amygdaloides*, and many of our whin-stone rocks, which contain pebbles crystallized and variously figured, both calcareous, siliceous, and of a mixture in which both these substances form distinct parts. The specimens of this kind, which I have from the whin-stone or porphyry rock of the Calton-hill, exhibit every species of mineral operation, in forming jasper, figured agate, and marble; and they demonstrate, that this had been performed by heat or fusion.

I do not mean to say, that this demonstration is direct; it is conditional, and proceeds upon the supposition, that the basaltic or porphyry rock, in which those specimens are found, is a body which had been in a melted state. Now, this is a supposition for which I have abundance of evidence, were it required; but naturalists are now sufficiently disposed to admit that proposition; they even draw conclusions from this fact, which, I think, they are not sufficiently warranted in doing; that is, from this appearance, they infer the former existence of volcanos in those places. For my part, though I have made the most strict examination, I never saw any vestige of such an event. That there are, in other countries, evident marks of volcanos which have been long extinguished, is unquestionably true; but naturalists, imagining that there are no other marks of subterraneous fire and fusion, except in the production of a lava, attribute to a volcano, as a cause, these effects, which only indicate the exertion of that power which might have been the cause of a volcano.

If the theory now given be just, a rock of marble is no less a mark of subterraneous fire and fusion, than that of the basaltes; and the flowing of basaltic streams among strata broken and displaced, affords the most satisfactory evidence of those operations by which the body of our land had been elevated above the surface of the sea; but it gives no proof that the eruptive force of mineral vapours had been discharged in a burning mountain. Now, this discharge is essential in the proper idea of a volcano.

Besides this internal mark of an unerupted lava in the substance of the stone or body of the flowing mass, there are others which belong to it in common with all other mineral strata, consolidated by subterraneous fire, and changed from the place of their original formation; this is, the being broken and dislocated, and having veins of foreign matter formed in their separations and contractions.

If these are mineral operations, proper to the lower regions of the earth, and exerted upon bodies under immense compression, such things will be sometimes found in the unerupted lavas, as well as in the contiguous bodies with which they are associated. If, on the contrary, these are operations proper to the surface of the earth, where the dissolving power of water and air take place, and where certain stalactical and ferruginous concretions are produced by these means; then, in erupted lavas, we should find mineral concretions, which concretions should be denied to bodies which had been consolidated at the bottom of the sea; that is to say, where, without the operation of subterraneous fire, no changes of that kind could have taken place, as has already been observed. But in the unerupted species of lava, that is to say, in our whin-stone, every species of mineral appearance is occasionally to be found. Let those who have the opportunity to examine, say, what arc to be found in proper lavas, that is, those of the erupted kind. Sir William Hamilton informed me, when I showed him those mineral veins and spars in our whin-stone, that he had never observed the like, in lavas We have now formed some conclusions with regard to the nature and production of those parts of the land of this globe which we have had the means of examining perfectly; but; from the accounts of travellers, and from, the specimens which are brought to us from distant parts, we have reason to believe, that all the rest of the earth is of the same nature with that which has been now considered. The great masses of the earth are the same every where; and all the different species of earths, of rocks or stone, which have as yet appeared, are to be found in the little space of this our island.

It is true, that there are peculiar productions in the mineral kingdom which are rare, as being found only in few places; but these things are merely accidental in relation to the land, for they belong in property to those parts of the mineral region which we never see. Such are, the diamond of the east, the platina of the west, and the tin of Cornwall, Germany, and Sumatra. Gold and silver, though found in many countries, do not appear to be immediately necessary in the production of a habitable country. Iron, again, is universal in the operations of the globe, and is found often in that profusion which equals its utility. Between these two extremes, we find all other minerals, that is to say, here and there in moderate quantity, and apparently in some proportion to their use. But all these substances are to be considered as the vapours of the mineral regions, condensed occasionally in the crevices of the land; and it is only the rocks and strata (in which those mineral veins are found) that are now examined with regard to their original composition, at the bottom of the sea, as well as to that, operation by which those bodies had been indurated in their substance, and elevated from the place in which they had been formed.

Thus, we have sufficient reason to believe, that, in knowing the construction of the land in Europe, we know the constitution of the land in every part of the globe. Therefore, we may proceed to form general conclusions, from the knowledge of the mineral region, thus acquired in studying those parts which are seen.

Having thus found, *first*, That the consolidated and indurated masses of our strata had suffered the effects of violent heat and fusion; *2dly*, That those strata, which had been formed in a regular manner at the bottom of the sea, have been violently bended, broken, and removed from their original place and situation; and, *lastly*, Having now found the most indubitable proof, that the melting, breaking, and removing power of subterraneous fire, has been actually exerted upon this land which we examine, we cannot hesitate in ascribing these operations as a cause to those effects which are exposed to our view. Now, these may be considered as consisting in the solid state and present situation of those stratified bodies, originally formed by subsidence in the ocean; appearances which cannot, in reason, be ascribed to any other cause, and which, upon this principle, are perfectly explained.

It is not meant to specify every particular in the means employed by nature for the elevation of our land. It is sufficient to have shown, that there is, in nature, means employed for the consolidating of strata, formed originally of loose and incoherent materials; and that those same means have also been employed in changing the place and situation of those strata. But how describe an operation which man cannot have any opportunity of perceiving? Or how imagine that, for which, perhaps, there are not proper data to be found? We only know, that the land is raised by a power which has for principle subterraneous heat; but, how that land is preserved in its elevated station, is a subject in which we have not even the means to form conjecture; at least, we ought to be cautious how we indulge conjecture in a subject where no means occur for trying that which is but supposition.

We now proceed, from the facts which have been properly established, to reason with regard to the duration of this globe, or the general view of its operations, as a living world, maintaining plants and animals.

Section 4. System Of Decay And Renovation Observed In The Earth

Philosophers observing an apparent disorder and confusion in the solid parts of this globe, have been led to conclude, that there formerly existed a more regular and uniform state, in the constitution of this earth; that there had happened some destructive change; and that the original structure of the earth had been broken and disturbed by some violent operation, whether natural, or from a super-natural cause. Now, all these appearances, from which conclusions of this kind have been formed, find the most perfect explanation in the theory which we have been endeavouring to establish;

for they are the facts from whence we have reasoned, in discovering the nature and constitution of this earth: Therefore, there is no occasion for having recourse to any unnatural supposition of evil, to any destructive accident in nature, or to the agency of any preternatural cause, in explaining that which actually appears.

It is necessary for a living or inhabited world, that this should consist of land and water. It is also necessary, that the land should be solid and stable, refilling, with great power, the violent efforts of the ocean; and, at the same time, that this solid land should be resolved by the influence of the sun and atmosphere, so as to decay, and thus become a soil for vegetation. But these general intentions are perfectly fulfilled in the constitution of our earth, which has been now investigated. This great body being formed of different mixed masses, having various degrees of hardness and solubility, proper soil for plants is supplied from the gradual resolution of the solid parts; fertility in those soils arises from the mixture of different elementary substances; and stability is procured to that vegetable world, by the induration of certain bodies, those rocks and stones, which protect the softer masses of clay and soil.

In this manner, also, will easily be explained those natural appearances which diversify the surface of the earth for the use of plants and animals, and those objects which beautify the face of nature for the contemplation of mankind. Such are, the distinctions of mountains and valleys, of lakes and rivers, of dry barren deserts and rich watered plains, of rocks which stand apparently unimpaired by the lapse of time, and sands which fluctuate with the winds and tides. All these are the effects of steady causes; each of these has its proper purpose in the system of the earth; and in that system is contained another, which is that of living growing bodies, and of animated beings.

But, besides this, man, the intellectual being, has, in this subject of the mineral kingdom, the means of gratifying the desire of knowledge, a faculty by which he is distinguished from the animal, and by which he improves his mind in knowing causes. Man is not satisfied, like the brute, in seeing things which are; he seeks to know how things have been, and what they are to be. It is with pleasure that he observes order and regularity in the works of nature, instead of being disgusted with disorder and confusion; and he is made happy from the appearance of wisdom and benevolence in the design, instead of being left to suspect in the Author of nature, any of that imperfection which he finds in himself.

Let us now take a view of that system of mineral economy, in which may be perceived every mark of order and design, of provident wisdom and benevolence.

We have been endeavouring to prove, that all the continents and islands of this globe had been raised above the surface of the ocean; we have also aimed at pointing out the cause of this translation of matter, as well as of the general solidity of that which is raised to our view; but however this theory shall be received, no person of observation can entertain a doubt, that all, or almost all we see of this earth, had been originally formed at the bottom of the sea. We have now another object in our view; this is to investigate the operations of the globe, at the time that the foundation of this land was laying in the waters of the ocean, and to trace the existence and the nature of things, before the present land appeared above the surface of the waters. We should thus acquire some knowledge of the system according to which this world is ruled, both in its preservation and production; and we might be thus enabled to judge, how far the mineral system of the world shall appear to be contrived with all the wisdom, which is so manifest in what are termed the animal and vegetable kingdoms.

It must not be imagined that this undertaking is a thing unreasonable in its nature; or that it is a work necessarily beset with any unsurmountable difficulty; for, however imperfectly we may fulfil this end proposed, yet, so far as it is to natural causes that are to be ascribed the operations of former time, and so far as, from the present state of things, or knowledge of natural history, we have it in our power to reason from effect to cause, there are, in the constitution of the world, which we now examine, certain means to read the annals of a former earth.

The object of inquiry being the operations of the globe, during the time that the present earth was forming at the bottom of the sea, we are now to take a very general view of nature, without descending into those particulars which so often occupy the speculations of naturalists, about the present state of things. We are not at present to enter into any discussion with regard to what are the primary and secondary mountains of the earth; we are not to consider what is the first, and what the last, in those things which now are seen; whatever is most ancient in the strata which we now examine, is supposed to be collecting at the bottom of the sea, during the period concerning which we are now to inquire.

We have already considered those operations which had been necessary in forming our solid land, a body consisting of materials originally deposited at the bottom of the ocean; we are now to investigate the source from whence had come all those materials, from the collection of which the present land is formed; and from knowing the state in which those materials had existed, previously to their entering the composition of our strata, we shall learn something concerning the natural history of this world, while the present earth was forming in the sea.

We have already observed, that all the strata of the earth are composed either from the calcareous relicts of sea animals, or from the collection of such materials as we find upon our shores. At a gross computation, there may perhaps be a fourth part of our solid land, which is composed from the matter that had belonged to those animals. Now, what a multitude of living creatures, what a quantity of animal economy must have been required for producing a body of calcareous matter which is interspersed throughout all the land of the globe, and which certainly forms a very considerable part of that mass! Therefore, in knowing how those animals had lived, or with what they had been fed, we shall have learned a most interesting part of the natural history of this earth; a part which it is necessary to have ascertained, in order to see the former operations of the globe, while preparing the materials of the present land. But, before entering upon this subject, let us examine the other materials of which our land is formed.

Gravel forms a part of those materials which compose our solid land; but gravel is no other than a collection of the fragments of solid stones worn round, or having their angular form destroyed by agitation in water, and the attrition upon each other, or upon similar hard bodies. Consequently, in finding masses of gravel in the composition of our land, we must conclude, that there had existed a former land, on which there had been transacted certain operations of wind and water, similar to those which are natural to the globe at present, and by which new gravel is continually prepared, as well as old gravel consumed or diminished by attrition upon our shores.

Sand is the material which enters, perhaps in greatest quantity, the composition of our land. But sand, in general, is no other than small fragments of hard and solid bodies, worn or rounded more or less by attrition; consequently, the same natural history of the earth, which is investigated from the masses of gravel, is also applicable to those masses of sand which we find forming so large a portion of our present land throughout all the earth[20].

Clay is now to be considered as the last of those materials of which our strata are composed; but, in order to understand the nature of this ingredient, something must be premised.

Clay is a mixture of different earths or hard substances, in an impalpable state. Those substances are chiefly the siliceous and aluminous earths. Other earths are occasionally mixed in clays, or perhaps always to be found in some small portion. But this does not affect the general character of clay; it only forms a special variety in the subject. A sensible or considerable portion

[20] Sand is a term that denotes no particular substance; although by it is commonly meant a siliceous substance, as being by far the most prevalent. Sand is one of the modifications, of size and shape, in a hard body or solid substance, which may be infinitely diversified. The next modification to be distinguished in mineral bodies is that of gravel; and this differs in no respect from sand, except in point of size. Next after gravel, in the order of ascent, come stones; and these bear nearly the same relation to gravel as gravel does to sand. Now, by stones is to be understood the fragments of rocks or solid mineral bodies; and there is a perfect gradation from those stones to sand. I have already endeavoured to explain the formation of those stony substances; and now I am treating of a certain system of circulation, which is to be found among minerals.

M. de Luc censures me for not giving the origin of sand, of which I form the strata of the earth. He seems to have misunderstood my treatise. I do not pretend, as he does in his theory, to describe the beginning of things; I take things such as I find them at present, and from these I reason with regard to that which must have been. When, from a thing which is well known, we explain another which is less so, we then investigate nature; but when we imagine things without a pattern or example in nature, then, instead of natural history, we write only fable.

M. de Luc, in the letter already mentioned, says, "that sand may be, and I think it is, a substance which has formed *strata* by *precipitation in a liquid*." This is but an opinion, which may be either true or false. If it be true, it is an operation of the mineral kingdom of which I am ignorant. In all the sand which I have ever examined, I have never seen any that might not be referred to the species of mineral substance from which it had been formed. When this author shall have given us any kind of information with regard to the production of sand *by precipitation in a liquid*, it will then be time enough to think of forming the strata of the earth with that sand.*

of calcareous earth, in the composition of clay, constitutes a marl, and a sufficient admixture of sand, a loam.

An indefinite variety of those compositions of clay form a large portion of the present strata, all indurated and consolidated in various degrees; but this great quantity of siliceous, argillaceous, and other compound substances, in form of earth or impalpable sediment, corresponds perfectly with that quantity of those same substances which must have been prepared in the formation of so much gravel and sand, by the attrition of those bodies in the moving waters.

Therefore, from the consideration of those materials which compose the present land, we have reason to conclude, that, during the time this land was forming, by the collection of its materials at the bottom of the sea, there had been a former land containing materials similar to those which we find at present in examining the earth. We may also conclude, that there had been operations similar to those which we now find natural to the globe, and necessarily exerted in the actual formation of gravel, sand, and clay. But what we have now chiefly in view to illustrate is this, that there had then been in the ocean a system of animated beings, which propagated their species, and which have thus continued their several races to this day.

In order to be convinced of that truth, we have but to examine the strata of our earth, in which we find the remains of animals. In this examination, we not only discover every genus of animal which at present exists in the sea, but probably every species, and perhaps some species with which at present we are not acquainted. There are, indeed, varieties in those species, compared with the present animals which we examine, but no greater varieties than may perhaps be found among the same species in the different quarters of the globe. Therefore, the system of animal life, which had been maintained in the ancient sea, had not been different from that which now subsists, and of which it belongs to naturalists to know the history.

It is the nature of animal life to be ultimately supported from matter of vegetable production. Inflammable matter may be considered as the *pabulum* of life. This is prepared in the bodies of living plants, particularly in their leaves exposed to the sun and light. This inflammable matter, on the contrary, is consumed in animal bodies, where it produces heat or light, or both. Therefore, however animal matter, or the pabulum of life, may circulate through a series of digesting powers, it is constantly impaired or diminishing in the course of this economy, and, without the productive power of plants, it would finally be extinguished.[21]

The animals of the former world must have been sustained during indefinite successions of ages. The mean quantity of animal matter, therefore, must have been preserved by vegetable production, and the natural waste of inflammable substance repaired with continual addition; that is to say, the quantity of inflammable matter necessary to the animal consumption, must have been provided by means of vegetation. Hence we must conclude, that there had been a world of plants, as well as an ocean replenished with living animals.

We are now, in reasoning from principles, come to a point decisive of the question, and which will either confirm the theory, if it be just, or confute our reasoning, if we have erred. Let us, therefore, open the book of Nature, and read in her records, if there had been a world bearing plants, at the time when this present world was forming at the bottom of the sea.

Here the cabinets of the curious are to be examined; but here some caution is required, in order to distinguish things perfectly different, which sometimes are confounded.

Fossil wood, to naturalists in general, is wood dug up from under ground, without inquiring whether this had been the production of the present earth, or that which had preceded it in the circulation of land and water. The question is important, and the solution of it is, in general, easy. The vegetable productions of the present earth, however deep they may be found buried beneath its surface, and however ancient they may appear, compared with the records of our known times, are new, compared with the solid land on which they grew; and they are only covered with the produce of a vegetable soil, or the alluvion of the present land on which we dwell, and on which they had grown. But the fossil bodies which form the

[21] See Dissertations on different subjects of Natural Philosophy, part II.

present subject of inquiry, belonged to former land, and are found only in the sea-born strata of our present earth. It is to these alone that we appeal, in order to prove the certainty of former events.

Mineralised wood, therefore, is the object now inquired after; that wood which had been lodged in the bottom of the sea, and there composed part of a stratum, which hitherto we have considered as only formed of the materials proper to the ocean. Now, what a profusion of this species of fossil wood is to be found in the cabinets of collectors, and even in the hands of lapidaries, and such artificers of polished stones! In some places, it would seem to be as common as the agate.

I shall only mention a specimen in my own collection. It is wood petrified with calcareous earth, and mineralised with pyrites. This specimen of wood contains in itself, even without the stratum of stone in which it is embedded, the most perfect record of its genealogy. It had been eaten or perforated by those sea worms which destroy the bottoms of our ships. There is the clearest evidence of this truth. Therefore, this wood had grown upon land which flood above the level of sea, while the present land was only forming at the bottom of the ocean.

Wood is the most substantial part of plants, as shells are the more permanent part of marine animals. It is not, however, the woody part alone of the ancient vegetable world that is transmitted to us in the record of our mineral pages. We have the type of many species of foliage, and even of the most delicate flower; for, in this way, naturalists have determined, according to the Linnaean system, the species, or at least the genus, of the plant. Thus, the existence of a vegetable system at the period now in contemplation, so far from being doubtful, is a matter of physical demonstration.

The profusion of this vegetable matter, delivered into the ocean, which then generated land, is also evidenced in the amazing quantities of mineral coal which is to be found in perhaps every region of the earth.

Nothing can be more certain, than that all the coaly or bituminous strata have had their origin from the substance of vegetable bodies that grew upon the land. Those strata, tho', in general, perfectly consolidated, often separate horizontally in certain places; and there we find the fibrous or vascular structure of the vegetable bodies. Consequently, there is no doubt of fossil coal being a substance of vegetable production, however animal substances also may have contributed in forming this collection of oleaginous or inflammable matter.

Having thus ascertained the state of a former earth, in which plants and animals had lived, as well as the gradual production of the present earth, composed from the materials of a former world, it must be evident, that here are two operations which are necessarily consecutive. The formation of the present earth necessarily involves the destruction of continents in the ancient world; and, by pursuing in our mind the natural operations of a former earth, we clearly see the origin of that land, by the fertility of which, we, and all the animated bodies of the sea, are fed. It is in like manner, that, contemplating the present operations of the globe, we may perceive the actual existence of those productive causes, which are now laying the foundation of land in the unfathomable regions of the sea, and which will, in time, give birth to future continents.

But though, in generalising the operations of nature, we have arrived at those great events, which, at first sight, may fill the mind with wonder and with doubt, we are not to suppose, that there is any violent exertion of power, such as is required in order to produce a great event in little time; in nature, we find no deficiency in respect of time, nor any limitation with regard to power. But time is not made to flow in vain; nor does there ever appear the exertion of superfluous power, or the manifestation of design, not calculated in wisdom to effect some general end.

The events now under consideration may be examined with a view to see this truth; for it may be inquired, Why destroy one continent in order to erect another? The answer is plain; Nature does not destroy a continent from having wearied of a subject which had given pleasure, or changed her purpose, whether for a better or a worse; neither does she erect a continent of land among the clouds, to show her power, or to amaze the vulgar man; Nature has contrived the productions of vegetable bodies, and the sustenance of animal life, to depend upon the gradual but sure destruction of a continent; that is to say, these two operations necessarily go hand in hand. But with such wisdom has nature ordered things in the economy of this world, that the destruction of one continent is not brought about without the renovation of the earth in the production of another; and the animal and vegetable bodies, for which the world above the surface of the sea is levelled with its bottom, are among the means employed in those operations, as well as the sustenance of those living beings is the proper end in view.

Thus, in understanding the proper constitution of the present earth, we are led to know the source from whence had come all the materials which nature had employed in the construction of the world which appears; a world contrived in consummate wisdom for the growth and habitation of a great diversity of plants and animals; and a world peculiarly adapted to the purposes of man, who inhabits all its climates, who measures its extent, and determines its productions at his pleasure.

The whole of a great object or event fills us with wonder and astonishment, when all the particulars, in the succession of which the whole had been produced, may be considered without the least emotion. When, for example, we behold the pyramids of Egypt, our mind is agitated with a crowd of ideas that highly entertains the person who understands the subject; but the carrying a heavy stone up to the top of a hill or mountain would give that person little pleasure or concern. We wonder at the whole operation of the pyramid, but not at any one particular part.

The raising up of a continent of land from the bottom of the sea, is an idea that is too great to be conceived easily in all the parts of its operations, many of which are perhaps unknown to us; and, without being properly understood, so great an idea may appear like a thing that is imaginary. In like manner, the co-relative, or corresponding operation, the destruction of the land, is an idea that does not easily enter into the mind of man in its totality, although he is daily witness to part of the operation. We never see a river in a flood, but we must acknowledge the carrying away of part of our land, to be sunk at the bottom of the sea; we never see a storm upon the coast, but we are informed of a hostile attack of the sea upon our country; attacks which must, in time, wear away the bulwarks of our soil, and sap the foundations of our dwellings. Thus, great things are not understood without the analysing of many operations, and the combination of time with many events happening in succession.

Let us now consider what is to be the subject of examination, and where it is that we are to observe those operations which must determine either the stability or the instability of this land on which we live.

Our land has two extremities; the tops of the mountains, on the one hand, and the sea-shores, on the other: It is the intermediate space between these two, that forms the habitation of plants and animals. While there is a sea-shore and a higher ground there is that which is required in the system of the world: Take these away, and there would remain an aqueous globe, in which the world would perish. But, in the natural operations of the world, the land is perishing continually; and this is that which now we want to understand.

Upon the one extremity of our land, there is no increase, or there is no accession of any mineral substance. That place is the mountain-top, on which nothing is observed but continual decay. The fragments of the mountain are removed in a gradual succession from the highest station to the lowest. Being arrived at the shore, and having entered the dominion of the waves, in which they find perpetual agitation, these hard fragments, which had eluded the resolving powers natural to the surface of the earth, are incapable of resisting the powers here employed for the destruction of the land. By the attrition of one hard body upon another, the moving stones and rocky shore, are mutually impaired. And that solid mass, which of itself had potential liability against the violence of the waves, affords the instruments of its own destruction, and thus gives occasion to its actual instability.

In order to understand the system of the heavens, it is necessary to connect together periods of measured time, and the distinguished places of revolving bodies. It is thus that system may be observed, or wisdom, in the proper adapting of powers to an intention. In like manner, we cannot understand the system of the globe, without seeing that progress of things which is brought about in time, thus measuring the natural operations of the earth with those of the heavens. This is properly the business of the present undertaking.

Our object is to know the time which had elapsed since the foundation of the present continent had been laid at the bottom of the ocean, to the present moment in which we speculate on these operations. The space is long; the data for the calculations are, perhaps, deficient: No matter; so far as we know our error, or the deficiency in our operation, we proceed in science, and shall conclude in reason. It is not given to man to know what things are truly in themselves, but only what those things are in his thought. We seek not to know the precise measure of any thing; we only understand the limits of a thing, in knowing what it is not, either on the one side or the other.

We are investigating the age of the present earth, from the beginning of that body which was in the bottom of the sea, to the perfection of its nature, which we consider as in the moment of our existence; and we have necessarily another aera, which is collateral, or correspondent, in the progress of those natural events. This is the time required, in the natural operations of this globe, for the destruction of a former earth; an earth equally perfect with the present and an earth equally productive of growing plants and living animals. Now, it must appear, that, if we had a measure for the one of those corresponding operations, we would have an equal knowledge of the other.

The formation of a future earth being in the bottom of the ocean, at depths unfathomable to man, and in regions far beyond the reach of his observation, here is a part of the process which cannot be taken as a principle in forming an estimate of the whole. But, in the destruction of the present earth, we have a process that is performed within the limits of our observation; therefore, in knowing the measure of this operation, we shall find the means of calculating what had passed on a former occasion, as well as what will happen in the composition of a future earth. Let us, therefore, now attempt to make this estimate of time and labour.

The highest mountain may be levelled with the plain from whence it springs, without the loss of real territory in the land; but when the ocean makes encroachment on the basis of our earth, the mountain, unsupported, tumbles with its weight; and with the accession of hard bodies, moveable with the agitation of the waves, gives to the sea the power of undermining farther and farther into the solid basis of our land. This is the operation which is to be measured; this is the mean proportional by which we are to estimate the age of worlds that have terminated, and the duration of those that are but beginning.

But how shall we measure the decrease of our land? Every revolution of the globe wears away some part of some rock upon some coast; but the quantity of that decrease, in that measured time, is not a measurable thing. Instead of a revolution of the globe, let us take an age. The age of man does no more in this estimate than a single year. He sees, that the natural course of things is to wear away the coast, with the attrition of the sand and stones upon the shore; but he cannot find a measure for this quantity which shall correspond to time, in order to form an estimate of the rate of this decrease.

But man is not confined to what he sees; he has the experience of former men. Let us then go to the Romans and the Greeks in search of a measure of our coasts, which we may compare with the present state of things. Here, again, we are disappointed; their descriptions of the shores of Greece and of Italy, and their works upon the coast, either give no measure of a decrease, or are not accurate enough for such a purpose.

It is in vain to attempt to measure a quantity which escapes our notice, and which history cannot ascertain; and we might just as well attempt to measure the distance of the stars without a parallax, as to calculate the destruction of the solid land without a measure corresponding to the whole.

The description which Polybius has given of the Pontus Euxinus, with the two opposite Bosphori, the Meotis, the Propontis, and the Port of Byzantium, are as applicable to the present state of things as they were at the writing of that history. The filling up of the bed of the Meotis, an event which, to Polybius, appeared not far off, must also be considered as removed to a very distant period, though the causes still continue to operate as before.

But there is a thing in which history and the present state of things do not agree. It is upon the coast of Spain, where Polybius says there was an island in the mouth of the harbour of New Carthage. At present, in place of the island, there is only a rock under the surface of the water. It must be evident, however, that the loss of this small island affords no proper ground of calculation for the measure or rate of wasting which could correspond to the coast in general; as neither the quantity of what is now lost had been measured, nor its quality ascertained.

Let us examine places much more exposed to the fury of the waves and currents than the coast of Carthagena, the narrow fretum, for example, between Italy and Sicily. It does not appear, that this passage is sensibly wider than when the Romans first had known it. The Isthmus of Corinth is also apparently the same at present as it had been two or three thousand years ago. Scilla and Charibdis remain now, as they had been in ancient times, rocks hazardous for coasting vessels which had to pass that strait.

It is not meant by this to say, these rocks have not been wasted by the sea, and worn by the attrition of moving bodies, during that space of time; were this true, and that those rocks, the bulwarks of the land upon those coasts, had not been at all impaired from that period, they might remain for ever, and thus the system of interchanging the place of sea and land upon this globe might be frustrated. It is only meant to affirm, that the quantity which those rocks, or that coast, have diminished from the period of our history, has either been too small a thing for human observation, or, which is more probable, that no accurate measurement of the subject, by which this quantity of decrease might have been ascertained, had been taken and recorded. It must be also evident, that a very small operation of an earthquake would be sufficient to render every means of information, in this manner of mensuration, unsatisfactory or precarious.

Pliny says Italy was distant from Sicily a mile and a half; but we cannot suppose that this measure was taken any otherwise than by computation, and such a measure is but little calculated to afford us the just means of a comparison with the present distance. He also says, indeed, that Sicily had been once joined with Italy. His words are: "Quondam Brutio agro cohaerens, mox interfuso mari avulsa.[22] " But all that we can conclude from this history of Pliny is, that, in all times, to people considering the appearances of those two approached coasts, it had seemed probable, that the sea formed a passage between the two countries which had been once united; in like manner as is still more immediately perceived, in that smaller disjunction which is made between the island of Anglesey and the continent of Wales.

The port of Syracuse, with the island which forms the greater and lesser, and the fountain of Arethusa, the water of which the ancients divided from the sea with a wall, do not seem to be altered. From Sicily to the coast of Egypt, there is an uninterrupted course of sea for a thousand miles; consequently, the wind, in such a stretch of sea, should bring powerful waves against those coasts: But, on this coast of Egypt, we find the rock on which was formerly built the famous tower of Pharos; and also, at the eastern extremity of the port Eunoste, the sea-bath, cut in the solid rock upon the shore. Both those rocks, buffeted immediately with the waves of the Mediterranean sea, are, to all appearance, the same at this day as they were in ancient times.[23]

Many other such proofs will certainly occur, where the different parts of those coasts are examined by people of observation and intelligence. But it is enough for our present purpose, that this decrease of the coasts in general has not been observed; and that it is as generally thought, that the land is gaining upon the sea, as that the sea is gaining upon the land.

To sum up the argument, we are certain, that all the coasts of the present continents are wasted by the sea, and constantly wearing away upon the whole; but this operation is so extremely slow, that we cannot find a measure of the quantity in order to form an estimate: Therefore, the present continents of the earth, which we consider as in a state of perfection, would, in the natural operations of the globe, require a time indefinite for their destruction.

[22] Lib. 3. cap. 8.
[23] Lettres sur l'Egypte, M. Savary.

But, in order to produce the present continents, the destruction of a former vegetable world was necessary; consequently, the production of our present continents must have required a time which is indefinite. In like manner, if the former continents were of the same nature as the present, it must have required another space of time, which also is indefinite, before they had come to their perfection as a vegetable world.

We have been representing the system of this earth as proceeding with a certain regularity, which is not perhaps in nature, but which is necessary for our clear conception of the system of nature. The system of nature is certainly in rule, although we may not know every circumstance of its regulation. We are under a necessity, therefore, of making regular suppositions, in order to come at certain conclusions which may be compared with the present state of things.

It is not necessary that the present land should be worn away and wasted, exactly in proportion as new land shall appear; or, conversely, that an equal proportion of new land should always be produced as the old is made to disappear. It is only required, that at all times, there should be a just proportion of land and water upon the surface of the globe, for the purpose of a habitable world.

Neither is it required in the actual system of this earth, that every part of the land should be dissolved in its structure, and worn away by attrition, so as to be floated in the sea. Parts of the land may often sink in a body below the level of the sea, and parts again may be restored, without waiting for the general circulation of land and water, which proceeds with all the certainty of nature, but which advances with an imperceptible progression. Many of such apparent irregularities may appear without the least infringement on the general system. That system is comprehended in the preparation of future land at the bottom of the ocean, from those materials which the dissolution and attrition of the present land may have provided, and from those which the natural operations of the sea afford.

In thus accomplishing a certain end, we are not to limit nature with the uniformity of an equable progression, although it be necessary in our computations to proceed upon equalities. Thus also, in the use of means, we are not to prescribe to nature those alone which we think suitable for the purpose, in our narrow view. It is our business to learn of nature (that is by observation) the ways and means, which in her wisdom are adopted; and we are to imagine these only in order to find means for further information, and to increase our knowledge from the examination of things which actually have been. It is in this manner, that intention may be found in nature; but this intention is not to be supposed, or vainly imagined, from what we may conceive to be.

We have been now supposing, that the beginning of our present earth had been laid in the bottom of the ocean, at the completion of the former land; but this was only for the sake of distinctness. The just view is this, that when the former land of the globe had been complete, so as to begin to waste and be impaired by the encroachment of the sea, the present land began to appear above the surface of the ocean. In this manner we suppose a due proportion to be always preserved of land and water upon the surface of the globe, for the purpose of a habitable world, such as this which we possess. We thus, also, allow time and opportunity for the translation of animals and plants to occupy the earth.

But, if the earth on which we live, began to appear in the ocean at the time when the last began to be resolved, it could not be from the materials of the continent immediately preceding this which we examine, that the present earth had been constructed; for the bottom of the ocean must have been filled with materials before land could be made to appear above its surface.

Let us suppose that the continent, which is to succeed our land, is at present beginning to appear above the water in the middle of the Pacific Ocean, it must be evident, that the materials of this great body, which is formed and ready to be brought forth, must have been collected from the destruction of an earth, which does not now appear. Consequently, in this true statement of the case, there is necessarily required the destruction of an animal and vegetable earth prior to the former land; and the materials of that earth which is first in our account, must have been collected at the bottom of the ocean, and begun to be concocted for the production of the present earth, when the land immediately preceding the present had arrived at its full extent.

This, however, alters nothing with regard to the nature of those operations of the globe. The system is still the same. It only protracts the indefinite space of time in its existence, while it gives us a view of another distinct period of the living world; that is to say, the world which we inhabit is composed of the materials, not of the earth which was the immediate predecessor of the present, but of the earth which, in ascending from the present, we consider as the third, and which had preceded the land that was above the surface of the sea, while our present land was yet beneath the water of the ocean. Here are three distinct successive periods of existence, and each of these is, in our measurement of time, a thing of indefinite duration.

We have now got to the end of our reasoning; we have no data further to conclude immediately from that which actually is: But we have got enough; we have the satisfaction to find, that in nature there is wisdom, system, and consistency. For having, in the natural history of this earth, seen a succession of worlds, we may from this conclude that there is a system in nature; in like manner as, from seeing revolutions of the planets, it is concluded, that there is a system by which they are intended to continue those revolutions. But if the succession of worlds is established in the system of nature, it is in vain to look for any thing higher in the origin of the earth. The result, therefore, of this physical inquiry is, that we find no vestige of a beginning,—no prospect of an end.

Chapter 2. An Examination Of Mr Kirwan's Objections To The Igneous Origin Of Stony Substances

A theory which is founded on a new principle, a theory which has to make its way in the public mind by overturning the opinions commonly received by philosophising men, and one which has nothing to recommend it but the truth of its principles, and the view of wisdom or design to which it leads, neither of which may perhaps be perceived by the generality of people, such a theory, I say, must meet with the strongest opposition from the prejudices of the learned, and from the superstition of those who judge not for themselves in forming their notions, but look up to men of science for authority. Such is the case with some part of the Theory of the Earth, which I have given, and which will probably give offence to naturalists who have espoused an opposite opinion. In order, then, to obtain the approbation of the public, it may not be enough to give a theory that should be true, or altogether unexceptionable it may be necessary to defend every point that shall be thought exceptionable by other theorists, and to show the fallacy of every learned objection that may be made against it. It is thus, in general, that truth and error are forced to struggle together, in the progress of science; and it is only in proportion as science removes erroneous conceptions, which are necessarily in the constitution of human knowledge, that truth will find itself established in natural philosophy.

Mr Kirwan has written a dissertation, entitled, *Examination of the Supposed Igneous Origin of Stony Substances*, which was read in the Royal Irish Academy. The object of that dissertation is to state certain objections, which have occurred to him, against the Theory of the Earth published in the Transactions of the Edinburgh Royal Society; and he has attacked that theory in all the points where it appears to him to be vulnerable. It is to these objections that I am now to give an answer. The authority given to this dissertation, by the Royal Irish Academy, as well as the reputation of the author, make it necessary for me to endeavour to put in their true light the facts alleged in that performance, and to analyse the arguments employed, in order to judge of the reasoning by which the theory of mineral fusion is refuted in this Examination.

A theory founded on truth, and formed according to the proper rules of science, can ever suffer from a strict examination, by which it would be but the more and more confirmed. But, where causes are to be traced through a chain of various complicated effects, an examination not properly conducted upon accurate analytical principles, instead of giving light upon a subject in which there had been obscurity and doubt, may only serve to perplex the understanding, and bring confusion into a subject which was before sufficiently distinct. To redress that evil, then, must require more labour and some address; and this is an inconveniency that may be looked for, more or less, in every controversial discussion.

I do not mean to enter any farther into the defence of my theory in this chapter, than what is necessary to answer a man of science and respectability, who has stated his objections. The observations which he has made appear to me to be founded on nothing more than common prejudice, and misconceived notions of the subject. I am therefore to point out that erroneous train of reasoning, into which a hasty superficial view of things, perhaps, has led the patron of an opposite opinion to see my theory in an unfavourable light. This, however, is not all; for, that train of inconsequential reasoning is so congenial with the crude and inconsiderate notion generally entertained, of solid mineral bodies having been formed by the infiltration of water into the earth, that no opportunity should be lost of exposing an erroneous manner of reasoning, which is employed in supporting a hypothesis founded upon certain operations of the surface of this earth that cannot be properly applied to the formation of mineral bodies. This object, therefore, so far as it may come in the way, will be attended to in this discussion, although I shall have another opportunity of farther enlarging upon that subject.

Our author begins by examining a geological operation, the very opposite to that of mineral consolidation, and which would seem to have little connection with the subject of this dissertation. In my theory, I advanced two propositions with regard to the economy of this world: First, That the solid masses of this earth, when exposed to the atmosphere, decay, and are resolved into loose materials, of which the vegetable soil upon the surface is in part composed; and, secondly, That these loose materials are washed away by the currents of water, and thus carried at last into the sea. Our author says "Here are two suppositions, neither of which is grounded on facts;" and yet he has but the moment before made the following confession: "That the soil, however, receives an increase from some species of stones that moulder by exposition to the air cannot be denied, but there is no proof that all soil has arisen from decomposition."—Surely *all soil*, that is made from the *hard and compact* body of the land, which is my proposition, must have arisen from*decomposition*; and I have no where said, that *all* the soil of this earth is made from the decomposition or detritus of those stony substances; for, masses of looser sand and softer substances contribute still more to the formation of vegetable soils.

With regard to the other proposition, our author says, "Soil is not constantly carried away by the water, even from mountains."—I have not said that it is *constantly* washed away; for, while it is soil in which plants grow, it is not travelling to the sea, although it be on the road, and must there arrive in time. I have said, that it is *necessarily* washed away, that is, occasionally. M. de Luc's authority is then referred to, as refuting this operation of water and time upon the soil. Now, I cannot help here observing, that our author seems to have as much misapprehended M. de Luc's argument as he has done mine. That philosopher, in his letters to the Queen, has described most accurately the decay of the rocks and solid mountains of the Alps and Jura, and the travelling of their materials by water, although he does not carry them to the sea. It is true, indeed, that this author, who supposes the present earth on which we dwell very young, is anxious to make an earth, *in time*, that shall not decay nor be washed away at all; but that time is not come yet; therefore the authority, here given against my theory, is the speculative supposition, or mere opinion, of a natural philosopher, with regard to an event which may never come to pass, and which I shall have occasion to consider fully in another place.

Our author had just now said, that I have advanced two suppositions, *neither of which is grounded on facts*: Now, with regard to the one, he has acknowledged, that the mouldering of stones takes place, which is the fact on which that proposition is grounded; and with regard to the other, the only authority given against it is founded expressly upon the moving of soil by means of the rain water, in order to make sloping plains of mountains. Here, therefore, I have grounded my propositions upon facts; and our author has founded his objections, first, upon a difficulty which he has himself removed; and, secondly, upon nothing but a visionary opinion, with regard to an earth which is not yet made, and which, when once made, is never more to change.

After making some unimportant observations,—of all water not flowing into the sea,—and of the travelled materials being also deposited upon the plains, etc. our author thus proceeds: "Hence the conclusion of our author relative to the imperfect constitution of the globe falls to the ground; and the pains he takes to learn, *by what means a decayed world may be renovated*, are superfluous."—The object of my theory is to show, that this decaying nature of the solid earth is the very *perfection* of its constitution, as a living world; therefore, it was most proper that I should *take pains to learn* by what means the decayed parts might be renovated. It is true, indeed, that this will be superfluous, when once that constitution of the earth, which M. de Luc thinks is preparing, shall be finished; but, in the mean time, while rivers carry the materials of our land, and while the sea impairs the coast, I may be allowed to suppose that this is the actual constitution of the earth.

I cannot help here animadverting upon what seems to be our author's plan, in making these objections, which have nothing to do with his examination. He accuses me of giving this world a false or imperfect constitution, (in which the solid land is considered as resolvable, and the materials of that land as being washed away into the sea,) for no other reason, that I can see, but because this may imply the formation of a future earth, which he is not disposed to allow; and, he is now to deny the stratified construction of this present earth to have been made by the deposits of materials at the bottom of the sea, because that would prove the existence of a former earth, which is repugnant to his notion of the origin of things, and is contrary, as he says, to reason, and the tenor of the Mosaic history. Let me observe, in passing, that M. de Luc, of whose opinions our author expresses much approbation, thinks that he proves, from the express words and tenor of the Mosaic history, that the present earth was at the bottom of the sea not many years ago, and that the former earth had then disappeared.

But, what does our author propose to himself, in refusing to admit my view of the operations which are daily transacting upon the surface of this earth, where there is nothing dark or in the least mysterious, as there may be in the mineral regions? Does he mean to say, that it is not the purpose of this world to provide soil for plants to grow in? Does he suppose that this soil is not moveable with the running water of the surface? and, Does he think that it is not necessary to replace that soil which is removed? This is all that I required in that constitution of the world which he has thus attacked; and I wish that he or any person would point out, in what respect I had demanded any thing unreasonable, or any thing that is not actually to be observed every day.

Thus I have endeavoured to show, that our author has attacked my theory in a part where I believe it must be thought invulnerable; but this is only, I presume, in order that he may make an attack with more advantage upon another part, viz. the composition of strata from the materials of an earth thus worn out in the service of vegetation,—materials which are necessarily removed in order to make way for that change of things in which consists the active and living system of this world. If he succeed in this attempt to refute my theory of the original formation of strata, he would then doubtless find it more easy to persuade philosophers that the means which I employ in bringing those materials again to light, when transformed into such solid masses as the system of this earth requires, are extravagant, unnatural, and unnecessary. Let us then see how he sets about this undertaking.

With regard to the composition of the earth, it is quoted from my theory, that *the solid parts of the globe are in general composed of sand, gravel, argillaceous and calcareous strata, or of various compositions of these with other substances*; our author then adds, "This certainly cannot be affirmed as a fact, but rather the contrary; it holds only true of the surface, the basis of the greater part of Scotland is evidently a granitic rock, to say nothing of the continents, both of the Old and New World, according to the testimony of all mineralogists." This proposition, with regard to the general composition of the earth, I have certainly not assumed, I have maintained it as a fact, after the most scrupulous examination of all that, with the most diligent search, I have been able to see, and of all that authors have wrote intelligibly upon the subject. If, therefore, I have so misrepresented this great geological fact on which my theory is absolutely founded, I must have erred with open eyes; and my theory of the earth, like others which have gone before it, will, upon close examination, appear to be unfounded, as the dissertation now before us is endeavouring to represent it.

Our author here, I think, alleges that the contrary to this, my fundamental proposition, is the truth; and he has given us Scotland as an example in which his assertion (founded upon the testimony of all mineralogists), is illustrated. Now my geological proposition should certainly be applicable to Scotland, which is the country that I ought to be best acquainted with; consequently, if what our author here asserts be true, I would have deserved that blame which he is willing to throw on me. Let me then beg the readers attention for a moment, that I may justify myself from that charge, and place in its proper light this authority, upon so material a point in geology.

I had examined Scotland from the one end to the other before I saw one stone of granite in its native place, I have moreover examined almost all England and Wales, (excepting Devonshire and Cornwall) without seeing more of granite than one spot, not many hundred yards of extent; this is at Chap; and I know, from information, that there is another small spot in the middle of England where it is just seen. But, let me be more particular with regard to Scotland, the example given in proof.

I had travelled every road from the borders of Northumberland and Westmoreland to Edinburgh; from Edinburgh, I had travelled to Port-Patrick, and from that along the coast of Galloway and Airshire to Inverary in Argyleshire, and I had examined every spot between the Grampians and the Tweedale mountains from sea to sea, without seeing granite in its place. I had also travelled from Edinburgh by Grief, Rannock, Dalwhiny, Fort Augustus, Inverness, through east Ross and Caithness, to the Pentland-Frith or Orkney islands, without seeing one block of granite in its place. It is true, I met with it on my return by the east coast, when I just saw it, and no more, at Peterhead and Aberdeen; but that was all the granite I had ever seen when I wrote my Theory of the Earth. I have, since that time, seen it in different places; because I went on purpose to examine it, as I shall have occasion to describe in the course of this work.

I may now with some confidence affirm, from my own observation, and from good information with regard to those places where I have not been, except the northwest corner, I may affirm, I say, that instead of the basis of the greatest part of Scotland being a granitic rock, which our author has maintained as an evident thing, there is very little of it that is so; not perhaps one five hundred part. So far also as I am to judge from my knowledge of the mineral construction of England and Wales, which I have examined with the greatest care, and from the mineral chart which my friend Mr Watt made for me from his knowledge of Cornwall, I would say that there is scarcely one five hundred part of Britain that has granite for its basis. All the rest, except the porphyry and basaltes, consists of stratified bodies, which are composed more or less of the materials which I mentioned, generally, in the above quotation, and which our author would dispute.

But do not let me take the advantage of this error of our author with regard to the mineralogy of Scotland, and thus draw what may be thought an undue conclusion in favour of my general theory; let us go over and examine the continent of Europe, and see if it is any otherwise there than in Britain. From the granite of the Ural mountains, to that which we find in the Pyrenees, there is no reason, so far as I have been able to learn, to conclude that things are formed either upon any other principle, or upon a different scale. But, instead of one five hundred part, let us suppose there to be one fiftieth part of the earth in general resting upon granite, I could not have expressed myself otherwise than I have done; for, when I maintained that the earth in general consisted of stratified bodies, I said that this was only *nine tenths, or perhaps ninety-nine hundredths* of the whole, and I mentioned that there were other masses of a different origin, which should be considered separately. Our author, on the contrary, asserts that the Old and New Worlds, as well as Scotland, are placed upon granite as a basis, which he says is according to the testimony of all mineralogists. I shall have occasion to examine this opinion of mineralogists, in comparing it with those masses of granite which appear to us; and I hope fully to refute the geological, as well as mineralogical notions with regard to that body. In the mean time, let me make the following reflection, which here naturally occurs.

My Theory of the Earth is here examined,—not with the system of nature, or actual state of things, to which it certainly should have corresponded,—but with the systematic views of a person, who has formed his notions of geology from the vague opinion of others, and not from what he has seen. Had the question been, How far my theory agreed with other theories, our author might very properly have informed his readers that it was diametrically opposite to the opinions of mineralogists; but, this was no reason for concluding it to be erroneous; on the contrary, it is rather a presumption that I may have corrected the error of mineralogists who have gone before me, in like manner as it is most reasonable to presume that our author may have corrected mine. Let us then proceed to examine how far this shall appear to be the case.

Our author has stated very fairly from the Theory, viz. *That all the strata of the earth, not only those consisting of calcareous masses, but others superincumbent on these, have had their origin at the bottom of the sea, by the collection of sand, gravel, shells, coralline, and crustaceous bodies, and of earths and clays variously mixed, separated, and accumulated.* He then adds, "Various geological observations contradict this conclusion. There are many stratified mountains of argillaceous slate, gneiss, serpentine, jasper, and even marble, in which either sand, gravel, shells, coralline, or crustaceous bodies are never, or scarce ever found."

Here our author seems to have deceived himself, by taking a very partial view of things which should be fully examined, and well understood, before general conclusions are to be drawn from those appearances; for, although those particular objects may not be visible in the strata which he has enumerated, or many others, they are found in those strata which are either immediately connected and alternated with them, or with similar strata; something to that purpose I think I have said; and, if I had not, it certainly requires no deep penetration to have seen this clear solution of that appearance of those objects not being found in every particular stratum. He says that those marks of known materials are never or scarce ever found;—by *scarce ever* he surely means that they are sometimes found; but if they shall only *once* be found, his argument is lost. I have not drawn my geological conclusion from every particle in strata being distinguishable, but from there being certain distinguishable particles in strata, and from our knowing what had been the former state and circumstances of those distinguished parts.

If every stone or part of a stratum, in which those known objects are not immediately visible, must be considered as so *many geological observations that contradict my theory*, (of strata being formed from the materials of a former earth), then, surely every stone and every stratum which visibly contains any of those materials, must prove my theory. But if every stratum, where these are found in any part of it, is to be concluded as having had its origin at the bottom of the sea; and, if every concomitant stratum, though not having those objects visible or sufficiently distinct, must be considered as having had the same or a similar origin, that pretended contradiction of my theory comes to no more than this, that every individual stone does not bear in it the same or equal evidence of that general proposition which necessarily results from the attentive consideration of the whole, including every part.

But to see how necessary it is to judge in this manner, not partially, but upon the whole, we may observe, that there are two ways by which the visible materials or distinguishable bodies of a former earth, not only *may* be rendered invisible in the composition of our present earth, but *must* be so upon many occasions. These are, *first*, by mechanical comminution, which necessarily happens, more or less, in that operation by which bodies are moved against one another, and thus transported from the land to the bottom of the deepest seas; *secondly*, by chemical operations, (whatever these may be, whether the action of water or of fire, or both), which are also necessarily employed for consolidating those loose materials, that are to form the rocks and stones of this earth, and by means of which those materials are to have their distinguishable shapes affected in all degrees and obliterated. Therefore, to demand the visible appearance of those materials in every stratum of the earth, or in every part of a stratum, is no other than to misunderstand the subject altogether. The geological observations, which have been thus alleged as contradicting my theory, are stratified bodies, containing proofs of the general origin which I attribute to the earth, but proofs which may not always be seen with equal facility as those which even convince the vulgar.

Our author has surely perplexed himself with what writers of late have said concerning primitive mountains as they are called, a subject of deeper search, than is commonly imagined, as I hope to show in the course of this work. It is an interesting subject of investigation, as giving us the actual view of those operations of nature which, in forming my Theory of the Earth, more general principles had led me to conclude *might be*. But, it is a subject which, I am afraid, will lead me to give farther offence to our author, however innocent I may be in giving nothing but what I have from nature.

The reason for saying so is this; I am blamed for having endeavoured to trace back the operations of this world to a remote period, by the examination of that which actually appears, contrary, as is alleged, "to reason, and the tenor of the Mosaic history, thus leading to an abyss, from which human reason recoils, etc." In a word, (says our author), "to make use of his own expression, *We find no vestige of a beginning.* Then this system of successive worlds must have been eternal." Such is the logic by which, I suppose, I am to be accused of atheism. Our author might have added, that I have also said—*we see no prospect of an end*; but what has all this to do with the idea of eternity? Are we, with our ideas of *time*, (or mere succession), to measure that of eternity, which never succeeded any thing, and which will never be succeeded? Are we thus to measure eternity, that boundless thought, with those physical notions of ours which necessarily limit both space and time? and, because we see not the beginning of created things, Are we to conclude that those things which we see have always been, or been without a cause? Our author would thus, inadvertently indeed, lead himself into that gulf of irreligion and absurdity into which, he alleges, I have *boldly plunged*.

In examining this present earth, we find that it must have had its origin at the bottom of the sea, although our author seems willing to deny that proposition. Farther, in examining the internal construction of this stratified and sea-born mass, we find that it had been composed of the moved materials of a former earth; and, from the most accurate and extensive examination of those materials, which in many places are indeed much disguised, we are led necessarily to conclude, that there had been a world existing, and containing an animal, a vegetable, and a mineral system. But, in thus tracing back the natural operations which have succeeded each other, and mark to us the course of time past, we come to a period in which we cannot see any farther. This, however, is not the beginning of those operations which proceed in time and according to the wise economy of this world; nor is it the establishing of that, which, in the course of time, had no beginning; it is only the limit of our retrospective view of those operations which have come to pass in time, and have been conducted by supreme intelligence.

My principal anxiety was to show how the constitution of this world had been wisely contrived; and this I endeavoured to do, not from supposition or conjecture, but from its answering so effectually the end of its intention, viz. the preserving of animal life, which we cannot doubt of being its purpose. Here then is a world that is not eternal, but which has been the effect of wisdom or design.

With regard again to the prospective view of the creation, How are we to see the end of that wise system of things which so properly fulfils the benevolent intention of its maker,—in giving sustenance to the animal part, and information to intellectual beings, who, in these works of nature, read what much concerns their peace of mind,—their intellectual happiness? What then does our author mean, in condemning that comprehensive view which I have endeavoured to take of nature? Would he deny that there is to be perceived wisdom in the system of this world, or that a philosopher, who looks into the operations of nature, may not plainly read the power and wisdom of the Creator, without recoiling, as he says, from the abyss? The abyss, from which a man of science should recoil, is that of ignorance and error.

I have thus shown, that, from not perceiving the wise disposition of things upon the surface of this earth for the preservation of vegetable bodies, our author has been led to deny the necessary waste of the present earth, and the consequent preparation of materials for the construction of another; I have also shown, that he denies the origin which I had attributed to the stratified parts of this earth, as having been the collection of moving materials from a former earth; and now I am come to consider the professed purpose of this paper, viz. the examination of solid stony substances which we find in those strata of our earth, as well as in more irregular masses. Here, no doubt, my theory would have been attacked with greater success, had our author succeeded in pointing out its error with regard to the original composition of those indurated bodies, to which I ascribe fusion as the cause of their solidity. For, if we should, according to our author's proposition, consider those consolidated bodies as having been originally formed in that solid state, here the door might be shut against any farther investigation;—But to what purpose?—Surely not to refute my theory, but to explode every physical inquiry farther on the subject, and thus to lead us back into the science of darkness and of scepticism. But let us proceed to see our author's sentiments on this subject.

As I had proved from matter of fact, or the actual appearances of nature, that all the strata of the earth had been formed at the bottom of the sea, by the subsidence of those materials which either come from the decaying land, or are formed in the sea itself, it was necessary that I should consider in what manner those spongy or porous bodies of loose materials, gathered together at the bottom of the sea, could have acquired that consolidated state in which we find them, now that they are brought up to our examination. Upon this occasion, our author says, "The particles which now form the solid parts of the globe need not be supposed to have originally been either spongy or porous, the interior parts at the depth of a few miles might have been originally, as at present, a solid mass." If, indeed, we shall make that supposition, we may then save ourselves the trouble of considering either how the strata of the earth have been formed or consolidated; for, they might have been so originally. But, how can a naturalist who had ever seen a piece of Derbyshire marble, or any other shell limestone, make that supposition? Here are, to the satisfaction of every body of common understanding who looks at them, bodies which are perfectly consolidated, bodies which have evidently been formed at the bottom of the sea, and therefore which were not originally a solid mass. Mr Bertrand, it is true, wrote a book to prove that those appearances were nothing but a *lusus naturae*; and, I suppose he meant, with our author, that those strata had been also originally, as at present, a solid mass.

With regard to the consolidation of strata, that cardinal point for discussion, our author gives the following answer: "Abstracting from his own gratuitous hypothesis, it is very easy to satisfy our author on this head; the concreting and consolidating power in most cases arises from the mutual attraction of the component particles of stones to each other." This is an answer with regard to the *concreting power*, a subject about which we certainly are not here inquiring. Our author, indeed, has mentioned a *consolidating power*; but that is an improper expression; we are here inquiring, How the interstices, between the collected materials of strata, deposited at the bottom of the sea, have been filled with a hard substance, instead of the fluid water which had originally occupied those spaces. Our author then continues; "If these particles leave any interstices, these are filled with water, which no ways obstructs their solidity when the points of contact are numerous; hence the decrepitation of many species of stones when heated."

If I understand our author's argument, the particles of stone are, by their mutual attractions, to leave those hard and solid bodies which compose the strata, that is to say, those hard bodies are to dissolve themselves; but, To what purpose? This must be to fill up the interstices, which we must suppose occupied by the water. In that case, we should find the original interstices filled with the substances which had composed the strata, and we should find the water translated into the places of those bodies; here would be properly a transmutation, but no consolidation of the strata, such as we are here to look for, and such as we actually find among those strata. It may be very easy for our author to form those explanations of natural phenomena; it costs no tedious observation of facts, which are to be gathered with labour, patience, and attention; he has but to look into his own fancy, as philosophers did in former times, when they saw the abhorrence of a vacuum and explained the pump. It is thus that we are here told the consolidation of strata *arises from the mutual attraction of the component particles of stones to each other*; the power, by which the particles of solid stony bodies retain their places in relation to each other, and resist separation from the mass, may, no doubt, be properly enough termed their mutual attractions; but we are not here inquiring after that power; we are to investigate the power by which the particles of hard and stony bodies had been separated, contrary to their mutual attractions, in order to form new concretions, by being again brought within the spheres of action in which their mutual attractions might take place, and make them one solid body. Now, to say that this is by their mutual attraction, is either to misunderstand the proper question, or to give a most preposterous answer.

It is not every one who is fit to reason with regard to abstract general propositions; I will now, therefore, state a particular case, in illustration of that proposition which has been here so improperly answered. The strata of Derbyshire marbles were originally immense collections at the bottom of the sea, of calcareous bodies consisting almost wholly of various fragments of the *entrochi*; and they were then covered with an indefinite number of other strata under which these *entrochi* must have been buried. In this original state of those strata, I suppose the interstices between the fragments of the coralline bodies to have been left full of sea-water; at present we find those interstices completely filled with a most perfectly solid body of marble; and the question is, whether that consolidating operation has been the work of water and solution, by our naturalist's termed infiltration; or if it has been performed, as I have maintained, by the softening power or heat, or introduction of matter in the fluid state of fusion. Our author does not propose any other method for the consolidation of those loose and incoherent bodies, but he speaks of the *mutual attraction of the component particles of stone to each other*; Will that fill the interstices between the coralline bodies with solid marble, as well as consolidate the coralline bodies themselves? or, if it should, How are those interstices to be thus filled with a substance perfectly different from the deposited bodies, which is also frequently the case? But, how reason with a person who, with this consolidation of strata, confounds the well known operation by which the mortar, made with caustic lime and sand, becomes a hard body! One would imagine that he were writing to people of the last age, and not to chemical philosophers who know so well how that mortar is concreted.

To my argument, That these porous strata are found *consolidated with every different species of mineral substance*, our author makes the following observation: "Here the difficulties to the supposition of an aqueous solution are placed in the strongest light; yet it must be owned that they partly arise from the author's own gratuitous supposition, that strata existed at the bottom of the sea previous to their consolidation;"—gratuitous supposition!—so far from being a supposition of any kind, it is a self evident proposition; the terms necessarily imply the conclusion. I beg the readers attention for a moment to this part of our author's animadversion, before proceeding to consider the whole; for, this is a point so essential in my theory, that if it be a gratuitous supposition, as is here asserted, it would certainly be in vain to attempt to build upon it the system of a world.

That strata may exist, whether at the bottom of the sea, or any other where, without being consolidated, will hardly be disputed; for, they are actually found consolidated in every different degree. But, when strata are found consolidated, at what time is it that we are to suppose this event to have taken place, or this accident to have happened to them? —Strata are formed at the bottom of water, by the subsidence or successive deposits of certain materials; it could not therefore be during their formation that such strata had been consolidated; consequently, we must necessarily *conclude*, without any degree of *supposition*, that *strata had existed at the bottom of the sea previous to their consolidation*, unless our author can show how they may have been consolidated previous to their existing.

This then is what our author has termed a gratuitous supposition of mine, and which, he adds, "is a circumstance which will not be allowed by the patrons of the aqueous origin of stony substances, as we have already seen."—I am perfectly at a loss to guess at what is here alluded to *by having been already seen*, unless it be that which I have already quoted, concerning things which have been never seen, that is, *those interior parts of the earth which were originally a solid mass*.—I have hardly patience to answer such reasoning;—a reasoning which is not founded upon any principle, which holds up nothing but chimera to our view, and which ends in nothing that is intelligible;—but, others, perhaps, may see this dissertation of our author's in a different light; therefore, it is my duty to analyse the argument, however insignificant it may seem to me.

I have minutely examined all the stratified bodies which I have been able, during a lifetime, to procure, both in this country of Britain, and from all the quarters of the globe; and the result of my inquiry has been to conclude, that there is nothing among them in an original state, as the reader will see in the preceding chapter. With regard again to the masses which are not stratified, I have also given proof that they are not in their original state, such as granite, porphyry, serpentine, and basaltes; and I shall give farther satisfaction, I hope, upon that head, in the course of this work. I have therefore concluded, That there is nothing to be found in an original state, so far as we see, in the construction of this earth. But, our author answers, That the interior parts *might have been in an original state of solidity*.—So might they have been upon the surface of the earth, or on the summits of our mountains; but, we are not inquiring What they *might have been*, but What they truly *are*. It is from this actual state in which the solid parts of the earth are found, that I have endeavoured to trace back the different states in which they must have been; and, by generalising facts, I have formed a theory of the earth. If this be a wrong principle or manner of proceeding in a physical investigation, or if, proceeding upon that principle, I have made the induction by reasoning improperly on any occasion, let this be corrected by philosophers, who may reason more accurately upon the subject. But to oppose a physical investigation with this proposition, *that things might have been otherwise*, is to proceed upon a very different principle,—a principle which, instead of tending to bring light out of darkness, is only calculated to extinguish that light which we may have acquired.

I shall afterwards have occasion to examine how far the philosophers, who attribute to aqueous solution the origin of stony substances, have proceeded in the same inductive manner of reasoning from effect to cause, as they ought to do in physical subjects, and not by feigning causes, or following a false analogy; in the mean time, I am to answer the objections which have been made to the theory of the earth.

In opposition to the theory of consolidating bodies by fusion, our author has taken great pains to show, that I cannot provide materials for such a fire as would be necessary, nor find the means to make it burn had I those materials. Had our author read attentively my theory he would have observed, that I give myself little or no trouble about that fire, or take no charge with regard to the procuring of that power, as I have not founded my theory on the *supposition* of subterraneous fire, however that fire properly follows as a conclusion from those appearances on which the theory is founded. My theory is founded upon the general appearances of mineral bodies, and upon this, that mineral bodies must necessarily have been in a state of fusion. I do not pretend to prove, demonstratively, that they had been even hot, however that conclusion also naturally follows from their having been in fusion. It is sufficient for me to demonstrate, That those bodies must have been, more or less, in a state of softness and fluidity, without any species of solution. I do not say that this fluidity had been without heat; but, if that had been the case, it would have answered equally well the purpose of my theory, so far as this went to explain the consolidation of strata or mineral bodies, which, I still repeat, must have been by simple fluidity, and not by any species of solution, or any other solvent than that universal one which permeates all bodies, and which makes them fluid.

Our author has justly remarked the difficulty of fire burning below the earth and sea. It is not my purpose here to endeavour to remove those difficulties, which perhaps only exist in those suppositions which are made on this occasion; my purpose is to show, that he had no immediate concern with that question, in discussing the subject of the consolidation which we actually find in the strata of the earth, unless my theory, with regard to the igneous origin of stony substances, had proceeded upon the supposition of a subterraneous fire. It is surely one thing to employ fire and heat to melt mineral bodies, in supposing this to be the cause of their consolidation, and another thing to acknowledge fire or heat as having been exerted upon mineral bodies, when it is clearly proved, from actual appearances, that those bodies had been in a melted state, or that of simple fluidity. Here are distinctions which would be thrown away upon the vulgar; but, to a man of science, who analyses arguments, and reasons strictly from effect to cause, this is, I believe, the proper way of coming at the truth. If the patrons of the aqueous origin of stony substances can give us any manner of scientifical, *i.e.* intelligible investigation of that process, it shall be attended to with the most rigid impartiality, even by a patron of the igneous origin of those substances, as he wishes above all things to distinguish, in the mineral operations, those which, on the one hand, had been the effect of water, from those which, on the other hand, had been the immediate effect of fire or fusion;—this has been my greatest study. But, while mineralists or geologists give us only mere opinions, What is science profited by such inconsequential observations, as are founded upon nothing but our vulgar notions? Is the figure of the earth, *e.g.* to be doubted, because, according to the common notion of mankind, the existence of an antipod is certainly to be denied?

I am not avoiding to meet that question with regard to the providing of materials for such a mineral fire as may be required; no question I desire more to be asked to resolve; but it must not be in the manner that our author has put that question. He has included this supposed difficulty among a string of other arguments by which he would refute my theory with regard to the igneous origin of stony substances, as if I had made that fire a necessary condition or a principle in forming my theory of consolidation. Now, it is precisely the reverse; and this is what I beg that mineral philosophers will particularly attend to, and not give themselves so much unnecessary trouble, and me so disagreeable a talk. I have proved that those stony substances have been in the fluid state of fusion; and from this, I have inferred the former existence of an internal heat, a subterraneous fire, or a certain cause of fusion by whatever name it shall be called, and by whatever means it shall have been procured. The nature of that operation by which strata had been consolidated, like that by which they had been composed, must, according to my philosophy, be decided by ocular demonstration; from examining the internal evidence which is to be found in those bodies as we see them in the earth; because the consolidating operation is not performed in our sight, no more than their stratification which our author has also denied to have been made, as I have said, by the deposits of materials at the bottom of the sea. Now, with regard to the means of procuring subterraneous fire, if the consolidating operation shall be thus decided to have been that of fusion, as I think I have fully shown, and for which I have as many witnesses, perhaps as there are mineral bodies, then our author's question, (how I am to procure a fire) in the way that he has put it, as an argument against the fusion, would be at least useless; for, though I should here confess my ignorance with regard to the means of procuring fire, the evidence of the melting operation, or former fluidity of those mineral bodies, would not be thereby in the least diminished. If again no such evidence for the fusion of those bodies shall appear, and it be concluded that they had been consolidated by the action of water alone, as our author seems inclined to maintain, he would have no occasion to start difficulties about the procuring of fire, in order to refute a theory which then would fall of itself as having no foundation.

But in order to see this author's notion of the theory which he is here examining, it may be proper to give a specimen of his reasoning upon this subject of heat. He says, "That my supposition of heat necessary for consolidating strata is *gratuitous*, not only because it is unnecessary, as we have already shown, but also because it is inconsistent with our author's own theory." Let us now consider those two propositions. *First*, it is unnecessary, *as we have already shown*;— I have already taken particular notice of what we have been shown on this occasion, viz. That the earth at a certain depth *may have been originally in a solid state*; and, that, where it is to be consolidated, this is done by the *mutual attraction of the stony particles.* Here is all that we have been shown to make subterraneous heat, for the consolidation of strata, unnecessary; and now I humbly submit, if this is sufficient evidence, that mineral heat is a gratuitous supposition.

Secondly, "*it is inconsistent with our author's own theory.*" Here I would beg the readers attention to the reasoning employed on this occasion. He says, "according to him these strata, which were consolidated by heat, were composed of materials gradually worn from a preceding continent, casually and successively deposited in the sea; Where then will he find, and how will he suppose, to have been formed those enormous masses of sulphur, coal, or bitumen, necessary to produce that immense heat necessary for the fusion of those vast mountains of stone now existing? All the coal, sulphur, and bitumen, now known, does not form the 100,000 part of the materials deposited within one quarter of a mile under the surface of the earth; if, therefore, they were, as his hypothesis demands, carried off and mixed with the other materials, and not formed in vast and separate collections, they could never occasion, by their combustion, a heat capable of producing the smallest effect, much less those gigantic effects which he requires."

Here is a comparative estimate formed between two things which have not any necessary relation; these are, the quantity of combustible materials found in the earth, on the one hand, and the quantity which is supposed necessary for hardening and consolidating strata, on the other. If this earth has been consolidated by the burning of combustible materials, there must have been a superfluity, so far as there is a certain quantity of these actually found unconsumed in the strata of the earth. Our author's conclusion is the very opposite; let us then see how he is to form his argument, by which he proves that the supposition of subterraneous heat for hardening bodies is gratuitous and unnecessary, as being inconsistent with my theory.

According to my theory, the strata of this earth are composed of the materials which came from a former earth; particularly these combustible strata that contain plants which must have grown upon the land. Let us then suppose the subterraneous fire supplied with its combustible materials from this source, the vegetable bodies growing upon the surface of the land. Here is a source provided for the supplying of mineral fire, a source which is inexhaustible or unlimited, unless we are to circumscribe it with regard to time, and the necessary ingredients; such as the matter of light, carbonic matter, and the hydrogenous principle. But it is not upon any deficiency of this kind that our author founds his estimate; it is upon the superfluity of combustible materials which is actually found in this earth, after it had been properly consolidated and raised above the surface of the sea. This is a method of reasoning calculated to convince only those who do not understand it; it is as if we should conclude that a person had died of want, because he had left provision behind him. Our author certainly means to employ nothing but the combustible minerals of the present earth, in feeding the subterraneous fire which is to concoct a future earth; in that case, I will allow that his provision is deficient; but this is not my theory.

I am not here to enter into any argument concerning subterraneous fire; the reader will find, in the foregoing theory, my reasons for concluding, That subterraneous fire had existed previous to, and ever since, the formation of this earth,—that it exists in all its vigour at this day,—that there is, in the constitution of this earth, a superfluity of subterranean heat,—and that there is wisely provided a proper remedy against any destructive effect to the system, that might arise from that superabundant provision of this necessary agent. Had our author attended to the ocular proof that we have of the actual existence of subterraneous fire, and to the physical demonstrations which I have given of the effects of heat in melting mineral bodies, he must have seen that those arguments of his, with regard to the difficulty or impossibility of procuring that fire, can only show the error of his reasoning. I am far from supposing that my theory may be free from inconsistency or error; I am only maintaining that, in all his confident assertions, this author has not hitherto pointed any of these out.

So far I have answered our author's objections as to consolidation, and I have given a specimen of his reasoning upon that subject; but with regard to my Theory of the Earth, although simple fluidity, without heat, would have answered the purpose of consolidating strata that had been formed at the bottom of the sea, it was necessary to provide a power for raising those consolidated strata from that low place to the summits of the continents; now, in supposing heat to be the cause of that fluidity which had been employed in the consolidation of those submarine masses, we find a power capable of erecting continents, and the only power, so far as I see, which natural philosophy can employ for that purpose. Thus I was led, from the consolidation of strata, to understand the nature of the elevating power, and, from the nature of that power, again to understand the cause of fluidity by which the rocks and stones of this earth had been consolidated.

Having thus, without employing the evidence of any fire or *burning*, been necessarily led to conclude an extreme degree of heat exerted in the mineral regions, I next inquire how far there are any appearances from whence we might conclude whether that active subterraneous power still subsists, and what may be the nature of that power. When first I conceived my theory, naturalists were far from suspecting that basaltic rocks were of volcanic origin; I could not then have employed an argument from these rocks as I may do now, for proving that the fires, which we see almost daily issuing with such force from volcanos, are a continuation of that active cause which has so evidently been exerted in all times, and in all places, so far as have been examined of this earth.

With regard to the degree of heat in that subterraneous fire, our author, after proving that combustible materials would not burn in the mineral regions, then says, that suppose they were to burn, this would be "incapable of forming a heat even equal to that of our common furnaces, as Mr Dolomieu has clearly shown to be the case with respect to volcanic heat." The place to which he alludes, I believe to be that which I have quoted from the Journal de Physique (Part I. page 139) to which I here beg leave to refer the reader. After what I have already said, this subject will appear to be of little concern to me; but, it must be considered, that my object, in these answers, is not so much to justify the theory which I have given, as it is to remove that prejudice which, to those who are not master of chemical and mineral subjects, will naturally arise from the opinion or authority of a scientific man, and a chemist; therefore, I think it my business to show how much he has misconceived the matter which he treats of, and how much he misunderstands the subject of my theory.

Mr Dolomieu alleges that the volcanic fire operates in the melting of bodies, not by the intensity of its heat, which is the means employed by us in our operations, but in the long continuance of its action. But in that proposition, this philosopher is merely giving us his opinion; and, this opinion our author mistakes, I suppose, for the fact on which that opinion had been (perhaps reasonably) founded. The reader will see, in the place quoted, or in the *avant-propos* to his *Mémoire sur les Iles Ponces*, the fact to be this; That the Chevalier Dolomieu finds those bodies which we either cannot melt in our fires, or which we cannot melt without changing them by calcination and vitrification, he finds, I say, these substances had actually been melted with his lavas; he also finds those substances, which are necessarily dissipated in our fires, to have been retained in those melted mineral substances. Had our author quoted the text, instead of giving us his own interpretation, he could not have offered a stronger confirmation of my theory; which certainly is not concerned with the particular intensity of volcanic fire, and far less with what may be the opinion of any naturalist with regard to that intensity, but only with the efficacy of that volcanic heat for the melting of mineral substances. Now this efficacy of volcanic fire, so far as we are to found upon the authority given on this occasion, is clearly confirmed by the observations of a most intelligent mineralist, and one who is actually a patron of the opposite theory to that which I have given. This being the state of the case, Must I not conclude, that our author has misunderstood the subject, and that he has been led to give a mutilated opinion of Mr Dolomieu, in order to refute my theory, when either the entire opinion, or the facts on which the opinion had been founded, would have confirmed it?

I have thus endeavoured to put in its true light a species of reasoning, which, while it assumes the air and form of that inductive train of thought employed by men of science for the investigation of nature, is only fit to mislead the unwary, and, when closely examined, will appear to be inconsequential or unfounded. How mortifying then to find, that one may be employed almost a lifetime in generalising the phenomena of nature, or in gathering an infinity of evidence for the forming of a theory, and that the consequence of this shall only be to give offence, and to receive reproach from those who see not things in the same light!—While man has to learn, mankind must have different opinions. It is the prerogative of man to form opinions; these indeed are often, commonly I may say, erroneous; but they are commonly corrected, and it is thus that truth in general is made to appear.

I wrote a general Theory for the inspection of philosophers, who doubtless will point out its errors; but this requires the study of nature, which is not the work of a day; and, in this political age, the study of nature seems to be but little pursued by our philosophers. In the mean time, there are, on the one hand, sceptical philosophers, who think there is nothing certain in nature, because there is misconception in the mind of man; on the other hand, there are many credulous amateurs, who go to nature to be entertained as we go to see a pantomime: But there are also superficial reasoning men, who think themselves qualified to write on subjects on which they may have read in books,—subjects which they may have seen in cabinets, and which, perhaps, they have just learned to name; without truly knowing what they see, they think they know those regions of the earth which never can be seen; and they judge of the great operations of the mineral kingdom, from having kindled a fire, and looked into the bottom of a little crucible.

In the Theory of the Earth which was published, I was anxious to warn the reader against the notion that subterraneous heat and fusion could be compared with that which we induce by our chemical operations on mineral substances here upon the surface of the earth; yet, notwithstanding all the precaution I had taken, our author has bestowed four quarto pages in proving to me, that our fires have an effect upon mineral substances different from that of the subterraneous power which I would employ.

He then sets about combining metals with sulphur in the moist way, as if that were any more to his purpose than is the making of a stalactite for the explanation of marble. Silver and lead may be sulphurated, as he says, with hepatic gas; but, Has the sulphurated solid ores of those metals, and that of iron, been formed in the moist way, as in some measure they may be by the fusion of our fires? But, even suppose that this were the case, Could that explain a thousand other appearances which are inconsistent with the operation of water? We see aerated lead dissolved in the excavations of our mines, and again concreted by the separation of the evaporated solvent, in like manner as stalactical concretions are made of calcareous earth; but, so far from explaining mineral appearances, as having had their concretions formed in the same manner, here is the most convincing argument against it; for, among the infinite variety of mineral productions which we find in nature, Why does no other example of aqueous concretion ever occur upon the surface of the earth except those which we understand so well, and which we therefore know cannot be performed in the bodies of strata not exposed to the evaporation of the solvent, a circumstance which is necessary.

I have given a very remarkable example of mineral fusion, in reguline manganese, (as the reader will see in page 68.) It is not that this example is more to the purpose of my theory than what may be found in every species of stone; but this example speaks so immediately to the common sense of mankind, (who are often convinced by a general resemblance of things, when they may not see the force of demonstration from an abstract principle) that I thought it deserved a place on that account, as well as being a curious example, But more particularly to my antagonist, who has been pleased (very improperly indeed) to try some part of my theory in the fire, here is an example which should have been absolutely in point, and without any manner of exception:—Has he acknowledged this?—No; he has, on the contrary, endeavoured to set this very example aside.

On this occasion, he says, "Manganese has been found in a reguline state by M. de la Peyrouse, and in small grains, as when produced by fire. True; but it was mixed with a large quantity of iron, which is often, found in that form without any suspicion of fusion. A fire capable of melting quartz might surely produce it in larger masses." We have here a kind of two arguments, for removing the effect of this example; and I shall consider them separately.

The first of these is, the not being suspected of having been in fusion; now, if this were to be admitted as an argument against the igneous origin of stony substances, it might have superseded the adducing of any other, for it is applicable perhaps to every mineral; but we must here examine the case more minutely.

This argument, of the manganese being in a mine of iron, if I understand it rightly, amounts to this, that, as iron ore is not suspected of having been melted, therefore, we should doubt the manganese having been so. If this be our author's meaning, it is not the fair conclusion which the case admits of; for, so far as the manganese appears evidently to have been in a melted state, the iron ore should be *suspected* of having been also in fusion, were there no other evidence of that fact. In science, however, it is not suspicion that should be employed in physical investigation; the question at present is; If the phenomena of the case correspond to the conclusion which the intelligent mineralist, who examined them, has formed? and, to this question, our author gives no direct answer. He says, *iron is often found in that form without any suspicion of fusion*. This is what I am now to answer.

The form in which the manganese appears is one of the strongest proofs of those masses having been in fusion; and, if iron should ever be found in that form, it must give the same proof of mineral fusion as this example of manganese; let us then see the nature of this evidence. The form of the manganese is that of a fluid body collecting itself into a spherical figure by the cohesion or attraction of its particles, so far as may be admitted by other circumstances; but, being here refilled by the solid part on which it rests, this spherical body is flattened by the gravitation of its substance. Now here is a regular form, which demonstrates the masses to have been in the state of fusion; for, there is no other way in which that form of those reguline masses could have been induced.

There now remains to be considered what our author has observed respecting the intensity of the fire and size of the masses. "A fire capable of melting quartz might surely produce it (meaning the manganese) in larger masses." M. de la Peyrouse says, that those masses were in all respects as if formed by art, only much larger, as the powers of nature exceed those of our laboratories. What then is it that is here meant to be disputed? We are comparing the operation of nature and that of art, and these are to be judged of by the product which we examine; but the quantity, in this case, or the size of the masses, makes no part of the evidence, and therefore is here most improperly mentioned by our author. With regard again to the nature of the fire by which the fusion had been produced, he is much mistaken if he imagines that the reduction of the reguline or metallic manganese depends upon the intensity of the heat; it depends upon circumstances proper for the separation of the oxygenating principle from the calx, in like manner as the calcination of calcareous spar must depend upon circumstances proper for allowing the separation of the carbonic acid or fixed air.

But do not let us lose sight of our proper subject, by examining things foreign or not so immediately to the purpose. We are only inquiring if those flattened spheres of native manganese had been formed by water, or if it were by fusion; for, our author agrees that there is no other way. Why then does he endeavour to evade giving a direct answer, and fly away to consider the quantity of the product, as if that had any thing to do with, the question, or as if that quantity were not sufficient, neither of which is the case. In short, our author's whole observation, on this occasion, looks as if he were willing to destroy, by insinuation, the force of an argument which proves the theory of mineral fusion; and that he wishes to render doubtful, by a species of sophistry, what in fair reasoning he cannot deny.

Our author has written upon the subject of phlogiston; one would suppose that he should be well acquainted with inflammable bodies at least; let us see then what he has to observe upon that subject. He quotes from my Theory, that spar, quartz, pyrites, crystallised upon or near each other, and adhering to coal, or mixed with bitumen, etc. are found; circumstances that cannot be explained in the hypothesis of solution in the moist way.—He then answers;—"Not exactly, nor with certainty; which is not wonderful: But they are still less explicable in the hypothesis of dry solution, as must be apparent from what has been already said. How coal, an infusible substance, could be spread into strata by mere heat, is to me incomprehensible."—It is only upon the last sentence that I am here to remark: This, I believe, will be a sufficient specimen of our author's understanding, with regard at least to my Theory which he is here examining.

The reader will see what I have said upon the subject of coal, by turning back to the second section of the preceding chapter. I had given almost three quarto pages upon that subject, endeavouring to explain how all the different degrees of *infusibility* were produced, by means of heat and distillation, in strata which had been originally more or less oily, bituminous, and *fusible*; and now our author says, that it is incomprehensible to him, how coal, *an infusible substance*, could be spread into strata by mere heat.—So it truly may, either to him or to any other person; but, it appears to me almost as incomprehensible, how a person of common understanding should read my Dissertation, and impute to it a thing so contrary to its doctrine.

Nothing can better illustrate the misconceived view that our author seems to have taken of the two opposite theories, (*i. e.* of consolidation by means of heat, and by means of water alone,) than his observation upon the case of mineral alkali. To that irrefragable argument (which Dr Black suggested) in proof of this substance having been in a state of fusion in the mineral regions, our author makes the following reply; "What then will our author say of the vast masses of this salt which are found with their full quantity of water of crystallization?"—There is in this proposition, insignificant as it may seem, a confusion of ideas, which it certainly cannot be thought worth while to investigate; but, so far as the doctrine of the aqueous theory may be considered as here concerned, it will be proper that I should give some answer to the question so triumphantly put to me.

Our author is in a mistake in supposing that Dr Black had written any thing upon the subject; he had only suggested the argument of this example of mineral alkali to me, as I have mentioned; and, the use I made of that argument was to corroborate the example I had given of sal gem. If, therefore, our author does not deny the inference from the state of that mineral alkali, his observation upon it must refer to something which this other example of his is to prove on the opposite side, or to support the aqueous instead of the igneous theory; and, this is a subject which I am always willing to examine in the most impartial manner, having a desire to know the true effect of aqueous solution in the consolidation of mineral bodies, and having no objection to allow it any thing which it can possibly produce, although denying that it can do every thing, as many mineralists seem to think.

The question, with regard to this example of our author's of a mineral alkali with its water of crystallization, must be this, Whether those saline bodies had been concreted by the evaporation of the aqueous solvent with which they had been introduced, or by the congelation of that saline substance from a fluid state of fusion; for, surely, we are not to suppose those bodies to have been created in the place and state in which we find them. With regard to the evaporation or separation of the aqueous solvent, this may be easily conceived according to the igneous theory; but, the aqueous theory has not any means for the producing of that effect in the mineral regions, which is the only place we are here concerned with. Therefore, this example of a concreted body of salt, whatever it may prove in other respects, can neither diminish the evidence of my Theory with regard to the igneous origin of stony substances, nor can it contribute to support the opposite supposition of an aqueous origin to them.

But to show how little reason our author had for exulting in that question which he so confidently proposed in order to defeat my argument, let us consider this matter a little farther. I will for a moment allow the aqueous theory to have the means for separating the water from the saline solution, and thus to concrete the saline substance in the bowels of the earth; this concretion then is to be examined with a view to investigate the last state of this body, which is to inform us with regard to those mineral operations. But, our author has not mentioned whether those masses appear to have been crystallised from the aqueous solution, or if they appear to have been congealed from the melted state of their*aqueous fusion*.—Has he ever thought of this? Now this is so material a point in the view with which that example has been held out to us, that, without showing that this salt had crystallised from the solution, he has no right to employ it as an example; and if, on the other hand, it should appear to have simply congealed from the state of aqueous fusion, then, instead of answering the purpose for which our author gave it, it would refute his supposition, as certainly as the example which I have given.

So far I have reasoned upon the supposition of this alkali, with its water of crystallization, being truly a mineral concretion; but, I see no authority for such a supposition: It certainly may be otherwise; and, in that case, our author would have no more right to give it as an example in opposition to Dr Black's argument, than he would have to give the crystallization of sea-salt, on Turk's Island, in opposition to the example which I had given, of the salt rock, at Northwych in Cheshire, having been in the state of fusion.

It certainly was incumbent on our author to have informed us, if those masses of salt were found in, what may be properly termed, their mineral state; or, if the state in which they are found at present had been produced by the influences of the atmosphere, transforming that saline substance from its mineral state, as happens upon so many other occasions; I am inclined to suspect that this last is truly the case. It may be thought illiberal in me to suppose a natural philosopher thus holding out an example that could only serve to lead us into error, or to mislead our judgment with regard to those two theories which is the subject of consideration. This certainly would be the case, almost on any other occasion; but, when I find every argument and example, employed in this dissertation, to be either unfounded or misjudged, Whether am I to conclude our author, on this occasion, to be consistent with himself, or not?

I have but one article more to observe upon. I had given, as I thought, a kind of demonstration, from the internal evidence of the stone, that granite had been in the fluid state of fusion, and had concreted by crystallization and congelation from that melted state. This no doubt must be a stumbling block to those who maintain that granite mountains are the primitive parts of our earth; and who, like our author, suppose that "things may have been originally, as at present, in a solid state." It must also be a great, if not an invincible obstacle in the way of the aqueous theory, which thus endeavours to explain those granite veins that are found traversing strata, and therefore necessarily of a posterior formation.

To remove that obstacle in the way of the aqueous theory, or to carry that theory over the obstacle which he cannot remove, our author undertakes to refute my theory with regard to the igneous origin of stony substances, by giving an example of granite formed upon the surface of the earth by means of water, or in what is called the moist way; and he closes his Dissertation with this example as an *experimentum crucis*. It is therefore necessary that I take this demonstration of our author into particular consideration; for, surely, independent of our controversy, which is perhaps of little moment, here is the most interesting experiment, as it is announced, that mineralogy could be enriched with.

"To close this controversy," says our author, "I shall only add, that granite, recently formed in the moist way, has been frequently found."—Of that remarkable event, however, he has selected only one example. This is to be found upon the Oder; and the authority upon which our author has given it, is that of Lasius Hartz.

The formation of a granite stone, from granite sand, by means of water, is inconsistent with our chemical knowledge of those mineral substances which constitute that stone; it is repugnant to the phenomena which appear from the inspection of the natural bodies of this kind; and it is directly contrary to the universal experience in granite countries, where, instead of any thing concreting, every thing is going into decay, from the loose stones and sand of granite, to the solid rock and mountains which are always in a state of degradation. Therefore, to have any credit given to such a story, would require the most scientific evidence in its favour. Now, in order that others may judge whether this has been the case in this example, I will transcribe what our author has said upon the subject; and then I will give the view in which it appears to me.

He says, "a mole having been constructed in the Oder in the year 1723, 350 feet long, 54 feet in height, 144 feet broad at bottom, and 54 at the top, its sides only were granite, without any other cement than moss; the middle space was entirely filled with granite sand. In a short time this concreted into a substance so compact as to be impenetrable by water."—Here is an example, according to our author, of *granite formed in the moist way*. But now, I must ask to see the evidence of that fact; for, from what our author has told us, I do not even see reason to conclude that there was the least concretion, or any stone formed at all. A body of sand will be *so compacted as to be impenetrable by water*, with the introduction of a very little mud, and without any degree of concretion; muddy water, indeed, cannot be made to pass through such a body without compacting it so; and this every body finds, to their cost, who have attempted to make a filter of that kind.

But I shall suppose Lasius has informed our author that there had been a petrifaction in this case; and, before I admit this example of the formation of granite, I must ask what sort of a granite it was;—whether of two, three, or four ingredients; and, how these were disposed. If, again, it were not properly a granite, but a stone formed of granite sand, What is the cementing substance?—Is it quartz, felt-spar, mica, or schorl?—or, Was it calcareous?

If our author knows any thing about these necessary questions, Why has he not informed us, as minutely as he has done with regard to the dimensions of the mole, with which we certainly are less concerned?

If, again, he knows no more about the matter than what he has informed us of, he must have strangely imposed upon himself, to suppose that he was giving us an example of the *formation of granite in the moist way*, when he has only described an effectual way of retaining water, by means of sand and mud.

Chapter 3. Of Physical Systems, And Geological Theories, In General

In the first chapter I have given a general theory of the earth, with such proofs as I thought were sufficient for the information of intelligent men, who might satisfy themselves by examining the facts on which the reasoning in that theory had been founded.

In the second chapter, I have endeavoured to remove the objections which have been made to that theory, by a strenuous patron of the commonly received opinion of mineralogists and geologists,—an opinion which, if not diametrically opposite, differs essentially from mine. But now I am to examine nature more particularly, in order to compare those different opinions with the actual state of things, on which every physical theory must be founded. Therefore, the opinions of other geologists should be clearly stated, that so a fair comparison may be made of theories which are to represent the system of this earth.

Now, if I am to compare that which I have given as a theory of the earth, with the theories given by others under that denomination, I find so little similarity, in the things to be compared, that no other judgment could hence be formed, perhaps, than that they had little or no resemblance. I see certain treatises named Theories of the Earth; but, I find not any thing that entitles them to be considered as such, unless it be their endeavouring to explain certain appearances which are observed in the earth. That a proper theory of the earth should explain all those appearances is true; but, it does not hold, conversely, that the explanation of an appearance should constitute a theory of the earth. So far as the theory of the earth shall be considered as the philosophy or physical knowledge of this world, that is to say, a general view of the means by which the end or purpose is attained, nothing can be properly esteemed such a theory unless it lead, in some degree, to the forming of that general view of things. But now, let us see what we have to examine in that respect.

We have, first, Burnet's Theory of the Earth. This surely cannot be considered in any other light than as a dream, formed upon the poetic fiction of a golden age, and that of iron which had succeeded it; at the same time, there are certain appearances in the earth which would, in a partial view of things, seem to justify that imagination. In Telliamed, again, we have a very ingenious theory, with regard to the production of the earth above the surface of the sea, and of the origin of those land animals which now inhabit that earth. This is a theory which has something in it like a regular system, such as we might expect to find in nature; but, it is only a physical romance, and cannot be considered in a serious view, although apparently better founded than most of that which has been wrote upon the subject.

We have then a theory of a very different kind; this is that of the Count de Buffon. Here is a theory, not founded on any regular system, but upon an irregularity of nature, or an accident supposed to have happened to the sun. But, are we to consider as a theory of the earth, an accident by which a planetary body had been made to increase the number of these in the solar system? The circumvolution of a planetary body (allowing it to have happened in that manner) cannot form the system of a world, such as our earth exhibits; and, in forming a theory of the earth, it is required to see the aptitude of every part of this complicated machine to fulfil the purpose of its intention, and not to suppose the wise system of this world to have arisen from, the cooling of a lump of melted matter which had belonged to another body. When we consider the power and wisdom that must have been exerted in the contriving, creating, and maintaining this living world which sustains such a variety of plants and animals, the revolution of a mass of dead matter according to the laws of projectiles, although in perfect wisdom, is but like a unite among an infinite series of ascending numbers.

After the theory of that eloquent writer, founded on a mere accident, or rather the error of a comet which produced the beautiful system of this world, M. de Luc, in his Theory of the earth, has given us the history of a disaster which befell this well contrived world;—a disaster which caused the general deluge, and which, without a miracle, must have undone a system of living beings that are so well adapted to the present state of things. But, surely, general deluges form no part of the theory of the earth; for, the purpose of this earth is evidently to maintain vegetable and animal life, and not to destroy them.

Besides these imaginary great operations in the natural history of this earth, we have also certain suppositions of geologists and mineralists with regard to the effect of water, for explaining to us the consolidation of the loose materials of which the strata of the earth had been composed, and also for producing every other appearance, or any which shall happen to occur in the examination of the earth, and require to be explained. That this is no exaggerated representation, and that this is all we have as a theory, in the suppositions of those geologists, will appear from the following state of the case.

They suppose water the agent employed in forming the solid bodies of the earth, and in producing those crystallised bodies which appear in the mineral kingdom. That this is a mere supposition will appear by considering; first, that they do not know how this agent water is to operate in producing those effects; nor have they any direct proof of the fact which is alleged, from a very fallaceous analogy; and, secondly, that they cannot tell us where this operation is to be performed. They cannot say that it is in the earth above the level of the sea: for, the same appearances are found as deep as we can examine below that level; besides, we see that water has the opposite effect upon the surface of the earth, through which it percolates dissolving soluble substances, and thus resolving solid bodies in preparing soil for plants. If, again, it be below the level of the sea, that strata of the earth are supposed to be consolidated by the infiltration of that water which falls from the heavens; this cannot be allowed, so far as whatever of the earth is bibulous, in that place, must have been always full of water, consequently cannot admit of that supposed infiltration.

But allowing those suppositions to be true, there is nothing in them like a theory of the earth,—a theory that should bring the operations of the world into the regularity of ends and means, and, by generalizing these regular events, show us the operation of perfect intelligence forming a design; they are only an attempt to show how certain things, which we see, have happened without any perceivable design, or without any farther design than this particular effect which we perceive. If we believe that there is almighty power, and supreme wisdom employed for sustaining that beautiful system of plants and animals which is so interesting to us, we must certainly conclude, that the earth, on which this system of living things depends, has been constructed on principles that are adequate to the end proposed, and procure it a perfection which it is our business to explore. Therefore, a proper system of the earth should lead us to see that wise contraction, by which this earth is made to answer the purpose of its intention and to preserve itself from every accident by which the design of this living world might be frustrated as this world is an active scene. or a material machine moving in all its parts, we must see how this machine is so contrived, as either to have those parts to move without wearing and decay, or to have those parts, which are wasting and decaying, again repaired.

A rock or stone is not a subject that, of itself, may interest a philosopher to study; but, when he comes to see the necessity of those hard bodies, in the constitution of this earth, or for the permanency of the land on which we dwell, and when he finds that there are means wisely provided for the renovation of this necessary decaying part, as well as that of every other, he then, with pleasure, contemplates this manifestation of design, and thus connects the mineral system of this earth with that by which the heavenly bodies are made to move perpetually in their orbits. It is not, therefore, simply by seeing the concretion of mineral bodies that a philosopher is to be gratified in his his intellectual pursuit, but by the contemplation of that system in which the necessary resolution of this earth, while at present it serves the purpose of vegetation, or the fertility of our soil, is the very means employed in furnishing the materials of future land.

It is such a view as this that I have endeavoured to represent in the theory which I have given. I have there stated the present situation of things, by which we are led to perceive a former state; and, from that necessary progress of actual things, I have concluded a certain system according to which things will be changed, without any accident or error. It is by tracing this regular system in nature that a philosopher is to perceive the wisdom with which this world has been contrived; but, he must see that wisdom founded upon the aptitude of all the parts to fulfil the intention of the design; and that intention is to be deduced from the end which is known to be attained. Thus we are first to reason from effect to cause, in seeing the order of that which has already happened; and then, from those known causes, to reason forwards, so as to conceive that which is to come to pass in time. Such would be the philosophy of this earth, formed by the highest generalisation of phenomena, a generalisation which had required the particular investigation of inductive reasoning.

That no such theory as this, founded upon water as an agent operating in the changes of this earth, has yet appeared, will, I believe be easily allowed. With regard again to fire as an agent in the mineral operations of this earth, geologists have formed no consistent theory. They see volcanoes in all the quarters of the globe, and from those burning mountains, they conjecture other mountains have been formed. But a burning mountain is only a matter of fact; and, they have not on this formed any general principle, for establishing what may be called a theory of the earth. Those who have considered subterraneous fires as producing certain effects, neither know how these have been procured, nor do they see the proper purpose for which they are employed in the system of this world. In this case, the agent fire is only seen as a destructive element, in like manner as deluges of water have been attributed by others to changes which have happened in the natural state of things. These operations are seen only as the accidents of nature, and not as part of that design by which the earth, which is necessarily wasted in the operations of the world, is to be repaired.

So far from employing heat or subterraneous fire as an agent in the mineral operations of the earth, the volcanic philosophers do not even attempt to explain upon that principle the frequent nodules of calcareous, zeolite, and other spatose and agaty substances, in those basaltic bodies which they consider as lavas. Instead then of learning to see the operation of heat as a general principle of mineral consolidation and crystallization, the volcanic philosophers endeavour to explain those particular appearances, which they think inconsistent with fusion, by aqueous infiltration, no otherwise than other mineralists who do not admit the igneous origin of those basaltic bodies. Thus, that great agent, subterraneous heat, has never been employed by geologists, as a general principle in the theory of the earth; it has been only considered as an occasional circumstance, or as the accident of having certain mineral bodies, which are inflammable, kindled in the earth, without so much as seeing how that may be done.

This agent heat, then, is a new principle to be employed in forming a theory of the earth; a principle that must have been in the constitution of this globe, when contrived to subsist as a world, and to maintain a system of living bodies perpetuating their species. It is therefore necessary to connect this great mineral principle, subterraneous fire or heat, with the other operations of the world, in forming a general theory. For, whether we are to consider those great and constant explosions of mineral fire as a principal agent in the design, or only as a casual event depending upon circumstances which give occasion to an operation of such magnitude, here is an object that must surely have its place in every general theory of the earth.

In examining things which actually exist, and which have proceeded in a certain order, it is natural to look for that which had been first; man desires to know what had been the beginning of those things which now appear. But when, in forming a theory of the earth, a geologist shall indulge his fancy in framing, without evidence, that which had preceded the present order of things, he then either misleads himself, or writes a fable for the amusement of his reader. A theory of the earth, which has for object truth, can have no retrospect to that which had preceded the present order of this world; for, this order alone is what we have to reason upon; and to reason without data is nothing but delusion. A theory, therefore, which is limited to the actual constitution of this earth, cannot be allowed to proceed one step beyond the present order of things.

But, having surveyed the order of this living world, and having investigated the progress of this active scene of life, death and circulation, we find ample data on which to found a train of the most conclusive reasoning with regard to a general design. It is thus that there is to be perceived another system. of active things for the contemplation of our mind;—things which, though not immediately within our view, are not the less certain in being out of our sight; and things which must necessarily be comprehended in the theory of the earth, if we are to give stability to it as a world sustaining plants and animals. This is a mineral system, by which the decayed constitution of an earth, or fruitful surface of habitable land, may be continually renewed in proportion as it is wasted in the operations of this world.

It is in this mineral system that I have occasion to compare the explanations, which I give of certain natural appearances, with the theories or explanations which have been given by others, and which are generally received as the proper theory of those mineral operations. I am, therefore, to examine those different opinions, respecting the means employed by nature for producing particular appearances in the construction of our land, appearances which must be explained in some consistent mineral theory.

These appearances may all be comprehended under two heads, which are now to be mentioned, in order to see the importance of their explanation, or purpose which such an explanation is to serve in a theory of the earth. The first kind of these appearances is that of known bodies which we find composing part of the masses of our land, bodies whose natural history we know, as having existed in another state previous to the composition of this earth where they now are found; these are the relicts or parts of animal and vegetable bodies, and various stony substances broken and worn by attrition, all which had belonged to a former earth. By means of these known objects, we are to learn a great deal of the natural history of this earth; and, it is in tracing that history, from where we first perceive it, to the present state of things, that forms the subject of a geological and mineralogical theory of this earth. But, we are more especially enabled to trace those operations of the earth, by means of the second kind of appearances, which are now to be mentioned.

These again are the evident changes which those known bodies have undergone, and which have been induced upon such collected masses of which those bodies constitute a part. These changes are of three sorts; *first*, the solid state, and various degrees of it, in which we now find those masses which had been originally formed by the collection of loose and incoherent materials; *secondly*, the subsequent changes which have evidently happened to those consolidated masses which have been broken and displaced, and which have had other mineral substances introduced into those broken and disordered parts; and, *lastly*, that great change of situation which has happened to this compound mass formed originally at the bottom of the sea, a mass which, after being consolidated in the mineral region, is now situated in the atmosphere above the surface of the sea.

In this manner we are led to the system of the world, or theory of the earth in general; for, that great change of situation, which our land has undergone, cannot be considered as the work of accident, or any other than an essential part in the system of this world. It is therefore a proper view of the necessary connection and mutual dependence of all those different systems of changing things that forms the theory of this earth as a world, or as that active part of nature which the philosophy of this earth has to explore. The animal system is the first or last of these; next comes the vegetable system, on which the life of animals depends; then comes the system of this earth, composed of atmosphere, sea, and land, and comprehending the various chemical, mechanical, and meteorologically operations which take place upon that surface where vegetation must proceed; and, lastly, we have the mineral system to contemplate, a system in which the wasting surface of the earth is employed in laying the foundation of future land within the sea, and a system in which the mineral operations are employed in concocting that future land.

Now, such must surely be the theory of this earth, if the land is continually wasting in the operations of this world; for, to acknowledge the perfection of those systems of plants and animals perpetuating their species, and to suppose the system of this earth on which they must depend, to be imperfect, and in time to perish, would be to reason inconsistently or absurdly. This is the view of nature that I would wish philosophers to take; but, there are certain prejudices of education or prepossession of opinion among them to be overcome, before they can be brought to see those fundamental propositions,—the wasting of the land, and the necessity of its renovation by the co-operation of the mineral system. Let us then consider how men of science, in examining the mineral state of things, and reasoning from those appearances by which we are to learn the physiology of this earth, have misled themselves with regard to physical causes, and formed certain mineralogical and geological theories, by which their judgment is so perverted, in examining nature, as to exclude them from the proper means of correcting their first erroneous notions, or render them blind to the clearest evidence of any other theory that is proposed.

When men of science reason upon subjects where the ideas are distinct and definite, with terms appropriated to the ideas, they come to conclusions in which there is no difference of opinion. It is otherwise in physical subjects, where things are to be assimilated, in being properly compared; there, things are not always compared in similar and equal circumstances or conditions; and there, philosophers often draw conclusions beyond the analogy of the things compared, and thus judge without data. When, for example, they would form the physical induction, with regard to the effect of fire or water upon certain substances in the mineral regions, from the analogy of such events as may be observed upon the surface of the earth, they are apt to judge of things acting under different circumstances or conditions, consequently not producing similar effects; in which case, they are judging without reason, that is, instead of inductive reasoning from actual data or physical truth, they are forming data to themselves purely by supposition, consequently, so far as these, imagined data may be wrong, the physical conclusion, of these philosophers may be erroneous.

It is thus that philosophers have judged, with regard to the effects of fire and water upon mineral substances below the bottom of the sea, from what their chemistry had taught them to believe concerning bodies exposed to those agents in the atmosphere or on the surface of the earth. If in those two cases the circumstances were the same, or similar, consequently the conditions of the action not changed, then, the inductive reasoning, which they employ in that comparison, would be just; but, so far as it is evidently otherwise, to have employed that inductive conclusion for the explanation of mineral appearances, without having reason to believe that those changed circumstances of the case should not make any difference in the action or effect, is plainly to have transgressed the rules of scientific reasoning; consequently, instead of being a proper physical conclusion, it is only that imperfect reasoning of the vulgar which, by comparing things not properly analysed or distinguished, is so subject to be erroneous. This vague reasoning, therefore, cannot be admitted as a part of any geological or mineral theory. Now I here maintain, that philosophers have judged in no other manner than by this false analogy, when they conclude that water is the agent by which mineral concretions have been formed. But it will be proper to state more particularly the case of that misunderstanding among mineral philosophers.

In forming a geological theory, the general construction of this earth, and the materials of which it is composed, are such visible objects, and so evident to those who will take the pains to examine nature, that here is a subject in which there cannot be any doubt or difference of opinion. Neither can there be any dispute concerning the place and situation of mass when it was first formed or composed; for, this is clearly proved, from every concomitant circumstance, to have been at the bottom of the sea. The only question in this case, that can be made, is, How that mass comes now to be a solid body, and above the surface of the sea in which it had been formed?

With regard to the last, the opinions of philosophers have been so dissonant, so vague, and so unreasonable, as to draw to no conclusion. Some suppose the land to be discovered by the gradual retreat of the ocean, without proposing to explain to us from whence had come the known materials of a former earth, which compose the highest summits of the mountains in the highest continents of the earth. Others suppose the whole of a former earth to have subsided below the bottom even of the present sea, and together with it all the water of the former sea, from above the summits of the present mountains, which had then been at the bottom of the former sea. The placing of the bottom of the sea, or any part of it, in the atmosphere so as to be dry land, is no doubt a great operation to be performed, and a difficult task to be explained; but this is only an argument the more for philosophers to agree in adopting the most reasonable means.

But though philosophers differ so widely in that point, this is not the case with regard to the concretion of mineral bodies; here mineralists seem to be almost all of one mind, at the same time without any reason, at least, without any other reason than that false analogy which they have inconsiderately formed from the operations of the surface of this earth. This great misunderstanding of mineralists has such an extensive and baneful effect in the judging of geological theories, that it will be proper here to explain how that has happened, and to show the necessity of correcting that erroneous principle before any just opinion can be formed upon the subject.

Fire and water are two great agents in the system of this earth; it is therefore most natural to look for the operation of those agents in the changes which are made on bodies in the mineral regions; and as the consolidated state of those bodies, which had been collected at the bottom of the sea, may have been supposed to be induced either by fusion, or by the concretion from a solution, we are to consider how far natural appearance lead to the conclusion of the one or other of those two different operations. Here, no doubt, we are to reason analogically from the known power and effects of those great agents; but, we must take care not to reason from a false analogy, by misunderstanding the circumstances of the case, or not attending to the necessary conditions in which those agents act.—We must not conclude that fire cannot burn in the mineral regions because our fires require the ventilation of the atmosphere; for, besides the actual exigence of mineral fire being a notorious matter of fact, we know that much more powerful means *may* be employed by nature, for that mineral purpose of exciting heat, than those which we practise.—We must not conclude that mineral marble is formed in the same manner as we see a similar stony substance produced upon the surface of the earth, unless we should have reason to suppose the analogy to be complete. But, this is the very error into which mineral philosophers have fallen; and this is the subject which I am now to endeavour to illustrate.

The manner in which those philosophers have deceived themselves when reasoning upon the subject of mineral concretion, is this: They see, that by means of water a stony substance is produced; and, this stony body so much resembles mineral marble as to be hardly distinguishable in certain cases. These mineral philosophers then, reasoning in the manner of the vulgar, or without analysing the subject to its principle, naturally attribute the formation of the mineral marble to a cause of the same sort; and, the mineral marble being found so intimately connected with all other mineral bodies, we must necessarily conclude, in reasoning according to the soundest principles, that all those different substances had been concreted in the same manner. Thus, having once departed one step from the path of just investigation, our physical science is necessarily bewildered in the labyrinth of error. Let us then, in re-examining our data, point out where lies that first devious step which had been impregnated with fixed air, or carbonic acid gas, (as it is called), dissolves a certain portion of mild calcareous earth or marble; consequently such acidulated water, that is, water impregnated with this gas, will, by filtrating through calcareous substances, become saturated with that solution of marble; and, this solution is what is called a *petrifying water*. When this solution is exposed to the action of the atmosphere, the acid gas, by means of which the stony substance is dissolved, evaporates from the solution, in having a stronger attraction for the atmospheric air; it is then that the marble, or calcareous substance, concretes and crystallises, separating from the water in a sparry state, and forming a very solid stone by the successive accretion from the solution, as it comes to be exposed to the influence of the atmosphere in flowing over the accumulating body. Here is the source of their delusion; for, they do not distinguish properly the case of this solution of a stony substance concreting by means of the separation of its solvent, and the case of such a solution being in a place where that necessary condition cannot be supposed to exist; such as, e.g., the interstices among the particles of sand, clay, etc. deposited at the bottom of the sea, and accumulated in immense stratified masses.

No example can better illustrate how pernicious it is to science to have admitted a false principle, on which a chain of reasoning is to proceed in forming a theory. Mineral philosophers have founded their theory upon that deceitful analogy, which they had concluded between the stalactical concretions of petrifying waters and the marble formed in the mineral regions; thus, blinded by prejudice, they shut the door against the clearest evidence; and it is most difficult to make them see the error of their principle. But this is not to be wondered at, when we consider how few among philosophising men remount to the first principles of their theory; and, unless they shall thus remount to that first step, in which the concreting operation of a dissolved stony substance is supposed to take place without the necessary conditions for the petrifying operation, it is impossible to be convinced that their theory, thus formed with regard to mineral concretion, is merely supposition, and has no foundation in matter of fact from whence it should proceed.

But this is not all; for, even supposing their theory to be well founded and just, it is plainly contradicted by natural appearances. According to that theory of aqueous consolidation, all the stratified bodies, of which this earth in general consists, should be found in the natural order of their regular formation; but, instead of this, they are found every where disturbed in that order more or less; in many places this order and regularity is so disturbed as hardly to be acknowledged; in most places we find those stratified bodies broken, dislocated, and contorted, and this aqueous theory of mineralists has neither the means for attaining that end, were it required in their theory, nor have they any such purpose in their theory, were that end attainable by the means which they employ. Thus blinded by the prejudice of a false analogy, they do not even endeavour to gratify the human understanding (which naturally goes in quest of wisdom and design) by forming a hypothetical or specious theory of the mineral system; and they only amuse themselves with the supposition of an unknown operation of water for the explanation of their cabinet specimens, a supposition altogether ineffectual for the purpose of forming a habitable earth, and a supposition which is certainly contradicted by every natural appearance.

Thus, in examining geological and mineralogical theories, I am laid under the disagreeable necessity of pointing out the errors of physical principles which are assumed, the prejudices of theoretical opinions which have been received, and the misconceived notions which philosophers entertain with regard to the system of nature, in which may be perceived no ineffectual operation, nor any destructive intention, but the wise and benevolent purpose of preserving the present order of this world. But, though thus misled with regard to the cause of things, naturalists are every where making interesting observations in the mineral kingdom, I shall therefore avail myself of that instructive information, for the confirmation of my theory.

It may now be proper to consider what must be required, in order to have a geological and mineral theory established upon scientific principles, or on such grounds as must give conviction to those who will examine the subject;

for, unless we may clearly see that there are means for attaining that desirable end, few philosophers will be persuaded to pursue this branch of knowledge.

A theory is nothing but the generalization of particular facts; and, in a theory of the earth, those facts must be taken from the observations of natural history. Nature is considered as absolutely true; no error or contradiction can be found in nature. For, if such contradiction were truly found, if the stone, for example, which fell to day were to rise again to-morrow, there would be an end of natural philosophy, our principles would fail, and we would no longer investigate the rules of nature from our observations.

Every natural appearance, therefore, which is explained, *i.e.* which is made to come into the order of things that happen, must so far confirm the theory to which it then belongs. But is it necessary, that every particular appearance, among minerals, should be thus explained in a general theory of the earth? And, is any appearance, which is not explained by it, to be considered as sufficient to discredit or confute a theory which corresponded with every other appearance? Here is a question which it would require some accuracy to resolve.

If we knew all the powers of nature, and all the different conditions in which those powers may have their action varied, that is to say, if we were acquainted with every physical cause, then every natural effect, or all appearances upon the surface of this earth, might be explained in a theory that were just. But, seeing that this is far from being the case, and that there may be many causes of which we are as yet ignorant, as well as certain conditions in which the known action of powers may be varied, it must be evident, that a theory of the earth is not to be confuted by this argument alone, That there are, among natural bodies, certain appearances which are not explained by the theory. We must admit, that, not having all the data which natural philosophy requires, we cannot pretend to explain every thing which appears; and that our theories, which necessarily are imperfect, are not to be considered as erroneous when not explaining every thing which is in nature, but only when they are found contrary to or inconsistent with the laws of nature, which are known, and with which the case in question may be properly compared.

But we may have different theories to compare with nature; and, in that case, the question is not, How far any of those theories should explain all natural appearances? but, How far any one particular theory might explain a phenomenon better than another? In this case of comparison, it will be evident, that if one theory explains natural appearances, then the opposite to that theory cannot be supposed to explain the same appearances. If for example, granite, porphyry, or basaltes, should be found naturally formed by fusion, the formation of those stones could not be supposed in any case as formed by water, although it could not be demonstrated that water is incapable of forming those mineral productions.

In like manner, if those three bodies were proved to have been actually formed by water alone, then, in other cases where we should have no proof, they could not be supposed as having been formed by fire or fusion. It must be evident, that an equal degree of proof of those two different propositions would leave our judgment in suspence, unless that proof were perfect, in which case, we would have two different causes producing similar effects. But, if we shall have a sufficient proof upon the one side, and only a presumptive proof or probability upon the other, we must reject that probability or presumption, when opposed by a proof, although that proof were only an induction by reasoning from similar effects as following similar causes. *A fortiori*, if there be on one side a fair induction, without the least suspicion of error, and on the other nothing but a mere presumption founded upon a distant analogy, which could not even properly apply, then, the inductive proof would be as satisfactory as if there had not been any supposition on the opposite side.

So far as a theory is formed in the generalization of natural appearances, that theory must be just, although it may not be perfect, as having comprehended every appearance; that is to say, a theory is not perfect until it be founded upon every natural appearance; in which case, those appearances will be explained by the theory. The theory of gravitation, though no ways doubtful, was not so perfect before the shape of this globe had been determined by actual measurement, and before the direction of the plummet had been tried upon Shihallion, as after those observations had been made. But a theory which should be merely hypothetical, or founded upon a few appearances, can only be received as a theory, after it has been found to correspond properly with nature; it would then be held a proper explanation of those natural appearances with which it corresponded; and, the more of those phenomena that were thus explained by the theory, the more would that, which had been first conjectural, be converted into a theory legitimately founded upon natural appearances.

Matter of fact is that upon which science proceeds, by generalization, to form theory, for the purpose of philosophy, or the knowledge of all natural causes; and it is by the companion of these matters of fact with any theory, that such a theory will be tried. But, in judging of matter of fact, let us be cautious of deceiving ourselves, by substituting speculative reasoning in place of actual events.

Nature, as the subject of our observation, consists of two sorts of objects; for, things are either active, when we perceive change to take place in consequence of such action, or they are quiescent, when we perceive no change to take place. Now, it is evident, that in judging of the active powers of nature from the quiescent objects of our information, we are liable to error, in misinterpreting the objects which we see; we thus form to ourselves false or erroneous opinion concerning the general laws of action, and the powers of nature. In comparing, therefore, generalised facts, or theory, with particular observations, there is required the greatest care, neither, on the one hand, to strain the appearances, so as to bring in to the theory a fact belonging to another class of things; nor, on the other, to condemn a proper theory, merely because that theory has not been extended to the explanation of every natural appearance.

But, besides the misinterpretation of matters of fact, we are also to guard against the misrepresentation of natural appearances. Whether warped by the prejudice of partial and erroneous theory, or deceived by the inaccuracy of superficial observation, naturalists are apt to see things in an improper light, and thus to reason from principles which cannot be admitted, and, which often lead to false conclusions. A naturalist, for example, comes to examine a cavity in the mines, he there finds water dropping down all around him, and he sees the cavity all hung with siliceous crystals; he then concludes, without hesitation, that here is to be perceived cause and effect, or that he actually sees the formation of those crystallizations from the operation of water. It is thus that I have been told by men of great mineral knowledge, men who must have had the best education upon that subject of mineralogy, and who have the superintendance of great mineral concerns in Germany, that they had actually seen nature at work in that operation of forming rock-crystal;—they saw what I have now described; they could see no more; but, they saw what had convinced them of that which, there is every reason to believe, never happened. With regard to my theory, I wish for the most rigorous examination; and do not ask for any indulgence whatever, whether with regard to the principles on which the theory is built, or for the application of the theory to the explanation of natural appearances. But, let not geologists judge my theory by their imperfect notions of nature, or by those narrow views which they take of the present state of things;—let not mineralogists condemn my theory, for no other reason but because it does not correspond with their false principles, and those gratuitous suppositions by which they had been pleased to explain to themselves every thing before. First let them look into their own theory, and correct that erroneous principle, with regard to the action of water, or the assumption of unknown causes, upon which they have reasoned in forming their vague notions of the mineral region, before they can be properly qualified to examine, impartially, a theory which employs another principle. Every thing which has come under my observation shall be, as far as I can, faithfully related; nor shall I withhold those which neither the present theory, nor any other that I am acquainted with, can, I think, explain.

Appearances cannot well be described except in relation to some theory or general arrangement of the subject; because the particular detail, of every part in a complicated appearance, would be endless and insignificant. When, however, any question in a theory depends upon the nature of an appearance, we cannot be too particular in describing that by which the question is to be decided. But though it be sometimes proper to be minute in a particular, it is always, and above all things, necessary to be distinct; and not to confound together things which are of different natures. For, though it be by finding similarity, in things which at first sight may seem different, that science is promoted and philosophy attained, yet, we must have a distinct view of those things which are to be assimilated; and surely the lowest state of knowledge in any subject, is the not distinguishing things which, though not to common observation different, are not truly the same.

To confound, for example one stone with another, because they were both hard, friable, and heavy, would be to describe, with the superficial views of vulgar observation; whereas science specifies the weight and hardness, and thus accurately distinguishes the stone.

Before naturalists had learned to distinguish what they saw, and to describe, in known terms, those natural appearances, a theorist must have generalised only from his proper observation. This has been my case. When I first conceived my theory, few naturalists could write intelligibly upon the subject; but that is long ago, and things are much altered since; now there are most enlightened men making observations, and communicating natural knowledge. I have the satisfaction, almost every day, to compare the theory, which I had formed from my proper observations, with the actual state of things in almost every quarter of the globe.

Whether, therefore, we mean to try a theory by its application to such phenomena as are well understood, or to learn something from the application of particular phenomena to a well established theory, we shall always find it interesting to have appearances described; particularly such as may be referred to some general rule, as circumscribing it to certain conditions, or as finding rule in rule, that is to say, discovering those particular conditions in which the general laws of action may be affected.

Instead, for example, of the rule which we find in the application of heat for the fusion and evaporation of mineral substances upon the surface of this earth, we may find it necessary to consider the effect which changed circumstances produce in the mineral regions, and occasion a change of that rule of action which we have learned from experience, when melting and evaporating those substances in the atmosphere or on the surface of the earth.

It is in this manner that a theory, which was formed by the generalization of particular facts, comes to be a source of information, by explaining to us certain appearances which otherwise we could not understand. Thus, it was not the appearance of the tides that taught the theory of gravitation; it was the theory of gravitation that made us understand the appearance of the tides. In like manner, the law of gravitation, which was demonstrated from the motion of the moon in her orbit round this earth, when applied to the paths of comets, explained that appearance. Our theory, of a central fire, has been formed upon the consolidation of the strata of this earth; but this theory is to be applied for the explanation of various different appearances. In this manner, two different purposes will be served; the trying of the theory by its application to phenomena; and the explanation of phenomena by the principles laid open in the theory.

I may repeat it; a theory of the earth must ultimately depend upon matter of fact or particular observation; but those observations must be distinct, and those distinguished things must be generalised. We have just now given for an example, a distinction among stones, in knowing them by their sensible qualities. But, besides distinguishing those objects, we are also to inquire into the origin and cause of those things which are distinguished. Here, again, we take into our aid the chemical as well as the mechanical properties of these several things; and hence learn to know on what their natural form and constitution may depend. Having thus attained the natural philosophy of stones, we next inquire into the place and application of those things in nature; and in this manner we acquire some knowledge with regard to the natural constitution of this earth. We find this earth composed of known things; it is therefore the operations, required in these compositions, which form the natural philosophy of this earth, considered as a body of solid land. But, the solid land is only one part of the globe; therefore, the philosophy of the globe proceeds still farther by knowing the constitution of this planetary body, as consisting of different parts united for a purpose, which is that of a world.

The general theory of this earth as a world, will thus appear to be a complex thing, which however founded upon simple principles, contains many subjects of discussion, and requires attention to a variety of particulars. For, not only the great features of this earth are to be explained by the theory, but also the most minute appearance, such as are to be found, even with microscopic observation, in every particular part.

Thus the nature, constitution, and cause of every particular appearance in the construction of this earth, are to be investigated in a geological theory, as well as that general constitution of the world in which all the particular parts are to be employed for a purpose.

If the subject here examined shall be found properly explained, there will remain little doubt with regard to the justness of the theory, which will then be applicable to other appearances that may occur; although every appearance is not to be explained, in a manner equally satisfactory, by any theory which is not perfect.

The first subject to be examined is the modern theory of primitive mountains. I have written several chapters upon that subject, having successively acquired more light in this interesting part of the theory, by observations of my own in several places of this country, as well as from the natural history of other countries.

I shall give these nearly in the order in which they occurred, or had been written.

Chapter 4. The Supposition Of Primitive Mountains Refuted

In the theory now given, the earth has been represented as a composition of different materials, which had existed in another form, and as the effect of natural operations; therefore, however various may be found the structure of our earth, and however dissimilar some parts of its composition may be in comparison with others, no part should be considered as original, in relation to the globe, or as primitive, in relation to second causes, *i.e.* physical operations by which those parts should have been formed. But it is pretended by naturalists, that there are certain primitive mountains in the earth, bodies which have had another origin than that of the general strata of the globe and subsequent masses; an origin, therefore, which cannot be considered as having been produced from natural operations, or as effected in the course of known causes. Now, if it can be made to appear, that there is no solid ground for this distinction; and if it can be shown, that there is truly no mineral body in this earth which may not have been produced by operations natural to the globe, we should thus procure a certain confirmation of the doctrine. This also will be the more interesting, in being deduced from a part of natural appearances, which seemed to be inconsistent with the theory.

Certain masses or mountains of granite, are the only bodies of this earth which have apparently a certain pretension to this species of originality. These, therefore, must be now the subject of our examination.

Granite, considered by itself, does not appear to have any claim to originality in its nature. It is composed of bodies which are capable of being analysed; and these are then found to be compositions of different substances, which are also sometimes variously proportioned. The feldspar and the mica, for example, as well as the schorl, are found variously coloured in different granites, and coloured in various proportions. Besides the variety in the composition, or chemical mixture of the different bodies which compose granite, this rock admits of a great diversity, from the variety of its mechanical mixture, or from the different species of bodies which are its constituent parts. M. de Saussure, who has examined this subject perhaps more than any other person, and who has had the very best opportunities for this purpose, says, that this composition may be found in all the different combinations which may be produced by every possible composition of 7 or 8 different kinds of stone, (page 108, Voyage dans les Alpes, etc.). Neither does this fill up the measure of its variety; for, another source of change is found in the grain of this rock stone; I have a specimen of this variety from the size almost of sand to that of some inches.

Were granite, therefore, to be supposed as in the original state of its creation, nature would be considered as having operated in an indefinite diversity of ways, without that order and wisdom which we find in all her works; for here would be change without a principle, and variety without a purpose. There is no reason, however, to suppose granite original, more than any other composite rock, although we may be ignorant of the particular process in which it is formed, and although, comparatively in relation to certain other rocks, granite, or certain masses of this composition, may be found of a more ancient date.

If granite be truly stratified, and those strata connected with the other strata of the earth, it can have no claim to originality; and the idea of primitive mountains, of late so much employed by natural philosophers, must vanish, in a more extensive view of the operations of the globe; but it is certain that granite, or a species of the same kind of stone, is thus found stratified. It is the *granit feuilletée* of M. de Saussure, and, if I mistake not, what is called *gneis* by the Germans. We have it also in our north alpine country of Scotland; of this I have specimens, but have not seen it in its place.

Granite being thus found stratified, the masses of this stone cannot be allowed to have any right of priority over the schistus, its companion in the alpine countries, although M. de Saussure, whose authority I would revere, has given it for the following reason; that it is found the most centrical in the chains of high mountains, or in alpine countries. Now, supposing this fact to be general, as he has found it in the Alps, no argument for the priority of those masses can be founded either upon the height or the situation of those granite mountains; for the height of the mountain depends upon the solidity and strength of the stone. Now though it is not to be here maintained that granite is the most durable of those alpine rocks, yet as a mountain, either granite in general, or in particular, certain species of it, may be esteemed such, consequently, this massy stone, remaining highest in the mountainous region, will naturally be considered as the centre, and according to this rule, as having the pre-eminence in point of seniority.

The rock which stands in competition with granite for the title of primitive in the order of mountains, is that micaceous stratified stone which is formed chiefly of quartz, but which admits of great variety like the granite. The difference between those two bodies does not consist in the materials of which they are composed, for, in their varieties, they may be in this respect the same, but in a certain regularity of composition, in this alpine stone, which evidently arises from stratification or subsidence in water.

If we shall thus consider all the varieties of this alpine stone as being of one kind, and call it granite, then we shall distinguish in this body two different species, from whence perhaps some interesting conclusion may be formed with regard to the operations of the globe. These two species are, *first*, granite regular in its composition, or stratified in its construction; and, *secondly*, granite in mass, or irregular in its construction. Let us now endeavour to make use of these generalizations and distinctions.

In examining the great diversity of our whinstone, trap, or basaltes, it is found at last to granulate into granite; at the same time those two different species of rock-stone may be distinguished. A perfect granite has not in its composition necessarily any argillaceous earth, farther than may be in the natural constitution of its distinct parts; whereas, a perfect basalt may have abundance of this substance, without any quartz or any siliceous body. A perfect granite, is, therefore, an extremely hard stone, having quartz and feldspar for its basis; but a perfect whin or basaltes may be extremely soft, so as to cut easily with a knife. In like manner granite is a composition which graduates into porphyry; but porphyry is only whinstone of a harder species. Therefore, though perfectly distinct, those three things graduate into each other, and may be considered as the same.

Granite and whinstone, or basaltes, though distinct compositions, thus graduating into each other; and whinstone, as well as porphyry, being without doubt a species of lava, we may consider the granite which is found in mass without stratification, in like manner as we do the masses of whinstone, basaltes, or Swedish trap, as having flowed in the bowels of the earth, and thus been produced by the chance of place, without any proper form of its own, or in an irregular shape and construction. In this manner would be explained the irregular shape or structure of those granite masses; and thus great light would be thrown upon the waved structure of the stratified alpine stone, which, though it has not been made to flow, has been brought to a great degree of softness, so as to have the original straight lines of its stratification changed to those undulated or waving lines which are in some cases extremely much incurvated.

It remains only to confirm this reasoning, upon our principles, by bringing actual observation to its support; and this we shall do from two of the best authorities. The Chevalier de Dolomieu, in describing the volcanic productions of Etna, mentions a lava which had flowed from that mountain, and which may be considered as a granite. But M. de Saussure has put this matter out of doubt by describing most accurately what he had seen both in the Alps and at the city of Lyons. These are veins of granite which have flowed from the contiguous mass into the stratified stone, and leave no doubt with regard to this proposition, that the granite had flowed in form of subterranean lava, although M. de Saussure has drawn a very different conclusion from this appearance. I have also a specimen from this country of a vein of granite in a granite stone, the vein being of a smaller grain than that of the rock which it traverses.[20]

Footnote 20: (return) This is what I had wrote upon, the subject of granite, before I had acquired such ample testimony from my own observations upon that species of rock. I have given some notice, in the 3d vol. of the Transactions of the Edinburgh R.S. concerning the general result of those observations, which will be given particularly in the course of this work.

It will thus appear, that the doctrine which of late has prevailed, of primitive mountains, or something which should be considered as original in the construction of this earth, must be given up as a false view of nature, which has formed the granite upon the same principle with that of any other consolidated stratum; so far as the collection of different materials, and the subsequent fusion of the compound mass, are necessary operations in the preparation of all the solid masses of the earth. Whatever operations of the globe, therefore, may be concluded from the composition of granite masses, as well as of the alpine strata, these must be considered as giving us information with regard to the natural history of this earth; and they will be considered as important, in proportion as they disclose to us truths, which from other strata might not be so evident, or at all made known.

Let us now examine the arguments, which, may be employed in favour of that supposition of primitive mountains.

The observations, on which naturalists have founded that opinion of originality in some of the component parts of our earth, are these; *first*, They observe certain great masses of granite in which stratification is not to be perceived; this then they say is an original mass, and it is not to be derived from any natural operation of the globe; *secondly*, They observe considerable tracts of the earth composed of matter in the order of stratification as to its general composition, but not as to its particular position, the vertical position here prevailing, instead of the horizontal which is proper to strata formed in water; this, therefore, they also term primitive, and suppose it to be from another origin than that of the subsidence of materials moved in the waters of the globe; *lastly*, They observe both strata and masses of calcareous matter in which they cannot distinguish any marine body as is usual in other strata of the same substance; and these calcareous masses being generally connected with their primitive mountains, they have also included these collections of calcareous matter, in which marine bodies are not observed, among the primitive parts which they suppose to be the original construction of this globe.

It may be proper to see the description of a calcareous alpine mountain. M. de Saussure gives us the following observations concerning a mountain of this kind in the middle of the Alps, where the water divides in running different ways towards the sea. It is in describing the passage of the Bon-Homme, (Tom. 2. V. dans les Alpes).

"§ 759. Sur la droite ou au couchant de ces rochers, on voit une montagne calcaire étonnante dans ce genre par la hardiesse avec laquelle elle élève contre le ciel ses cimes aigues et tranchantes, taillées à angles vifs dans le costume des hautes cimes de granit. Elle est pourtant bien sûrement calcaire, je l'ai observée de près, et on rencontre sur cette route les blocs qui s'en détachent.

"Cette pierre porte les caractères des calcaires les plus anciennes; sa couleur est grise, son grain assez fin, on n'y apperçoit aucun vestige de corps organisés; ses couches sont peu épaisses, ondées et coupées fréquemment par des fentes parallèles entr'elles et perpendiculaires à leurs plans. On trouve aussi parmi ces fragmens des brèches calcaires grises."

Here is a mountain which will rank with the most primitive of the earth; But why? only because it is extremely consolidated without any mark of organised body. Had there been in this mountain but one single shell, we should not then have scrupled to conclude that the origin of this lofty mountain had been the same with every marble or limestone in the earth. But though, from the structure of this stone, there is no mark of its having been formed immediately of the calcareous parts of animals, there is every mark of those calcareous strata having been formed like other marbles by deposit in the waters of the globe.

These two things are also homologated by the equal or perfect consolidation of their substance; for, as it is to be proved that all stratified marbles have been consolidated by the fusion of their substance, we must attribute the same consolidating cause to those alpine masses; the frequent veins that divide those calcareous strata which M. de Saussure has here described, also prove the nature of the consolidating cause, (see Chap. 1. page 111.).

This mountain, considered by itself, may perhaps afford no data by which a naturalist might read the circumstances of its origin. But, Is a theory of the earth to be formed upon such a negative observation? and, Is there any particular in this mountain, that may not be shown in others of which the origin is not in any degree doubtful?

It is not to be disputed, that there are parts of the solid body of our earth which may be considered as primary or prior, compared with others that are posterior, in relation to the time of their formation, and much less changed with regard to the state in which they had been originally formed:—But it is here denied, that there are any parts of the earth which do not appear to have had the same origin with all the rest, so far as this consists in the collection of materials deposited at the bottom of the waters [24]; for there is no solid mass of land that may not be traced to this origin, either from its composition, or from its local connection with other masses, the nature of which in this respect are known. We have already given examples of this from sufficient authority. The evidence, therefore, of those primary masses being original in relation to the natural operations of the globe, is reduced to this assertion, that there are no vestiges of organised bodies to be found in those primary masses. Let us now examine how far this testimony for the originality of those masses is to be admitted in fact and sound reasoning.

The matter in question at present is this, that there are certain tracts of countries in which no vestige of organised bodies are found; now, let us suppose the fact to be true or well grounded, Can we conclude from this that there had been originally no organised bodies in the composition of those masses?—Such a conclusion could only be formed in making a supposition, that every organised body deposited in a mass of matter, whether homogeneous or heterogeneous, should be preserved without change, while the collected mass, in which it had been deposited, changes as much as possible by the operation both of fire and water. But this supposition is erroneous, and cannot be admitted; and the study of marbles will demonstrate this truth, that the calcareous relics of organised bodies are changed, in the consolidating operations of the globe, in every degree, from the smallest alteration to the greatest, when they become indistinguishable any farther to our sight.

Therefore, from the supposition of no appearance of marine bodies in the pretended primitive masses, there is no sufficient evidence or reason to

[24] There are no collection of those alpine masses in which may not be found in some of them sand, mica, and gravel; but these materials prove the existence of an earth, on which those fragments of greater masses had been formed, and more or less worn by attrition.

conclude, that those masses have not had a marine origin; because, the traces of organised bodies may be obliterated by the many subsequent operations of the mineral region; and which operations, the present state of those masses certify beyond dispute.

We are now to examine the fact, how far the ground on which that false reasoning had been founded is strictly true.

In the first place, then, it must be considered, that the alleged fact is nothing but a negative assertion, importing that no mark of organised bodies had been observed, in certain stones and strata which some naturalists have examined with that view. But, though many naturalists have looked for them without success, it does not follow that such marks may not be found; it indeed proves that such a task is difficult, and the success of it, to a particular, most precarious; accident, however, may bring about what the greatest industry has not been able to attain. Secondly, there is good reason to believe that this asserted negation is not absolutely true; for I have in my possession what I consider as proof of the contrary; I found it in Wales, and I think it is in what may be considered as primitive mountains;—it is the mark of shells in a stone of that kind.

Thus, I had formed my opinion with regard to this alleged fact, long before I had seen any description either of the Alps or Pyrennean mountains; and now I have no reason to change that opinion. It may indeed be alleged, that the strata of marble or limestone, containing marine bodies found in those mountains, are secondary strata, and not the primitive. To this I can give no reply, as the descriptions given of those strata do not enable me to decide this point.

At the village of Mat, under the Mont Blatten for example, there is a quarry of schistus or black slate, in which are often found the print and the bones of fishes. (Discours sur l'Histoire Naturelle de la Suisse, page 225.). If this may be considered as an alpine or primitive schistus, it would be decisive of the question: But it would require to have it well ascertained that this schistus is truly one of those which are esteemed primitive, or that it is properly connected with them.

But though I cannot find in those interesting descriptions which we now have got, any one which is demonstrative of this truth, that calcareous marine objects are found in the primitive strata, this is not the case with regard to another object equally important in deciding this question, Whether the primitive strata are found containing the marks of organised bodies?

M. de Dellancourt, in his *Observations Minéralogiques*, Journal de Physique Juillet 1786, in describing the mountains of Dauphiné, gives us the following fact with regard to those alpine vertical strata.

"La pierre constituante de la montagne d'Oris est en général le *Kneifs* ou la roche feuilletée mica et quartz à couches plus ou moins ferrées quelquefois le schorl en roche pénétré de stéatite. Les couches varient infiniment quant à leur direction et à leur inclinaisons. Cette montagne est cultivée et riche dans certain cantons, surtout autour du village d'Oris, mais elle est très-escarpée dans beaucoup d'autres. Entre le village d'Oris et celui du Tresnay est une espèce de combe assez creuse formée par la chute des eaux des cimes supérieures des rochers. Cette combe offre beaucoup de schiste dont les couches font ou très-inclinées ou perpendiculaires. Entre ces couches il s'en est trouvé de plus noires que les autres et capable de brûler, mais difficilement. Les habitans ont extrait beaucoup de cette matière terreuse, et lui ont donné le nom de charbon de terre. Ils viennent même à bout de la faire brûler, et de s'en servir l'hiver en la mêlant avec du bois. Ce schiste noir particulier m'a paru exister principalement dans les endroits ou les eaux se sont infiltrées entre les couches perpendiculaires, et y ont entraîné diverse matières, et sur-tout des débris de végétaux que j'ai encore retrouvés à demi-noirs, pulvérulens et comme dans un état charbonneux."

This formation of coal, by the infiltration of water and carrying in of vegetable bodies, certainly cannot be admitted of; consequently, from this description, there would seem to be strata of coal alternated with the alpine schisti. But the formation of mineral coal requires vegetable matter to have been deposited along with those earthy substances, at the bottom of the sea. The production of vegetable bodies, again, requires the constitution of sea and land, and the system of a living world, sustaining plants at least, if not animals.

In this natural history of the alpine schisti, therefore, we have a most interesting fact, an example which is extremely rare. Seldom are calcareous organised bodies found among those alpine strata, but still more rarely, I believe, are the marks of vegetable bodies having contributed in the formation of those masses. But however rare this example, it is equally decisive of the question, Whether the alpine schisti have had a similar origin as the other strata of the globe, in which are found abundance of animal and vegetable bodies, or their relics? and we are authorised to say, that since those perfect alpine strata of Dauphiné have had that origin, all the alpine schisti of the globe have been originally formed in a similar manner. But to put this matter out of doubt:

In this summer 1788, coming from the Isle of Man, Mr Clerk and I travelled through the alpine schistus country of Cumberland and Westmoreland. We found a limestone quarry upon the banks of Windermere, near the Low-wood Inn. I examined this limestone closely, but despaired of finding any vestige of organised body. The strata of limestone seem to graduate into the slate or schistus strata, between which the calcareous are placed. Fortunately, however, I at last found a fragment in which I thought to perceive the works of organised bodies in a sparry state; I told Mr Clerk so, and our landlord Mr Wright, who had accompanied us. I have brought home this specimen, which I have now ground and polished; and now it is most evidently full of fragments of entrochi. Mr Wright then told me he had seen evident impressions of marine objects, as I understood from the description, in the slate of those mountains; and he was to send me specimens so soon as he could procure them.

Here is one specimen which at once overturns all the speculations formed upon that negative proposition. The schistus mountains of Cumberland were, in this respect, as perfect primitive mountains as any upon the earth, before this observation; now they have no claim upon that score, no more than any limestone formed of shells.

When I first announced my belief that such objects in natural history might be found, I little thought to have seen it realised, to such a degree as has now happened in the little circle of my knowledge. In the summer 1791, Professor Playfair was to pass through Cumberland. I begged that he would inquire of Mr Wright, at the Low-wood Inn, for those objects which he was to endeavour to procure for me, and to examine the limestone quarry in which I had found the specimen with entrochi. He went through another part of those primary mountains, and has found examples of this kind in the schisti; concerning which he has written me the following account.

"In a visit which I made to the Lakes of Cumberland in September 1791, in company with the Hon. Francis Charteris, I met with a limestone full of marine objects, though from its position it is certainly to be reckoned among the primary strata. The place where we found this stone was in the district of Lancashire, that is west of Windermere Lake, on the road from Ambleside to the north end of Coniston Lake, and not far from the point when you come in sight of the latter. Just about this spot we happened to meet with one of those people who serve as guides to travellers in those parts, and who told us, among other things, that stones with shells in them were often found not far from where we were then walking. We immediately began to look about for specimens of that kind, and soon met with several; the most remarkable of which was in a rock that rose a little above the surface, about 300 or 400 yards to the right of the road. It was a part of a limestone stratum, nearly vertical, and was full of bivalves with the impressions as strong as in a common secondary limestone. The strata on both sides had the same inclination, and were decidedly primary, consisting of the ordinary micaceous schistus. This however I need not remark to you, who know so well from your own observations that the whole of the country I am now speaking of has every character of a primary one. I, only mention it, that it may not be supposed that the rock in question was some fragment of a secondary stratum that remained, after the rest was washed away, superincumbent on the primary.

"After I had seen this rock, I recollected that you had told me of something of the same kind that you saw in a quarry at Low-wood Inn; and it may be that both belonged to the same stratum or body of strata; for the direction of the strata, as nearly as I could observe, was from S.W. to N.E.; and this also is nearly the bearing of Low-wood from the place where we now were. I send you a specimen, which you can compare with those you brought from the lime quarry at Low-wood."

I have examined this specimen, and find it to be the common schistus of that country, only containing many bivalve shells and fragments of entrochi and madrapore bodies, and mixed with pyrites.

I have already observed that one single example of a shell, or of its print, in a schistus, or in a stone stratified among those vertical or erected masses, suffices to prove the origin of those bodies to have been, what I had maintained them to be, water formed strata erected from the bottom of the sea, like every other consolidated stratum of the earth. But now, I think, I may affirm, that there is not, or rarely, any considerable extent of country of that primary kind, in which some mark of this origin will not be found, upon careful examination; and now I will give my reason for this assertion. I have been examining the south alpine country of Scotland, occasionally, for more than forty years back, and I never could find any mark of an organised body in the schistus of those mountains. It is true that I know of only one place where limestone is found among the strata; this is upon Tweed-side near the Crook. This quarry I had carefully examined long ago, but could find no mark of any organised body in it. I suppose they now are working some other of the vertical strata near those which I had examined; for, in the summer 1792, I received a letter from Sir James Hall, which I shall now transcribe. It is dated at Moffat, June 2. 1792.

"As I was riding yesterday between Noble-house and Crook, on the road to this place, I fell in with a quarry of alpine limestone; it consists of four or five strata, about three feet thick, one of them single, and the rest contiguous; they all stand between the strata of slate and schist that are at the place nearly vertical. In the neighbourhood, a slate quarry is worked of a pure blue slate; several of the strata of slate near the limestone are filled with fragments of limestone scattered about like the fragments of schist in the sandstone in the neighbourhood of the junction on our coast.[25]

[25] This has a reference to very curious observations which we made upon the east coast where these mountains terminate, and which I am to describe in the course of this work.

"Among the masses of limestone lately broken off for use, and having the fractures fresh, I found the forms of cockles quite distinct; and in great abundance.—I send you three pieces of this kind," etc.

It may perhaps be alleged that those mountains of Cumberland and Tweedale are not the primary mountains, but composed of the secondary schistus, which is every where known to contain those objects belonging to a former earth. Naturalists who have not the opportunity of convincing themselves by their proper examination, must judge with regard to that geological fact by the description of others. Now it is most fortunate for natural history, that it has been in this range of mountains that we have discovered those marks of a marine origin; for, I shall afterwards have occasion to give the clearest light into this subject, from observations made in other parts of those same mountains of schist, by which it will be proved that they are the primary strata; and thus no manner of doubt will then remain in the minds of naturalists, who might otherwise suspect that we were deceiving ourselves, by mistaking the secondary for the primitive schistus.

1 have only farther to observe, that those schisti mountains of Wales, of Cumberland, and of the south alpine part of Scotland, where these marine objects have been found, consist, of that species of stone which in some places makes the most admirable slate for covering houses; and, in other parts, it breaks into blocks that so much resemble wood in appearance, that, without narrow inspection, it might pass for petrified wood.

We are therefore to conclude that the marks of organised bodies in those primary mountains are certainly found; at the same time the general observation of naturalists has some foundation, so far as the marks of organised bodies are both rarely to be met with in those masses, and not easily distinguished as such when they are found.

But this scarcity of marine objects is not confined to those primary mountains, as they are called; for among the most horizontal strata, or those of the latest production, there are many in which, it is commonly thought, no marine calcareous objects are to be found; and this is a subject that deserves to be more particularly considered, as the theory may thus receive some illustration.

Sandstone, coal, and their accompanying strata, are thought to be destitute of calcareous marine productions, although many vestiges of plants or vegetable productions are there perceived. But this general opinion is neither accurate nor true; for though it be true that in the coal and sandstone strata it is most common to find marks of vegetable production, and rarely those calcareous bodies which are so frequent in the limestone, yet it is not unusual for coal to be accompanied with limestone formed of shells and corals, and also with ironstone containing many of those marine objects as well as wood. Besides, sandstone frequently contains objects which have been organised bodies, but which do not belong to the vegetable kingdom, at least to no plant which grows upon the land, but would seem to have been some species of zoophite perhaps unknown.

I have also frequently seen the vestige of shells in sandstone, although in these strata the calcareous bodies are in general not perceived. The reason of this is evident. When there is a small proportion of the calcareous matter in the mass of sand which is pervious to steam and to the percolation of water, the calcareous bodies may be easily dissolved, and either carried away or dispersed in the mass; or even without being thus dispersed by means of solution, the calcareous matter may be absorbed by the siliceous substance of the stratum by means of fusion, or by heat and cementation. The fact is, that I have seen in sandstone the empty mould of marine shells with some siliceous crystallization, so far as I remember, which corresponded perfectly with that idea. The place I saw this was in a fine white sandstone accompanying the coal, upon the sea side at Brora in Sutherland.

Mineralogy is much indebted to Mr Pallas for the valuable observations which he has given of countries so distant from the habitations of learned men. The physiology of the globe has also been enriched with some interesting observations from the labours of this learned traveller. But besides giving us facts, Mr Pallas has also reasoned upon the subject, and thus entered deep into the science of Cosmogeny; here it is that I am afraid he has introduced some confusion into the natural history of the earth, in not properly distinguishing the mineral operations of the globe, and those again which belong entirely to the surface of the earth; perhaps also in confounding the natural effects of water upon the surface of the earth, with those convulsions of the sea which may be properly considered as the accidental operations of the globe. This subject being strictly connected with the opinions of that philosopher with regard to primitive mountains, I am obliged to examine in this place matters which otherwise might have come more properly to be considered in another.

M. Pallas in his *Observations sur la formation des montagnes*, (page 48) makes the following observations.

"J'ai déjà dit que *la bande de montagnes primitives schisteuses* hétérogènes, qui, par toute la terre, accompagne les chaines granitiques, et comprend les roches quartzeuses et talceuses mixtes, trapézoïdes, serpentines, le schiste corne, les roches spathiques et cornées, les grais purs, le porphyre et le jaspre, tous rocs fêlés en couches, ou presque perpendiculaires, ou du moins très-rapidement inclinées, (les plus favorables à la filtration des eaux), semble aussi-bien que le granit, antérieure à la création organisée. Une raison très-forte pour appuyer cette supposition, c'est que la plupart de ces roches, quoique lamelleuse en façon d'ardoise, n'a jamais produit aux curieux la moindre trace de pétrifactions ou empreintes de corps organisés. S'il s'en est trouvé, c'est apparemment dans des fentes de ces roches où ces corps ont été apportés par un deluge, et encastrées apres dans une matière infiltrée, de même qu'on a trouvé des restes d'Eléphans dans le filon de la mine d'argent du Schlangenberg.[26] Les caractères par lesquels plusieurs de ces roches semblent avoir souffert des effets d'un feu-très-violent, les puissantes veines et amas des minéraux les plus riches qui se trouvent principalement dans la bande qui en est composée, leur position immédiate sur le granit, et même le passage, par lequel on voit souvent en grand,

[26] This is a very natural way of reasoning when a philosopher finds a fact, related by some naturalists, that does not correspond with his theory or systematic view of things. Here our author follows the general opinion in concluding that no organised body should be found in their primitive strata; when, therefore, such an object is said to have been observed, it is supposed that there may have been some mistake with regard to the case, and that all the circumstances may not have been considered. This caution with regard to the inaccurate representation of facts, in natural history, is certainly extremely necessary; the relicts of an elephant found in a mineral vein, is certainly a fact of that kind, which should not be given as an example in geology without the most accurate scientifical examination of the subject.

changer le granit en une des autres espèces; tout cela indique une origine bien plus ancienne, et des causes bien différentes de celles qui ont produit les montagnes secondaires."

Here M. Pallas gives his reason for supposing those mountains primitive or anterior to the operations of this globe as a living world; *first*, because they have not, in general, marks of animals or plants; and that it is doubtful if they ever properly contain those marks of organised bodies; *secondly*, because many of those rocks have the appearance of having suffered the effects of the most violent fire. Now, What are those effects? Is it in their having been brought into a fluid state of fusion. In that case, no doubt, they may have been much changed from the original state of their formation; but this is a very good reason why, in this changed state, the marks of organised bodies, which may have been in their original constitution, should be now effaced.

The *third* reason for supposing those mountains primitive, is taken from the metallic veins, which are found so plentifully in these masses. Now, had these masses been the only bodies in this earth in which those mineral veins were found, there might be some species of reason for drawing the conclusion, which is here formed by our philosopher. But nothing is so common (at least in England) as mineral veins in the strata of the latest formation, and in those which are principally formed of marine productions; consequently so far from serving the purpose for which this argument was employed, the mineral veins in the primitive mountains tend to destroy their originality, by assimilating them in some respect with every other mass of strata or mountain upon the globe.

Lastly, M. Pallas here employs an argument taken from an appearance for which we are particularly indebted to him, and by which the arguments which have been already employed in denying the originality of granite is abundantly confirmed. It has been already alleged, that granite, porphyry, and whinstone, or trap, graduate into each other; but here M. Pallas informs us that he has found the granite not only changed into porphyry, but also into the other alpine compositions. How an argument for the originality of these mountains can be established upon those facts, I am not a little at a loss to conceive.

The general mineralogical view of the Russian dominions, which we have, in this treatise, may now be considered with regard to that distinction made by naturalists, of primitive, secondary, and tertiary mountains, in order to see how far the observations of this well informed naturalist shall be found to confirm the theory of the earth which has been already given, or not.

The Oural mountains form a very long chain, which makes the natural division betwixt Europe and Asia, to the north of the Caspian. If in this ridge, as a centre of elevation, and of mineral operations, we shall find the greatest manifestation of the violent exertion of subterraneous fire, or of consolidating and elevating operations; and if we shall perceive a regular appearance of diminution in the violence or magnitude of those operations, as the places gradually recede from this centre of active force; we may find some explanation of those appearances, without having recourse to conjectures which carry no scientific meaning, and which are more calculated to confound our acquired knowledge, than to form any valuable distinction of things. Let us consult M. Pallas how far this is the case, or not.

After having told us that all those various alpine schisti, jaspers, porphyries, serpentines, etc. in those mountains, are found mutually convertible with granite, or graduating into each other, our author thus continues, (p. 50).

"On entrevoit de certaines loix à l'égard de l'arrangement respectif de cet ordre secondaire d'anciennes roches, par tous les systèmes de montagnes qui appartiennent à l'Empire Russe. La chaîne Ouralique, par exemple, a du côté de l'Orient sur tout sa longueur, une très-grande abondance de schistes cornés, serpentins et talceux, riches en filons de cuivre, qui forment le principal accompagnement du granite, et en jaspres de diverses couleurs plus extérieurs et souvent comme entrelacés avec les premiers, mais formant des suites de montagnes entières, et occupant de très-grands espaces. De ce même côté, il y paraît beaucoup de quartz en grandes roches toutes pures, tant dans la principale chaîne que dans le noyau des montagnes de jaspre, et jusques dans la plaine. Les marbres spateux et veinés, percent en beaucoup d'endroits. La plupart de ces espèces ne paraissent point du tout à la lisière occidentale de la chaîne, qui n'est presque que de roche mélangée de schistes argileux, alumineux, phlogistique, etc. Les filons des mines d'or mêlées, les riches mines de cuivre en veines et chambrées, les mines de fer et d'aimant par amas et montagnes entières, sont l'apanage de la bande schisteuse orientale; tandis que l'occidentale n'a pour elle que des mines de fer de dépôts, et se montre généralement très-pauvre en métaux. Le granit de la chaîne qui borde la Sibérie, est recouvert du côté que nous connaissons de roches cornées de la nature des pierres à fusil, quelquefois tendant à la nature d'un grais fin et de schistes très-métallières de différente composition. Le jaspre n'y est qu'en filons, ou plans obliques, ce qui est très-rare pour la chaîne Ouralique, et s'observe dans la plus grande partie de la Sibérie, à l'exception de cette partie de sa chaîne qui passe près de la mer d'Okhotsk, ou le jaspre forme derechef des suites de montagnes, ainsi que nous venons de le dire des monts Ourals; mais comme cette roche tient ici le côté méridionale de la chaîne Sibérienne, et que nous ne lui connaissons point ce côté sur le reste de sa longueur, il se pourrait que le jaspre y fût aussi abondant. Il faudrait, au reste, bien plus de fouilles et d observations pour établir quelque chose de certain sur l'ordre respectif qu'observent ces roches."

I would now ask, if in all this account of the gradation of rock from the Oural mountains to the sandy coast of the Baltic, there is to be observed any clear and distinctive mark of primitive, secondary, and tertiary, mountains, farther than as one stratum may be considered as either prior or posterior to another stratum, according to the order of superposition in which they are found. We have every where evident marks of the formation of strata by materials deposited originally in water; for the most part, there is sufficient proof that this water in which those materials had been deposited was the sea; we are likewise assured that the operations of this living world producing animals, must have, for a course of time, altogether inconceivably been exerted, in preparing materials for this mass; and, lastly, from the changed constitution of those masses, we may infer certain mineral operations that melt the substance and alter the position of those horizontal bodies. Such is the information which we may collect from this mineral description of the Russian Dominions.

If we compare some of the Oural mountains with the general strata of the Russian plains, then, as to the contained minerals, we may find a certain diversity in those two places; at the same time, no greater perhaps than may be found betwixt two different bodies in those same plains, for example, chalk and flint. But when we consider those bodies of the earth, or solid strata of the globe, in relation to their proper structure and formation, we surely can find in this description nothing on which may be founded any solid opinion with regard to a different original, however important conclusions may perhaps be formed with regard to the operations of the globe, from the peculiar appearances found in alpine.

From this detail of what is found in the Oural mountains, and in the gradation of country from those mountains to the plains of Russia, we have several facts that are worthy of observation. First extensive mountains of jasper. I have a specimen of this stone; it is striped red and green like some of our marly strata. It has evidently been formed of such argillaceous and siliceous materials, not only indurated, so as to lose its character, as an argillaceous stone, but to have been brought into that degree of fusion which produces perfect solidity. Of the same kind are those hornstein rocks of the nature of flint, sometimes tending to the nature of a fine sandstone. Here is the same induration of sandstone by means of fusion, that in the argillaceous strata has produced jasper. But oblique veins of jasper are represented as traversing these last strata; now this is a fact which is not conceivable in any other way, than by the injection or transfusion of the fluid jasper among those masses of indurated strata.

All this belongs to the east side of the mountains. On the west, again, we find the same species of strata; only these are not changed to such a degree as to lose their original character or construction, and thus to be termed differently in mineralogy.

Our author then proceeds. (p. 53.)

"Nous pourrons parler plus décisivement sur les *montagnes secondaires et tertiaires* de l'Empire, et c'est de celles-là, de la nature, de l'arrangement et du contenu de leurs couches, des grandes inégalités et de la forme du continent d'Europe et d'Asie, que l'on peut tirer avec plus de confiance quelques lumières sur les changemens arrivés aux terres habitables. Ces deux ordres de montagnes présentent la chronique de notre globe la plus ancienne, la moins sujette aux falsifications, et en même-tems plus lisible que le caractère des chaînes primitives; ce font les archives de la nature, antérieures aux lettres et aux traditions les plus reculées, qu'il étoit réservé à notre siècle observateur de feuiller, de commenter, et de mettre au jour, mais que plusieurs siècles après le nôtre n'épuiseront pas.

"Dans toute l'étendue de vastes dominations Russes, aussi bien que dans l'Europe entière, les observateurs attentifs ont remarqué que généralement la band schisteuse des grandes chaînes se trouve immédiatement recouverte ou cottée par la *bande calcaire*. Celle-ci forme deux ordres de montagnes, très-différentes par la hauteur, la situation de leurs couches, et la composition de la pierre calcaire qui les compose; différence qui est très-évidente dans cette bande calcaire qui forme la lisière occidentale de toute la chaîne Ouralique, et dont le plan s'étend par tout le plat pays de la Russie. L'on observerait la même chose à l'orient de la chaîne, et dans toute l'étendue de la Sibérie, si les couches calcaires horizontales n'y étaient recouvertes par les dépôts postérieures, de façon qu'il ne paraît à la surface que les parties les plus faillantes de la bande, et si ce pays n'étoit trop nouvellement cultivé et trop peu exploité par des fouilles et autres opérations, que des hommes industrieux ont pratiqué dans les pays anciennement habités. Ce que je vais exposer sur les deux ordres de montagnes calcaires, se rapportera donc principalement à celles qui sont à l'occident de la chaîne Ouralique.

"Ce côté de la dite chaîne consiste sur cinquante à cent verstes de largeur, de roche calcaire solide, d'un grain uni, qui tantôt ne contient aucune trace de productions marines, tantôt n'en conserve que des empreintes aussi légères qu'éparses. Cette roche s'élève en montagnes d'une hauteur très-considérable, irrégulières, rapides, et coupées de vallons escarpés. Ses couches, généralement épaisses, ne sont point de niveau, mais très-inclinées à l'horizon, paralleles, pour la plupart, à la direction de la chaîne, qui est aussi ordinairement celle de la bande schisteuse;—au lieu que du côté de l'orient les couches calcaires sont au sens de la chaîne en direction plus ou moins approchante de l'angle droite. L'on trouve dans ces hautes montagnes calcaires de fréquentes grottes et cavernes très-remarquables, tant par leur grandeur que par les belles congélations et crystallizations stalactiques dont elles s'ornent. Quelques-unes de ces grottes ne peuvent être attribuées qu'à quelque bouleversement des couches; d'autres semblent devoir leur origine à l'écoulement des sources souterraines qui ont amolli, rongé et charrié une partie de la roche qui en étoit susceptible.

"En s'éloignant de la chaîne, on voit les couches calcaires s'aplanir assez rapidement, prendre une position horizontale, et devenir abondantes en toute forte de coquillages, de madrépores, et d'autres dépouilles marines. Telles on les voit par-tout dans les vallées les plus basses qui se trouvent aux pieds des montagnes (comme aux environs de la rivière d'Oufal; telles aussi, elles occupent tout l'étendue de la grande Russie, tant en collines qu'en plat pays; solides tantôt et comme semées de productions marines; tantôt toutes composées de coquilles et madrépores brisées, et de ce gravier calcaire qui se trouve toujours sur les parages ou la mer abonde en pareilles productions; tantôt, enfin, dissoutes en craie et en marines, et souvent entremêlées de couches de gravier et de cailloux roulés."

How valuable for science to have naturalists who can distinguish properly what they see, and describe intelligibly that which they distinguish. In this description of the strata, from the chain of mountains here considered as primitive, to the plains of Russia, which are supposed to be of a tertiary formation, our naturalist presents us with another species of strata, which he has distinguished, on the one hand, in relation to the mountains at present in question, and on the other, with regard to the strata in the plains, concerning which there is at present no question at all. Now, let us see how these three things are so connected in their nature, as to form properly the contiguous links of the same chain.

The primary and tertiary masses are bodies perfectly disconnected; and, without a medium by which they might be approached, they would be considered as things differing in all respects, consequently as having their origins of as opposite a nature as are their appearances. But the nature and formation of those bodies are not left in this obscurity; for, the secondary masses, which are interposed, participate so precisely of what is truly opposite and characteristic in the primary and tertiary masses, that it requires nothing more than to see this distinction of things in its true light, to be persuaded, that in those three different things we may perceive a certain gradation, which here takes place among the works of nature, and forms three steps distinguishable by a naturalist, although in reality nothing but the variable measure of similar operations.

We are now to assimilate the primary and tertiary masses, which are so extremely different, by means of the secondary masses, which is the mean. The primary and tertiary differ in the following respects: The one of these contains the relicts of organised bodies which are not observed in the other. But in the species containing these distinguishable bodies, the natural structure and position of the mass is little affected, or not so much as to be called into doubt. This, however, is not the case with the other; the species in which organised bodies do not appear, is in general so indurated or consolidated in its structure, and changed in its position, that this common origin of those masses is by good naturalists, who have also carefully examined them, actually denied. Now, the secondary masses may be considered, not only as intermediate with respect to its actual place, as M. Pallas has represented it, but as uniting together the primary and tertiary, or as participating of the distinguishing characters of the other two. It is homologated with the primitive mountains, in the solidity of its substance and in the position of its strata; with the tertiary species, again, in its containing marks of organised bodies. How far this view of things is consistent with the theory of the earth now given, is submitted to the consideration of the unprejudiced.

Let us see what our learned author has said farther on this subject, (page 65).

"Je dois parler d'un ordre de montagnes très-certainement postérieur aux couches marines, puisque celles-ci, généralement lui servent de base. On n'a point jusqu'ici observé une suite de ces *montagnes tertiaires*, effet des catastrophes les plus modernes de notre globe, si marquée et si puissante, que celle qui accompagne la chaine Ouralique ou côté occidentale fur tout la longueur. Cette suite de montagnes, pour la plupart composées de grais, de marnes rougeâtres, entremêlées de couches diversement mixtes, forme une chaîne par-tout séparée par une vallée plus ou moins large de la bande de roche calcaire, dont nous avons parlé. Sillonnée et entrecoupée de fréquens vallons, elles s'élève souvent à plus de cent toises perpendiculaires, se répand vers les plaines de la Russie en traînées de collines, qui séparent les rivières, en accompagnant généralement la rive boréale ou occidentale, et dégénère enfin en déserts sableux qui occupent de grands espaces, et s'étendent surtout par longues bandes parallèles aux principales traces qui suivent les cours des rivieres. La principale force de ces montagnes tertiaires est plus près de la chaîne primitive par-tout le gouvernement d'Orenbourg et la Permie, ou elle consiste principalement en grais, et contient un fond inépuisable de mines de cuivre sableuses, argileuses, et autres qui se voient ordinairement dans les couches horizontales. Plus loin, vers la plaine, sont des suites de collines toutes marneuses, qui abondent autant en pierres gypseuses, que les autres en minerais cuivreux. Je n'entre pas dans le détail de celles-ci, qui indiquent sur-tout les sources salines; mais je dois dire des premières, qui abondent le plus et dont les plus hautes élévations des plaines, même celle de Moscou, sont formées, qu'elles contiennent très-peu de traces de productions marines, et jamais des amas entiers de ces corps, tels qu'une mer reposée pendant des siècles de suite a pu les accumuler dans les bancs calcaires. Rien, au contraire, de plus abondant dans ces montagnes de grais stratifié sur l'ancien plan calcaire, que des troncs d'arbres entières et des fragmens de bois pétrifié, souvent minéralisé par le cuivre ou le fer; des impressions de troncs de palmires, de tiges de plantes, de roseau, et de quelques fruits étrangers; enfin des ossemens d'animaux terrestres, si rares dans les couches calcaires. Les bois pétrifiés se trouvent jusques dans les collines de sable de la plaine; l'on en tire, entr'autres, des hauteurs sablonneuses aux environs de Sysran sur la Volga, changés en queux très-fin, qui a conservé jusqu'à la texture organique du bois, et remarquables sur-tout par les traces très-évidentes de ces vers rongeurs qui attaquent les vaisseaux, les pilotis et autres bois trempés dans la mer, et qui sont proprement originaires de la mer des Indes."

This philosopher has now given us a view of what, according to the present fashion of mineral philosophy, he has termed *montagnes primitives, secondaires, et tertiaires*. The first consists in masses and strata, much indurated and consolidated, and greatly displaced in their position; but the character of which is chiefly taken from this, that they contain not any visible mark of animal or vegetable bodies.

The second are formed in a great measure of marine productions, are often no less consolidated than those of the first class, and frequently no less changed in their natural shape and situation.

The third again have for character, according to this learned theorist, the containing of those organised bodies which are proper to the earth, instead of those which in the second class had belonged to the sea; in other respects, surely there is no essential difference. It is not pretended that these tertiary strata had any other origin, than that of having been deposited in water; it is not so much as suspected, that this water had been any other than that of the sea; the few marine bodies which M. Pallas here acknowledges, goes at least to prove this fact: and with regard to the mineral operations which had been employed in consolidating those water formed strata, it is impossible not to be convinced that every effect visible in the other two are here also to be perceived.

From this view of mineral bodies, taken from the extensive observations of the Russian dominions, and from the suppositions of geologists in relation to those appearances, we should be led to conclude that the globe of this earth had been originally nothing but an ocean, a world containing neither plant nor animal to live, to grow and propagate its species. In following a system founded on those appearances, we must next suppose, that to the sterile unorganised world there had succeeded an ocean stored with fish of every species. Here it would be proper to inquire what sustained those aquatic animals; for, in such a system as this, there is no provision made for continuing the life even of the individuals, far less of feeding the species while, in an almost infinite succession of individuals, they should form a continent of land almost composed of their *exuviae*.

If fish can be fed upon water and stone; if siliceous bodies can, by the digesting powers of animals, be converted into argillaceous and calcareous earths; and if inflammable matter can be prepared without the intervention of vegetable bodies, we might erect a system in which this should be the natural order of things. But to form a system in direct opposition to every order of nature that we know, merely because we may suppose another order of things different from the laws of nature which we observe, would be as inconsistent with the rules of reasoning in science, by which the speculations of philosophy are directed, as it would be contrary to common sense, by which the affairs of mankind are conducted.

Still, however, to pursue our visionary system, after a continent had been formed from the relicts of those animals, living, growing, and propagating, during an indefinite series of ages, plants at last are formed; and, what is no less wonderful, those animals which had formed the earth then disappear; but, in compensation, we are to suppose, I presume, that terrestrial animals began. Let us now reason from those facts, without either constraining nature, which we know, or forming visionary systems, with regard to things which are unknown. It would appear, that at one period of time, or in one place, the matter of the globe may be deposited, in strata, without containing any organised bodies; at another time, or in another place, much animal matter may be deposited in strata, without any vegetable substance there appearing; but at another period, or at another time, strata may be formed with much vegetable matter, while there is hardly to be observed any animal body. What then are we to conclude upon the whole? That nature, forming strata, is subject to vicissitudes; and that it is not always the same regular operation with respect to the materials, although always forming strata upon the same principles. Consequently, upon the same spot in the sea, different materials may be accumulated at different periods of time, and, conversely, the same or similar materials may be collected in different places at the same time. Nothing more follows strictly from the facts on which we now are reasoning; and this is a conclusion which will be verified by every appearance, so far as I know.

Of this I am certain, that in a very little space of this country, in many places, such a course of things is to be perceived. Nothing so common as to find alternated, over and over again, beds of sand-stone without animal bodies, beds of coal and schistus abounding with vegetable bodies, beds of lime-stone formed of shells and corals, and beds or particular strata of iron-stone containing sometimes vegetable sometimes animal bodies, or both. Here, indeed, the strata are most commonly inclined; it is seldom they are horizontal; consequently, as across the whole country, all the strata come up to the day, and may be seen in the beds of our rivers, we have an opportunity of observing that great variety which is in nature, and which we are not able to explain. This only is certain, from what we see, that there is nothing formed in one epoch of nature, but what has been repeated in another, however dissimilar may be the operations which had intervened between those several epochs.

It must not be alleged, that the heights of the Oural mountains, or the hardness of their rocks, make an essential distinction between them and the argillaceous or arenaceous strata of the plains; solidity and hardness, as well as changes in their height and natural position, has been superinduced in operations posterior to the collection of those masses,—operations which may be formed in various degrees, even in the different parts of the same mass. If this is the case, there can be no difficulty in conceiving a stratum, which appears to be argillaceous or marly in the plains, to be found jasper in the Oural mountains. But there is nothing in the Oural mountains, that may not be found some where or other in the plains, although the soft and easily decomposing argillaceous strata be not found upon the Oural mountains, or the Alps, for this reason, that had those mountains been formed of such materials, there had not been a mountain there at this day.

But surely the greatest possible error, with regard to the philosophy of this earth, would be to confound the sediment of a river with the strata of the globe; bodies deposited upon the surface of the earth, with those sunk at the bottom of the sea; and things which only form the travelled or transported soil, with those which constitute the substratum or the solid earth. How far M. Pallas has committed this oversight, I leave others to determine. After mentioning those strata in which wood is found petrified, and metallic minerals formed, he thus proceeds, (page 69).

"Dans ces mêmes dépôts sableux et souvent limoneux, gisent les restes des grands animaux de l'Inde: ces ossemens d'éléphans, de rhinocéros, de buffles monstrueux, dont on déterre tous les jours un si grand nombre, et qui font l'admiration des curieux. En Sibérie, où l'on à découvert le long de presque toutes les rivières ces restes d'animaux étrangers, et l'ivoire même bien conservé en si grande abondance, qu'il forme un article de commerce, en Sibérie, dis je, c'est aussi la couche la plus moderne de limon sablonneux qui leur sert de sépulture, et nulle part ces monumens étrangers sont si frequens, qu'aux endroits où la grande chaine, qui domine surtout la frontière méridionale de la Sibérie, offre quelque dépression, quelque ouverture considérable.

"Ces grands ossemens, tantôt épars tantôt entassés par squelettes, et même par hécatombes, considérée dans leurs sites naturels, m'ont sur-tout convaincu de la réalité d'un déluge arrivé sur notre terre, d'une catastrophe, dont j'avoue n'avoir pu concevoir la vraisemblance avant d'avoir parcouru ces places, et vu, par moi-même, tout ce qui peut y servir de preuve à cet évènement mémorable [27]. Une infinité de ces ossemens couchés dans des lits mêlés de petites tellines calcinées, d'os de poissons, de glossopètres, de bois chargés d'ocre, etc. prouve déjà qu'ils ont été transportés par des inondations. Mais la carcasse d'un rhinocéros, trouvé avec sa peau entière, des restes de tendons, de ligamens, et de cartilages, dans les terres glacées des bords du Viloûi, dont j'ai déposé les parties les mieux conservées au cabinet de l'Académie, forme encore une preuve convaincante que ce devait être un mouvement d'inondation des plus violens et des plus rapides, qui entraîna jadis ces cadavres vers nos climats glacés, avant que la corruption eût le tems, d'en détruire les parties molles. Il seroit à souhaiter qu'un observateur parvint aux montagnes qui occupent l'espace entre les fleuves Indighirka et Koylma où selon le rapport des chasseurs, de semblables carcasses d'éléphans et d'autres animaux gigantesques encore revêtues de leurs peaux, ont été remarquées à plusieurs reprises."

The question here turns upon this, Are the sea shells and glossopetrae, which are thus found deposited along with those skeletons, in their natural state, or are they petrified and mineralised. If the productions of the sea shall here be found collected along with bodies belonging to the surface of the earth, and which had never been within the limits of the sea, this would surely announce to us some strange catastrophe, of which it would be difficult, perhaps, to form a notion; if, on the contrary, those marine productions belong to the solid strata of the earth, in the resolution or decay of which they had been set at liberty, and were transported in the floods, our author would have no reason from those appearances to

[27] Voyez le Mémoire, imprimé dans le XVII. volume des nouveaux Commentaires de l'Académie Imperiale de Petersbourgh.

conclude, there had existed any other deluge than those produced by the waters of the land[28].

Having thus endeavoured to remove this prevailing prejudice, of there being primitive parts in this earth, parts of which the composition and constitution are not to be explained upon the principles of natural philosophy, it will be proper to inquire, how far there may be in the theory, which has now been given, principles by which may be explained those appearances that have led natural philosophers to form conclusions, of there being in this earth parts whose origin may not be traced; and of there being parts whose origin may not be explained upon the same principles which apply so well to all the rest.

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[28] Since writing this, I find my doubts in a great measure resolved, in reading M. Pallas's Journal, translated from the German by M. Gauthier de la Peyronie. What I had suspected is, I think, confirmed in the distinct account which M. Pallas has given of those occasions in which the bones of land animals and marine objects are found buried together. The marine objects are mineralised; consequently, they have proceeded from the decomposition of the solid strata; and, having been travelled in the running water of the surface of the earth, they must have been deposited in those beds of rivers, which now are dry, alongst with the bones, or the entire bodies of terrestrial animals, the remains of which are now found there. This argument, from the state of those marine bodies will not be allowed, perhaps by the generality of mineralists, who attribute to the operations of water every species of petrifaction or mineralisation; but, until some species of proof be given with regard to the truth of that theory, which vulgar error first suggested, I must reason from a theory, in proof of which I have given clear examples, and, I think, irrefragable arguments, which shall be more and more illustrated. Thus may be removed the necessity of a general deluge, or any great catastrophe, in order to bring together things so foreign to each other; but at the same time we would ascertain this fact, That formerly the Elephant and Rhinoceros had lived in Siberia. (See Voyage de Pallas, Tom. II. p. 377 and 403.)

Chapter 5. Concerning That Which May Be Termed The Primary Part Of The Present Earth

In the present theory, it is maintained, that there is no part of the earth which has not had the same origin, so far as this consists in that earth being collected at the bottom of the sea, and afterwards produced, as land, along with masses of melted substances, by the operation of mineral causes. But, though all those things be similar, or equal, as to the manner of their production, they are far from being so with regard to the periods of their original composition, or to the subsequent operations which they may have undergone.

There is a certain order established for the progress of nature, for the succession of things, and for the circulation of matter upon the surface of this globe; and, the order of time is associated with this change of things. But it is not in equal portions that time is thus combined with dissimilar things, nor always found, in our estimation, as equally accompanying those which we reckon similar. The succession of light and darkness is that which, in those operations, appears to us most steady; the alternation of heat and cold comes next, but not with equal regularity in its periods. The succession of wet and dry upon the surface of the earth, though equally the work of nature and the effect of regular causes, is often to us irregular, when we look for equal periods in the course of things which are unequal. It is by equalities that we find order in things, and we wish to find order every where.

The present object of our contemplation is the alternation of land and water upon the surface of this globe. It is only in knowing this succession of things, that natural appearances can be explained; and it is only from the examination of those appearances, that any certain knowledge of this operation is to be obtained. But how shall we acquire the knowledge of a system calculated for millions, not of years only, nor of the ages of man, but of the races of men, and the successions of empires? There is no question here with regard to the memory of man, of any human record, which continues the memory of man from age to age; we must read the transactions of time past, in the present state of natural bodies; and, for the reading of this character, we have nothing but the laws of nature, established in the science of man by his inductive reasoning.

It has been in reasoning after this manner, that I have endeavoured to prove, that every thing which we now behold, of the solid parts of this earth, had been formerly at the bottom of the sea; and that there is, in the constitution of this globe, a power for interchanging sea and land. If this shall be admitted as a just view of the system of this globe, we may next examine, how far there are to be found any marks of certain parts of our earth having more than once undergone that change of posture, or vicissitude of things, and of having had reiterated operations of the mineral kingdom changing their substance, as well as altering their positions in relation to the atmosphere and sea.

Besides the gradual decay of solid land, exposed to the silent influences of the atmosphere, and to the violent operations of the waters moving upon the surface of the earth, there is a more sudden destruction that may be supposed to happen sometimes to our continents of land. In order to see this, it must be considered, that the continents of our earth are only raised above the level of the sea by the expansion of matter, placed below that land, and rarefied in that place: We may thus consider our land as placed upon pillars, which may break, and thus restore the ancient situation of things when this land had been originally collected at the bottom of the ocean. It is not here inquired by what mechanism this operation is to be performed; it is certainly by the exertion of a subterranean power that the land is elevated from the place in which it had been formed; and nothing is more natural than to suppose the supports of the land in time to fail, or be destroyed in the course of mineral operations which are to us unknown. In that case, whatever were remaining of that land, which had for millions of ages past sustained plants and animals, would again be placed at the bottom of the sea; and strata of every different species might be deposited again upon that mass, which, from an atmospheric situation, is now supposed to be lower than the surface of the sea.

Such a compound mass might be again resuscitated, or restored with the new superincumbent strata, consolidated in their texture and inclined in their position. In that case, the inferior mass must have undergone a double course of mineral changes and displacement; consequently, the effect of subterranean heat or fusion must be more apparent in this mass, and the marks of its original formation more and more obliterated.

If, in examining our land, we shall find a mass of matter which had been evidently formed originally in the ordinary manner of stratification, but which is now extremely distorted in its structure, and displaced in its position,—which is also extremely consolidated in its mass, and variously changed in its composition,—which therefore has the marks of its original or marine composition extremely obliterated, and many subsequent veins of melted mineral matter interjected; we should then reason to suppose that here were masses of matter which, though not different in their origin from those that are gradually deposited at the bottom of the ocean, have been more acted upon by subterranean heat and the expanding power, that is to say, have been changed in a greater degree by the operations of the mineral region. If this conclusion shall be thought reasonable, then here is an explanation of all the peculiar appearances of the alpine schistus masses of our land, those parts which have been erroneously considered as primitive in the constitution of the earth.

We are thus led to suppose, that some parts of our earth may have undergone the vicissitudes of sea and land more than once, having been changed from the summit of a continent to the bottom of the sea, and again erected, with the rest of that bottom, into the place of land. In that case, appearances might be found to induce natural philosophers to conclude that there were in our land primary parts, which had not the marine origin which is generally to be acknowledged in the structure of this earth; and, by finding other masses, of marine origin, superincumbent upon those primary mountains, they might make strange suppositions in order to explain those natural appearances.

Let us now see what has been advanced by those philosophers who, though they term these parts of the earth *primordial*, and not *primitive*, at the same time appear to deny to those parts an origin analogous to that of their secondary mountains, or strata that are aquiform in their construction.

M. de Luc, after having long believed that the strata of the Alps had been formed like those of the low countries, at the bottom of the sea, gives an account of the occasion by which he was first confirmed in the opposite opinion.[29] Like a true philosopher, he gives us the reason of this change.

"Ce fut une espèce de *montagne* très commune, et que j'avois souvent examinée qui dessilla mes yeux. La pierre qui la compose est de la classe appellée *schiste*; son caractère générique est d'être *feuilletée*; elle renferme *l'ardoise* dont on couvre les toits. Ces *feuillets* minces, qu'on peut prendre pour des *couches*, et qui le font en effet dans quelques pierres de ce genre, rappelloient toujours l'idée vague de dépôts des eaux. Mais il y a des masses dont la composition est plutôt par fibres que par feuillets, et dont le moëllon ressemble aux copeaux de bois d'un chantier. Le plus souvent aussi les feuillets sont situés en toute suite de sens dans une même *montagne*, et quelquefois même verticalement, Enfin il s'en trouve de si tortillés, qu'il est impossible de les regarder comme des dépôts de l'eau.

"Ce fut donc cette espèce de montagne qui me persuada la première que toutes les montagnes n'avoient pas une même origine. Le lieu où j'abjurai mon erreur, étoit un de ces grands *chantiers* pétrifiés, qui, par la variété du tortillement, et des zig-zags des fibres du moëllon qui le composoit, attira singulièrement mon attention. C'étoit un sort grand talus qui venoit d'une face escarpée; j'y montai pour m'approcher du rocher, et je remarquai, avec étonnement, des multitudes de paquets enchevêtrés les uns dans les autres, sans ordre ni direction fixe; les uns presqu'en rouleaux; les autres en zig-zag; et même ce qui, séparé de la montagne, eût peu être pris pour des *couches*, le trouvoit incliné de toute manière dans cette même face de rocher. *Non*, me dis-je alors à moi-même; *non, l'eau n'a pu faire cette montagne.... Ni celle-là donc*, ajoutai-je en regardant ailleurs.... *Et pourquoi mieux celle-là? Pourquoi toutes les montagnes devroient-elles être le produit des eaux, seulement parce qu'il y en a quelques-unes qui annoncent cette origine*? En effet, puis qu'on n'a songé aux eaux, comme cause des montagnes, que par les preuves

[29] Lettres Physique et Morales sur l'Histoire de la Terre, tom. 2. pag. 206.

évidentes que quelques-unes offroient de cette formation; pourquoi étendre cette conséquence à toutes, s'il y en a beaucoup qui manquent de ces caractères? C'est comme le dit Mr. d'Alembert, qu'on généralise ses premières remarques l'instant d'apres qu'on ne remarquoit rien."

Science is indebted to this author for giving us so clear a picture of natural appearances, and of his own reasoning upon those facts, in forming his opinion; he thus leads astray no person of sound judgment, although he may be in error. The disposition of things in the present case are such, that, reasoning from his principles, this author could not see the truth; because he had not been persuaded, that aquiform strata could have been so changed by the chemical power of fusion, and the mechanical force of bending while in a certain state of softness.

But though, in this case, the reasoning of this philosopher is to be justified, so far as he proceeded upon principles which could not lead him to the truth, his conduct is not so irreproachable in applying them to cases by which their fallacy might have been detected. This author acknowledges calcareous strata to be aquiform in their original; but, in those mountains which he has so much examined, he will find those aquiform bodies have undergone the same species of changes, which made him conclude that those schistus mountains had not been truly aquiform, as he at first had thought them. This would have led him to reason back upon his principles, and to say, *If one species of strata may be thus changed in its texture, and its shape, may not another be equally so? Therefore, may not the origin of both be similar*?

But least I should do injustice to this author, to whom we are indebted for many valuable observations in natural history, I shall transcribe what he has said upon the subject, being persuaded that my readers will not think this improper in me, or impertinent to the argument.

"Quand nous fumes une fois persuadés que la mer n'avoit pas fait toutes les *montagnes*, nous entreprîmes de découvrir les caractères distinctifs de celles qui lui devoient leur origine; et s'il étoit, par exemple, des matières qui leur fussent propres. Mais nous y trouvâmes les mêmes difficultés qu'on rencontre dans tout ce qu'on veut classer dans la nature. On peut bien distinguer entr'elles les choses qui ont fortement l'empreinte de leur classe; mais les confins échappent toujours.

"C'est là, pour le dire en passant, ce qui a pu conduire quelques philosophes à imaginer cette *chaîne des êtres* où ils supposent, que, de la pierre à l'homme et plus haut, les nuances sont réellement imperceptibles. Comme si, quoique les limites soyent cachées à nos sens, notre intelligence ne nous disoit pas, qu'il y a un *saut*, une distance même infinie, entre le plus petit degré d'organization *propageante*, et la matière unie par la simple cohésion: entre le plus petit degré de *sensibilité*, et la matière insensible: entre la plus petite capacité d'observer et de transmettre ses observations, et l'instinct constamment le même dans l'espèce. Toutes ces différences tranchées existent dans la nature; mais notre incapacité de rien connoître à fond, et la necessité où nous sommes de juger de tout sur des apparences, nous fait perdre presque toutes les limites, parce que sur ces bords, la plupart des phénomènes sont équivoques. Ainsi la plante nous paroît se rapprocher de la pierre, mais n'en approche jamais réellement.

"On éprouve la même difficulté à classer les montagnes; et quoique depuis quelque tems plusieurs naturalistes ayent aussi observé qu'elles n'ont pas toutes la même origine, je ne vois pas qu'on soit parvenu à fixer des caractères infaillibles, pour les placer sûrement toutes dans leurs classes particulières.

"Après avoir examiné attentivement cet objet, d'après les phénomènes que j'ai moi-même observés, et ce que j'ai appris par les observations des autres; j'ai vu que c'étoit là un champ très vaste, quand on vouloit l'embrasser en entier, et trop vaste pour moi, qui n'étois pas libre d'y consacrer tout le tems qu'il exige. Je me suis donc replié sur mon objet principal, savoir *la cause qui a laissé des dépouilles marines dans nos continens*, et l'examen des hypothèses sur cette matière.

"Les phénomènes ainsi limités, se réduisent à ceci: qu'il y a dans nos continens des montagnes visiblement formées par des *dépôts successifs de la mer* et a l'égard des quelles il n'y a besoin de rien imaginer, si ce n'est la manière dont elles en sont sorties: qu'il y en a d'autres au contraire, qui ne portent aucun des caractères de cette cause, et qui, si elles ont été produites dans la *mer*, doivent être l'effet de toute autre cause que de simples dépôts successifs, et avoir même précédé l'existence des animaux marins. J'abandonne donc les classes confuses où ces caractères sont équivoques, jusqu'à ce qu'elles servent à fonder quelque hypothèse; ayant assez de ces deux classes très distinctes pour examiner d'apres elles tous les systèmes qui me sont connus.

"Là où ces deux classes de montagnes sont mêlées, on remarque que celles qui sont formées par *couches*, et qui renferment des *corps marins*, recouvrent souvent celles de l'autre classe, mais n'en sont jamais recouvertes. On a donc naturellement conclu, que lors même que la *mer* auroit en quelque part à la formation des montagnes où l'on ne reconnoît pas son caractère, celles auxquelles elle a travaillé seule, en enlevant des matières dans certaines parties de son fond et les déposant dans d'autres, font au moins les dernières formées. On les a donc nommées *secondaires*, et les autres *primitives*.

"J'adopterai la première de ces expressions; car c'est la même qui nous étoit venu à l'esprit à mon frère, et à moi longtemps avant que nous l'eussions vue employer; mais je substituerai celle de *primordiales à primitives* pour l'autre classe de *montagnes*, afin de ne rien décider sur leur origine. Il est des *montagnes*, dont jusqu'à present on n'a pu démêler la cause: voila le fait. Je ne dirai donc pas qu'elles ont été créées ainsi, parce qu'en physique je ne dois pas employer des expressions sur lesquelles on ne s'entend pas. Sans doute cependant, que l'histoire naturelle ni la physique ne nous conduisent nullement à croire que notre globe ait existé de toute éternité; et lorsqu'il prit naissance, il fallut bien que la matière qui le composa fut de quelque nature, ou sous quelque première forme intégrante. Rien donc jusqu'ici n'empêche d'admettre que ces *montagnes* que je nommerai *primordiales*, ne soient réellement *primitives*; je penche même pour cette opinion à l'égard de quelques unes. Mais il y a une très grande variété entr'elles; et quoiqu'elles soyent toutes également exclues de la classe *secondaire*, elles ne sont pas toutes semblables: il y en a même un grand nombre dont les matières ont une certaine configuration qui semble annoncer qu'elles ayent été molles et durcies ensuite, quoique par une toute autre cause que celle qui a agi pour former les montagnes secondaires."

Here I would beg leave to call the attention of philosophers to this observation of a naturalist who explains all petrification, and the consolidation of strata by aqueous infiltration. If he has here found reason to conclude that, in those primordial parts of the earth, there are a great number which, from their present configuration, must have been in a soft state and then hardened, and this by a quite different cause from that which he supposes had produced the consolidation and hardness of the secondary parts; this is entering precisely into my views of the subject, in ascribing all the consolidation of the earth, whether primary or secondary, to one general cause, and in tracing this cause, from its effects, to be no other than the fusion of those bodies. It must be evident, that if this philosopher has seen good reason for concluding such a softening cause, which had operated upon the primary parts, to be quite different from that which he ascribes to the consolidation of the secondary, which is the effect of water, it must then, I say, be evident that the softening cause of the primary parts, if not heat, by which every degree of fusion may be produced, must be an occult cause, one which cannot be admitted into natural philosophy.

By thus choosing to consider mountains as of two distinct kinds, one aquiform which is understood, and the other primordial which is not to be known, we supersede the necessity of reconciling a theory with many appearances in nature which otherwise might be extremely inconvenient to our explanation, if not inconsistent with our system. Our author no doubt has thus relieved himself from a considerable difficulty in the philosophy of this earth, by saying here is a great part which is not to be explained. But I would beg leave to observe, that this form of discussion, with regard to a physical subject, is but a mere confession of our ignorance, and has no tendency to clear up another part of the subject of which one treats, however it may impress us with a favourable opinion of the theorist, in allowing him all the candour of the acknowledgement.

The general result of the reasoning which we now have quoted, and what follows in his examination, seems to terminate in this; that there are various different compositions of mountains which this author cannot allow to be the production of the sea; but it is not upon account of the matter of which they are formed, or of the particular mixture and composition of those species of matter, of which the variety is almost indefinite. According to this philosopher, the distinction that we are to make of those primordial and secondary competitions, consists in this, that the first are in such a shape and structure as cannot be conceived to be formed by subsidence in water.

M. de Saussure has carefully examined those same objects; and he seems inclined to think that they must have been the operation of the ocean; not in the common manner of depositing strata, but in some other way by crystallization. The present theory supposes all those masses formed originally in the ordinary manner, by the deposits or subsidence of materials transported in the waters, and that those strata were afterwards changed by operations proper to the mineral regions.

But the subject of the present investigation goes farther, by inquiring if, in the operations of the globe, a primary and secondary class of bodies may be distinguished, so far as the one may have undergone the operations of the globe, or the vicissitudes of sea and land, oftener than the other, consequently must be anterior to the later productions both in time and operation, although the original of all those bodies be the same, and the operations of the earth, so far as we see in the effects, always proceed upon the same principles. This is an extensive view of nature to which few have turned their thoughts. But this is a subject to which the observations described by this author have evidently a reference.

In his 113th letter, he has given us a view of one of those parts of the earth that are proper to be examined in determining this question so important in the genealogy of land, although no ways concerned in altering the principles upon which nature in forming continents must proceed.

It is in describing the nature of the mountains about *Elbingerode*; and he begins in ascending from Hefeld.

"Cette partie extérieure de la chaîne est *primordiale*: c'est du *granit* à *Hereld* et au commencement de la route; puis quand on passe dans d'autres vallées, on trouve les *schistes* et la *roche grise* dans tout le pied des montagnes: mais des qu'on est arrivé à une certain hauteur, on voit de la *pierre à chaux* par couches étendue sur ces matières; et c'est elle qui forme le sommet de ces mêmes montagnes; tellement que la plaine élevée, qui conduit à *Elbingerode*, est entièrement de *pierre à chaux*, excepté dans sa partie la plus haute ou cette pierre est recouverte des mêmes *grès* et sables *vitrescibles* qui sont sur le schiste du Bruchberg et sur la *pierre à chaux* dans la *Hesse* et le pays de Gottingue.

"Les environs d'Elbingerode étant plus bas que ces parties recouvertes de matières vitrescibles, montrent la *pierre à chaux* à nud; et l'on y trouve de très beaux marbres, dont les nuances jaunes, rouges et vertes sont souvent très vives, et embellies par les coupes des *corps marins*.

"Cependant le schiste n'est pas enseveli partout sous ces dépôts de la mer; on le retrouve en quelques endroits, et même avec de *filons*.

"Ainsi au milieu de ces matières *calcaires* qui forment le sol montueux des environs *d'Elbingerode*, paroît encore le *schiste* sur lequel elles ont été déposées: Et en montant à la partie la plus élevée de ces mêmes environs, on trouve que la *pierre à chaux* est recouverte elle-même d'une *pierre sableuse* grise par couches, dans laquelle on voit quantité de petits fragmens de *schiste* posés de plat. C'est la que se trouve une des mines de *fer* dont le minerai va en partie à la *Koningshutte*, mais en plus grande partie à la *Rothechutte*, qui n'est qu'à une lieue de distance. On perce d'abord la couche sableuse; sous elle se trouve de la *pierre à chaux* grise; puis une couche de *pierre à chaux ferrugineuse*, remplie de*corps marins*, et surtout *d'entroques*: C'est cette *couche* qui est ici le *minerai*; et elle appartient à la formation de cette éminence comme toutes les autres *couches*. Cette mine se nomme *bomshey*: elle n'est pas riche; mais elle sert de *fondant* aux matières ferrugineuses tirées des filons des montagnes primordiales en même tems qu'elle leur ajoute son *fer*dans la fonte. A quelque distance de là on a percé un autre puits; qui a transversé d'abord une sorte de pierre, que je ne saurois nommer, mais qui ressemble fort à une *lave*poreuse. Au dessous de cette couche on a retrouvé la *pierre à chaux* ordinaire; puis la *couche ferrugineuse* y continue; mais elle diffère un peu de ce qu'elle est dans l'autre mine, une partie de sa substance étant convertie en *jaspe*.

"Mais ce qui est digne de la plus grande attention dans cette contrée, est un filon peu distant nomme *Buchenberg*, qui appartient en partie au Roi, et en partie à Mr. le Comte de*Wernigerode*. La montagne en cette endroit montre une vallée artificielle de 70 à 80 pieds de profondeur, de 20 à 30 de largeur dans le haut, et de 400 toises en étendue. C'est le creusement qu'on a déjà fait en suivant ce *filon* de *fer*, que l'on continue à exploiter de la même manière sur les terres de Mr. le Comte de *Wernigerode*. La matière propre de la montagne *est* de *schiste*; et la vallée qui se forme de nouveau à mesure qu'on enlève la *gangue* du *filon*, a sûrement déjà existé dans la mer sous la forme d'une *fente*, qui a été remplie, et en particulier des ingrédiens dont on fait aujourd'hui le *fer*."

Here is a supposition of our author that corresponds to nothing which has yet been observed any where else, so far as I know. It is concerning a mineral vein, one which does not appear to differ in any respect from other mineral veins, except in being worked in that open manner which has given our author an idea of its being a valley. He then supposes that valley (or rather empty vein) to have been in this mountain when at the bottom of the sea, and that this mineral vein had then been filled with those materials which now are found in that space between the two sides of the separated rock. This is a very different operation from that of infiltration, which is commonly supposed to be the method of filling mineral veins; but, we shall soon see the reason why our author has here deserted the common hypothesis, and has adopted another to serve the occasion, without appearing to have considered how perfectly inconsistent those two suppositions are to each other. That mineral veins have been filled with matter in a fluid state, is acknowledged by every body who has either looked at a mineral vein in the earth, or in a cabinet specimen; mineralists and geologists, in general, suppose this to have been done by means of solutions and concretions, a supposition by no means warranted by appearances, which, on the contrary, in general demonstrate that the materials of those veins had been introduced in the fluid state of fusion. But here is a new idea with regard to the filling of those veins; and, I would now beg the reader's attention to the facts which follow in this interesting description, and which have suggested that idea to our author.

"Quand cette matière accidentelle est enlevée, on voit la coupe du *schiste* des deux côtes de la *fente*, faisant un *toit* et un *mur*, parce que la *fente* n'est pas absolument verticale: des qu'il y a un peu d'inclinaison, on distingue un *toit* et un mur, comme j'ai l'honneur de l'expliquer à V.M. On ne connoît point encore l'étendue de ce filon, ni dans sa profondeur, où l'on ne peut pas s'enfoncer beaucoup de cette manière, ni dans la longueur, selon laquelle on continue à l'exploiter.

"Voilà donc un *filon*, à la rigueur de la définition que j'en ai donné à V.M. c'est à dire, une *fente* dans la montagne naturelle, *comblée* de *matière* étrangère. Mais ce qu'il y a d'extraordinaire ici, c'est que cette *matière* vient de la *mer*: ce sont différentes *couches aquiformes*, dont quelques unes sont remplies de *corps marins*. Il y a des *couches* d'une*terre martiale* fort brune et sans liaison: d'autres, au contraire toujours *martiales*, sont très dures et renferment de très beau jaspe sanguin: d'autres enfin sont de vrai *marbre* gris veinées de rouge. C'est dans ce marbre que font les *corps marins*, savoir des coquillages et des spongites; et il est lui-même martial comme tout le reste: les mineurs le nomment*Kubrimen*, et ne l'employent que comme un *fondant* pour d'autres *minéraux de fer*.

"A ce *filon*, s'en joignent d'autres plus embarrassans. Ils viennent du *toit*, qu'ils divisent par de larges *fentes* comblées, aboutissantes au *filon* principale. Ils font de même *calcaires*et marins faits par *couches*; mais ces *couches* ont une si grande inclinaison, que je ne puis les comprendre: il faut qu'il y ait eu d'étranges bouleversemens dans ces endroits-là[30].

"Ces *fentes* se sont faites, et ont été remplies, dans la *mer*; puisque les matières qui les remplissent sont de la classe de ses dépôts très connoissables, et qu'il contiennent des*dépouilles marines*. Mais ce qui embarrasse alors c'est que les autres *filons* ne soyent pas dans le même cas. N'est ce point là encore un indice, que ces *fentes* out été d'abord et

[30] Here, no doubt, are appearances which it is impossible to explain by the theory of infiltration; it is the filling of mineral veins, and their branches or ramifications, with marble containing marks of marine objects. But, if we shall suppose this marble to have been in the fluid state of fusion, as well as the iron-ore and jasper, we may easily conceive it introduced into the principal vein and its branches. The description here given of those appearances is by no means such as to enable us to judge particularly of this case, which surely merits the most accurate investigation, and which, I doubt not, will give physical demonstration of the fusion of those mineral substances. I know that shells have been found within the body of veins in Germany; but, a stratification of those materials in a vein was never heard of before, so far as I know.

principalement remplies de matières, poussées du fond par la même force qui secouoit les montagnes[31].

"Ce *filon* n'est pas le seul dans le *Hartz* qui donne des signes *marins*. Il y en a un autre, qui même se rapproche davantage de la nature du commun des *filons*, et où l'on trouve aussi des *coquillages*. C'est celui de *Haus-Hartzbergerzug*, pres de *Clausthal*, où, dans les *Halles* de quelques mines de plomb abandonnées, et dans une forte *d'ardoise*, on trouve de petites *moules* ou *tellines* striées, d'une espèce particulière que j'ai vue dans des *ardoises secondaires d'Arotzen* en *Waldek* et de *Sombernon* en *Bourgogne*. Il y a donc certainement quelques *filons* faits par les dépôts de la *mer* dans les *fentes* de montagnes *primordiales*; comme au contraire il y a des *filons* métalliques sans indices *marins*, dans des montagnes évidemment *secondaires*, telles que celles de *Derbyshire*, ou les *filons* de *plomb* traversent des couches de *pierre à chaux*."

Here again our author seems to me to refute his own supposition, That a chasm in the schistus rock may have existed at the bottom of the sea, and been then filled from above with such materials as were transported by the moving water to that place, is not impossible; but nobody, who knows the nature of a common metallic vein, can ever suppose it to have been filled in that manner. Our author then adds, "On ne fait réellement que commencer dans ce genre d'observations, considérées quant à la Cosmologie; ainsi il ne faut point désespérer que tout cela ne se dévoile un jour, et que nous n'acquerrions ainsi un peu plus de connoissance sur ce qui se passoit dans la *mer ancienne*.

"En revenant vers *Elbingerode*, nous retrouvâmes ces *schistes*, qui paroissent au travers des *marbres:* ils sont donc la continuation de la masse *schisteuse* à laquelle appartient le*filon*, dont je viens de parler. Ce *filon* à été formé dans une *fente*, restée ouverte et vide: les dépôts de la *mer* l'ont comblée, en

[31] But what is this power by which matter is to be forced from the bottom of the sea to the top of the mountains? For, unless we can form some idea of that power which, as a cause, we ascribe to the perceived effect, we either say nothing to the purpose, or we employ a preternatural cause. It is not sufficient to imagine a power capable of raising from the bottom of the sea the materials deposited in the abyss; it is also necessary to find a power capable of softening bodies which are hard, and of thus consolidating those masses which are formed of loose or unconnected materials. Such a power, indeed, the present theory assumes; and, so far as this shall be implied in the supposition of our author, it will thus have received a certain conformation.

même tems qu'ils formoient les couches de *marbre*, qui sont à l'extérieur. En effet, ce *filon* contient des *couches marines ferrugineuses*, de la même nature que celles des collines calcaires voisines formées sur le schiste.

"Nous partîmes *d'Elbingerode* dans l'après midi pour nous rapprocher de Clausthal. Notre chemin fut encore quelque tems sur des sommités *calcaires*; et avant que d'en sortir, nous trouvâmes une autre mine singulière à *Arenfeld*. C'est encore un vrai *filon*; mais dans une montagne de *pierre à chaux:* C'est à-dire, que cette montagne a aussi été *fendue*, et que la *fente* a été remplie d'une *gangue*. La matière de ce *filon* est encore *calcaire* en plus grande partie; mais cette *pierre à chaux* distincte est *ferrugineuse*, et parsemée de concrétions de *jaspe* comme celles *d'Elbingerode:* on y trouve aussi une matière verdâtre, qui, comme le *jaspe*, ne fait pas effervescence avec l'eau forte."

Here is a phenomenon which is altogether incompatible with the theory that this author has given us for the explanation of those appearances. He supposes empty crevices in the schistus mountains at the bottom of the sea; these crevices he supposes filled by the deposits of the sea, at the same time, and with the same materials with which the lime-stone strata were formed above the schistus mountains; but we find one of those same veins in these secondary calcareous strata. Now, tho' we should be disposed to allow, that, in the primordial mountain, of which we are supposed not to know the origin, there might have been empty crevices which were afterwards filled with materials transported by the sea, this cannot be admitted as taking place in the loose or incoherent materials deposited above the schistus. Consequently, this theory of our author, which is evidently erroneous with regard to the veins in the lime-stone, must, in the other case, be at least examined with a jealous eye.

"Le haut de cette partie des montagnes *calcaires* étoit encore recouvert de *sable* et de grès *vitrescibles*: et continuant à marcher, sans aucune inflexion sensible, nous nous trouvâmes subitement sur les *schistes*; d'où nous montâmes plus rapidement. Puis traversant quelques petites vallées nous arrivâmes sur les montagnes qui appartiennent au prolongement du *Brocken* ou *Blocksberg*. La matière dominante est alors le *granit*; mais il est tout en blocs le long de cette route, et ces blocs se trouvent à une telle distance de tout sommité intacte de cette pierre, qui est aisé de juger non seulement qu'ils ne sont pas dans leur place originaire, mais encore qu'il ne sont arrivés là par aucune des causes naturelles qui agissent dans les montagnes; savoir, la pesanteur, la pente, et le cours des eaux. Ce sont donc de violentes explosions qui ont dispersé ces blocs; et alors ils deviennent un nouveau trait cosmologique de quelque importance: car rien ne se meut, ni ne paroît s'être mu depuis bien des siècles, dans ces lieux qui montrent tant de désordre: un tapis de verdure couvre tout, en conservant les contours baroques du sol. Le bétail ne sauroit pâturer dans de telles prairies; mais l'industrieux montagnard fait y faucher [32].

"*Oberbruck*, ou nous avions été la précédente fois, se trouva sur notre route, et nous y passames aussi la nuit, dans l'espérance de pouvoir monter le lendemain sur le *Brocken*; mais il fut encore enveloppé de nuages; ainsi nous continuâmes à marcher vers *Clausthal*, passant de nouveau par le *Bruchberg*, où le *sable* et ses gres recouvrent le *schiste*; puis arrivant à une autre sommité, nous y trouvâmes la même pierre *sableuse* par couches, mêlée de parcelles de *schiste*, que nous avions vue sur les montagnes *calcaires d'Elbingerode*. Il est donc toujours plus certain que le sol primordial de toutes ces montagnes existoit sous les eaux de l'ancienne mer; puisqu'il est recouvert de diverses fortes de dépôts, connus pour appartenir à la *mer*; et

[32] M. de Saussure endeavours to explain those appearances of transported blocks of granite by another cause; this is a certain *debacle* of the waters of the earth, which I do not understand. M. de Luc again attempts to explain it by violent explosions; I suppose he means those of a volcano. But he has not given us the evidence upon which such an opinion may be founded, farther than by saying that those blocks could not have come there by the natural operations of the surface. By this must be meant, that, from the nearest summit of granite, there is not, at present, any natural means by which these blocks might be transported to that place. But it is not with the present state of things that we are concerned, in explaining the operations of a distant period. If the natural operations of the surface change the shape of things, as is clearly proved by every natural appearance, Why form an argument against a former transaction, upon the circumstances of the present state of things? Our author does not seem to perceive, that, from this mode of reasoning, there is is an insuperable objection to his violent explosions having been employed in producing those effects. For, had there been such a cause, the evidence of this must have remained; if the surface of the earth does not undergo great changes: If, again, this surface be in time much changed, How can we judge from the present shape, what might have been the former posture of things?

This author, indeed, does not allow much time for the natural operations of the globe to change its surface; but, if things be not greatly removed from the state in which the violent operations of the globe had placed them, Why does he not point out to us the source of this great disorder which he there perceives? From what explosion will be explained the blocks of granite which are found upon the Jura, and which must have come from the mass of *Mont Blanc*? If these dispersed blocks of stone are to be explained by explosion, there must: have been similar explosions in other countries where there is not the smallest appearance of volcanic eruptions; for, around all our granite mountains, and I believe all others, there are found many blocks of granite, travelled at a great distance, and in all directions.

que les *fentes* des *filons* existoient dans cette *mer ancienne*; puisqu'elle en a rempli elle-même quelques unes, et qu'elle a recouvert de ses dépôts quelques autres *filons* tout formés. Quant à celles des matières de ces *filons*, qui ne paroissent pas être *marines* (et c'est de beaucoup la plus grande quantité), j'ai toujours plus de penchant d'en attribuer une partie à l'opération des *feux souterreins*, à mesure que je vois diminuer la probabilité de les assigner entièrement à *l'eau*. Mais quoi-qu'il en soit, ces gangues ne font pas de même date que les montagnes[33].

"Le lendemain de notre arrivée a *Clausthal*, qui étoit le 13e, nous allâmes visiter d'autres mines de *fer* en montagnes secondaires, situées au côté opposé du Hartz. Elles sont auprès de *Grund* l'une des *villes de mines*, et près du lieu ou sortira la nouvelle *galerie d'écoulement* à laquelle on travaille, etc.

"Arrivés à *Grund* les officiers mineurs vinrent, comme à l'ordinaire, accompagner Mons. de *Reden* aux *mines* de leur département. Celles-ci, sans être plus extraordinaires que celles qui nous avions vues à *Elbingerod*, ou sans aider mieux jusqu'ici à expliquer ce qu'elles ont toutes d'extraordinaire, nous donnent au moins des indices probables de grands accidens. Ces montagnes de *Grund* sont encore de l'espèce remarquable, dont la base est de *schiste*, et le haut de *pierre à chaux*. Les mines qu'on y exploit sont de *fer*, et se trouvent dans cette matière *calcaire*; mais elles y sont sous des apparences tout-à-fait étranges. La montagne où nous les vîmes principalement le nomme *Iberg*. On y poursuit des masses de *pierre à fer*, de l'ensemble desquelles les mineurs ne peuvent encore se rendre compte d'une manière claire. Ils ont trouvé dans cette montagne des *cavernes*, qui

[33] I most willingly admit the justness of our author's view, if he thus perceives the operation of fire in the solids of our earth; but it is not for the reasons he has given us for discovering it here more than in other places; for there is not a mineral vein, (so far at least as I have seen), in which the appearances may be explained by any thing else besides the operation of fire or fusion. It is not easy to conceive in what manner our author had conceived the opinions which he has displayed in these letters. He had no opinion of this kind, or rather he was persuaded that subterraneous fire had no hand in the formation of this earth before he came to this place of the Hartz; here he finds certain appearances, by which he is confirmed in his former opinion, that water had operated in forming mineral veins; and then he forms the idea that subterraneous fire may have operated also. But, before the discovery of the chasms in the schistus mountains having been filled with the stratified materials of the sea, How had he supposed veins to be filled? If this philosopher had before no opinion of subterraneous fire, as instrumental in that operation, How comes he now to change that former opinion? For, unless it be the extraordinary manner of filling these open crevices in the mountains by matter deposited immediately from the sea, there is certainly no other appearance in this mineral country of the Hartz, that may not be found in any other, only perhaps upon a smaller scale.

ressemblent à l'encaissement de *filons* déjà exploités, ou non formés; c'est-à-dire, que ce sont des *fentes* presque verticales, et vides, Le *minerai* qu'ils poursuivent est en *Rognons*; c'est à dire, en grandes masses sans continuité décidée. Cependant ces masses semblent se succéder dans la montagne suivant une certaine direction; tellement que les mineurs savent déjà les chercher, par des indices d'habitude. La substance de cette *pierre à fer* particulière renferme des crystallizations de diverses espèces. Il y a des *druses de quartz*, ou de petits cristaux de quartz qui tapissent des cavités; il y a aussi du *spath* commun, et de celui qu'on nomme pesant; on y trouve enfin une forte de crystallization nommée*Eisenman* (*homme de fer*) par les mineurs; se sont des amas de cristaux noir-âtres, qui ressemblent à des groupes de grandes lentilles plattes, et ces cristaux sont *ferrugineux*.

"Entre les signes de bouleversement que renferme ce lieu, est un rocher nommé *Gebichensten*, qui est en *pierre à chaux*, ce que *l'Ebrenbreitstein* de *Coblentz* est en pierre sableuse: c'est-à-dire, que ses *couches*, remplies de *corps marins*, sont presque verticales; ceux de ces corps qu'on y trouve en plus grande quantité, sont des *madrépores*. Ce rocher s'élève comme un grand obélisque, au-dessus des *cavernes*, dont j'ai parlé; montrant par le côté ses *couches*, qui se trouvent, comme je l'ai dit, dans une situation presque verticale. Sa base est déjà bien minée, tant par les *cavernes*, que par la *pierre à fer* qu'on en tire; et je ne me hasardai dessus, que parce que je me dis, qu'il y a des millions contre un à parier, que ce n'est pas le moment où il s'enfoncerait. Mais je n'en dirois pas autant, s'il s'agissoit de m'y loger à demeure.

"Quoique tout ce lieu là soit fort remarquable, il se pourrait que ce ne fut qu'un phénomène particulier. Les *cavernes* peuvent devoir leur origine à la même cause que celle de Schartzfeld; et le dérangement des rochers supérieurs à des enfoncemens occasionnés par ces *cavernes*. Rien n'est si difficile que de retracer aujourd'hui ces fortes d'accidens à cause des changemens que le tems y a opérés. S'ils sont arrivés sous les eaux de la *mer*, on conçoit aisément les altérations qui ont dû succéder; et si c'est depuis que nos continens sont à sec, les eaux encore, tant intérieures qu'extérieures, et la végétation, en ont beaucoup changé l'aspect."

This author has a theory by which he explains to himself the former residence of the sea, above the summits of our mountains; this, however, is not the theory by which we are now endeavouring to explain appearances; we must therefore be allowed to reason from our own principles, in considering the facts here set forth by our author.

Nothing, I think, is more evident, than that in this mineral country of the Hartz, we may find the clearest marks of fracture, elevation, and dislocation of the strata, and of the introduction of foreign matter among those separated bodies. All those appearances, our author would have to be nothing but some particular accident, which is not to enter into the physiology of the earth. I wish again to generalise these facts, by finding them universal in relation to the globe, and necessarily to be found in all the consolidated parts of our land.

It was not to refute our author's reasoning that I have here introduced so much of his observations, but to give an extensive view of the mineral structure of this interesting country. This therefore being done, we now proceed to what is more peculiarly our business in this place, or the immediate subject of investigation, viz. the distinction of primary and secondary strata.

"Dans le voisinage de cette montagne, il y a une autre fort intéressante, que je vis le jour suivant. Quoiqu'en traitant des volcans, j'aie démontré que la formation des montagnes, par soulèvement, étoit sans example dans les faits, et sans fondement dans la théorie, je ne laisseroi pas de m'arrêter au phénomène que présente cette montagne; parce qu'il prouvera directement que les *couches calcaires* au moins, ont été formées *à la hauteur ou elles sont*; c'est-a-dire qu'elles n'ont pas été soulevées.

"Voulant prendre l'occasion de mon retour à *Hanovre*, pour traverser les avant-corps du *Hartz*, dans quelque nouvelle direction; je résolus de faire ce voyage à cheval, et de prendre ma route droite vers *Hanovre*, au-travers des collines; ce qui me conduisit encore à *Grund* puis à *Münchehof Brunshausen, Engelade, Winsenburg* et *Alfeld*, où enfin, traversant la *Leine* j'entrai dans la grande route.

"Je quittai donc *Clausthal* (et avec bien du regret) le 14 au matin; et revenant d'abord à *Grund*, je le laissai sur ma droite, ainsi que *l'Iberg*; et plus loin, du même côté, une autre montagne nommée *Winterberg* dont la base est *schiste*, et le sommet plus haut que Clausthal, entièrement composé de *couches calcaires*. De *Grund* je montai vers une montagne nommée *Ost Kamp*; et je commençai là à donner une attention particulière au sol. Le long de mon chemin, je ne trouvai longtemps que des schistes, qui montroient leurs points en haut, comme à l'ordinaire, et avec tous leurs tortillemens de feuillets. Mais arrivé au haut de la montagne, j'y vis des carrières de *pierre à chaux*, où les couches absolument régulières, et qui ont peu d'épaisseur sur le *schiste* suivent parfaitement les contours du *sommet*. Ces lits de *pierre à chaux* n'ont certainement pas été soulevés du fond de la *mer*sur le dos des schistes; lors même qu'à cause de la grande inclinaison des feuillets de ceux-ci on voudroit le attribuer à quelque révolution telle que le *soulèvement*; (ce que je n'admettrois point). Car si ces lits *calcaires*, ayant été faits au fond de la *mer*, avoyent été soulevés avec les schistes, ne feroient-ils pas brisés et bouleversés comme eux? Il est donc evident, que quoiqu'il soi arrivé au schiste qui les porte, ces lits, et tous les autres de même genre qui sont au haut de ces montagnes, ont été déposées au niveau où ils sont; et que par conséquent la *mer* les surpassoit alors. Ainsi le système de soulèvement perd son but, s'il tend à expliquer pourquoi nous avons des *couches*, formées par la mer, qui se trouvent maintenant si fort au dessus de son niveau. Il est évident que ces *couches* n'ont pas été soulevées; mais que la *mer* s'est *abaissée*. Or c'est là le grand point cosmologique à expliquer: tous les autres, qui tiennent à la structure de certaines montagnes inintelligibles, n'appartiendront qu'à *l'histoire naturelle*, tant qu'ils ne se lieront pas avec celui-la."

Here are two things to be considered; the interesting facts described by our author, and the inference that he would have us draw from those facts. It would appear from the facts, that the body of schistus below, and that of lime-stone above, had not undergone the same disordering operations, or by no means in the same degree. But our author has formed another conclusion; he says, that these lime-stone strata must have been formed precisely in the place and order in which they lie at present; and the reason for this is, because these strata appeared to him to follow perfectly the contour of the summit of this mountain. Now, had there been in the top of this mountain a deep hollow encompassed about with the schistus rock; and had this cavity been now found filled with horizontal strata, there might have been some shadow of reason for supposing those strata to have been deposited upon the top of the mountain. But to suppose, *first*, that shells and corals should be deposited upon the convex summit of a mountain which was then covered by the sea; *secondly*, that these moveable materials should remain upon the summit, while the sea had changed its place; and, *lastly*, that those shells and corals left by the sea upon the top of a mountain should become strata of solid limestone. and have also metallic veins in it, certainly holds of no principle of natural philosophy that I am acquainted with. If, therefore, such an appearance as this were to be employed either in illustration or confirmation of a theory, it would itself require to be explained; but this is a task that this cosmologists does not seem willing to undertake.

He has formed a hypothesis for explaining the general appearance of that which was once the bottom of the sea being now found forming the summits of our mountains; but surely this philosopher will acknowledge, that those natural appearances, in any particular place, will be the same, whether we suppose the bottom of the sea to have been raised, as in the present theory, or the surface of the sea to have sunk according to his hypothesis. For, it is equally easy to suppose a portion of the earth to have been raised all this height, as to suppose all the rest of the surface of the globe to have sunk an equal space, while a small portion of the bottom of the sea, remaining here and there fixed in its place, became the highest portion of the globe. Consequently, whatever evidence this philosopher shall find in support of his theory of the present earth, (a subject which it is not our purpose to examine) it cannot be allowed that he has here brought any argument capable of disproving the elevation of the bottom of the sea; a supposition which other theories may require.

I would now observe, in relation to the present theory, that so far as this author has reasoned justly from natural appearances, his conclusions will be found to confirm the present supposition, that there is to be perceived the distinction of primordial, and that of secondary, in the masses of this earth, without altering the general theory either with respect to the original formation of those masses, or to their posterior production.

Here one of two things must be allowed; either that those strata of schistus had been broken and distorted under a mass of other superincumbent strata; or that those superincumbent strata had been deposited upon the broken and distorted strata at the bottom of the sea. Our author, who has examined the subject, inclines to think, that this last has been the case. If, therefore, strata had been deposited upon broken and bare rocks of schistus, it is probable that these had been sunk in the sea after having been exposed to the atmosphere, and served the purpose of land upon the globe.[34]

An example of the same kind also occurs in the *Discours sur l'Histoire Naturelle de la Suisse*; and this author of the *Tableaux de la Suisse* has given a very distinct description of that appearance, which is perhaps the more to be valued as a piece of natural history, as this intelligent author does not pretend to any geological theory, but simply narrates what he has seen, with such pertinent observations on the subject as naturally must occur to a thinking person on the spot.—(Discours, etc. page 228. Entrée au pays de Grisons).

"Du village d'Elen on continue à monter le reste du petit vallon pendant une lieue et demie parmi les mêmes espèces de pierres qu'on vient de décrire; en passant au travers de bois et de forêts de sapins et de quelques pâturages dont ce haut est couvert, on parvient au pied du Bundnerberg, montagne des grisons, qui forme la tête du vallon. On laisse à droite un fond ou espèce d'entonnoir, entouré de très-hautes montagnes inaccessibles, pour s'enfourrer à gauche entre des rochers qui font fort resserrés, où coule un torrent. Ce lieu seroit horreur si on ne se trouvoit accoutumé, par degrés, à voir de ces positions effrayantes: tout y est aride, il n'y a plus d'arbres ni de végétaux ce sont des rochers entassés les un sur les autres; ce lieu paroit d'autant plus affreux que le passage a été subit, et qu'en sortant de bois et

[34] This is also supported by another very interesting observation contained in this letter. M. de Luc observes, that in this country the schistus is generally covered by strata of lime-stone, and that these lime-stone strata are again covered with those of sand-stone, in which are found a great many fragments of schistus lying flat. Therefore, while those sand-stone strata were collecting at the bottom of the sea, there had been rocks of schistus in some other place, from whence those fragments bad been detached.

des forêts, on se trouve tout-à-coup parmi ces rochers qui s'élèvent comme des murailles, et dont on ne voit pas la cime; cette gorge ou cette entrée qui se nomme Jetz, est la communication du Canton du Glaris aux Gritons; on a dit précédemment qu'il y en avoit une plus aisée par le Gros-Thal ou le grand vallon. Ce passage est très-curieux pour la Lithogeognosie, il est rare de trouver autant de phénomènes intéressans rassemblés, et des substances aussi variées par rapport à leurs positions; c'est le local qui mérite le plus d'être examiné en Suisse, et la plus difficile que nous ayons parcouru. On se souviendra que nous avons continuellement monté depuis Glaris, et que nous nous trouvons au pied de ces montagnes ou de ces pics étonnans qui dominent les hautes Alpes; on trouve ici la facilité peu commune de pouvoir examiner, et voir le pied ou les fondemens de ces colosses qui couronnent le globe, parce qu'ils sont ordinairement entourés de leurs débris et de leurs éboulemens qui en cachent le pied. Ici c'est une roche de schiste bleuâtre, dure et compact, traversée de filons de quartz blanc, et quelquefois jaunâtre, dans laquelle on a taillé un sentier pour pouvoir en franchir le pied. Cette roche s'élève à une hauteur prodigieuse, est presque verticale, et ces couches sont à quatre-vingt degrés d'inclinaison. L'imagination est effrayée de voir que de pareilles masses ayent pu être ébranlées et déplacées au point d'avoir fait presque un quart de conversion. Après avoir monté et suivi cette roche parmi les pierres et les décombres, une heure et demie, on trouve cette roche de schiste surmontée d'autres rochers fort hauts qui sont calcaires, et dont les lits sont fort horizontaux. Les schistes, qui sont directement sous les roches calcaires, conservent la même inclinaison qu'elles ont à leur pied."

Here is an observation which certainly agrees with that given by M. de Luc, and would seem to confirm this conclusion, that strata had been deposited upon those *schisti* after they had been changed from their natural or horizontal position, and become vertical; at the same time, this conclusion is not of necessary consequence, without examining concomitant appearances, and finding particular marks by which this operation might be traced; for the simply finding horizontal strata, placed above vertical or much inclined schiste, is not sufficient, of itself, to constitute that fact, while it is acknowledged that every species of fracture, dislocation, and contortion, is to be found among the displaced strata of the globe.

Since writing this chapter, I am enabled to speak more decisively upon that point, having acquired more light upon the subject, as will appear in the next chapter.

Chapter 6. The Theory Of Interchanging Sea And Land Illustrated By An Investigation Of The Primary And Secondary Strata

Section 1. A Distinct View Of The Primary And Secondary Strata

Having given a view of what seems to be the primary and secondary strata, from the observations of authors, and having given what was my opinion when I first wrote that chapter, I am now to treat of this subject from observations of my own, which I made since forming that opinion.

From Portpatrick, on the west coast, to St Abb's Head, on the east, there is a tract of schistus mountains, in which the strata are generally much inclined, or approaching to the vertical situation; and it is in these inclined strata that geologists allege that there is not to be found any vestige of organised body. This opinion, however, I have now proved to be erroneous.

There cannot be any doubt with regard to the original formation of those stratified bodies, as having been formed of the materials that are natural to this earth, viz. the detritus of former bodies; and as having been deposited in water, like the horizontal strata: For the substances and bodies of which they are visibly composed are no other than those which form the most regular horizontal strata, and which are continually travelling, or transported at the bottom of the sea, such as gravel, and sand, argillaceous and micaceous bodies.

On each side of this ridge of mountains, which towards the east end is but narrow, there is a lower country composed of strata in general more horizontal; and among which strata, besides coal, there are also found the relics of organised bodies.

Abstracting at present from any consideration of organised bodies among the materials of those strata, it may be affirmed, that the materials which form the strata in the mountains and in the low country, are similar, or of the same nature; that they have, in both places, been consolidated by the same means, viz. heat and fusion; and that the same or similar accidents have happened to them, such as change from their original position, and mineral veins traversing them in various shapes. Yet still there is a distinctive character for those two bodies, the alpine and the horizontal strata; for, while the horizontal position appears natural to the one, and the changes from that particular state to be only an accident, the vertical position appears to be more natural to the other, which is seldom found horizontal.

Therefore, altho' it is unquestionable that the strata in the alpine and low countries had the same or a similar original, yet, as the vertical position, which is the greatest possible change in that respect, is more natural to the alpine strata, or only necessary in the natural order of those bodies, we are to consider this great disorder or change from the natural state of their original formation, as the proper character of those alpine strata. But then it is also necessary to include in this character a general hardness and solidity in those vertical strata, otherwise they would not have been properly alpine, or have resisted the wearing and washing powers of the globe, so as to have remained higher than the others; for, the vertical position, or great inclination of those strata, should rather have disposed them the more to dissolution and decay. Let us now see how far we shall be justified in that general conclusion, by the examination of those bodies.

The fact is certain, that those alpine bodies are much harder, or less subject to dissolution and decay, than the horizontal strata. But this must be taken in the general, and will by no means apply to particular cases which might be compared. Nothing, for example, more solid than the lime-stones, or marbles, and iron-stones; nothing more hard or solid than the chirt or flint; and all these are found among the horizontal strata. But, while some strata among those horizontal beds are thus perfectly solid, others are found with so slight degrees of consolidation, that we should not be able to ascribe it to the proper cause, without that gradation of the effect, which leads us to impute the slightest degree of consolidation to the same operations that have produced the complete solidity. While, therefore, the most perfect solidity is found in certain strata, or occasionally among the horizontal bodies, this forms no part of their character in general, or cannot be considered as a distinctive mark, as it truly is with regard to the alpine strata.

These last have a general character of consolidation and indissolubility, which is in a manner universal. We are, therefore, now to inquire into the cause of this distinction, and to form some hypothesis that may be tried by the actual state of things, in being compared with natural appearances.

As the general cause of consolidation among mineral bodies, formed originally of loose materials, has been found to consist in certain degrees of fusion or cementation of those materials by means of heat; and as, in the examination of the horizontal strata we actually find very different degrees of consolidation in the several strata, independent of their positions in relation to height or depth, we have reason to believe that the heat, or consolidating operation, has not been equally employed in relation to them all.

We are not now inquiring how an inferior stratum should have been heated in a lesser degree, or not consolidated, while a superior stratum had been consolidated in the most perfect manner; we are to reason upon a fact, which is, that the horizontal strata in general appear not to have been equally or universally consolidated; and this we must attribute to an insufficient exertion of the consolidating cause. But, so far as the erecting cause is considered as the same with that by which the elevated bodies were consolidated, and so far as the vertical situation is a proof of the great exertion of that subterraneous power, the strata which are most erected, should in general be found most consolidated.

Nothing more certain than that there have been several repeated operations of the mineralising power exerted upon the strata in particular places; and all those mineral operations tend to consolidation: Therefore, the more the operations have been repeated in any place, the more we should find the strata consolidated, or changed from their natural state. Vertical strata have every appearance from whence we should be led to conclude, that much of the mineral power had been exerted upon them, in changing their original constitution or appearance. But the question now to be considered is this, How far it may appear that these masses of matter, which now seem to be so different from the ordinary strata of the globe, had been twice subjected to the mineral operations, in having been first consolidated and erected into the place of land, and afterwards sunk below the bottom of the sea, in order a second time to undergo the process of subterraneous heat, and again be elevated into the place where they now are found.

It must be evident, here is a question that may not be easy to decide. It is not to the degree of any change to which bodies may be subject, that we are to appeal, in order to clear up the point in question, but to a regular course of operations, which must appear to have been successively transacted, and by which the different circumstances or situations of those masses are to be discovered in their present state. Now, though it does not concern the present theory that this question be decided, as it is nothing but a repetition of the same operations that we look for; nevertheless, it would be an interesting fact in the natural history of this earth; and it would add great lustre to a theory by which so great, so many operations were to be explained. I am far from being sanguine in my expectations of giving all the satisfaction in relation to this subject that I could wish; but it will be proper to state what I have lately learned with regard to so curious a question, that others, who shall have the opportunity, may be led to inquire, and that thus the natural history of the earth may be enlarged, by a proper investigation of its mineral operations.

With this view I have often considered our schistus mountains, both in the north and south; but I never found any satisfactory appearance from whence conclusions could be formed, whether for the question or against it. The places I examined were those between the alpine countries and the horizontal strata; here, indeed, I have frequently found a confused mass, formed of the fragments of those alpine strata mixed with the materials of the horizontal bodies; but not having seen the proper shape and connection of those several deposits, I always suspended my judgment with regard to the particular operations which might have been employed in producing those appearances.

I had long looked for the immediate junction of the secondary or low country strata with the alpine schistus, without finding it; the first place in which I observed it was at the north end of the island of Arran, at the mouth of Loch Ranza; it was upon the shore, where the inclined strata appeared bare, being; washed by the sea. It was but a very small part that I could see;

but what appeared was most distinct. Here the schistus and the sandstone strata both rise inclined at an angle of about 45°; but these primary and secondary strata were inclined in almost opposite directions; and thus they met together like the two sides of a *lambda*, or the rigging of a house, being a little in disorder at the angle of their junction. From this situation of those two different masses of strata, it is evidently impossible that either of them could have been formed originally in that position; therefore, I could not here learn in what state the schistus strata had been in when those of the sand-stone, &c, had been superinduced.

Such was the state of my mind, in relation to that subject:, when at Jedburgh upon a visit to a friend, after I had returned from Arran, and wrote the history of that journey; I there considered myself as among the horizontal strata which had first appeared after passing the Tweed, and before arriving at the Tiviot. The strata there, as in Berwickshire, which is their continuation to the east, are remarkably horizontal for Scotland; and they consist of alternated beds of sand-stone and marl, or argillaceous and micaceous strata. These horizontal strata are traversed in places with small veins of whin-stone, as well as greater masses forming rocks and hills of that material; but, except it be these, (of which there are some curious examples), I thought there could be nothing more of an interesting nature to observe. Chance, however, discovered to me what I could not have expected or foreseen.

The river Tweed, below Melrose, discovers in its bed the vertical strata of the schistus mountains, and though here these indurated bodies are not veined with quartz as in many places of the mountains, I did not hesitate to consider them as the same species, that is to say, the marly materials indurated and consolidated in those operations by which they had been so much changed in their place and natural position. Afterwards in travelling south, and seeing the horizontal softer strata, I concluded that I had got out of the alpine country, and supposed that no more of the vertical strata were to be observed.

The river Tiviot has made a wide valley as might have been expected, in running over those horizontal strata of marly or decaying substances; and the banks of this river declining gradually are covered with gravel and soil, and show little of the solid strata of the country. This, however, is not the case with the Jed, which is to the southward of the Tiviot; that river, in many places, runs upon the horizontal strata, and undermines steep banks, which falling shows high and beautiful sections of the regular horizontal strata. The little rivulets also which fall into the Jed have hollowed out deep gullies in the land, and show the uniformity of the horizontal strata.

In this manner I was disposed to look for nothing more than what I had seen among those mineral bodies, when one day, walking in the beautiful valley above the town of Jedburgh, I was surprised with the appearance of vertical strata in the bed of the river, where I was certain that the banks were composed of horizontal strata. I was soon satisfied with regard to this phenomenon, and rejoiced at my good fortune in stumbling upon an object so interesting to the natural history of the earth, and which I had been long looking for in vain.

Here the vertical strata, similar to those that are in the bed of the Tweed, appear; and above those vertical strata, are placed the horizontal beds, which extend along the whole country.

The question which we would wish to have solved is this; if the vertical strata had been broken and erected under the superincumbent horizontal strata; or if, after the vertical strata had been broken and erected, the horizontal strata had been deposited upon the vertical strata, then forming the bottom of the sea. That strata, which are regular and horizontal in one place, should be found bended, broken, or disordered at another, is not uncommon; it is always found more or less in all our horizontal strata. Now, to what length this disordering operation might have been carried, among strata under others, without disturbing the order and continuity of those above, may perhaps be difficult to determine; but here, in this present case, is the greatest disturbance of the under strata, and a very great regularity among those above. Here at least is the most difficult case of this kind to conceive, if we are to suppose that the upper strata had been deposited before those below had been broken and erected.

Let us now suppose that the under strata had been disordered at the bottom of the sea, before the superincumbent bodies were deposited; it is not to be well conceived, that the vertical strata should in that case appear to be cut off abruptly, and present their regular edges immediately under the uniformly deposited substances above. But, in the case now under consideration, there appears the most uniform section of the vertical strata, their ends go up regularly to the horizontal deposited bodies. Now, in whatever state the vertical strata had been in at the time of this event, we can hardly suppose that they could have been so perfectly cut off, without any relict being left to trace that operation. It is much more probable to suppose, that the sea had washed away the relics of the broken and disordered strata, before those that are now superincumbent had been begun to be deposited. But we cannot suppose two such contrary operations in the same place, as that of carrying away the relics of those broken strata, and the depositing of sand and subtile earth in such a regular order. We are therefore led to conclude, that the bottom of the sea, or surface of those erected strata, had been in very different situations at those two periods, when the relics of the disordered strata had been carried away, and when the new materials had been deposited.

If this shall be admitted as a just view of the subject, it will be fair to suppose, that the disordered strata had been raised more or less above the surface of the ocean; that, by the effects of either rivers, winds, or tides, the surface of the vertical strata had been washed bare; and that this surface had been afterwards sunk below the influence of those destructive operations, and thus placed in a situation proper for the opposite effect, the accumulation of matter prepared and put in motion by the destroying causes.

I will not pretend to say that this has all the evidence that should be required, in order to constitute a physical truth, or principle from whence we were to reason farther in our theory; but, as a simple fact, there is more probability for the thing having happened in that manner than in any other; and perhaps this is all that may be attained, though not all that were to be wished on the occasion. Let us now see how far any confirmation may be obtained from the examination of all the attending circumstances in those operations.

I have already mentioned, that I had long observed great masses of *debris*, or an extremely coarse species of pudding-stone, situated on the south as well as north sides of those schistus mountains, where the alpine strata terminate in our view, and where I had been looking for the connection of those with the softer strata of the low country. It has surely been such appearances as these which have often led naturalists to see the formation of secondary and tertiary strata formed by the simple congestion of *debris* from the mountains, and to suppose those masses consolidated by the operation of that very element by which they had been torn off from one place and deposited in another. I never before had data from whence to reason with regard to the natural history of those masses of gravel and sand which always appeared to me in an irregular shape, and not attended with such circumstances as might give light into their natural history; but now I have found what I think sufficient to explain those obscure appearances, and which at the same time will in some respect illustrate or confirm the conjecture which has now been formed with regard to the operations of the globe in those regions.

In describing the vertical and horizontal strata of the Jed, no mention has been made of a certain pudding-stone, which is interposed between the two, lying immediately upon the one and under the other. This puddingstone corresponds entirely to that which I had found along the skirt of the schistus mountains upon the south side, in different places, almost from one end to the other. It is a confused mass of stones, gravel, and sand, with red marly earth; these are consolidated or cemented in a considerable degree, and thus form a stratum extremely unlike any thing which is to be found either above or below.

When we examine the stones and gravel of which it is composed, these appear to have belonged to the vertical strata or schistus mountains. They are in general the hard and solid parts of those indurated strata, worn and rounded by attrition; particularly sand or marl-stone consolidated and veined with quartz, and many fragments of quartz, all rounded by attrition. In this pudding-stone of the Jed, I find also rounded lumps of porphyry, but have not perceived any of granite.[35] This however is not the case in the

[35] A view of this object is seen in Plate 3d. It is from a drawing taken by Mr Clerk of Eldin.

pudding-stone of the schistus mountains, for, where there is granite in the neighbourhood, there is also granite in the pudding-stone.

From this it will appear, that the schistus mountains or the vertical strata of indurated bodies had been formed, and had been wasted and worn in the natural operations of the globe, before the horizontal strata were begun to be deposited in those places; the gravel formed of those indurated broken bodies worn round by attrition evince that fact. But it also appears that the mineral operations of the globe, melting and consolidating bodies, had been exerted upon those deposited strata above the vertical bodies.

This appears evidently from the examination of our pudding-stone. The vertical strata under it are much broken and injected with ferruginous spar; and this same spar has greatly penetrated the pudding-stone above, in which are found the various mineral appearances of that spar and iron ore.

But those injecting operations reach no farther up among the marl strata in this place; and then would appear to have been confined to the pudding-stone. But in another place, about half a mile farther up the river, where a very deep section of the strata is discovered, there are two injections from below; the one is a thin vein of whin-stone or basaltes, full of round particles of steatites impregnated with copper; it is but a few inches wide, and proceeds in a kind of zigzag. The other appears to have been calcareous spar, but the greatest part of it is now dissolved out. The strata here descend to the bottom of the river, which is above the place of the pudding-stone and vertical strata. Neither are these last discoverable below the town of Jedburgh, at least so far as I have seen; and the line of division, or plane of junction of the vertical and horizontal strata, appears to decline more than the bed of the river.

But it may be asked, how the horizontal strata above, among which are many very strong beds, have been consolidated. The answer to this question is plain. Those strata have been indurated or consolidated in no other manner than the general strata of the earth; these being actually the common strata of the globe; while the vertical or schistus strata are the ordinary strata still farther manufactured, (if we may be allowed the expression) in the vicissitude of things, and by the mineral operations of the globe. That those operations have been performed by subterraneous heat has been already proved; but I would now mention some particular appearances which are common or general to those strata, and which can only be explained upon that principle.

The red marly earth is prevalent among those strata; and it is with this red ferruginous substance that many of the sand-stone strata are tinged. It is plain that there had been an uniform, deposits of that sand and tinging earth; and that, however different matter might be successively deposited, yet that each individual stratum should be nearly of the same colour or appearance, so far as it had been formed uniformly of the same subsiding matter. But, in the most uniform strata of red sand-stone, the fracture of the stone presents us with circular spots of a white or bluish colour; those little spheres are in all respects the same with the rest of the stone, they only want the tinging matter; and now it may be inquired how this has come about.

To say that sphericles of white sand should have been formed by subsiding along with the red sand and earth which composed the uniform stratum whether of sand-stone or marl, (for it happens equally in both,) is plainly impossible, according to our notion of that operation in which there is nothing mysterious. Those foliated strata, which are of the most uniform nature, must have been gradually accumulated from the subsiding sand and earth; and the white or colourless places must have had their colour destroyed in the subsequent cementing operations. It is often apparent, that the discharging operation had proceeded from a centre, as some small matter may be perceived in that place. I know not what species of substance this has been, whether saline or phlogistic, but it must have had the power of either volatilising or changing the ferruginous or red tinging substance so as to make it lose its colour.

I have only mentioned spherical spots for distinctness sake; but this discharging operation is found diversifying those strata in various ways, but always referable to the same or similar causes. Thus, in many of the veins or natural cracks of those strata, we find the colour discharged for a certain space within the strata; and we often see several of those spots united, each of them having proceeded from its own centre, and uniting where they approached. In the two veins above mentioned, of whin-stone and spar traversing the strata, the colour of the strata is, discharged more or less in the places contiguous with the veins.

I am now to mention another appearance of a different kind. Those strata of marl are in general not much consolidated; but among, them there are sometimes found thin calcareous strata extremely consolidated, consequently much divided by veins. It is in the solid parts of those strata, perfectly disconnected from the veins, that there are frequent cavities curiously lined with crystals of different sorts, generally calcareous, sometimes containing also those that are siliceous, and often accompanied with pyrites. I am persuaded that the origin of those cavities may have been some hollow shells, such as *echini* or some marine object; but that calcareous body has been so changed, that it is not now distinguishable; therefore, at present, I hold this opinion only as conjecture.

Having, in my return to Edinburgh, travelled up the Tiviot, with a view to investigate this subject of primary and secondary operations of the earth, I found the vertical strata, or alpine schistus, in the bed of the river about two miles below Hawick. This was the third time I had seen those vertical bodies after leaving the mountains of Lauderdale. The first place was the bed of the river Tweed, at the new bridge below Melrose; but here no other covering is to be seen above those vertical strata besides the soil or travelled earth which conceals every thing except the rock in the bed of the river. The second place was Jedburgh, where I found the vertical strata covered with the horizontal sandstone and marl, as has been now described. The third place was the Tiviot, and this is that which now remains to be considered.

Seeing the vertical strata in the bed of the river, I was desirous to know if those were immediately covered with the horizontal strata. This could not be discovered in the bed of the river where the rock was covered upon the banks with travelled earth. I therefore left the river, and followed the course of a brook which comes from the south side. I had not gone far up the bank, or former boundary of the Tiviot, when I had the satisfaction to find the vertical strata covered with the pudding-stone and marly beds as in the valley of the Jed.

It will now be reasonable to suppose that all the schistus which we perceive, whether in the mountains or in the valleys, exposed to our view had been once covered with those horizontal strata which are observed in Berwickshire and Tiviotdale; and that, below all those horizontal strata in the level country, there is at present a body or basis of vertical or inclined schistus, on which the horizontal strata of a secondary order had been deposited. This is the conclusion that I had formed at Jedburgh, before I had seen the confirmation of it in the Tiviot; it is the only one that can be formed according to this view of things; and it must remain in the present state until more evidence be found by which the probability may be either increased or diminished.

Since writing this, I have read, in the Esprit de Journaux, an abstract of a memoir of M. Voigt, upon the same subject, which I shall now transcribe.

"La mer a commencé par miner les montagnes primitives dont les débris se sont précipités au fond. Ces débris forment la premiere couche qui est posée immédiatement sur les montagnes primitives. D'après l'ancien langage de mineurs, nous avons jusqu'aujourd'hui appellé cette couche *le sol mort rouge*, parce qu'il y a beaucoup de rouge dans son mélange, qu'elle forme le sol ou la base d'autres couches, et peut-être de toutes, qu'elle est entierement inutile et, en quelque facon, morte pour l'exploitation des mines. Plusieurs se sont efforcés de lui donner un nom harmonieux; mais ils ne l'ont pu sans occasionner des équivoques. Les mots *Brèche Puddinstone Conglomérations*, &c. désignent toujours des substances autres que cette espèce de pierre.

"Il est très agréable de l'examiner dans les endroits où elle forme des montagnes entières. Cette couche est composée d'une quantité prodigieuse de pierres arrondies, agglutinées ensemble par une substance argileuse rouge et même grise, et le toute a acquis assez de dureté. On ne trouve dans sa composition aucune espèce de pierre qui, à en juger par les meilleures observations, puisse avoir été formée plus tard qu'elle; on n'y voit par-tout que des parties et des produit des montagnes primitives principalement de celles qui abondent le plus dans ces contrées. Le sol mort, par exemple, qui compose les montagnes des environs de Walbourg, près d'Eisenach, contient une quantité de gros morceaux de granit et de schiste micacé; c'est vraisemblablement parce que les montagnes primitives les plus voisines de Rhula, etc. sont, pour la plus part, formées de ces deux espèces de pierres. Près de Goldlauter, le sol mort consiste presque tout en porphyre, substance dont sont formées les montagnes primitives qui y dominent; et le Kiffauserberg dans la Thuringe a probablement reçu ces morceaux arrondis de schiste argileux des montagnes voisine du Hartz. Vous trouverez ici que le schiste argileux existoit déjà lorsque la mer a jetté les premiers fondemens de nos montagnes stratifiées. Je serois fort étonné que quelqu'un me montrât un sol mort qui contînt un morceaux de gypse, de marne, de pierre puante et autres. Quoiqu'il en soit il n'est pas aisé d'expliquer pourquoi on ne trouve point de corps marins pétrifiés dans cette espèce de pierre. C'est peut-être que, par l'immense quantité de pierres dures roulées dans le fond de la mer, ils ont été brisés avant qu'ils aient commencé de s'agglutiner ensemble. Mais on rencontre sur-tout au Kiffhauserberg des troncs d'arbres entiers pétrifiés; preuve qu'il y avoit déjà ou de la végétation avant que l'océan destructeur se fût emparé de ces cantons, ou du moins que quelques isles avoient existé au-dessus de la surface."

Here we find the same observations in the mountains of Germany that I have been making with regard to those of Scotland. I have formerly observed masses of the same kind in the west of England, to the east of the Severn; but I could not discover any proper connection of that mass with the regular strata. I have also long observed it in many parts of Scotland, without being able to attain a sufficiently satisfactory idea with regard to those particulars by which the alternation of land and water, of the superficial and internal mineral operations of the globe, might be investigated.

It will be very remarkable if similar appearances are always found upon the junction of the alpine with the level countries. Such an appearance, I am inclined to think, may be found in the Val d'Aoste, near Yvrée. M. de Saussure describes such a stone as having been employed in building the triumphal arch erected in honour of Augustus. "Cet arc qui étoit anciennement revêtu de marbre, est construit de grands quartiers d'une espèce assez singulière de poudingue ou de grès à gros grains. C'est une assemblage de fragmens, presque touts angulaires, de toutes sortes de roches primitives feuilletées, quartzeuses, micacées; les plus gros de ces fragmens n'atteignent pas le volume, d'une noisette. La plupart des édifices antiques de la cité l'Aoste et de ses environs, sont construits de cette matière; et les gens du pays sont persuadés que c'est une composition; mais j'en ai trouvé des rochers en place dans les montagnes au nord et au-dessus de la route d'Yvrée."

We may now come to this general conclusion, that, in this example of horizontal and posterior strata placed upon the vertical *schisti* which are prior in relation to the former, we obtain a further view into the natural history of this earth, more than what appears in the simple succession of one stratum above another. We know, in general, that all the solid parts of this earth, which come to our view, have either been formed originally by subsidence at the bottom of the sea, or been transfused in a melted state from the mineral regions among those solid bodies; but here we further learn, that the indurated and erected strata, after being broken and washed by the moving waters, had again been sunk below the sea, and had served as a bottom or basis on which to form a new structure of strata; and also, that those new or posterior strata had been indurated or cemented by the consolidating operations of the mineral region, and elevated from the bottom of the sea into the place of land, or considerably above the general surface of the waters. It is thus that we may investigate particular operations in the general progress of nature, which has for object to renovate the surface of the earth necessarily wasted in the operation of a world sustaining plants and animals.

It is necessary to compare together every thing of this kind which occurs; it is first necessary to ascertain the fact of their being a prior and posterior formation of strata, with the mineral operations for consolidating those bodies formed by collection of the moveable materials; and, secondly, it is interesting to acquire all the data we can in order to form a distinct judgment of that progress of nature in which the solid body of our land is alternately removed from the bottom of the sea into the atmosphere, and sunk again at the bottom of the sea.

I shall now transcribe what M. Schreiber has wrote in relation to this subject. It is in a memoir concerning the gold mine of Gardette, published in the Journal de Physique.

"Avant de quitter la montagne de la Gardette qu'il me soit permis de rapporter une observation qui peut-être n'est pas dénuée de tout intérêt pour les naturalistes; je l'ai faite dans une galerie à environ cinquante-trois toises à l'ouest du principal puit laquelle a été poussée sur la ligne de réunion de la pierre calcaire, et du granit feuilleté ou gneiss pour fonder le filon dans cet endroit. Ce filon a six pouces d'épaisseur, et consiste en quartz entre-mêlé d'ochre martiale, de pyrite cuivreuse et galène. Cette dernière est souvent recouverte de chaux de plomb grise, et de petits cristaux de mine de plomb jaune donnant dans l'analyse un indice d'or. Ce filon finit à la réunion de la pierre calcaire au gneiss. Cette réunion se fait ici dans la direction d'une heure 6/8 de la boussole de raineur, et sous un inclinaison, occidentale de 26 degrés.

"Mais ce qu'il y a de remarquable, c'est que le gneis ne participe en rien de la pierre calcaire quoiqu'il n'en soit séparé que par une couche d'une pouce d'épaisseur de terre argileuse et calcaire, tandis que le rocher calcaire renferme beaucoup de fragmens de granit et de gneis, dans le voisinage de cette réunion.

"Cette observation prouve incontestablement que le granit et le gneis avoient déjà acquis une dureté capable de résister aux infiltration des parties calcaire, et qu'ils existoient à-peu-près tels qu'ils sont aujourd'hui lorsque la pierre calcaire commença à se former; autrement elle n'auroit pu saisir et envelopper des morceaux détachés de ces rochers auxquels on donne avec raison l'épithète de primitif ou de première formation."

M. Schreiber continues his reasoning upon those mineral appearances, in adducing another argument, which I do not think equally conclusive. He says, "Le filon de la Gardette devoit pareillement exister avant la montagne calcaire, car s'il s'étoit formé apres, je ne voit pas la raison pour laquelle il s'y seroit arrêté court, et pourquoi il ne se seroit pas prolongé dans cette espèce de rocher." It is not necessary, in the formation of a vein, that it should proceed in traversing all the strata which then are superincumbent; it is reasonable to suppose, and consistent with observation to find them stop short in proceeding from one stratum to another. Had M. Schreiber found any pieces of the vein contained in the calcareous rock, he would have had good reason for that assertion; but, to conclude that fact from grounds which do not necessarily imply it, is not to be permitted in sound reasoning, if certainty is the object, and not mere probability.

Section 2. The Theory Confirmed From Observations Made On Purpose To Elucidate The Subject

Having got a distinct view of the primary and secondary mineral bodies or strata of the globe, and having thus acquired a particular object to inquire after, with a view to investigate or illustrate this piece of natural history, I was considering where we might most probably succeed in finding the junction of the low country strata and alpine schistus. I inquired of Mr Hall of Whitehall, who had frequent opportunities of traversing those mountains which lie between his house in the Merse and Edinburgh; and I particularly entreated him to examine the bed of the Whittater, which he executed to my satisfaction.

Mr Hall having had occasion to examine the Pease and Tour burns, in planning and superintending the great improvement of the post road upon Sir James Hall's estate while Sir James was abroad, he informed me that the junction of the schistus and sand-stone strata was to be found in the Tour burn. Professor Playfair and I had been intending a visit to Sir James Hall at Dunglass; and this was a motive, not so much to hasten our visit, as to chose the most proper time for a mineral expedition both upon the hills and along the sea shore.

It was late in the spring 1788 when Sir James left town, and Mr Playfair and I went to Dunglass about the beginning of June. We had exceeding favourable weather during the most part of our expedition; and I now propose to give an account of the result of our observations.

Dunglass burn is the boundary between the counties of East Lothian and Berwickshire; and it is almost the boundary between the vertical and horizontal strata. To the north-west of this burn and beautiful dean are situated the coal, lime-stone, marl, and sand-stone strata; they are found stretching away along the shore in a very horizontal direction for some time, but become more and more inclined as they approach the schistus of which the hills of Lammermuir to the south are composed.

Though the boundary between the two things here in question be easily perceivable from the nature of the country at the first inspection, by the rising of the hills, yet this does not lead one precisely to the junction; and in the extensive common boundary of those two things, the junction itself is only to be perceived in few places, where the rock is washed bare by the rivers or the sea, and where this junction is exposed naked to our view. The sea is here wearing away the coast; and the bank, about 200 feet high, is gradually falling down, making in some places a steep declivity, in others a perpendicular cliff. St Abb's Head and Fast Castle are head lands projecting into the sea, and are the bulwarks of this shore, which is embayed to the westward, where the sea preys upon the horizontal strata. The solid strata are every where exposed either in the cliff or on the shore; we were therefore certain of meeting with the junction in going from Dunglass to Fast Castle, which is upon the schistus. But this journey can only be made by sea; and we first set out to examine the junction in the Tour and Pease burns, where we had been informed it was to be found.

In the bottom of those rivulets the sand-stone and marly strata appear pretty much inclined, rising towards the schistus country. The two burns unite before they come to the shore; and it is about midway between this junction and the bridges which are thrown over those two hollows, that the junction is to be found.

The schistus strata here approach towards vertical; and the sand-stone strata are greatly inclined. But this inclination of those two different strata are in opposite directions; neither does the horizontal section of those two different strata run parallel to the junction; that is to say, the intersection of those two different strata is a line inclined to the horizon.

At Jedburgh the schistus was vertical, and the strata horizontal; and there was interposed a compound bed of pudding-stone, formed of various water-worn bodies, the gravel of the schistus strata, and porphyries. Here again, though we have not a regular pudding-stone, we have that which corresponds to it, as having been the effect of similar circumstances. These are the fracture and detritus of the schistus, while the strata were deposited upon the broken ends of the schistus at the bottom of the sea. Most of the fragments of the schistus have their angles sharp; consequently, they had not travelled far, or been much worn by attrition. But more or less does not alter the nature of an operation; and the pudding-stone, which at Jedburgh is interposed between the vertical schistus and horizontal strata, is here properly represented by the included fragments of schistus in the inclined strata.

The line of this junction running, on the one hand, towards Fast Castle eastward, and, on the other, towards the head of Dunglass burn westward, our business was to pursue this object in those two different directions. But it was chiefly in the sea coast that was placed our expectations, having recollection of the great banks of gravel under which the strata are buried about Oldhamstocks, near which, from all appearances, the junction was to be expected.

Having taken boat at Dunglass burn, we set out to explore the coast; and, we observed the horizontal sand-stone turn up near the Pease burn, lifting towards the schistus. We found the junction of that schistus with the red sand-stone and marly strata on the shore and sea bank, at St. Helens, corresponding in general with what we had observed in the burns to the westward. But, at Siccar Point, we found a beautiful picture of this junction washed bare by the sea. The sand-stone strata are partly washed away, and partly remaining upon the ends of the vertical schistus; and, in many places, points of the schistus strata are seen standing up through among the sand-stone, the greatest part of which is worn away. Behind this again we have a natural section of those sand-stone strata, containing fragments of the schistus.

After this nothing appears but the schistus rocks, until sand-stone and marl again are found at Red-heugh above the vertical strata. From that bay to Fast Castle we had nothing to observe but the schistus, which is continued without interruption to St Abb's Head. Beyond this, indeed, there appears to be something above the schistus; and great blocks of a red whin-stone or basaltes come down from the height and lie upon the shore; but we could not perceive distinctly how the upper mass is connected with the vertical schistus which is continued below.

Our attention was now directed to what we could observe with respect to the schisti, of which we had most beautiful views and most perfect sections. Here are two objects to be held in view, in making those observations; the original formation or stratification of the schisti, and the posterior operations by which the present state of things has been procured. We had remarkable examples for the illustration of both those subjects.

With regard to the first, we have every where among the rocks many surfaces of the erected strata laid bare, in being separated. Here we found the most distinct marks of strata of sand modified by moving water. It is no other than that which we every day observe upon the sands of our own shore, when the sea has ebbed and left them in a waved figure, which cannot be mistaken. Such figures as these are extremely common in our sand-stone strata; but this is an object which I never had distinctly observed in the alpine schisti; although, considering that the original of those schisti was strata of sand, and formed in water, there was no reason to doubt of such a thing being found. But here the examples are so many and so distinct, that it could not fail to give us great satisfaction.

We were no less gratified in our views with respect to the other object, the mineral operations by which soft strata, regularly formed in horizontal planes at the bottom of the sea, had been hardened and displaced. Fig. 4. represents one of those examples; it was drawn by Sir James Hall from a perfect section in the perpendicular cliff at Lumesden burn. Here is not only a fine example of the bendings of the strata, but also of a horizontal shift or hitch of those erected strata.

St Abb's Head is a promontory which, at a distance, one would naturally conclude to be composed of the schisti, as is all the shore to that place; but, as we approached it, there was some difference to be perceived in the external appearance, it having a more rounded and irregular aspect. Accordingly, upon our arrival, we found this head-land composed of a different substance. It is a great mass of red whin-stone, of a very irregular structure and composition. Some of it is full of small pebbles of calcareous spar, surrounded with a coat of a coloured substance, different both from the whin-stone ground and the inclosed pebble. Here ended our expedition by water.

Having thus found the junction of the sand-stone with the schistus or alpine strata to run in a line directed from Fast Castle to Oldhamstocks, or the heads of Dunglass burn, we set out to trace this burn, not only with a view to observe the junction, if it should there appear, but particularly to discover the source of many blocks of whin-stone, of all sizes, with which the bed of this burn abounds.

The sand-stone and coal strata, which are nearly horizontal at the mouth of this burn, or on the coast, become inclined as we go up the course of the rivulet; and of this we have fine sections in the bank. The Dean of Dunglass is formed of precipitous and perpendicular rocks, through which the running water has worn its way more than a hundred feet deep; above this Dean the banks are steep and very high, but covered with soil, which here is a deep gravel. The burn runs all the way up to Oldhamstocks upon the sand-stone strata; but there, these are traversed by a high whin-stone dyke, which crosses the burn obliquely, as we found it on both banks though not in the bed of the burn; it is in the south bank below the village, and on the north above it. Here is the source of the whin-stone which we were looking for; it is the common blue basaltes, of the same nature with the Giant's Causeway, but with no regular columnar appearance.

Above Oldhamstocks we again found the sand-stone in the bank, but it soon disappeared under a deep cover of gravel, and the burn then divided into several rivulets which come from the hills. We traced the one which led most directly up to the mountains, in expectation of meeting with the schistus, at least, if not the junction of it with the sandstone. But in this we were disappointed. We did not however lose our labour; for, though the junction which we pursued be not here visible, we met with what made it sufficiently evident, and was at the same time an object far more interesting in our eyes.

I have already quoted Mr Voigt's description of the *sol mort rouge*; he says, that in places it forms entire mountains; here we have a perfect example of the same thing; and the moment we saw it, we said, here is the *sol mort rouge*. We ascended to the top of the mountain through a gully of solid pudding-stone going into decay, and furnishing the country below with that great covering of gravel, soil, and water worn stones. We were now well acquainted with the pudding-stone, which is interposed between the horizontal and alpine strata; but from what we had seen to the eastward, we never should have dreamed of meeting with what we now perceived. What we had hitherto seen of this pudding-stone was but a few fragments of the schistus in the lower beds of sand-stone; here a mountain of water-worn schisti, imbedded in a red earth and consolidated, presented itself to our view. It was evident that the schisti mountains, from whence those fragments had come, had been prior to this secondary mass; but here is a secondary mountain equal in height to the primary, or schisti mountains, at the basis of which we had seen the strata superinduced on the shore. Still, however, every thing here is formed upon the same principle, and nothing here is altered except the scale on which the operation had been performed.

Upon the coast, we have but a specimen of the pudding-stone; most of the fragments had their angles entire; and few of them are rounded by attrition. Here, on the contrary, the mountain is one pudding-stone; and most of the fragments are stones much rounded by attrition. But the difference is only in degree, and not in kind; the stones are the same, and the nature of the composition similar. Had we seen the mass of which this mountain is only a relict, (having been degraded by the hands of time), we should have found this pudding-stone at the bottom of our sand-stone strata; could we have penetrated below this mass of pudding-stone, we should have found our schistus which we left on the shore at St. Helens and in the Tour burn. In Tiviotdale the vertical schisti are covered with a bed of pudding-stone, the gravel of which had been much worn by attrition, but the thickness of that bed is small; here again the wearing operation has been great, and the quantity of those materials even more than in proportion to those operations. We returned perfectly satisfied; and Sir James Hall is to pursue this subject farther when he shall be in those mountains shooting muir game.

We had now only one object more to pursue; this was to examine the south side of those mountains of Lammermuir upon the sea shore, in order to see the junction of the primary schistus with the coal strata of Berwickshire. Mr Hall was to meet us at the Press, and we were afterwards to go with him to Whitehall. We met accordingly; but the weather was rainy; and we went directly to Whitehall. I had often seen the pudding-stone in great masse; in the banks of the Whiteader, as it comes out of the mountains, but then I had not seen its connection neither, on the one hand, with the schisti, nor, on the other, with the sand-stone strata. We knew that at Lammerton upon the sea coast there was coal, and consequently the sand-stone strata; and reasoning upon those data we were sure that our proper course of investigation was to trace the river Ey to the shore, and then go south the coast in search of the junction of the schistus with the horizontal strata. This we executed as well as the weather would permit; but had it to regret, that the rainy season was not so favourable for our views, as it was agreeable to the country which had been suffering with the drought.

It is needless now to enlarge upon this subject. I shall only mention that we found the red marly strata above the pudding-stone in the bed of the Ey and its branches; we then traced the schistus down the Ey, and found a mass of the most consolidated pudding-stone upon the coast to the north of the harbour of Eymouth. But this mass did not rest on the schistus; it is immediately upon a mass of whin-stone; and the schistus is in the harbour, so that this whin-stone mass seems to be here interposed between the pudding-stone and schistus. We then pursued the coast southwards until we found the junction of the schistus and sand-stone strata about two miles from Eymouth; but here the junction was not attended with any pudding-stone that we could perceive.

Having found the same or similar appearances from the one end to the other, and on both sides of that range of mountains which run from sea to sea in the south of Scotland, we may now extend our view of this mineral operation in comprehending every thing of the same kind which we meet with in our island or any other distant country.

Thus perhaps the pudding-stone of the south of England will be considered in the same light as having been formed of the *débris* and *détritus* of the flinty bodies.

In the island of Arran, there is also a pudding-stone, even in some of the summits of the island, exactly upon the border of the schistus district, as will be described in the natural history of that island. This pudding-stone is composed of gravel formed of the hardest parts of the schistus and granite or porphyry mountains. That compound parasitical stone has been also again cemented by heat and fusion; I have a specimen in which there is a clear demonstration of that fact. One of the water-worn stones which had been rounded by attrition, has in this pudding-stone been broken and shifted, the one half slipping over the other, three quarters of an inch, besides other smaller slips in the same stone. But the two pieces are again cemented; or they had been shifted when the stone was in that soft state, by which the two pieces are made perfectly to cohere. Those shifts and veins, in this species of stone, are extremely instructive, illustrating the mineral operations of the globe.

In like manner to the north of the Grampians, along the south side of Loch Ness, there are mountains formed of the debris of schistus and granite mountains, first manufactured into sand and gravel, and then consolidated into a pudding-stone, which is always formed upon the same principle. The same is also found upon the south side of those mountains in the shire of Angus.

I may also give for example the African *Brechia*, which is a pudding-stone of the same nature. This stone is composed of granites or porphyries, serpentines and schisti, extremely indurated and perfectly consolidated. It is also demonstrable from the appearance in this stone that it has been in a softened state, from the shape and application of its constituent parts; and in a specimen of it which I have in my cabinet, there is also a demonstration of calcareous spar flowing among the gravel of the consolidated rock.

This fact therefore of pudding-stone mountains, is a general fact, so far as it is founded upon observations that are made in Africa, Germany, and Britain. We may now reason upon this general fact, in order to see how far it countenances the idea of primitive mountains, on the one hand, or on the other supports the present theory, which admits of nothing primitive in the visible or examinable parts of the earth.

To a person who examines accurately the composition of our mountains, which occupy the south of Scotland, no argument needs be used to persuade him that the bodies in question are not primitive; the thing is evident from inspection, as much as would be the ruins of an ancient city, although there were no record of its history. The visible materials, which compose for the most part the strata of our south alpine schisti, are so distinctly the *debris* and *detritus* of a former earth, and so similar in their nature with those which for the most part compose the strata on all hands acknowledged as secondary, that there can remain no question upon that head. The consolidation, again, of those strata, and the erection of them from their original position, and from the place in which they had been formed, is another question.

But the acknowledging strata, which had been formed in the sea of loose materials, to be consolidated and raised into the place of land, is plainly giving up the idea of primitive mountains. The only question, therefore, which remains to be solved, must respect the order of things, in comparing the alpine schisti with the secondary strata; and this indeed forms a curious subject of investigation.

It is plain that the schisti had been indurated, elevated, broken, and worn by attrition in water, before the secondary strata, which form the most fertile parts of our earth, had existed. It is also certain that the tops of our schistus mountains had been in the bottom of the sea at the time when our secondary strata had begun to be formed; for the pudding-stone on the top of our Lammermuir mountains, as well as the secondary strata upon the vertical schisti of the Alps and German mountains, affords the most irrefragable evidence of that fact.

It is further to be affirmed, that this whole mass of water-formed materials, as well as the basis on which it rested, had been subjected to the mineral operations of the globe, operations by which the loose and incoherent materials are consolidated, and that which was the bottom of the sea made to occupy the station of land, and serve the purpose for which it is destined in the world. This also will appear evident, when it is considered that it has been from the appearances in this very land, independent of those of the alpine schisti, that the present theory has been established.

By thus admitting a primary and secondary in the formation of our land, the present theory will be confirmed in all its parts. For, nothing but those vicissitudes, in which the old is worn and destroyed, and new land formed to supply its place, can explain that order which is to be perceived in all the works of nature; or give us any satisfactory idea with regard to that apparent disorder and confusion, which would disgrace an agent possessed of wisdom and working with design.

Chapter 7. Opinions Examined With Regard To Petrifaction, Or Mineral Concretion

The ideas of naturalists with regard to petrifaction are so vague and indistinct, that no proper answer can be given to them. They in general suppose water to be the solvent of bodies, and the vehicle of petrifying substances; but they neither say whether water be an universal menstruum, nor do they show in what manner a solid body has been formed in the bowels of the earth, from that solution. It may now be proper to examine this subject, not with a view to explain all those petrifactions of bodies which is performed in the mineral regions of the earth, those regions that are inaccessible to man, but to show that what has been wrote by naturalists, upon this subject, has only a tendency to corrupt science, by admitting the grossest supposition in place of just principle or truth, and to darken natural history by introducing an ill conceived theory in place of matter of fact.

M. le Comte de Buffon has attempted to explain the crystallization of bodies, or production of mineral forms, by the accretion or juxtaposition of elementary bodies, which have only form in two dimensions, length and breadth; that is to say, that mineral concretions are composed of surfaces alone, and not of bodies. This however is only an attempt to explain, what we do not understand, by a proposition which is either evidently contradictory, or plainly inconceivable. It is true that this eloquent and ingenious author endeavours to correct the palpable absurdity of the proposition, by representing the constituent parts of the mineral bodies as "*de lames infiniment minces*;" but who is it does not see, that these infinitely thin plates are no other than bodies of three dimensions, contrary to the supposition; for, infinitely thin, means a certain thickness; but the smallest possible or assignable thickness differs as much from a perfect superficies as the greatest.

M. de Luc has given us his ideas of petrifaction with sufficient precision of term and clearness of expression; his opinion, therefore, deserves to be examined; and, as his theory of petrifaction is equally applicable to every species of substance, it is necessary again to examine this subject, notwithstanding of what has been already said, in the first part of this work, concerning consolidation and mineral concretion from the fluid state of fusion.

This author has perhaps properly exposed Woodward's Theory of Petrification in saying [36], "Son erreur à cet égard vient de ce qu'il n'a point réfléchi sur la manière dont se fait la*pétrifaction*. Il ramollit d'abord les *pierres* pour y faire entrer les coquilles, sans bien connoître l'agent qu'il y employe; et il les duroit ensuite, sans réfléchir au comment." To avoid this error or defect, M. de Luc, in his Theory of Petrifaction, sets out with the acknowledged principle of cohesion; and, in order to consolidate strata of a porous texture, he supposes water carrying minute bodies of all shapes and sizes, and depositing them in such close contact as to produce solidity and concretion. Now, if Dr Woodward softened stones without a proper cause, M. de Luc, in employing the specious principle of cohesion, has consolidated them upon no better grounds; for, the application of this principle is as foreign to his purpose, as is that of magnetism. Bodies, it is true, cohere when their surfaces are closely applied to each other; But how apply this principle to consolidation?—only by supposing all the separate bodies, of which the solid is to be composed, to be in perfect contact in all their surfaces. But this, in other words, is supposing the body to be solid; and, to suppose the agent, water, capable of thus making hard bodies solid, is no other than having recourse to the fortuitous concourse of atoms to make a world; a thought which this author would surely hold in great contempt.

He then illustrates this operation of nature by those of art, in building walls which certainly become hard, and which, as our author seems to think, become solid. But this is only an imperfect or erroneous representation of this subject; for, mortar does not become hard upon the principle of petrification adopted by our author. Mortar, made of clay, instead of lime, will not acquire a stony hardness, nor ever, by means of water, will it be more indurated than by simply drying; neither will the most subtile powder of chalk, with water and sand, form any solid body, or a proper mortar. The

[36] Lettres Physiques et Morales.

induration of mortar arises from the solution of a stony substance, and the subsequent concretion of that dissolved matter, operations purely chemical. Now, if this philosopher, in his Theory of Petrifaction, means only to explain a chemical operation upon mechanical principles, why have recourse, for an example in this subject, to mineral bodies, the origin of which is questioned? Why does he not rather explain, upon this principle, the known concretion of some body, from a fluid state, or, conversely, the known solution of some concreted body? If again he means to explain petrifaction in the usual way, by a chemical operation, in that case, the application of his polished surfaces, so as to cohere, cannot take place until the dissolved body be separated from the fluid, by means of which it is transported from place to place in the mineral regions. But it is in this preliminary step that lies all the difficulty; for, could we see how every different substance might be dissolved, and every dissolved substance separated from its solvent at our pleasure, we should find no difficulty in admitting the cohesion of hard bodies, whether by means of this doctrine of polished surfaces, or by the principle of general attraction, a principle which surely comprehends this particular, termed a cohesive power.

It must not be alleged, that seeing we know not how water dissolves saline bodies, therefore, this fluid, for any thing that we know, may also dissolve crystal; and, if water thus dissolves a mineral substance in a manner unknown to us, it may in like manner deposit it, although we may not be able to imagine how. This kind of reasoning is only calculated to keep us in ignorance; at the same time, the reasoning of philosophers, concerning petrifaction, does not in general appear to be founded on any principle that is more sound. That water dissolves salt is a fact. That water dissolves crystal is not a fact; therefore, those two propositions, with regard to the power of water, are infinitely removed, and cannot be assimilated in sound physical reasoning. It is no more a truth that water is able to dissolve salt, than that we never have been able to detect the smallest disposition in water to dissolve crystal, flint, quartz, or metals. Therefore, to allege the possibility of water being capable of dissolving those bodies in the mineral regions, and of thus changing the substance of one body into another, as naturalists have supposed, contrary to their knowledge, or in order to explain appearances, is so far from tending to increase our science, that it is abandoning the human intellect to be bewildered in an error; it is the vain attempt of lulling to sleep the scientific conscience, and making the soul of man insensible to the natural distress of conscious ignorance.

But besides that negative argument concerning the insolubility of crystal, by which the erroneous suppositions of naturalists are to be rejected, crystal in general is found regularly concreted in the cavities of the most solid rock, in the heart of the closest agate, and in the midst of granite mountains. But these masses of granite were formed by fusion; I hope that I shall give the most satisfactory proof of that truth: Consequently, here at least there is no occasion for the action of water in dissolving siliceous substances in one place, in order to concrete and crystallise it in another.

In these cavities of the solid granite rock, where crystal is found regularly shooting from a basis which is the internal surface of the cavity, we find the other constituent substances of the granite also crystallised. I have those small cavities, in this rock, from the island of Arran, containing crystal, felt-spar, and mica, all crystallised in the same cavity[37]. But this is nothing to the *druzen* or crystalline concretions, which are found in a similar manner among metallic and mineral substances in the veins and mines; there, every species of mineral and metallic substance, with every variety of mixture and composition, are found both concreted and crystallised together in every imaginable shape and situation.

Here is an infinite operation, but an operation which is easily performed by the natural arrangement of substances acting freely in a fluid state, and concreting together, each substance, whether more simple or more

[37] The Chevalier Dolomieu makes the following observation. Journal de Physique, Juillet 1791.
"J'ai été étonné de trouver au centre d'un énorme massif de granit, que l'on avoit ouvert avec la poudre pour pratiquer un chemin, des morceaux, gros comme le poing et au dessous, de spath calcaire blanc, très-effervescent, en grandes écailles, ou lames entrecroisées. Il n'occupoit point des cavités particulières, il n'y paroissoit le produit d'une infiltration qui auroit rempli des cavités, mais il étoit incorporé avec les feld-spath, le mica, et le quartz, faissoit masse avec eux, et ne pouvoit se rompre sans les entraîner avec lui."
This great naturalist is convinced that the spar had not been here introduced by infiltration, although that is the very method which he employs to form concretions, not only of spar but of crystal, zeolite, and pyrites, in the closest cavities of the most solid rocks of basaltes. These four substances in this stone were so mixed together that nothing but the fusion of the whole mass could explain the state in which they appeared; but, thinking that such a supposition could not be allowed, this naturalist, like a man of science when his data fail, leaves the matter without any interpretation of his own. This however is what he has not done in the case of basaltes, or that which he mistakes for proper lavas, as I shall have occasion to show.

compound, directing itself by its internal principle of attraction, and affecting mechanically those that are concreting around it.

We see the very same thing happen under our eye, and precisely in the same manner. When a fluid mass of any mineral or metallic substance is made to congeal by sudden cooling on the outside, while the mass within is fluid, a cavity is thus sometimes formed by the contraction of the contained fluid; and in this cavity are found artificial *druzen*, as they may be called, being crystallizations similar to those which the mineral cavities exhibit in such beauty and perfection.

Petrification and consolidation, in some degree, may doubtless be performed, in certain circumstances, by means of the solution of calcareous earth; but the examples given by M. de Luc, of those bodies of lime-stone and agate petrified in the middle of strata of loose or sandy materials, are certainly inexplicable upon any other principle except the fusion of those substances with which the bodies are petrified[38].

This subject deserves the strictest attention; I propose it as a touchstone for every theory of petrification or perfect consolidation. First, There are found, among argillaceous strata, insulated bodies of iron-stone, perfectly consolidated; secondly, There are found, in strata of chalk and lime-stone, masses of insulated flints; thirdly, There are found, in strata of sea sand, masses of that sand cemented by a siliceous substance; fourthly, In the midst of blocks of sand-stone, there are found masses of loose or pure sand inclosed in crystallised cavities; and in this sand are found insulated masses of crystallised spar, including within them the sand, but without having the sparry or calcareous crystallization disturbed by it. There are also other globular masses of the same kind, where the sparry crystallization is either not to be observed, or appears only partially[39]: And now, lastly, In strata of shell-sand, there are found masses of consolidated lime-stone or marble. In all those cases, the consolidated bodies are perfectly insulated in the middle of strata, in which they must of necessity have been petrified or consolidated; the stratum around the bodies has not been affected by the petrifying substance, as there is not any vestige of it there; and here are

[38] Vid. Lettre 28 et Lettre 103. Lettres Physiques et Morales.
[39] Mem. de l'Académie Royale des Sciences, an. 1775.

examples of different substances, all conspiring to prove one uniform truth. Therefore, a general theory of petrification or consolidation of mineral bodies must explain this distinct fact, and not suffer it any longer to remain a *lusus naturae*.

Let us now consider what it is that we have to explain, upon the supposition of those concretions being formed from a solution. We have, first, To understand what sort of a solution had been employed for the introducing of those various substances; secondly, How those concretions had been formed from such solutions within those bodies of strata; and, lastly, How such concretions could have been formed, without any vestige appearing of the same substance, or of the same operation, in the surrounding part of the stratum. Whatever may be the difficulty of explaining those particular appearances by means of fusion and mechanical force, it is plainly impossible to conceive those bodies formed in those places by infiltration, or any manner of concretion from a state of solution.

Naturalists, in explaining the formation of stones, often use a chemical language which either has no proper meaning, or which will not apply to the subject of mineral operations. We know the chemical process by which one or two stony concretions may be formed among bodies passing from one state to another. When, therefore, a change from a former state of things in mineral bodies is judged by naturalists to have happened, the present state is commonly explained, or the change is supposed to have been made by means of a similar process, without inquiring if this had truly been the case or not. Thus their knowledge of chemistry has led naturalists to reason erroneously, in explaining things upon false principles. It would be needless to give an example of any one particular author in this respect; for, so far as I have seen, it appears to be almost general, every one copying the language of another, and no one understanding that language which has been employed.

These naturalists suppose every thing done by means of solution in the mineral kingdom, and yet they are ignorant of those solvents. They conceive or they imagine concretions and crystallizations to be formed of every different substance, and in every place within the solid body of the earth, without considering how far the thing is possible which they suppose. They are constantly talking of operations which could only take place in the cavities of the earth above the level of the sea, and where the influence of the atmosphere were felt; and yet this is the very place which we have it in our power to examine, and where, besides the stalactite, and one or two more of the same kind, or formed on the same principle, they have never been able to discover one of the many which, according to their theory, ought always to be in action or effect. So far from knowing that general consolidating operation, which they suppose to be exerted in filling up the veins and cavities of the earth by means of the infiltrating water of the surface, they do not seem fully to understand the only operation of this kind which they see. The concretion of calcareous matter upon the surface of the earth is perhaps the only example upon which their theory is founded; and yet nothing can be more against it than the general history of this transaction.

Calcareous matter, the great *vinculum* of many mineral bodies, is in a perpetual state of dissolution and decay, in every place where the influences of air and water may pervade. The general tendency of this is to dissolve calcareous matter out of the earth, and deliver that solution into the sea. Were it possible to deny that truth, the very formation of stalactite, that operation which has bewildered naturalists, would prove it; for it is upon the general solubility of calcareous matter exposed to water that those cavities are formed, in which may be found such collections of stalactical concretion; and the general tendency of those operations is to waste the calcareous bodies through which water percolates. But how is the general petrifaction or consolidation of strata, below the surface of the sea, to be explained by the general dissolution of that consolidating substance in the earth above that level? Instead of finding a general petrifying or consolidating operation in the part of the earth which we are able to examine, we find the contrary operation, so far at least as relates to calcareous spar, and many other mineral bodies which are decomposed and dissolved upon the surface of the earth.

Thus in the surface of the earth, above the level of the sea, no petrifying operation of a durable nature is found; and, were such an operation there found, it could not be general, as affecting every kind of substance. But, even suppose that such a general operation were found to take place in the earth above the level of the sea, where there might be a circulation of air and percolation of water, How could the strata of the earth below the level of the sea be petrified? This is a question that does not seem to have entered into the heads of our naturalists who attempt to explain petrifaction or mineral concretion from aqueous solutions. But the consolidation of loose and incoherent things, gathered together at the bottom of the sea, and afterwards raised into rocks of various sorts, forms by far the greatest example of petrification or mineral operation of this globe. It is this that must be explained in a mineral theory; and it is this great process of petrifaction to which the doctrine of infiltration, whether for the mechanical purpose of applying cohesive surfaces, or the chemical one of forming crystallizations and concretions, will not by any means apply.

Nothing shows more how little true science has been employed for the explanation of phenomena, than the language of modern naturalists, who attribute, to stalactical and stalagmical operations, every superficial or distant resemblance to those calcareous bodies, the origin of which we know so well. It is not a mere resemblance that should homologate different things; there should be a specific character in every thing that is to be generalised. It will be our business to show that, in the false stalactites, there is not the distinctive character of those water formed bodies to be found.

In the formation of stalactical concretions, besides the incrustation as well as crystallization of the stony substance from the aqueous vehicle by which it had been carried in the dissolved state, we have the other necessary accompanyments of the operation, or collateral circumstances of the case. Such, for example, is that tubular construction of the stalactite, first formed by the concretion of the calcareous substance upon the outside of the pendant gut of water exposed to the evaporation of the atmosphere; we then see the gradual filling up of that pervious tube through which the petrifying water had passed for a certain time; and, lastly, we see the continual accretion which this conducting body had received from the water running successively over every part of it. But among the infinite number of siliceous concretions and crystallizations, as well as those of an almost indefinite variety of other substances, all of which are attributed to solution, there is not the least vestige of any collateral operation, by which the nature of that concretion might be ascertained in the same manner. In all those cases, we see nothing but the concreted substances or their crystallizations; but, no mark of any solvent or incrusting process is to be perceived. On the contrary, almost all, or the greatest part of them, are so situated, and attended with such circumstances, as demonstrate the physical impossibility of that being the manner in which they had been concreted; for, they are situated within close cavities, through which nothing can pervade but heat, electricity, magnetism, etc.; and they fill those cavities more or less, from the thinnest incrustation of crystals to the full content of those cavities with various substances, all regularly concreted or crystallised according to an order which cannot apply to the concretion of any manner of solution.

That there is, in the mineral system, an operation of water which may with great propriety be termed *infiltration*, I make no doubt. But this operation of water, that may be employed in consolidating the strata in the mineral regions, is essentially different from that which is inconsiderately employed or supposed by mineralists when they talk of infiltration; these two operations have nothing in common except employing the water of the surface of the earth to percolate a porous body. Now, the percolation of water may increase the porousness of that body which it pervades, but never can thus change it from a porous to a perfect solid body. But even the percolation of water through the strata deposited at the bottom of the sea, necessarily required, according to the supposition of naturalists, must be refused; for, the interstices of those strata are, from the supposition of the case, already filled with water; consequently, without first removing that stagnant water, it is in vain to propose the infiltration of any fluid from the surface.

This is a difficulty which does not occur in our theory, where the strata, deposited at the bottom of the sea, are to be afterwards heated by the internal fires of the earth. The natural consequence of those heating operations may be considered as the converting of the water contained in the strata into steam, and the expulsion of steam or vapour, by raising it up against the power of gravity, to be delivered upon the surface of the earth and again condensed to the state of water.

Let us now conceive the strata, which had been deposited at the bottom of the sea, as exhausted of their water, and as communicating with the surface of the earth impregnated with water. Here again we have the power of gravity to operate in carrying down water to that place which had been before exhausted by the power of heat; and in this manner, by alternately employing those two great physical agents, we cannot doubt that nature may convey soluble substances from above, and deposit them below for the purpose of consolidating porous bodies, or of filling with saline and earthy matter those interstices which had been originally filled with water, when the strata were deposited at the bottom of the sea. How far any marks of this operation may be perceived, by carefully examining our mines and minerals, I know not; I can only say that, on the contrary, whenever those examined objects were clear and distinct, with the concomitant circumstances, so as to be understood, I have always found the most certain marks of the solid bodies having concreted from the fluid state of fusion. This, however, does not exclude the case of infiltration having been previously employed; and I would intreat mineralists, who have the opportunity of examining the solid parts of the earth, to attend particularly to this distinction. But do not let them suppose that infiltration can be made to fill either the pores or veins of strata without the operation of mineral heat, or some such process by which the aqueous vehicle may be discharged.

Not only are mineral philosophers so inconsiderate, in forming geological theories upon a mere supposition or false analogy, they have even proceeded, upon that erroneous theory, to form a geological supposition for explaining the appearances of strata and other stony masses in employing a particular physical operation, which is, that of*crystallization*[40]. Now crystallization may be considered as a species of elective concretion, by which every particular substance, in passing from a fluid to a solid state, may assume a certain peculiar external shape and internal arrangement of its parts, by which it is often distinguished. But, to suppose the solid mineral

[40] Journal de Physique; Avril 1753.

structure of the earth explained, like an enigma, by the word *crystallization*, is to misunderstand the science by which we would explain the subject of research; and, to form a general mineral theory thus upon that term, is an attempt to generalise without a reason. For, when it were even admitted that every solid body is crystallised, we thus know no more of the geology of this earth, or understand as little of the general theory of mineral concretion, as we did before;—we cannot, from that, say whether it be by the operation of solution or of fusion which had produced the perceived effect.

M. de Carosi has wrote a treatise upon certain petrifactions[41]. In the doctrine of this treatise there is something new or extraordinary. It will therefore be proper to make some observations on it.

The object of this treatise is to describe the generation of silex and quartz, with their modifications or compositions, formed within mineral bodies of a different substance. The natural history contained in this little treatise is well described and sufficiently interesting. But It is chiefly in order to examine the means which, according to the theory of this treatise, are employed in petrifying bodies, that I consider it in this place.

The first section of this treatise has for title, *Generation du Caillou et du Quartz de la terre calcaire pure*. It may be worth while to compare the natural history of this part of the earth with the flint and chert found in our chalk and lime-stone countries. I shall therefore transcribe what is worth observing upon that subject (p. 5.).

"Nous rencontrons chez nous dans les parties le plus montagneuses, et les moins couvertes de terreau, ou tout-au plus de sable, entre de purs rochers calcaires une quantité incroyable de cailloux (silex) tant en boules, que veines, couches, et débris. Au premier coup d'oeil l'on s'imagine que ce font des débris de montagnes éloignées, qui y furent amenés par les eaux, mais, en examinant la chose de plus pres, on est convaincu, que ce sont tout au contraire, des parties détachées des montagnes de la contrée. Car il y a sur presque toute l'étendue de nos montagnes calcaires une couche, ou pour mieux dire, un banc composé de plusieurs couches de base calcaire, mais qui

[41] Sur la Generation du Silex et du Quartz en partie. Observations faites en Pologne 1783, à Cracovie.

ou sont parsemées irrégulièrement de boules, de rognons, de veines, et de petits filons de silex, ou qui contiennent cette pierre en filon, veines, et couches parallèles, et régulièrement disposées. Les boules et rognons de silex y font depuis moins de la grandeur d'une petite noisette, jusqu'au diamètre de plus de six pouces de nôtre mesure. La plupart de ces boules tant qu'elles sont dans l'intérieur caché de la roche vive, et qu'elles n'ont rien souffert de l'impression de l'air, ont, pour l'ordinaire, une croûte de spath calcaire, au moyen de la quelle elles sont accrues à la roche mere; ou pour mieux dire la croûte spatheuse fait l'intermède entre le silex, et la roche calcaire, par où se fait le passage de l'une à l'autre. Mais ceci ne vaut que de boules de silex entièrement formées. C'est dont on peut même se convaincre à la vue, par beaucoup de pierres dont le pavé de la ville de Cracovie est composé. Mais là, ou le silex n'est pas encore entièrement achevé, la croûte spatheuse manque, en revanche on y voit évidemment le passage par degrés successifs de la roche calcaire au silex qui y est contenu, et les nuances de ce passage sont souvent si peu marquées que même les acides minéraux ne suffisent pas à les déterminer, ce n'est que le briquet, qui nous aide à les découvrir. On voit bien ou la pierre calcaire s'enfonce en couleur, l'on s'apperçoit, où sa dureté, ses cassures changent, mais, comme elle y souffre encore quelque impression des acides, l'on ne sauroit déterminer au juste le point, ou elle a déjà plus de la nature du silex, que de celle de la chaux, qu'en la frappant du briquet.

"Tels sont les cailloux en boules et rognons avant leur état de perfection, il y aura même au milieu une partie de pierre calcaire non changée.

"Ceux au contraire, ou la nature à achevé son ouvrage, ont une croûte de chaux endurcie, et sont purement du silex fini, mais de toutes couleurs, d'un grain et d'une texture plus ou moins fine, qui passe assez souvent par degrés dans les différentes variétés du noble silex. Ils ont, pour l'ordinaire, dans leur intérieur une cavité, mais pas toujours au centre, et qui vient apparemment de la consommation de cette partie calcaire qui y resta la dernière, et n'en fut changée ou dissolute et séparée, que lorsque le reste du silex étoit déjà entièrement fini. Ces cavités sont toujours, ou enduites de calcédoine en couche concentriques recouverte de petits cristaux fort brillans et durs de quartz, ou bien seulement de ces derniers-ci. Par-fois il y a aussi du spath calcaire crystallisé, mais cela est extrêmement rare. Quelque-fois enfin ces cavités sont remplies d'une noix de calcédoine. Je n'ai réussi qu'une seule fois en cassant un pareil silex en boule d'y trouver encore le reste de l'eau de crystallisation."

The only remark that I would here make is this, that, if the crystallization of those close cavities in the *silex* had at any time required water of solution, it must always have required it. But, if there had been water of solution contained in those close cavities, for the crystallization of the various things which are often found within them, How comes it that this water is almost never found? I have good reason to believe that water contained within a solid flint will not make its escape, as does that contained in the *anhydrites* of Mount *Berico*, which are composed of a porous calcedony. But the siliceous crystallizations within close cavities is a curious subject, which we shall have occasion to examine more particularly in treating of agates. We now proceed to the next section, which is the generation of silex and quartz in marl, (p. 19.)

"Il y a des contrées, chez nous, qui out des étendus assez considérables en long et en large, de montagnes de pierre de marne calcaire, dans lesquelles on rencontre le même phénomène que dans celles de chaux pure; c. a. d. nous y trouvons du silex de différentes variétés, et dans tous les degrés successifs de leur formation, et de leur perfection. Outre cela, nous y voyons encore quelque chose, qui semble nous conduire à la découverte des moyens, dont se sort la nature pour effecteur cette opération, et qui nous étoit caché dans les montagnes de chaux pure: ces bancs de pierre marnesilicieuse, contiennent une partie considérable de pyrites sulfureuses, qui non seulement y forment une grande quantité de petits sillons, mais toute la masse de la montagne est rempli de parcelles souvent presqu'imperceptibles de ce minéral. Ces pyrites sont évidemment des productions du phlogistique et de l'acide contenu dans la montagne.

"L'eau, qui s'y trouve ordinairement en assez grande abondance, en détacha, extraha d'un et l'autre, et les combina après tous les deux ensemble. Cette même eau les dissout derechef, et en fait de nouvelles combinaisons. C'est ce qu'on voit évidemment là, ou la nature, ayant commencé ses opérations, il n'y est resté de la pyrite, qu'une portion de la partie inflammable liée à une base terrestre. Dans ces endroits la marne n'est que fort peu sensible aux acides, et de blanche qu'elle étoit, sa couleur est devenue presque noire. C'est là qu'on observe les différens degrés du changement de la marne en silex, contenant, même encore, par fois, de parties pyritéiques non détruites dans son intérieur. Et comme la nature forme ici, de même, que dans la chaux pure les silex, la plupart en boules ou rognons; comme les différent degrés de métamorphoses de la marne en silex, sont ici beaucoup plus nombreuses que là, de sorte qu'il y a des bandes entières, qui mériteroient plutôt d'être appellés bandes silicieuses, que marneuses; comme il y a, enfin, une grande quantité de pyrites, qu'ailleurs, il est très probable qu'elle se serve là du même moyen qu'ici pour opérer la métamorphose en question.

"Ne nous précipitons, cependant, pas à en tirer plus de conséquences; poursuivons plutôt le fil de notre récit.

"Le silex, qui se trouve ici, est non seulement de différents degrés de perfection, il est de plus d'une espèce. Il y a de la pierre à feu, 2 de la calcédoine, 3 des agathes, et 4 différentes nuances et passages des espèces ordinaires aux fines du silex.

"La pierre à feu, est, ordinairement dans son état de perfection d'un grain assez fin, d'une couleur grise plus ou moins foncée, et même donnant, dans le noirâtre, plus ou moins diaphane; ses cassures sont concentriques ou coquillées, et sa masse est assez compacte. Outre sa conformation ordinaire en boules et rognons, elle fait presque toujours la noix de ursins marins, qui y font en grand nombre, et dont la coquille est le plus souvent, et presque toujours de spath calcaire, même au milieu d'une boule de silex parfait.

"Les calcédoines et agathes de ces couches sont toujours (au moins, je ne les ai pas encore vues autrement) de coraux et autres corps marins pétrifiés. Donc, il faut que les couches de pierres roulées, d'où j'ai tiré ma collection citée plus haut, soyent des débris de montagne» détruites de cette espèce. Il y en a qui sont très parfaites comme celles qui composent ma collection, d'autres méritent plutôt d'être rangées parmi les passages du silex ordinaire, et ses espèces plus fines; d'autres encore sont, en effet, de vraies agathes, mais qui renferment dans leur intérieur plus ou moins de parties non parfaites presque calcaires, qui s'annoncent d'abord par leur couleur blanche, par leur gros grains relativement au reste, par leur opacité, par leur mollesse respective, et souvent même par leur sensibilité pour les acides minéraux. Mais celles, qui sont finies, quoiqu'elles ayent, pour la plupart, une couleur presque noire, ne laissent, cependant, pas d'avoir aussi des teintes plus claires comme brunâtres, verdâtres, rougeâtres, jaunâtres, bleuâtres, tachetées, veinées, etc. Leur clarté n'est pas moins variable, que leur couleur, il y en a de presqu'opaques, comme aussi de presque transparentes, sur tout là, ou la calcédoine prédomine.

"Le quartz s'y trouve comme dans les pierres de la premiere section, c, a, d, crystallisé, en groupes dans de petites cavités; quelquefois aussi en veines. La calcédoine y est de même, ou bien en mamelons, ou bien en stalactites, lorsqu'elle a de la place pour s'y déposer.

"Un phénomène encore plus curieux que cela est cette belle pyrite sulphureuse jaune, comme de l'or, qui est quelquefois parsemée par tout la substance de pétrifications agathisées, et qui apparemment y fut déposée après la dite métamorphose à la faveur des petits pores, qui y étoient restés ouverts."

I would beg that mineralists, who use such language as this, would consider if it contains a distinct idea of the operation which they would thereby describe, or if it does not contain either a contradiction or an inconceivable proposition. It supposes a calcareous body to be metamorphosed, somehow by means of the mountain acid, into a siliceous body. But, finding many bodies of pyrites contained within that solid flint, it is said, that, when the calcareous body was flintified, there were left in it cavities which were afterwards filled with pyrites. Let us reflect a moment upon this doctrine. These cavities were first open to the outside of the flinty body; but now the pyrites with which they had been filled is insulated in the solid flint. Here three things are required; first, The calcareous body is to be flintified, at the same time leaving the body full of small cavities open to the outside; secondly, These cavities are to be filled with pyrites; lastly, These mineral bodies are to be so inclosed within the flint, as to leave no vestige of the former processes. This marly mountain itself, which had been formed of loose materials gathered together at the bottom of the sea, was first to be filled with pyrites, in various shapes, by means of the phlogistic and the acid of the mountain. Here is proposed to us an operation which is totally unknown, or of which we have no kind of idea. But, let us suppose pyrites formed in this mountain, (of whatever chemical substances), by means of water; Why should water again undo that pyrites, in order to form other concretions? And, Why should the flint be formed first with cavities, and then made solid, after pyrites had been introduced into those cavities of the agate, and, as our author expresses it, *parsemée pour toute la substance?* Here are suppositions which are not only perfectly gratuitous, but are also inconsistent with any thing that we understand. This is not explaining nature; it is only feigning causes[42].

The third section has for title, "*Generation du Silex et Quartz de la Pierre Puante*." Here we find an example worthy of being recorded, as contributing to throw great light upon those mineral operations; however, the opinion of our author and mine, upon this subject, differ widely. He proceeds thus:

"Cette pierre n'est, comme chacun le sçait, qu'une pierre calcaire contenant du bitume.

"Nos montagnes n'en contiennent seulement pas de simples couches, mais il y en a même de grandes bancs fort épais.

"Le caillou, ou silex qui s'y génère, forme, tantôt de gros blocs informes, qui occupent des cavités dans l'intérieure des montagnes, tantôt, enfin, en forme de filons.

"J'ai remarqué cette métamorphose sur trois endroits différens, dans chacun des quels la nature a autrement opéré.

[42] The description of those insulated siliceous bodies, containing in their closed cavities all the usual concretions of calcedony and crystals, as well as full of small pyrites floating in the solid flint, are extremely interesting to a mineral system, or such a geological theory as should explain the present state of things in those strata that had been formed by deposits of known materials at the bottom of the sea; they are indeed such appearances as may be found, more or less, in all consolidated strata. But it is this author's explanation of that petrifaction which is our present object to consider; and, as he is so particular in giving us his theory upon the subject, it is easy to detect the error of his reasoning. Were those naturalists who explain things only in general, by saying that water is the agent, and infiltration the means employed by nature;—were these naturalists, I say, to give us as particular a description of their process, it would appear as inconsistent with the nature of things as that which we have from this author, who examines nature very minutely, and who sees distinctly that the infiltrating theory is inapplicable for the explanation of those petrifactions.

"Sur l'un, la pierre puante fait un banc horizontal dans une montagne de pierre calcaire crystalline, ou d'une espèce de marbre, qui contient des couches et filons de métal. Ce banc de pierre puante y fait le toit d'une couche de galène de plomb et de pierre calaminaire, et dans ses cavités et fentes il y a non seulement des blocs de grandeur différente, mais aussi des veines et petites bandes courtes de silex, tant ordinaire, que noble c, a, d, de la pierre à feu, de calcédoine, d'agathes, et même d'une espèce de cornaline jaune et rouge pâle. Je ne m'arrêterai pas à en détailler les variétés, parce qu'elles sont trop accidentelles. Je ne les connois pas même toutes, il s'en faut de beaucoup, parce qu'elles se trouvent dans des anciennes mines négligées, peut être depuis plus d'un siècle, et par conséquent peu accessibles. Je ne doute, cependant pas, que, si l'on pouvoit mieux sonder le terrain, on y trouveroit bien plus encore du peu que j'ai cité. Parmi ce silex, il y a aussi de petites groupes et de petites veines de quartz solide et crystallisé.

"Au second endroit la pierre puante fait un filon, ou si l'on veut, une couche ou bande verticale, qui partage la montagne en deux parties presqu'égales de l'épaisseur de trois aunes à peu près. La montagne, ou cela se voit est aussi une ancienne mine de cuivre et de plomb, consistant en plusieurs variétés de marbre, différent en couleur et en grain, déposées par couches les unes sur les autres. Le filon de silex est formé de feuilles alternatives de pierre puante et de silex, tous les deux de couleur brun de bois à peu prés; mais le silex est plus foncé que sa compagne. Ces feuilles alternatives, consistent d'autres bien plus minces encore, qui souvent n'ont pas l'épaisseur d'une ligne, mais ce qu'il y a de plus curieux, c'est que la même feuille est d'un but de pierre porque, qui, vers le milieu, passe successivement en silex, qui, à son tour, vers l'autre but, qui étoit exposé à l'air repasse par les mêmes gradations en une espèce de tuffe calcaire. Ce qui nous fait voir évidemment la génération et la destruction du silex, même avec une partie des moyens par lesquels elle s'opère. Comme l'endroit de cette découverte n'est accessible qu'à la superficie, je ne saurois dire s'il y a d'autres variétés de silex outre la dite. Il l'est à supposer autant par analogie, que par quelques morceaux qui ont de petites veines transversales d'une espèce de calcédoine, et qui sont, même, sur leur fentes, garnis de petits cristaux de roche. Mais ce qu'il y a de sur c'est que ce filon, parvenu à une certaine profondeur, s'ennoblit et contient du métal, c. a. d. de la galène de plomb, et de la pyrite cuivreuse, j'y en ai trouvés de morceaux, qui en font de preuves incontestables. Le caillou d'ici est un grain fin d'une texture forte, peu transparent, donne beaucoup d'étincelles au briquet, mais ses cassures sont écailleuses.

"La montagne calcaire du troisième lieu a une couche de pierre puante épaisse de plusieurs aunes, qui, derechef contient de petites couches irrégulières et des bandes transversales de silex, qui ont jusques à six pouces passés d'épaisseur. La pierre puante est d'une couleur gris-brune, d'un grain assez fin, et d'un tissu assez dur; ses cassures sont irrégulières, mais plus la pierre s'approche du silex, plus elles donnent dans le coquillé. Le silex ordinaire est d'un brun de bois, d'un grain assez fin, et d'un tissu résistant, et ses cassures sont égales à la pierre porque. Ce n'est pas là la seule variété, il y a, aussi, de la calcédoine et des agathes de couleurs différentes. Même la pierre à feu est assez souvent traversée de veines de calcédoine, de quartz crystallisé, et de spath calcaire blanc en feuilles et en crystaux. Il arrive que la même veine est composée de ces trois espèces de pierres à la fois, de sorte que l'une semble passer dans l'autre, parce que les limites réciproques sont, souvent, assez indistinctes. Il est évident, que le silex est formé de la pierre puante, parce qu'on remarque ici les mêmes phénomènes dont j'ai parlé plus haut, c. a. d. les passages successifs de l'une dans l'autre pierre, tant en montant qu'en descendant."

There is nothing particular in the siliceous mixture in this species of lime-stone, except the vein of that substance. It is evident that this vein, traversing the mountain, had been introduced in the fluid state of fusion. I do not mean to say, that, in this particular case now described, the evidence of that truth peculiarly appears; but that, from the general nature of mineral veins breaking and traversing the solid strata of the globe, no other conclusion can be formed; and that in the particulars of this example there is nothing that could lead us to suppose any other origin to the petrifactions contained in this vein of stinking lime-stone. It is plain, that our author has imagined to himself an unknown manner of executing his mineral metamorphoses. He sees plainly that the common notion of infiltration will not at all explain the evident confusion of those calcareous and siliceous bodies which appear to him to be metamorphosing into each other. Nothing, indeed, can explain those phenomena but a general cause of fluidity; and there is no such general cause besides that of heat or fusion.

But to show how mineralists of great merit, gentlemen who have examined systematically and with some accuracy, may impose upon themselves in reasoning for the explanation of mineral appearances from limited notions of things, and from the supposition of these having been formed where they now are found, that is, upon the surface of the earth, I would beg leave to transcribe what this author has said upon this species of petrifaction. It is not that he is ignorant of what mineralists have already said upon the subject; it is because he sees the incompetency of their explanations in those particular cases; and that he would employ some other more effectual means. (p. 50.)

"Toute terre calcaire à changer dans une autre doit, avant toute chose, être rendue réfractaire ce qui ne peut se faire qu'en la saturant avec un acide. Mais une terre simplement, saturée d'un acide, est d'une réduction fort aisée, vu que l'acide n'y tient pas trop fort, d'ailleurs ce n'est qu'un sel neutre terreux fort facile â dissoudre dans une quantité suffisante d'eau. Or pour rendre cette union plus constante, il faut que la terre alcaline s'assimile intimement à l'acide, ce qui ne se sera jamais sans un intermedeliant, qui homogène les parties de ce nouveau corps, et pour que cela ce fasse il est indispensable, qu'il s'opère une dissolution foncière des parties terrestres de la chaux, qui facilite l'ingress à l'acide, et à l'intermède pour qu'ils s'y lie bien fortement. Supposons qu'il se forme une liqueur savonneuse de l'acide et du phlogistique, que l'air fixe, mis en liberté, ouvre les interstices des parties qui constituent la terre alcaline, qu'apres cela cette liqueur savonneuse ayant l'entrée libre s'assimile à la terre en proportion requise, que l'eau, qui servoit de véhicule dans cette operation, s'évapore successivement, et emporte le superflu des ingrediens, pour qu'il se puisse opérer le rapprochement le plus exacte des parcelles ou molécules homogénées de nouveau corps qu'enfin les molécules les plus pures et les mieux affinées soyent réunies en forme liquide dans des cavités, et que par l'évaporation et séparation de l'eau, ou elles nageoient, il s'en forme des crystaux n'auronsnous pas une boule de silex, avec de crystaux de quartz dans ses creux intérieurs."

The supposed case is this; a calcareous body is to be metamorphosed into a siliceous nodule, having a cavity within it lined with quartz, crystals, etc. M. de Carosi means to inform us how this may be done. Now, as this process requires no other conditions than those that may be found upon the surface of this earth, the proper way to prove this hypothetical theory, would be to exhibit such a mineral body produced by those means. But, even supposing that such a process were to be exhibited, still it would remain to be explained, how this process, which requires conditions certainly not be found at the bottom of the sea, could be accomplished in that place, where the strata of the earth had been deposited, accumulated, consolidated, and metamorphosed.

This mineral process, which has been now described, will no doubt revolt the opinions of many of our chemists as well as naturalists; and I should not have thought of transcribing it, but as an example of that inconclusive reasoning which prevails in mineralogical writings upon this subject.

But this is not all. We have, upon this occasion, a most remarkable example of the fallaceous views that may be taken of things; and of the danger to science when men of sense and observation form suppositions for the explanation of appearances without that strict conformity with the principles of natural philosophy which is requited on all occasions. Both M. de Carosi, and also M. Macquart [43], to whom our author communicated his ideas and proper specimens, assert, that from their accurate experience, they find calcedony growing daily, not only in the solid body of gypsum, etc. while in the mine, but also in the solid stone when taken out of the mine, and preserved in their cabinet.

What answer can be made to this positive testimony of these gentlemen, by a person who has not seen any such a thing, and who has not the opportunity of examining the cases in which those naturalists may have perhaps been led into some delusion? Were I however to conjecture upon a subject in which I have not any positive information, I should suppose that

[43] Vid. Essais de Minéralogie par M. Macquart.

some part of the calcedony, like the *oculus mundi* when dipped in water, may be so transparent, while containing some portion of humidity, that it is not easily distinguishable from the gypsum in which it is concreted; but that in having the humidity evaporated, by being taken out of the mine and exposed to the dry air, those portions of calcedony, which did not before appear, may be perceived by becoming more opaque[44].

There is, however, a subject in which I can more freely accuse this author of being deceived. This naturalist says, that calcareous stones become silex by a certain chemical operation; and that those flinty bodies, in being exposed upon the surface of the earth, out of their natural bed, are again, by a contrary chemical operation, changed from flint to a calcareous substance. I will give it in his own words, (p. 56.)

"Cela dit, venons au fait. Tout silex progénéré de chaux, détaché de son lieu natal, et exposé aux changemens de saisons, s'amollit, reçoit de crevasses, perd sa transparence, devient, enfin, tout-à-fait opaque, le phlogistique s'en évapore, l'acide en est détaché, lavé, et de terre vitrescible, qu'il étoit, il redevient chaux, comme il étoit auparavant."

Here is no question with regard to mere opinion, but to matter of fact; and, in this case, nothing is more evident, than that upon the surface of this earth, that is, in the examinable parts above the level of the sea, there is no transition either of calcareous bodies into flint, nor of flinty bodies into calcareous substance. Calcareous matter is constantly dissolved by water, when it is exposed to the washing of that fluid; and it is even dissolved out

[44] From the description given in this treatise, and from the drawings both of M. de Carosi and M. Macquart, I find a very valuable inference to be made, so much the more interesting, as I have not found any example of the like before. This arises from the intimate connection which is here to be perceived between agate and gypsum. Now, upon this principle, that the agate-calcedony had been formed by fusion, a truth which, from the general testimony of minerals, I must presume, it is plain, that those nodules of gypsum had been in the fluid state of fusion among those marly strata, and that the gypseous bodies had been penetrated variously with the siliceous substance of the calcedony.
The description of those siliceous penetrations of gypsum is followed by this conclusion: "En voila assez, je crois pour faire voir que le silex ci-décrit est effectivement une émanation du gypse, et non pas une matière hétérogène amenée d'autre part et déposée, ou nous la voyons." In this instance our author had convinced himself that the calcedony concretions had not been formed, as he and other mineralists had before supposed, by means of infiltration; he has not, however, substituted any thing more intelligible in its stead. I do not pretend that we understand mineral fusion; but only that such mineral fusion is a thing demonstrable upon a thousand occasions; and that thus is to be explained the petrification and consolidation of the porous and naturally incoherent strata of the earth.

of the most perfect union or combination with siliceous substance, and the most solid composition of an insoluble body, as may be perceived in the decaying of feld-spar. A superficial view of flints, which have come out of a body of chalk, may have created such an opinion, which will not either bear the light of chemical or mineral investigation. The subject of these chalk flints will be minutely examined in its proper place.

Our author has carefully examined the subject of flintification; and the country where he makes his observations would seem to be well disposed for such a research. He has had great opportunity and inclination to examine the subject which he writes upon; and he has given a distinct account of what be has seen. His description of the flintification of sand-stone is extremely interesting. I will therefore transcribe it, both as a valuable portion of natural history, and also in order to contrast this author's opinion, with regard to the means employed by nature in petrifying bodies, and that which I maintain to be the general consolidating operation of the globe. It is Section V. *Generation du Caillou du Silex du Grès, ou Pierre Sabloneuse*.

"Tout grès est susceptible de cette métamorphose quant au grain et quant à la couleur; depuis la bréccia quartzeuse jusqu'à la pierre à rasoir; et depuis le grès blanc jusqu'au brun et presque noirâtre, tient ou non tient, dur, ou presque friable, c'est indifférent, toutes ces variétés donnent du silex, et surtout de la calcédoine, de la cornaline, et des agathes. Quant au ciment je l'y ai toujours remarqué calcaire et faisant effervescence avec les acides dans les endroits de la pierre qui n'étoient point encore changés; et jamais je n'ai vu ce changement dans du grès dont le ciment fut ou quartzeux ou argileux et réfractaire. Ainsi le ciment entre pour quelque chose dans ce changement.

"Le commencement de cette métamorphose paroit (autant que j'ai pu l'observer dans mes débris roulés) se faire par le ciment, qui dissout là, où les agens eurent l'accès libre, rend les grains en quartz mobiles, les emporte, les mêle avec sa masse dense-liquide, les dissout, même en partie, et forme, dans cet état, des veines et de masses calcédonieuse, carneoliques, ou d'une autre espèce de silex, au milieu du grés peu, ou pas du tout, changé. Car autant que je puis voir, ce n'est pas par couches ou veines qu'elle s'opère, mais par boules et masses rond-oblongues. Au commencement ces veines et tâches sont fort minces, et le reste du grés n'est point du tout, ou à peine sensiblement changé hormis qu'il gagne, plus de consistance, à proportion du changement souffert. Mais à mesure que le silex y augmente et se perfectionne, on y apperçoit les degrés par lesquels a passé cette operation. Les nuance du passage d'une pierre à l'autre deviennent plus visibles, les veines et masses de silex grandissent au point, même, qu'il y a jusqu'aux trois quart du grés changé en silex clair comme de l'eau n'ayant que fort peu de grains de sable nageants dans sa masse. Des morceaux de cette espèce sont rares à la vérité, mais j'en ai, cependant, trouvé quelques uns. Ordinairement, dans les beaux morceaux, le silex fait la base, et le sable y est, comme nageant tantôt en grains séparés tantôt en parties et flocons. Dans les pieces moins belles, le sable fait la base, et le silex sert à la fois de ciment, et forme aussi plus ou moins de veines, qui traversent la masse en maintes et maintes directions. Mais si c'est un grès à gros grains, ou de la breccia, alors le reste prend la nature silicieuse mêlé de sable fin, et les gros grains de quartz restent tels, qu'ils étoient, sans changer. J'ai déjà remarqué que cette métamorphose semble s'opérer, comme celle des cailloux d'origine calcaire en forme approchans la sphérique, il faut encore y a jouter, que j'ai lieu de croire, qu'elle se fasse aussi du dedans en dehors, tout, comme la décomposition se fait du dehors au dedans.

"Il arrive dans cette pierre, comme dans toute autre, qu'il se forme des crystallisations dans les cavités. Lorsqu'elles sont de silex, leur figure est toujours mamelonnée, mais leur eau ou pureté, leur grandeur et leur couleur n'est pas par tout égale. Il y en a qui sont grands, et de la plus pure calcédoine, d'autres sont petits et chaque goutte ou mamelon contient un grain de sable, de facon que cela a l'air d'un grès crystallisè en mamelons ou stalagmitique. D'autres encore sont, de calcédoine, mais recouverts d'une croûte, tantôt blanche qui fait effervescence avec l'acide minéral, et qui est, par conséquent, de nature calcaire; tantôt cette croûte est bleue foncée nuancée de bleu-celeste; tantôt, enfin, elle est noire, mais toutes les deux réfractaires. Outre ces crystallisations silicieuses, il y en a, quoique rarement, de quartzeuses, qui ou forment de petites veines de crystal, ou bien des groupes de crystaux quartzeux, ou qui enfin, enduisent les mamelons de silex."

Our author then makes a specification of the different varieties; after which he continues, p. 69.

"Après tout ceci, l'on conviendra j'espère, que nôtre grais est une pierre bien singulière, et surpassant, à bien des égards, le grais, faussement dit crystallisé, de Fontainebleau. La raison de la figure du grais François est fort évidente, c'est le spath calcaire, qui lui sert de ciment, qui la lui fit prendre; mais qu'est-ce qui opère les métamorphoses racontées dans notre grai siliceux? Seroit-ce son ciment calcaire ou marneux par les mêmes raisons, qui font changer la marne en silex? La chose est très-probable, et je n'en saurois pas même, deviner d'autre. En ce cas la nature auroit un moyen d'opérer par la voie humide, ce que nous faisons dans nos laboratoires en quelque façon, par la voie sèche, c, a, d, de fondre et liquéfier la terre vitrescible, au moyen des alcalis; secret que nous lui avons déjà arraché en partie, en faisant la liqueur silicieuse."

"Je n'ose, cependant, décider pas même hypothétiquement, sur cette matière, pour n'avoir pu observer la nature dans ses ateliers, et parce que je ne possède que des pièces, qui détachées de leur lieu natal, depuis un très long-tems, furent exposées aux intempéries des saisons, où elles peuvent avoir souffert bien de changemens."

There cannot be a more fair exposition of facts; and it is only our author's opinion of this mineral transmutation that I would controvert. I do not pretend to understand the manner of operating that our author here supposes nature to take. I only maintain, that here, as every where in general, the loose and incoherent strata of the globe have been petrified, that is, consolidated, by means of the fusion of their substances; and this I think is confirmed from the accurate description here given of the flintification of sand-stone. Here is described very distinctly an appearance which is very common or general on those occasions; this is the parts or particles of stone floating in the fluid siliceous substance, and there dissolving more or less.

M. de Carosi describes very systematically the generation of silex, calcedony, onyx, and quartz, in calcareous earth, marl, gypsum, sand-stone, and also what he terms *terre glaise, ou de l'Argile*. It is in this last that we find a perfect analogy with what is so frequent in this country of Scotland. These are the agates, calcedonies, calcareous and zeolite nodules, which are found produced in our whin-stone or subterraneous lavas, that is, the amygdaloides of Crondstedt. Naturalists explain the formation of those nodular bodies differently. The Chevalier de Dolomieu supposes these rocks to have been erupted lavas, originally containing cavities; and that these cavities in the solid rock had been afterwards filled and crystallised, by means of infiltration, with the different substances which are found variously concreted and crystallised within the solid rocks. Our author, on the contrary, supposes these formed by a species of chemical transmutation of calcareous and argillaceous earths, which, if not altogether incomprehensible, is at least not in any degree, so far as I know, a thing to be understood.

This is not the place where that subject of these particular rocks, which is extremely interesting, is to be examined. We shall afterwards have occasion to treat of that matter at large. It is sufficient here to observe, that our author finds occasion to generalise the formation of those petrifactions with the flintifications in calcareous and gypseous bodies. When, therefore, the formation of any of them shall be demonstrated, as having taken its origin in the fusion of those substances, this mode of operation, which is generalised in the consolidation of strata, will be properly inferred in all the rest.

Petrifaction is a subject in which mineralogists have perhaps wandered more widely from the truth than in any other part of natural history; and the reason is plain. The mineral operations of nature lie in a part of the globe which is necessarily inaccessible to man, and where the powers of nature act under very different conditions from those which we find take place in the only situation where we can live. Naturalists, therefore, finding in stalactical incrustation a cause for the formation of stone, in many respects analogous to what is found in the strata of the earth, and which had come from the mineral region in a consolidated state, have, without due consideration, attributed to this cause all the appearances of petrifaction or mineral concretion. It has been one of the objects of this work to show that this operation of incrustation, or petrifaction by means of solution, is altogether ineffectual for producing mineral concretions; and that, even were it capable of forming those mineral bodies, yet that, in the solid parts of this earth, formed by a deposit of travelled materials at the bottom of the sea, the conditions necessary to this incrustating process do not take place.

Those enlightened naturalists who have of late been employed in carefully examining the evidences of mineral operations, are often staggered in finding appearances inconsistent with the received doctrine of infiltration; they then have recourse to ingenious suppositions, in order to explain that enigma. In giving examples of this kind. I have in view both to represent the natural history these mineralists furnish us with, which is extremely interesting, and also to show the various shapes in which error will proceed, when ingenious men are obliged to reason without some necessary principle in their science. We have just now had an example in Europe; I will next present the reader with one from Asia.

M. Patrin, in his *Notice Minéralogique de la Daourie*, (Journal de Physique, Mars 1791) gives us a very distinct account of what he met with in that region. Describing the country of Doutchersk upon the river Argun, in Siberia, he proceeds thus:

"Ces collines sont formées d'un hornstein gris qui paroit se convertir en pierre calcaire par l'action des météores; car tout celui qu'on prend hors du contact de l'air donne les plus vives étincelles, et ne fait pas la moindre effervescence avec les acides, même après avoir été calciné; et l'on observe celui qui est à découvert, passer, par nuances insensibles, jusqu'à l'état de pierre calcaire parfaite de couleur blanchâtre."

Here M. Patrin has persuaded himself, probably from an imperfect examination of the subject, that there takes place a mineral metamorphosis, which certainly is not found in any other part of the earth, and for which he does not find any particular cause. The natural effect of the meteors, in other parts of the earth, is to dissolve the calcareous substance out of bodies exposed to those agents; and the gradation from the one of those two things to the other, which seems to be the data on which he had proceeded in forming his conclusion, is not sufficient to prove the metamorphosis, even were there not so strong a physical objection to it; for, it is by no means unusual for mineral bodies to graduate thus from one substance to another. However that be, this is not the principal object of the example[45].

After speculating upon the effect of the ancient ocean upon the mountains of that country, he proceeds as follows:

"Je laisse ces conjectures pour remarquer un fait singulier: la colline, qui est au nord de l'église de la fonderie, a son arrête composée de ce hornstein qui se décompose en pierre calcaire; mais ici, les parties, qui sont ainsi décomposées, offrent une substance calcédonieuse disposées par zones concentriques, comme on l'observe dans les agates d'oberstein; mais ce ne sont point ici des corps parasites formés par infiltration dans des cavités pré-existantes comme les agates; on voit que ce sont les parties constituantes de la roche qui,*par un travail interne*, et par une sorte de crystallisation, out pris cette disposition régulière (que ce mot de *crystallisation* ne révolte point, j'appelle ainsi toute tendance à prendre une forme constante, polyèdre ou non polyèdre.) Les couches les plus voisine du centre sont nettes et distinctes; peu-à-peu elles le sont moins, et enfin elles s'évanouissent et se confondent avec le fond de la roche. Chaque assemblage de ces zones a une forme ronde ou ovale plus ou moins régulière de sept à huit pouces de diamètre.

[45] Here we have well informed naturalists reasoning with all the light of our present mineralogy, and maintaining, on the one hand, that gypsum is transformed into calcedony, by the operation of the meteors, or some such cause; and, on the other, that a siliceous substance is by the same means converted into lime-stone. What should we now conclude from this?—That calcareous and siliceous substances were mutually convertible. But then this is only in certain districts of Poland and Siberia. Every where, indeed, we find strange mixtures of calcareous and siliceous bodies; but neither mineralists nor chemists have, from these examples, ventured to affirm a metamorphosis, which might have spared them much difficulty in explaining those appearances.

This is a subject that may be taken in very different lights. In one view, no doubt, there would appear to be absurdity in the doctrine of metamorphosis, as there is now a days acknowledged to be in that of *lusus naturae*; and those reasoning mineralists might thus, in the opinion of some philosophers, expose their theory to contempt and ridicule. This is not the light in which I view the subject. I give those gentlemen credit for diligently observing nature; and I applaud them for having the merit to reason for themselves, which would seem to be the case with few of the many naturalists who now speak and write upon the subject.

Let us now draw an inference, with regard to this, in judging of the different theories. Either the received system concerning mineral operations is just, in which case those gentlemen, who employ a secret metamorphosis, may be to blame in laying it aside; or it is erroneous and deficient; and, in that case, they have the merit of distinguishing the error or deficiency of the prevailing system. How far they have seen the system of nature, in those examples which they have described, is another question. In the mean time, I am to avail myself of the testimony of those gentlemen of observation, by which the insufficiency at least of the received mineral system is acknowledged.

"Cela ressemble en grand à ce qu'on observe dans les pierres oeillées, et la cause est vraisemblablement la même. Je le répète, je regarde cette disposition régulière comme une véritable cristallisation, qui peut s'opérer et qui s'opère en effet dans l'intérieur des corp les plus solide, tant qu'ils sont fournis à l'action des agens de la nature.

"Tous ceux qui visitent l'intérieur de la terre savent que les roches mêmes le plus compactes y sont intimement pénétrées d'humidité, et ce fluide n'est certainement pas l'eau pure; c'est l'agent qui opère toutes les agrégations, toutes les cristallisations, tous les travaux de la nature dans le règne minéral. On peut donc aisément concevoir qu'à la faveur de ce fluide, il règne, dans les parties les plus intimes des corps souterrains, une circulation qui fait continuellement changer de place aux élémens de la matière, jusqu'a ce que réunis par la force des affinités, les corpuscules similaires prennent la forme que la nature leur a assignée."

Those nodular bodies or figured parts which are here inclosed in the rock, are evidently what may be called calcedony agates. M. Patrin is persuaded, from the examination of them, that they had not been formed in the manner of German agates, which he supposes is by mean of infiltration; and he has endeavoured to conceive another manner of operating, still however by means of water, which I suppose, according to this hypothesis, is to dissolve substances in one part, and deposits them in another, There must certainly be some great *desideratum* in that mineral philosophy which is obliged to have recourse to such violent suppositions. First, water is not an universal solvent, as it would require to be, upon this supposition; secondly, were water allowed to be an universal menstruum, here is to be established a circulation that does not naturally arise from the mixture of water and earth; and, lastly, were this circulation to be allowed, it would not explain the variety which is found in the consolidation and concretion of mineral bodies.

So long, therefore, as we are to explain natural appearances by reasoning from known principles, and not by ascribing those effects to preternatural causes, we cannot allow of this regular operation which M. Patrin alleges to be acting in the interior parts of the most solid bodies. This is indeed evident, that there has been a cause operating in the internal parts of the most solid bodies, a cause by which the elements, or constituent parts of those solid bodies, have been moved and regularly disposed, as this author very well observes must have been the case in our agates or eyed stones; but to ascribe to water this effect, or to employ either an ineffectual or an unknown cause, is not to reason philosophically with regard to the history of nature; it is to reason phantastically, and to imagine fable.

M. Monnet has imagined a petrifying power in water very different from any that has hitherto been conceived, I believe, by natural philosophers, and I also believe, altogether inconsistent with experience or matter of fact; but as it is not without good reason that this naturalist has been induced to look out for a petrifying cause different from any hitherto supposed, and as he has endeavoured very properly to refute the systems of petrification hitherto received, I would beg leave to transcribe his reasoning upon the subject in corroboration of the present theory of consolidation by the means of fusion.

It is upon occasion of describing one of the species of alpine stone or schistus which contains quartzy particles. *Nouveau voyage minéralogique, etc.* Journal de Physique Aoust 1784.

"Il y a loin de cette pierre, que je regarde comme une variété de roches ardoisées, aux véritable ardoises. La composition de toutes ces pierres est due aux terres quartzeuses et argileuses, et à la terre talqueuse, que je démontrerai un jour être une espèce particulière et distincte des autres, qui constitue les bonnes ardoises, et fait, ainsi que le quartz, qu'elles résistent aux injures de l'air, sans s'effleurir, comme je ferai voir que cette terre, qu'on désignera sous la dénomination de terre talqueuse, si l'on veut, résiste au grand feu sans se fondre. Les différences de toutes ces pierres, quoique composées des mêmes matières, mais dans des proportions différentes, sont frappantes, et pourroient faire croire qu'elles n'appartiennent pas à ce genre. Mais qui ne voit ici que toutes ces différences, ou ces variétés, ne sont dues qu'aux modifications de la matière première, qu'elle a éprouvées, soit en se mêlant avec des matières hétérogènes, prévenantes du débris des êtres qui ont existé, comme l'argile, par exemple, qui, de l'aveu de presque tous les naturalistes, est le produit de l'organization des plantes, ou soit en se mêlant avec de la matière déjà solidifiée depuis long-temps? Or nous ne craignons pas de dire, ce que nous avons dit plusieurs fois quand l'occasion s'en est présentée, que cette matière unique, que se modifie selon les occasions et les circonstances, et qui prend un caractère analogue au matières qu'elle rencontre, est l'eau, que beaucoup de naturalistes cherchent vainement ailleurs. Ils ne peuvent comprendre, malgré les exemples frappans qui pourroient les porter à adopter cette opinion, que ce fluide général soit l'élément des corps solides du règne minéral, comme il est de ceux du règne végétal et du règne animal. L'on cherche sérieusement, par des expériences chimiques, à découvrir si l'eau est susceptible de se convertir en terre comme si la nature n'avoit pas d'autre moyen que nous de la faire passer de l'état fluide à l'état solide. Voyez le spath calcaire et le quartz transparens; est il à présumer qu'ils ne sont que le résultat du dépôt des matières terreuses fait par les eaux? Mais, dans ce ca-là encore, il faut supposer que l'eau qui est restée entre ces partie s'est solidifiée; car, qu'est-elle donc devenue, et quel est donc le lien qui a uni ces parties et leur a fait prendre une forme régulière? Il est vrai qu'on nous parle d'un suc lapidifique; mais c'est-la un être de raison, dont il seroit bien plus difficile d'établir l'existence, que de croire à la solidification de l'eau. On nous donne cependant comme un principe certain que l'eau charie d'un lieu à un autre les matières qu'il a dissoutes, et qu'elle les dépose à la maniere des sels. Mais c'est supposer une chose démentie par l'experience; savoir, que l'eau ait la propriété de dissoudre les matières terreuses, telles que la quartzeuse. A la vérité, M. Auchard de Berlin y joint de l'air fixe; mais cet air fixe ne sauroit tenir en dissolution un atome de quartz dans l'eau; et quelle qu'ait été l'exactitude de ceux qui ont répété les expériences de M. Auchard, on n'a pu réussir à imiter la nature, c'est-à-dire, à former des cristaux quartzeux, comme il a annoncé. Que l'eau ait la faculté de tenir en dissolution quelques petites parties de terre calcaire, au moyen de cet air fixe, il n'en faut pas conclure qu'elle puisse former de cette maniere tous les cristaux calcaires, sans que l'eau elle-même y concoure pour sa part; car ce seroit conclure quelque fois que la partie seroit égale au tout. Voyez ces géodes calcaire et argileuses, qui renferment des cristaux nombreux de quartz ou de spath calcaire; ne sont ils que le résultat du dépôt de l'eau qui y a été renfermée, ou que la cristallization pure et simple des molécules que vous supposez avoir été tenues en dissolution par cette eau? Il naîtroit de cette opinion une foule d'objections qu'il seroit impossible de résoudre. Cependant M. Guettard, dans la minéralogie du Dauphiné, qui vient de paroître, ouvrage très-estimable à beaucoup d'égards, explique, selon cette maniere de penser, la formation de cristallizations quartzeuses qu'on trouve dans certaines géodes de cette province, et celle des mines de cristal des hautes montagnes. En supposant même comme vraie l'explication qu'il en donne, on trouveroit en cela un des plus grands problème, et des plus difficiles à résoudre qu'il y ait en minéralogie; car d'abord il faudroit expliquer comment un si petite quantité d'eau que celle qui a été renfermée dans les géodes, et celle qui est parvenue dans les fentes des rochers, ont pu fournir un si grande quantité de matière que celle qui constitue ces cristallisations, et ce qui n'est pas le moins difficile à concevoir, comment l'eau a pu charrier cette matière à travers tant de matières différentes, et la conserver précisément pour cette destination; comment, par exemple, l'eau est venue déposer de la terre quartzeuse dans les masses énormes de pierres calcaires, qui forment la côté qui domine le village de Champigny, à quatre lieues de Paris, au delà de Saint-maur; car s'il nous faut citer un exemple frappant de cette singularité, et à portée d'être vue des naturalistes qui sont dans la capitale, je ne puis mieux faire que de citer cette côté, une des plus curieuses de la France, et que je me propose de fair connoître en détail dans la troisième partie de la minéralogie de la France. On verra, dis-je, dans cette bonne pierre à chaux, et une de plus pure des environs de Paris, de très-abondantes cristallisations de quartz transparent, et quelque fois de belle eau, que les ouvriers sont forcés de séparer de la partie calcaire, à laquelle elles adhèrent fortement. Mais c'est trop nous arrêter à combattre une opinion qui doit son origine aux premières idées qu'ont eues les premiers observateurs en minéralogie, qui se détruira d'elle même comme tant d'autres dont il nous reste à peine le souvenir."

We find here an accurate naturalist, and a diligent observer, who, in conformity with what my sentiments are upon the subject, thinks it impossible that the crystallizations in close cavities, and concretions of different solid substances within each other, which so frequently occur in the mineral regions, could have been produced, by means of solution and crystallization, from a fluid vehicle. But what has he now substituted in place of this solution, in order to explain appearances?—a mere supposition, viz.

that nature may have the power of converting water, in those secret places, into some other thing; or rather that the substance of water is here converted into every other thing; for, though he has only mentioned quartz and calcareous spar, what mineral substance is there that may not be found in those close cavities? They are actually almost all, not even excepting gold; for, small grains of gold are inclosed within the cavities of a porous stone, in the Siberian mine. Now, for what purpose should nature, (to the power of which we are not to set a limit) have such an object in view as to convert water into every thing, unless it were to confound human understanding? For, so far as human experience has been as yet able to reach, there would appear to be certain elementary substances; and among these is water, or the principles of that fluid[46] . But because water is so generally found in bodies, and so necessarily in most of the operations of this world, why convert it into every other thing? Surely, for no better reason than that there has not occurred to this mineralist any other way of explaining certain natural appearances which aqueous solution could not produce. Here is no dispute about a matter of fact; it is on all hands allowed, that in certain cavities, inaccessible to any thing but heat and cold, we find mineral concretions, which contain no water, and which, according to the known operations of nature, water could not have produced; must we therefore have recourse to water acting according to no known principle, that is to say, are we to explain nature by a preternatural cause?

I dare say that this is not the view that M. Monnet takes of the subject, when he thinks to explain to himself the concretion of those different substances by means of water; but, according to my apprehension of the matter, his theory, when sifted to the bottom, will bear no other construction; and, unless he shall consider water like the matter of heat, as

[46] Water is now considered by men of science, as a compound substance; this doctrine, which seems to follow so necessarily from the experiments of the French philosophers, must be tried by the growing light of chemical science. In the oxygenating operation of inflammable and combustible bodies when burning, those ingenious chemists overlooked the operation of *phlogistic matter*, which has no weight, and which escapes on that occasion, as I have had occasion to show in a dissertation upon phlogiston, and in the Philosophy of Light, Heat, and Fire. How far this view, which I have given of those interesting experiments, may lead to the explanation of other collateral phenomena, such as that of the water produced, I will not pretend to conjecture. One thing is evident, that if the weight of the water, procured in burning inflammable and vital air, be equal to that of those two gasses, we would then have reason to conclude, either that water were a compound substance, or that vital air, and inflammable vapour were compounds of water and the matter of light, or solar substance.

capable of producing the fluidity of fusion, and of being also again abstracted from the fluid, by pervading the most solid body, which would then be a substance different from water, he must employ this aqueous substance as a menstruum or solvent for solid bodies, in the same manner as has been done by those naturalists whom he he justly censure, and conform to those erroneous ideas which first observations, or inaccurate knowledge of minerals, may have suggested to former naturalists.

It is the dissolution and concretion of siliceous substance, no doubt, that gives such difficulty to our naturalists in explaining petrifaction: they have, however, something apparently in their favour, which it may be proper now to mention.

In the *first* place, although siliceous substance is not soluble, so far as we know, by simple water, it is soluble by means of alkaline substance; consequently, it is possible that it may be dissolved in the earth.

Secondly, The water of Giezer in Iceland, actually petrifies bodies which are alternately imbibed with that hot water and exposed to the air. This water, therefore, not only contains siliceous substance in a dissolved state, but deposits this again, either by means of cooling, or being aerated, or of evaporating. Consequently, without knowing the principle upon which it proceeds, we here perceive a natural operation by which siliceous petrifaction may be performed.

Lastly, We have another principle for the dissolution of siliceous substance. This is the fluor acid which volatilises the siliceous substance. This, however, requires certain conditions, which cannot be found as a general cause in the mineral regions.

Thus we would seem to have every thing necessary for explaining the concretion and crystallization of siliceous bodies, provided we could find the proper conditions requisite for that operation; for whether it shall be by means of acid or alkaline substances that siliceous matter is to be dissolved, volatilised, and transported from one place to another, it is necessary that those dissolving substances should be present upon those occasions. Nor is it sufficient only to dissolve the siliceous substance which is to be transported; the necessary conditions for the concretion again of the dissolved substances, whatever these may be, are also absolutely required for this operation. Now, though those requisite conditions may be, upon many occasions, allowed in the earth, it is not according to the theory of our modern naturalists, who explain petrifaction upon the principles of simple infiltration of water, that any advantage can be taken of those conditions; nor are natural appearances to be explained without employing more complicated chemical agents in the mineral regions.

To this subject of the petrifactions of Giezier, I may now add the information which we have received in consequence of a new voyage from this country to Iceland.

When Sir Joseph Banks returned from his expedition to Iceland, he landed at this place; and, having brought specimens of the petrifications of Giezer, Dr Black and I first discovered that these were of a siliceous substance. I have always conjectured that the water of Giezer must be impregnated with flinty matter by means of an alkaline substance, and so expressed my opinion in the Theory of the Earth published in the Transactions of the Edinburgh Royal Society. We have therefore been very desirous of procuring some of that water, in order to have it analysed.

An opportunity favourable to our views has occurred this summer. Mr Stanley set out from this place with the same purpose of examining Iceland. He was so good as to ask of Dr Black and I what inquiries we would incline that he should make. We have now, by the favour of this gentleman, obtained specimens of the petrifactions of Giezer; and, what is still more interesting, we have procured some of the water of those petrifying boiling springs.

It appears from these specimens, that the boiling water which is ejected from those aqueous volcanoes, if we may use the expression, is endued with the quality of forming two different species of petrifaction or incrustation; for, besides the siliceous bodies, of which we had before received specimens, the same stream of water incrustates its channel with a calcareous substance. All the specimens which I have seen consist of incrustation, some purely siliceous, some calcareous, and others mixed of those two, more or less.

Dr Black has been analysing the water; and he finds in it siliceous matter dissolved by an alkaline substance, in the manner of liquor silicum[47]. My conjecture has thus been verified.

It must not be alleged that nature may operate in the mineral regions, as she does here upon the surface in the case of Giezer. Such an argument as this, however sound it may be in general, will not apply to the subject of which we treat at present. There is no question about the limiting the powers of nature; we are only considering nature as operating in a certain determined manner, viz. by water acting simply upon the loose materials of the land deposited at the bottom of the sea, and accumulated in regular strata, one upon another, to the most enormous depth or thickness. This is the situation and condition of things in which nature is to operate; and we are to find the means of consolidating those strata, and concreting every species of substance in almost every possible composition, according to some known physical principle. Here is an operation which is limited; for, we must reason strictly, according to the laws of nature, in the case which we have under consideration; and we cannot suppose nature as ever transgressing those laws.

It is acknowledged, that, by means sometimes of an aeriform, sometimes of an alkaline, perhaps also of an acid substance, calcareous matter is dissolved in the earth, and certain metallic substances, such as lead and iron. This solution also, upon particular occasions, (where the proper conditions for separating the solvent from the dissolved substance exist), forms certain concretions; these are sometimes a mere incrustation, as in the case of the siliceous incrustation of Giezer, sometimes again in a crystallised or sparry form, as in the case of stalactical concretions. But here is no question of those cases where the proper conditions may be found; first, of dissolving the substance which is afterwards to be concreted; secondly, of separating the menstruum from the dissolved substance; and, lastly, of removing the fluid deprived of its solution, and of supplying a new solution in its room; the question is, how far those concretions are formed where those conditions do not take place. Now, this last case is that of almost all mineral concretions.

[47] See Trans. of the Edin. Royal Society.

It must not be here alleged that certain concretions have been found in mines posterior to these having been worked by man; consequently, that those concretions have been formed by nothing but the infiltration of water. In those cases, where such concretions are truly found, I am persuaded that all the conditions proper to that operation will also be found; and it is only, I believe, in those cases where such proper conditions may be found, that this aqueous concretion ever appears. Now, if we shall except calcareous stalactite, and the bog ore of iron, How seldom is it that any appearance of those aqueous mineral concretion ever is found? Those very few cases in which they are found, afford the strongest proof against these being operations general to the globe, or proper mineral concretions; because it is only where all the necessary conditions conspire in each contributing its part, that the effect is accomplished; and this is a thing which cannot possibly take place in the aquiform strata below the surface of the sea. But, without attending to this clear distinction of things perfectly different, naturalists are apt to see false analogies, and thus in generalising to form the most erroneous theories.

I shall now give an example of this fallaceous manner of reasoning; it is in the case of certain mineral appearances which are erroneously considered as stalactical concretions.

The only true stalactical bodies are of a calcareous substance; they are formed by water containing this substance in a dissolved state; and the principles upon which this particular concretion is formed are well known. It is therefore easy to compare other concretions, which may have some superficial resemblance to these stalactical bodies, in order to see if they have proceeded upon the same principle of concretion from a dissolved state, or by water depositing its dissolved substance in a similar manner.

There are two different mineral substances which give appearances of this sort. These are certain concretions of calcedony, and also of iron-ore, which are thought to have such resemblance to stalactical concretions as, by some superficial observers, to be reckoned of the same kind. It is now proposed to show that those conclusions are not well founded; and that, in this case of calcedony and iron-ore, it could not be upon the principle of stalactical concretion that the bodies now in question had their forms.

The principle upon which calcareous substance is dissolved in water, and made to concrete by the evaporation of the acid substance, or fixed air by which it had been dissolved, is too well known to require any explanation in this place; we are only to consider the sensible effects of those operations of which we know so well the proper conditions.

There are just two distinct views under which we may consider all stalactical concretions formed; these are the incrustation of the calcareous substance concreting upon a foreign body, and the incrustation of the same substance upon itself. By the first any manner of shape may be formed, provided there be a solid body, upon the surface of which the calcareous solution is made to pass. By the second, again, we have various forms; but we know the principles upon which they had been made. These are the shape and motions of the fluid which gives the calcareous concretion. Now, these principles are always to be perceived, more or less, in all the bizarre or fantastical, as well as regular shapes which are produced by stalactical concretions. At present, we shall confine our views to one particular shape, which is simple, regular, and perfectly understood wherever it is formed.

Drops of water falling from a roof, and forming stalactite, produce first tubular bodies, and then gradually consolidate and increase those pendulous bodies by incrustation. These appearances are thought to be observed in the calcedony and ferruginous concretions, which has led some mineralists to conclude, that those concretions had been formed in the same manner, by means of water. We are now to show that these mineral appearances are not analogous to stalactites in their formation, and that they have evidently been formed in a different manner.

It must be evident, that, in the formation of those pendulous bodies, each distinct stalactite must be formed by a separate drop of water; consequently, that no more stalactites can be formed in a given space, than there could have subsisted separate drops of water. Now, a drop of water is a very determined thing; and thus we have a principle by which to judge of those mistaken appearances.

Let us suppose the gut of water to be but one eighth of an inch, although it is a great deal more, we should have no stalactites formed nearer to each other than that measure of space. But those mineral concretions, which are supposed to be stalactical, are contained in half that space, or are nearer to each other than the tenth or twentieth of an inch. I have them like needles, and in every degree of proximity or contiguity, at the same time that they are perfectly solid. Therefore, it is plainly impossible that they could have been formed upon this principle of calcareous stalactite. But, it is only by this false resemblance, that any argument can be formed for the concretion of those bodies from an aqueous solution; in every other respect they are true mineral concretions; and, that these have had a very different origin, has been already the subject of investigation, and will be more particularly examined in the course of this work.

The term *infiltration*, which has been much employed for explaining mineral appearances, is too vague, imperfect, or unexplicit, for science, whether as the means of knowing nature, or the subject of confutation. This is not the case with that of stalactite; here is a term that implies a certain natural operation, or a most distinct process for attaining a certain end; and we know the principles upon which it proceeds, as well as the several steps that may be traced in the general result. It is an operation which has not only been analysed to its principles; it is also a process which is performed by man, proceeding on his acquired knowledge. Now, were this operation common to the mineral regions, as it is proper to the surface of this earth; we could not remain in any degree of suspense with regard to the origin of those mineral bodies; for, having the true clue of knowledge, we should be able to unravel the most intricate and mysterious appearance. But, so far from this being the case, the more we come to inquire into nature, and employ this principle, the less we find it applicable, and the more involved in darkness is our science.

The places where these false appearances of stalactite are found, are precisely those in which, from the nature of things, all possibility for such an operation is excluded. For, How can this take place within a closs cavity in the mineral regions? The term *vegetation* may as well be employed for the explanation of those appearances: But what would now be said of such an explication? It is high time that science were properly applied to the natural history of this earth, and mineralists not allowed to impose upon themselves with false reasoning, or to please themselves with the vain attempt of explaining visible effects by unknown causes.

Such various inconsistent opinions, respecting petrifaction or mineral concretion, as I have now exposed, opinions that are not founded on any sound physical principle, authorise me to conclude that they are all erroneous. If this be admitted, it will follow that we have no proof of any proper mineral concretion except that which had proceeded by congelation from the fluid state of fusion. This has been the doctrine which I have held out in my Theory of the Earth; and this will be more and more confirmed as we come to examine particular mineral appearances.

Chapter 8. The Nature Of Mineral Coal, And The Formation Of Bituminous Strata, Investigated

Section 1. Purpose Of This Inquiry

In the first chapter, I have given a perfect mark by which to judge, of every consolidated stratum, how far that had been the operation or effect of water alone, or if it had been that of heat and fusion. This is the particular veins or divisions of the consolidated stratum, arising from the contraction of the mass, distended by heat, and contracted in cooling. It is not an argument of greater or lesser probability; it is a physical demonstration; but, so far as I see, it would appear to be for most mineralists an unintelligible proposition. Time, however, will open the eyes of men; science will some day find admittance into the cabinet of the curious. I will therefore now give another proof,—not of the consolidation of mineral bodies by means of fusion, for there is no mineral body in which that proof is not found,—but of the inconsistency of aqueous infiltration with the appearances of bodies, where not only fusion had been employed for the consolidation, but where the application of heat is necessary, and along with it the circumstances proper for *distillation*.

Short-sighted naturalists see springs of water issuing from the earth, one forming calcareous incrustations, the other depositing bituminous substances. Here is enough for them to make the theory of a world; on the one hand, solid marble is explained, on the other, solid coal. Ignorance suspects not error; their first step is to reason upon a false principle;—no matter, were they only to reason far enough, they would soon find their error by the absurdity into which it lands them. The misfortune is, they reason no farther; they have explained mineralogy by infiltration; and they content themselves with viewing the beautiful specimens in their cabinet. the supposed product of solution and crystalization. How shall we inform such observators; How reason with those who attend not to an argument!

As naturalists have explained all mineral concretions from aqueous or other solution, and attributed to infiltration the formation of those stony bodies in which there are marks of their original composition, so have they explained to themselves, I suppose, the origin of those bituminous bodies which are found among the strata of the earth. In the case of stony substances, I have shown how unfounded all their theories are for the production of those concretions, crystallizations, and consolidated bodies. I am here to examine the subject of inflammable and combustible bodies, which I believe have been little considered by those theorists who suppose mineral bodies consolidated by infiltration. It is here that we shall find an infinite difference between the aqueous and igneous theories; for, we shall find it impossible to explain by the one certain operations which must have necessarily required the great agent generally employed in the other.

The subject of this chapter is a touch-stone for every theory of the earth. In every quarter of this globe, perhaps in every extensive country, bituminous strata are to be found; they are alternated with those which are called aquiform, or which had been evidently formed by subsidence of certain moved materials at the bottom of the sea; so far, therefore, all those strata have had the same origin. In this point I think I may assert, that all the different theories at present are agreed; and it is only concerning certain transformations of those strata, since their original collection, that have been ascribed to different causes.

Of these transformations, which the strata must have undergone, there are two kinds; one in relation to change of place and position; the other in relation to solidity or consistence. It is only the last of those two changes which is here to be the subject of consideration; because, with regard to the first, there is nothing peculiar in these bituminous strata to throw any light, in that respect, upon the others. This is not the case with regard to the transformation in their chemical character and consistence; bituminous bodies may not be affected by chemical agents, such as fire and water, in the same manner as the argillaceous, siliceous, micaceous, and such other strata that are alternated with the bituminous; and thus we may find the means for investigating the nature of that agent by which those strata in general have been transformed in their substance; or we may find means for the detecting of false theories which may have been formed with regard to those operations in which the original deposits of water had been changed.

We have had but two theories, with regard to the transformation of those bodies which have had a known origin, or to the change of their substance and consistence; the one of these which I have given is that of heat or fusion; the other, which I wish to be compared with mine, is that of water and infiltration. It is by this last that all authors hitherto, in one shape or another, have endeavoured to explain the changes that those strata must have undergone since the time of their first formation at the bottom of the sea. They indiscriminately apply the doctrine of infiltration to those strata of mineral coal as to any other; they say that bituminous matter is infiltrated with the water, impregnates certain strata of earth with bituminous matter, and thus converts them into mineral coal, and bituminous strata. This is not reasoning physically, or by the inductive method of proceeding upon matter of fact; it is reasoning fantastically, or by making gratuitous supposition founded merely on imagination. It was thus that natural philosophers reasoned before the age of science; the wonder now is, how men of science, in the present enlightened age, should suffer such language of ignorance and credulity to pass uncensured.

The subject which I am now to treat of consists of peculiar strata of the earth, bodies which we may investigate through all the stages of their change, which is extreme; for, from vegetable bodies produced upon the habitable earth, they are now become a mineral body, and the most perfect coal,—a thing extremely different from what it had been, and a thing which cannot be supposed to have been accomplished by the operation of water alone, or any other agent in nature with which we are acquainted, except the action of fire or heat. It is therefore impossible for a philosopher, reasoning upon actual physical principles, not to acknowledge in this a complete proof of the theory which has been given, and a complete refutation of that aqueous operation which has been so inconsiderately supposed as consolidating the strata of the earth, and forming the various mineral concretions which are found in that great body.

To see this, it will be sufficient to trace the progress of vegetable and animal substances, (bodies which had certainly lived by means of a former earth), to this changed state in which they have become perfect mineral bodies, and constitute a part of the present earth. For, as these changes are perfectly explained by the one theory, and absolutely inconsistent with the other, there arises from this a conviction that must be irresistible to a person who can give proper attention to a chain of reasoning from effect to cause.

But if we thus succeed to illustrate the theory of the earth by the natural history of those particular strata, we have but one step farther to make in order to bring all the other parts of the earth, whether stratified or not, into the most perfect consistence with the theory; now this step, it will be most easy to make; and I shall now mention it, that so the reader may keep it in his view: Pyrites is a sulphureo-metallic substance, which cannot be produced by means of water, a substance which the influences of the atmosphere decomposes or separates into its elements, and which even our imperfect art may be considered as able to produce, by means of fusion in our fires. Therefore, the finding of this creature of fire intimately connected with those consolidated strata of mineral coal, adds the greatest confirmation, were it necessary, to the doctrine of those mineral bodies having been consolidated by fusion. This confirmation, however, is not necessary, and it is not the only thing which I am at present to illustrate in that doctrine. What I have now in view is, to homologate the origin of those coal strata, with the production of every other mineral substance, by heat or fusion; and this is what the intimate connection of pyrites with those strata will certainly accomplish. This will be done in the following manner:

Pyrites is not only found in great masses along with the coal strata; it is contained in the veins which traverse those strata, and in the minute ramifications of those veins, which are occasioned by the contraction of the mass, and generally divide it into small cubical pieces; but besides that extrinsic connection, (as it may be called,) with the stratum of coal, pyrites is found intimately connected with that solid body, in being mixed with its substance. If, therefore, it were proved, that either the one or other of those two substances had been consolidated by fusion, the other must be acknowledged as having had the same origin; but now I am to prove, from the natural history of mineral coal, that pyrites had been there formed by fusion; and then, by means of the known origin of that sulphureo-metallic substance, we shall extend our knowledge to the origin of every other mineral body.

The process of this argument is as follows: Every mineral body, I believe, without exception, will be found so intimately connected with pyrites, that these two things must be concluded as having been together in a fluid state, and that, whatever may have been the cause of fluidity in the one, this must have also caused the fluidity in the other; consequently, whatever shall be proved with regard to the mineral operations of pyrites, must be considered as proved of every other mineral substance. But, from the connection of pyrites with mineral coal, it is to be proved that the origin of this metallic body had been fusion; and then it will appear, that all other mineral bodies must have been more or less in fusion, or that they must have been consolidated by means of heat, and not by any manner of solution or aqueous infiltration. I therefore now proceed to take a view of the natural history of coal strata,—a subject which mineralogists seem not inclined to engage with, although the most ample data are to be found for that investigation.

Section 2. Natural History Of Coal Strata, And Theory Of This Geological Operation.

Fossil coal is the species of stratum best understood with regard to its accidents, as being much sought after; at least, this is the case in many parts of Britain, where it supplies the place of wood for burning. This fossil body has the most distinguished character; for, being inflammable or combustible in its nature, there is no other species of stratum that may be confounded with it.

But, though coal be thus the most distinguishable mineral, and that which is best understood in the science of mining, it is perhaps the most difficult to be treated of in the science of mineralogy; for, not having properly any distinguishable parts, we have nothing in the natural constitution of this body, as we have in most other strata, to lead us to the knowledge of its original state or first formation.

The varieties of coal are distinguished by their different manner of burning; but, from appearances of this kind, no perfect judgement can be formed with regard to the specific manner in which those strata had been made; although, from chemical principles, some conclusion may be drawn concerning certain changes which they have undergone since they had been formed.

Thus we have one species of coal which is extremely fusible, abounds with oil, and consequently is inflammable; we have another species again which is perfectly fixed and infusible in the fire; therefore, we may conclude upon principle, that, however, both those coals must have undergone the operation of heat and fusion, in bringing them to their present state, it is only the last that has become so much evaporated as to become perfectly fixed, or so perfectly distilled, as to have been reduced to a caput mortuum.

The argument here employed is founded upon this fact; that, from the fusible species of coal, a caput mortuum may be formed by distillation, and that this chemical production has every essential quality, or every peculiar property, of the fixed and infusible species; although, from the circumstances of our operation, this caput mortuum may not have precisely the exterior appearance of the natural coal. But, we have reason to believe, it is not in the nature of things to change the infusible species, so as to make it fusible or oily. Now, that this body was not formed originally in its present state, must appear from this, that the stratum here considered is perfectly solid; but, without fusion, this could not have been attained; and the coal is now supposed to be infusible. Consequently, this fixed substance, which is now, properly speaking, a perfect coal, had been originally an oily bituminous or fusible substance. It is now a fixed substance, and an infusible coal; therefore, it must have been by means of heat and distillation that it had been changed, from the original state in which this stratum had been formed.

We have thus, in the examination of coal strata upon chemical principles, received a certain lesson in geology, although this does not form a proper distinction by which to specify those strata in general, or explain the variety of that mineral. For, in this manner, we could only distinguish properly two species of those strata; the one bituminous or inflammable; the other proper coal, burning without smoke or flame. Thus it will appear that, as this quality of being perfectly charred is not originally in the constitution of the stratum, but an accident to which some strata of every species may have been subjected, we could not class them by this property without confounding together strata which had differences in their composition or formation. Therefore, we are led to inquire after some other distinction, which may be general to strata of fossil coal, independent of those changes which this substance may have undergone after it had been formed in a stratum.

Perfect mineral coal being a body of undistinguishable parts, it is only in its resolution that we may analyse it, and this is done by burning. Thus, in analysing coal by burning, we have, in the ashes alone, that by which one species of coal may be distinguished from another; and, if we should consider pure coal as having no ashes of itself, we should then, in the weight of its ashes, have a measure of the purity of the coal, this being inversely as the quantity of the ashes. Now, though this be not accurately true, as the purest coal must have some ashes proper to itself, yet, as this is a small matter compared with the quantity of earthy matter that may be left in burning some species of coal, this method of analysis may be considered as not far removed from the truth.

But, in distinguishing fossil coal by this species of chemical analysis, not only is there to be found a perfect or indefinite gradation from a body which is perfectly combustible to one that is hardly combustible in any sensible degree, we should also fall into an inconveniency similar to that already mentioned, of confounding two things extremely different in their nature, a bituminous body, and a perfect charcoal. Thus, if we shall found our distinction upon the fusibility and different degree of having been charred, we shall confound fossil coals of very different degrees of value in burning, or of very different compositions as strata; if, again, we found it upon the purity of composition, in judging from the ashes, we shall confound fossil bodies of very different qualities, the one burning with much smoke and flame, the other without any; the one fusible almost like wax, the other fixed and infusible as charcoal.

It will now appear, that what cannot be done in either the one or other of those two methods, may in a great degree, or with considerable propriety, be performed in employing both.

Thus, whether for the economical purposes of life, or the natural history of fossil coal, those strata should be considered both with regard to the purity of their composition as inflammable matter deposited at the bottom of the sea, and to the changes which they have afterwards undergone by the operation of subterranean heat and distillation.

We have now considered the original matter of which coal strata are composed to be of two kinds; the one pure bitumen or coal, as being perfectly inflammable or combustible; the other an earthy matter, with which proper coal may be variously mixed in its composition, or intimately connected, in subsiding from that suspended state by which it had been carried in the ocean. It is a matter of great importance, in the physiology of this globe, to know that the proper substance of coal may be thus mixed with heterogeneous bodies; for, supposing that this earthy matter, which has subsided in the water along with coal, be no farther connected with the combustible substance of those strata, than that it had floated in the waters of the ocean, and subsided *pari passu* with the proper materials of the coal, we hence learn a great deal with regard to the state in which the inflammable matter must have been at the time of its formation into strata. This will appear by considering, that we find schistus mixed with coal in the most equal or uniform manner, and in almost every conceivable degree, from the purest coal to the most perfect schistus. Hence we have reason to conclude, that, at the formation of those strata, the bituminous matter, highly subtilised, had been uniformly mixed with the earth subsiding in the water.

Not only is the bituminous matter of coal found mixed in every different proportion with the earthy or uninflammable materials of strata, but the coaly or bituminous composition is found with perhaps every different species of substance belonging to strata. This is certain, that we have the coaly matter intimately mixed with argillaceous and with calcareous strata.

Thus it will appear, that it is no proper explanation of the formation of coal strata, to say that vegetable matter is the basis of those strata; for though, in vegetation, a substance proper for the formation of bituminous matter is produced, it remains to know by what means, from a vegetable body, this bituminous matter is produced, and how it comes to be diffused in that subtile state by which it may be uniformly mixed with the most impalpable earth in water. Could we once resolve this question, every other appearance might be easily explained. Let us therefore now endeavour to discover a principle for the resolving of this problem.

There are two ways in which vegetable bodies may be, in part at least, resolved into that subtilised state of bituminous matter after which we inquire; the one of these is by means of fire, the other by water. We shall now consider these severally as the means of forming bituminous strata, although they may be both employed by nature in this work.

When vegetable bodies are made to burn, there is always more or less of a fuliginous substance formed; but this fuliginous substance is no other than a bituminous body in that subtilised state in which it is indefinitely divided, and may be mixed uniformly with any mass of matter equally subtilised with itself. But this is precisely what we want, in order to compose the strata of coal in question. If, therefore, there were to be found in the ocean such a fund of this fuliginous substance as might suffice for the formation of bituminous strata, no difficulty would be left in explaining the original of fossil coal. But tho' sufficient quantity of this fuliginous matter might not be found for the explanation of natural appearances, yet there cannot be a doubt that more or less of this matter must be produced in the mineral operations of the globe, and be found precisely in that place where it is required for the forming of those strata of coal.

In order to conceive this, we are to consider, that there are actually great quantities of coal strata in a charred state, which indicates that all their more volatile oleaginous or fuliginous matter had been separated by force of subterranean heat; and, we are to suppose that this had been transacted at the bottom of the ocean: Consequently, a subtile oleaginous, bituminous, or fuliginous substance, must have been diffused in that ocean; and this bituminous matter would be employed in forming other strata, which were then deposited at the bottom of the waters.

But besides this quantity of bituminous matter which is necessarily formed in the mineral operations of the earth, and with regard to the quantity of which we can never form a proper estimate, there must enter into this same calculation all the fuliginous matter that is formed in burning bodies upon the surface of this earth. This bituminous matter of smoke is first delivered into the atmosphere, but ultimately it must be settled at the bottom of the sea. Hence though, compared with the quantity that we think required, each revolution of the globe produces but a little in our estimation, yet the progress of time, in reforming worlds, may produce all that is necessary in the formation of our strata.

There now remains to explain the other way in which bituminous matter may be obtained from vegetable bodies, that is, by means of water. For this purpose we must begin with a part of natural history that will throw some light upon the subject.

All the rivers in Scotland run into the sea tinged with a brown substance; this is most evident in some of them after a flood, and while yet the river is swelled; but, in travelling to the north of Scotland in the summer season, without any rain, I saw all the rivers, without exception, of a brown colour, compared with a river of more clear water. This colour proceeds from the moss water, as it is called, which runs into the rivers, or the infusion of that vegetable substance which forms combustible turf, called peat. Now, this moss water leaves, upon evaporation, a bituminous substance, which very much resembles fossil coal. Therefore, in order to employ this vegetable infusion, delivered into the ocean for the purpose of forming bituminous strata at its bottom, it is only required to make this bituminous matter separate and subside.

If now we consider the immense quantity of inflammable vegetable substance, dissolved in water, that is carried into the sea by all the rivers of the earth, and the indefinite space of time during which those rivers have been pouring in that oily matter into the sea; and if we consider, that the continual action of the sun and atmosphere upon this oily substance tends, by inspissation, to make it more and more dense or bituminous, we cannot hesitate in supposing a continual separation of this bituminous matter or inspissated oil from the water, and a precipitation of it to the bottom of the sea. This argument is corroborated by considering, that, if it were otherwise, the water of the sea must have, during the immense time that rivers are proved to have run, be strongly impregnated with that oily or bituminous substance; but this does not appear; therefore we are to conclude, that there must be the means of separating that substance from the water in which it had been dissolved.

If there is thus, from the continual perishing of animal and vegetable bodies upon the surface of this earth and in the sea, a certain supply of oily or bituminous matter given to the ocean, then, however small a portion of this shall be supposed the whole oily or inflammable matter produced upon the surface of the earth, or however long time it may require for thus producing a stratum or considerable body of coal, we must still see in this a source of the materials proper for the production of that species of strata in the bottom of the sea.

We have now considered the proper materials of which pure fossil coal is chiefly formed; we have at present to consider what should be the appearances of such a substance as this collected at the bottom of the sea, and condensed or consolidated by compression and by heat. We should thus have a body of a most uniform structure, black, breaking with a polished surface, and more or less fusible in the fire, or burning with more or less smoke and flame, in proportion as it should be distilled or inspissated, less or more, by subterranean heat. But this is the description of our purest fossil coals, which burn in giving the greatest quantity of heat, and leave the smallest quantity of ashes.

In order to form another regular species of coal, let us suppose that, along with the bituminous substance now considered, there shall be floating in the water of the ocean a subtile earthy substance, and that these two different substances shall subside together in an uniform manner, to produce a stratum which shall be covered with immense weight, compressed, condensed, and consolidated as before, we should thus have produced a most homogeneous or uniform body to appearance, but not so in reality.

The mixture of heterogeneous matter, in this case, is too minute to be discovered simply by inspection; it must require deep reflection upon the subject, with the help of chemical analysis, to understand the constitution of this body, and judge of all the circumstances or particulars in which it differs from the former. It is worth while to examine this subject with some attention, as it will give the most instructive view of the composition of bituminous strata, both those which are not considered as coal, and also the different species of that mineral body.

In the first place then, if the mixture of those two different substances had been sufficiently perfect, and the precipitation uniform, the solid body of coal resulting from this mixture, would not only appear homogeneous, but might break equally or regularly in all directions; but the fracture of this coal must visibly differ from the former, so far as the fracture of this heterogeneous coal cannot have the polished surface of the pure bituminous body; for, the earthy matter that is interposed among the bituminous particles must affect the fracture in preventing its surface from being perfectly smooth. This imperfect plane of the fracture may be improved by polishing; in which case the body might be sufficiently smooth to have an agreeable polish; but it cannot have a perfect polish like a homogeneous body, or appear with that glassy surface which is naturally in the fracture of the pure bituminous coal.

But this is also a perfect description of that species of coal which is called in England Kennel coal, and in Scotland Parrot coal. It is so uniform in its substance that it is capable of being formed on the turning loom; and it receives a certain degree of polish, resembling bodies of jet.

Thus, we have a species of coal in which we shall find but a small degree of fusibility, although it may not be charred in any degree. Such an infusible coal may therefore contain a great deal of aqueous substance, and volatile oily matter; consequently may burn with smoke and flame. But this same species of coal may also occasionally be charred more or less by the operation of subterranean heat; and, in that case, we should have a variety of coal which could only be distinguished, from a similar state of pure bituminous coal, by the ashes which they leave in burning. At least, this must be the case, when both species are, by sufficient distillation, reduced to the state of what may be properly termed a chemical coal.

But in the natural state of its composition, we find those strata of kennel or parrot coal, possessing a peculiar property, which deserves to be considered, as still throwing more light upon the subject.

We have been representing these strata of coal as homogeneous to appearance, and as breaking indifferently in all directions; this last, perhaps, is not so accurate; for they would seem to break chiefly into two directions, that is, either parallel or perpendicular to the bed. Thus we have this coal commonly in rectangular pieces, in which it is extremely difficult to distinguish the direction of the bed, or stratification of the mass. By an expert eye, however, this may be in general, or at least sometimes, distinguished, and then, by knowing the habit of the coal in burning, a person perfectly ignorant of the philosophy of the matter may exhibit a wonderful sagacity, or even of power over future events, in applying this body to fire; for, at his pleasure, and unknown to those who are not in the secret; he may apparently, in equal circumstances, make this coal either kindle quietly, or with violent cracking and explosions, throwing its splinters at a distance.

The explanation lies in this, that, though the rectangular mass of coal appears extremely uniform in its structure, it is truly a stratified mass; it is therefore affected, by the sudden approach of fire in a very different manner, according as the edge of the stratum, which is seen in four of the sides of this supposed cube, shall be applied to the fire, or the other two sides, which are in the line of the stratum, or parallel to the bed of coal. The reason of this phenomenon now remains to be considered.

When the edge of the coal is exposed to the fire, the stratification of the coal is opened gradually by the heat and expanding vapours, as a piece of wood, of a similar shape, would be by means of wedges placed in the end way of the timber. The coal then kindles quietly, and quickly flames, while the mass of this bituminous schistus is opening like the leaves of a book, and thus exhibits an appearance in burning extremely like wood. But let the fire be applied to the middle of the bed, instead of the edge of the leaves, and we shall see a very different appearance; for here the expanded aqueous vapours, confined between the *laminae*, form explosions, in throwing off splinters from the kindling mass; and this mass of coal takes fire with much noise and disturbance.

The ashes of this coal may be determined as to quality, being in general a subtile white earth; but, as to quantity, the measure of that earth produces an indefinite variety in this species of coal; for, from the kennel or parrot coal, which is valuable for its burning with much flame, to that black schistus which our masons use in drawing upon stone, and which, though combustible in some degree, is not thought to be a coal, there is a perfect gradation, in which coal may be found with every proportion of this earthy alloy.

Among the lowest species of this combustible schistus are those argillaceous strata in Yorkshire from whence they procure alum in burning great heaps of this stone, which also contains sulphur, to impregnate the aluminous earth with its acid. We have also, in this country, strata which differ from those aluminous schisti only in the nature of the earth, with which the bituminous sediment is mixed. In the strata now considered, the earth, precipitated with the bituminous matter, being calcareous, has produced a limestone, which, after burning especially, is perfectly fissile.

Therefore, with regard to the composition of mineral coal, the theory is this. That inflammable, vegetable, and animal substances, in a subtilised state, had subsided in the sea, being mixed more or less with argillaceous, calcareous, and other earthy substances in an impalpable state. Now, the chemical analysis of fossil coal justifies that theory; for, in the distillation of the inflammable or oily coal, we procure volatile alkali, as might be naturally expected.

Thus we have considered fossil coal as various, both in its state and composition; we have described coal which is of the purest composition, as well as that which is most impure or earthy; and we have shown that there is a gradation, from the most bituminous state in which those strata had been formed in being deposited at the bottom of the sea, to the most perfect state of a chemical coal, to which they have been brought by the operation of subterranean fire or heat.

We have been hitherto considering fossil coal as formed of the impalpable parts of inflammable bodies, united together by pressure, and made to approach in various degrees to the nature of a chemical coal, by means of subterranean heat; because, from the examination of those strata, many of them have evidently been formed in this manner. But vegetable bodies macerated in water, and then consolidated by compression, form a substance of the same kind, almost undistinguishable from some species of fossil coal. We have an example of this in our turf pits or peat mosses; when this vegetable substance has been compressed under a great load of earth, which sometimes happens, it is much consolidated, and hardens, by drying, into a black body, not afterwards dilutable or penetrated by water, and almost undistinguishable in burning from mineralised bodies of the same kind.

Also, when fossil wood has been condensed by compression and changed by the operation of heat, as it is frequently found in argillaceous strata, particularly in the aluminous rock upon the coast of Yorkshire, it becomes a jet almost undistinguishable from some species of fossil coal.

There cannot therefore be a doubt, that if this vegetable substance, which is formed by the collection of wood and plants in water upon the surface of the earth, were to be found in the place of fossil coal, and to undergo the mineral operations of the globe, it must at least augment the quantity of those strata, though it should not form distinct strata by itself.

It may perhaps be thought that vegetable bodies and their impalpable parts are things too far distant in the scale of magnitude to be supposed as subsiding together in the ocean; and this would certainly be a just observation with regard to any other species of bodies: But the nature of vegetable bodies is to be floatant in water; so that we may suppose them carried at any distance from the shore; consequently, the size of the body here makes no difference with regard to the place or order in which these are to be deposited.

The examination of fossil coal fully confirms those reasonable suppositions. For, *first*, The strata that attend coal, whether the sandstone or the argillaceous strata, commonly, almost universally, abound with the most distinct evidence of vegetable substances; this is the impressions of plants which are found in their composition. *Secondly*, There is much fossil coal, particularly that termed in England clod coal, and employed in the iron foundry, that shows abundance of vegetable bodies in its composition. The strata of this coal have many horizontal interstices, at which the more solid shining coal is easily separated; here the fibrous structure of the compressed vegetable bodies is extremely visible; and thus no manner of doubt remains, that at least a part of this coal had been composed of the vegetable bodies themselves, whatever may have been the origin of the more compact parts where nothing is to be distinguished.

The state in which we often find fossil wood in strata gives reason to conclude that this body of vegetable production, in its condensed state, is in appearance undistinguishable from fossil coal, and may be also in great quantity; as, for example, the Bovey coal in Devonshire.

Thus the strata of fossil coal would appear to be formed by the subsidence of inflammable matter of every species at the bottom of the sea, in places distant from the shore, or where there had been much repose, and where the lightest and most floatant bodies have been deposited together. This is confirmed in examining those bodies of fossil coal; for, though there are often found beds of sand-stone immediately above and below the stratum of the coal, we do not find any sand mixed in the strata of the coal itself.

Having found the composition of coal to be various, but all included within certain rules which have been investigated, we may perceive in this an explanation of that diversity which is often observed among the various strata of one bed of coal. Even the most opposite species of composition may be found in the thickness of one bed, although of very little depth, that is to say, the purest bituminous coal may, in the same bed, be conjoined with that which is most earthy.

Fossil coal is commonly alternated with regular sand-stone and argillaceous strata; but these are very different bodies; therefore, it may perhaps be inquired how such different substances came to be deposited in the same place of the ocean. The answer to this is easy; we do not pretend to trace things from their original to the place in which they had been ultimately deposited at the bottom of the sea. It is enough that we find the substance of which we treat delivered into the sea, and regularly deposited at the bottom, after having been transported by the currents of the ocean. Now the currents of the ocean, however regular they may be for a certain period of time, and however long this period may be protracted, naturally change; and then the currents, which had given birth to one species of stratum in one place, will carry it to another; and the sediment which the moment before had formed a coal stratum, or a bed of that bituminous matter, may be succeeded either with the sediment of an argillaceous stratum, or covered over with a bed of sand, brought by the changed current of the sea.

We have now considered all the appearances of coal strata, so far as these depend upon the materials, and their original collection. But, as those bituminous strata have been changed in their substance by the operation of subterranean heat and inspissation, we are now to look for the necessary consequences of this change in the body of the stratum; and also for other mineral operations common to fossil coal with consolidated strata of whatever species.

If coal, like other mineral strata, have been inspissated and consolidated by subterranean heat, we should find them traversed with veins and fissures; and, if the matter found in those veins and fissures corresponds to that found in similar places of other strata, every confirmation will be hence given to the theory that can be expected from the consideration of those bituminous strata. But this is the case; we find those fissures filled both with calcareous, gypseous, and pyritous substances. Therefore, we have reason to conclude, that the strata of fossil coal, like every other indurated or consolidated body in the earth, has been produced, *first*, by means of water preparing and collecting materials proper for the construction of land; and, *secondly*, by the operation of internal fire or subterranean heat melting and thus consolidating every known substance of the globe.

Not only are those sparry and pyritous substances, which are more natural to coal strata, found forming veins traversing those strata in various directions, but also every other mineral vein may occasionally be found pervading coal mines, or traversing bituminous strata. Gold, silver, copper, lead, calamine, have all, in this manner, been found in coal.

There remains now only to consider those bituminous strata of fossil coal in relation to that change of situation which has happened more or less to every stratum which we examine; but which is so much better known in those of coal, by having, from their great utility in the arts of life, become a subject for mining, and thus been traced in the earth at great expense, and for a long extent.

Coal strata, which had been originally in a horizontal position, are now found sometimes standing in an erect posture, even almost perpendicular to the plane in which they had been formed. Miners therefore distinguish coal strata according as they deem them to approach to the one or other of those two extremes, in terming them either flat or edge seams or veins. Thus, it will appear, that every possible change from the original position of those strata may have happened, and are daily found from our experience in those mines.

But besides the changed position of those strata, in departing from the horizontal line or flat position in which they had been formed, there is another remarkable change, termed by miners a *trouble* in the coal. The consideration of this change will further illustrate the operations of nature in placing that which had been at the bottom of the sea above its surface.

Strata, that are in one place regularly inclined, may be found bended, or irregularly inclined, in following their course. Here then is a source of irregularity which often materially effects the estimates of miners, judging from what they see, of those parts which are to be explored; and this is an accident which they frequently experience.

But, without any change in the general direction of the stratum, miners often find their coal broke off abruptly, those two parts being placed upon a higher and lower situation in respect to each other, if flat beds, or separated laterally if they are edge seams. This is by miners termed a *slip, hitch*, or *dyke*.

These irregularities may either be attended with an injected body of subterraneous lava or basaltes, here termed whin-stone, or they may not be attended, at least apparently, *i.e.*immediately, with any such accident. But experienced miners know, that, in approaching to any of those injected masses of stone, which are so frequent in this country, their coal is more and more subject to be troubled.

As there is, in this country of Scotland, two different species of mountains or hills, one composed both in matter and manner exactly similar to the Alps of Switzerland, the other of whin-stone, basaltic rock, or subterraneous lava; and as the fossil coal, argillaceous and sand-stone strata, are found variously connected with those hills, nothing can tend more to give a proper understanding, with regard to the construction of the land in general, of the globe than a view of those different bodies, which are here found much mixed together in a little space of country, thus exhibiting, as it were in miniature, what may be found in other parts of the world, upon a larger scale, but not upon any other principle. I will therefore endeavour to give a short description of the mineral state of this country with regard to coal, so far as my experience and memory will serve.

This country might very properly be considered as consisting of primary and secondary mountains; not as supposing the primary mountains original and inexplicable in their formation, any more than those of the latest production, but as considering the one to be later in point of time, or posterior in the progress of things. The first are those which commonly form the alpine countries, consisting of various schisti, of quartzy stone, and granites. The second, again, are the whinstone or basaltic hills scattered up and down the low country, and evidently posterior to the strata of that country, which they break, elevate, and displace.

Thus there are in this country, as well as every where else, three things to be distinguished; first, the alpine or elevated country; secondly, the flat or low country; and, thirdly, that which has been of posterior formation to the strata which it traverses, in whatever shape or quality; whether as a mountain, or only as a vein; whether as a basaltes, a porphyry, or a granite, or only as a metal, a siliceous substance, or a spar.

Those three things which are here distinguished do not differ with regard to the chemical character of their substances; for, in each of these, every different substance is to be found, more or less; and it is not in being composed of materials peculiar to itself, that makes an alpine country be distinguished from a flat country; it is chiefly in the changes which the strata of the alpine country have been made to undergo, posterior to their original collection, that the rocks of the alpine country differ from those of the flat country.

But the observation that is most to the purpose of the present subject of bituminous strata, is this; it is chiefly in the strata of the flat country that fossil coal are found; there are none that I know of in all the alpine countries of Scotland; and it is always among the strata peculiar to the flat country that fossil coal is found. Now, this appearance cannot be explained by saying that the materials of mineral coal had not existed in the world while those primary strata were formed in the sea. I have already shown, (chap. 4.) that there had been the same system of a world, producing plants, and thus maintaining animals, while the primary strata were formed in the sea; I have even adduced an example of coal strata among those primary schisti, although this be an extremely rare occurrence: Consequently, we are under the necessity of looking out for some other cause.

If the changes which have been evidently superinduced in the strata of alpine countries arise from the repeated operations of subterranean fire, or to the extreme degree in which those strata have been affected by this consolidating and elevating cause, it will be natural to suppose that the bituminous or combustible part among those stratifications, may have been mostly consumed upon some occasion during those various and long continued operations; whereas, in the flat beds of the low country, although there is the most perfect evidence for the exertion of heat in the consolidation of those strata, the general quantity of this has been a little thing, compared with the universal manifestation of this cause in the operations of the alpine countries, the strata of which have been so much displaced in their situations and positions.

To illustrate this, strata of sand-stone are found in both the alpine and flat countries of Scotland. About Leadhills, for example, there are abundance of those strata; but, in the flat country, the generality of the sand-stone is so little changed as to appear to every enlightened naturalist aquiform strata; whereas the most enlightened of those philosophers will not perhaps attribute the same original to a similar composition in the alpine country, which is so much changed from its original state. It is not because there had been wanting a sufficient degree of heat to consolidate the sand-stone in the coal country; for I can show specimens of sand-stone almost contiguous with coal, that have been extremely much consolidated in this manner. But this is only a particular stratum; and the general appearance of the sand-stone, as well as other strata in the coal countries, is that of having been little affected by those subterranean operations of heat by which those bodies in the alpine country have been changed in their structure, shape, and position.

If we shall thus allow the principle of consolidation, consequently also of induration, to have been much exerted upon the strata of the alpine country, and but moderately or little upon those of the low country of Scotland, we shall evidently see one reason, perhaps the only one, for the lesser elevation of the one country above the level of the sea, than the other. This is because the one resists the powers which have been employed in leveling what has been raised from the bottom of the sea, more than the other; consequently, we find more of the one remaining above the level of the sea than of the other.

Let us now take the map of Scotland, in order to observe the mixture of those two different species of countries, whereof the one is generally low and flat, the other high and mountainous; the one more or less provided with fossil coal, the other not.

From St Abb's Head, on the east of Scotland, to the Mull of Galloway, on the west, there runs a ridge of mountains of granite, quartz, and schistus strata, which contain not coal. On each side of this ridge we find coal countries; Northumberland, on the one side, and, on the other, the shires of Ayr, Lanark, and the Lothians; the one is a mountainous country, the others are comparatively low or flat countries. Let us now draw another alpine line from Buchan and Caithness, upon the east, to the island of Jura, on the west; this traverses a mountainous country destitute of coal, and, so far as I know, of any marks of marine bodies. But, on each side of this great alpine ridge, we find the hard country skirted with one which is lower, flatter, or of a softer nature, in which coal is found, upon the one side, in the shires of Fife, Clackmannan, and Stirling; and, on the other, in that hollow which runs from the Murray Frith south-west, in a straight line, directed upon the end of Mull, and composed, for the most part, of water very little above the level of the sea. Here, to be sure, the coal is scarce, or not so evident; but there is coal upon the sea coast in several places of this great Bay betwixt Buchan and Caithness; and the lowness of the country, across this part of the island, is almost sufficient testimony that it had been composed of softer materials.

Thus the coal country of Scotland may be considered as in one band across the island, and included in the counties of Ayr, Lanark, and all those which border upon the Frith of Forth. Now, in all this tract of coal and tender strata, we do not find ridges of alpine stone or primary mountains, but we find many hills of solid rock, little mountains, from 500 to 1000 feet high; such as that beautiful conical hill North Berwick Law, Torpender Law, Arthur's Seat, the Lowmands, and others of inferior note. That is to say, the whole of this included space, both sea and land, has been invaded from below with melted masses of whin-stone, breaking up through the natural strata of the country, and variously embossing the surface of the earth at present, when all the softer materials, with which those subterranean lavas had been covered, are washed away or removed from those summits of the country. Hence there is scarcely a considerable tubercle, with which this country also abounds, that may not be found containing a mass of whin-stone as a nucleus.

But besides those insulated masses of whinstone that form a gradation from a mountain to a single rock, such, for example, as that on which the Castle of Edinburgh is built, we find immense quantities of the same basaltic rock interjected among the natural strata, always breaking and disordering them, but often apparently following their directions for a considerable space with some regularity. We also find dykes of the same substance bisecting the strata like perpendicular veins of rock; and, in some places, we see the connection of these rocks of the same substance, which thus appear to be placed in such a different form in relation to the strata.

It will thus appear, that the regular form, and horizontal direction of strata throughout this country of coal, now under contemplation, has been broken and disordered by the eruption and interjection of those masses of basaltic stone or subterraneous lava; and thus may be explained not only the disorders and irregularities of coal strata, but also the different qualities of this bituminous substance from its more natural state to that of a perfect coal or fixed infusible and combustible substance burning without smoke. This happens sometimes to a part of a coal stratum which approaches the whin-stone.

Having thus stated the case of combustible or bituminous strata, I would ask those naturalists, who adhere to the theory of infiltration and the operation of water alone, how they are to conceive those strata formed and consolidated. They must consider, that here are immense bodies of those combustible strata, under hundreds, perhaps thousands, of fathoms of sand-stone, iron-stone, argillaceous and calcareous strata. If they are to suppose bituminous bodies collected at the bottom of the sea, they must say from whence that bitumen had come; for, with regard to the strata below those bituminous bodies, above them, and between them, we see perfectly from whence had come the materials of which they are formed. They cannot say that it is from a collection of earthy matter which had been afterwards bituminized by infiltration; for, although we find many of those earthy strata variously impregnated with the bituminous and coaly matter, I have shown that the earthy and the bituminous matter had subsided together; besides, there are many of those coaly and bituminous strata in which there is no more than two or three *per cent.* of earthy matter or ashes after burning; therefore the strata must have been formed of bituminous matter, and not simply impregnated with it.

To avoid this difficulty, we shall allow them to form their strata, which certainly is the case in great part, by the collection of vegetable bodies; then, I desire them to say, in what manner they are to consolidate those bodies. If they shall allege that it is by simple pressure, How shall we conceive the numerous veins of spar and pyrites, which traverse those strata in all directions, to be formed in those bodies consolidated by the compression of the superincumbent masses?—Here is a manifest inconsistency, which proves that it could not be. But, even were we to suppose all those difficulties to be over come, there is still an impossibility in the way of that inconsiderate theory, and this will appear more fully in the following chapter.

Section 3. The Mineralogical Operations Of The Earth Illustrated From The Theory Of Fossil Coal

There is not perhaps a greater difference among the various qualities of bodies than that which may be observed to subsist between the burning of those two substances, that is, the inflammable bodies on the one hand, and those that are combustible on the other. I have treated of that distinction in Dissertations upon subjects of Natural Philosophy, part 3d. where I have considered the different effects of those two kinds of bodies upon the incident light; and, in a Dissertation upon the Philosophy of Fire, etc. I have distinguished those two kinds of substances in relation to their emitting, in burning, the fixed light which had constituted a part of those inflammable and combustible bodies.

All animals and vegetable bodies contain both those different chemical substances united; and this phlogistic composition is an essential part in every animal and vegetable substance. There are to be found in those bodies particular substances, which abound more or less with one of those species of phlogistic matter, but never is the one species of those burning substances to be found naturally, in animal and vegetable bodies, without being associated with the other; and it is all that the chemical art can do to separate them in a great degree upon occasion. Pure ardent spirit may perhaps be considered as containing the one, and the most perfect coal the other; the chemical principle of the one is proper carbonic matter; and of the other it is the hydrogeneous principle, or that of inflammable air.

Thus we so far understand the composition of animal and vegetable substances which burn or maintain our fires; we also understand the chemical analysis of those bodies, in separating the inflammable from the combustible substance, or the volatile from the fixed matter, the oil from what is the proper coal. It is by distillation or evaporation, the effect of heat, that this separatory operation is performed; and we know no other means by which this may be done. Therefore, wherever we find peculiar effects of that separatory operation, we have a right to infer the proper cause.

The subject, which we are to consider in this section, is not the composition of strata in those of mineral coal, but the transformation of those, which had been originally inflammable bodies, into bodies which are only combustible, an end which is to be attained by the separation of their volatile or inflammable substances. In the last section, I have shown of what materials the strata of mineral coal had been originally formed; these are substances containing abundance of inflammable oil or bitumen, as well as carbonic matter which is properly combustible; and this is confirmed by the generality of those strata, which, though perfectly consolidated by fusion, retain still their inflammable and fusible qualities. But now the object of investigation is that mineral operation by which some of those strata, or some parts of a fusible and inflammable stratum, have been so changed as to become infusible and only combustible.

We have now examined those strata which may be considered as either proper mineral coal, or as only a bituminous schistus; we are now to class along with these another species of this kind of matter, which has had a similar origin, although it may assume a different character.

According to the common observations of mankind, the eminent quality by which coal is to be distinguished, is the burning of that substance, or its capacity for making a fire. Therefore, however similar in other respects, a substance which had not that eminent quality of coal could hardly be considered as being allied to it; far less could it be supposed, as being in every other respect the same. We are however to endeavour to show, that there are truly substances of this kind, substances which to common observation, having none of the properties of coal with respect to fire, consequently, no utility for the purpose of burning, might be considered as another species of mineral, while at the same time they are truly at bottom a composition very little different from those which we have considered as the most perfect coal.

It must be recollected that we have distinguished coal in general as of two different species, one perfect or proper coal, containing no perceptible quantity of either oil or phlegm; the other as burning with smoke and flame, consequently containing both aqueous and oleaginous substances which it emits in distillation. It is the first of these which we are now to consider more particularly, in order to see the varieties which may be found in this species of mineral substance.

When that bituminous fossil, which is the common coal of this country, is submitted to heat it is subject to melt more or less, and emits smoke which is composed of water and oil. If it be thus completely distilled, it becomes a perfect coal of a porous or spongy texture. Such a substance as this is extremely rare among minerals; I have however found it. It is in the harbour of Ayr, where a whinstone dyke traverses the coal strata, and includes some of that substance in the state of coals or cinder. I pointed this out many years ago to Dr Black; and lately I showed it to Professor Playfair.

But the culm of South Wales, the Kilkenny coal of Ireland, and the blind coal of Scotland, notwithstanding that these are a perfect coal, or charred to a coal, have nothing of the porous construction of the specimen which I have just now mentioned; they are perfectly solid, and break with a smooth shining surface like those which emit smoke and flame.

Here is therefore a mineral operation in the preparation of those coals which we cannot imitate; and here is the clearest evidence of the operation of mineral fire or heat, although we are ignorant of the reason why some coal strata are charred, while others are not, and why, in some particular cases, the charred coal may be porous or spungy like our coaks, while in general those blind coals (as they are called) are perfectly solid in their structure.

But to what I would call more particularly the attention of mineral philosophers is this, that it is inconceivable to have this effect produced by means of water; we might as well say that heat were to be the cause of ice. The production of coal from vegetable bodies, in which that phlogistic substance is originally produced, or from animal bodies which have it from that source, is made by heat, and by no other means, so far as we know.

But, even heat alone is not sufficient to effect that end, or make a perfect coal; the phlogistic body, which is naturally compound, consisting of both inflammable and combustible substances, must be separated chemically, and this must be the operation of heat under the proper circumstances for distillation or evaporation.

Here is the impossibility which in the last chapter I have alleged the aqueous theory has to struggle against; and here is one of the absolute proofs of the igneous theory. Not only must the aqueous part of those natural phlogistic bodies be evaporated, in order to their becoming coal, but the oily parts must also, by a still increased degree of heat, be evaporated, or separated by distillation from the combustible part. Here, therefore, is evidently the operation of heat, not simply that of fusion in contradiction to the fluidity of aqueous solution, but in opposition to any effect of water, as requiring the absence or separation of that aqueous substance.

But those natural appearances go still farther to confirm our theory, which, upon all occasions, considers the compression upon the bodies that are submitted to the operation of heat, in the mineral regions, as having the greatest efficacy in modifying that operation. Coal strata, which are in the neighbourhood of each other, being of those two opposite species, the one fusible and inflammable, the other infusible and combustible, afford the clearest proof of the efficacy of compression; for, it is evident, that the coal, which was once bituminous or fusible, cannot be charred without the distillation of that substance; therefore, prevent the distillation by compression and the charring operation cannot proceed, whatever should be the intensity of the heat; and then, fusion alone must be the effect upon the bituminous body. But now, as we have both those species of coal in the vicinity of each other, and even the same strata of coal part charred, while the rest is not, this natural appearance, so far from being a stumbling block, as it must be to the opposite theory, is most clearly explained by the partial escape of vapours from the mineral regions, and thus confirms the theory with regard to the efficacy of compression.

It is owing to the solidity of those natural charred coals, and the want of oil, that they are so very difficult of kindling; but, when once kindled in sufficient quantity, they make a fire which is very durable. There are even some of them which, to common observation, seem to be altogether incombustible. I have of this kind a specimen from a stratum at Stair, which shall be afterwards mentioned.

M. Struve, in the Journal de Physique for January 1790, describes a mineral which he calls *plombagine charbonneuse ou hexaëdre*; and gives for reason, *parce qu'elle ressemble extrêmement au charbon de pierre schisteux, ou d'hexaëdre*. He says farther, "Il est très commun, dans une roche qui forme un passage entre les granits et les brèches, qu'on n'a trouvée jusqu'à présent qu'on masses roulées dans le pays de Vaud." He concludes his paper thus: "Ce fossile singulier ne paroît pas appartenir à la Suisse seule. J'ai dans ce moment devant les yeux une substance parfaitement semblable, si on excepte la couleur qui tient le milieu entre le gris de fer et le rouge modéré; elle vient du pays de Gotha de la Friedrischs-grube, proche d'Umneau. On le regarde comme un eisenrahm uni à du charbon de pierre."

The specimen which I have from Stair upon the water of Ayr, so far as I can understand, perfectly resembles this *plombagine* of M. Struve. It consumes very slowly in the fire, and deflagrates like plumbago with nitre. Now this comes from a regular coal stratum; and what is more remarkable, in this stratum is contained a true plumbago, Farther up the country, the Earl of Dumfries has also a mine containing plumbago along with other coal strata; and though the plumbago of these two mines have not all the softness and beauty of the mineral of the same species from Cumberland, they are nevertheless perfect plumbago.

I have a specimen of steatetical whinstone or basaltes from some part of Cumberland, in which is contained many nodules of the most perfect and beautiful plumbago. It is dispersed through this stone in rounded masses of all sizes from a nut to a pin's head; and many of these are mixed with pyrites. There is therefore reason to believe that this plumbago had been in fusion.

Now, if we consider that every species of coal and every species of plumbago are equally, that is, perfectly combustible, and yield, in burning, the same volatile principles, differing only perhaps a little in the small quantity of fixed matter which remains, we shall be inclined to believe, that they have all the same origin in a vegetable substance; and that they are diversified by some very small composition of other matter. This being allowed, one thing is certain, that it is by the operation of mineral fire or heat that those combustible substances, however composed, have been brought to their present state of coal, although we are ignorant of the circumstances by which their differences and their peculiar chemical and mechanical qualities have been produced.

Let us resume in a few words. There is not perhaps one substance in the mineral kingdom by which the operation of subterraneous heat is, to common understanding, better exemplified than that of mineral coal. Those strata are evidently a deposit of inflammable substances which all come originally from vegetable bodies. In this state of their formation, those coal strata must all be oleagenous or bituminous. In many of them, however, these volatile parts are found wanting; and, the stratum is found in the state of the most perfect coal or caput mortuum. There, is, I presume, no other means to be found by which this eminent effect could be produced, except by distillation; and, this distillation perhaps proceeded under the restraining force of an immense compression.

To this theory it must not be objected, that all the strata of coal, which are found in the same place or neighbourhood, are not reduced to that caput mortuum or perfect coaly state. The change from a bituminous to a coaly substance can only take place in proportion as the distillation of the volatile parts is permitted. Now this distillation must be permitted, if any passage can be procured from the inflammable body submitted to the operation of subterraneous heat; and, one stratum of coal may find vent for the passage of those vapours, through some crevice which is not open to another. In this way, doubtless, some of those bodies have been inspissated or reduced to a fixed coal, while others, at a little distance, have retained most of their volatile parts.

We cannot doubt of this distilling operation in the mineral regions, when we consider that in most places of the earth we find the evident effects of such distillation of oily substances in the naphta and petroleum that are constantly emitted along with water in certain springs. These oily substances are no other than such as may be procured, in a similar manner, from the fusible or inflammable coal strata; we have therefore every proof of this mineral operation that the nature of things admit of. We have also sufficient evidence that those fusible and inflammable coals, which have not been distilled to a caput mortuum, had been subjected to the operation of subterraneous heat, because we find those fusible coals subject to be injected with pyrites, as well as the more perfect coal.

If we now consider those various appearances of mineral bodies which are thus explained by the theory of mineral fire, or exertion of subterraneous heat, appearances which it is impossible to reconcile by any supposition of aqueous solution, or that unintelligible language of mineral infiltration which has of late prevailed, we shall be fully satisfied, that there is a uniform system in nature of providing a power in the mineral regions, for consolidating the loose materials deposited at the bottom of the sea, and for erecting those masses of mineralized substances into the place of land; we shall thus be led to admire the wisdom of nature, providing for the continuation of this living world, and employing those very means by which, in a more partial view of things, this beautiful structure of an inhabited earth seems to be necessarily going into destruction.

THEORY OF THE EARTH

WITH PROOFS AND ILLUSTRATIONS.

By

JAMES HUTTON

IN FOUR PARTS.

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Introduction

By the present theory, the earth on which we dwell is represented as having been formed originally in horizontal strata at the bottom of the ocean; hence it should appear, that the land, in having been raised from the sea, and thus placed upon a higher level, had been of a different shape and condition from that in which we find it at the present time. This is a proposition now to be considered.

In whatever order and disposition the hard and solid parts of the land were at the time of its emerging from the surface of the sea, no provision would have then been made for conducting the rivers of the earth; therefore, the water from the heavens, moving from the summits of the land to the shores, must have formed for themselves those beds or channels in which the rivers run at present; beds which have successively changed their places over immense extents of plains that have often been both destroyed and formed again; and beds which run between the skirts of hills that have correspondent angles, for no other reason but because the river has hollowed out its way between them.

In this view of things, the form of our land must be considered as having been determined by three different causes, all of which have operated, more or less, in producing the present state of those things which we examine. First, There is a regular stratification of the materials, from whence we know the original structure, shape, and situation of the subject. Secondly, There are the operations of the mineral region, some of which have had regular effects upon the strata, as we find in the veins or contractions of the consolidated masses; others have had more irregular effects, but which may still be distinguished by means of our knowing the original state and structure of those masses. Lastly, There are operations proper to the *surface* of this globe, by which the form of the habitable earth may be affected; operations of which we understand both the causes and the effects, and, therefore, of which we may form principles for judging of the past, as well as of the future. Such are the operations of the fun and atmosphere, of the wind and water, of the rivers and the tides.

It is the joint operation and result of those three different causes that are to be perceived in the general appearances of this earth, and not the effects of any one alone; although, in particular places of the earth, the operation peculiar to each of these may be considered by itself, in abstracting those of the others, more or less. Thus there are several views in which the subject is to be examined, in order to find facts with which the result of the theory may be compared, and by which confirmation may be procured to our reasoning, as well as explanation of the phenomena in question.

CHAPTER 1. FACTS IN CONFIRMATION OF THE THEORY OF ELEVATING LAND ABOVE THE SURFACE OF THE SEA

The first object now to be examined, in confirmation of the theory, is that change of posture and of shape which is so frequently found in mountainous countries, among the strata which had been originally almost plain and horizontal. Here it is also that an opportunity is presented of having sections of those objects, by which the internal construction of the earth is to be known. It is our business to lay before the reader examples of this kind, examples which are clearly described, and which may be examined at pleasure.

No person has had better opportunities of examining the structure of mountains than M. de Saussure, and no body more capable of taking those comprehensive views that are so necessary for the proper execution of such a task. We shall therefore give some examples from this author, who has every where described nature with a fidelity which even inconsistency with his system could not warp. Speaking of the general situation of the beds of the Saleve, (p. 179.)

«Dans quelques endroits, et même presque partout, les couches descendent tout droit du haut de la montagne jusques à son pied: mais au dessus de Collonge le sommet arrondi en dos d'âne présente des couches qui descendent de part et d'autre, au sud-est vers les Alpes, et au nord-ouest vers notre vallée; avec cette difference, que celles qui descendent vers les Alpes parviennent jusques au bas; au lieu que celles qui nous regardent sont coupées à pic, à une grande hauteur.

«Ces deux inclinaisons ne sont pas les seules que l'on observe dans le bancs du mont Saleve, ils en ont encore une troisième; ils sont relevés vers le milieu de la longueur de la montagne, et descendent de là vers ses extrémités. Cette pente, qui sur le Grand Saleve n'est pas bien sensible, devient très remarquable au Petit Saleve, et même très rapide à son extrémité. Les dernières couches au nord au dessus d'Étrembières descendent vers le nord-nord-est, sous un angle de 40 au 50 degrés.

«On verra, dans le cours de cet ouvrage, combien le montagnes calcaires ont fréquemment cette forme.

«§ 235. Outre ces grandes couches qui constituent le corps de la montagne, et qui peuvent en général être mises dans la classe des couches horizontales, on en trouve d'autres dont l'inclinaison est absolument différente. Elles sont situés au bas de Grande Saleve du coté qui regarde notre vallée; on les voit appliquées contre les tranches inférieures des bancs horizontaux ou très-inclinées en appui contre la montagne.

«Ces couches s'élèvent en quelques endroits, par exemple, entre Veiry et Crévin, à peu-près à la moitié de la hauteur du Grande Saleve. Celles qui touchent immédiatement la montagne, sont le plus inclinées; on en voit là de verticales et même quelque fois de renversées en sens contraire, qui sont soutenues par le plus extérieures. Celle ci font avec l'horizon un angle de 60 à 65 degrés. Ces couches sont souvent très étendues, bien suivies, et continues à de très-grandes distances. Leur assemblage forme une épaisseur considérable au pied de la montagne. Elles ont cependant été rompues, et manquent même totalement dans quelques places. Cela même donne la facilité de les bien observer, parce qu'en se postant dans ces intervalles, on peut les prendre en flanc, et voir distinctement leurs tranches, et tout leur structure.

«On observe ces couches non-seulement au pied de rocs nuds du Grand Saleve, mais encore dans la partie de sa pente qui est boisée par exemple au dessous de la croisette, le chemin qui de ce hameau descend au village de Collonge, passe sur les couches inclinées, comme celles que je viens de décrire.»

In § 237, the description is continued.

«En suivant le pied de la montagne entre le Coin et Crévin, on voit reparaître nos couches verticales ou très inclinées qui vis à vis du Coin, ont été détruites comme je viens de le dire. Ces couches là ou elles sorte que l'on peut comparer toutes les couches de la montagne à celles d'un jeu de cartes ployé en deux suivant sa longueur.»

In considering the chains of the Jura, on the west side of that which looks to the lake, our author has the following interesting observations, p. 275.

«Les chaînes dont il est composé, à mesure qu'ils s'éloignent de la haute ligne orientale perdent graduellement de leur hauteur et de leur continuité; le plus occidentales ne forment pas, comme la premiere, des chaînes de montagnes élevée et non interrompues; ce sont des monticules allongés il est vrai, mais isolés ou qui du moins ne sont unis que par leurs bases.

«§ 338. Leur structure n'est pas la même dans toute l'étendue du Jura. La forme primitive la plus générale ressemble cependant à celles de la haute chaîne; c'est-à-dire, que ce sont de voûtes, composées et remplies d'arcs concentriques.

«C'est surtout entre Pontarlier et Besançon, que l'on rencontre des collines qui ont régulièrement cette structure. La grande route traverse de larges vallées, dans lesquelles les couches sont horizontales; mais ces vallées sont séparées par des chaînes peu élevées dont le couches arquées montent jusques au haut de la montagne, et descendent ensuite du coté opposé. On en voit aussi de la même forme dans la Prévôté de Moutier Grand Val. La birs traverse des rochers qui offrent à découvert la construction intérieure des montagnes; les couches de roc forment dans cet endroit des voûtes élevées l'une sur l'autre en suivant le contour extérieur de la montagne.—*Dict. Géog. de la Suisse, tom.* 2. *p.*150.

«D'autres fois le sommet de la montagne est plus aigu que n'est celui d'une voûte, et les couches paralelles entr'elles, mais inclinées à l'horizon en sens contraire, présentent dans leur section, la form d'un chevron ou d'un lambda [Greek: L].

«§ 339. Mais cette même structure presente fréquemment une singularité remarquable. Ce sont des bancs perpendiculaires à l'horizon qui occupent à-peu-pres le milieu ou le coeur de la montagne et qui séparent les couches d'une des faces de celles de la face opposée.

«J'ai observé plusieurs montagnes secondaires, et du Jura et d'ailleurs, et surtout un grande nombre de montagne primitive, dont la structure est la même [48].»

«§ 340. Les couches perpendiculaires à l'horizon, que l'on rencontre fréquemment dans le Jura ont presque toutes leurs plans dirigés du nord-nord-est au sud-sud-ouest, suivant la direction générale de cette chaîne de montagne. Cette observation est d'une assez grande importance parce qu'elle exclut ou rend du moins improbable l'idée d'un bouleversement.

«J'ai cru pendant long-temps que toutes les couches dévoient avoir été formées dans une situation horizontale, ou peu inclinée à l'horizon, et que celles que l'on rencontre dans une situation perpendiculaire, ou très-inclinées, avoient été mises dans cet état par quelque révolution; mais à force de rencontrer des couches dans cette situation, de les voir dans de montagnes bien conservées, et qui ne paroissoient point avoir subi de bouleversement, et d'observer une grande régularité dans la forme et dans la direction de ces couches; je suis venu à penser que la nature peut bien avoir aussi formé de ces bancs très-inclinés, et même perpendiculaire à la surface de la terre.»

Here the reasoning of our author is sufficiently just; he sees too much order in the effect to ascribe it to a cause merely fortuitous. But surely nothing in those appearances hinders the conclusion, that the strata now found in ail possible positions, had been originally horizontal when at the bottom of the sea, and that they had been afterwards regularly bent and broken, by the same cause which operated in placing them above the level of the ocean. The force of this argument will appear, by considering the various regular and irregular positions in which they are found.

«§ 242. Dans quelques endroits du Jura, on voit des espèces de demi-cirques formés par des rochers dont le couches sont de portions de la surface d'un même cône et tendent à un centre commun élevé au dessus de l'horizon.

[48] This correspondency in the shape of the primitive and secondary mountains of our author, of which the structure is the same, is an important observation for our theory, which makes the origin of those two different things to be similar; it is inconsistent, however, with the notion of primitive parts, which some philosophers have entertained.

«Ainsi auprès de Pontarlier, etc.

«§ 343. Mais il est bien plus fréquent de voir des montagnes dont les couches ont la forme d'une demi-voûte, et qui vues de profil présentent, comme notre montagne de Saleve, un pente douce d'une coté, et des escarpemens de l'autre.

«Plusieurs vallées du Jura sont situées entre deux chaine de montagnes qui ont cette forme, et qui se presentent réciproquement leur faces escarpées. On croit même apercevoir quelque correspondance, entre les couches de ces montagnes opposées, et l'on diroit qu'elles furent anciennement unies, et que la partie intermédiaire a été détruite, ou que la montagne s'est fendue du haut en bas, et que ses deux moitiés se sont écartées pour faire place à la vallée qu'elles renferment.

«§ 346. Pour résumer en peu de mots les idées que je me forme de la structure du Jura; je dirai que je crois qu'il est composé de différentes chaînes à-peu-près paralleles entr'elles, et à celles des Alpes, mais tirant un peu plus du nord au midi: que la chaine la plus élevée et la plus voisine des Alpes, a eu originairement la forme d'une dos d'âne dont les pentes partent du faite, recouvrent les flancs, et descendent jusques au pieds de la montagne: que les chaînes suivantes du coté de l'ouest, sont composées de montagnes graduellement moins élevées et moins étendues; que les couches de ces montagnes ont généralement la forme de voûtes entières ou de moitié de voûtes; et qu'elles viennent mourir dans des plaines, qui ont pour base des bancs calcaires tout à fait horizontaux de la même nature que ceux du mont Jura, et qui furent peut-être anciennement continus avec eux.»

Our author has here described most accurately, not only the present shape and positions of particular strata, but the general shape and structure of the land him the Saleve and Jura, which are not in the Alps, to the plains of France, where the strata are generally in a more horizontal situation.

Having thus seen the structure of what are commonly termed the secondary mountains, a structure which prevails generally in all parts of the land, at least in all that which is not primitive in the estimation of naturalists, who suppose a different origin to different parts, it will now be thought a most interesting view of nature, to see the same accurate examination of the structure of the earth, from those secondary mountains of Geneva to the center of the Alps, where we find such a variety of mountains of different materials, (whether they shall be called primitive or secondary) and where such opportunity is found for seeing the structure of those mountains. For, if we shall find the same principles, here prevailing in the formation of those supposed primitive mountains as are found over all the earth in general, and as are employed in fashioning or shaping every species of material, it will be allowed us to conclude, that, in this situation of things, we have what is general in the formation of land, notwithstanding imaginary distinctions of certain parts which had been formed one way, and of others which are supposed to be operations of an opposite nature.

This question therefore will be properly decided in our author's journey to the Alps; for, if we shall there find calcareous strata perfectly consolidated, as they should be by the extreme operation of subterranean heat and fusion; if we find materials of every species formed after the manner of stratification; and if all those different strata variously consolidated shall be found in all positions, similar to those which we have now seen in the examination of the Jura and Saleve, with this difference, that the deplacement and contorsion may be more violent in those highly consolidated strata, we shall then generalise an operation by which the present state of things must have been produced; and in those regular appearances, we shall acknowledge the operation of an internal heat, and of an elevating power.

«§ 287. Les pentes rapides des bancs dont est formé le mole, les directions variées de ces mêmes bancs sont aussi conformes à une observation générale et importante, que le montagnes secondaires sont d'autant plus irrégulières et plus inclinées qu'elles s'approchent plus des primitives.

«A la verité, quelque montagnes calcaires même à de grandes distances des primitives ont ça et là des couches inclinées et même quelquefois verticales; mais ces exception locales n'empêchent pas qu'il ne soit vrai qu'en general, les bancs calcaires, que l'on trouve dans les plaines qui sont éloignées des hautes montagnes, ont leurs bancs ou horizontaux ou peu inclinés; tandis, qu'au contraire, les montagnes qui s'approchent, du centre des grands chaînes, n'ont que très-rarement des couches horizontales, et presentent presque par-tout des couches fortement et diversement inclinées.»

That is to say, that there is no place of the earth, however plain and horizontal in general may be the strata, in which examples are not found of this manner of disordering or displacing strata; at the same time they are more crested and more disordered in proportion to the mountainous nature of the country. Here is the proposition contained in that general observation of natural history; and this is a proposition which either naturally flows from the theory, or is perfectly consistent with it.

«§ 360, a. Le rocher dont j'ai parlé (§ 354) qui touche celui de la Dole, et qui porte le nom de Vouarne, est d'une structure singulière. Les bancs dont il est composé sont escarpés, les uns en montant contre le nord-est sous un angle de 40 à 50 degrés; les autres en s'élevant contre le sud-est.

«§ 361. En avant de ce rocher, du coté l'est, on en voit un autre d'une structure très remarquable. Il a la forme d'un chevron aigu ou d'un lambda [Greek: L]. on le nomme, sans doute à cause de sa forme, le Rocher de fin Château. Les bancs dont il est composé sont très inclinés à l'horizon, et s'appuient réciproquement contre leurs sommités respectives. Les planches que l'on dresse en appui les unes contre les autres pour les faire secher, peuvent donner une idée de la situation de les bancs. Cette forme n'est pas rare dans ces rochers calcaires; mais elle est bien plus fréquente encore, et plus décidée dans le rochers primitifs, comme nous le verrons dans la suite.

«Le rocher de fin château presente dans cette forme même une circonstance très-remarquable; c'est que l'intervalle que les jambes du lambda [Greek: L] laissent entr'elles, est rempli par des couches perpendiculaires à l'horizon. On diroit que ces couches chassées en haut par une force souterraine, ou soulevé de part et d'autre, des bancs qui sont demeurés appuyés contre elles. Nous avons déjà vu des rochers de cette forme, § 339.»

Here the truth of our theory is so evident, that this philosopher naturally acknowledges it without intention.

In his Journey to Mont Blanc, he observes, page 364, «Un peu au delà de Contamine on passe sous les ruines du château de Faucigny, bâti sur le sommet d'un rocher escarpé, qui fait partie de la base du môle. Tant qu'on est immédiatement au dessous de ce rocher on ne démêle pas bien sa structure; mais après l'avoir passe, on peut voir à l'aide d'une lunette, qu'il est composé de couches perpendiculaires à l'horizon, et dirigées du nord-est au sud-ouest. Au dessous de ce rocher au sud-est, on voit d'autres couches verticales, mais dont les plans coupent à l'angle droits ceux des premiers.

«A une bonne demi-lieue de ce château on observe, comme au pied du Mont Saleve, une masse de rochers, dont les couches minces, presque perpendiculaires à l'horizon, sont adossées aux escarpemens de couches épaisses et bien suivies, qui paroissent horizontales.»

Speaking of the Mont Brezon, our author says, page 369,

«Mais le pied de cette montagne est encore, comme celui de Saleve, couvert de grandes couches presque perpendiculaires à l'horizon et appuyées contre le corps même de la montagne. Et quoique le Brezon se termine â une petite demi-lieue de la Bonne Ville, cependant ses couches qui sont appuyées contre le pied de la chaîne méridionale, et qui tournent ainsi le dos à l'Arve, continuent de régner jusques au village de Siongy pendant l'espace de prés de deux lieues. Elles sont à la verite coupées par une petite vallée à l'extrémité du pied du Brezon, mais elles recommencent au de là de cette coupure.

«§ 446. Cette petite vallée, qui s'ouvre au pied du Brezon, est étroite et tortueuse; les angles saillans engrenées dans les angles rentrans y sont extrêmement sensibles. Elle conduit au village de Brezon, qui est situé derrière la montagne de ce nom.

«Au dessus de ce village sont de grands et beaux pâturages avec des chalets qui ne sont habités qu'en été, et que l'on nomme les Granges de Solaison. C'est là que j'allois coucher quand je visitois le Brezon et les montagnes voisines. Les granges de Solaison sont dominées, au sud-est par le monts Vergi, chaîne calcaire très élevée, dont j'ai aussi parcouru les sommets qui se voyent des environs de Genève, sur la droite du môle.

«Cette chaîne court du nord-est au sud-ouest, et vient se terminer derrière les montagnes qui bordent notre route à droite.

«§ 447. On peut, des environs de Siongy, observer la structure de la dernière montagne de cette chaine; elle est très remarquable. Les couches horizontales au sommet se courbent presqu'à angles droits, et descendent de là perpendiculairement du coté du nord-ouest. On diroit qu'elles ont été ployées par une violent effort; on les voit séparées et éclatées en divers endroits.

«§ 449. Le mole se termine à la jonction du Giffre avec l'Arve; ses dernières couches descendent avec rapidité dans le lit de cette petite riviere,

«Les montagnes qui suivent le môle, et qui forment après lui le coté septentrional de la vallée de l'Arve, sont basses et indifférentes, une seule est remarquable par sa forme pyramidale, et par ses couches qui convergent á son sommet, et lui donnent la forme d'un chevron.

«§ 450. La ville même de Cluse est bâtie sur le pied d'une montagne, dont la structure est très extraordinaire; on en juge mieux à une certain distance que de la ville même.

«Cette montagne de forme conique émoussée, ou plutôt parabolique, est pour ainsi dire coiffée d'une bande de rochers, qui du haut de sa tête descendent à droite et à gauche jusques à son pied. Ces rochers nuds sont relevées par le fond de verdure dont le reste de montagne est couverte. Ils sont composés de plusieurs bandes parallèles entr'elles; les extérieures sont blanches et épaisses, les intérieures sont brunes et plus minces. Le corps même de la montagne, dont on apperçoit çà et là les rochers au travers du bois, qui les couvre, paroi composé de couches irrégulières et diversement inclinées. On pourroit soupçonner que cette bande n'est que le reste d'une espèce de callote qui vraisemblablement couvroit autrefois toute la montagne.

«§ 463. Des que l'on est sorti de la ville de Cluse, on voit en se retournant sur la droite, les rochers en surplomb sous lesquels on a passé avant de traverser l'Arve. On distingue d'ici le profil des couches de ces rochers; et on reconnoit qu'elles sont presque perpendiculaires à l'horizon.

«Ces couches sont adossées à d'autres couches calcaires et verticales comme elles, mais qui sont la continuation de couches à-peu-près horizontales: on diroit qu'une force inconnue a ployé à angles droits l'extrémité de ces couches, et les a ainsi contrainte à prendre une situation verticale.

«§ 467. Si du grande chemin qui est au pied de la caverne, on jette les yeux sur le rocher dans lequel est son ouverture, on observera que les bancs de ce rocher sont très épais, et composés d'une pierre calcaire grise; qu'au dessus cette pierre grise on en voit une autre de couleur brune, dont les couches font très minces; mais qui par leur répétition forment une épaisseur considérable.

«Ces couches de pierres à feuillets minces, continuent jusques à Sallanches et au de là; et sont renfermées par dessus et par dessous entre des bancs de pierre grise compacte et à couches épaisses. Quelquefois la pierre grise qui sert de base, ou comme disent les mineurs, de plancher à la brune, s'enfonce et alors celle-ci paroit à fleur de terre; ailleurs cette pierre grise se relève et porte la brune à une grande hauteur.

«Cette pierre brune et feuilletée est comme la grise de nature calcaire; mais un mélange d'argile, et peut-être un peu de matière grasse ou phlogistique lui donnent sa couleur brune et la disposent à se rompre en fragmens angulaires et à cotés plans.

«Ce genre de pierre est fort sujet à avoir ses couches fléchies ou ondées en forme de S de Z ou de C. Près de la caverne, on, voit une lacune dans le milieu des bancs du roc gris; les couches minces ont rempli cette lacune, mais elles sont dans cet espace extrêmement tourmentées. On comprend que ce vide et ce remplacement, se sont faits dans le temps même de la formation de ces rochers.»

We have the following description of the Cascade Mountain, p. 396.

«Les couches de cette montagne sont la continuation des couches supérieures du rocher de la cascade, et forment des arcs concentriques, tournés en sens contraire; en sorte que la totalité de ces couches a la forme d'une S, dont la partie supérieure se recourbe fort en arrière.

«Le rocher de la cascade, représenté par la planche IV. est tout calcaire; les couches, qui sont au dessous des lettres d et e, sont composées de ce roc gris compact dont les bancs, comme nous l'avons vu plus haut, sont ordinairement épais, mais les couches extérieures entre e et f, sont du roc brun à couches minces, dont nous avons aussi parlé. Ces même couches minces se voyent encore à l'intersection de perpendiculaire qui passent par lettres a et e.

«Ici dont c'est le roc gris qui est renfermé entre deux bancs de roc brun au lieu qu'auprès de la caverne, c'étoit le roc brun, qui étoit resserré entre deux bancs de roc gris; mais cette différence n'est pas ce qu'il y a de plus difficile à expliquer; c'est la forme arquée de ces grandes couches dont il faudroit rendre raison.»

Having measured this rock geometrically, the result is as follows:

«Le plus grand des arcs de cercle que forment ces couches extérieures de ce rocher, a donc pour corde une ligne d'environ 800 pieds: dans toute cette étendue, ces couches de même que les intérieures sont suivies sans interruption.

«Je dois cependant avertir, qu'en avant du rocher de la cascade à la hauteur de la lettre a, et au dessous, on voit des couches détachées des circulaires, et indépendantes d'elles; ce sont de plans inclinés en appui contre le corps de la montagne, semblables à ceux que j'ai observé au pied du mont Saleve, et d'une formation vraisemblablement plus récente que le corps même de la montagne.

«Mais derrière ces plans, on voit les couches arquées, qui sont horizontales dans le bas, servir de base au rocher, se relever ensuite sur la droite, et venir en tournant former le faite de ce même rocher.»

«It may be interesting to hear our author's reasoning upon this subject, more especially as it will give more faith or light, if it were possible, to his descriptions, which are irreproachable.

«§ 473. Il s'agiroit à present de dire quelle force a pu donner à ces couches cette situation; comment elles out pu être retroussées de façon que les plus basses soient devenues les plus élevées?

«La première idée qui se présente est celle des eaux souterrains. Ce qui pourroit même faire soupçonner que ces couches ont été réellement relevées par une force souterraine c'est que, sur la droite du rocher qu'elles forment, il y à un vide ou il manque à peu-pres ce qu'il faudroit pour former la hauteur de la cascade; car la montagne que l'on voit sous les lettres g et h, est sur une ligne beaucoup plus reculée. Sur la droite de ce vide ces couches recommencent sur la ligne de celles qui sont recourbées; on les voit coupées à pic de leur coté, avec les mêmes couleurs, la même épaisseur, mais dans une situation horizontale.

«J'ai observé dans plus d'une montagne des couches ainsi retroussées, aupres desquelles on voit le vide qu'elles paroissent avoir laissé en se repliant sur elles mêmes.

«Dans l'ober Hasli la vallée de Meiringen au dessus du village de Stein.

«Dans le canton de Uri, sur le bords du lac de Lucerne, on en voit aussi plusieurs exemples bien distincts.

«Une montagne plus rapprochée de notre cascade, et qui presente aussi ce phénomène, est située derrière elle au nord-est entre le village de Seiz et les granges des Fonds. Cette montagne porte le nom d'Anterne. Elle est plus élevée que celle du Nant d'Arpenaz, ses couches forment des arcs concentriques plus grands et plus recourbés encore, et l'on voit de même à leur droite un vide qu'elles semblent avoir laissé en se levant et se repliant sur la gauche.

«Mais malgré ces observations, ce n'est pas sans peine que j'ai recours à ces agens presque sur-naturelles, sur-tout quand je n'aperçois aucun de leurs vestiges; car cette montagne et celle d'alentour ne laissent apercevoir aucune trace du feu. Je laissé donc cette question en suspens; j'y reviendrai plus d'une fois, et même avant la fin de ce chapitre.

«Il faut à present jetter un coup-d'oeil sur les montagnes de l'autre coté de l'Arve.

«§ 474. Vis-à-vis de la cascade de l'autre coté de la rivière, on voit un chaine de montagnes extrêmement élevées, qui présentent leurs escarpemens au dessus de Sallenche, et contre le Mont Blanc. Leurs couches descendent par conséquent vers la vallée du Reposoir, située à leur pied au nord-ouest.

«Mais au pied des escarpemens de cette même chaine, on voit une rangée de bases montagnes paralleles à sa direction, inclinées en appui contre ses escarpemens et qui descendent en pente douce vers Sallenche; de même encore une fois qu'au mont Saleve.

«§ 475. De la cascade jusques à St Martin, on voit fréquemment à sa gauche des couches singulièrement contournées, et toujours dans cette espèce de pierre calcaire brune que nous suivons depuis si long-tems. Quelques-unes de ces couches forment presqu'un cercle entier, les plus remarquables sont à une demi-lieue de la cascade. Elles représentent des arcs dont les convexités se regardent à peu près comme dans un X; mais avec des plans situes obliquement entre les deux convexités, et des couches planes et horizontales immédiatement au-dessus de l'arc de la gauche.

«Ces diverses couches sont si bien suivies dans tous leurs contours, et si singulièrement entrelacées que j'ai peine à croire qu'elles ayent été formées dans une situation horizontale, et qu'ensuite des bouleversemens leur ayent donné ces positions bizarres.

«Déjà il faudroit supposer que ces bouleversemens se sont faits dans un tems ou ces couches étoient encore molles et parfaitement flexibles, car on n'y voit rien de rompu, leurs courbures, même les plus angulaires, sont absolument entières.

«Ensuite il faudroit, que ces couches, dans cet état de mollesse, eussent été froissées et contournées d'une maniere tout-à-fait étrange, et presqu'impossible à expliquer en détail. D'ailleurs des explosions souterraines rompent, déchirent, et ne soulèvent pas avec le ménagement qu'exigeroit la conservation de continuité de toutes ces parties.

«La crystallization peut seul, à mon avis, rendre raison de ces bizarreries; nous voyons, comme je l'ai déjà dit, des albâtres formés pour ainsi dire sous nos yeux par de vrayes crystallizations dans les crevasses, et dans les cavernes des montagnes, presenter des couches dans lesquelles on observe des jeux tout aussi singuliers[49].»

«Je ne repugnerois donc pas à croire que le rocher de la cascade a pu être formé dans la situation dans laquelle il se presente; si ce vuide à sa droite, ses couches qui, bien que suivies, montrent pourtant quelques ruptures dans les flexions un peu fortes, et ses grands bancs de cette pierre grise compacte, qui n'est point si sujette à ces formes bizarres, n'éstablissoient pas une difference sensible entr'elles et celles que nous venons examiner.»

It is impossible to be more impartial than M. de Saussure has proved himself to be on this occasion, or to reason more in the manner in which every philosopher ought to reason on all occasions.

But to see the full value of this author's impartiality, notwithstanding of his system, let us follow him in the second volume of Voyages dans les Alpes. It is in chap. XX. entitled, Poudingues de Valorsine, that we find the following description, with his reasoning upon that appearance.

«On voit la (page 99.) que la base de cette montagne est un vrai granit gris à grains médiocres, et dont la structure n'a rien de distinct; mais au-dessus de ces granits on trouve des roches feuilletées quartzeuses mélangées de mica et de feldspath genre moyenne entre le granit veiné et la roche feuilletée ordinaire. Leurs couches courent du nord au sud, comme la vallée de Valorsine, et font avec l'horizon un angle de 60 degrés, en s'appuyant au couchant contre cette même vallée. Ces roches continuent dans la même situation jusques à ce qu'apres une demi-heure de marche, on les perd de

[49] M. de Saussure would explain the various shape and contortions of strata upon the principles of crystallization; but surely he has not adverted to the distinction of crystallization as an operation giving form or shape, and as giving only solidity or hardness, which last, it is apprehended, is the only sense in which our author here considers crystallization, although, from the way in which he has employed this principle, it would seem that it is the figure which is to be explained by it. This conjecture is supported by the example of alabaster or *stalactites*, with which he compares the section of those mountains; for, in the example of implicated figures of the stalactite marble, similar to those of the present distorted strata, crystallization has nothing to do with that part of the figure which corresponds to the case now under consideration; it forms indeed certain figures of crystals in the mass by which also the configuration of some minute parts, affected by those crystals, is determined; but the figure of those alabasters, which is to be compared with the present subject, arises solely from the current of petrifying water along the surface of the mass. This mass, therefore, being formed by succession from that water, crystallising calcareous earth, and carrying colouring parts of other earth, gives an appearance of stratification to a figure which is absolutely inconsistent with stratification; an operation which is performed by depositing materials at the bottom of the sea, and which the marine bodies contained in some of the strata sufficiently attest.

vue sous la verdure qui tapisse une petite plaine, située au milieu des bois, et qui se nomme le *plan des Cebianes*.

«§ 689. De-là, en montant obliquement du coté du sud, on rencontre de grands blocs d'un schiste gris ou de couleur de lie-de-vin, quelquefois même d'un violet decidé, qui renferment une grande quantite de cailloux étrangers, les uns angulaires, les autres arrondis, et de différentes grosseurs, depuis celle d'un grain de sable jusqu'à celle de la tête. Je fus curieux de voir ces poudingues dans leur lieu natal; je montai droit en haut pour y arriver; mais là quel ne fut pas mon étonnement de trouver leur couches dans une situation verticale!

«§ 690. On comprendra sans peine la raison de cet étonnement si l'on consideré qu'il est impossible que ces poudingues aient été formées dans cette situation.

«Que des particules de la plus extrême ténuité, suspendues dans un liquide, puissent s'agglutiner entr'elles et former des couches verticales, c'est ce que nous avons la preuve en fait dans les albâtres, les agathes, et même dans les crystallizations artificielles. Mais qu'une pierre toute formée, de la grosseur de la tête, se soit arrêtée au milieu d'une parois verticale, et ait attendu là que les petites particules de la pierre vinssent l'envelopper, la souder et la fixer dans cette place, c'est une supposition absurde et impossible. Il faut donc regarder comme une chose démontrée, que ces poudingues ont été formés dans une position horizontale, ou à peu-près telle, et redressés, ensuite après leurs endurcissement. Quelle est la cause qui les a redressés? c'est ce que nous ignorons encore; mais c'est déjà un pas, et un pas important, au milieu de la quantité prodigieuse de couches verticales que nous rencontrons dans nos Alpes, que d'en avoir trouvé quelques-unes dont on soit parfaitement sûr qu'elles ont été formées dans une situation horizontale.

«§ 691. La nature même de la matière qu'enveloppe les cailloux de ces poudingues rend ce fait plus curieux et plus décisif. Car si c'étoit une pâte informe et grossière, on pourroit croire que ces cailloux et la pâte qui les lie ont été jetés pêle-mêle dans quelques crevasses verticales, où la partie liquide c'est endurcie par le dessèchement. Mais bien loin de-là, le tissu de cette pâte est d'une finesse admirables; c'est une schiste, dont les feuillets élémentaires sont excessivement minces, mêlés de mica, et parfaitement parallèles aux plans qui divisent les couches de la pierre. Ces couches mêmes sont très-régulières, bien suives et de différentes épaisseurs, depuis une demi pouce jusques à plusieurs pieds. Celles qui sont minces contiennent peu et quelquefois point de cailloux étrangers, et on observe quelques alternatives de ces couches minces sans cailloux et des couches épaisses qui en contiennent. La couleur du fond de ce schiste varie beaucoup; il est ici gris, là verdâtre, le plus souvent violet ou rougeâtre; on en voit aussi qui est marbré de ces différentes couleurs. Ses couches sont dirigées du nord au sud exactement comme celles des roches granitoïdes qui sont au-dessous, § 688. mais l'inclinaison du schiste est beaucoup plus grande, ses couches sont souvent tout-à-fait verticales, et lorsqu'elles ne le sont pas, elles montent de quelques degrés du même coté que les roches dont je viens de parler; c'est-à-dire, du coté de l'ouest.

«§ 692. Les cailloux enclavés dans ce schiste sont, comme je l'ai dite, de différentes grandeurs, depuis celle du grain de sable, jusques à 6 ou 7 pouces de diamètre; ils appartiennent tous à la classe des roches que j'appelle primitives; je n'y ai cependant pas vu de granit en masse; seulement des granits feuilletés, des roches feuilletées, mélangées de quartz et de mica; des fragmens même de quartz pur; mais absolument aucun schiste purement argileux, ni aucune pierre calcaire, rien qui fît effervescence avec l'eau-forte, et la pâte même qui renferme ces cailloux n'en fait aucune. Leur forme varie; les uns sont arrondis et ont manifestement perdu leurs angles par le frottement; d'autres ont tous leurs angles vifs, quelques uns même ont la forme rhomboïdale qu'affectent si fréquemment les roches de ce genre. Dans les parties de la pierre ou ces cailloux étrangers sont entassés en très-grand nombre, les élémens du schiste n'ont pas eu la liberté de s'arranger et de former des feuillets parallèles; mais par-tout où les cailloux laissent entr'eux des intervalles sensibles, les feuillets reparoissent, et sont constamment paralleles, et entr'eux et aux plans qui divisent les couches.

«§ 693. Les bancs de ces schistes poudingues forment dans la montagne une épaisseur d'environ cent toises, comptées de l'est à l'ouest transversalement aux couches, et je l'ai suivie dans le sens de la longueur l'espace de plus d'une lieue; on ne peut pas la suivre plus long-temps, parce que les bancs se cachent et s'enfoncent sous la terre.»

Here M. de Saussure, who is always more anxious to establish truth, than preserve theory, gives up the formation of the alpine strata by crystallization. Let us now see how he acknowledges the evidence of softness in those strata. It is in his description of the Val de Mont Joye, Tom. 2d. page 173.

«Ce sont des roches dures à fond de quartz, ou de feldspath blanc, confusément cristallisé, avec des veines noires de mica ou de schorl en petites lames. Ces veines, qui pénètrent tout au travers de la pierre, sont la section des couches dont elle est composée; on les voit, ici planes et parallèles, entr'elles; la en zig-zags, renfermés entre de plans parfaitement parallèles; accident dont les étoffes tout-à-la-fois rayées et chinées donnent encore le dessin. Ces anfractuosités des couches sont-elles un effect de la crystallization, ou bien d'un mouvement de pression qui a refoulé des couches planes lorsqu'elles étoient encore flexibles, après quoi d'autres couches planes sont venues se former sur elles.»

M. de Saussure has no idea of strata formed at the bottom of the sea, being afterwards softened by means of heat and fusion. He had already given up the supposition of those vertical or highly inclined strata having been formed in their present position; but had this geologist seen that it was the same cause by which those strata had both been raised in their place and softened in their substance, I am persuaded that he would have freely acknowledged, in this zig-zag shape, which is so common in the alpine strata, the fullest evidence of the softening and the elevating power.

At the *Tour de Fols*, near St Bernard, M. de Saussure found an appearance the most distinct of its kind, and worthy to be recorded as a leading fact in matters of geology.*Voyages dans les Alpes*, Tome 2d. pag. 454.

«La direction général des couches de ces rochers et des ardoises qui les séparent, est donc du midi au nord, ou plus exactement du sud-sud-ouest au nord-nord-est; mais cette direction est coupée à angles droits par des couches d'ardoises et de feuillet quartzeux, qui passent du levant au couchant par le milieu des couches qui courent du midi au nord.»

Clearly as this fact must demonstrate, to a reasoning person, the fracture and dislocation of strata, our author, who knows so well the reasoning of naturalists on such an occasion, gives us his opinion as follows: «Quant à la raison de ce fait, on peut l'attribuer à de boulversemens, et c'est ce qui me paroît le plus vraisemblable. On pourroit cependant supposer qu'il existoit au milieu de ces couches une grande fissure, qui a été remplie par des couches transversales. Mais il faudroit pour cela que ce remplissage se fût fait dans le temps même de la formation de ce montagne, puisque les ardoises et les pyramides quartzeuses, donc la direction est transversales, sont précisément de la même nature que les autres; et il faudrait encore supposer, qu'elles ont été formées dans la situation très-inclinée qu'on leur voit aujourd'hui; supposition que l'on aura quelque peine à admettre.»

In this second volume, M. de Saussure gives us a general view with regard to the mountains which border the valley of the Rhône, p. 543.

«§ 1095. Cette suite de montagnes calcaire que nous avons côtoyée depuis St Maurice jusques à Chillon, ne presente presque nulle part des couches régulières et horizontales: elles sont presque par-tout inclinées, fléchies, et paroissent avoir été tourmentées par des causes violentes: car de simples affaissemens ne suffisent pas à mon gré pour rendre raison de toutes leurs formes. Leurs escarpemens sont aussi assez irrégulièrement situés; la plus grande partie d'entr'eux paroît cependant tournée du côté de la vallée du Rhône.

«La suite des montagnes qui correspond à celle-ci sur la rive gauche du Rhône et du lac est aussi calcaire, et à-peu-pres aussi irrégulière. La plupart de ces montagnes, celles surtout qui sont les plus voisines du lac, sont escarpées, et du coté du lac et de celui du Rhône. Les vallées qui les séparent paroissent les diviser en chaînes paralleles au lac, qui courent du nord-est au sud-ouest. Les plus voisines du lac sont escarpées contre lui, comme je viens de le dire, tandis que les plus éloignées du lac, ou les plus proches du centre des Alpes, sont inclinées contre ces mêmes Alpes. *Le Val de lie* sépare ces deux ordres de montagnes: cette vallée riche et fertile a la forme d'un berceau; les deux chaînes qui la bordent s'élèvent en pente douce de son côté, et tournent leurs escarpemens, l'une contre le lac, l'autre contre les Alpes; au reste je n'ai point parcouru ces montagnes, je n'ai pu en juger qu'en les observant de loin.

«Mais ce dont on peut être certain, c'est que, si les montagnes qui bordent ces deux rives de la vallée du Rhône, se ressemblent par leur nature, qui est calcaire de part et d'autre elles ne se ressemblent point par leur structure. On n'y voit aucune correspondance, ni dans les positions, ni dans les formes: Les vallées qui les séparent ne se correspondent pas non plus. Ce défaut de correspondance me paroît encore réveiller l'idée des bouleversemens.»

The general result, from these observations of our author, is this. First, there is no distinction to be made of what is termed primary and secondary mountains, with regard to the position of their strata; every different species of stratum, from the stratified granite and quartzy *schistus* of the Alps to the *oolites* of the Jura and Saleve, being found in every respect the same; whether this shall be supposed as arising from their original formation, or, according to the present theory, from a subsequent deplacement of strata formed originally in a horizontal situation.

Secondly, it appears that, in all those alpine regions, the vertical position of strata prevails; and that this appearance, which seems to be as general in the alpine regions of the globe as it is here in the mountainous regions of the Alps, has been brought about both by the fracture and flexure of those masses, which, if properly strata, must have been originally extended in planes nearly horizontal. Whereas, in descending from that mountainous region towards the more level country of France, the same changes in the natural position of strata are observed, with this difference, that here they are in a less degree. Now that those vertical strata had been originally formed at the bottom of the sea is evident from this author's observation, which has been already referred to (vol. 1st, page 23).

Thirdly, in all those accurate observations of a naturalist, so well qualified for this purpose, there appears nothing but what is perfectly consistent with such a cause as had operated by slow degrees, and softened the bodies of rocks at the same time that it bended them into shapes and positions inconsistent with their original formation, and often almost diametrically opposite to it; although there appeared to our author an insurmountable difficulty in ascribing those changes to the operation of subterranean fire, according to the idea hitherto conceived of that agent.

This grand mineral view of so large a tract of country is the more interesting, in that there has not occurred the least appearance of volcanic matter, nor basaltic rock, in all that space, where so great manifestation is made of those internal operations of the globe by which strata had been consolidated in their substance, and erected into positions the most distant from that in which they had been formed.

It is peculiarly satisfactory to me, and I hope also to my readers, to have the observations of so able a philosopher and so diligent a naturalist to offer in confirmation of a theory which had been formed from appearances of the same kind in a country so far distant from those of our author now described, as are the Alps of Savoy from those of Scotland. It gives me a singular pleasure, in thus collecting facts for the support of my opinion, to contribute all I can to recommend the study of a work in natural history the most exemplary of its kind; and a work which will remain the unalterable conveyance of precious information when theories making a temporary figure may be changed.

To a person who understands the present theory, there can be no occasion here to give the particular applications which will naturally occur in reading those various descriptions. In these examples are contained every species of bending, twisting, and displacement of the strata, from the horizontal state in which they had been originally formed to the vertical, or even to their being doubled back; and although M. de Saussure had endeavoured to reason himself into a belief of those inverted strata having been formed in their present place, it is evident that he had only founded this opinion upon a principle which, however just, may here perhaps be found misplaced; it is that of not endeavouring to explain appearances from any supposition of which we have not full conviction. I flatter myself, that when he shall have considered the arguments which have here been employed for the manifold, the general operations of subterranean fire, as well as for the long continued operations of water on the surface of the erected land, he will not seek after any other explanation than that which had naturally occurred to himself upon the occasion, and which he most ingenuously declares to have great weight, although not sufficient to persuade him of its truth.

Chapter 2. The Same Subject Continued, With Examples From Different Countries

Our theory, it must be remembered, has for principle, that all the alpine as well as horizontal strata had their origin at the bottom of the sea, from the deposits of sand, gravel, calcareous and other bodies, the materials of the land which was then going into ruin; it must also be observed, that all those strata of various materials, although originally uniform in their structure and appearance as a collection of stratified materials, have acquired appearances which often are difficult to reconcile with that of their original, and is only to be understood by an examination of a series in those objects, or that gradation which is sometimes to be perceived from the one extreme state to the other, that is from their natural to their most changed state. M. de Saussure who will not be suspected of having any such theory in his view, will be found giving the most exemplary confirmation to that system of things.

I would therefore beg leave farther to transcribe what he has observed most interesting with regard to that gradation of changed strata. It is in the high passage of the Bon-Homme, tom. 2. p. 179.

«Depuis le col, dont je viens de parler, jusqu'a la croix, qui suivant l'usage, est placée au point le plus élevé du passage, on a trois quarts de lieue, ou une petite heure de route, dans laquelle on traverse des grès, des brèches calcaires, des pierres calcaires simples de couleur grise, d'autres calcaires bleuâtres et des ardoises: ces alternatives se répètent à plusieurs reprises. Parmi ces grès on en trouve qui renferment des cailloux roulés, et qui font effervescence avec les acides; d'autres qui ne renferment point de cailloux, et qui ne font point d'effervescence.

«Quelques-uns de ces grès m'out paru remarquables par leur ressemblance avec des roches feuilletées; ils sont compactes mêlés de mica; un suc quartzeux remplit tous les interstices de leurs grains, et leur donne une dureté et une solidité singuliers; il n'y a personne, qui en voyant des morceaux détachés de cette pierre, ne la prît pour une roche feuilletée; mais quand on la trouve dans le lieu de sa formation, et qu'on voit les gradations qui la lient avec des grès indubitables, par exemple avec ceux qui renferment des cailloux roulés, on ne peut plus douter de sa nature. Ces couches sont en général inclinées de 30 degrés en descendant au sud-est.»

Our author would here make a distinction of the *roche feuilletée* and the *grès*; the one he considers as primitive, and as having had an origin of which we are extremely ignorant; the other he considers as a secondary thing, and as having been formed of sand deposited at the bottom of moving water, and afterwards becoming stone. This great resemblance, therefore, of those two things so different in the opinion of naturalists, struck him in that forcible manner. Nothing can be a stronger confirmation of the present theory, which gives a similar origin to those two different things, than is the observation of so good a naturalist, finding those two things in a manner undistinguishable.

He thus proceeds: «J'ai vu dans les Vosges de très-beaux grès du même genre; ils ne ressembloient cependant pas autant à des roches primitives, parce qu'ils ne contenoient pas de mica. Mais ce qu'il y a ici de plus digne d'attention, et que l'on ne voit point dans les Vosges, c'est de trouver des grès de cette nature renfermés entre des bancs de pierre calcaire. Cependant plus ces grès s'éloignent de la roche primitive, qui forme la base de la montagne, et moins ils sont solides et quartzeux jusqu'à ce qu'enfin les plus élevés font effervescence avec l'eau-forte.»

Here again the alpine lime-stones, which, according to the present naturalists, should be primitive, are plainly homologated in their origin with strata formed of sand.

Our author proceeds, (p. 181,) § 765, «Le haut du passage du Bon-Homme, au pied de la croix est d'ardoises minces mêlées de feuillets de quartz. En descendant au Chapiu, on trouve ces mêmes ardoises alternant avec des couches de grès mince feuilleté, mêlé de mica, puis des calcaires simples, puis des brèches calcaires qui renferment des fragmens calcaires à angles vifs. Toutes ces couches descendent au sud-est suivant la pente de la montagne, mais avec un peu plus de rapidité.

«Comme cette montagne est absolument dégarnie d'arbres, on y voit d'un coup-d'oeil les progrès de l'action des eaux. Des sillons à peine visibles dans le haut, s'élargissent et s'approfondissent graduellement vers le bas, où ils forment enfin des ravines profondes, que l'on pourrait presque nommer des vallées. Ces sillons ramifies sur toute la pente de la montagne et remplis encore de neige, tandis que leurs intervalles sont couverts de gazon, forment sur ce fond verd une broderie blanche, dont l'effet est extrêmement singulier. Lorsque je passai là, le 13 Juillet 1774, tous les enfoncemens de ces neiges étoient couverts de la poudre rouge que j'ai décrite § 646.

«Vers la bas de la descente, on trouve des chalets que je m'étonnai de voir construits en pierres de taille, d'une forme très régulière; je demandai la raison de cette recherche, peu commune dans les montagnes, et j'appris que c'étoit la nature qui avoit fait tous les frais de cette taille. Effectivement je trouvai un peu plus bas une profonde ravine, creusée par les eaux dans des couches d'un beau grés qui se divise de lui-même, et que l'on voit dans sa position originelle actuellement divise en grands parallélépipèdes rectangles. Est-ce une retraite opérée par le dessèchement, ou n'est-ce pas plutôt l'affaissement successif des couches qui les a divisées de cette manière? C'est ce que je ne déciderai pas dans ce cas particulier.»

The only thing which, in this particular case, makes our author express his wonder, is the extreme regularity of these natural divisions of stone; for, the same appearances are to be found in every case of consolidated strata, though not always with such extreme regularity. But this is one of the most irrefragable arguments for those various bodies having been consolidated by means of heat and fusion. The contraction of the mass, consolidated by fusion or the effect of fire, is the cause of those natural divisions in the strata; and the regularity, which is always to be observed more or less, depends upon the proper circumstances of the case, and the uniform nature of the mass.

(Page 184.) «Le matin avant de partir du Chapiu, j'allai voir si les beaux grès rectangulaires, que j'avois observés la veille descendoient jusqu'au bas de la montagne; j'y trouvai effectivement des grès mais à couches minces, et qui ne se divisoient point avec régularité; en revanche, je vis des couches de ce grés ployées et reployées en zig-zags, comme celles que j'avois rencontrées aux contamines, § 755, et ces couches ondées étoient aussi renfermées entre de couches planes et parallèles. Ce phénomène est bien plus rare dans les grès, que dans les roches feuilletées proprement dites.»

Thus every appearance is found by which the primitive *schisti* are perfectly resembled, both as to their original formation and their accidents, with the strata, which are acknowledged by naturalists as being the common operation of the sea.

Our author then gives an account of the *Passage de Fours*, in which he makes the following observations:

«§ 776. Tout près du sommet du Col, on rencontre de beaux bancs de grès jaunâtre qui sortent de dessous la pierre calcaire, et qui pourtant ne font aucune effervescence avec les acides.

«§ 777. Je mis deux heures et trois quarts à monter depuis le hameau du Glacier jusqu'au haut du Col, d'où l'on descend à la croix du Bon-Homme. J'envoyai mes mulets m'attendre à cette croix, et je m'acheminai avec Pierre Balme sur ma droite, pour atteindre le faite de la montagne dont la cime arrondie me paroissoit devoir dominer sur toutes les montagnes d'alentour. J'ai donné à cette sommité, qui n'avoit point de nom, celui de *Cime des Fours*, à cause du passage qu'elle domine. De grandes plaques de neige couvroient en divers endroits la route que j'avois à faire pour y aller; le roc se montroit cependant assez pour que l'on pût reconnoître sa nature.

«§ 778. Je traversai d'abord des couches des grès qui étoient la continuation de celles dont je viens de parler, § 776. Je trouvai ensuite des bancs d'une espèce de poudingue grossier, dont le fond étoit ce même grès rempli de cailloux arrondis. Quelques uns de ces bancs se sont décomposés, et les eaux out entraîné les parties de sable qui lioient les cailloux, en sorte que ceux-ci sont demeurés libres et entassés exactement comme au bord d'un lac ou d'une rivière. Il étoit si étrange de marcher à cette hauteur sur des cailloux roulés, que Pierre Balme en témoigna son étonnement, même avant, que j'en parlasse. On auroit été tenté de croire qu'une cascade tombant anciennement de quelque rocher plus élevé, détruit dès-lors par le temps, avoit arrondi ces cailloux, si on n'en trouvoit pas de semblables encore enclavés dans les couches régulières du grès qui compose le haut de cette montagne.

«§ 779. Quoique depuis long-temps je ne doute plus que les eaux n'aient couvert et même formé ces montagnes, et qu'il y en ait même des preuves plus fortes que l'existence de ces cailloux roulés, cependant leur accumulation sur cette cime avoit quelque chose de si extraordinaire, et qui parloit aux sens un langage si persuasif, que je ne pouvois pas revenir de mon étonnement. Si en marchant sur ces cailloux, et en les observant, j'oubliois pour un moment le lieu où j'étois, je me croyois au bord de notre lac; mais, pour peu que mes yeux s'écartassent à droite ou à gauche, je voyois au-dessous de moi des profondeurs immenses; et ce contraste avoit quelque chose qui tenoit d'un rêve; je me représentois alors avec une extrême vivacité les eaux remplissant toutes ces profondeurs, et venant battre et arrondir à mes pieds ces cailloux sur lesquels je marchois, tandis que les hautes aiguilles formoient seules des isles au-dessus de cette mer immense; je me demandois ensuite quand et comment ces eaux s'étoient retirées. Mais il fallut m'arracher à ces grandes spéculations et employer plus utilement mon temps à l'exacte observation de ces singuliers phénomènes.»

The fact here worthy of observation is the effect of time in decomposing this *grès*, or sand-stone, which contains the gravel. All the other appearances follow naturally from the situation of this place, which is a summit, and does not allow of such a collection of water as might travel or transport the loose gravel, although it has been sufficient for carrying away the sand. This decomposition of the sand stone we shall find also explained from what follows of the description of this place.

«§ 780. Tous les bancs de grès que l'on voit sur cette montagne ne renferment pas des cailloux roulés; il y a des alternatives irrégulières, de bancs de grés pur, et de bancs de grès mêlé de cailloux. Les plus élevés n'en contiennent point. Le plus haut de ceux qui en renferment est un banc bien suivi d'un pied d'épaisseur, et qui monte de 30 degrés au nord-nord-ouest.

«Quelques-uns de ces bancs, remplis de cailloux, offrent une particularité bien remarquable; on voit à leur surface extérieure, exposée à l'air, une espèce de réseau formé par des veines noires solides, et saillantes de deux ou trois pouces au-dessus de la surface de la pierre; les mailles de ce réseau sont quelquefois irrégulieres, mais ce sont pour la plupart des quadrilatères obliquangles, dont les côtés ont huit à dix pouces de longueur. Comme ces pierres ont toutes un tendance à se partager en rhomboïdes, il paroît qu'il y a eu anciennement des fentes qui divisoient les bancs en parties de cette forme; et que ces fentes ont été remplies par du sable qui a été cimenté par un suc ferrugineux; ce gluten solide a rendu ces parties plus dures que le reste de la pierre; et lorsque les injures de l'air ont rongé la surface de ces bancs, les mailles du réseau sont demeurées saillantes.

«Les cailloux arrondis, qui out été long-temps exposés à l'air, out aussi pris par dehors une teinte noirâtre ferrugineuse, mais ceux qui sont encore renfermés dans les bancs de grés ont comme lui une couleur jaunâtre. Je n'en trouvai là aucun qui ne fut de nature primitive, et la plupart étoient de feldspath gris ou roux très-dur, et confusément crystallisé. Ce sont donc des pierres qui n'ont point naturellement une forme arrondie; et qui, par conséquent, ne tiennent celle qu'elles ont ici, que du roulement, et du frottement des eaux.

«Tous ces grès font effervescence avec l'eau-forte, mais les parties du réseau ferrugineux en font beaucoup moins que le fond même du grès. De même si l'on compare entr'eux les grès qui renferment des cailloux avec ceux qui n'en contiennent pas, on trouve dans ceux-ci plus de gluten calcaire, l'eau-forte diminue beaucoup plus leur cohérence.

«Sur la cime même de la montagne, ces grès sont recouverts par une ardoise grise, luisante, qui s'exfolie à l'air. Et si l'on redescend de cette même cime par le nord-est, du côté opposé au passage des Fours, on retrouvera des bancs d'un grès parfaitement semblable, et qui se divisent là d'eux-mêmes en petits fragmens parallélépipèdes.

«Du haut de cette cime, élevée de 1396 toises au-dessus de la mer, on a une vue très entendue. Au nord et au nord-ouest les vallées de Mont Joie, de Passy, de Sallanches; au couchant la haut cime calcaire dont j'ai parlé, § 759; au sud les montagnes qui s'étendent depuis le Chapiu jusqu'au Col de la Seigne; à l'est, ce même Col que l'on domine beaucoup. Sur la droite de ce col, on voit du côté de l'Italie la chaîne du Cramont, et plusieurs autres chaînes qui lui sont parallèles, tourner tous leurs escarpemens contre la chaîne centrale, de même qu'on voit du côte de la Savoye, les chaînes du Reposoir, de Passy, de Servoz, tourner en sens contraire leurs escarpemens contre cette même chaîne. Car c'est-la une des vues très étendues sur les deux cotés opposés des Alpes; puisque l'on découvre d'ici les montagnes de Courmayeur et de l'Allée Blanche, qui sont du côté méridional de la chaine, et celles du Faucigny et de la Tarentaise, qui sont du côté septentrional. Or les sites d'ou l'on jouit tout á-la-fois de ces deux aspects sont très rares; parce que les hautes cimes de la chaîne centrale sont presque toutes inaccessibles, et les cols par lesquels on la traverse sont presque tous tortueux, étroite, et ne présentent pour la plupart que de vues très bornées.»

We have here two facts extremely important with regard to the present theory. The one of these respects the original formation of those alpine strata; the other the elevation of those strata from the bottom of the sea, and particularly the erection of those bodies, which had been formed horizontal, to their present state, which is that of being extremely inclined. It is to this last, that I would now particularly call the attention of my readers.

It is rarely that such an observation as this is to be met with. Perhaps it is rarely that this great fact occurs in nature, that is, so as to be a thing perceptible; it is still more rare that a person capable of making the observation has had the opportunity of perceiving it; and it is fortunate for the present theory, that our author, without prejudice or the bias of system, had been led, in the accuracy of a general examination, to make an observation which, I believe, will hardly correspond with any other theory but the present.

If strata are to be erected from the horizontal towards the vertical position, a subterraneous power must be placed under those strata; and this operation must affect those consolidated bodies with a certain degree of regularity, which however, from many interfering circumstances, may be seldom the object of our observation. If indeed we are to confine this subterraneous operation to a little spot, the effect may be very distinctly perceived in one view; such are those strata elevated like the roof of a house, which M. de Saussure has also described. But when the operation of this cause is to be extended to a great country, as that of the Alps, it is not easy to comprehend, as it were, in one view, the various corresponding effects of the same cause, through a space of country so extensive, and where so many different and confounding observations must be made. In this case, we must generalize the particular observations, with regard to the inclinations of strata and their direction, in order to find a similar effect prevailing among bodies thus changed according to a certain rule; this rule then directs our understanding of the cause. The general direction of those alpine strata, in this place, is to run S.E. and N.W. that is to say, this is the horizontal line of those inclined beds. We also find that there is a middle line of inclination for those erected strata in this alpine region; as if this line had been the focus or centre of action and elevation, the strata on each side being elevated towards this lint, and declined from it by descending in the opposite direction.

The view which our author has now given us from this mountain is a most interesting object, and it is a beautiful illustration of this theory; for, the breaking of the tops of mountains, composed of erected strata, must be on that side to which their strata rise; and this rupture being here towards the central line of greatest elevation, the ridges must in their breaking generally respect the central ridge. But this is the very view which our enlightened observator has taken of the subject; and it is confirmed in still extending our observations westward through the kingdom of France, where we find the ridges of the Jura, and then those of Burgundy gradually diminishing in their height as they recede from the centre of elevation, but still preserving a certain degree of regularity in the course of their direction.

But our author has still further observed that this is a general rule with regard to mountains. I will give it in his own words, Tom. 2. (p. 338.)

«§ 918. Mais la chaîne centrale n'est pas la seule primitive qu'il y ait de ce côté des Alpes. Du haut du Cramont en se tournant du côté de I'Italie, on voit un entassement de montagnes qui s'étendent aussi loin que peut aller la vue. Parmi ces montagnes on en distingue un au sud-ouest qui est extrêmement élevée: son nom est *Ruitor*: elle se présente au Cramont à-peu-près près sous le même aspect que le Mont-Blanc à Genève; sa cime est couverte de neiges, un grand glacier descend de sa moyenne région, et il en sort un torrent qui vient se jetter dans la riviere de la Tuile. Cette haut montagne, de nature primitive, est au centre d'une chaîne de montagnes moins élevées, mais primitives comme elle, et qui passent au-dessus du val de Cogne. On voit de la cime du Cramont des montagnes secondaires situées entre le Cramont et cette chaîne primitive, et on reconnoît que les couches de ces montagnes s'élèvent contre cette chaîne en tournant le dos à la chaîne centrale.

«§ 939. L'inclinaison du Cramont et de la chaîne contre le Mont-Blanc, n'est donc pas un phénomène qui n'appartienne qu'à cette seule montagne; il est commun à toutes les montagnes primitives, dont c'est une loi générale que les secondaires qui les bordent, ont de part et d'autre leurs couches ascendantes vers elles. C'est sur le Cramont, que je fis pour la première fois, cette observation alors nouvelle, que j'ai verifié ensuite sur un grand nombre d'autres montagnes, non pas seulement dans la chaîne des Alpes, mais encore dans diverses autres chaînes, comme je le ferai voir dans le IVe. volume. Les preuves multipliées que j'en avois sous les yeux au moment où je l'eus faite, et d'autres analogues que ma mémoire me rappela d'abord, me firent soupçonner son universalité, et je la liai immédiatement aux observations que je venois de faire sur la structure du Mont-Blanc et de la chaîne primitive dont il fait partie. Je voyois cette chaîne composée de feuillets que l'on pouvoit considérer comme des couches; je voyois ces couches verticales dans le centre de cette chaîne et celles des secondaires presque verticales dans le point de leur contact avec elles, le devenir moins à de plus grandes distances, et s'approcher peu-à-peu de la situation horizontale à mesure qu'elles s'éloignoient de leur point d'appui. Je voyois ainsi les nuances entre les primitives et les secondaires, que j'avois déjà observées dans la matière dont elles sont composées, s'étendre aussi à la forme et à la situation de leurs couches; puisque les sommités secondaires que j'avois là sous les yeux se terminoient en lames piramidales aigues et tranchantes, tout comme le Mont-Blanc, et les montagnes primitives de la chaîne. Je conclus de tout ces rapports, que, puisque les montagnes secondaires avoient été formées dans le sein des eaux, il falloit que les primitives eussent aussi la même origine. Retraçant alors dans ma tête la suite des grandes révolutions qu'a subies notre globe, je vis la mer, couvrant jadis toute la surface du globe, former par des dépôts et des crystallisations successives, d'abord les montagnes primitives puis les secondaires; je vis ces matières s'arranger horizontalement par couches concentriques; et ensuite le feu ou d'autres fluides élastiques renfermes dans l'intérieur du globe, soulever et rompre cette écorce, et faire sortir ainsi la partie intérieure et primitive de cette même écorce, tandis que ses parties extérieures ou secondaires demeuroient appuyées contre les couches intérieures. Je vis ensuite les eaux se précipiter dans les gouffres crevés et vides par l'explosion des fluides élastiques; et ces eaux, en courant à ces gouffres, entraîner à de grandes distances ces blocs énormes que nous trouvons épars dans nos plaines. Je vis enfin après la retraite des eaux les germes des plantes et des animaux, fécondés par l'air nouvellement produit, commencer à se développer, et sur la terre abandonnée par les eaux, et dans les eaux mêmes, qui s'arrêtèrent dans les cavités de la surface.

«Telles font les pensées que ces observations nouvelles m'inspirèrent en 1774. On verra dans le IVe. volume comment douze ou treize ans d'observations et de réflections continuelles sur ce même sujet auront modifié ce premier germe de mes conjectures; je n'en parle ici qu'historiquement, et pour faire voir qu'elles sont les premières idées que le grande spectacle du Cramont doit naturellement faire éclore dans une tête qui n'a encore épousé aucun système.»

How far these appearances, which had suggested to this philosopher those ideas, agree with or confirm the present theory, which had been founded upon other observations, is here submitted to the learned.

We have now not only found a cause corresponding to that which can alone be conceived as producing this evident deplacement of bodies formed horizontally at the bottom of the sea, but we have also found that this same cause has operated every where upon those strata, in consolidating by means of fusion the porous texture of their masses. Now when the evidence of those two facts are united, we cannot refuse to admit, as a part of the general system of the earth, that which is every where to be observed, although not every where to such advantage as in those regular appearances, which our author has now described from those alpine regions.

I have only one more example to give concerning this great region of the Alps belonging to Savoy and Switzerland. It is from the author of Les Tableaux de la Suisse.

[50] «On s'embarque à Fluelen à une demi-lieue d'Altorf sur le lac des quatre Waldstoett ou cantons forestiers; les bords de ce lac sont des rochers souvent à pic et d'une très grande élévation et la profondeur de ses eaux proportionnée. Ces roches sont toutes calcaires, et souvent remarquables par la position singulière de leurs couches. A une demi-lieue environ de Fluelen, sur la droite, des couches de six pouces environ d'épaisseur sont déposées en zig-zags comme une tapisserie de point-d'hongrie; à une lieue et demie à côté de couches bien horizontales, de quatre à cinq pieds d'épaisseur il y en a de contournées de forme circulaire et d'elliptiques. Il seroit difficile de se faire une idée de la formation de pareilles couches, et d'expliquer comment les eaux ont pu les deposer ainsi.»

Having thus given a view of a large tract of country where the strata are indurated or consolidated and extremely elevated, without the least appearance of subterraneous fire or volcanic productions, it will now be proper to compare with this another tract of country, where the strata, though not erected to that extreme degree, have nevertheless been evidently elevated, and, which is principally to the present purpose, are superincumbent upon immense beds of basaltes or subterranean lava. This mineral view is now to be taken from M. de Luc, Lettres *Phisiques* et Morales, Tom. 4.

This naturalist had discovered along the side of the Rhine many ancient volcanos which have been long extinct; but that is no part of the subject which we now inquire after; we want to see the operations of subterraneous lava which this author has actually exposed to our view without having seen it in that light himself. He would persuade us, as he has done himself, that there had been in the ancient sea volcanic eruptions under water which formed basaltic rocks; and that those eruptions had

[50] Discours sur l'Hist. Nat. de la Suisse, page CLV.

been afterwards covered with strata formed by the deposits made in that sea; which strata are now found in the natural position in which they had been formed, the sea having retreated into the bowels of the earth, and left those calcareous and arenaceous strata, with the volcanic productions upon which they had been deposited, in the atmosphere.

It would be out of place here to examine the explanation which this author has given with regard to the consolidation of those deposited strata which is by means of the filtration of water, but as in this place there occurs some unusual or curious examples of a particular consolidation of limestone or calcareous deposits, as well as similar consolidations of the siliceous sort, it may be worth while to mention them in their place that so we may see the connection of those things, and give all the means of information which the extremely attentive observations of this naturalist has furnished to the world of letters.

At Oberwinter our author remarks a stratum of consolidated sand above volcanic matter, Tome 4, p. 162. «Tant que j'ai parcouru le pied du cône, je n'ai vu qu'un terrain composé de ces débris, et cultivé en vignes. Mais après l'avoir dépassé, j'ai trouvé la coupe verticale d'une colline à couches pierreuses, si réguliers, que je les ai prises au premier coup d'oeil pour de la pierre à chaux. L'esprit de nitre m'a détrompé: c'est une pierre sableuse très compacte, dont les couches, qui n'ont souvent que quelques pouces d'épaisseur, s'élèvent par une pente insensible vers le cône volcanique qu'elle recouvrent de ce coté là sans aucune apparence de désordre. Ces couches qui sont visiblement des dépôts de la mer, quoique je n'y ai pas trouvé de corps marins, ont été formées depuis que le cône s'étoit élevé.»

This is a species of reasoning which this acute naturalist would surely not have let pass in any other cosmologist. But here the love of system, or a particular theory, seems to have warped his judgment. For, had our author been treating of beds or bodies deposited in water, and preserving the natural situation in which they had been formed, he would have had reason to conclude that the superior bed was of the latest formation; but here is no question of superincumbent strata; it is a stratum which is superincumbent on a lava; and it is equally natural to suppose the lava posterior to the stratum as the stratum posterior to the lava.

Our author meets with a limestone too much erected in its position to be supposed as in its natural place, and then he explains this phenomenon in the following manner, p. 333. «Les rochers d'Ehrentbreitstein et de Lahnstein sont donc des faits particuliers. Ces rochers là ont été formes par des dépôts de la mer: Les corps marin qu'ils renferment en font foi. Dès lors ils ont dû avoir dans leur origine la seule position que la mer pût leur donner; l'horizontale ou légèrement inclinée. Leur couches sont aujourd'hui rompues, et leur inclination n'est plus celle de dépôts immédiats de la mer. Les collines, auxquelles elle appartenoient, sont en même tems entourées de volcans anciens; et il est naturel d'en conclure, que c'est à eux que ces grands rochers doivent leur position actuelle.»

Here one would expect our author is to allow that volcanos may erect rocks in heightening them in their place; but this is not the light in which it has been seen by him, as will appear from what follows. «L'enfoncement d'une de leurs cotés n'est rien, quand on considère le prodigieuse excavation qui ont dû se faire, pour porter au dehors toutes les montagnes, les collines, et les plaines volcaniques qui se trouvent dans ce vaste circuit.»

When a small portion of a stratum is examined, such as the present case, it is impossible from inspection to determine, whether it owes its inclined position to the sinking or the raising of the ground; the stratum is changed from its original position, but whether this has been brought about by the raising of the one side, or the sinking of the other is not apparent from what then is seen. But unless we are to explain the appearance of strata above the level of the sea by a supposition which is that of the retreat of the ocean, a theory which this author has adopted, it is as impossible to explain the present appearance of horizontal strata as of those that are inclined. At the same time, if a power placed below the strata is to be employed for the purpose of raising them from the bottom of the sea, to the place in which we find them at present, it is impossible that this should be done without the fracture of those strata in certain places; and it is much more difficult to conceive this operation not to be attended with changing the natural horizontal position of strata, and thus leaving them in many places inclined, than otherwise by supposing that this internal power of the globe should elevate the strata without changing their original position.

With this description of strata on the Rhine, we may compare that of M. Monnet respecting those which he found upon the Meuse, (Nouveau Voyage Minéralogique, etc. Journal Physique, Aoust, 1784.)

Speaking of the schistus, or slate, he adds: «Mais ces petites veines nous donnent lieu de faire une observation importante; c'est qu'elles se présentent assez communement perpendiculaire, tandis que les grands bancs d'ardoises, ceux qu'on exploite, sont, comme nous l'avons dit, couchés sur une ligne de 15 à 20 degrés. J'ai parlé des montagnes de marbre qui sont derrière Givet, et de celles sur la quelle est situé Charlemont. J'ai fait voir que bien loin que les bancs de marbre, qui forment la montagne du Givet, soient horizontaux comme on seroit tenté de le croire, d'après les principes de quelques naturalistes systématiques, qui pensent que tous les bancs de pierres calcaires ne sauroient être autrement; j'ai fait voir, dis-je, que ces bancs sont presque perpendiculaire à l'horizon; et de plus, qu'ils sont tellement collés les uns contre les autres, qu'à peine on peut les distinguer.»

The changed structure and position of the strata, now exemplified from the observations both of M. de Saussure and M. de Luc, observations made in a great extent from France to Germany, show the effects without the means by which those effects had been produced; and, in this case, it is by judging from certain principles of natural philosophy that the cause is discovered in the effect.

We are now to see the deplacement of at least a great body of earth in another light, by having at the same time in our view both the cause and the effect. Nothing can give a more proper example of this than the mine of Rammelsberg; and no description better adapted to give a clear idea than that of M. de Luc, which I shall now transcribe. Lettres Phisiques et Morales, Tome 3. p. 361 to 364.

«Deux *filons* principaux occupent les mineurs dans le *Rammelsberg*: filons immenses, car ils ont jusqu'à 18 ou 20 toises d'épaisseur dans une étendue dont on ne connoit pas encore les bornes. L'un de ces *filons* fait avec l'horizon un angle de 25 degrés; c'est l'inférieur: l'autre s'élève de 45 degrés: et leur distance étant peu considérable, leurs plans doivent se rencontrer dans un point qui n'est pas fort éloigné des mines. Leurs *directions* sont aussi différentes: celle du *filon* de 35 degrés est à 6½ *heures*; et celle du *filon* de 45 degrés est a 5*h.*-1/2: tellement qu'ils se croisent à l'endroit ou est percé le puits des pompes.

«On est embarrassé d'expliquer l'état de cette montagne par des secousses. Il faut au moins supposer que la montagne entière a été culbutée, et encore reste-t-il à comprendre, comment s'est soutenue cette grande piece qui sépare les filons, et qui, en supposant vuides les espaces de ceux-ci, se trouveroit absolument en l'air.

«Ce phénomène important à l'histoire des montagnes, je veux dire ces intersections des *filons*, est très fréquent dans les mines et très remarqué par les mineurs. Il arrive souvent que des *filons*, qui sont à la même *heure*, c'est-à-dire, qui ont des *directions* semblables vers l'horizon, ont une chute ou inclinaison différente, et telle que leurs deux plans se coupent à une certaine profondeur. Si le mineur ne s'en apperçoit pas assez tôt, et que des le commencement de son exploitation, il n'étançonne pas fortement partout ou il enlevé les *filons*, tout son ouvrage peut être écrasé par l'enfoncement de la pièce qui les séparoit. Cette pièce même a un nom chez le mineurs; ils la nomment *Bergkiel*, c'est-à-dire coin de la matière de la montagne: et quand deux filons sont voisins l'une de l'autre, le géomètre souterrain en étudie l'inclinaison pour juger à l'avance s'il y aura un *Bergkiel*; et qu'en ce cas la mineur prenne ses précautions, en conservant des appuis naturels dans la gangue, ou s'en faisant d'artificiels, à mesure qu'il s'enfonce. Or si, en élevant les filons, ce coin se trouve sans appui; comment s'est-il soutenu avant que les filons fussent formés?

«Voilà une question forte embarrassante. Mais peut-être n'a-t-on pas fait assez d'attention jusqu'ici à la mauvaise gangue, qui se trouve être de la même nature que la montagne. Peut-être trouveroit on par la, qu'en même tems que les fentes se font faites, il y est tombé des pièces des còtés, qui ont empêché la réunion des parties de la montagne; fragmens qui, aujourd'hui, font partie des *filons*, et qu'on pourroit laisser encore pour appuis naturels, n'exploitant qu'autour d'eux lorsqu'on auroit appris à les connoître.

«Ce peu d'inclinaison des *filons* du Rammelsberg rappelleroit l'idée des *couches* formées de dépôts successifs, s'ils étoient parallèles. Mais leur manque de parallélisme en tout sens exclut cette explication. Car dans toutes les montagnes qui doivent leur formation aux dépôts des eaux, les *couches* sont parallèles; et l'on sent bien qu'elles doivent l'être.

«La nature des *filons* du *Rammelsberg* est aussi différente de celle de *Claustbat* que l'est leur situation. C'est un massif compacte, et presque partout le même, de minéral de*plomb* et *argent* pauvre, pénétré de *pyrite* sulphureuse. Ils sont traversés en plusieurs endroits par de *Ruscheln*, qui ont fait glisser le toit vers le *mur*; tellement que malgré l'épaisseur de ces *filons*, on crut une fois en avoir trouvé la fin. Ils sont aussi coupés dans leur intérieur, en sens différens, par d'autres plus petits *filons*, composés de matières très différentes; surtout d'une *pyrite cuivreuse* dure et pauvre, et que par cette raison on ne tente pas de séparer.

«En mettant à part ces petits *filons* particuliers, ainsi que les Ruscheln, dus probablement les uns et les autres à des causes postérieures à celles qui ont produit les filons principaux, la masse compacte de ceux-ci réveille beaucoup l'idée d'une matière fondue; en même tems qu'on seroit fort embarrassé à concevoir, d'où viendroit cette matière, si distincte de toute autre, lorsqu'on voudroit l'attribuer à l'eau.

«Cette idée, que je dois à Mr. de Redden, perfectionnée par l'étude des phénomènes, donnera peut-être un jour le mot de toutes ces énigmes.»

Here is the clearest evidence that an enormous mass of mountain had been raised by a subterranean force; that this force had acted upon an enormous column of melted minerals, the specific gravity of which is great; and that this fluid mass had suspended a great wedge of this mountain, or raised it up. Now, if by means which are natural to the globe, means which are general to the earth, as appearing in every mineral vein, this mass of mountain had been raised up and suspended twenty fathoms, there is no reason why we should suppose nature limited, whether in raising a greater mass of earth, or of raising it a greater height. That the height to which the land of this globe shall be raised, is a thing limited in the system of this earth, in having a certain bounds which it shall not exceed, cannot be disputed, while wisdom in that system is acknowledged; but it is equally evident, that we cannot set any other bounds to the operation of this cause, than those which nature appears actually to have observed in elevating a continent of land above the level of the sea for the necessary purpose of this world, in which there is to be produced a variety of climates, as there is of plants, from the burning coast under the equator to the frozen mountains of the Andes.

Here therefore we have, although upon a smaller scale, the most perfect view of that cause which has every where been exerted in the greater operations of this earth, and has transformed the bottom of the sea to the summits of our mountains. Now, this moving power appears to have been the effect of an internal fire, a power which has been universally employed for the consolidation of strata, by introducing various degrees of fusion among the matter of those masses, and a power which is peculiarly adapted to that essential purpose in the system of this earth, when dry land is formed by the elevation of what before had existed as the bottom of the sea.

I hope it will not be thought that too much is here adduced in confirmation of this part of the theory. The elevation of strata from their original position, which was horizontal, is a material part; it is a fact which is to be verified, not by some few observations, or appearances here and there discovered in seeking what is singular or rare, but by a concurrence of many observations, by what is general upon the surface of the globe. It is therefore highly interesting not only to bring together that multitude of those proofs which are to be found in every country, but also to give examples of that variety of ways in which the fact is to be proved. Were it necessary, much more might be given, having many examples in this country of Scotland, in Derbyshire, and in Wales, from my proper observation; but, in giving examples for the confirmation of this theory, I thought it better to seek for such as could not be suspected of partiality in the observation.

Chapter 3. Facts In Confirmation Of The Theory, Respecting Those Operations Which Re-Dissolve The Surface Of The Earth

We have now discussed the proof of those mineral operations by which the horizontal strata, consolidated at the bottom of the sea, had been changed in their position, and raised into the place of land. The next object of our research is to see those operations, belonging to the surface of the earth, by which the consolidated and erected strata have been again dissolved, in order to serve the purpose of this world, and to descend again into the bottom of the sea from whence they came.

Of all the natural objects of this world, the surface of the earth is that with which we are best acquainted, and most interested. It is here that man has the disposal of nature so much at his will; but here, man, in disposing of things at the pleasure of his will, must learn, by studying nature, what will most conduce to the success of his design, or to the happy economy of his life. No part of this great object is indifferent to man; even on the summits of mountains, too high for the sustaining of vegetable life, he sees a purpose of nature in the accumulated snow and in majestic streams of the descending ice. On every other spot of the surface of this earth, the system of animal and vegetable life is served, in the continual productions of nature, and in the repeated multiplication of living beings which propagate their species.

But, for this great purpose of the world, the solid structure of this earth must be sacrificed; for, the fertility of our soil depends upon the loose and incoherent state of its materials; and, that state of our fertile soil necessarily exposes it to the ravages of the rain upon the inclined surface of the earth. In studying this part of the economy of nature, we may perceive the most perfect wisdom in the actual constitution of things; for, while it is so ordered that the solid mass of earth should be resolved for the purpose of vegetation, the perishable soil is as much as possible preserved by the protection of those solid parts; and these consolidated masses are resolved in so slow a manner, that nothing but the most philosophic eye, by reasoning upon a chain of facts, is able to discover it. Thus it may be concluded, that the apparent permanency of this earth is not real or absolute; and that the fertility of its surface, like the healthy state of animal bodies, must have its period, and be succeeded by another.

The study of this subject must tend to enlarge the mind of man, in seeing what is past, and in foreseeing what must come to pass in time; and here is a subject in which we find an extensive field for investigation, and for pleasant satisfaction. The hideous mountains and precipitous rocks, which are so apt to inspire horror and discontentment in minds which look at sensible objects only for immediate pleasure, afford matter of the most instructive speculation to the philosopher, who studies the wisdom of nature through the medium of things. As, on the one hand, the summit of the mountain may be supposed the point of absolute sterility, so, on the other, the sandy desert, moved by nothing but the parching winds of continents distant from the sources of abundant rains, finishes the scale of natural fertility, which thus diminishes in the two opposite extremes of hot and dry, of cold and wet; thus is provided an indefinite variety of soils and climates for that diversity of living organised bodies with which the world is provided for the use of man. But, between those two extremes, of mountains covered with perpetual snow, and parched plains in which every living thing must perish, we find the most pleasant subject of contemplation, in studying the means employed in nature for producing the beautiful and benevolent system of hills and valleys, of fertile soils and well watered plains, of the most agreeable circumstances and proper situations for every thing that lives, and for the preservation of an indefinite variety of organised bodies which propagate their species.

Without this philosophic view of things, the prospect of the surface of this earth is far from giving always satisfaction or contentment to the mind of man, who is subject to be continually displeased with that which is presented to his view, and which, in his opinion, is not the best; in his partial views of things, it is either too high or too low, too cold or too warm, too moist or too dry, too stiff for the labour of his plough, or too loose for the growing of his corn. But, considering nature as the common parent of living growing propagating bodies, which require an indefinite variety of soils and climates, the philosopher finds the most benevolent purpose in the end proposed, or effect which is attained, and sees perfect wisdom in the effectual means which are employed. This is the view that I would wish men of science to take; and it is for this purpose that I am now to examine the phenomena of the surface of this earth.

If strata, formed at the bottom of the sea, had been consolidated by internal operations proper to the earth, and afterwards raised for the purpose of a habitable world; and if, for the purpose of vegetation, the solid land must be resolved into soil by the dissolution and separation of its parts, as is required in the theory, the strata, instead of being entire immediately below the soil, should be found in a mutilated state; the ends of hard and solid beds should present their fractures or abrupt sections immediately under the confused materials with which they are covered; and the softer strata should appear to suffer gradual resolution and decay, by which may be perceived their transition into soil, the most important part of all the operations of the globe which do not immediately concern our life.

These are facts which every person of observation has it in his power to verify; they are facts for which nothing further can be laid than that the thing is truly so; and they are facts from which the most important arguments might be formed, were any doubt to be entertained concerning the justness of the theory which has now been given.

The theory consists in this, that it is necessary to have a habitable country situated in the atmosphere, or above the surface of the sea.

It is difficult to say precisely what constitutes a habitable country. A resting place out of the water suffices for such amphibious animals as, while they necessarily live in the atmosphere, feed in the sea. Man, more versatile in his nature than most animals, and more capable of adapting his manners to his circumstances, is even sometimes found subsisting in situations where the land affords him little more than it does the seal on which he feeds. The growth of terrestrial plants, however, seems necessary to the idea of a habitable country; and, for the growth of plants, there is required soil: Now, this is only to be procured by the resolution or decay of solid land.

We are not to consider the resolution of our land as being the effect of accident, while it is performed by the operations of the sun and atmosphere, by the alternate action of moisture and of drought, and by the casual operations of a river in a flood. Nothing is more steady than the resolution of our land; nothing rests upon more certain principles; and there is nothing which in science may be more easily investigated.

Calcareous, argillaceous, and other soluble earths, compose many of the strata; but in many more, which are partly or chiefly composed of insoluble substances, those soluble earths are mixed in various proportions. Now, when the siliceous substance, which is the insoluble part, shall be supposed resisting every effort of the elements towards its dissolution, those compound masses upon the surface of the earth, however endued with hardness and solidity, are gradually impaired by the dissolution of some of their constituent parts, and by the separation of others which are thus exposed to the ablution of water. In like manner, by the resolution of the surrounding parts, the solid *silex*, which is supposed to be insoluble, is removed from its bed, and thus suffers new parts of the solid land to be exposed to those injuries of the air, by which the general good of plants, of animals, and even of future worlds, are consulted.

The solid land is resolved into stones, gravel, sand, earths, and clays; all or either of these, by retaining moisture, and affording places for the roots of plants, are disposed for vegetation in different degrees; a mixture of the different earths being, upon the whole, the best suited to that purpose; and this compound body, mixed with vegetable or animal substances, becoming a most luxuriant soil.

Soils are thus formed, either by the resolution of the surface of that land upon which they are to rest, or by the transportation of those solid parts to be again deposited upon another basis. In this manner soils are constantly changing upon the same spot; sometimes they are meliorated, at other times impoverished. From the tops of the mountains to the shores of the sea, all the soils are subject to be moved from their places, by the natural operations of the surface, and to be deposited in a lower situation; thus gradually proceeding from the mountain to the river, and from the river, step by step, into the sea. Countries are thus formed at the mouths of rivers in the sea, so long as the quantities of materials transported from the land exceeds that which is carried from the shore, by tides and currents, into the deeper water.

The soil, with which the surface of this earth is always covered more or less, is extremely various, both with respect to quantity and quality; it is found resting upon the solid parts; and those solid parts are always more or less affected by the influences of the atmosphere near the surface of the earth. Those parts of the strata which approach the surface are always in a decayed state; and this sometimes may be observed for very considerable depths, according as the quality of the materials, and the situation of the place dispose to that effect. This general observation however may be formed, that, *cet. par.* the strata become always more solid, or are found in their sound and natural state, more and more in proportion as we sink into the earth, or have proceeded from the surface.

There is nothing of which we have more distinct experience than this, That, universally upon the surface of the earth, the solid parts are dissolving and always going into decay; whereas, at a sufficient depth below, they are found in their natural consolidated state. The operations of man in digging into the ground, as well as the sections of the earth so often formed by brooks and rivers, affords such ample testimony of this truth that nothing farther need be observed upon this head only that this is a most important operation in the natural economy of the globe, and forms a subject of the greatest consequence in the present Theory of the Earth, which holds for principle, that the strata are consolidated in the mineral regions far beyond reach of human observation.

Consistently with this view of things, the strata or regular solid parts, under the soil or travelled earth, should be found in some shape corresponding to the represented state of those things, when affected by the powers which have acted upon the surface of the earth. Here, accordingly, the strata are always to be observed with those marks of resolution, of fracture, and of separation, which have most evidently arisen from the joint operation of those several causes that have been now explained. But though every operation of the globe be necessarily required for the explanation of those appearances which we now examine, it is principally the action of the sun and atmosphere, and the operations of the waters flooding the surface of the earth, that form the proper subject of the present investigation.

It must not be imagined that, from the present state of things, we may be always able to explain every particular appearance of this kind which occurs; for example, why upon an eminence, or the summit of a ridge of land which declines on every side, an enormous mass of travelled soil appears; or why in other places, where the immediate cause is equally unseen, the solid strata should be exposed almost naked to our view. We know the agents which nature has employed for those purposes; we know the operations in which the solid parts are rendered soil of various qualities and for different purposes; and when we find the marks of those natural operations in places where, according to the present circumstances, the proper agents could not have acted or existed, we are hereby constrained to believe, that the circumstances of those places have been changed, while the operations of nature are the same.

It is thus that we shall find reason to conclude an immense period of time, in those operations which are measured by the depradations of water acting upon the surface of the earth; a period however which is to be esteemed a little thing compared with that in which a continent had taken birth and gone into decay; but a period which interests us the more to examine, in that it approaches nearer to another period, for the estimation of which *some data* may perhaps be found by naturalists and antiquaries, when their researches shall be turned to this subject. It is only in this manner that there is any reasonable prospect of forming some sort of calculation concerning that elapsed time in which the present earth was formed, a thing which from our present data we have considered as indefinite.

In this view which we are now taking of the surface of the earth, nothing is more interesting than the beds of rivers; these take winding courses around the hills which they cannot surmount; sometimes again they break through the barrier of rocks opposed to their current; thus making gaps in places by wearing away the solid rock over which they formerly had run upon a higher level; and thus leaving traces of their currents in the furrowed sides of rocky mountains, far from the course of any water at the present time.

So strongly has M. de Saussure been impressed with this and some other appearances, that he has imagined a current of water which, however in the possibility of things, is not in nature; and which moreover could not have produced the appearances now mentioned, which is the work of time, and the continued operation of a lesser cause. We are further obliged to him for the following facts.

Vol. 1. (page 163.) «Les tranches nues et escarpées des grandes couches du petit et surtout du grande Saleve, présentent presque partout les traces les plus marquées du passage des eaux, qui les ont rongées et excavées, on voit sur ces rochers, des sillons à peu près horizontaux, plus ou moins larges et profonds; il a de 4 à 5 pieds de largeur, et d'une longueur double ou triple, sur 1 ou 2 pieds de profondeur. Tous ces sillons ont leur bords terminés des courbures arrondies; telles que les eaux ont coutume de les tracer. Je dis qu'ils sont à peu près horizontaux, parce qu'ils sont par fois inclinés de quelques degrés, en descendant vers le sud-sud-ouest, suivant la pente qu'a du avoir le courant.» This is evidently the effect of a river running along the side of a rock of such soft materials as may be worn by the friction of sand and stones; and such are the materials of the rocks now considered. Notwithstanding that it is so easy to explain this appearance by the operation of natural causes, M. de Saussure proceeds in taking it in another view. «De tels filons ne sauroient avoir été tracés par les eaux des pluies; car celles-ci forment des excavations, ou perpendiculaires à l'horizon ou dirigées suivant la plus grande inclinaison des faces des rochers; au lieu que celles la font tracées presqu'horizontalement sur de faces tou-à-fait verticales.» Here our author takes it for granted that things upon the surface of this earth were always the same as at present; and he reasons justly from these principles. But we are now tracing a former state of things; and those furrowed rocks testify the former current of a river by their side.

This operation of rivers undermining the sides of mountains, and causing scenes of ruin and destruction, may be illustrated by what our author has described under the title of*Ravage du temps sur les Rochers de Saleve*, §236. «Là ou ces couches manquent, il est aisé de voir qu'elles ont été détruites par le tems; les couches même horizontales, contres lesquelles elles out appuyées, ont souffert en bien des endroits des altérations considérables.

«Un peintre qui voudroit monter son imagination, et se faire des grandes idées des ravages du tems sur de grands objects, devroit aller au pied de Saleve, à l'extrémité des ces grands rochers, au-dessus du coin, hameau fort élevé de la paroisse de Collonge.

«On voit là des rochers taillés à pic à la hauteur de plusieurs centaines de pied avec des faces, ici planes et uniformes, là partagées et sillonnes par les eaux.

«La base de ces rochers est couverte de débris et de fragmens énormes, confusément entassés; un de ces débris soutenu fortuitement par d'autres est demeuré, et paroît de près un obélisque quadrangulaire d'une hauteur prodigieuse; de plus loin on reconnoît que sa sommité est une arrête tranchante, et qu'il a la forme d'un coin; et c'est peut-être cette forme qui a donné son nom au hameau qu'il domine.

«L'Angle même de la montagne est partagé par une fente qui le traverse de part en part. Cette profonde fissure mérite qu'on la voye, et même qu'on la pénètre. Elle est tortueuse, et dans quelques endroits si étroite, qu'à peine un homme peut il y passer. Quand vous y êtes engagés vous trouvez des places ou les sinuosités du rocher vous cache le ciel, plus loin elles le laissent apercevoir par échappées; ailleurs vous voyez des blocs de rochers engagés dans la crevasse, et suspendus au-dessus de votre tête.»

In his route from Contamine to Bonneville, he observes, page 365, «Enfin vis-a-vis la Bonne-ville, ces mêmes escarpemens des bases du mole, présentent une grande échancrure, qui paroît être le vuide qu'a laissé une montagne qui s'est anciennement écroulée; ses débris sont encore entassés au-dessous de l'échancrure. Il paroît même qu'elle étoit plus élevée que ses voisines, j'en juge par leur couches qui montent à droite et à gauche, contre le vuide qu'elle à laissé.

«§ 493. En suivant la route de servez, on voit sur sa gauche la continuation des rocs escarpés qui couronnent les montagnes situées au-dessus de Passy.

Un de ces rochers est si élevé, et en même tems si mince que l'on a peine à concevoir qu'il puisse se tenir debout et résister aux orages.

«C'est auprès de cette sommité élevée qu'étoit située une montagne qui s'éboula en 1751, avec un fracas si épouvantable, et une poussière si épaisse et si obscure, que bien de gens crurent que c'étoit la fin du monde.»

Vitaliano Donati, who was sent from Turin to examine this phenomenon, says in his letter, which M. de Saussure transcribes, that the great snows, which fell that year in Savoy, increasing the operation of some lakes, the waters of which continually undermined this mountain, occasioned the fall of three millions of cubic toises of rock.

In describing the Saleve, our author proceeds to mention other appearances equally conclusive with regard to the operations of water, but such as may be found over all the surface of the globe, to have been brought about by natural causes. «Ce que l'on nomme le Grottes de l'Hermitage, ou ces excavations profondes de 30 pieds, et 8 ou 10 fois aussi longues produites par la destruction totale de plusieurs couches de rocher.

«La gorge même de Monetier, ou cette grande échancrure qui sépare le grand Saleve du petit, et dans le fond de laquelle est renfermé le joli vallon de Monetier, paroît avoir été formée par un courant semblable, qui descendant des Alpes par la vallée de l'Arve, venoit se jetter dans notre grand courant; car les couches correspondantes du grand et du petit Saleve indiquent leur ancienne jonction; et l'on ne comprend pas quel agent auroit pu détacher et emporter la pièce énorme qui manque en cet endroit à la montagne.»

Further, in treating of the changes made in the form of the Jura by the ravages of time, our author observes, page 273, vol. I.

«Le faite de la montagne, battu de tous cotés par les vents, et par les pluies, a souffert des altérations les plus grandes: ici les couches du coté du lac ont été detruites, et laissent voir les sommités des couches opposées, dont les escarpemens paroissent tourner contre ce même lac; là, ce font les couches du coté de la vallée de Mijoux, qui out été emportées, et la montagne en pente uniforme de notre coté, est escarpée du coté de celle vallée; plus loin, le faite entier a été enlevé, et là on voit des abaissemens ou des gorges comme aux Faucilles, à St. Serge, etc.

«Les flancs et la base de La montagne ont aussi été dégradés par les torrens que produisent la pluie et les neiges fondues, qui ont formé de larges et profondes excavations.»

These ravages of time, or rather of the wasting operations of the surface of the earth, however great, compared with the little changes that we find in our experience, or in the most ancient record of our histories, are little things, considering the softness and solubility of the materials, and compared with the wasting of the Alps, which we find in tracing up those same rivers to their sources in the icy valleys. Let us go up the Arve to the valley of Chamouni. From this fertile valley, M. de Saussure heads us up the Montanvert, 428 fathoms above the level of the valley, and consequently 954 above that of the sea.

From this mountain we descend again into the high frozen valley which runs between the granite mountains, and pours its ice into the valley of Chamouni.

In this high valley, which communicates with an immensity of the like kind, we find ourselves among the most hard and durable materials. Here we must perceive, that most enormous masses of those solid materials had, in the course of time, been wasted by the flow effects of air and water, of the sun and frost, in order to hollow out those barren valleys of immense extent, which have, during an amazing tract of time, contributed from their solid rocks to the formation of travelled soils below, but which materials have long ago been travelling in the sea. The sides of those valleys are solid rock here exposed naked to our view. It is to such a place as this that we should go to see the operations of the surface wasting the solid body of the globe, and to read the unmeasurable course of time that must have flowed during those amazing operations which the vulgar do not see, and which the learned seem to see without wonder!

M. de Saussure, in his second volume of *Voyages dans les Alps*, has given us a most interesting view of this scene, p. 6.

«En montant au Montanvert, on a toujours sous ses pieds la vue de la vallée de Chamouni, de l'Arve qui l'arrose dans toute la longueur, d'une soule de villages et de hameaux entourés d'arbres et de champs bien cultivés. Au moment ou l'on arrive au Montanvert, la scène change; et au lieu de cette riante et fertile vallée, on se trouve presqu'au bord d'un précipice, dont le fond est une vallée beaucoup plus large et plus étendue, remplie de neige et de glace, et bordée de montagnes colossales, qui étonnent par leur hauteur et par leurs formes, et qui effraient par leur stérilité et leurs escarpements.»

It is the cause of this appearance, of deep valleys and colossal mountains, that I would now wish my readers to perceive. This is a thought which seldom strikes the mind of wondering spectators, viewing those lofty objects; they are occupied with what they see, and do not think how little what they see may have been, compared with what had been removed in the gradual operations of the globe. We have but to suppose this scene hewn out of the solid mass of country raised above the level of the valley; and, that this had been the case, must appear from the examination of all around.

Let us follow our author up those valleys between the solid granite mountains, valleys which properly are great rivers of ice moving, grandly but slowly, the ruins of those mountains upon which they were gathered. It is the Glacier de Bois upon which he is set out, (p. 26.)

«Après une bonne demi-heure de marche sur le glacier, nous traversons une arrête de glace chargée de terre, de sable et de débris de rocher. J'ai parlé dans le 1er. vol. de ces arrêtes parallèles à la longueur de glaciers, que l'on voit souvent dans le milieu de leur largeur, ou à des distances plus ou moins grandes de leurs bords. J'ai fait voir qu'elles sont produites par des débris qui du haut des montagnes, roulent sur le glacier, et qui entraînés par la glace sur laquelle ils reposent suivent comme elle une direction oblique en descendant tout-à-la-fois vers le milieu et vers le bas de la vallée.

«Dix minutes après, nous traversâmes une seconde arrête plus haute que la premiere, et nous jugeâmes que sous ces débris la glace étoit de 20 ou 25 pieds plus élevée que dans les endroits où l'air et les rayons du soleil agissent librement sur elle. On rencontre une troisième arrête à vingt minutes de la seconde, et la quatrième, qui est la dernière, la suit de très-près.

«Ici nous nous trouvons au point où le glacier des bois se divise, comme je l'ai dit, § 611, en deux grandes branches, dont l'une tourne à droite vers le Mont-Blanc, et prend le nom de glacier de *Tacul*, et l'autre à gauche se nomme le glacier de *Lechaud*. Il seroit, sans doute, plus intéressant de suivre celle de la droite, et de s'approcher ainsi du Mont-Blanc; ses pentes de neige et de glace, qui se presentent à nous, semblent même n'être point absolument inaccessibles: mais ce sont des apparences trompeuses; des glaciers entrecoupés de profondes crevasses masquées çà et là par des couches minces de neige les approches de cette redoutable montagne, quoique peut-être en choisissant une année ou il seroit tombé beaucoup de neige, et en prenant le temps où cette neige seroit encore ferme, quelque chasseur adroit et courageux pourroit tenter cette route.

«Comme dans ce moment cette entreprise est absolument impraticable, nous suivons la branche gauche de la vallée, et après deux heures de marche sur le glacier des bois, nous en sortons au pied de celui du Taléfre, c'est-à-dire, à l'endroit où celui-ci vient verser sa glace dans celui-là qui a changé de nom, et qui s'appelle ici le *glacier de Léchaud*.

«La vue du glacier du Taléfre est ici majestueuse et terrible. Comme la pente par laquelle il descend est extrêmement rapide, les glaçons se pressant mutuellement, se dressent, se relèvent, et présentent des tours, des pyramides diversement inclinées, qui semblent prêtes à écraser le voyageur téméraire qui oseroit s'en approcher.

«Pour parvenir au sommet de ce glacier, où il est moins incliné et par cela même moins inégal, nous gravissons le rocher qui est à la gauche du côté du couchant. Ce rocher se nomme *le Couvercle*; il est dominé par une cime inaccessible, qui, suivant l'usage du pays, est décorée du nom *aiguille*, et, en prenant le nom du glacier le plus proche, s'appelle*l'aiguille du Taléfre*.

«La pente, par laquelle on gravit le couvercle, est excessivement rapide; on suit une espèce de sillon creusé dans le roc par la nature; quelques pointes de roc aux quelles on se cramponne, en montant avec les mains, autant et plus qu'avec les pieds, ont fait donner à ce passage le nom *d'égralets* ou de petits degrés. Ce passage n'est cependant point dangereux, parce que le roc, qui est un granit très-cohérent, permet d'assurer toujours solidement les mains et les pieds; mais la rapidité le rend un peu effrayant à la descente.

«Lorsqu'on est au haut des égralets, on suite un pente beaucoup moins rapide; on marche tantôt sur du gazon, tantôt sur de grandes tables de granit, et on arrive ainsi au bord du plan du glacier du Taléfre. On nomme le *plan* d'un glacier la partie élevée et à-peu-près horizontale dans laquelle on peut le traverser.

«Nous avions mis une heure et un quart à monter du glacier de Léchaud au plan de celui du Taléfre. Nous fumes tentés de nous reposer un moment avant d'entrer sur celui-ci. Tout nous invitoit à choisir cette place, un beau gazon arrosé par un ruisseau qui sortoit de dessous la neige et qui rouloit son eau crystalline sur un sable argenté, et ce qui étoit plus séduisant encore, une vue d'une étendue et d'une beauté dont une description ne peut donner qu'une bien foible idée.

«§ 631. En effet comment peindre, à l'imagination des objets qui n'ont rien de commun avec tout ce que l'on voit dans le reste du monde; comment faire passer dans l'âme du lecteur cette impression mêlée d'admiration et de terreur qu'inspirent ces immenses amas de glaces entourés et surmontés de ces rochers pyramidaux plus immenses encore; le contraste de la blancheur des neiges avec la couleur obscure des rochers, mouillés par les eaux que ces neiges distillent, la pureté de l'air, éclat de la lumière du soleil, qui donne à tous ces objets une netteté et une vivacité extraordinaires; le profond et majestueux silence qui regne dans ces vastes solitudes, silence qui n'est troublé que de loin en loin par le fracas de quelque grand rocher de granit ou de glace qui s'écroule du haut de quelque montagne; et la nudité même de ces rochers élevés, où l'on ne découvre ni animaux, ni arbustes, ni verdure. Et quand on se rappelle la belle végétation, et les charmans paysages que l'on a vus le jours précédens dans le basses vallées, on est tenté de croire qu'on a été subitement transporté dans un autre monde oublié par la nature, ou sur une comète dans son aphélie. La vue du Montanvert ne donne de celle-ci qu'une idée très-imparfaite; là on ne voit qu'un seul glacier, au lieu que d'ici vous voyez les trois grands glaciers des Bois, de Léchaud et du Tacul, sans compter un grand nombre d'autres moins considérables qui, comme celui du Taléfre, versent leurs glaces dans les glaciers principaux.

«Les rochers innombrables que l'on voit au-dessus de ces glaciers sont tous de granit, car s'il y a, comme j'en suis certain, des rochers feuilletées, interposées entre ces granits, des*gneufs*, par exemple, ou des roches de corne; comme elles étoient plus tendres que les granits, leurs parties faillantes ont été détruites par les injures de l'air, et il ne reste plus que leurs bases, cachés au fond des gorges qui séparent les hautes pyramides.»

This is a fact which, independent of the good authority we have here, we would have been naturally led, from the theory, to suppose. For, in wearing out the solid mass, which had been once continuous among those mountains, something must have determined the situation of those valleys; but what so likely as some parts more destructible by the wasting operations of the surface than others, which are therefore less impaired, and remain more high.

Now, whatever may be our theory with regard to the origin or formation of these solid masses of the globe, this must be concluded for certain,—that what we see remaining is but a specimen of what had been removed,—and that we actually see the operations by which that great work had been performed: we only need to join in our imagination that portion of time which, upon the surest principles, we are forced to acknowledge in this view of present things.

CHAPER 4. THE SAME SUBJECT CONTINUED, IN GIVING STILL FARTHER VIEWS OF THE DISSOLUTION OF THE EARTH

To have an idea of this operation of running water changing the surface of the earth, one should travel in the Alps; it is there that are to be seen all the steps of this progression of things, and so closely connected in the scene which lies before one, that there is not required any chain of argument, or distant reasoning from effect to cause, in order to understand the natural operations of the globe, in the state of things which now appears. So strongly are the operations of nature marked in those scenes, that even a description is sufficient to give a lively idea of the process which had been transacted. With this view, I shall here transcribe, from the *Tableau de la Suisse*, a description of that remarkable passage by the mountain of St. Gothard, from Switzerland to Italy, hoping, that, even independent of the illustration hereby given to the theory, the reader will be pleased to see such a picture of that country as will either excite new ideas in a person who has not seen such scenes, or call up those which it is proper for a naturalist to have[51].

«Nous allons donner les observations que nous avons faites, en montant le Saint Gothard par le côté septentrional, et nous terminerons ce que nous avons à dire par la description du haut de cette montagne. Il y a aux environs d'Altorf, chef-lieu du canton d'Uri, de grands terrains couverts de pierres roulées, dont la plus grande partie est amenée par le Schechen, torrent qui descend de la vallée du même nom, et l'autre par la Reuss qui descend du St. Gothard. Sans se donner beaucoup de peines, on y a la facilite de voir et d'examiner une grande variété de pierres d'espèces différentes et de connoître d'avance les rochers qui composent les montagnes qu'on va parcourir; nous répétons ici que toutes les pierres arrondies ont pris cette forme par le roulis qu'elles ont essuyées dans les torrens, en se précipitant

[51] Tableaux de la Suisse Discours, etc. p. 113. Route d'Altorf au St. Gothard.

avec les eaux qui les ont amenées: plus nous avons parcouru de montagnes, plus nous nous sommes confirmés que cette observation étoit vraie et exact. Si on a la constance de suivre une espèce jusqu'au lieu de son origine ou position premiere, on l'y trouvera anguleuse, et n'ayant subi d'autres changemens que celui que le tems imprime à toutes les substances qui restent en place; on verra qu'à mesure qu'elles s'éloignent de leur premiere position leurs angles et leurs parties saillantes se détruisent, et qu'elles finissent par prendre la forme ronde ou approchante, en raison de leurs dureté et du chemin qu'elles auront parcouru. Nous renvoyons à ce sujet ce qui a été dit vers le commencement de ces observations, en parlant du Trient. Nous ajoutons seulement qu'il n'y a guère d'espèce de pierres roulées dans les montagnes, dont nous n'ayons pas trouvé les rochers analogues, et qu'avec du tems et les courses convenables, en observant bien les directions des montagnes et des torrents, on les trouveroit toutes. Altorf est entouré de très-hautes montagnes, des vallons aboutissent de tous côtes dans ses environs, parce-que c'est le lieu le plus bas où les eaux vont se jetter dans le lac de Wahlasthall ou de Lucerne, à l'extrémité duquel Altorf est situé; le vallon est assez couvert dans le bas, il est cultivé dans quelques parties, et il y a des arbres fruitiers; c'est sur-tout aux environs de Birglen qu'on rencontre beaucoup de pierres roulées et des rochers amenés par les eaux.

«Les rochers sont de pierre calcaire, et continuent jusqu'à Silenen à deux lieues d'Altorf; les montagnes sont fort hautes et fort escarpées des deux côtés du vallon, de beaux près sont dans le bas; quelque arbres fruitiers et sur-tout des noyers sont à mi-côte, et entre les rochers, des forêts de sapins. Avant d'arriver à Silenen, on apperçoit le glacier de Tittlis; il est sur le territoire d'Engelberg, et on trouve encore quelques hêtres; derrière les montagnes boisées il s'en élève d'autre nues et arides. Des points et des vues admirables par la dégradation des montagnes et pour le sauvage, s'offrent de toutes parts. Des chalets, des habitations isolées, sont situés au pied des plus affreux rochers qui les menacent d'une ruine prochaine. L'habitant y vit sans crainte, entouré de son pré et de son petit bien dont il est tranquille possesseur.

«La chaleur concentrée dans ce vallon y fait mûrir différentes productions peu recherchées; à la verité, ce sont des fruits fort communs, excellens pour le pays, parce qu'on n'y en connoit pas de meilleurs. C'est du petit village d'Amsteeg entouré de fort hautes montagnes, qu'on commence à monter ce qu'on nomme le Saint Gothard general: le chemin devient plus roide, la Reuss y est plus resserrés et roule ses eaux dans un lit fort profond et très-escarpé, des torrens des cascades, tombent de différens endroits des deux côtés de ce vallon et de belles forêts de sapin, où il y a des arbres prodigieux pour la hauteur, varient les points de vues; on s'élève beaucoup au-dessus du fond des vallons par des chemins rapides: l'exposition plus heureuse fait cultiver du jardinage et des arbres fruitiers; il y a beaucoup de chanvre dans ces environs. De l'autre côté du vallon, sur la gauche de la Reuss, est une usine ou on fabriquoit de l'alum et du vitriol, les travaux ont cessé, ces établissemens et l'exploitation des mines sont peu connus et peu suivis en Suisse. La Reuss semble toujours s'enfoncer d'avantage, par-tout elle roule ses flots avec bruit et fracas, elle s'est creusée un lit à des profondeurs incroyables; il n'y a point d'endroit ou l'on puisse mieux voir cet étonnant travail des eaux que sur le pont du Pfaffensprung, à une demi-lieue de Vassen; il est à une hauteur si effrayante que le premier mouvement, quand on regarde au bas du pont, est de se tenir au parapet, et le second de le quitter, dans la crainte qu'il ne manque, ce n'est que par réflexion qu'on y revient, On voit la progression et le travail successif de l'eau du haut jusqu'en bas; la roche a des sinuosités où des angles arrondis, rentrans et faillans, alternativement de chaque côté, et dont saillans sont opposes aux rentrans, de façon qu'il reste peu d'espace pour apercevoir l'eau, ce canal ou ce, gouffre n'ayant pas plus de deux toises et demie de large. Depuis Silenen on ne voit plus de pierres calcaires, les rochers sont schisteux argileux, mêlé de beaucoup de quartz; le lit de la Reuss est rempli de granits, mais qui viennent des montagnes supérieures. Au-dessus du pont, dont nous venons de faire mention, on rencontre un passage des plus pittoresques, composé de moulins, de scieries, de chutes d'eau, dominés par le village de Vassen, et entourés de montagnes fort extraordinaire. Une roche argileuse sur un plan incliné, s'est détachée de la hauteur, et a emporté un pont et un moulin.

«On monte beaucoup après avoir passé Vassen; ces environs sont d'une variété étonnante pour la beauté et la singularité des paysages. Des nappes d'eau, des cascades qui se précipitent de roches en roches, forment dix et quinze chutes avant de se perdre dans les sapins qui contrastent avec la blancheur des eaux toutes réduites en écume. Des maisons d'une construction particulière, placées contre les rochers pour les mettre à l'abri des avalanches, des poutres jetées sur différentes masses de rochers pour passer la Reuss et autres torrens dont les eaux sont bouillonnantes et jaillissantes, des arcades de pierres pour joindre des rochers suspendus sur ces précipices, rochers de mille formes bizarres occupent le voyageur, et ne lui donnent plus le tems d'apercevoir les mauvais pas qu'il franchit. Il y a sans doute des hommes assez malheureux, qui ne verroient que des dangers, et ne seroient occupés que de leurs craintes et des terreurs paniques; c'est en effet une grande privation de ne pas sentir les beautés de la nature, elle devient un malheur réel quand ce plaisir se trouve remplacé par des angoisses et de la frayeur. Un tableau d'un autre genre nouveau, et pour lequel les expressions manquent, est une forêt rasée et abattue par une avalanche, il y a quelques années, ces sapins de plus de cent pied de long, ont eu le tems de perdre leurs feuilles et de permettre à la vue de passer à travers cette énorme quantité de bois et de branches entre lacées de mille manières bizarres, et d'apercevoir des rocs épars, des eaux qui circulent autour, et tombent quelque fois en cascades. C'est une spectacle qui devient effrayant quand on pense à la force et à la violence du moyen qui a pu occasionner un pareil effet. On recueille dans ce canton la résine des mélèzes. Quoique Vassen soit déjà fort élevé, on y cultive encore quelque jardinage, et il y a aussi quelque cerisiers sauvages. Il y a environ cinq-lieues jusqu'à Altorf.

«Après avoir passé Vassen, on trouve cinq ou six superbes cascades formées par la Reuss. Elle fait un bruit à étourdir: la chaleur qu'il faisoit, avoit procuré une abondante fonte de neige, et l'eau avoit beaucoup augmenté depuis le matin. Des bouleaux, des sapins, et des mélèzes, groupés ensemble, formoient des contrastes agréables par la variété et le mélange des différens verts. Les chemins sont faits à grand frais et avec beaucoup de soin; on a jetté des arcades en différens endroits pour joindre les rochers, et faire passer les chemins par-dessus; on entend mugir la Reuss sous ses pieds elle écume par-tout, il faut être accoutumé à ce spectacle pour n'en pas être effrayé. Les rochers de droite et de gauche sont par-tout à pic et d'une granit, qui est jaunâtre dans différens endroits; dans d'autres, il est décomposé, passant à l'état d'argile; c'est le felds-path qui subit le premiere ce changement. Des quartiers de rochers des parties de montagnes sont épars; des chalets, des habitations solitaires sont placé aux environs des endroits où il y a quelque pâturage. Il y a un de ces rochers qui est une belle masse de granit, appellée la Pierre du Diable; on n'oublie pas de la faire remarquer, parce qu'il y a un conte populaire à son sujet que de graves auteurs nous ont conservé. Le vallon se rétrécit beaucoup avant d'arriver à Gestinen.

«On a élevé par-tout de murailles à de très-grandes hauteur pour faire le chemin. Tout ce travail, vu le local, est incroyable pour la difficulté; de gros blocs de granits sont rangés sur les bords du chemin pour servir de barrières dans les endroits les plus dangereux. Ces passages sont si étroit qu'il faut peu de chose pour les interrompre. Le pont du Diable est d'une seul arche à plein ceintre de quatre toises d'ouverture deux et demie de large, et de douze toises d'élévation au-dessus de l'eau; le fracas et la rapidité avec laquelle l'eau passe sous ce pont, ne permettent gueres qu'on la considère tranquillement de dessus le pont, on est toujours tenté de s'en éloigner.—La distance depuis Gestinen jusqu'à Teufelsbruck ou pont du Diable, qui est environ deux lieues, suffit pour prouver ce que nous disons; cette vallée, qu'on nomme Schollenen, offre à chaque pas des difficultés vaincues, des rochers franchis, des intervalles comblés par des murailles, où il a fallu employer des montagnes de pierres.

«Les chemins sont pavés partout mieux que dans beaucoup de villes; des chevaux et des mulets chargés les fréquentent toute l'année; et dans quels pays ces grands travaux ont-ils été exécutes? Dans un véritable chaos de rochers et montagnes dont partie sont bouleversés, et l'autre paroît prête à s'écrouler sur le passant, qui ne voit sous ses pieds que des écueils, des gouffres et des précipices, au fond desquels roule un torrent écumant et furieux. Si les rochers sont menaçans, les avalanches sont encore plus dangereuses dans ce redoutable passage; il n'y a point d'année qu'il ne périsse des hommes et des bêtes de somme; on fait voir un endroit où une avalanche transporta à plus de cent toises au-dela de la Reuss, dix-neuf chevaux et mulets chargés ainsi que leurs conducteurs; dans d'autres endroits des quartiers de rochers prodigieux qui ont été déplacés et transportés de même.

«Après avoir passé le pont du Diable, le chemin tourne à gauche, puis à droite, pour monter une rampe assez rapide, très-bien pavée, qui conduit à une ouverture dans le rocher, c'est le seul passage qui se presente, nommé Urner-Loch, trou du pays d'Urner ou Urseren; un rocher fort élevé est sur la gauche, et les cascades de la Reuss à droite; l'entrée du passage est obscure, c'est une galerie souterraine pratiquée dans le roc, haute de neuf pieds environ de façon qu'un homme peut y passer à cheval, de onze pieds de large et trente-deux toises de long; on a pratiqué dans le milieu une ouverture pour donner du jour; cette roche est toute de granit, ainsi que celles qui sont autour du pont du Diable; Il y a environ soixante ans que cette galerie a été ouverte; le chemin passoit auparavant en dehors sur une espèce de pont qui tournoit le rocher, et se trouvoit exactement suspendu et fort mal assuré au-dessus des cascades de la Reuss; de frequens accidens, de grands frais pour reconstruire et entretenir ce pont, souvent entraîné par les eaux, ont necessité l'ouverture de ce passage.

«En sortant de ce passage obscur, on est surpris d'entrer dans une plaine ouverte, riante et couverte de verdure, et de voir couler à côté de soi une onde limpide et tranquille. Ce tableau est d'autant plus frappant qu'on vient de voir le contraste le plus effrayant; ce passage souterrain est comme le rideau qui se lève entre deux décorations, dont l'une representoit le chaos et le bouleversement de la nature, et l'autre celle de la nature naissante et parée des premiers et des plus simples ornemens; cette plaine est unie, de forme ovale, couverte d'un vaste gazon et de pâturages, entre lesquels serpente doucement la Reuss: sur ces bords il y a quelques buissons et peu d'arbres, ce sont des aulnes. Des cabanes de bois, des chalets isolés et solitaires sont répandus ca et là à l'entrée du vallon: à gauche est le village d'In-der-Matt bâti en pierres, et à neuf; dans le fond celui de hospital et situé sur le penchant d'un coteau, il est dominé par une grosse tour: les montagnes du St. Gothard servent de fond au tableau, elles sont trop éloignées pour laisser apercevoir leur aridité; des montagnes nues, couvertes d'une verdure légère sans arbres et sans buissons, bordent les deux côtés du vallon: enfin tout paroît jeune et d'une création nouvelle au premier coup d'oeil, qui met le spectateur dans l'état où est un homme à son réveil après un rêve épouvantable, où il n'a vu que des objets effrayans; il se trouve heureux et content d'être en sûreté et hors des dangers qui le menaçoient, tant les impressions de son rêve lui sont encore présentes.

«Ce vallon offre des remarques intéressantes pour l'histoire naturelle, sa position, sa forme, et son nivellement ne laissent aucun doute que cet emplacement n'ait été le séjour des eaux; en examinant les bords du lit de la Reuss, on reconnoît que le terrain de ce vallon est par couches horizontales de pierres argileuses; le pied des montagnes qui entourent le vallon sur la droite est de pierre calcaire grise, à la même hauteur, et à mi-côte, sur la gauche, on trouve de la pierre ollaire. Voilà encore une de ces circonstances où il seroit intéressant de connoître la hauteur exacte de cette pierre calcaire, et de pouvoir comparer son niveau avec d'autres que nous avons déjà observé être aussi déposées au pied des montagnes dans de petits vallons fort élevés, analogues à celui dont il est question. Quelque secousse aura rompu l'enceinte de rocher qui fermoit ce bassin: l'écoulement des eaux aura achevé de creuser ce passage, où coule actuellement la Reuss, et le vallon qui est au-dessous. Quoique les angles rentrans et saillans des montagnes ayent lieu dans quelque endroits, il s'en faut de beaucoup que ce soit une règle certaine: le vallon qui descend du Saint Gothard à Altorff est une de ces exceptions. Une autre chose remarquable dans ce vallon, c'est qu'au sortir du passage souterrain que nous avons dit être creusé dans le granit, il y a tout à côté sans interruption, et formant la même masse de rocher, de la pierre schisteuse micacée, mêlée de quartz, dont les couches sont perpendiculaire, se fendent et tombent par morceaux, qui ont la forme de poutres ou de bois équarris. Cette espèce de roche est aussi haute que celle de granit, et composée, dans des proportions différentes, des mêmes parties intégrantes que le granit; n'a-t-elle pas été apposée et formée contre celle de granit, qui assurément doit être plus ancienne, puisqu'elle est enveloppée par la roche schisteuse[52]?

[52] Here is an example of the junction of the granite with the schistus; and probably here will be a proper opportunity of investigating the formation of those two things. Our author here supposes the granite to be the primary, and the schistus to be the secondary body; on the contrary, I believe that schistus to be the primary in relation to the granite, and that the granite had invaded the schistus, as will be made to appear in its proper place.

Ce vallon, d'une bonne lieue de longueur sur moitié de largeur, peut occasionner bien des réflexions; nous avons été obligé de passer rapidement sur ces objets, nous ne faisons que les indiquer. Au-haut de la montagne rapide, qui est au-dessus du village d'In-der-Matt, il y a un petit bois de sapins, auquel il est défendu de toucher sous peine de la vie. Il est réservé contre les avalanches; ce sont les seules arbres qu'on voie sur les hauteurs environnantes; derrière ce bois on apperçoit un glacier d'où descend un torrent qui va se jetter dans la Reuss; il amène, ainsi que les autres qui descendent de ce coté, des pierres schisteuses micacées, mêlées de quartz, de même nature que celle qui est à coté du passage souterrain. On monte par un beau chemin au village de Hospital, qui dépend aussi du pays d'Urseren: tout ce canton est renommé pour ces excellens fromages. Il n'y a que des pâturages et point d'autre culture. Le bois, qui est de première nécessité dans un pays aussi froid, aussi élevé et toujours entouré de neige, y manque totalement, on est obligé de l'aller chercher dans la vallée de Schollenen, et on traine sur la neige le bois de charpente. Le village de Hospital est situé sur des roches schisteuses mêlées de mica et de quartz, elles sont bleues, verdâtres, et grises. C'est à Hospital qu'est la rencontre de différens chemins pour passer le Saint-Gothard; il y en a un qui venant du Vallais, passe à côté du glacier du Rhône et par la montagne de Fourk. Un second qui vient des Grisons, passe par Disentis et Chiamut entre les sources du bas Rhin. Ce sont des sentiers: qu'on juge de ce qu'ils peuvent être d'après le grand chemin que nous venons de décrire, qui conduit de la Suisse en Italie.

«Sur la droite du village de Hospital est un vallon que nous avons visité jusqu'au village de Zum-d'Orff, à une grand demi-lieue. Il y règne aussi une couche de pierre calcaire à même hauteur, au bas de la montagne qui renferme le vallon, et nous prions de remarquer qu'elle est aussi sur la droite, et que sur la gauche il y à de pierre ollaire; une masse énorme de cette espèce, sous laquelle on travailloit depuis long-tems pour en tirer de quoi faire des poêles, ayant perdu son équilibre, est tombée sur le côté. Les rochers qui dominent, sont des rochers schisteuse micacées avec du quartz. Ce dernier village fait aussi partie de la vallée d'Urseren, c'est le pays habité le plus élevé de l'Europe; les habitons sont forts et robustes; les montagnes de ce canton étant nues, arides, et fort rapide, les avalanches y sont fréquentes.

«C'est au sortir de Hospital qu'on monte véritablement le Mont Saint Gothard: le chemin est escarpé, pavé, et bien entretenu. Par un vallon à droite descend le Garceren, torrent qui vient des glaciers; son eau est blanchâtre, se jette dans la Reuss, et en trouble la limpidité; les rochers sont de plus en plus dépouillés, secs et arides, on trouve les derniers buissons, des aulnes rabougris. La Reuss tombe de rocher en rocher, des blocs et des quartiers énormes, qui remplissent son lit, lui barrent souvent le passage; ses eaux s'élancent par-dessus quand elle ne peut le contourner; on ne voit enfin que des rochers, des abymes et des précipices; on marche néanmoins en sûreté au milieu de ce désordre de la nature; les chemins sont bien pavés, et assez larges pour que deux chevaux ou deux mulets chargés puissent y passer de front. Sur un rocher à droite, à une lieue de Hospital environ, on trouve taillés dans le roc les limites entre le pays d'Urseren, et la partie Italienne ou vallée de Livenen; ainsi tout sommet du St. Gothard appartient à la partie Italienne, qui est actuellement sujette du canton d'Uri. On parvient enfin sur un terrain plus uni, et une espèce de plateau, c'est le haut du Saint Gothard; à une demi-lieue sur la droite, entre des rochers forts hauts, forts escarpés et à pic, est une espèce d'entonnoir, ou se rassemblent les eaux des neiges fondues; elles y forment le petit lac de Luzendro, gelé le trois quarts de l'année, d'ou la Reuss tire sa source en partie; car le glaciers du mont de la Fourche ou Fourk dans le haut Vallais, fournissent aussi un torrent qui est regardé comme la seconde source de la Reuss; le Rhône prend sa source dans la partie opposée du même glacier. Le haut du Saint Gothard est un vrai vallon, puisque des cimes, des pyramides, des montagnes prodigieuses, composées toutes de rochers, s'élèvent au-dessus, et l'entourent de tous côtés. L'espace qui est entre ces rochers a une forme a-peu-prés circulaire; il paroît avoir été un fond qui a été élevé et comblé jusqu'au point ou il est par les débris des montagnes qui le dominent, et qui s'y amoncèlent encore actuellement sous nos yeux; il a une espéce de niveau qui va un peu en pente du côté du midi, et du côté du Nord par lesquels se fait l'écoulement des eaux fournies par la fonte des neiges, dont la Reuss et le Tessin sont les canaux. Des masses étonnantes de rochers remplissent la surface de ce vallon: elles y sont placées dans une désordre qui ne ressemble point aux positions des rochers actuels, et autorise à croire qu'elles y ont été jetées et culbutées au hazard. Ces masses isolées sont toutes de granit, composé de quartz, de feldspath, et de mica verdâtre; le chemin qui traverse ce vallon tourne autour de ces masses. Il faut que les pics élevés qui bordent ce vallon ayent été beaucoup plus hauts qu'ils ne le sont actuellement pour avoir pu fournir à combler cette étendue, qui a une lieue au moins. Il n'est pas douteux non plus, que les vastes montagnes qui font au pied de toutes celles qui forment l'enceinte du Gothard, au moyen desquelles on trouve un accès plus facile, et des rampes moins rapides pour s'élèvent comme par degrés à cette hauteur, qui composent enfin ces montagnes de seconde et de troisieme formation, ne doivent leur existence qu'aux débris de ces colosses qui dominent tout. L'examen de ce qui se passe sous nos yeux journellement, ne peut nous laisser aucun doute sur l'abaissement de montagnes. Il n'y a point de torrent, point d'écoulement d'eaux, quelque petit qu'il soit, qui n'entraîne en descendant des montagnes, des terres, des graviers, ou des sables, pour les porter plus bas. Les grands torrens, les fleuves, les rivières, gonflés par les fontes subites des glaces et des neiges, entraînent des rochers entières, creusent de vastes et profonds ravins; ces masses de rochers diminuent par le choc et le frottement qu'elles essuient entre elles, et sur les rochers sur lesquels elles passent, dont elles occasionnent reciproquement la destruction; ce sont des débris de cette espéce de trituration qui troublent les eaux, et dont le dépôt élève insensiblement les bords des rivières, forme le limon fécondant de nos plaines, et va former jusque dans le sein des mers ces atterrissemens, ces barres, et ces bancs qui en reculent les bornes. Les rochers les plus durs, ces granits que les meilleurs outils ont tant de peine à façonner, ne résistent point au tems et aux intempéries des saisons; leur superficie se dénature et se décompose souvent au point de ne pas les reconnoître: des lichens, des petites mousses s'insinuent dans leur tissu, l'eau y pénètre, et la gelée sépare leurs parties; s'ils se trouvent placé sur une pente de façon à pouvoir être entraîné par les eaux, la plus grosse masse est bientôt réduite à peu de chose, apres avoir parcouru un plan incliné; quels changemens ne doit pas avoir opéré cette marche constante de la nature. A quel point n'est elle pas rendu méconnoissable la superficie du globe que nous habitons. Pour peu qu'on réfléchisse que les montagnes fournissent continuellement aux plaines, et que celle-ci ne rendent rien aux montagnes, on pourra se faire quelque idée des changemens que la révolution des siècles à du opérer. Aussi n'est ce que sur les hautes montagnes qu'on apperçoit encore parmi leurs vastes débris, les matériaux qui ont servi et servent aux créations nouvelles que la nature opère journellement, qu'ils sont grands, qu'ils sont majestueux ces antiques débris! que l'homme est petit, qu'il est confondu quand il ose y porter un regard curieux!»

In this picture of the Alps, there is presented to our view the devastation of solid rocks by agents natural to the surface of the earth; here is the degradation of mountains in the course of time. Of these ruins plains are formed below; and these plains are continually shifting their place, in affording materials to be washed away and rolled in the rivers, and in receiving from the higher grounds the spoils of ruined rocks and mountains. Such operations are general to the globe, or are to be found over all this earth; but it is not every where that we have descriptions proper to give just ideas of this subject, which escapes the common observation of mankind.

As I have given an example in the Alps of Savoy and Switzerland, it may be proper to give some view of the same operation in those of the Pyrénées (Essai sur la Minéralogie des Monts Pyrénées) page 76.

«La vallée d'Aspe est arrosée dans toute sa longueur, par le Gave, qui prend sa source vers les frontières d'Espagne: dans les temps de pluie et d'orage, cette rivière est colorée en rouge par des terres composées de schiste rougeâtre, qui s'éboulent: des montagnes de Gabedaille et de Peyrenère: au reste les eaux du Gave profondément encaissées dans leur lit ne peuvent plus contribuer à la fecondité des plaines qu'elles ont formées.

«On observe, en suivent cette rivière que lorsque les montagnes courent parallèlement, les angles faillans qu'elles forment correspondent aux angles rentrans; cette règle générale sert à établir que les vallées des Pyrénées, qu'il faudroit plutôt appeler *de gorges* puisqu'elles n'ont qu'une demi-lieue dans leur plus grande largeur, sont l'ouvrage des eaux; mais doit on les ranger parmi celles que M. de Buffon a démontré avoir été creusées par les courans de la mer, ou les supposer formées par les torrens qui se précipitent des montagnes?

«Ne croyez pas, dit M. d'Arcet, en faisant mention des vallées des Pyrénées, que les eaux aient pris ces routes parce qu'elles les ont trouvées frayées antérieurement à leur cours; ce sont les eaux même d'en-haut, qui, se ressemblant peu-à-peu, se sont ouvert de force ces passages: elles se sont creusé ces lits dans le temps passés, comme elles les creusent encore tous les jours. *Voyez la Discours sur l'État Actuel de Pyrénées, p..* 10.

(p. 86.) «Les pierres que les eaux du Val de Canfrac entraînent, sont rarement usées dans leurs angles; on en trouve peu dont la figure soit arrondie, comme celle des pierres que roulent les torrens de la partie septentrionale des Pyrénées; le sol des environs de Jacia, plus élevé que celui des plaines du côté de la France, s'oppose a ce qu'elles soient emportées à d'assez grandes distances, et avec la rapidité necessaire pour recevoir, par un long frottement, une figure arrondie: on ne voit point de pierres roulées dans les plaines qui entourent cette ville, les bancs calcaires ne sont couverts que d'une croûte de terre peu épaisse; un telle formation diffère de celle qu'on observe au pied des monts Pyrénées, du côté de la France, ou le sol de plusieurs contrées est composé des débris que les rivières y ont déposés[53]; une partie de l'Égypte, selon Hérodote, a été pareillement formée des matières que le Nil y a apportées; Aristotle la nomme l'ouvrage du fleuve: c'est pourquoi les Éthiopiens se vantoient que l'Égypte leur étoit redevable de son origine. Les habitans de Pyrénées pourroient dire la même chose de presque toutes les contrées situées le long de la chaine septentrionale, depuis l'océan jusqu'à la Méditerranée, et qui forment cette espace d'isthme qui sépare les deux mers: c'est ainsi que

[53] The notion, that the water-worn gravel, which we so frequently find upon the surface of the earth, had been the effect of rivers transporting the rocks and stones, is not accurate or in perfect science. That stones are thus continually transported is certain; it is also indisputable, that in this operation they are broken and worn by attrition, more or less; but, that angular stones of the hardest substance are thus made into that round gravel, which we find so abundantly in many places forming the soil or loose materials of the surface, is a conclusion which does not necessarily follow from the premises, so far as there is another way of explaining those appearances, and that by a cause much more proportioned to the effect.

The view which I take of the subject is this; first, that those water-worn materials had their great roundness from the attrition occasioned by the waves of the sea upon some former coast. Secondly, that, after having been thus formed by agitation on the shores, and transported into the deep, this gravel had contributed to the formation of secondary strata, such as the puddingstone which has been described in Part I. Chap 5, and 6; and, lastly that it has been from the decay and resolution of those secondary strata, in the wafting operations of the surface, that have come those rounded siliceous bodies, which could not be thus worn by travelling in the longest river.

la nature change continuellement la surface de notre globe; elle élève les plaines, abaisse les montagnes; et l'eau est principal agent qu'elle emploie pour opérer ces grandes révolutions; il ne faut que du temps, pour que le mot de Louis XIV. à son petit-fils, se réalise. La postérité pourra dire un jour; *il n'y a plus de Pyrénées*. On conçoit combien cette époque est éloignée de nous. M. Gensanne a trouvé, par des observations qu'il pretend non équivoques, que la surface de ces montagnes baisse d'environ dix pouces par siècle; ainsi, en les supposant seulement de quinze cens toises au-dessus du niveau de la mer, et toujours susceptibles du même degré d'abaissement, il s'écoulera un million d'années avant leur destruction totale.»

I do not know in what manner M. Gensanne made his calculation; I would suspect it was from partial, and not from general observations. We have mountains in this country, and those not made of more durable materials than what are common to the earth, which are not sensibly diminished in their height with a thousand years. The proof of this are the Roman roads made over some of those hills. I have seen those roads as distinct as if only made a few years, with superficial pits beside them, from whence had been dug the gravel or materials of which they had been formed.

The natural operation of time upon the surface of this earth is to dissolve certain substances, to disunite the solid bodies which are not soluble, but which, in having been consolidated by fusion, are naturally separated by veins and cutters, and to carry those detached bodies, by the mechanic force of moving water, successively from stage to stage, from places of a higher situation to those below.

Thus the beds of rivers are to be considered as the passages through which both the lighter and heavier bodies of the land are gradually travelling; and it is through them that those moveable bodies are from time to time protruded towards the sea shore. But, in the course of rivers, it often happens that there intervenes a lake; and this must be considered as a repository for heavy bodies which had been transported by the force of running water, in the narrow bed through which it was obliged to pass; for, being arrived in the lake, the issue of which is above the level of its bottom, the moving water loses its force in protruding heavy bodies, which therefore it deposits. Thus the bottom of the lake would be filled up, before the heavy materials which the river carries could be made to advance any farther towards the sea.

Reasoning upon these principles, we shall find, that the general tendency of the operations of water upon the surface of this earth is to form plains of lakes, and not, contrarily, lakes of plains. For example, it was not the Rhône that formed the lake of Geneva; for, had the lake subsisted in its present state, while the Rhône had transported all the matter which it is demonstrable had passed through that channel from the Alps, the bed of the lake must have been made a plain through, which the river would continue to pass, but in a changing channel, as it does in any other plain. We are therefore led to believe, that the passage of the Rhône through the lake, in its present state, is not a thing of long existence, compared with the depredations which time had made by that river upon the earth above the lake. But how far there are any means for judging, with regard to the causes of that change which must have taken place, and produced the present state of things about this lake, can only be determined by those who have the proper opportunity of examining that country.

If lakes are not in the natural constitution of the earth, when this is elevated from the sea into the place of land, they must be formed by some posterior operation, which may be now considered.

There are in nature, that is, in the natural operations of the globe, two ways by which a lake may properly be formed in a place where it had not before existed. One of these is the sliding or overshooting of a mountain or a rock, which, being undermined by the river, and pressed by its weight, may give way, and thus close up the defile through which the river had worn for itself a passage. The other is the operation of an earthquake, which may either sink a higher ground, or raise a lower, and thus produce a lake where none had been before. To which, indeed, may be added a third, the dissolution of saline or soluble earthy substances which had filled the place.

So many must have been those alterations upon the surface of the earth which we inhabit, and so short the period of history by which, from the experience of man, we have to judge, that we must be persuaded we see but little of those operations which make any sensible change upon the earth; and we should be cautious not to form a history of nature from our narrow views of things; views which comprehend so little of the effects of time, that they may be considered as nothing in the scale by which we are to calculate what has passed in the works of nature.

To form an idea of the quantity of the solid land which has been carried away from the surface of the earth, we must consider our land, with the view of a mineralist, as having all the soil and travelled materials removed, so as we might see the terminations of all the strata, where these are broken off and left abrupt. Now, the generality of those strata are declined from the horizontal plane in which they had been formed, and shew that the upper extremity had been broken off and carried away; and the quantity of that which has been carried away, since the time of the formation of those strata, so far as may be judged from the nature and situation of what remains, must be concluded as very great. This is best to be observed in mountainous countries, where not only the causes of this destruction of the land are more powerful, but the opportunities of investigating the effects more frequent, from the washing away of the loose soil or covering.

The correspondent angles of the valleys among mountains is a subject of this nature, in which may be perceived a visible waste of the solid mountain which has those correspondent angles. I am happy to have an authority so much better than my own observations to give on this occasion, where the question relates to what is common or general in these appearances. It is that of M. de Luc, Lettres Physique et Morales, tom. 2. p. 221. «Mais avant de finir sur les montagnes *primordiales*, il faut que je revienne à ces*angles saillans et rentrans alternativement opposés*, qui lorsque Mr. Bourguet les annonça, firent un si grand bruit parmi les naturalistes qu'on ne douta plus que toutes les montagnes ne fussent l'ouvrage de la *mer*. Voici ce que c'est que ce phénomène prétendu démonstratif.

«Lorsqu'on voyage dans les vallées, on va ordinairement en tournoyant; et quand un angle saillant oblige à courber la route, on trouve assez souvent un angle rentrant qui lui fait face, et la vallée conserve à peu près la même largeur. M. Bourguet ayant fait cette remarque, et considérant que les bords opposés d'une rivière qui serpente, offrent la même opposition des angles saillans et rentrans, en conclut en général, que les montagnes avoient été formées par les courans de la mer.

«Si toutes les montagnes, et les *Alpes* par exemple, avoient tous les autres caractères qu'exige une telle formation celui-là sans doute ne paroîtroit pas les contredire; et l'on ne peut même disconvenir, qu'au premier coup d'oeil, ces zig-zags ne ressemblent beaucoup aux effets des eaux courantes. Cependant ce caractère appartient bien plus aux eaux qui se frayent une route, qu'à celles qui font des dépôts. Un rivière qui creuse son lit, se détourne à la rencontre d'un obstacle, et ronge le côté opposé; c'est ce qui produit ses méandres. Mais on ne voit point les mêmes causes de zig-zags dans les courans au sein de la mer; à moins qu'il n'y ait déjà des montagnes.

«En effet si l'on considère les montagnes et les collines qui par leurs couches et les corps étrangers qu'elles renferment, montrent sans équivoque qu'elles sont l'ouvrage des eaux, on les trouvera le plus souvent rangées sans ordre. Quelquefois elles ne paroissent que des monceaux posés çà et là; comme dans une grand partie du *Piémont*. Ou si elles sont sous la forme de chaînes continues, on y trouve peu de parallélisme, c'est-à-dire de ces angles rentrans opposés aux angles saillans: tel est le Jura.

«Mais si les courans de la mer ont trouvé des montagnes toutes faites, et qu'ils les ayent traversées, dans quelque sens que ce soit; ils se sont frayé des routes dans les endroits où la resistance étoit moindre, et ont rongé les bords de leurs canaux à la manière des rivières. On doit donc y trouver du parallélisme.

«Si maintenant on considère la chaîne des *Alpes*, on verra qu'elle répond fort bien à cet effet naturel. Quoique ces montagnes forment une chaîne dans leur ensemble, leurs parties supérieures ne montrent aucune sorte d'arrangement particulier, aucune trace de zig-zags: c'est dans le fond des grandes vallées, ou dans les coupures qui servent à l'écoulement des eaux, que ce parallélisme des côtés opposés se remarque; quoiqu'avec bien des exceptions. Et ce qu'il y a de plus important à considérer, c'est que ces grandes vallées ou les angles saillans et rentrans forment l'engrènement le plus sensible, coupent ordinairement la chaîne en travers, au lieu de la suivre; ce qui annonce plutôt destruction qu'édification.

«Ainsi *les angles saillans et rentrans alternativement opposes dans les vallées des montagnes*, peuvent bien contribuer à prouver qu'elles ont été toutes sous les eaux de la *mer*; mais non que la mer les aît toutes faites. C'est ici donc un nouvel exemple de la nécessité de considérer attentivement les idées qui paroissent le plus naturelles au premier coup d'oeil: car cet aperçu étoit bien un de ceux qu'on est tenté d'admettre sans examiner autre chose que la vérité du fait.»

Here we have the testimony of this author concerning the nature of those causes by which the shape of the surface of the earth, in those regular appearances of corresponding parts, had been determined, viz. That these had been destroying operations, and not those by which the mountains had been formed. We differ, however, from this naturalist with regard to the particular agent here employed. It will be shown, in a subsequent chapter, that there is almost as little reason to conclude from this appearance, that the space between the correspondent angles had been hollowed by the currents of the sea, as that those angles had been formed by matters deposited in that shape and situation.

Farther, treating of the calcareous mountains, the same author observes, (Lettre 38. p. 229.)

«Cette chaîne extérieure des *Alpes* évidemment d'origine *marine*, a cependant des caractères qui la distinguent de la plupart des autres montagnes de la même classe; et ces caractères semblent annoncer plus d'antiquité. Je crois d'abord pouvoir les regarder comme les montagnes *secondaires* les plus hautes de notre continent. (Je ne parle ici que des montagnes marines.) Ensuite leur destruction est beaucoup plus grande que celle d'aucune autre montagne de ce genre qui me soit connue: car elles sont presque aussi couronnées de pics que les *Alpes primordiales*; et ces *pics*, étant par *couches*, montrent des restes d'anciens sommets qui devoient avoir une grande étendue. Ce qui, joint à quelques dérangemens dans leurs couches, paroît indiquer que ces montagnes ont été exposées plus longtemps que la plupart des autres montagnes *secondaires*, aux revolutions qu'essuyoit le fond de la *mer*; et qu'elles en sont sorties déjà fort altérées.»

There is at present no question concerning the particular shape in which the mountains of the earth had come out of the waters of the sea. We are considering the wasting of those mountains, in being exposed to the atmosphere and waters of the earth; and the operation that the sea may have had upon their surface, is a subject for judging of which we have not the smallest data, unless by taking the thing for granted, or supposing that the present state of things is that former shape after which we inquire. Now, this is a species of reasoning that M. de Luc would certainly explode; for he admits, as we shall afterwards find, great changes among the mountains of the Alps, from the influences of the atmosphere, perhaps more rapid changes than we are disposed to allow. Therefore, to call in the aid of the ocean, for the degradation of these secondary calcareous mountains, holds of no reason that I can see, unless it be that of diminishing the time which otherwise would have been required in bringing about those changes by the atmosphere alone.

To conclude: Whether we examine the mountain or the plain; whether we consider the degradation of the rocks, or the softer strata of the earth; whether we contemplate nature, and the operations of time, upon the shores of the sea, or in the middle of the continent, in fertile countries, or in barren deserts, we shall find the evidence of a general dissolution on the surface of the earth, and of decay among the hard and solid bodies of the globe; and we shall be convinced, by a careful examination, that there is a gradual destruction of every thing which comes to the view of man, and of every thing that might serve as a resting place for animals above the surface of the sea.

Chapter 5. Facts In Confirmation Of The Theory Respecting The Operations Of The Earth Employed In Forming Soil For Plants

I have distinguished the mineral operations of the earth, by which solid bodies are formed of loose materials, as well as the resolving or decomposing operations which are proper to the surface exposed to the sun and atmosphere. I have also pointed out the end or intention of those several operations, and likewise the means by which they have been brought about. We may now turn our view to that part of the system in which an indefinite variety of soils, for the growth of plants and life of animals, is to be provided upon the face of the earth, corresponding to that diversity which, in the wisdom of nature, has been made of climates.

In this last view, now to be considered, some confirmation should be given to the Theory, in finding the soil, or travelled materials upon the surface of the land, composed of earth, that is, of sand and clay, of stones and gravel; the earth and stones as arising from the resolution and separation of the solids in the neighbourhood of the place; the gravel, again, as having often travelled from more distant parts.

It would be very improper to adduce any example of a particular, where the force of the argument lies in the generality alone. It is enough to have mentioned the facts which are to be examined: Every person of inquiry and observation will judge for himself how far those facts are true.

But there is one general remark that may be made on this occasion, where the operations of the surface are concerned, and which may assist the investigation of this subject; it is with regard to the gravel or stones worn by attrition, which may have come from a distance. In proportion as hard and insoluble stones are near to their natural beds, they will be found with the sharp angles of their fracture, unless there may have been a cause of agitation and attrition on the spot; they will also be in greater quantity, *cet. par.* in this place; whereas the farther they may have travelled, they will naturally incline to be more rounded, and, in equal circumstances, will always be more scarce.

We have thus principles by which to judge of every appearance in relation to the travelled materials of our soil. When, for example, we find an immense quantity of the hardest stones worn round by attrition, and collected not far distant from their native place, we cannot suppose that they have acquired their shape by the attrition in the distance they have travelled, but in an agitation which they must have received nearly in the place from whence they came. Such is the gravel in the chalk country of England. Around London, in all directions, immense quantities of gravel are round, which consists almost entirely of flint worn or rounded by attrition; but this is the very centre of the chalk country, at least of England; and no doubt the same appearances will be found in France. We must therefore conclude, that the south of England was under water when that gravel was formed; and that immense quantities of the chalk above had been destroyed by the agitation of the sea in preparing such quantities of gravel which still remain upon the land; besides the immense quantities which must have been dispersed all around during the operation, as well as carried into the sea by the rivers since the elevation of our land. It is not uncommon to find this gravel twenty or thirty feet deep; and masses are found of much greater thickness. Were these masses of gravel formed in a deep hollow place, they would draw to no conclusion beyond the appearance itself; but they are, on the contrary, in form of hills; and therefore they serve as a kind of measure or indication of what had been carried away when these were left remaining.

We may observe a series or a progress in those forming and destroying operations, by which, on the one hand, the flinty bodies, already formed in the mineral region, were again destroyed, in being diminished by their mutual attrition; and, on the other hand, those diminished bodies were again consolidated into one mass of flinty stone, without the smallest pore or interstice. This example is to be found in the puddingstone of England. It consists of flint pebbles, precisely like Kensington gravel, penetrated or perfectly consolidated by a flinty substance. Here are the two opposite processes of the globe carried on at the same time and nearly in the same place. But it must be considered, that our land was then in the state of emerging from the sea, and those operations of subterranean fire fit for elevating land was then no doubt exerted with great energy; at present, no such thing appears in this place. But, from the momentary views we have of things, it would be most unphilosophical to draw such absolute conclusions.

The argument now employed rests upon the identity of the substance of the gravel with that of the entire flint, which is found in the chalk country; and it goes to prove that the sea had worn away a great deal of that chalk country above the place upon which this body of gravel is now resting; consequently that the sea had formerly flowed over that country covered with gravel, and had dispersed much of that gravel in transporting it to other regions, where that species of flint was not naturally produced. By a parity of reasoning, the gravel produced in the neighbouring regions, and which would be proper to those places, as consisting of their peculiar productions, must have been likewise dispersed and mixed with the surrounding bodies of gravel. But as in the country of which we are now treating, there are considerable regions, the different productions of which are perfectly distinct, we have a proper opportunity of bringing those conclusions of the theory to the test of observation.

For this purpose, let us examine the different countries which surround the chalk regions of England, France, and Flanders; if the gravel upon those neighbouring countries contain flint which the country does not naturally produce; and if the mixture of this flint among the gravel, which is proper to the country itself, be with regard to quantity in proportion to the vicinity of the flint country, the Theory will then be confirmed; and there is no doubt that this is so. On the other hand, let us examine the gravel about London, which is far distant from any place that produces quartz; if we shall find a very small proportion of quartz gravel in this flinty soil, we may be assured that the quartz has travelled from a distance, and that the Theory is thus approved. This is actually the case, and I have seen puddingstone containing quartz gravel among the flint.

In confirmation of this view of the travelled soil, it may be observed, that in lower Saxony about Hamburgh, and for a great way to the south-west, the gravel is mostly of broken flint, such as is around the chalk countries: Yet it is at a distance from the chalk of Flanders; there is however at Luxemburgh chalk with flint, the same as in England and France. Therefore the flinty soil of that country, in like manner, demonstrates the great destruction of the solid parts, and illustrates the formation of soil by the remainder of the hard parts below, and the alluvion of other parts.

There is most undoubted evidence that the solid body of our land had been formed at the bottom of the sea, and afterwards raised above the surface of the water; but, in the case which has now been described, it appears that the travelled soil of the surface of our land had been lately under the surface of the sea. We have thus therefore traced the different steps in the operations of nature, of which the last step may be considered as thus exposed to our view almost as much as the operations of man in building the Pyramids of Egypt. But surely there are other documents to be found in examining the different coasts of this island with attention; and there must be a consistency in the general appearance which never fails to attend on truth.

From the south to the north of this island, there are, in many places, the most evident marks of the sea having been upon a higher level on the land; this height seems to me to amount to about 40 or 50 feet perpendicular at least, which the land must have been raised. Some of those facts may now be mentioned.

Upon the banks of the Thames, I have found sea shells in the travelled soil a considerable height above the level of the sea. In low Suffolk there are great bodies of sea shells found in the soil which the farmers call *crag,* and with it manure their land. I do not know precisely the height above the sea; but I suppose it cannot exceed 100 feet. In the Frith of Forth there are, in certain places, particularly about Newhaven, the most perfect evidence of a sea bank, where the washing of the sea had worn the land, upon a higher level than the present. The same appearance is to be found at Ely upon the Fife coast, where the sea had washed out grottos in the rocks; and above Kinneel, there is a bed of oyster shells some feet deep appearing in the side of the bank, about 20 or 30 feet above the level of the sea, which corresponds with the old sea banks. I have seen the same evidence in the Frith of Cromarty, where a body of sea shells, in a similar situation, was found, and employed in manuring the land. There are many other marks of a sea beach upon a higher level than the present, but I mention only those which I can give with certainty.

We have been considering an extensive country more or less covered with gravel; such is England south of Yorkshire; both upon the east and west sides of the island. This country having no high mountainous part in the middle, so as to give it a considerable declivity towards the shores and rivers, the gravel has remained in many places, and in some parts of a considerable thickness. But in other parts of the island, where the declivity of the surface favours the transportation of gravel by the currents of water, there is less of the gravel to be found in the soil, and more of the fragments of stone not formed into gravel. Still, however, the same rule holds with regard to tracing the gravel from its source, and finding particular substances among the gravel of every region, in proportion to the quantity of country yielding that substance, and the vicinity to the place from whence it came.

Here are principles established, for the judging of a country, in some respects, from a specimen of its gravel or travelled stones. In this manner, I think, I can undertake to tell from whence had come a specimen of gravel taken up any where, at least upon the east side of this island. Nor will this appear any way difficult, when it is considered, that, from Portland to Caithness or the Orkneys, there are at least ten different productions of hard stone in the solid land which are placed at proper distances, are perfectly distinguishable in the gravel which is formed of them, and with all of which I am well acquainted. Let us suppose the distance to be 600 miles, and this to be divided equally into 10 different regions of 60 miles each, it must be evident that we could not only tell the region, which is knowing within 60 miles of the place, but we could also tell the intermediate space, by seeing an equal mixture of the gravel of two contiguous regions; and this is knowing within 30 miles of the place. If this be allowed, it will not seem difficult to estimate an intermediate distance from the different proportions of the mixed gravel. This is supposing the different regions to be in all respects equal, which is far from being in reality the case; nevertheless, a person well acquainted with the different extent and various natures of those regions, may make allowances for the different known circumstances that must have influenced in those operations, although it is most probable there will be others which must be unknown, and for which he can make no allowance.

The author of the Tableaux de la Suisse has entered very much into this view of things; he has given us some valuable observations in relation to this subject, which I would here beg leave to transcribe[54].

«Nous avons dit précédemment que c'étoit entre Orfière et Liddes que nous avions vu les derniers granites roulés, on n'en rencontre plus dans tout le reste de la route jusqu'au haut du Mont St. Bernard. Les rochers qui dominent ce sommet ne sont pas composés de granites, et quoiqu'on ne puisse aborder jusqu'à leur plus grande élévation, on peut juger de leurs espèces, par les masses qui s'en précipitent. D'où peuvent donc provenir ces masses roulées de granites qui se trouvent jetés et répandus sur le penchant et au bas de ce mont? Il y a peut-être quelque montagne ou rocher de granite que nous n'avons pas été à portée de voir: il faudroit plus d'un mois pour faire un pareil examen et parcourir les montagnes environnantes, et faute de pouvoir parvenir à certains sommets, examiner scrupuleusement les fonds pour juger des hauts. De pareilles recherches sont plus difficiles et plus longues qu'on ne le croit communement quand on veut réellement voir et observer. Beaucoup de vallons sont comblés à des hauteurs prodigieuses, par les amas et les débris provenant des montagnes supérieures: ils cessent d'être des vallons, pour former ou faire partie de montagnes. Ces déplacement et des bouleversemens, changeant la direction et le courant des torrens, entraînent dans des parties bien opposées des débris qu'on croiroit devoir chercher et trouver ailleurs. On seroit induit en erreur, en voulant suivre toujours le cours actuel des eaux qui descendent des montagnes. Ce n'est pas dans cette occasion seul mais l'Allemagne, la Corse, la Sardaigne, et beaucoup de pays de hautes montagnes, nous out fourni également des exemples de masses de rochers roulés de différentes espèces dont il n'existoit pas de rochers pareils, dans toutes les parties élevées environnantes, à plusieurs lieues, à plusieurs journées de chemin, et souvent totalement inconnus dans les pays d'alentour. Si nous avons remarqué les même espèces de rochers faisant corps, et attachés au sol, à

[54] Discours sur l'Histoire Naturelle de la Suisse, p. 27.

une ou plusieurs lieues de distance; nous avons vu souvent que des montagnes plus hautes étoient entre ces masses roulées et les rochers, d'ou on auroit pu supposer qu'elles ont été arrachées: il repugne à croire que des masses, d'un poids prodigieux, ayent été transportées et roulées en travers d'un vallon profond, pour remonter et passer de l'autre côté d'une montagne. Nous abandonnons, a ceux qui travaillent dans le cabinet, à l'arrangement du globe, la recherche des moyens que la nature a employé pour produire de pareils effets. Nous nous contenterons, ainsi que nous avons promis, de rendre compte de ce que nous avons vu et observé, et d'engager ceux qui auront la facilité de faire des remarques analogues de constater leurs observations en indiquant toujours les lieux fidèlement, ainsi que nous le faisions pour la Suisse.»

Here the experience of our naturalist amounts to this, that, in those operations by which the solid land is wasted, and the hard materials worn by attrition and transported, it is not always evident from whence had come every particular body of stone or mineral which had travelled by means of water; nor the particular route which, in descending from a higher to a lower place, the protruded body had been made to take, although, in general, these facts may be discovered without much difficulty. Now, this state of things is no other than the natural consequence of the great wasting of the surface and solid parts of our land, and the unequal degradation of this surface, by which means the shape of the earth is so changed, that it would often be impossible, from the present state, to judge of the course in which many bodies had been travelled by water.

M. de Saussure has described a very curious appearance of this kind: It is the finding the travelled materials of Mont Blanc, or fragments detached from the summit and centre of the Alps, in such places as give reason to conclude that they had passed through certain openings between the mountains of the Jura. This is a thing which he thinks could not happen according to the ordinary course of nature; he therefore ascribes this appearance to some vast *debacle*, or general flood, which had with great impetuosity transported all at once those heavy bodies, in the direction of that great current, through the defiles of the Alps, or the openings of those mountains.

In giving this beautiful example of the wasting and transporting operations of this earth, this naturalist overlooks the principles which I would wish to inculcate; and he considers the surface of the earth, in its present state, as being the same with that which had subsisted while those stones had been transported. Now, upon that supposition, the appearances are inexplicable; for, How transport those materials, for example, across the lake of Geneva? But there is no occasion to have recourse to any extraordinary cause for this explanation; it must appear that all the intervening hollows, plains, and valleys, had been worn away by means of the natural operations of the surface; consequently, that, in a former period of time, there had been a practicable course in a gradual declivity from the Alps to the place where those granite masses are found deposited. In that case, it will be allowed that there are natural means for the transportation of those granite masses from the top of the Alps, by means of water and ice adhering to those masses of stone, at the same time perhaps that there were certain summits of mountains which interrupted this communication, such as the Jura, etc. through the openings of which ridges they had passed.

In this case of blocks of alpine stones upon the Jura, the question is concerning the transportation of those stones; but, in other cases, the question may be how those blocks were formed.

That many such blocks of stone are formed by the decay of the rock around them, is clearly proved by the observations of M. Hassenfratz, published in the *Annales de Chimie*, October 1791. He has particularly mentioned a place on the road from Saint-Flour to Montpellier, where an amazing collection of these blocks of granite is to be seen. It is here particularly that he observes these blocks to be the more durable parts which remain after the rock around them is decayed and washed away. The proof is satisfactory; the operation is important to the present theory; and therefore I shall give it in his own words.

«Tous les blocs de granit dur dégagés et sortis entièrement des masses qui forment les montagnes, posent immédiatement sur le granit friable ou sur d'autres blocs durs qui eux-mêmes sont sur le granit friable.

«Quoique la plupart des blocs de granit dur, que l'on observe sur toute l'étendue de ce terrain granitique, soient entièrement sortis et dégagés de la masse de pierre qui forme la montagne, on en rencontre cependant qui ne sont pas encore tout-à-fait dégagés. Et c'est ici l'observation essentielle qui conduit directement à l'explication du phénomène de l'arrangement, de l'entassement, et de *l'amoncellement* des blocs d'une manière simple et absolue.

«On voit sur la surface du terrain des portions de blocs durs qui semblent sortir peu à peu, et se dégager de la masse de granit friable; celui-ci se décompose et se réduit en poussière tout autour de cette masse dure que les causes de décomposition du granit friable semblent respecter.

«Quelques-uns de ces blocs durs, sortans de la montagne granitique, sont déjà considérable; on distingue qu'ils n'y tiennent plus que par une très-petite partie; d'autres commencent à paroître se dégager, ils ne *saillent*, ils ne sortent encore que de quelque pieds, et même de quelques pouces. Enfin, en examinant soigneusement et attentivement toute la surface de ce terrain granitique, on apperçoit tous les intermédiaires entre un bloc de granit dur contenu et enchassé dans la masse totale du granit friable et un bloc entièrement dégagé.

«Ces observations, suivies avec attention, ne laissent aucun doute que les blocs de granit que l'on observe sur toute l'étendue de ce terrain granitique, n'aient fait autrefois partie d'une couche considérable de granit décomposable qui couvroit ces montagnes et exhaussoit leur sol; que cette couche, dont il semble impossible d'apprécier la hauteur, malgré les blocs considérable qui restent et qui attestent son existence, a été décomposée par l'air et l'intempérie des saisons; que la poussière, le sable résultans de cette décomposition, ont été entraînés par les eaux, et déposés à divers points de la surface de la globe; et que ces blocs ont été peu-à-peu dégagés de la couche, ainsi qu'il s'en dégage encore tous les jours.»

To enable the reader to form a notion of what these blocks are, I shall farther give what our author has said in describing this place where they are found.

«C'est après avoir quitté le terrain volcanique, c'est dans le terrain granitique que j'ai trouvé des blocs énormes de granit, qui ont fixé mon attention.

«Toute l'étendue du terrain granitique que j'ai traversée, se trouve presque couverte de ces masses; les uns sur les sommets des montagnes les plus élevées, les autres sur la pente et dans les vallées. Plusieurs de ces masses sont arrangées les uns sur les autres avec un art inimitable, les autres sont isolées et éparses.

«Peu de ces masses m'ont présenté un spectacle plus beau et plus imposant que celles que l'on rencontre à 6 heures de marche de S. Flour, à une petite demi heure avant d'arriver à la Garde.

«Là, sur le sommet d'une montagne, est un amas considérable de blocs de granit, étonnans par leur volume et leur nombre. La grande route passe à travers, et circule autour de ces masses que les constructeurs des chemins n'ont pas osé attaquer.

«Le voyageur est pénétré d'admiration en voyant l'ordre et l'arrangement symétrique de ces blocs monstrueux par leur masse, et qu'il ne cesse d'observer en suivant la trace tortueuse du chemin qui les contourne.

«Quelques-uns de ces blocs sont posés purement et simplement les uns sur les autres, et forment une colonne isolée; le plus gros sert de base, et les autres, graduellement plus petits, son posés dessus. On voit jusqu'à trois de ces blocs immédiatement l'un sur l'autre.

«D'autres fois, le bloc qui sert de base est beaucoup plus petit que celui qui le couvre immédiatement; et s'arrangement de ces deux blocs présente l'aspect d'un champignon.

«Plus souvent plusieurs blocs séparés les uns des autres, forment la base, et un ou plusieurs blocs sont posés immédiatement dessus, sans ordre constant, tantôt inclinés, mais toujours d'une manière stable et fixe, propre à resister aux plus grands efforts.

«Enfin, par fois, des masses plus petites placées entre les grosses, semblent assurer la situation fixe de l'ensemble des blocs; mais ces rencontres sont fort rares.»

Here is a distinct view of this part of nature; a view in which the present state of things plainly indicates what has passed, without our being obliged to raise our imagination to so high a pitch as is sometimes required, when we take the mountains themselves, instead of these blocks, as steps of the investigation. Here is a view, therefore, that must convince the most scrupulous, or jealous with regard to the admitting of theory, first, that those mountains had been much higher; secondly, that they had been degraded in their present place; thirdly, that this continent has subsisted in its present place for a very long space of time, during the slow progress of those imperceptible operations; and, lastly, that much of the solid parts of this earth has been thus travelled by the waters to the sea, after serving the purpose of soil upon the surface of the land.

But though M. Hassenfratz has thus given us a most satisfactory view of the natural history of those blocks of stone which are now upon or near their native place, this will not explain other appearances of the same kind, where such blocks are found at great distances from their native places, in situations where the means of their transportation is not to be immediately perceived, such as those resting upon the Jura and Saleve, and where blocks of different kinds of stone are collected together. These last examples are the records of something still more distant in the natural history of this earth; and they give us a more extensive view of those operations by which the surface of this earth is continually changing. It is, however, extremely interesting to this Theory of the Earth, to have so distinctly ascertained some of those first steps by which we are to ascend in taking the more distant prospect; and these observations of M. Hassenfratz answer this end most completely.

Thus all the appearances upon the surface of this earth tend to show that there is no part of that surface to be acknowledged as in its original state, that is to say, the state in which it had come immediately from the mineral operations of the globe; but that, every where, the effects of other operations are to be perceived in the present state of things. The reason of this will be evident, when we consider, that the operations of the mineral kingdom have properly in view to consolidate the loose materials which had been deposited and amassed at the bottom of the sea, as well as to raise above the level of the ocean the solid land thus formed. But the fertility of the earth, for which those operations were performed, and the growth of plants, for which the surface of the earth is widely adapted, require a soil; now the natural, the proper soil for plants, is formed from the destruction of the solid parts. Accordingly, we find the surface of this earth, below the travelled soil, to consist of the hard and solid parts, always broken and imperfect where they are contiguous with the soil; and we find the soil always composed of materials arising from the ruin and destruction of the solid parts.

Chapter 6. A View Of The Economy Of Nature, And Necessity Of Wasting The Surface Of The Earth, In Serving The Purposes Of This World

There is not perhaps one circumstance, in the constitution of this terraqueous globe, more necessary to the present theory, than to see clearly that the solid land must be destroyed, in undergoing the operations which are natural to the surface of the earth, and in serving the purposes which are necessary in the system of this living world. For, all the land of the present earth being a certain composition of materials, perfectly similar to such as would result from the gradual destruction of a continent in the operations of the inhabited world, this composition of our land could not be explained without having recourse to preternatural means, were there not in the constitution of this earth an active cause necessarily, in the course of time, destroying continents.

It is therefore of great importance to this Theory, to show, that the land is naturally wasted, though with the utmost economy; and that the continents of this earth must be in time destroyed. It is of importance to the happiness of man, to find consummate wisdom in the constitution of this earth, by which things are so contrived that nothing is wanting, in the bountiful provision of nature, for the pleasure and propagation of created beings; more particularly of those who live in order to know their happiness, and who know their happiness on purpose to see the bountiful source from whence it flows.

We are to conceive the continent of the earth, when first produced above the surface of the ocean, to be in general consolidated, with regard to its structure, by the same mineral operations which are necessarily employed in raising it from its primary situation at the bottom of the sea, to that in which we now inhabit it.

We are now to consider the purpose of this mineral body, exposed to the influences of the atmosphere, that so we may see the intention of its solid composition, as well as that of its resolution, or natural solubility when thus exposed; and we are to trace the ultimate effects of this order of action in the economy of the globe, that so we may perceive the wisdom of nature perpetuating the system of a living world in an endless succession, of changing perishable forms.

The purpose of the land of this earth, in being placed above the sea and immersed in the atmosphere, is to sustain a system of plants and animals. But; for the purpose of plants; there is required a soil; and, as there is in the vegetable system a vast variety of plants with different habits or natural constitutions, there is also required a diversity of soils, in which those vegetable bodies are to be made to live and prosper. From the bare rock exposed to the sun and wind, to the tender mud immersed in water, there is a series to be observed; and in every stage or step of this gradation, there are plants adapted to those various soils or situations. Therefore nothing short of that diversity of soils and situations, which we find upon the surface of the earth, could fulfill the purpose of nature, in producing a system of vegetables endued with such a diversity of forms and habits.

The soil or surface of this earth is no more properly contrived for the life and sustenance of plants, than are those plants for that diversity of animals, which will thus appear to be the peculiar care of nature in forming a world. Scarce a plant perhaps that has not its peculiar animal which feeds upon its various productions; scarce an animal that has not its peculiar tribe of plants on which the economy of its life, its pleasure, or its prosperity must depend.

If we shall suppose the continent of our earth to be a solid rock, on which the rain might fall, and the wind and waves might dash perpetually, without impairing its mass or changing its constitution, what an imperfect world would we have! how ill adapted to the preservation of animal and vegetable life! But the opposite extreme would equally frustrate the intention of nature, in producing bounteously for the various demands of that multiplicity of species which the author of this world has thought proper to produce.

For if, instead of a solid rock, we shall suppose a continent composed of either dry sand or watery mud, without solidity or stability, how imperfect still would be that world for the purpose of sustaining lofty trees and affording fruitful soils!

We have now mentioned the two extreme states of things; but the constitution of this earth is no other than an indefinite number of soils and situations, placed between those two extremes, and graduating from the one extreme, in which some species of animals and plants delight in finding their prosperity, to the other, in which another species, which would perish in the first, are made to grow luxuriantly. That is to say, the surface of this earth, which is so widely adapted to the purpose of an extensive system of vegetating bodies and breathing animals, must consist of a gradation from solid rock to tender earth, from watery soil to dry situations; all this is requisite, and nothing short of this can fulfil the purpose of that world which we actually see.

We have been representing this continent of our earth as coming out of the ocean a solid mass, which surely it is in general, or in a great degree; but we find the surface of this body at present in a very different state; and now it will be proper to take a view of this change from solid rock to fertile soil.

Upon this occasion I shall give the description of nature from the writings of a philosopher who has particularly studied this subject. It is true that M. de Luc, who furnishes the description, draws, from this process of nature, an argument for the perpetual duration or stability of mountains; and this is the very opposite of that view which I have taken of the subject; but as, in this operation of nature producing plants on stones, he allows the surface of the solid stone to be changed into earth and vegetables, it is indifferent to the present theory how he shall employ this earth and vegetable substance, provided it be acknowledged that there is a change from the solid state of rock to the loose or tender nature of an earth, from the state of a body immovable by the floods and impenetrable to the roots of plants, to one in which some part of the body may be penetrated and removed.

[55]«Les pluies et les rosées forment partout où elles séjournent, des dépôts qui sont la première source de toute *végétation*. Ces dépôts sont toujours mêlés des semences des*mousses*, que l'air charie continuellement, et

[55] Histoire de la Terre, Tom. 2. page 26.

auxquelles se joignent bientôt les semences presque aussi abondantes des *gramens*, qui sont l'herbe dominante de nos prairies. Ainsi partout où la pluie a formé quelque petit dépôt, il croît de la mousse ou des *gramens*. Ceux-ci demandent un peu plus de *terre végétale* pour croître, ils germent, et se conservent principalement dans les intervalles et les creux des pierres: mais la *mousse* croît bientôt sur la surface la plus unie. Il n'est aucune pierre long-temps exposée à l'air, qui soit parfaitement polie; l'action de l'air, du soleil, des eaux, des gelées, detruiroit ce poli quand il existeroit. Le moindre creux alors reçoit un dépôt de la pluie, et nourrit un brin de*mousse,* ces brins poussent des racines; et de nouveaux jets autour d'eux, qui contribuent à arrêter l'eau de la pluie et de la rosée, et par ce moyen à arrêter les dépôts Nourriciers.»

«Quand la mousse a multiplié ses filets, les dépôts s'augmentent plus rapidement encore; les brins de la *mousse,* en séchant et pourrissant, en forment eux-mêmes; car leur substance n'étoit que ces mêmes dépôts façonnés: d'autres semences charriées par l'air, qui au-paravant glissaient sur les pierres, parce que rien ne les retenoit, tombent dans le fond de la *mousse*, et y trouvent l'humidité nécessaire pour produire leurs premières racines: celles-ci s'entrelassent dans la *mousse*, où elles se conservent à l'abri du soleil, et sont alors autant de petites bouches qui pompent les sucs, que l'air, les pluies, et les rosées y déposent. Ces premières plantes sont foibles, quelque fois même elles ne parviennent pas à leur perfection: mais elles ont contribué à fixer la *terre végétable*. En séchant et se décomposant, elles se transforment en cette *terre*, qui tombe au fond de la *mousse*, et qui prépare ainsi de la nourriture pour de nouvelles plantes qui alors prospèrent et fructifient.

«Nous connoissons peu encore ce que c'est que cette *terre végétable*, ce dépôt des pluies ou en général de l'air. Cependant, en rassemblant les phénomènes, on peut conjecturer, que la plupart des corps terrestres sont susceptibles d'être changés en cette substance, et qu'il ne s'agit pour cette transformation que de les décomposer. J'entends par là une telle division de leurs parties, que devenant presque des élémens, elles puissent être intimement mêlées à l'eau, et pompées avec elle par les tuyaux capillaires des plantes. En un mot, il semble suffisant qu'une matière puisse entrer en circulation dans les végétaux, pour qu'elle serve à en développer le tissu, et qu'elle y prenne la figure et les qualités que chacun de ces laboratoires est propres à produire.

«Nous pouvons accélérer de bien des manières la transformation des matières terrestres en *terre végétable*. La fermentation, la calcination, une plus grande exposition à l'air, différens mélanges, rendent propres à la végétation, des matières qui ne l'étoient par elles-mêmes: voila ce que peuvent nos soins. Mais l'air travaille sans cesse et en mille manières. Son simple frottement sur tous les corps, en enlève des particules si atténuées que nous ne les reconnoissons plus. La *poussière* de nos appartemens en est peut-être un exemple. De quelque nature que soient les corps dont elle se détache, c'est une poudre grisâtre qui semble être partout la même. La formation de la *terre végétable* a probablement quelque rapport à celle-là. Toute la surface de la terre, les rocs les plus durs, les sables et les graviers les plus arides, les métaux même, éprouvent l'action*rongeante* de l'air et leurs particules atténuées, décomposées, recomposées de mille manières, sont probablement la source principal de la végétation. *L'air* lui-même ainsi que*l'eau*, s'y combinent: beaucoup d'observations et d'expériences nous prouvent que ces deux fluides fournissent leur propre substance aux parties solides des végétaux, et par conséquent à la *terre végétable* qui les produit et qu'ils déposent. Quantité de plantes se nourrissent de *l'eau* seule, et nous laissant cependant en se séchant, un résidu de matière solide permanente. *L'air* aussi se *fixe* dans les corps terrestres, il fait partie de leur substance solide; les chimistes savent de plus en plus, et le *fixer*, et lui redonner son élasticité primitive, par divers procédés: et avant la multitude d'expériences qui se sont de nos jours sur cet objet intéressant de la physique, le Dr. Hales avoit montré, que les végétaux renferment une très-grande quantité *d'air*, qui s'y trouve sans ressort et comme matière constituante.

«Voila donc probablement les sources où la nature puise peu à peu la *terre végétable* dont elle recouvre la surface de nos continens. Ce sont les particules, peut-être, de tous les corps tant solides que fluides, extraites ou fixées par des procédés qui les rapprochent de leurs premiers élémens, et leur font prendre à nos yeux une même apparence. Ces particules sont ainsi rendues propres à circuler dans les semences des plantes, à en étendre le tissu à y prendre toutes les propriétés qui caractérisent chaque espéce, et à les conserver tant que la plante existe. Ces mêmes particules, après la destruction des plantes, prennent le caractère général de *terre végétable*, c'est-à-dire de provision toute faite pour la végétation.

«Les plus petits recoins des montagnes, qui peuvent arrêter l'eau de la pluie, sont certainement fertilisés; ce ne sont pas seulement les grandes surfaces plates, ni les pentes; ce sont même les faces escarpées des rochers les plus durs. S'il s'y fait quelque crevasse, un arbre s'y établit bientôt; et souvent il contribue, par l'accroissement de ses racines, à accélérer la chute du lambeau de rocher qui l'avoit reçu. S'il y a quelque petite terrasse, ou seulement quelque partie saillante grande comme la main, elle est bientôt gazonnée. Les plus petites sinuosités se peuplent de plantes; et les surfaces les plus unies, celles mêmes qui sont tournées vers la bas, reçoivent au moins quelqu'une de ces *mousses* plates, nommés *lichen* par les botanistes, qui ne font en apparence que passer une couleur sur la pierre. Mais cette couche est écaillée, et elle loge bientôt de petites plantes dans ses replis; de celles qui veulent l'ardeur du soleil, si le rocher est au midi, ou la fraîcheur de l'ombre, s'il est au nord: c'est sur ces rochers en un mot, qui paroissent nues aux spectateurs ordinaires, que se trouve la plus grande variété de ces petites plantes, qui font les délices des botanistes, et l'une des sources les plus abondantes où la médicine puise les secours réels qu'elle fournit à l'humanité.

«Quelle richesse dans les ressources de la nature! La pesanteur n'est pas plus prête à entraîner les pierres qui se détachent des montagnes, que l'air à fournir de semences celles qui se fixent: et dès qu'une fois elles sont recouvertes de plantes, elles sont certainement fixées pour toujours, du moins contre les injures de l'air. Le fait même nous l'annonce. Si ces ravins ou ces terreins quelconques, tendoient encore à rouler ou à se dégrader, en un mot à se detruire de quelque manière que ce fut, ils ne le recouvriroient, ni de *mousses* ni d'aucune autre plante. La première végétation est due à quelque dépôt de *terre végétable*; et les pluies ou l'air n'en forment que lentement; le moindre mouvement la détruite. Le terrein est donc bien certainement fixe quand il se recouvre de plantes; et s'il s'y accumule de la *terre végétable*, c'est un signe bien evident que rien ne l'attaque plus: car elle seroit la première emportée si quelque cause extérieure tendoit a detruire le sol qui la porte.»

The doctrine here laid down by our author consists in this; first, That there is a genus of plants calculated to grow upon rocks or stones; those hard bodies then decay, in decomposing themselves, and affording sustenance to the plants which they sustain. Secondly, That by this dissolution of those rocks, and the accumulation of those vegetable bodies, there is soil prepared for the nurture and propagation of another genus of plants, by which the surface of the earth, naturally barren, is to be fertilised. It is also in this natural progress of things that the solid parts of the globe come to be wasted in the operations of the surface, and that lofty rocks are levelled, in always tending to bring the uneven surface of the earth to a slope of vegetating or fertile soil.

Here we are to distinguish carefully between the facts described by this author, who has seen so much of nature, and the conclusion which he would draw from his principles. The surface of most stones are dissolved, or corroded by the air and moisture. This gives lodgement to the roots of plants, which grow, die, and decay; and these are carried away with the earthy parts of the solid stone, in order to form a vegetable soil for larger plants, growing upon some bottom or resting place to which that earth is carried. Here is so far the purpose of rocks, to sustain a genus of plants which are contrived to live upon that soil; and here is so far a purpose for certain plants, in decomposing rocks to form a soil for other plants which have been made upon a larger scale, and are adapted to the use of man, the ultimate in the view of nature.

Our author concludes thus: (p. 37.) «Le tems ne fera qu'augmenter l'épaisseur de la couche de *terre végétable* qui couvre les montagnes, et qui les garantit ainsi de plus en plus de cette destruction à laquelle on les croit exposés: les pluies en un mot, au lieu de les dégrader comme on se l'imagine y accumuleront leurs dépôts. Tel est l'agent simple qu'employe si admirablement le Createur pour la conservation de son ouvrage.»

Such, indeed, is the admirable contrivance of the system, that, in the works of nature, nothing shall be destroyed more than is necessary for the preservation of the whole. But, that the whole is preserved by the necessary destruction of every individual body, and the change of every part which comes within the examination of our senses, is sufficiently evident to require no farther illustration in this place, where we are contemplating the destruction of the strongest things, by means the most effectual, though really slow, and apparently most feeble.

In his 30th letter, this author describes the progress of nature, in bringing precipitous rocks to that slope and covering of soil which is to maintain plants of every kind, and to establish woods. (P. 40.) «J'ai l'honneur d'exposer à V.M. les causes qui garantissent de destruction extérieure les terreins sur lesquels la *pesanteur* ne peut plus agir que pour les consolider. Mais ce n'est pas ainsi que sont actuellement la plupart de nos montagnes; il en est peu qui soyent déjà parvenus à cet état permanent. Tout roc nud est attaqué par l'air et les météores, et il tend à se détruire quelle que soit sa dureté. Mais ce seroit peu que cette destruction extérieure; elle pourroit même cesser enfin totalement par l'effet seul des*mousses*, s'il n'y avoit pas des causes plus puissantes qui pendant quelque tems agissent dans l'intérieur.

«Il n'est presque point de rocher qui offre à l'air une seule masse compacte; ils sont ou crevassés, ou formés par couches; et l'eau s'insinue toujours dans ces fentes. Quand cette eau vient à se geler, elle agit comme un coin pour écarter les pièces entre lesquelles elle se trouve. V.M. seroit étonnée de la grandeur des masses que cette cause peut mouvoir: elle agit exactement comme la poudre à canon dans les mines; détachant toutes les pièces extérieures qui commencent à se séparer, et en découvrant ainsi de nouvelles. Chaque hiver renouvelle donc la surface de certains rochers, ou facilite l'ouvrage pour les hivers suivans.

Plusieurs autres causes agissent encore pour séparer les rochers déjà crevassés, qui se trouvent à l'extérieur des faces escarpées. Le petit moellon qui s'y accumule, les dépôts des pluies, les plantes qui y croissent, les alternatives de l'humidité et de la sécheresse, les vicissitudes de la chaleur, les vents même, sont autant de causes continuellement agissantes quand la *pesanteur* les seconde. Les rochers escarpés se détruisent donc par de continuels éboulemens.

«Mais toutes ces matières qui tombent, ne sont pas perdues pour les montagnes; il s'en perd même bien peu. Elles s'arrêtent au pied des rochers dont elles sont successivement détachées; et là elles s'entassent, s'élevant en forme de *talus* contre ces rochers eux-mêmes.»

If the solid body of the Alps, the most consolidated masses of our land, is thus reduced to the state of soil upon the surface of the earth contrived for the use of plants, *a fortiori*, softer bodies, less elevated and less consolidated masses, will be considered as easily arriving at the purpose for which the surface of the earth has been intended. We only wish now to see the ultimate effect that necessarily follows from this progress of things; and how, in this course of nature, the land must end, however long protracted shall be the duration of this body, and however much economy may be perceived in this gradual waste of land;—a waste which by no means is so slow as not to be perceived by men reasoning in science; although scientific men, either reasoning for the purpose of a system which they had devised, or, deceived by the apparent state of things which truly change, may not acknowledge the necessary consequence of what they had perceived.

Let us now suppose all the solid mass of land, contained in our continent, to be transformed into soil and vegetable earth, it must be evident that no covering of plants, or interlacing of vegetable fibres, could protect this mass of loose or incoherent materials from the ravages of floods, so long as rivers flowed, nor from being swallowed by the ocean, so long as there were winds and tides. From the border of the land upon the shore, to the middle of the ocean, there is either at present an equable declivity at the bottom of the sea, or every thing tends to form this declivity, in gradually moving bodies along this bottom. But, however gradual the declivity of the bottom, or however slow the progress of loose materials from the shore towards the deepest bottom of the sea, so long as there are moving powers for those materials, they must have a progress to that end; the law of gravitation, always active, must prevail, and sooner or later the moving sea must swallow up the land.

But, along the borders of our continent, and in the courses of our rivers, there are rocks; these must be surmounted or destroyed, before the parts which they protect can be delivered up to the influence of those moving powers which tend to form a level; and we may be assured that those bulwarks waste. The bare inspection of our rocky coasts and rivers will satisfy the enlightened observator of this truth; and to endeavour to prove this to a person who has not principles by which to reason upon the subject, or to one who has false principles, by which he would create perpetual stability to decaying things, would be but labour lost.

In proportion as the solid bulwark is destroyed, so is the soil which had been protected by it; and, in proportion as the solid parts of the mass of land are exposed to the influences of the atmosphere and water, by the ablution of the soil, more soil is prepared for the growth of plants, and more earth is detached from the solid rock, to form deep soils upon the surface of the earth, and to establish fertile countries at the mouths of rivers, even in making encroachment on the space allotted for the sea. But this production of land, in augmentation of our coasts, is only made by the destruction of the higher country. While, therefore, we allow that there is any augmentation made to the coast, or any earthy matter travelling in our rivers, the land above the coast cannot be stable, nor the constitution of our earth fixed in a state which has no tendency to be removed.

M. de Luc, in his Histoire de la Terre, would make the mountains last for ever, after they have come to a certain slope. He sums up his reasoning upon this subject in these words: «L'adoucissement des pentes arrête d'abord l'effet de ces deux grandes causes causes de destruction de montagnes, la *pesanteur* et les *eaux*: la végétation ensuite arrêté l'effet de toutes les petites cause.»

If all the great and little causes of demolition are arrested by the slope of mountains and the growth of plants, the surface of the earth might then remain without any farther change; and this would be a fact in opposition to the present theory, which represents the surface of the earth as constantly tending to decay, for the purpose of vegetation, and as being only preserved from a quick destruction by the solid rocks protecting, from the ravages of the floods and sea, the loose materials of the land. It will therefore be proper to show, that this author's argument does not go to prove his proposition in the terms which he has given it, which is, that those sloped mountains are to last for ever, but only that these causes, which he has so well described, make the destruction of the mountains become more slow[56].

The slope which our author gives to his mountains, in order to secure them from the ravages of time, is that which, according to his own reasoning, renders them fertile and proper for the culture of man; but fertile soil yields always something to the floods to carry away; and, while any thing is carried from the soil, the land must waste, although it may not then waste at the rate of those within the valleys of the Alps. According to the doctrine of this author, our mountains of Tweeddale and Tiviotdale, being all covered with vegetation, are arrived at that period in the course of things when they should be permanent. But is it really so? Do they never waste? Look at the rivers in a flood;—if these run clear, this philosopher has reasoned right, and I have lost my argument. Our clearest streams run muddy in a flood. The great causes, therefore, for the degradation of mountains never stop as long as there is water to run; although, as the heights of mountains diminish, the progress of their diminution may be more and more retarded.

Let us now see how far our author has reasoned justly with regard to vegetation, which, he says, stops the effects of all the little causes of destruction; this is the more necessary, as, in the present theory, it is the little causes, long continued, which are considered as bringing about the greatest changes of the earth.

Along the courses of our rivers there are plains between the mountains of greater or lesser extent; these are almost always fertile, and generally cultivated when large; when small, they are in pasture. The origin of these

[56] This also would appear to be a part of that wise system of nature, in which nothing is done in vain, and in which every thing tends to accomplish the end with the greatest marks of economy and benevolence. Had it been otherwise, and the demolishing powers of the land increased, in a growing rate with the diminution of the height, the changes of this earth and renovation of our continent, in which occasionally animal life must suffer, would necessarily require to be often repeated; and, in that case, chaos and confusion would seem to be introduced into that system which at present appears to be established with such order and economy that man suspects not any change; it requires the views of scientific men to perceive that things are not at present such as they were created; it requires all the observation of a natural philosopher to know that in this earth there had been change, although it is not every natural philosopher that observes the benevolence accompanying this constitution of things which must subsist in change.

fertile soils, and their perpetual change, is to be described with a view to show, that vegetation, although most powerful in stopping the ravages of water, and for accumulating soil retained by this means, does it only for a time; after which the soil is again abandoned to the ravages of the running water, when no more protected by the vegetation.

Let us suppose the river running upon the one side of the haugh (which is the name we gave those little fertile plains) and close by the side of the mountain. In this case the bed of the river is deepest at the side of the mountain, which it undermines, leaving a falling *(un éboulement)* on that side; on the other side, the river shelves gradually from the plain, and leaves soil in its bottom or stony bed upon the side of the haugh, in proportion as it makes advances in carrying away the bank at the bottom of the sloping mountain. The part which vegetation takes in this operation is now to be considered.

When the river has enlarged its bed by preying upon one side, whether of the mountain or the haugh, the water only covers it in a flood; at other times, it leaves it dry. Here, among the rocks and stones, the feeds of plants, left by the water or blown by the wind, spring up and grow; and, in little floods, some sand and mud is left among those plants; this encourages the growth of other plants, which more and more retain the fertile spoils of the river in its floods. At last, this bed of the river is covered perfectly with plants, which having retained plenty of fertile soil, although still rooted among the stones, opposes to the river a resistance which its greatest velocity is not able to overcome. In this state, the haugh is always deepening or increasing its soil, and has its surface heightened. At last, when this soil becomes so high as only to be flooded now and then, it becomes most fertile, as the heavier parts are carried in the bed of the river, and the lighter soil deposited upon the plain. The operations of the river, upon the plain, thus increase at the same time the height and fertility of the haugh. But this operation, of accumulated soil upon the stony bottom, has a period, at which time the river must return again upon its steps, and sweep away the haugh which it had formed. This is the natural course of things; and it happens necessarily from the deepening of the soil. Let us then examine this operation.

When no more soil is left upon the stony bottom than is sufficient for the covering of the ground, and rooting of plants which are also fixed in the solid ground or bottom of the soil, the water is not able to carry away the plants; and these plants protect the surface of loose soil. When again there is a depth of soil accumulated upon the haugh, the surface only is protected by the vegetable covering. But what avails it to the soil to be protected from above, when undermined by the enemy! The vegetable roots now no longer reaching to the bottom where solidity is found, the tender soil below is easily washed away by the continued efforts of the stream; and the unsupported meadow, with the impregnable texture of its leaves, its roots, and its fibres, falls ruinously into the river, and is born away in triumph by the flood. The water thus reclaims its long deserted bed,—only in order to pass from it again, and circulate or meander from hill to hill in varying perpetually its course.

Now this progress of the river, or this changing of its bed, is determined by the strong resistance of the new made haugh, humbly standing firm in the protection of its vegetation, while the elevated surface of the older haugh, deserted by the inferior soil which it had ceased to protect, falls a victim to its exalted state, and passes away to aggrandize another. This is the fate of haughs or plains erected by the operations of a river, and again destroyed in the natural course of things, or in the very continuation of that active cause by which they had been formed.

The water is constantly carrying the moveable soil from the higher to the lower place; vegetation often disputes the possession of these spoils of ruined mountains for a while; but, in the end, this vegetable protector, not only delivers up to the destroying cause the mineral soil which it had preserved, but, by its buoyancy in water, it facilitates the transportation of the stony parts to which this fibrous body is attached. Over and over a thousand times may be repeated this alternate possession of the transferable soil, by moving water on the one part and by fixed vegetation on the other, but at last all must land upon the shore, whether the river tends. Thus the mountain and the plain, the vegetable earth and the plants produced in that soil, must all return into the sea from whence either they themselves or their materials had come. In proportion as the mountains are diminished, the haugh or plain between them grows more wide, and also on a lower level; but, while there is a river running in a plain, and floods produced in the seasons of rain, there can be nothing stable in this constitution of things evidently founded upon change.

The description now given is from the rivers of this country, where it is not unfrequent to see relicts of three or four different haughs which had occupied the same spot of ground upon different levels, consequently which had been formed and destroyed at different periods of time. But the same operation is transacted every where; it is seen upon the plains of Indostan, as in the haughs of Scotland; the Ganges operates upon its banks, and is employed in changing its bed continually as well as the Tweed[57] . The great city of Babylon was built upon the haugh of a river. What is become of that city? nothing remains,—even the place, on which it stood, is not known.

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[57] An Account of the Ganges and Burrampooter Rivers, by James Rennel, Esquire. Philosophical Transactions, 1781.

Chapter 7. The Same Subject Continued, In Giving A View Of The Operations Of Air And Water Upon The Surface Of The Land

We have but to enlarge our thoughts with regard to things past by attending to what we see at present, and we shall understand many things which to a more contracted view appear to be in nature insulated or without a proper cause; such are those great blocks of granite so foreign to the place on which they stand, and so large as to seem to have been transported by some power unnatural to the place from whence they came. We have but to consider the surface of this earth as having been upon a higher level; as having been every where the beds of rivers, which had moved the matter of strata and fragments of rocks, now no more existing; and as thus disposed upon different planes, which are, like the haughs of rivers, changing in a continual succession, but changing upon a scale too slow to be perceived. M. de Luc has given a picture which is very proper to assist our imagination in contemplating a more ancient state of this earth, although in this he has a very different end in view, and means to show that the world, which we inhabit at present, is of a recent date. It is in the 32d letter of his Histoire de la Terre, which I beg leave here to transcribe.

«Des montagnes basses (comme le *Jura*, qui est bas comparativement aux Alpes) sont bientôt fixées par ce moyen. Il ne se fait presque qu'un seul *talus* depuis leur sommet jusques dans les basses vallées, ou sur la plaine. Aussi l'état de ces montagnes est-il déjà presqu'entièrement *fixé*: on y voit très peu de rochers nuds qui s'éboulent, excepté, auprès des *rivières*. C'est dans ces lieux-la que l'ouvrage tarde le plus à se finir. Le bas des *talus* est miné par l'eau; leur surface s'éboule donc, pour ainsi dire, sans cesse, et laisse à découvert les rochers des sommets, qui par la continuent aussi à *s'ébouler*. Mais les vallées s'élargissent enfin; et les *talus* s'éloignant ainsi des *rivières*, commencent à éprouver les influences du repos.»

Here nothing can be more positively described than the natural destruction of those mountains by the operation of the rivers which run between them; and this is from the authority of matter of fact, which, on all occasions, this author faithfully describes. At the same time, we are desired to believe, upon no better authority than the imagination of a person hurried on by system, that those mountains are absolutely to come to rest. I am aware of the danger to which a spirit of systematising leads; and I wish for nothing more than to have my Theory strictly examined, in comparing it with nature.

Our author thus proceeds: «La vue seule de la chaine du *Jura* nous apprend donc ce que deviendroit enfin toutes les montagnes. Dans la plus grande partie de son étendue, il ne souffre plus aucun changement ruineux: la *végétation* le recouvre presque partout. Les bas sont cultivés de toute sorte de manière suivant leur exposition; les sommets sont couverts de pelouses, qui forment les pâturages les plus precieux. Cette gazonade s'étend aussi sur toutes les parties des pentes qui ne sont pas trop rapides, et le reste est couvert de bois.

«J'ai parcouru fort souvent le pied de ces montagnes: leur état est presque partout tel que je viens d'avoir l'honneur de la descrire à V.M. J'ai sur-tout observé avec attention les lits des *torrens* qui, en descendent pour se rendre dans les lacs de *Geneva*, de *Neufchâtel* et de *Bienne*, ainsi que dans l'Aar et dans le Rhin: et hormis ceux de ces *torrens* qui viennent des gorges où les terrains sont encore escarpés, ils ne roulent plus que l'ancien gravier qu'ils out apporté autrefois.

«Mais il n'en est pas ainsi des *Alpes*, des *Pyrénées*, et des autres montagnes, qui, comme celles-là, sont beaucoup plus élevées, ou qui sans l'être davantage ont été livrées aux influences de l'air dans un désordre plus grand. Dans ce genre de montagnes il reste encore à la *végétation* de bien grandes conquêtes à faire.

«Ces montagnes ne sont pas telles que V.M. pourroit se les figurer naturellement; il faut y être monté pour s'en former une juste idée. Ce sont des montagnes sur d'autres montagnes. De près on ne voit que les parties inférieures; de loin tout se confond; il faut donc être arrivé sur une des premières *terrasses* pour voir les secondes; sur celles-ci pour les troisièmes; et ainsi de suite.

«La plupart de ces *terrasses* successives sont de grandes plaines, dominées par des rochers qui s'éboulent, et forment des *talus*. Si dans la succession des siècles, les *éboulemens*de ces bandes de rochers en amphithéâtre finissoient sans emporter les plaines qu'ils soutiennent, et que les *torrens* eussent creusé leur lit pendant ce tems là à quelque distance des *talus* tout seroit fini par cette première operation. Mais il y a peu de hautes montagnes où les arrangemens soient si simples: souvent ces bandes empiètent les unes sur les autres en *s'éboulant*, et alors le repos est bien différé.

«Supposons que ces *terrasses* soient étroites, et que leurs murs, c'est-à-dire les rochers qui les soutiennent, soient fort élevés. Les *terrasses* alors ne suffiront pas pour recevoir les*éboulemens* qui doivent se faire sur elles car le dessus de chacune d'elles s'étrécit de plus en plus par la destruction du rocher qui la soutient. Il pourra donc arriver que ce talus, s'étant étendu jusqu'au bord de la terrasse, se trouve reposer sur une base qui s'éboule encore; et même cela arrive très souvent; de sorte qu'à chaque rétrécissement de la base, le*talus* lui-même s'éboule. Ainsi deux *talus*, qui étoient peut-être déjà en pleine végétation par la lenteur des éboulemens des rochers qui les formoient, pourront être fort reculés à cet égard; le *talus* supérieur, parce que la surface fertilisée glissera en bas; et le *talus* inférieur, parce que la sienne sera ensevelie sous de nouveaux décombres.

«Les montagnes qui sont dans ce cas seront proportionnellement plus abaissées que les autres; parce que leurs *talus* se confondant ainsi et devenant par là fort étendus demeureront longtemps à devenir solides. Les eaux partant de fort haut, auront le tems de s'y rassembler et de devenir destructives vers le bas. Au lieu que dans les montagnes où les terrasses subsisteront encore après que tous les rochers se seront *éboulés*, les eaux étant reçues par reprises, perdront beaucoup de leur rapidité. Elles se rassembleront dans les enfoncemens des petites vallées supérieures, elles s'y formeront des lits qu'elles ne rongeront presque point; et la *végétation* restera tranquille partout.»

Let us now consider the height of the *Alps*, in general, to have been much greater than it is at present; and this is a supposition of which we have no reason to suspect the fallacy; for, the wasted summits of those mountains attest its truth. There would then have been immense valleys of ice sliding down in all directions towards the lower country, and carrying large blocks of granite to a great distance, where they would be variously deposited, and many of them remain an object of admiration to after ages, conjecturing from whence, or how they came. Such are the great blocks of granite which now repose upon the hills of *Saleve*. M. de Saussure, who has examined them carefully, gives demonstration of the long time during which they have remained in their present place. The lime-stone bottom around being dissolved by the rain, while that which serves as the basis of those masses stands high above the rest of the rock, in having been protected from the rain. But no natural operation of the globe can explain the transportation of those bodies of stone, except the changed state of things arising from the degradation of the mountains.

Every thing, therefore, tends to show that the surface of the earth must wear; but M. de Luc, although he allows the principles on which this reasoning is founded, labours to prove that those destructive causes will not operate in time. Now, What would be the consequence of such a system?—That the source of vegetation upon the surface of the earth would cease at last, and perfect sterility be necessarily the effect of allowing no farther degradation to the surface of the earth; for, What is to supply the matter of plants? Water, air, and light alone, will not suffice; there are necessarily required other elements which the earth alone affords. If, therefore, this world is to continue, as it has done, to form continents of calcareous strata at the bottom of the ocean, the animals which form these strata, with their *exuviae*, must be fed. But, on what can they be fed? not on water alone; the consequence of such a supposition would lead us to absurdity; nor can they be fed on any other element without the dissolution of land. According to my views of things, it is certain that those animals are ultimately fed on vegetable bodies; and it is equally certain, that plants require a soil on which they may not only fix their fibrous roots, but find their nourishment at least in part; for, that air, water, and the matter of light, also contribute, cannot be doubted. But if animals, which are to form the strata of the earth, are to be fed on plants, and these are to be nourished by the matter of this earth, the waste of vegetable matter upon the surface of the earth must be repaired; the exhausted soil must be transported from the surface of the land; and fertility must be restored by the gradual decay of solid parts, and by the successive removal of soil from stage to stage. What a reverie, therefore, is that idea, of bringing the earth to perfection by fixing the state of its vegetable surface!

The description of those natural operations, which M. de Luc has given with a view to establish the duration of the mountains, is founded upon nothing but their destruction. These beds of rivers, which, according to our author, are *hardly* to be wasted any more, will not satisfy a philosopher, who requires to see no degree of wasting in a body which is to remain for ever, or continue without change. But, however untenable this supposition of a fixed state in the surface of this earth, the accuracy of the natural philosopher may still be observed in the absurdity of the proposition. «L'état des *montagnes* sera *fixe*, partout où les *rivières* seront arrivées au point de n'emporter pas plus de limon hors de leur enceinte, que l'air et les pluies n'y déposeront de *terre végétable*, et voila enfin quel sera le repos, l'état permanent de la surface de notre globe. Car alors il y aura compensation entre les destructions et les réparations simultanées, et les montagnes sûrement ne s'abaisseront plus.»

Surely, if there is in the system of nature wisdom, we may look for compensation between the destroying and repairing operations of the globe. But why seek for this compensation in the *rest* or immobility of things? Why suppose perfection in the want of change? The summit of the Alps was once the bottom of the sea; the existence of our land depended then upon the change of seas and continents. But has the earth already undergone so great changes, and is it not yet arrived at the period of its perfection? How can a philosopher, who is so much employed in contemplating the beauty of nature, the wisdom and goodness of Providence, allow himself to entertain such mean ideas of the system as to suppose, that, in the indefinite succession of time past, there has not been perfection in the works of nature? Every material being exists in motion, every immaterial being in action and in passion; rest exists not any where;

nor is it found in any other way, except among the parts of space. Surely it is contrary to every species of philosophy, whether ancient or modern, to found a system on the inutility of repose, or place perfection in the vacuity of rest, when every thing that truly exists, exists in motion; when every real information which we have is derived from a change; and when every excess in nature is compensated, not by rest, but by alternation.

M. de Luc allows the rivers to carry matter always to the sea; but then, at a certain period, this matter carried by the floods is to be compensated to the mountains by the vegetable earth received from the air and rains. Here is a proposition which should be well considered, before it be admitted as a principle, which shall establish the perpetuity of these mountains, if it be true; or, if false, assure us of their future demolition. Let us now examine it.

If from air and rain there is produced earth which cannot afterwards be resolved by the operation of those elements, and thus again dissolved in the air and water of the land, then this author might have had some pretext, however insufficient, for alledging that it might be possible to compensate the loss of mineral substances, carried off the surface of the earth, by the production of this vegetable matter from the air and rain; but, when there is not sufficient reason to conclude that any substance, produced in vegetation, can resist the continued influences of the air and water, without being decomposed in its principles, and at last entirely dissolved in water, the cautious argument here employed by this author, for the permanency of mountains, must appear as groundless in its principle as it would be insufficient for his purpose, were it to be admitted; but this will require some discussion.

That which preserves vegetable bodies so long from dissolution in water, is what may be called the inflammable or phlogistic composition of those bodies. This composition is quickly resolved in combustion; but it is no less surely resolved by the influences of the sun and atmosphere, only in a slower manner. Therefore, to place the permanency of this earth, or any of its surface, upon a substance which in that situation necessarily decays, is to form a speculation inconsistent with the principles of natural philosophy[58].

But even supposing that the degradation of mountains were to be suspended by the pretended compensation which is formed, by the rivers carrying mineral mud into the sea, and the air and rain producing vegetable earth; in what must this operation end? In carrying into the sea, to be deposited at its bottom, all the vegetable earth produced by the air and rain. But our cosmologist, in thus procuring an eternal station to his mountains, has not told us whether this transmutation of the air and rain be a finite operation, or one that is infinite; whether it be in other respects confident with the natural operations of the globe; and whether, to have the air and water of the globe converted into earth, would ultimately promote, or not, that perfection which he wishes to establish. Here, therefore, in allowing to this philosophy all its suppositions, it would be necessary to make another compensation, in preserving mountains at the expense of air and rain; and, the waste of air and water, which are limited, would require to be repaired.

It is not in our purpose here to treat of moral causes; but this author having endeavoured to fortify his system by observing, that the world certainly cannot be ancient, since men have not ceased as yet to quarrel and fight, (Lettre 34.) it may be proper to observe, that the absolute rest of land, like the peace among mankind, will never happen till those things are changed in their nature and constitution, that is to say, until the matter of this globe shall be no more a living world, and man no more an animal that reasons from his proper knowledge, which is still imperfect. If man must learn to

[58] It is from inadvertency to this fact in natural history, the consuming of vegetable substances exposed to the influences of the atmosphere, that M. de Luc, in his *Histoire de la Terre*, has pretended to determine the past duration of the German heaths as not of a very high antiquity. He has measured the increase of the vegetable soil, an increase formed by the accumulation of the decayed heath; and, from the annual increase or deposits of vegetable matter on that surface, he has formed a calculation which he then applies to every period of this turfy augmentation, not considering that there may be definitive causes which increase with this growing soil, and which, increasing at a greater rate in proportion as the soil augments, may set a period to the further augmentation of that vegetable soil. Such is fire in the burning of those parched heaths; such is the slower but constant and growing operation of the oxygenating atmosphere upon this turfy substance exposed to the air and moisture. This author has very well described the constant augmentation of this vegetable substance in the morasses of that country, as it also happens in those of our own; but there is a wide difference in those two cases of peat bog and healthy turf; the vegetable substance in the morass is under water, and therefore has its inflammable quality or combustible substance protected from the consuming operation of the vital or atmospheric air; the turfy soil, on the contrary, is exposed to this source of resolution in the other situation.

reason, as children learn to speak, he must reason erroneously before he reasons right; therefore, philosophers will differ in their opinions as long as there is any thing for man to learn. But this is right; for, how are false opinions to be corrected, except in being opposed by the opinions of other men? It is foolish, indeed, for men to quarrel and fight, because they differ in opinion. Man quarrels properly, when he is angry; and anger perhaps is almost always ultimately founded upon erroneous opinion. But, in nature, there is no opinion; there is truth in every thing that is in nature; and in man alone is error. Let us, therefore, in studying nature, learn to know the truth, and not indulge erroneous notions, by endeavouring to correct, in nature, that which perhaps is only wrong in our opinion.

Having shown that every thing, which is moveable upon the surface of the land, tends to the sea, however slowly in its pace, we are now to examine, what comes of those materials deposited within the regions of the waves, still however within the reach of man, and still subservient more immediately to that soil on which plants grow, and man may dwell.

As, from the summit of the land, the natural tendency of moveable bodies is to fall into the water of the sea, so, from the borders of the land or coast, there being a declivity towards the deepest bottom of the sea, and there being currents in the waters of the ocean occasionally rendered more rapid on the shore, every moveable thing must tend to travel from the coast, and to proceed alone; the shelving bottom of the sea into the unfathomable deep, when they are beyond the reach of man or the possibility of returning to the shore.

But it is not every where upon the coast that those materials are equally delivered; neither is it every where along the shore that the currents of the ocean are equally perceived, or operate with equal power in moving bodies along the shelving bottom of the sea. Hence in some places deep water is found washing rocky coasts, where the waste of land is only to be perceived from what is visibly wanting in the continuity of those hard and solid bodies. In other places, again, the land appears to grow and to encroach upon the space which had been occupied by the sea; for here the materials of the land are so accumulated on the coast, that the bottom of the sea is filled up, and dry land is formed in the bafon of the sea, from those materials which the rivers had brought down upon the shore.[59]

Holland affords the very best example of this fact. It is a low country formed in the sea. This low land is situated in the bottom of a deep bay, or upon the coast of a shallow sea, where more materials are brought by the great rivers from the land of Germany than what the currents of the sea can carry out into the deep. Here banks of sand are gathered together by streams and tides; this sand is blown in hillocks by the wind; and those sand hills are retained by the plants which have taken root and fixed those moving sands. Behind that chain of hillocks, which line the sea shore, the waters of the rivers formed a lake, and the bottom of this lake had been gradually filled up or heightened by materials travelling in the rivers, and here finding rest. It grew up until it became a marsh; then man took possession of the soil; he has turned it to his own life; and, by artificial ramparts of his forming, preserves it in the present state, some parts above the level of the sea, others considerably below the ordinary rise of tides. M de Luc, who has given a very scientific view of this country in his Lettres Physiques et Morales, has there also furnished us with the following register of what had been found by sinking in that soil. It was at Amsterdam at the year 1605 in making a well.

[59] We are not however to estimate this operation, of forming soil by the muddy waters of a river depositing sediment, in the manner that M. de Luc has endeavoured to calculate the short time elapsed in forming the marshlands of the Elbe. This philosopher, with a view to show that the present earth has not subsisted long since the time it had appeared above the surface of the sea, has given an example of the marsh of *Wisebhafen* where the earth, wasted by inundation, was in a very little time replaced, and the soil heightened by the flowings of the Elbe, and this he marks as a leading fact or principle, in calculating the past duration of our continents, of which he says, we are not to lose sight (Tome 5, p. 136.) But here this philosopher does not seem to be aware, that he is calculating upon very false grounds, when he compares two things which are by no means alike, the natural operations of a river upon its banks, making and unmaking occasionally its haughs or level lands, that is to say, alternately making and destroying, and the artificial operations of man receiving the muddy water of a tide-way into the still water of a pond formed by his ramparts; yet, it is by this last operation that our author forms an estimate which he applies to the age of this earth, in calculating how long time might have been required for producing the marsh lands of the Elbe.

I would here ask if he can calculate what time it may have required to hollow out the bed of the Elbe from its source to the sea; and to tell how often the marsh-lands, which he now sees cultivated, had been formed and destroyed by the river before they were cultivated in their present state; or if there is any security that they shall not again be taken away by the river, and again formed in the same place. If this is the case, that the river is constantly changing the fertile lands, which it forms by its inundation, what judgement are we to form by calculating the quantity of sediment in a certain measure of its muddy water.

«Voici la désignation des matières qui furent trouvées en partant de la surface.

51 pieds, mêlés de sable tourbeux, de fable

des dunes pur et d'argile ou

limon.

22.—-de même sable des dunes pur,

et d'argile bleuâtre.

14.—-du même sable pur.

87 pieds.—Ou rien encore n'indiquoit la

présence de la mer.

55.—-de sable marin, et de limon,

mêles l'un et l'autre de coquilles

dans plusieurs couches.

142 pieds.—Soit la plus grande profondeur,

où s'est manifestée la présence

de la mer.

49.—-Argille dure sans mélange de

coquilles, soit que ce soit une

couche argilleuse continentale,

ou les premiers dépôts des

fleuves; ce qu'il est difficile de

Déterminer.

191 pieds.

13.—-Sable mêlé de pierres; qui est

enfin sûrement le sol vierge

continental.

28.—-Sable pur; continental encore;

car j'ai remarqué partout

dans la Geest, que c'est

dans la couche supérieure, à

une petite profondeur que se

trouvent les pierres; au-dessous

le sable est pur.

232 pieds.—C'est à cette profondeur, ou

dans la masse de ces deux dernières

couches, que se trouva

l'eau douce, et par conséquent

le vrai sol continental.»

The light that we have from this pit which has been made in the soil, according to my view of the subject, is this, that here is the depth of 232 feet in travelled soil, and no solid bottom found at this distance from the surface or level of the sea. How far this depth may be from the bottom of these travelled materials is unknown; but this is certain, that all that depth, which has been sunk, had been filled up with those materials[60].

It will thus appear of what unstable materials is composed the land of that temporary country. It will also be evident, that, by removing the sand banks

[60] An interesting map for the use of natural history would be made by tracing the places (behind this country of loose or travelled soil) where the solid strata appear above the level of the sea. We should be thus able to form some notion of the quantity of materials which had been deposited in the water of this sea. But, though we might thus enlarge our views a little with regard to the transactions of time past, it would only be in a most imperfect manner that we would thus form a judgment; for, not knowing the quantity of sand and mud carried out by the currents from the German sea into the Atlantic, we could only thus perceive a certain minimum, which is perhaps a little portion of the whole.

of this coast, the whole of this low country would be swallowed by the sea, notwithstanding every effort that the power of man could make. But it may be alledged, that those sand banks are increasing still with the alluvion of Germany, instead of being in a decreasing state. I should also incline to believe that this is truly the case; but, though we may acknowledge the growth of land upon the coast of Holland, we must deny that a stable country can be formed in the bed of the sea by such means. For, however increasing may be the sand in the German sea, and however great additions may be made of habitable country to the coast of Holland, yet, as the islands of Great Britain and Ireland are worn by attrition on the shores, and are wasted by being washed away into the ocean, the causes for the accumulation of sand in the German sea must cease in time, when, in this progress of things, the sand banks, on which depends the existence of Holland, must diminish, and at last be swept away, in leaving the solid coast of Germany to be again buffeted by the waves, as is at present the coasts of Ireland, France, and Spain.

This reasoning is, indeed, very far removed from that which is commonly employed for the purpose of conducting human operations, or establishing the political system of a nation; it is not, however, the less interesting to man, in that it cannot direct him immediately in his worldly affairs; and it is the only way of reasoning that can be employed in order to enlighten man with a view of those operations which are not to be limited in time, and which are to be concluded as in the system of nature, a system which man contemplates with much pleasure, and studies with much profit.

Thus we have shown, that, from the top of the mountain to the shore of the sea, which are the two extremities of our land, every thing is in a state of change; the rock and solid strath dissolving, breaking, and decomposing, for the purpose of becoming soil; the soil travelling along the surface of the earth, in its way to the shore; and the shore wearing and wasting by the agitation of the sea, an agitation which is essential to the purposes of a living world. Without those operations, which wear and waste the coast, there would not be wind and rain; and, without those operations which wear and waste the solid land, the surface of the earth would become sterile. But showers of rain and fertile soil are necessarily required in the system of this world; consequently, the dissolution of the rocks, and solid strata of the earth, and the gradual, flow, but sure destruction of the present land, are operations necessary in the system of this world; so far from being evils, they are wisely calculated, in the system of nature, for the general good.

Chapter 8. The Present Form Of The Surface Of The Earth Explained, With A View Of The Operation Of Time Upon Our Land

It is not to *common* observation that it belongs to see the effects of time, and the operation of physical causes, in what is to be perceived upon the surface of this earth; the shepherd thinks the mountain, on which he feeds his flock, to have been always there, or since the beginning of things; the inhabitant of the valley cultivates the soil as his father had done, and thinks that this soil is coeval with the valley or the mountain. But the man of scientific observation, who looks into the chain of physical events connected with the present state of things, sees great changes that have been made, and foresees a different state that must follow in time, from the continued operation of that which actually is in nature.

It is thus that enlightened natural history affords to philosophy principles, from whence the most important conclusions may be drawn. It is thus that a system may be perceived in that which, to common observation, seems to be nothing but the disorderly accident of things; a system in which wisdom and benevolence conduct the endless order of a changing world. What a comfort to man, for whom that system was contrived, as the only living being on this earth who can perceive it; what a comfort, I say, to think that the Author of our existence has given such evident marks of his good-will towards man, in this progressive state of his understanding! What greater security can be desired for the continuance of our intellectual existence,—an existence which rises infinitely above that of the mere animal, conducted by reason for the purposes of life alone.

The view of this interesting subject, which I had given in the first part, published in the Transactions of the Edinburgh Royal Society, has been seen by some men of science in a light which does not allow them, it would appear, to admit of the general principle which I would thereby endeavour to establish. Some contend that the rivers do not travel the material of the decaying land;—Why?—because they have not seen all those materials moved. Others alledge, that stones and rocks may be formed upon the surface of the earth, instead of being there all in a state of decay. These are matters of fact which it is in the power of men who have proper observation to determine; it is my business to generalise those facts and observations, and to bring them in confirmation of a theory which is necessarily founded upon the decaying nature and perishing state of all that appears to us above the surface of the sea.

Nothing is more evident, than that the general effect of mineral operations is to consolidate that which had been in an incoherent state when formed at the bottom of the sea, and thus to produce those rocks and indurated bodies which constitute the basis of our vegetable soil; but, that indurating or consolidating operation is not the immediate object of our observation; and, to see the evidence of that operation, or the nature of that cause, requires a long chain of reasoning from the most extensive physical principles. Our present subject of investigation requires no such abstract distant *media*, by which the effect is to be connected with its cause; the actual operation in general is the object of our immediate observation; and here we have only to reason from less to more, and not to homologate things which may, to men of narrow principles, appear to be of different kinds. But even here we find difficulty in persuading those who have taken unjust views of things; for, those who will not deny the truth of every step in this chain of reasoning, will deny the end to which it leads, merely because they are not disposed to admit the progress of that order which appears in nature.

In the last chapter, I have been using arguments to prove that M. de Luc has reasoned erroneously, in concluding the future stability of a continent; and I have been endeavouring to show that our continent is necessarily wasted in procuring food to plants, or in serving the various purposes of a system of living animals. We have now in view to illustrate this theory of the degradation of the surface of the earth; a theory necessarily leading to that system of the world in which a provision is made for future continents; and a theory explaining various natural appearances which otherwise are not to be understood. A door may thus be opened for the investigation of natural history, particularly that which traces back, from the present state of things, those operations of nature which are more immediately connected with what we take much pleasure to behold, viz. the surface of the earth stored with such a variety of beautiful plants, and inhabited by such a diversity of animals, all subservient to the use of man.

There are two ways in which we may look for the transactions of time past, in the present state of things, upon the surface of this earth, and read the operations of an ancient date in those which are daily transacted under our eye. The one of these is to examine the soil, and to trace the origin of that which we find loose upon the surface of the earth, or only compacted by the soft and cohesive nature of some of its materials. In thus studying the soil we shall learn the destruction of the solid parts; and though, by this means, we cannot form an estimate of the quantity of this destruction which had been made, we shall, upon many occasions, see a certain *minimum* of this quantity which may perhaps astonish us.

The second method here proposed, is to examine the solid part of the earth, in order to learn the quantity of matter which had been separated from this mass. Here also we shall not be able to compute the quantity of what had been destroyed; but we shall every where find a certain *minimum* of this quantity, which will give us an extensive view with regard to the operation of the elements and seasons upon the surface of this earth. We shall now examine more particularly those two ways of judging with regard to the operations of time past, and the changes which have been made upon the surface of our land, by those active causes, which, being in the constitution of this earth, must continue to operate with undiminished power, and tend to preserve the *whole* amidst the destruction of its particular parts.

The quality of the soil or travelled earth of the globe is various; because the solid parts, from the destruction of which the soil is formed, consist of very different substances, in the different portions of each country. Thus, in one part of a country, the soil will be calcareous, or containing much of that species of substance; in another, again, it will be argillaceous; in another sandy, where the prevailing substance is siliceous. These are the original soils; other substances may be considered as adventitious to this soil, though natural to the surface of the earth, which is covered with plants and animals. The substance of those animal and vegetable bodies, mixed with the soil, adds greater fertility to the earth, and gives a soil which is still more compounded in its nature, but still composed of those materials now enumerated.

We have been now supposing the solid parts below, or in the same field, as furnishing materials of which the soil is formed; this soil then partakes of the nature of those solid parts, whether more simple or more compound. There is, however, another subject of variety, or still greater composition in soils; this is the transportation of materials from a distance; and this, in general, is performed by the ablution of water, in following the declivity of the surface. But sand is sometimes travelled by the wind, and proceeds along the surface of the earth, without regard to the declivity, and changes the nature of soil in those places which happen to be exposed to this accident.

There cannot be any extensive, great, or distant travelling of sand or soil by means of the wind, except in those places which are sterile for want of rain, and thus are destitute of rivers and of streams; for, these running waters form every where a bar to this progressive movement of the soil, even if the sterility or dryness should permit the blowing of the sand. But the operation of streams and rivers, carrying soil and stones along the surface of the earth, is constant, great, and general over all the globe, so far as a superfluity of water, in the seasons of rain, falls upon the earth.

From the amazing quantity of those far travelled materials, which in many places are found upon the surface of the ground, we may with certainty conclude, that there has been a great consumption of the most hard and solid parts of the land; and therefore that there must necessarily have been a still much greater destruction of the more soft and tender substances, and the more light and subtile parts which, during those operations of water, had been floated away into the sea. This appears from the enormous quantities of stones and gravel which have been transported at distances that seem incredible, and deposited at heights above the present rivers, which renders the conveyance of those bodies altogether inconceivable by any natural operation, or impossible from the present shape of the surface. This therefore leads us to conclude, that the surface of the earth must have been greatly changed since the time of those deposits of certain foreign materials of the soil. Examples of this kind have been already given. I shall now give one from the Journal de Physique.

«Les bords du Rhône aux environs de Lyon, et sur la longueur de quarante lieues, et de plus, des montagnes entières, dans le même pays, sont formes de pierres dont on ne trouve les analogues que dans la Suisse. Ce fait presqu'incompréhensible est accompagné de beaucoup de circonstances qui méritent d'être détaillées dans un discours plus longue que celui-ci. Il y a cependant une que je ne peux pas m'empêcher de rapporter ici, comme une suite de ce que je viens de dire.

«Dans cette grand catastrophe, à laquelle j'attribue le transport de ces matières alpines, il se fit de grandes échancrures dans le Jura; les plus profondes que j'aie vues sont celles de Jougue de Sainte-Croix, du val de Mousthier Travers, de Someboz au val de Saint-Inver, une cinquième aux environs du village de Grange, trois lieues plus bas que Bienne, et une sixième à quatre à cinq lieues plus bas que Soleure, à l'endroit dit la cluse. Cette dernière est la plus profonde, et se trouve de niveau avec les eaux de l'Aar. Beaucoup de ces matières étrangères au Jura, ont passé par ces échancrures, et sans doute, par bien d'autres et se sont répandues, dans plusieurs de ces vallées. J'en ai vu un suite bien marquée qui a passé par Jougue, par Saint-Antoine, part Mont Perreux, les Grangettes, les Granges Friards, Oye, et qui est allée jusqu'aux plaines de Pontarlier. Cette suite est en ligne droite vis-à vis l'échancrure de Jougue, et la direction de la vallée qui est au bas de ce village. On en trouve quelques morceaux à Metabiefs, mais je n'en ai point vu aux Longevilles, ni à Roche-Jean. Il y en a au-dessus de Saint-Croix ou d'autres ont pu passer aussi pour aller de même aux environs de Portarlier. Il y en a dans le val de Mousthier-Travers jusqu'au dessus de village de Butte; elles ont même passé les roches de Saint-Sulpice du côté des Verrières de Suisse, ou l'on a été obligé d'en faire sauter de gros blocs avec de la poudre pour dégager la grande route; il y en a dans les vallées de Tavannes, et de Delemont; on en trouve bien plus loin, j'en ai vu près de Roulans, et je ne douterois pas que les pierres meulières de Moissez et des environs n'eussent la même origine.»

M. de Saussure, who has so well observed every thing that can be perceived upon the surface of the earth, gives us the following remarks which are general to mountainous countries. (Voyages dans les Alpes, tome 2d § 717).

«Dans le haut des vallées entourées de hautes montagnes, on ne voit point de cailloux roulées, qui soient étrangers à la vallée même dans laquelle on les trouve; ceux que l'on y rencontre ne sont jamais que les débris des montagnes voisines. Dans le plaines au contraire, et à l'embouchure des vallées, qui aboutissent aux plaines et même assez haut sur les pentes des montagnes qui bordent ces plaines, on trouve des cailloux et des blocs que l'on diroit tombés du ciel, tant leur nature diffère de toute ce que l'on voit dans les environs.»

Here are facts which can only be explained in supposing that the valleys have been hollowed out of the solid mass, by the gradual operation of the rivers. In that case stones, travelled from a far, will be found at considerable heights, upon the sides of the valleys at their under end, or where, as our author says, they terminate in plains.

We have a striking example of the operation of time and the influences of the atmosphere, in wasting the surface of the rocks, and forming soil upon the earth; this is the kaolin of the Chinese, or the true porcelain earth, which is the produce of granite countries. The feldspar of the granite rock exposed to the atmosphere is corroded very slowly indeed, by the effects of air and moisture, and in having the soluble earth or calcareous part of its composition dissolved; the surface of this stone, thus, in a long course of time, becomes opaque in having the white siliceous earth exposed to view, and thus appears like a calcined substance. The snows and rain detaches from this surface of the rock the white earth, which being deposited in the plain below, forms a stratum of kaolin more or less pure, according to the circumstance of the place.

As this operation of the atmosphere upon the surface of granite is so extremely slow as to be altogether unmeasurable to man; and as there are in many places of the earth inexhaustible quantities of this kaolin, notwithstanding a small portion only of the ablution of the rock had been retained upon the surface and deposited by itself, it must appear that much time had been required for amassing those beds of kaolin, and that these operations, which in the age of a continent is nothing, or only as a day, are, with regard to the experience of man, unmeasurable.

For approbation of this theory, it is not necessary to show, that wherever there is granite found, there should be also kaolin observed; but it is necessary that wherever kaolin is found, there should be also granite or feldspar to explain its origin; and to this proof the theory is most willingly submitted. The following are the places which have come to my knowledge. First Loch Dune in the shire of Ayr; this lake receives its water from the granite hills which are at its head. Secondly, some small lakes which receive the washings of the granite mountain, Crifle, in East Galloway. Thirdly, Cornwall, a county in which I have not been, but which is sufficiently known as possessing kaolin and granite.

Another example from a very distant country we have both from M. Pallas, in the Oural mountains, and from M. Patrin, who has given a mineralogical *notice* of the Douari,*Journal de physique, Mars* 1791. Here we find the following observation.

«Parmi les chose intéressantes qu'offrent les rives de Chilea, on remarque au dessous de la fonderie, des collines de petunt-fé blanc comme la neige, parsemé de mica argentin de la plus grande ténuité. Dans le voisinage de ce petunt-fé est une argile micacée, qui en est peut-être une décomposition: on essaya en ma présence d'en faire de la poterie qui avoit tous les caractères du meilleurs biscuit de porcelaine.»

We have now been endeavouring to illustrate the wasting and washing away of the solid land, in the examples of decayed rocks and water worn stones, all of which are traceable, though at a great distance, to their source; we are now to consider another species of substance, which is still more particular as to the place of its production, or to its original situation, this being only in the veins of the earth. Among all the various productions of mineral veins, we have only now in view some particular metallic substances which do not seem to waste and be dissolved, as many of them are, in being long exposed to the influence of air and rain. When, therefore, the solid parts of the land are wasted in time, and carried away from the surface of the earth, the contents of the veins, which are occasionally found in those decayed parts of the land, are also carried away in the stream; but as the specific gravity of those metallic contents is much greater than the other stony materials moved in the stream, they sink to the bottom, and tend much more to be deposited upon the land, than those stones which had moved with them from their place. Hence it is, that deposits, rich in those metallic substances, are formed in certain places of the soil; and these are sought for, upon account of the value of their contents. Thus, stream tin, which in the time of the Romans formed a subject of traffic, is still found in the soil of Cornwall, even in great profusion, at this day.

Nothing can tend more to illustrate this travelling of the wasted surface of the solid land, than the contents of those mineral veins suffering in the general destruction of things, but partly saved from that total ablution by which so much of the solid parts had been made to disappear; and nothing can, in a more beautiful manner, show this order of things, than the method practised by the Cornish miners in quest of the original country of that metal, by *shoding*, (as it is called) upwards in running back the tract in which the stream tin had been conveyed. This is done by trying parcels of the soil, in always mounting to see from whence the mineral below had come.

Gold is thus found almost in every country but it is only in the most sparing manner that it may thus be in general procured, by reason of the few veins in which gold is found, and the small quantity of this metal contained in those veins. America, however, affords an example of veins rich in gold, and it is also there that quantities of stream gold is found in the soil, bearing a due proportion to the number and riches of the veins.

I shall give an example concerning the situation in which this stream gold is found in Peru (Voyage au Pérou, par M. Bouguer, page 49.)

«Cette Cordelière occidentale contient beaucoup d'or de même que le pied de l'orient, et celui d'une autres chaîne très-longue qui s'en détache un peu au sud de Popayan, et qui après avoir passé par Santa Fé de Bogota, et par Mérida, va se terminer vers Caracas sur la mer du nord; outre que l'or en paillettes occupe toujours des postes assez bas à l'égard du reste de la Cordelière, on ne peut aussi jamais le découvrir qu'en enlevant presque toujours deux couches de différentes terres qui le cachent. La première, qui est de la terre ordinaire, a trois ou quatre pieds d'épaisseur et quelquefois dix ou douze. On trouve souvent au dessous une couche moins épaisse qui tire sur le jaune, et plus bas est une troisième qui a une couleur violette, qui a souvent trois ou quatre pieds d'épaisseur, mais qui n'a aussi quelquefois qu'un pouce, et c'est cette troisième dans laquelle l'or est mêlé. Au dessous la terre change encore de couleur, elle devient noire comme à la surface du sol, et elle ne contient aucun métal. D'ailleurs on ne creuse pas indistinctement par tout. On se détermine à chercher en certains endroits plutôt qu'en d'autres par la pente de terrain. On agit comme si l'or avant que d'avoir été couvert par les deux couches supérieures, avoit été charrié par des eaux courantes. On s'est assuré aussi que les terres une fois *lavées* ou dépouillée de leurs richesses n'en produisent point d'autres; ce qui prouve que l'or y avoit été comme déposé.»

Therefore, whether we consider the quantity or the quality of the materials which are found composing the soil upon the surface of the earth, we must be led to acknowledge an immense waste of the solid parts, in procuring those relicts which indicate what had been destroyed.

We have now to examine what is left of that solid part which had furnished the materials of our soil; this is the part which supports the vegetable or travelled earth, and this earth sustains the plants and animals which live upon the globe. It is by this solid part that we are to judge concerning the operations of time past; of those destructive operations by which so great a portion of the earth had been wasted and carried away, and is now sunk at the bottom of the sea.

Man first sees things upon the surface of the earth no otherwise than the brute, who is made to act according to the mere impulse of his sense and reason, without inquiring into what had been the former state of things, or what will be the future. But man does not continue in that state of ignorance or insensibility to truth; and there are few of those who have the opportunity of enlightening their minds with intellectual knowledge, that do not wish at some time or another to be informed of what concerns the whole, and to look into the transactions of time past, as well as to form some judgment with regard to future events.

It is only from the examination of the present state of things that judgments may be formed, in just reasoning, concerning what had been transacted in a former period of time; and it is only by seeing what had been the regular course of things, that any knowledge can be formed of what is afterwards to happen; but, having observed with accuracy the matter of fact, and having thus reasoned as we ought, without supposition or misinformation, the result will be no more precarious than any other subject of human understanding. To those who thus exercise their minds, the following remarks may furnish a subject for some speculation. Now, though to human policy it imports not any thing, perhaps, to know what alterations time had made upon the form and quantity of this earth, divided into kingdoms, states, or empires, or what may become of this continent long after every kingdom now subsisting is forgotten, it much concerns the present happiness of man to know himself, to see the wisdom of that system which we ascribe to nature, and to understand the beauty and utility of those objects which he sees.

There are two different operations belonging to the surface of this globe which we are now to consider, and by which we shall be enabled to form some computation of what had been in space and time, from that which now appears. Moving water is the means employed in both those operations; but, in the one case, it is the water of the sea; in the other again, it is the water of the land. The effect of the one operation is the wasting of the coast, and the diminution of that basis on which our land and soil depends; of the other, again, it is the degradation of our mountains, and the wasting of our soil. In the course of this last operation, there is also occasionally land formed in the sea, in addition to our coast.

With regard to the wearing of the coast by the agitation of the waves, this is an operation of which some understanding is to be formed from the surest of all records, from a careful examination of our shores which are in this decaying state, and by observing what has been removed from those portions which we find remaining. Few people have either the skill or the opportunity of thus judging of the state of our earth from that which actually appears; but there is no person, who studies this science of geology, that may not satisfy himself with regard to the truth of this theory, by looking into our maps and charts, and making proper allowances for causes which cannot appear in the maps, but which may be understood by a person of knowledge making observations on the spot. In order to assist this study, the following observations may be made.

It is a general observation among mariners, that a high coast and rocky shore have deep water; whereas a low coast, and sandy shore, are as naturally attended with shallow water. The explanation of this fact will appear by considering, that a steep rocky coast is occasioned by the sea having worn away the land; and, when that is the case, we are not to expect sand should be accumulated upon that shore, so as to make the sea shallow. Look round all the coasts of Great Britain and Ireland that are exposed to the wide ocean, as likewise those of France and Norway, deep water, and a worn coast, are universally to be acknowledged. If again the coast is shallow, this is a proof that the land affords more materials than the sea can carry away; consequently, instead of being impaired, the coast may here increase and be protruded from the land. Such is the case in many places along the coast of North America, where several reasons concur in accumulating sand upon that coast; for, not only is the shore plentifully provided with sand from the rivers of that continent, but also the sand of the Mexican Gulf would appear to be carried along this coast with the stream which flows here towards the north, and which has thus contributed to form the banks of Newfoundland.

The second general observation is to be considered as respecting the shape of coasts, in like manner as the first had in view their elevations. Now, it is plain that the shape of the coast, in any part of the land, must depend upon a combination of two different causes. The first of these is the composition of the land or solid parts of the coast; if this be uniform and regular, so will be the shape of the coast; if it is irregular and mixed, consisting of parts of very different degrees of hardness and resistance to the wasting operations, the coast will then be, *cet. par.* irregular and indented. The second, again, respects the wearing power. If this wearing power shall be supposed to be equally applied to all the coast; and, if every part of that coast were of an equal quality or resisting power, no explanation could be given, from the present state of things, for the particular shape of that coast, which ought then to be wasted in an equable manner by the sea. But neither is the coast, of any extensive country at least, composed of such uniform materials; nor is the application of the wearing power to the coast an equal thing; and this will form the subject of another observation. The third general observation, therefore, regards the operations of the sea upon the coast, and the effects which may be perceived in consequence of that cause, independent of the qualities of the coast, or supposing them in general to be alike. Here, according to the theory, we should expect to find deep water and an indented coast upon a country, in proportion as that coast is exposed to the violence of the sea, or is open directly to the ocean. We have but to look along the west coast of Norway, the north-west of Scotland, the west of Ireland, and the south-west of England and of France; and we shall soon be convinced that the sea has made ravages upon those coasts in proportion to its power, and has left them in a shape corresponding to the composition of the land, in destroying the softer, and leaving the harder parts[61].

With those hard and rugged coasts of Britain and Ireland, let us contrast the east coasts; What a difference between these and the west side! Upon the west side, there are no sand banks left upon the coast; the mariner has nothing there to fear but rocks. It is otherwise on the east; here we find a tamer coast, and, in many places, a sandy bottom. On the west, nothing appears opposed to the storm of the ocean except the hardest and most solid rock; on the east, we find coasts exposed to the sea which could not have remained in a similar situation on the west. Let us but compare the two opposite coasts of England, viz. the promontory of Norfolk and Suffolk upon the one side, and Pembrokeshire and Carnarvonshire on the other, both similarly exposed, the one to the north east storm of the German sea, the other to the south west billows of the Atlantic. What a striking difference! The coast in the bay of Cardigan is a hard and strong coast compared with that of Norfolk and Suffolk; the one is strong schistus, the other the most

[61] M. de Lamblardie, *ingénieur des ponts et chaussées*, has made a calculation, seemingly upon good grounds, with regard to the wasting of a part of the coast of France, between the Seine and the Somme. This coast is composed of *falaises*, (or chalk cliffs, like the opposite coast of England), which are 200 feet high above the level of the sea, composed of strata of marl, separated by beds of flint. This coast is found to be wasted, at an average, at the rate of one foot *per annum*. We may thus perhaps form some idea of the time since the coast of France and that of England had been here united, or one continued mass of those strata which are the same on both those coasts.

tender clay; yet the soft coast stands protuberant to the sea, the harder coast is hollowed out into a bay; the one has no protection but the sands with which it is surrounded, the other had not remained till this day but for the protection of the most solid rocks of Pembrokeshire and Carnarvonshire, which oppose the fury of the waves.

The last general observation which I shall propose, has, for its subject, a more enlarged view than those now taken of the coast, a view indeed which is not so immediately the object of our observation, but which is nevertheless to be made most evident, by means of the others now considered. We have seen that the land exposed to the sea is destroyed, and the coast wasted more or less, in proportion to the wearing causes, and to the different resisting powers opposed to those causes of decay; we are now to make our observations with regard to the extent and quality of that which has been already destroyed, a subject which can only be conjectured at from the scientific view which may be taken of things, and from the careful examination of that which has been left behind upon the different coasts.

Our land is wasted by the sea; and there is also a natural progress to be observed which necessarily takes place on this occasion; for, the coast is found variously indented, that is to say, more or less, according as the land is exposed to this wasting and wearing operation of the sea, and according as the wasted land is composed of parts resisting with different degrees of power the destroying cause. The land, thus being worn and wasted away, forms here and there peninsulas, which are the more durable portions of that which had been destroyed around; and these remaining portions are still connected with the main land, of which they at present form a part.

But those promontories and peninsulas are gradually detached from the main land, in thus forming islands, which are but little removed from the land. An example of this we have in Anglesay, which is but one degree removed from the state of being a promontory. These islands again, in being subdivided, are converted into barren rocks, which point out to us the course in which the lost or wasted land upon the coast had formerly existed.

To be satisfied of this, let us but look upon the western coast of Scotland; from the islands of St. Kilda to Galloway, on the one side, and to Shetland on the other; in this tract, we have every testimony, for the truth of the doctrine, that is consistent with the nature of the subject. The progress of things is too slow to admit of any evidence drawn immediately from observation; but every other proof is at hand; every appearance corresponds with the theory; and of every step in the progress, from a continent of high land to the point of a rock sunk below the surface of the sea, abundant examples may be found. We do not see the beginning and ending of any one island or piece of country, because the operation is only accomplished in the course of time, and the experience of man is only in the present moment. But man has science and reason, in order to understand what has already been from what appears; and we have but to open our eyes to see all the stages of the operation although not in one individual object. Now, where the nature of things will not admit of having all and every step of the progress to be perceived in one object, an indefinite progression in the various states of different objects, showing the series or gradation from a continent to a rock, must form a proof in which no deficiency will be found.

I have given for example the coast of Scotland; but all over the world where there is a coast not covered with sand, or where it is exposed to the violence of the sea, it is the same. Take the map of any country, provided it be sufficiently particular, and you will see the breaking of continents or islands, first, into promontories or peninsulas; secondly, into islands which stand on the same solid basis with the continent; and, lastly, into rocks which are related to the islands, in like manner as those parasitical islands are related to the head lands and the shore. Here is a general fact, from the simple inspection of which we must conclude one of two things; either that those rocks and smaller islands, which we have termed parasitical, are in a state of progression, by which in time they will be joined to the main land, and form one continent; or that they are in a state of degradation, by which in time they will be made to disappear. There is no other supposition to be made; and, of that alternative, there is no room to hesitate a moment which to choose. This is not a matter of mere probability, it is the subject of physical demonstration. Should we find an old manuscript in a similar condition, we could not conclude with more certainty, that the deficient or intervening places had been destroyed, than we here conclude that the part which is now wanting, between the two remaining portions of the same rock or strata, had once connected those two portions, and had been destroyed by the operation of those causes which are every day employed in still increasing the breach.

Though over all the world, where the shore is washed bare by the sea, examples are to be found which require but to be seen to give compleat conviction, it is not in every place that the eye of a naturalist has been employed in taking this view of the coast; nor is it upon every occasion that enlightened philosophers of this kind have given their thoughts upon the subject. M. de Spallanzani has given us the following observations with regard to the coast of Italy[62].

«Autant l'intérieur du petit bourg de Porto-venere et les rochers qui l'environnent sont a l'abri des tempêtes, autant les parties extérieures sont exposées aux coups de mer les plus violens, lorsqu'elles sont en proie au deux terribles vents d'Afrique et à celui du sud-est. Ce dernier en particulier soulève les flots avec tant de violence et à une telle hauteur contre les écueils qui servent de défense à ce petit terrain, que la mer semble menacer de l'engloutir. J'ai été le témoin d'un de ces orages, et quoique je fusse à l'abri de tout danger, je ne pourroit vous representer l'horreur que me fit éprouver ce spectacle. J'ai voulu prendre avec exactitude la hauteur moyenne de l'élevation des flots dans les plus violens coups de vent; et quand je vous en parlerai vous serez étonné de leur force et de l'étendue de leurs effets. Les rochers qui sont à la partie méridionale de Porto-venere se rongent et se détruisent peu-à-peu de même que les trois isles voisines *Tiro*, le *petit Tiro*, et *Palmarin*. On le remarque surtout dans cette dernier: les bords voisins de la terre ont une pente douce; ils sont couverts d'arbres et de plantes, tandis que la partie opposée est déserte et inaccessible couverte de précipices, de ruines et d'horreurs; les autres parties du rivage sont renfermées par la rivière du ponent et par celle du levant, de même que celles qui s'approchent des côtes de Provence. Il me paroît que la mer a beaucoup gagné sur le terre dans ces parages; et pour parler seulement de

[62] Observations sur la Physique, etc. Juillet 1786.

Palmarin, la plus grande, et la plus remarquable des trois îsles que j'ai nommées, je crois être suffisamment fondé pour conclure que la même pente facile et longue qu'on observe du côte de la terre avoit aussi existé du côte de la mer; mais que cette dernière avoit été détruite par les orages, qui se sont succédés pendant le cours de siècles. La vue réfléchie de ces trois îsles me force à les regarder comme ayant été autre fois réunies, et formant une îsle seule par leur réunion, ou plutôt comme une presqu'île attenante à Porto-Venere.»

We have a still more interesting observation made upon this same coast of Italy, by a naturalist to whom the world is much indebted for his excellent remarks upon what he has, by his great industry, brought to light. I mean the Chevalier de Dolomieu; where-ever he goes, natural history reaps the benefit of the most enlightened observations. We are now to avail ourselves of his Mémoire sur les Iles Ponces.

The pumice islands form part of a chain of land that may be traced forming a circular line from the cape Missene to the mount Circello at the other side of the Gulf of Gaeta. The islands of Ischia and Procida, which form part of this chain of land, might, from the inspection of the map, be allowed as having once formed a continuation of the land from the continent of Italy, even without the testimony of natural history, that traces this connection from the materials of those masses which now are separated.

The pumice islands form the middle part of that chain, and are the farthest removed from that continent of which it is probable they once formed a part. They are connected with the promontory of Missene on the one hand, as being of the same or similar volcanic origin, and on the other with mount Circello, by a curious circumstance in the island Zanone, which, but a little more of the devouring operation of the sea, would have concealed from our observation.

The island of Ventotiene, which is the nearest of them to Ischia, would appear to be the ancient island of Pendataria, in which Julia was confined. The marks of degradation in this island, I would wish to give in the Chevalier's own words, (p. 52.)

«Cette îsle continue à être devorée par la mer, elle l'attaque dans toutes les parties de son contour, où elle trouve peu de resistance, et elle ne cesse de creuser, principalement, tous les escarpemens du nord. Il paroît, par les vestiges des antiquités qui sont sur la pointe dite *di Nevola*, que sous l'Empire de César cette îsle avoit encore une étendue plus considérable. Il s'y fait journellement des éboulemens; on peut prévoir qu'elle diminuera progressivement, qu'elle se divisera, et que dans les temps à venir elle sera réduite aux rochers de laves qui la supportent, et qui seuls peuvent résister, pendant une longue suite de siècles, à tous les efforts des flots; ce ne sera sûrement pas la seule terre que le temps et la mer auront dévorée, et que les vicissitudes de la nature ont fait disparoître avant que l'histoire en ait pu constater l'existence.»

As the island of Ventotiene connects this group of the pumice islands with the continent of Missene, that of Zanone, on the other side, connects them with the continent at mount Circello. Here is a fact of which our author now gives proper evidence.

It would appear that Mount Circello is composed of an alpine limestone. But in the north end of the island of Zanone, the Chevalier de Dolomieu finds a small part of a similar limestone in vertical strata, closely united with the volcanic materials of the islands now under consideration. It is impossible that this portion of calcareous rock could be formed in its present situation, and we have but to examine nature in order to be convinced that this limestone part had been once continued from Mount Circello. Here again I beg leave to give this author's own words, (page 141.)

«Cette réunion de deux matières aussi différentes par leur origine que le font celles qui forment l'Isle Zanone, est une circonstance des plus singuliers. La pierre calcaire ne contient point de coquillages; sa densité sa dureté; son odeur fétide annonce une origine ancienne; elle n'est point formée par un dépôt de nouvelle date; elle diffère des pierres calcaires-coquillière qui recouvrent les volcans du Padouan et du Vicentin, et de celles qui se sont mêlés avec les produits du feu dans les volcans éteintes de la Sicile: les laves ici reposent sur elle: elle paroît donc antérieure à l'époque des irruptions qui ont élevé les îsles ponces. Par sa nature elle est semblable aux pierres du Mont Circé, et à celles de l'intérieure de l'Apennin; il semble que cette portion de montagne calcaire, abstraction faite des matières volcaniques qui lui sont réunies, a appartenu à quelqu'unes des montagnes qui dépendent de la chaine qui traverse l'Italie; car il n'est pas possible que ni elle ni le Mont Circé ayent été formés seules et isolés ainsi que nous les voyons. Mais quand ont-ils été détachées? étoient-ils déjà isolés lorsque les feux ont commencé la formation des îsles ponces? ou seroit-ce la même révolution qui les auroit séparés du continent, et qui a opéré le désordre que nous voyons dans ces îsles volcanique? On ne peut former sur toutes ces questions que des conjectures bien vagues.»

Our present inquiry is only with regard to the operation of those causes which we now perceive to be acting upon the coasts of the land; which must be considered as having been operating for a long time back, and which must be considered as continuing to operate. One example more I wish to give, not only as it is much to the purpose, and properly described, but because it contains the natural history of a coast well known from the circumstance of the Giant's Causeway which it contains; a coast composed of stratified chalk indurated and consolidated to a species of marble or lime-stone, and of great masses of basaltes or columnar whin-stone. Now, though our present object is not the formation of land, yet, knowing the mineral constitution of this land, the coast of which we are considering as having been worn by the action of the sea, the view here to be given, of the white marble and basaltic cliffs, is satisfactory in the highest degree. It is from Letters concerning the Northern Coast of the County of Antrim, by the Reverend William Hamilton, A. M.

«The chalky cliffs of the island of Raghery, crowned by a venerable covering of brown rock, form a very beautiful and picturesque appearance as one sails towards them; and, if the turbulence of the sea does not restrain the eyes and fancy from expatiating around, such a striking similitude appears between this and the opposite coast, as readily suggests an idea that the island might once have formed a part of the adjoining country, from whence it has been disunited by some violent shock of nature.

«You, to whom demonstration is familiar, will wonder to see two shores, seven or eight miles asunder, so expeditiously connected by such a slender and fanciful middle term as apparent similitude; and yet the likeness is so strong, and attended with such peculiar circumstances, that I do not entirely despair of prevailing even on you to acknowledge my opinion as a probable one.

«It does not appear unreasonable to conclude, that, if two pieces of land, separated from each other by a chasm, be composed of the same kind of materials, similarly arranged, at equal elevations, these different lands might have been originally connected, and the chasm be only accidental. For, let us conceive the materials to be deposited by any of the elements of fire, air, earth, or water, or by any cause whatever, and it is not likely that this cause (otherwise general) should in all its operations regularly stop short at the chasm.

«The materials of which the island of Raghery is composed are accurately the same as those of the opposite shore; and the arrangement answers so closely, as almost to demonstrate, at first view, their former union. But to explain this more clearly, it will be necessary to give you a general sketch of this whole line of coast.

«The northern coast of Antrim seems to have been originally a compact body of lime-stone rock, considerably higher than the present level of the sea; over which, at some later period, extensive bodies of vitrifiable stone have been superinduced in a state of softness. The original calcareous stratum appears to be much deranged and interrupted by those incumbent masses. In some places it is depressed greatly below its ancient level; shortly after it is borne down to the water's edge, and can be traced under its surface. By and by it dips entirely, and seems irretrievably lost under the superior mass. In a short space, however, it begins to emerge, and, after a similar variation, recovers its original height.

«In this manner, and with such repeated vicissitudes of elevation and depression, it pursues a course of forty miles along the coast from Lough Foyle to Lough Larne.

«It naturally becomes an object of curiosity to inquire what the substance is from which the lime-stone seems thus to have shrunk, burying itself (as it were in terror) under the covering of the ocean: And, on examination, it appears to be the columnar basaltes, under which the lime-stone stratum is never found; nor indeed does it ever approach near to it without evident signs of derangement.

«Thus, for example, the chalky cliffs may be discovered a little eastward from Portrush; after a short course, they are suddenly depressed to the water's edge, under Dunluce Castle, and, soon after, lost entirely in passing near the basalt-hill of Dunluce, whose craigs, near the sea, are all columnar. At the river Bush the lime-stone recovers, and skims a moment above the level of the sea, but immediately vanishes in approaching towards the great basalt promontory of Bengore, under which it is completely lost for the space of more than three miles.

«Eastward from thence, beyond Dunsaverock Castle, it again emerges, and, rising to a considerable height, forms a beautiful barrier to White Park Bay and the Ballintoy shore. After this it suffers a temporary depression near the basalt hill of Knocksoghy, and then ranges along the coast as far as Ballycastle Bay.

«Fairhead, standing with magnificence on its massy columns of basaltes, again exterminates it; and once again it rises to the eastward, and pursues its devious course, forming, on the Glenarm shores, a line of coast the most fantastically beautiful that can be imagined.

«If this, tedious expedition have not entirely worn out your patience, let us now take a view of the coast of Ragery itself, from the lofty summit of Fairhead, which overlook it. Westward we see its white cliff rising abruptly from the ocean, corresponding accurately in materials and elevation with those of the opposite shore, and like them, crowned with a venerable load of the same vitrifiable rock. Eastward, we behold it dip to the level of the sea, and soon give place to many beautiful arrangements of basalt pillars which form the eastern end of the island, and lie opposite to the basaltes of Fairhead, affording in every part a reasonable presumption that the two coasts were formerly connected, and that each was created and deranged by the same causes extensively operating over both.

«But it is not in these larger features alone that the similitude may be traced; the more minute and accidental circumstances serve equally well to ascertain it.

«Thus, an heterogeneous mass of freestone, coals, iron-ore, etc. which forms the east side of Ballycastle Bay, and appears quite different from the common fossils of the country, may be traced also directly opposite, running under Rathlin, with circumstances which almost demonstrably ascertain it to be the same vein.

«What I would infer from hence is, that this whole coast has undergone considerable changes; that those abrupt promontories, which now run wildly into the ocean, in proud defiance of its boisterous waves, have been rendered broken and irregular by some violent convulsion of nature; and that the island of Ragery, standing as it were in the midst between this and the Scottish coast, may be the surviving fragment of a large tract of country which, at some period of time, has been buried in the deep.»

Besides this argument of the gradation from a continent of land to a bare rock, we have another from the consideration of those rocks themselves, so far as these could not be formed by nature in their present state, but must have been portions of a greater mass. How, for example, could a perpendicular mountain, such as St. Kilda, have been produced in the ocean? Of whatever materials we shall suppose it formed, we never shall find means for the production of such a mass in its present insulated state. Let us take examples of this kind near our coast, and of known rocks. Staffa and Ailsa, on the west coast, and the Bass, upon the east, are mountains of either whin-stone or granite, similar to many such mountains within the land; and they are perpendicular around, except perhaps on one part. It is demonstrable that such basaltic rock as contains zeolite and calcareous spar, as most of our whin-stones do, could not have been the eruption of a volcano, consequently those rocks must have been masses protruded in a fluid state, under an immense cover of earth at the time of their production; and they could not have risen immediately out of the sea, with all their various minerals, their veins and cutters, their faces and their angles.

In like manner, the east coast of Caithness is a perpendicular cliff of sand-stone, lying in a horizontal position, and thus forming a flat country above the shore. But along this coast there are small islands, pillars, and peninsulas, of the same strata, corresponding perfectly with that which forms the greater mass. Now, shall we suppose those strata of sand-stone to have been formed in their place, and to have reached no farther eastward into the sea?—It is unsupposable. Or, shall we conceive that the sea, which has made such depredations in land composed of much more solid materials, had spared this, and had not wasted much more than that now pointed out by the ruins which remain?—Impossible; we must suppose that there had once existed much land where nothing now is found but sea. But, if we are to suppose much to have been wasted, where shall we stop in this process of restoring continents? That is the question now to be discussed.

With this view, let us now turn our attention to the north-west coast of Europe, in consulting the general as well as the most particular maps. Upon the one extremity of Britain, we find Cornwall separating it as it were from the main land; and, from this promontory, the Scilly Isles pointing out what had been destroyed in that direction, which is here to be considered as the line of greatest resistance. But what a quantity of the soft materials, or less resisting parts on either side, has been destroyed! Upon the other extremity of Britain, we find the country of Scotland, forming itself into promontories and islands, and those islands and rocks pointing out to us what had been the former extent of our continent and land around. But, in following this connection of things, we cannot refuse to acknowledge that Ireland had formerly been in one mass of land with Britain, in like manner as the Orkneys had been with Scotland[63].

It will be still less possible to refuse the junction of England with the continent of France; the testimony of that peculiar body of chalk and flint, which borders each of those opposite coasts, forms an argument which is irrefragable. Now, in order to complete our continent, we have only to connect the Shetland islands with the coast of Norway. But this is a notion which, however probable it may appear, is not proposed as a fact immediately supported by natural appearances; it is only to be considered as an enlarged view in which we may contemplate the operations of this earth upon a more extended scale; one which may be conceived as a step in our cosmogeny, and one which, while it illustrates the theory of the earth

[63] I have the most satisfactory evidence of this fact, in finding the schistus of Galloway and of England in the opposite coast of Ireland, corresponding to its direction in stretching from the coasts of Britain.

already given, is by no means required in order to confirm a theory founded upon appearances which leave no manner of doubt.

Chapter 9. The Theory Illustrated, With A View Of The Summits Of The Alps

There are two different directions in which we may observe the destruction of our land to proceed; in the one of these, the basis of our continent is diminished by the incroachment of the sea; in the other, again, it is the height of the land above the level of the sea that is lowered. We have been considering the incroachment of the sea upon the continent; let us now examine how far there may also appear sufficient documents, by which we may be led to conclude a long progress in time past, for the destruction of the solid mass of earth above the sea, without diminishing its basis.

If we shall suppose this earth composed of horizontal strata, and of one level surface, without the least protuberance remaining by which we might be informed of what had been removed by time in the operation of second causes, we should be ignorant of every thing of cosmogeny but this, That the strata of the globe had been originally formed (by the sea) in the same shape as we had found them on the surface of the land. But this is not the shape of the surface of our continent: We have every where abundance of eminences, sufficient to give us great information with regard to what had passed in former periods of time, if the strata of the globe were in that regular shape which they had originally assumed in being deposited at the bottom the sea.

The strata, however, are not in that regular shape and position from whence we might learn, by examining the remaining portions, what had been carried away from the surface in general; they are found variously inclined to the horizon; and this we find both occasioned from the fracture and flexure of those bodies, thus changed from their natural horizontal state. Thus, though there are in many places immense masses of strata cut off abruptly, and exposed to view, without the remainder appearing, we cannot from hence form any estimate of the general quantity of destruction; at the same time, it must be evident, from a general inspection, that there has been an immense quantity removed; and that an immense time had been required in bringing about those revolutions of things, which are not done by violent changes, but by slow degrees.

Besides that general conclusion with regard to the destruction of the strata, there is also in many places a demonstration of that fact, from a measured minimum of the quantity which had been removed. It is to the mining business chiefly that we are indebted for that demonstration of which we now shall give an example.

The coal strata, about Newcastle upon Tyne, dip to the south-east at the rate of one in twelve, or thereabouts. This is but little removed from the horizontal position; at the same time, the strata come all up to the soil or surface in a country which is level, or with little risings. But in those strata there is a slip, or hitch, which runs from north-east to south-west, for 17 or 18 miles in a straight line; the surface on each side of this line is perfectly equal, and nothing distinguishable in the soil above; but, in sinking mines, the same strata are found at the distance of 70 fathoms from each other. Here therefore is a demonstration, that there had been worn away, and removed into the sea, 70 fathoms more from the country on the one side of this line, than from that on the other. It is far from having given us all the height of country which has been washed away, but it gives us a minimum of that quantity.

The examination of what is commonly called a secondary country is not sufficient to give us an idea of the immense operation of time in wearing the surface of this earth. It is not that those countries of inferior hardness and elevation have been spared in the course of time, but because we have not, in those levelled countries, such great remainders, by which we are to judge the quantity of what is lost. In the alpine country, again, though it be the same system of things with that which takes place in the lower country, the revolution of things is more marked for our view; and the ravages of time, in destroying the solid parts of the globe, in order to make soil of that which is removed, may be seen in all the steps of that important operation; whereas, in the more level countries, the scale of elevation is imperceptible, and that of time is so slow as renders our examination fruitless. It is the Alps, therefore, chiefly that we are to take for an example, in tracing this operation of nature upon the surface of this earth, and forming some idea of the course of time that must have flowed during that operation in which the height of our land had been diminished.

On whatever side we approach the Alps, we find some great river discharging the waters which had been gathered above, and with that water all the waste of earth and stone which had been made among those lofty masses of decaying rock. Now, we find this river running in a valley proportioned, in general, to this vehicle, in which is travelled the wreck of ruinous mountains. Spacious plains attend those mighty streams; and, tho' sometimes we find the greatest rivers much confined between approaching hills of solid rock, the valley opens again, and, on the whole, is always corresponding to the current of water which has successively run in all the quarters of this plain. Here a question occurs; Has this valley been made by the operation of the river itself, or has it been the effect of other causes? Let us now resolve that question.

If the valley was made for the river by any other natural cause, either we should tell by what means this work had been performed, or all reasoning upon the subject is at an end, and fancy substituted in its place. If again the river be considered as the means employed by nature in making this valley, then all the solid parts between the bounding mountains must have been removed, and the fertile plains must have been formed by the water depositing those materials which we find in the soil, and which had come originally from the solid mountains. There is no occasion to enter into any argument to prove this fact; nobody that examines the matter will find any reason to doubt; and it would be as unreasonable for those to doubt who have not examined, as for those who find no reasonable subject of doubt to disbelieve.

We are now to suppose the great river to have formed the valley and extensive plain in which the water runs,—a valley corresponding to the grandeur of the river by which it has been formed. But, as we ascend this great valley, we find other valleys branching from this main valley; and, in all those subordinate valleys, we find rivers corresponding in like manner with the magnitude of the valley. Here, therefore, is infinitely more than a single river, and a valley corresponding to the river; here is a *system* of rivers and of valleys, things calculated in perfect wisdom, or properly adapted to each other.

Now it is just as easy, by our theory, to explain this system of rivers and valleys, as it is to understand the single appearance of a river and a valley. But it is only in this manner that such a complicated operation, of a series in rivers and their valleys, is to be explained; and we can neither suppose the land to be formed with this intention by a supernatural cause, nor imagine any other natural cause so arranging things, upon the surface of the earth, as to form this perfect system, which holds of nothing but itself; a system in which is manifested wisdom, so far as all the parts are properly adapted to each other, and thus made to answer that intention which is so visible in the economy of this world.

The direction of the principal valleys of the Alps, or every mountainous region of the globe, may be considered as proceeding from the centre of that region to the plain country in which each river is to terminate; each secondary river with its valley then branches from the primary as from a stem, consequently runs in a direction perpendicular or inclined to the other. But the secondary rivers also have their branches; and subordinate branches still are branched. In thus tracing rivers and their branchings, we come at last to rivulets that only run in times of rain, and at other times are dry. It is here I would wish to carry my reader, in order to be convinced, with his proper observation, of this great fact,—that the rivers, in general, have hollowed out their valleys.

The changes of the valley of the main river are but slow, the plain indeed is wasted in one place, but it is repaired in another, and we do not perceive the place from whence that repairing matter had proceeded. Therefore, that which here appears does not immediately suggest to the spectator what had been the state of things before the valley had been hollowed out, or before that plain, through which the river runs so naturally as being in the lowest place, was made. But it is otherwise in the valley of the rivulet; no person can examine this subject without seeing that the rivulet carries away matter which cannot be repaired except by wearing away some part of the mountain, or the surface of that place upon which the rain, which forms the stream, is gathered. In those rivulets, or their little plains, we see the detached parts remaining in the soil, and also the place from whence those detached parts were taken. Here we need no long chain of reasoning from effect to cause; the whole operation is in a manner before our eyes. In this case, it requires but little study to replace the removed parts; and thus to see the work of nature, resolving the most hard and solid masses by the continued influences of the sun and atmosphere. In this state of things, we are easily made to understand how heavy bodies are travelled along the declivity of the earth, by means of water running from the height.

Such is the system of rivers and their valleys; nor is there upon the continent a spot on which some river has not run. But, in the Alps of Switzerland and Savoy, there is another system of valleys, above that of the rivers, and connected with it. These are valleys of moving ice, instead of water. This icy valley is also found branching from a greater to a lesser, until at last it ends upon the summit of a mountain, covered continually with snow. The motion of things in those icy valleys is commonly exceeding slow, the operation however of protruding bodies, as well as that of fracture and attrition, is extremely powerful.

To illustrate those operations of excavating the valleys of rivers and of thus undermining mountains which fall by their proper weight, I shall transcribe some descriptions of what is to be found among the Alps. But first I would wish to carry my reader to the summit of that country, to examine the state of that part which nothing can have affected but the immediate influences of the sun and air. After having thus formed some idea of the summit of this wasting country, we shall next examine the valleys through which the materials of the degraded summit must have travelled.

In order to give a proper idea of this central part of the Alps, which is so interesting a part in the natural history of the earth, M. de Saussure, in the plates of his *Voyages dans les Alpes*, tom. 2. has given us two views, the one in profile, the other in face, of the Mont-Blanc. I have caused copy those plates, which are necessary to be consulted in reading the following description of this centre of the Alps.

This author has taken much pains to form, to himself a proper idea of the object which we have now in view; and he gives a description of the Mont-

Blanc as seen from the top of the Cramont. It is that description which I am now to transcribe[64].

§ 910. «Le premier objet de mon étude fut le Mont Blanc. Il se présente ici de la maniere la plus brillante et la plus commode pour l'observateur. On l'embrasse d'un seul coup-d'oeil, depuis sa base jusqu'à sa cime, et il semble avoir écarté et rejeté sur ses épaules son manteau de neiges et de glaces pour laisser voir à découvert la structure de son corps. Taillé presqu'à pic dans une hauteur perpendiculaire de 1600 toises, les neiges et les glaces ne peuvent s'arrêter que dans un petit nombre d'échancrures, et il montre partout à nud le roc vif dont il est composé.

«Sa forme paroît être celle d'une pyramide, qui presente au sud-est du côté du Cramont une de ses faces. L'arrête droite de cette pyramide du côté du sud-ouest, monte au sommet, en faisant avec l'horison un angle de 23 à 24 degrés. L'arrête gauche du coté du nord-est, monte au même sommet sous un angle de 23 à 24 degrés, en sorte que l'angle au sommet est d'environ 130 degrés.

«Cette pyramide paroît elle même composée de grands feuillets triangulaires ou pyramidaux. Trois de ces grands feuillets ont leurs bases dans l'Allée-Blanche, et forment ensemble tout l'avant corps de la base de la pyramide. Chacun de ces feuillets, vu de l'Allée-Blanche, paroît une grande montagne, je les ai décrits dans le chapitre précédent sous le noms de Mont-Pétéret, Mont-Rouge, et Mont-Broglia, § 830, 831, 834. Mais du haut du Cramont, on voit plus nettement leur forme, et leur ensemble, on distingue, par exemple, qu'ils sont eux-mêmes composés de grandes feuilles pyramidales; on voit que les injures du temps ont détruit la pointe du Mont-Rouge, tandis que celles des deux autres pyramides sont demeurées entières.

«Ces trois feuillets ne s'élèvent pas jusqu'à la moitié de la hauteur du Mont-Blanc; d'autres feuillets plus petits, situés derrière et au-dessus d'eux, et placés sur deux lignes principales qui convergent au sommet, achèvent de couvrir la face de cette grande pyramide. Ces feuillets sont tous de forme pyramidale; les plus petits sont les plus aigus; j'en ai mesuré plusieurs, dont

[64] Voyage dans les Alpes, tom. 2.

l'angle au sommet n'étoit que de 70 degrés. Tous, absolument tous, ont leurs plans parallèles à l'Allée-Blanche, et par conséquent dirigés du nord-est au sud-ouest.

«§ 911. Quant à la matière dont est composée cette grande et haute montagne, toute sa cime et toute sa base, tant au centre que du côté du nord-est, sont indubitablement de granit; mais le côté sud-ouest de la base, ou le Mont-Broglia que nous avons vu de près, § 834, est d'une pierre moins dure, mélangée de schorl, de feldspath, de mica, de quartz gras et de pyrites.

«On voit très-bien du haut du Cramont que cette partie de la base n'est point du granit; sa couleur est d'un brun rougeâtre, elle ne se termine point par des arrêtes vives et nettes, n'est point composée de grandes tables planes. Ce font cependant des feuillets pyramidaux, mais petits et pressés les unes contre les autres; à mesure qu'ils s'approchent du sommet, et par cela même du coeur de la montagne, ils perdent leur couleur rouge, leurs angles deviennent plus vifs, leurs tables plus grandes et plus planes, et enfin prés de la cime, et à la cime même, ce sont de vrais granits parfaitement caractérisés. On peut donc conclure, que le corps entier du Mont-Blanc, et même ces bases avancées du côté de l'Italie, sont toutes de granit, excepté la base de l'arrête extérieure du côté du sud-ouest.

«§ 912. La montagne qui touche le Mont-Blanc du côté du nord-est, et qui, vue de Genève, forme en quelque maniere le premiere escalier en descendant de la cime, est aussi composée de tables de granit qui paroissent dirigées du nord-est au sud-ouest. Mais la sommité qui suit celle-ci en tirant toujours au nord-est, et qui forme le second escalier, paroît avoir quelques feuillets tournans autour de son corps pyramidal, comme les feuillets d'un artichaux, et comme j'ai dépeint l'aiguille du Midi, *tome* I. *pl.* 6. En tirant plus encore au nord-est, on reconnoît les Jorasses que nous avons vues du haut du Taléfre, § 637, elles paroissent d'ici, après le Mont-Blanc et ses escaliers, les sommités les plus élevées de toute cette chaîne, et elles semblent résulter de l'assemblage de plusieurs suites de feuillets pyramidaux convergents vers leur sommet. En général toutes les cimes élevées que l'on peut distinguer dans cette chaine, depuis le Mont-Blanc jusqu'au col Ferret, sont soutenues par des augives composées d'une ou de plusieurs suites de feuillets pyramidaux appuyés les uns contre les autres; les extérieures ont leurs bases dans le fond de la vallée, et les intérieures remontent par degrés jusqu'au haut des cimes. Les deux escaliers du Mont-Blanc sont les seules sommités qui n'aient pas des augives de ce genre.

«§ 913. Je demande á present quelle idée on peut se faire de l'origine de ces feuillets plans et de toutes ces pyramides grandes et petites qui résultent de leur assemblage, si on ne les considère pas comme les restes ou les noyaux les plus durs des couches qui out résisté aux ravages du temps, tandis que les parties intermédiaires, qui les lioient entr'elles, out été détruites par ces mêmes ravages.

«Mais jusqu'à quel point la crystallization a-t-elle contribué á déterminer ces formes pyramidales? doit-on considérer le Mont-Blanc ou telle autre de ces aiguilles, comme un énorme crystal? C'est une question de théorie que j'examinerai ailleurs. Quant à présent je me contenterai de conclure, que la face méridionale de la chaîne centrale des Alpes est, comme la face septentrionale de cette même chaîne, composée, pour la plus grande partie, de couches de granit à-peu-près verticales, et dirigées pour la plupart du nord-est au sud-ouest.»

This theoretical question of our author is so properly connected with the natural history which he has here given us, that it is not difficult to resolve it in the most satisfactory manner.

Here is an enormous mass of granite, the origin of which we are not now inquiring after, but the causes of its present form. The internal part of this granite subsists in a state of the most perfect solidity; the external again is evidently in a decaying state. This is a fact which we learn from the nature of feldspar, of which granite is in part composed; this crystallised substance is every where decomposed, where long exposed to the atmosphere. But it is not this gradual decay of the mass of granite perishing equably from its external surface, and resolved into some of its component parts, that we are here to consider; it is only mentioned to show that the mass of granite is subject to decay, when exposed to the influence of the atmosphere, like every other compound mineral body, and to lose that perfect solidity which we find in the centre of the mass.

We find the granite masses not only subject to decay from the external surface, by the decomposition of the feltspar, or the dissolution of its constituent parts, but also liable to be separated into blocks of different degrees of regularity, commonly rectangular or approaching to the rhombic shape. This is the consequence, either of larger veins and fissures, filled with matter which is still more dissolvable than is the substance of the granite, or else by imperceptible crevices or cutters, into which the atmospheric influences gradually insinuate, and form at last a visible separation.

In examining the tops of granite mountains, or where this rock is exposed to the weather, we may perceive those two species of decay proceeding together. The external surface of the stone, where there is a sufficient mixture of feltspar, is separating into grains which form a species of sand, being nothing but the particles of granite separating by means of the decaying sparry part. But a similar progress may be observed, from the external surface penetrating in lines the mass of solid rock, and dividing that mass into the rectangular blocks into which those exposed places are gradually resolved.

Now the tops of all those mountains are formed into an assemblage of pyramids, declining in height from the central pyramid; and all those pyramids are again in like manner subdivided into lesser pyramids. But the smallest of those pyramids are no other than the rectangular blocks into which those granite masses always separate by the influence of the atmosphere.

It will now be evident, that those mountains, thus resolving into separate blocks, must acquire this series of pyramidal constructions; for, in every particular mass of mountain, there must be a central part, from which the separated blocks cannot be removed, while those around, or towards the sides, are detached by the swelling water upon freezing, and separated from the more central masses which are thus the latest of being removed.

It is impossible to see this series of pyramidal relics, without at the same time perceiving that manner of formation, by the gradual resolution of the solid mass of granite, as it comes to be exposed in succession to the influences of the atmosphere, which M. de Saussure has termed *les ravage du temps*.

But if it be in this manner, that time wastes the solid masses of this globe; and if all the solid masses of the earth have acquired their solid state by the same means, *i.e.* by heat and fusion, as is maintained in the present theory, we should find similar pyramidal mountains formed of different materials. Now there can be nothing more different than masses of lime-stone and those of granite. But pyramidal mountains are equally formed of those two different materials. In plate V, under the letter B, may be seen the calcareous pyramids which are near the *col de la Seigne*, and which in plate VI. are represented under the letter G.

Here is a view of the summit of the Alps, from whence we may be allowed to draw the most important conclusions in favour of our theory.

This summit is of solid granite, a mass in which there is no stratification, such as is to be perceived in all the other masses of those alpine regions. With regard again to the extent of this mass of granite, its basis is about two leagues in breadth, by at least thrice that space in length; and now we are to consider in what shape this mass of granite presents itself to our view.

The summit of Mont Blanc, which may be considered as in the centre of this mass, is a pyramid; and this great central pyramid is surrounded by a number of other great pyramids of the same kind. The points of those pyramids are extremely lofty; and, having sides often vastly steep, if not perpendicular, those colossal pyramids rise from the icy valleys in such a shape as has given occasion to their being named *needles*. Thus we find the whole space of this granite mass consisting of a mixture of icy valleys, and pyramidal rocks on which hardly any thing rests.

Now, these lofty rocks or pointed mountains must have been either originally formed of that shape, or posteriorly hewn out by the hand of nature, gradually wasting mountains in the course of time, and operations of the surface. If it is by the first that we are to explain the present state of things, then observation is superfluous, and our reasoning is at an end; for, when even observation should not contradict the proposition, which it actually does, it would be useless, as it can afford no data from a former state, which is supposed to have been no other than it is at present; and reasoning cannot be admitted if we have no data. Therefore, if we are to reason upon the subject, we are obliged to admit, that nature must have hollowed out of the solid rock all those pyramidal mountains, and a system of inclined valleys carrying the ice from the summits.

Let us now reason from our principles, in order to see how far the present appearances of things would naturally result from those wasting causes acting upon a mass of granite, of a given basis and of sufficient height, during a space of time which is unlimited.

We are to suppose our mass of granite without any structure except that of the veins and cutters, formed by the contraction of the solid mass in cooling. Now, those separations will naturally give direction to the operation of the wasting causes, whether we consider these as chymical or mechanical. Hollow tracts would thus be formed in the solid mass; in those hollow ways would flow the water, carrying the detached portions of the rock; and those hard materials, by their attrition upon the solid mass, would more and more increase the channels in which they move. Thus there would be early formed a system of valleys in this rock, and among those valleys a number of central points, or summits over which no running water would carry hard materials to operate upon the solid rock over which it flows.

Here therefore, in the nature of things, is placed the rudiments of our needles, those colossal pyramids which acquire height gradually as the valleys widen, and whose *apices* may arrive at an angle of a certain degree of acuteness. But what a waste of rock to have formed all those needles which we find rising from the icy valleys round Mount Blanc!

Upon the supposition that this had been the origin of those pyramidal mountains, it must be evident, that there is a *ne plus ultra* of acuteness to which the *apex* of a pyramid would in time arrive; and that then the decaying summit would tumble by the lump alternately, and regain the acuteness of its point. Now, if this be the case, although we cannot see the process, which is too slow for human observation, we should actually find them in all the stages of this progress. But this is precisely the state in which the summits of those mountains are to be found. M. de Saussure gives a view of one of those pyramids, which will serve to illustrate this subject in the most perfect manner. It is from the Montanvert that this object is to be perceived. (Voyages dans les Alpes, vol. 2.).

These high peaks of solid rock demonstrate the manner in which those enormous masses of mountains are degraded, and also the means which are employed by nature for that purpose; but this scene, however well represented, is too far removed, in its appearance, from the ordinary mountains of this earth, to satisfy the doubts of every reader or to generalise a principle which must be universal in the system of this earth. We therefore have occasion for a mean, by which the extreme of those alpine summits shall be generalised or connected with our low inclined plains; and, on this occasion, I will give M. de Saussure's most excellent description of the Breven. Nothing can better suit our present purpose than the subject of this natural history; and I am persuaded that most readers will be better informed by the description of this naturalist, than they would be by their own observation.

«§. 639. J'ai déjà plusieurs fois nommé cette montagne, qui est située immédiatement au-dessus du Prieuré de Chamouni, du côté du nord-ouest: elle est liée par sa base avec les Aiguilles-rouges, dont j'ai aussi parlé dans le premier volume. Mais sa cime est nue, isolée, arrondie sur les derrières, et coupée à pic du côté de Chamouni. C'est à tous égards une des montagnes les plus intéressantes pour un naturaliste.

«J'y montai pour la premiere fois en 1760, et je ne crois pas qu'aucun naturaliste l'eût visitée avant moi; j'y retournai l'année suivante; j'y allai encore en 1767, et j'y montai enfin pour la dernière fois en 1781, afin de vérifier mes anciennes observations, et de me mettre en état d'en donner une description plus exacte.

«§ 640. On peut du Prieuré monter au sommet du Bréven et redescendre dans le même jour, mais c'est une course pénible, car il faut au moins cinq heures pour monter, et la pente est extrêmement rapide. On peut cependant faire à mulet le premier tiers de cette montée. Comme je voulus avoir le tems d'observer tout avec soin, j'y destinai deux jours, et j'allai coucher le premier jour dans un chalet, nommé *Plianpra*, qui, en partant du Prieuré, est aux deux tiers de la hauteur totale de la montagne.

«En montant à Plianpra, on fait près des trois quarts du chemin sur des débris tombés et roulés du haut de la tête du Bréven. La colline même sur laquelle est bâti le village du Prieuré n'est composée que des débris de cette montagne; ces débris ont débouché par une gorge que nous traversons en montant, et se versant ensuite à droite et à gauche, ils ont pris la forme d'un cône, dont le sommet est au milieu de cette gorge. Les collines de ce genre et de cette forme se rencontrent bien fréquemment dans les vallées bordées par de hautes montagnes.

«Ces débris, qui ne viennent pas seulement de la tête du Bréven, mais de ses flancs et de sa base, sont des roches feuilletées mélangées de quartz, de mica et de feldspath dans toutes les proportions imaginables. De ces différentes proportions naissent différens degrés de dureté, depuis le granit feuilleté le plus dur jusques à la roche micacée la plus tendre.

«§ 641. Les rochers au pied desquels on passe avant de gravir la montée rapide et herbée qui aboutit à Plianpra, sont composés d'une roche feuilletée assez dure, dont les couches bien parallèles aux veines intérieures de la pierre, suivent la direction de l'aiguille aimantée et sont très-inclinées à l'horison.

«Le chalet de Plianpra est situé au milieu d'une assez grande prairie en pente douce du côté de la vallée de Chamouni, et dominée du côté opposé par les rocs nus qui forment les sommités de la chaîne du Bréven. Du bord de cette prairie, on a une très-belle vue du Mont-Blanc, de la vallée de Chamouni et des glaciers qui y aboutissent. Ces mêmes objets se présentent avec bien plus d'éclat de la cime du Bréven; cependant la vue de Plianpra mériteroit bien que ceux qui n'auroient pas la force ou le courage d'aller jusques à la cime, montassent du moins jusque là pour s'en former une idée.

«Comme je ne voulois monter sur le Bréven que lendemain, j'employai le reste de la journée à observer les environs du chalet. J'examinai surtout avec soin des rochers situés à une demi-lieue au nord au-dessus du chalet, qui de loin paroissent colorés en rouge, comme plusieurs sommités de cette chaîne: c'est par cette raison qu'elle porte le nom*d'Aiguilles-rouges*.

«§ 642. Je trouvai que c'étoient encore des granits veinés, mélangés de quartz, de feldspath, de mica et de fer qui colore la pierre en se décomposant au-dehors: cette teinte pénètre même quelquefois assez avant dans l'intérieur. Ces rochers sont divisés par couches bien distinctes, à-peu-près verticales, et dans la direction de l'aiguille aimantée, comme celles que j'avois observées au-dessous du chalet. Ces couches sont coupées par des fentes à-peu-près perpendiculaires à leurs plans, et qui sont pour la plupart parallèles à l'horison, de maniere que ces rochers se trouvent ainsi divisés en grandes pieces de forme à-peu-près rhomboïdale. Les veines mêmes intérieures de la pierre sont aussi très-bien prononcées, et exactement parallèles à ses couches; observation générale et de la plus grande importance, parce qu'elle prouve que ces couches sont bien de vraies couches, et non point des fissures produites fortuitement par la retraite ou par un affaissement inégal des parties du rocher. Ces veines sont dessinées sur le fond blanc de la pierre des feuillets minces de mica noirâtre; elles sont tantôt planes, tantôt ondées, mais toujours régulières et parallèles entr'elles, excepté là où il se rencontre des noeuds; encore reprennent-elles leur direction après en avoir fait le tour. Comme le mica s'y trouve en petite quantité, la pierre est dure, et ne se brise qu'à grands coups de marteau. Lorsqu'on l'observe de près dans sa cassure, on voit que les petites lames ou écailles de mica sont constamment couchées dans le sens des veines de la pierre. Ces mêmes écailles n'ont presque aucune adhérence entr'elles, en sorte que les feuillets dont la pierre est composée, n'adhèrent entr'eux que par les points où il ne se trouve point de mica.

«§ 643. Je me demandois à moi-même, en observant cette pierre, s'il étoit possible qu'elle eût été formée dans cette situation verticale; si ces écailles incohérentes auroient pu venir s'attacher à ces murs verticaux, et si le mouvement des eaux, clairement indiqué par le tissu feuilleté de la pierre, n'auroit pas dû les détacher et les faire tomber à mesure qu'elles se formoient. Je me demandois encore, si les fentes qui coupent ces feuillets, perpendiculairement à leurs plans, ne dateroient point d'un tems ou ces couches auroient été horisontales, et n'auroient point été produites alors par le poids et l'affaissement inégal des parties de la pierre. Mais pour admettre cette supposition, il faudroit expliquer comment ces bancs, d'abord horisontaux, ont pu se redresser; pourquoi ce redressement a été si fréquent, si régulier, etc. etc. Je réserve pour un autre tems la discussion de ces grandes questions; mais je ne crois pas inutile de faire apercevoir la liaison qu'ont avec la théorie des observations si minutieuses en apparence.

«En faisant ces réflexions, je retournai au chalet de Plianpra où je passai la nuit sur de la paille que j'avois fait étendre auprès du feu, parce que la soirée étoit extrêmement fraîche.

«§ 645 On commence à monter par de jolis sentiers peu inclinés, pratiqués le long d'un grand rocher semblable à ceux que j'avois observés la veille. On a ensuite le choix de monter, ou par des pentes couvertes de rocailles un peu fatigantes, ou par des gazons extrêmement rapides. Ceux-ci paroissent d'abord plus agréables et moins pénibles; cependant ces gazons sont si serrés et si glissans, qu'ils en deviennent dangereux, au moins pour ceux qui n'ont pas l'habitude des montagnes. Ces rocailles sont débris de roches feuilletées, semblables à celles que l'on rencontre en montant du Prieuré à Plianpra.

«§ 646. B. Au bout d'une heure de marche, on arrive au pied d'un rocher assez escarpé, qu'il faut escalader pour parvenir à la cime de la montagne. C'est une roche micacée, mais qui contient cependant assez de quartz pour avoir de la consistance. Elle se sépare par feuillets si décidés, que sans employer d'autre instrument que mes mains, j'en détachai une dalle, qui avoit sept pieds de hauteur sur quatre de largeur, et à peine un pouce dans sa plus grande épaisseur.

«J'avois quelque desir de descendre de-là au pied des grandes tables verticales qui composent la tête du Bréven, pour les observer de près et comparer ainsi leur base avec leur cime; mais de cet endroit la chose est impossible, la pente est d'une telle rapidité qu'une pierre médiocrement grosse, que je mis en mouvement, roula avec beaucoup de vitesse, en entraîna d'autres, celles-ci d'autres, et elles formèrent enfin un torrent de pierres qui se précipita avec un fracas mille fois répété par les grands rochers du Bréven.

«Comme donc je ne pouvois pas descendre, je montai par le passage ordinaire, qui est une espèce de couloir ou de cheminée ouverte, adossée à un rocher presqu'à pic, de 40 ou 50 pieds de hauteur. Bien des curieux sont venus jusques au pied de ce passage sans oser le franchir; mais je vis en revenant qu'à un demi-quart de lieue plus au nord, on trouve un autre passage extrêmement commode, qui mène au même but, et qu'il faut par conséquent toujours préférer.

«Ce rocher une fois escaladé, on monte par une pente douce, sans danger et sans fatigue, jusqu'au sommet du Bréven.

«§ 646. C. En montant le long du bord, du côté de Chamouni, j'eus un plaisir inexprimable à contempler les magnifiques tables de granit dont est composée toute la tête de cette montagne. Car bien que les écailles du mica noirâtre dont cette roche est mélangée, soient parallèles entr'elles et lui donnent ainsi quelque ressemblance avec une roche feuilletée, cependant la quantité de quartz et de feldspath qui entrent dans sa composition, son extrême dureté, le peu de disposition qu'elle a à se fondre dans le sens de ses feuillets, la placent, sinon pour le nomenclateur, du moins pour le naturaliste, dans la classe des vrais granits [65]; et le parfait parallélisme de ces feuillets avec les faces des grandes tables, ou des grandes divisions du rocher, démontre que ces tables sont des couches, et non des parties séparées par des fissures accidentelles.»

«L'extrême régularité de ces tables achève de démontrer que ce sont de véritables couches. Leurs plans qui sont ici à découvert dans une hauteur perpendiculaire de plus de 500 pieds, sont parfaitement suivis, comme taillés au ciseau, dirigés tous comme l'aiguille aimantée, et verticaux, à quelques degrés près dont ils s'appuyent contre le corps de la montagne. On s'assure en montant que cette structure est celle de la montagne entière; on voit les profils d'une infinité de ces couches, on passe sur les

[65] «La dénomination de *granit veiné* que j'ai, à ce que je crois, employée le premier, a paru très-heureuse à quelques naturalistes, et a, au contraire, souverainement déplu à quelques autres. Un de ces derniers prétend que ce que je nomme granit veiné n'est qu'un amas de gravier graniteux, et par conséquent une espèce de grès grossier. Mais je voudrois que ceux qui de bonne foi pourroient croire que j'aie commis une erreur aussi grossière et aussi fréquemment répétée, observassent les granits du Bréven; et j'en enverrais volontiers à ceux d'entr'eux que le souhaiteroient. Lorsqu'ils verroient que les parties de quartz et de feldspath qui entrent dans leur composition, ont tous leurs angles vifs et tranchans, que ces parties sont intimement unies entre elles et empâtées les unes avec les autres, comme dans les granits en masse; que leur cohérence est aussi grande que dans ces derniers granits, et que cette roche n'en diffère absolument, comme je l'ai déjà dit, que par le parallélisme qu'observent entr'elles les lames rares de mica dont elle est mélangée: je suis persuadé qu'ils reconnoîtroient qu'elle a tous les caractères essentiels du ranit, qu'elle doit avoir la même origine, et qu'en un mot elle est au granit proprement dit, ce qu'une pierre calcaire feuilletée est à une pierre calcaire dans laquelle on ne distingue point de feuillets.»

sommités de ces tranches verticales, et on les voit se prolonger dans cette même direction tout au travers de la montagne. Or je demande si un naturaliste qui aura observé cet ensemble et ces détails pourra regarder cette montagne comme le produit du concours fortuit de grains de sable agglutinés entr'eux.

«Ces tables sont coupées un peu obliquement à leurs plans par des fentes dont la plupart sont à-peu-près horizontales et d'autres trés-inclinées à l'horizon. La pierre se trouve ainsi très-fréquemment coupée en parallélépipèdes obliquangles. Ces mêmes fentes rendent raison, d'une observation que j'avois faite en 1776. En examinant avec une bonne lunette, depuis une fenêtre du Prieuré, les faces verticales des couches de la sommité du Bréven, j'avois remarqué un grand dieze ♯ bien nettement écrit sur la face de la montagne, je le vis de prés en 1781, et je reconnus qu'il étoit formé par quatre de ces fentes qui se coupoient obliquement.

«§ 647. La cime de la montagne est une pointe mousse, coupée à pic du côté de la vallée de Chamouni et arrondie de tous les autres côtés. Cette tête est entièrement couverte de débris et de blocs confusément entassé. On est étonné de trouver là ces débris, car cette cime est absolument isolée, et séparée par de larges et profondes vallées des sommités qui la surpassent en hauteur: il semble que ces débris n'aient pu tomber que du ciel; mais quand on les examine avec soin, on voit qu'ils sont du même genre de pierre que la montagne elle même; et que tous leurs angles font vifs, leurs faces planes et leur forme souvent rhomboïdale. On reconnoît donc par là que les parties supérieures de la montagne, qui sont plus exposées aux injures de l'air et qui ne sont pas assujetties par des masses situées au-dessus d'elles, se délitent et se separent. Je trouvai cependant sur la cime une pierre d'une espece différente; c'étoit une roche composée de schorl noir en aiguilles, de quartz et de grenats; sa forme étoit exactement rhomboïdale. Mais ce genre de pierre se rencontre assez souvent en filons dans les roches feuilletées et dans les granits veinés; il est donc vraisemblable que le filon auquel ce fragment avoit appartenu s'est détruit avec la partie supérieure du rocher, du moins n'en ai-je pu trouver aucun indice dans la partie solide de la montagne.

«L'admirable régularité des couches de cette cime élevée mérite l'attention des amateurs de la géologie, et la vue qu'elle présente dédommageroit seule de la peine d'y monter.

«§ 648. Mon but principal dans la premiere course que je fis au Bréven étoit de prendre de là une idée juste des glaciers de la vallée de Chamouni, de leur forme, de leur position, et de l'ensemble des montagnes sur lesquelles ils sont situés. Comme cette montagne est postée à-peu-près au milieu de la vallée de Chamouni, en face du Mont-Blanc et vis-à-vis des principaux glaciers qui en descendent, c'étoit certainement un des meilleurs observatoires que l'on pût choisir dans cette intention. J'y montai par le jour le plus beau et le plus clair; c'étoit mon premier voyage dans les hautes Alpes, je n'étois point encore accoutumé à ces grands spectacles; en sorte que cette vue fit sur moi une impression qui ne s'effacera jamais de mon souvenir.

«On découvre tout-à-la-fois et presque dans un seul tableau les six glaciers qui vont se verser dans la vallée de Chamouni, les cimes inaccessibles entre lesquelles ils prennent leur naissance; le Mont-Blanc surtout, que l'on trouve d'autant plus grand, d'autant plus majestueux, qu'on l'observe d'un lieu plus élevé. On voit ces étendues immenses de neige et de glaces, dont, malgré leur distance, on a peine à soutenir l'éclat, ces beaux glaciers qui s'en détachent comme autant de fleuves solides qui vont entre de grandes forêts de sapins, descendre en replis tortueux, et se verser au fond de la vallée de Chamouni; les yeux fatigués de l'éclat de ces neiges et de ces glaces se reposent délicieusement ou sur ces forêts, dont le verd foncé contraste avec la blancheur des glaces qui les traversent, ou dans la fertile et riante vallée qu'arrosent les eaux qui découlent de ces glaciers.»

Our object at present is not to see the degradation of that great mass of granite out of which have been hewn, by the hand of time and influences of the atmosphere, these lofty pyramids which surround Mont-Blanc; it is to see the degradation of that immense mass of vertical or highly inclined strata, out of which that great mass of granite rises; and it is to understand the conical and rounded forms which are to be perceived more or less in all the inferior mountains, where apparently the degradation has come to a stand, and where the surface is actually employed in vegetation, or in maintaining the system of living bodies in this world.

How high those vertical strata may have been erected, or how much may have been wasted of that mass in forming the mountains and their valleys, is a question which it is impossible to resolve: It is evident, however, that this quantity must have been very great. In the Mont-Rosa we find those strata at present in the horizontal situation, as high as the summits of those granite pyramids that overlook the mass of vertical strata which we are now considering; and, in those mountains of Rosa, the valleys are most profound. It is therefore most reasonable to suppose, that the mass out of which the Breven and all the other mountains had been formed, was once as high, at least, as the summit of Mont-Blanc. It is altogether inconceivable, that this mass of vertical and horizontal strata could have been formed, either originally, or by any mineral operation, into the present shape of things; therefore, we must look out for another cause.

Let us now suppose them degraded by the hand of time, and all their moveable materials transported in the floods; In what state would they be left for our examination?—Here is a question that must decide the theory of those mountains; for, if it is not possible to conceive the present appearances as arising from any other cause than this gradual degradation which we see operating at present, we must conclude that this is the system of nature established for the purpose of this world. But this is the very state in which they are found; every where the solid parts are going into decay, and furnishing those heaps of earth and stones that form the slopes by which we ascend from step to step. Wherever earth and stones may lie, there they are found to form a bank for vegetation; whenever these loose materials are carried away to a lower; station, the more solid parts above are still decaying in order to furnish more. There is not one step in all this progress, (of the summit of the solid mountain forming earth and stones, and travelling to the sea) that is not to be actually perceived, although it is only *scientifically* that man, who reasons in the present moment, may see the effect of time which has no end.

The summit of the granite pyramids of Mont-Blanc, the summit of the Breven, that of the Saleve[66] , and of every little hillock upon the surface of the earth, attest this truth, that there is no other natural means by which this end may be attained. It is true, indeed, that geologists every where imagine to themselves great events, or powerful causes, by which these changes of the earth should be brought about in a short space of time; but they are under a double deception; *first* with regard to time which is limited, whereas they want to explain appearances by a cause acting in a limited time; *secondly*, with regard to operation, their supposition of a great *debacle* is altogether incompetent for the end required. How, for example, accumulate the *debris* of the Breven, as we have now seen, upon the summit of that mountain, by the force of running water? But this is only one of a thousand appearances that proves the operations of time, and refutes the hypothesis of violent causes.

From the top of those decaying pyramids to the sea, we have a chain of facts which clearly demonstrate this proposition, That the materials of the wasted mountains have travelled through the rivers; for, in every step of this progress, we may see the effect, and thus acknowledge the proper cause. We may often even be witness to the action; but it is only a small part of the whole progress that we may thus perceive, nevertheless it is equally satisfactory as if we saw the whole; for, throughout the whole of this long course, we may see some part of the mountain moving some part of the way. What more can we require? Nothing but time. It is not any part of the process that will be disputed; but, after allowing all the parts, the whole will be denied; and, For what?—only because we are not disposed to allow that quantity of time which the ablution of so much wasted mountain might require.

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[66] See Part II. chap. 30.

CHAPTER 10. THE THEORY ILLUSTRATED WITH A VIEW OF THEVALLEYS OF THE ALPS

Such is the summit of the Alps, a body wasting by the influence of the elements, slowly changing, but in actual decay. This mass of granite is arrived at such a perfect state of degradation as leaves no trace of its original shape or height, from whence we might compute the quantity which has been lost, or time which had flowed in bringing about that event. We are now to take a view of the valleys that are formed at the same time that the mountains are degraded.

To the valleys of ice succeed those formed by water upon the same principle by moving the hard materials procured from the summits. Let us now begin at the bottom of one of those fertile valleys, and ascend, tracing the marks of time and labour in those operations by which the surface of the earth is modified according to the system of the globe.

(M. Bourrit [67], *Nouvelle Description des Alpes.*) «Saint-Maurice est entre le Rhône et une montagne; «Quoique la situation de Saint-Maurice paroisse l'exposer au malheur d'être un jour ensevelie sous les ruines des montagnes, cependant on ne vit pas ici avec moins de sécurité qu'ailleurs: ce qu'il y a de plus à craindre, c'est la submersion du pays; ce malheur pourrait arriver si l'une ou l'autre des montagnes qui forment la gorge, venoit à tomber soit par un tremblement de terre, soit par des affaissemens considérables: cette gorge étant étroite, le Rhône ne pourroit plus s'écouler il s'étendroit nécessairement au large, bientôt toute la vallée jusqu'à Martigni, Sion même, rentreroit sous les eaux qui l'ont autrefois couvert, et tout ce pays ne formeroit plus qu'un lac, à moins que le Rhône ne se fît jour sous les rochers renversés, comme il passe au travers de ceux qui semblent lui disputer le passage à cinq-lieues au-dessous de Genève.»

«Avant de pénétrer dans le Vallais, il convient d'en donner une idée générale: il forme cette partie des Alpes connue sous le nom d'Alpes

[67] M. Bourrit, etc.

Pennines; il contient non-seulement les plus hautes montagnes des Alpes, mais encore la plus longue vallée qui il y ait en Europe, puis qu'elle a trente-quatre lieues depuis Saint-Maurice jusqu'à-la source du Rhône, qui la traverse dans toute cette étendue: sa largeur est depuis demi-lieu jusqu'à une lieue et demie; sa direction suit le soleil. Outre cette vallée, il y en a d'autres qui y viennent aboutir dans diverses directions: celle-ci sont enclavées dans les deux chaînes de montagnes qui bordent la grande vallée; quelques-unes remontent à quatre lieues et même à six, dans les sinuosités que forment les rochers qui bordent les deux côtés du fleuve.»

To give an idea of these valleys which proceed to the icy tops of mountains, or to the high valleys of ice, I shall transcribe some descriptions of this country from the Tableaux de la Suisse Discours, etc. page 21.

«*Route au Mont-Saint Bernard.*

«On passe par Martigny pour aller au Mont du grand Saint-Bernard; cette ville est un dépôt pour les marchandises qui vont et viennent d'Italie. Le château à côté de cette ville est situé sur des rochers calcaires qui bordent la Drance dans cette partie; ce torrent prend sa source au Mont Saint-Bernard. On compte huit lieues de Martigny à l'Hospice situé sur ce mont; à une demie-lieue on commence à monter insensiblement; le chemin est beau et peut se faire en voiture jusqu'au bourg Saint-Pierre.

«Le vaste base de ces monts accumulés n'est qu'un composé des débris des montagnes supérieures; on rencontre ici des granits roulés, composés de quartz, de feld-spath, et de mica; des graviers et des sables provenant de la décomposition des granits des pierre calcaire grise, puis de grosse masses de granit arrondies, dont il seroit difficile d'assigner l'origine, puisque toutes les montagnes à portée de la vue et qui forme cette gorge sont absolument de pierres micacées par lits et par couches, ou schisteuses mêlées de gros et petits rognons, de filons et de veines de quartz; elles font en général toutes feu avec le briquet. Le chemin et la Drance qu'on passe et repasse plusieurs fois, occupent tout le fond de la vallée qui devient fort étroite. On rencontre des pierres schisteuses, quartzeuses et sablonneuses, seules sans mélange d'autre espèces.

«Saint-Branchier, bon village, est situé entre des montagnes très-hautes et trés-escarpées composées des mêmes espèces des pierres schisteuses micacées que les précédentes; elles sont de couleur bleuâtre, vue en grandes masses et inclinées à l'horison; cette inclinaison suivant la même direction de ce côté ci de la Drance, et les couches se correspondant l'une à l'autre, on voit que ce torrent s'y est creusé un passage. En avançant, on trouve de l'ardoise feuilletée bleue avec des veines de spath calcaire, ensuite une grande quantité de granits et de pierres calcaires roulées, sans que les montagnes environnantes changent d'espèces; les montagnes à l'est sont bien cultivées, rapportent différentes sortes de grains, avant et après avoir passé orsiére; on retrouve de l'ardoise entre ce village et Liddes et les derniers granits roulés.

«La Drance est ici fort resserrée et trés encaissée; ce n'est pas sans frémir qu'on s'apperçoit, quand on est sur deux morceaux de bois jetés d'une roche à l'autre, appellés ici pont, qu'on a un gouffre de plus de trois cent pieds au dessous de soi, il faut être sur cette espèce de pont pour s'en apercevoir et distinguer les différents sinuosités tracées sur chaque côté de cette roche du haut jusqu'en bas; ce sont autant de preuves des différentes hauteurs où l'eau a passé avant de parvenir à sa profondeur actuelle.

«La dernier village qu'on rencontre, avant d'arriver au Saint-Bernard, est le bourg Saint-Pierre, on mont insensiblement jusqu'à ce village, et on ne peut plus se servir de voitures pour aller au-delà. Les montagnes sont plus rapides, il n'y a plus de chemin fait, et on n'en peut point pratiquer, moins a cause de la quantité des rochers dont toute cette partie est couverte que par la difficulté de les entretenir ou de les renouveler chaque année, parce que les torrens et les avalanches les detruiroient; de plus on ne pourroit y travailler que trois ou quatre mois de l'année, les huit ou neuf autres mois le pays, au dela du bourg, étant presque toujours couvert de neige. La truite ne remonte pas au-delà du bourge Saint-Pierre, elle se trouve arrêtée par les cascades et chutes trop considérables de la Vassorée qui va se jetter dans la Drance. Ce torrent sort encaissé et resserré dans le lit qu'il s'est creusé, provient d'un glacier qu'on rencontre en montant le Saint-Bernard qui porte le même nom. L'entrée du valais est fermée et défendue de ce coté par le lit de la Vassorée; c'est le fosse le plus profond et le plus escarpé qui existe.

Des ouvrage crénelés et une porte sont placés à l'entrée du bourg Saint-Pierre, nous avons donné un dessin de la chute de ce torrent, on voit le travail des eaux dans le rocher qu'il a miné et où il s'est ouvert un passage.

«On compte trois lieues de ce bourg à l'Hospice, sur le haut du Saint-Bernard; c'est le passage le plus fréquenté pour communiquer du Bas-Vallais en Italie par le Piémont et la vallée d'Aost; le transport des marchandises ne se fait qu'à dos de mulets et de chevaux; c'est du produit de ces transports que vivent la plupart des habitans qui sont des deux côtés de ce mont; celui des fromages, qui est la principale production de ces hautes Alpes, fait le plus fort article. On ne rencontre sur cette route que des rochers entassés les uns sur les autres, entre lesquels on passe par mille détours, en suivant les petits vallons qu'ils forment. Des torrents des eaux y roulent et s'y précipitent de tous côtés; on voit dans ces bas, de bois de sapins mêlés de quelques pins et puis des mélèzes; ils diminuent insensiblement, leurs végétation est moins vigoureuse, les arbres sont plus rares les derniers qu'on rencontre sont des mélèzes à une heure de Saint-Pierre. Plus loin, on ne voit plus que des buissons bas et rabougris; au bord de quelque ruisseau ou torrent ce sont des aulnes ou vergnes; le dernier arbrisseau que nous avons vu, entre les mélèzes et les aulnes, est un sureau sans fruit. Les pâturages, l'herbe et le gazon suivent la même progression. Ce n'est-que dans quelques endroits, d'où les eaux n'on pas entraîné une restant de terre végétale, qu'il se voit un gazon fin, menu et serré; de petites fleurs, aussi bases que ces gazons, nuancées des plus belles et des plus vives couleurs, y forment des groupes de la plus grande beauté; des mousses non moins curieuses que variées, couvrent et colorent quelques parties de rochers; le reste n'offre à l'oeil que d'énormes masses de rochers, entrecoupés de fentes, de crevasses; des pierres culbutées et amoncelées dans les fonds, qui font en partie couverts de neïge.

«A une demie lieue de l'Hospice dans une vallon assez large pour une pareille hauteur, nommé les Envers des Foireuse, on rencontre une énorme quantité de pierre roulées qui remplissent presque tout le haut de ce vallons. Cet amas de pierres provient des glaciers et des hauteurs qui descendent du Mont-Velan, qui est la partie la plus élevée du groupe de montagnes, qui forment le grand Saint Bernard. Là sont des neiges et des glaciers de cette partie, fournit aussi la Drance qui va se jetter dans le Rhône au dessous de Martigny. On ne voit de ces pierres roulées qu'en cet endroit, elles viennent directement des glaciers, elles ont été charriées par les eaux qui en viennent, et ne peuvent avoir pris leur forme que par les même causes, dont nous avons parlé ci-devant dans l'observation faite en Savoie sur les pierres roulées; elles sont toutes, ainsi que les rochers au-dessus, d'ou-elles proviennent, composées de parties micacées-argilleuses, plus ou moins mêlées de partie de rognons, de veines et de filons de quartz, par lits et par couches irrégulières, plus ou moins épaisses. Les parties micacées de ces pierres sont variées de différentes nuances, tirant sur le gris, le bleu, le verd, et le jaune; ces nuances sont quelquefois mêlées. Tous les rochers composans ce côté de montagne tourné au nord, sont de la même espèce. Nous n'y avons pas vu un seul granit, c'est-à-dire, une pierre composée de petites masses irrégulières de quartz, mêlées et agglutinées, avec des parties micacées argilleuses, et quelquefois mélangés de feldspath. Parmi ces pierres, il y en a quelques-unes provenant du même filon, qui contiennent de la pyrite cuivreuse dans un filon de quartz.

«Nous avons dit precedement que c'étoit entre Orfière et Liddes que nous avions vu des derniers granites roulés, on n'en rencontre plus dans toute le reste de la route jusqu'au haut du Mont Saint-Bernard. Les rochers, qui dominent ce sommet, ne sont pas composes de granites, et quoiqu'on ne puisse aborder jusqu'à leurs plus grands élévation, on peut juger de leurs espèces, par les masses qui s'en précipitent.

«(Page 35.) Malgré la chaleur qu'il avoit fait le jour de l'arrivée au Saint-Bernard, la nuit fut froide; le lendemain (31 Juillet) le haut de la montagne étoit enveloppé de nuages épais, mais tranquilles, il n'y avoit point d'agitation dans l'air on assuroit qu'il faisoit beau au-dessous de ce sommet; nous fûmes visiter le revers meridional de la montagne qui conduit au val d'Aost; après une demie heure de marche, nous fumes hors de cet atmosphère sombre et humide, le soleil étoit chaud, le ciel pur et serein: on voyoit dans le lointain les sommets des plus hautes montagnes enveloppés dans les nuages comme le Saint-Bernard: les sommets les plus à portée étoient découverts et éclairés par le soleil; ces rochers terminés en pointe, en pyramides et en aiguilles, sembloient s'élancer dans la région pure de l'éther: des vallons profonds, des écueils, et des précipices effrayants les entouraient. Toutes ces masses sont, comme dans la partie opposée de la montagne, des pierre schisteuses, argilleuses et micacées: le plupart schisteuses, c'est-à-dire par feuillets, par lits ou par couches différemment inclinées, le toute mêlé de veines et de parties quartzeuses, de couleurs variées, mais les verdâtres dominent: il y a de plus sur la hauteur de ce revers des masses et des blocs prodigieux, sans mélange, de quartz blanc et grenu à sa superficie, lesquels, au premier coup-d'oeil, paroissoient être de marbre de Carare; à quelque distance c'est un chaos immense de blocs de pierres de toutes grandeurs, jetés, culbutés, entassés dans la plus grand confusion; c'est la même espèce de pierre micacée; il faut que des sommets, des rochers prodigieux se soient écroulés pour avoir produit un pareil désordre qui ressemble à la destruction d'un mond.

«(Page 40.) On trouve aux environs du couvent quelques schistes argilleux ou ardoises grises feuilletées détruites à moitié. On ne voir nulle part de ces ardoises sur pied ou formant des masses attachées au sol; il faut que les couches ou les lits de ces ardoises, qui avoient été formés et placés sur ces hauts, ayent été détruits et renversés par le temps.

«Enfin toute cette montagne, une des plus hautes des Alpes Poenines, qui conserve des neiges et de glaces permanentes, est composée en général de pierres et de roches schisteuses, dont les couches et les lits sont plus on moins sensibles et inclinés, et d'une grande dureté. Leurs parties constituantes sont un mica argilleux dont les lames ou les parties sont plus ou moins grandes et brillantes et diversement colorées: elles sont traversées de filons et de veines mêlés de rognons et de globule de quartz ordinairement blanc, quelquefois vitreux, transparent, opaque ou grenu: nous n'y avons vu des granits que sur le penchant de la montagne; ils y étoient isolés et roulés. Quelqu'un qui aura plus de temps, plus de loisir, découvrira peut-être d'où ces masses proviennent[68].»

We have here a picture of one of those valleys which branch from, or join the main valley of the Rhône. In this subordinate valley, there is the most evident marks of the operations of water hollowing out its way, in flowing

[68] M. de Saussure, in his 2d volume of Voyages dans les Alpes, has shown the origin of these travelled granites, and traced the way by which they have come.

from the summits of the mountains, and carrying the fragments of rocks and stones along the shelving surface of the earth; thus wearing down that surface, and excavating the solid rock. On the summit of the mountain, again, there is an equal proof of the operation of water and the influences of the atmosphere continued during a long succession of ages. It is impossible perhaps to conjecture as to the quantity of rock which has been wasted and carried away by water from this alpine region; the summits testify that a great deal had been above them, as that which remains has every mark of being the relicts of what had been removed, and moved only by those operations which here are natural to the surface of the earth. Let us now abstract any consideration of that quantity above the summits of those mountains, as a quantity which cannot be estimated; and let us only consider all the cavity below the summits of those ridges of mountains to have been hollowed out by those operations of running water which we now have in view.

In taking this view of the mountains on each side which supply the water of the Rhône, what an immense quantity of stones, of sand, and fragments of rock, must have travelled in the bed of that river, or bottom of that valley which receives the torrents coming from the mountains! The excavation of this great valley, therefore, will not be found any way disproportionate to that which is more evident in the branches; and, though the experience of man goes for nothing in this progress of things, yet, having principles in matter of fact from whence he may reason back into the boundless mass of time already elapsed, it is impossible that he can be deceived in concluding that here is the general operation of nature wasting and wearing the surface of the earth for the purposes of this world, and giving the present shape of things, which we so much admire in the contrast of mountains and plains, of hills and valleys, although we may not calculate with accuracy, or ascribe to each particular operation every individual appearance.

With a view to corroborate what has been here alledged of the valley of the Rhône, I would beg leave to transcribe still more from the same author. From the immense masses of horizontal strata remaining upon both sides of the valley of the Rhône, with a face broken off abruptly, we shall find the most perfect evidence of that which had been carried away in the course of time, and in the forming of those valleys.

«(Page 49.) Route au Bains de Loiche. Nous quitterons un moment les bords du Rhône pour visiter les bains de Loiche, afin de ne pas revenir sur nos pas. De Sierre on passe par Claré et Salge, en laissant le Rhône sur la droite; tout ce terrain est calcaire et fort pierreux. A Faren (villages qui ne font point sur les cartes) on commence à monter la montagne de Faren; le chemin est fort rapide et mauvais, et dure une bonne heure et demie; on trouve sur le haut de cette montagne de blocs de granit composés de quartz, de feld-spath, et de mica, d'où viennent-ils? On ne voit que des roches calcaires et point de montagne plus élevée au-dessus; on passe par un bois de pins, on parvient enfin à un escarpement à pic, dont on n'a point d'idée pour la hauteur; on reste stupéfait de voir le gouffre qu'on a devant soi, et on ne prévoit pas trop comment on parviendra dans ce fond, où la vue a peine à distinguer la Dala, gros torrent qui y précipite ses eaux. On a taillé à grands frais un sentier tortueux dans cette roche toute calcaire; On a eu soin de garnir le coté scabreux du sentier avec des pierres ou des garde fou, pour rendre ce passage moins effrayant; ces précautions ne peuvent guérir de la crainte de voir tomber d'énormes quartiers de rochers suspendus au-dessus de soi, ils sont fendus et crevassés partout, et menacent de se précipiter à chaque instant; on ne peut même s'empêcher de remarquer qu'il y en a qui sont tombés nouvellement! Ce sont des mineurs Tiroliens qui ont fait cet ouvrage, ainsi que le passage du Mont-Gemmi.

«Quand on est descendu au tiers environ de cet énorme fond, on passe sur les décombres de cette vaste montagne, et par un bois de pins et de sapins; la vue ne perce pas dans ce fond ténébreux, on entend plutôt le bruit du torrent qu'on ne l'apperçoit. Ayant eu occasion de voir et d'examiner par la suite ces bas et le pied de cette étonnante montagne calcaire, nous avons vu dans plus d'un endroit qu'elle pose, et que ces fondements sont un lit de schistes argilleux ou d'ardoises feuilletées sans mélange, que ce lit est détruit et se détruit dans différens endroits, qu'il est incliné et affaissé dans d'autres, et que c'est la destruction qui a occasionné la chute d'une partie de cette montagne; elle est par-tout à pic de ce côté, et a subi successivement ces renversements qui paroissent plus anciens les unes que les autres, car ces débris sont plus ou moins couverts de bois, d'arbres, et de productions végétales.

«On continue la route à mi côte au travers de ces débris. Le sommet de ces montagnes éclairés par le soleil, étoit peint de rouge, de jaune, de blanc, de bleu, et de noir, dans les endroits où les eaux avoient coulé par-dessus, ils ressemblent de loin à des murailles, des tours, des forts, et des fortifications de différentes formes placées pour se défendre contre des ennemis qui viendroient par les airs. Les neiges qu'on apperçoit dans différents endroits, produisent des chutes d'eau, des cascades, dont partie se réduit en vapeurs avant d'atteindre le bas: le haut des montagnes qu'on voit de l'autre côté de ce vallon, est également calcaire, elles sont plus basses, couverts d'arbres et de sapins; au lieu que celles dont il est question sont nues et arides; elles sont le séjour des neiges et sont partie de la Gemmi.

«Une de plus haute montagnes du Vallais, et située sur une terrain très-élevé, est la Gemmi; elle fait partie de la grande chaîne qui sépare le Canton de Berne du Vallais. Elle est remarquable, à cause de l'importance du chemin qu'on y a pratiqué, des grandes difficultés qu'il a fallu surmonter, et qu'elle est la seule communication entre les deux Cantons. Nous parlerons de ce chemin, après avoir décrit la nature de ce prodigieux rocher. La Gemmi est la partie la plus haute de cette chaîne qui commence aux galleries; elle est en general calcaire. On commence a monter insensiblement en sortant de Loiche; on traverse beaucoup de pâturages; on voit quelques champs de seigle qui étoient encore sur pied et à moitié verts, des bosquets et de petits bois de sapins. Des masses considérables des rochers, des monceaux de pierres entassées descendues des hauteurs, couvrent cette superficie qui devient d'autant plus rapide qu'on approche plus du pied du rocher: cette pente qui est au pied de l'escarpement et de toutes les autres montagnes, est formé des pierres et des sables qui tombent des hauts et produisent, à la longue, des talus formes en pain de sucre, adosses contre les parties escarpées; les plus grosses pierres roulent et se précipitent plus bas, servent de point d'appui aux nouveaux matériaux qui s'y arrêtent, augmentent la hauteur des talus, en élargissant les basis, et finissent par devenir des montagnes très considérables qui ont augmenté en raison de la quantité des débris qu'ont pu fournir les parties plus élevées; c'est ce qu'on nomme montagnes de troisième formation, composées des ruines de celles qui dominent ces talus; ces éboulemens sont ordinairement plus fertiles, plus couverts de végétaux, d'arbres et de forêts, sur-tout s'ils sont composés de différentes espèces de débris. Nous avons déjà vu que les montagnes calcaires sont elles-mêmes assises sur des couches et des lits d'ardoise ou de schiste, qui, par l'arrangement de leurs feuillets et de leurs couches, paroissent aussi avoir été arrangés et formés successivement; quelle est donc la base primitive sur laquelle sont appuyées et reposent ces masses qui étonnent l'imagination, à quelle profondeur faudra-t-il l'aller chercher? Si nous concevons la formation et la manière dont se sont accrues et élevées ces troisièmes montagnes, pouvons-nous imaginer comment se sont arrangées celles qui sont si élevées au-dessus d'elles, ce tout que rien ne domine. C'est en examinant en considérant ces grands spectacles que ces réflections nous viennent; nous nous arrêtons, pour continuer à décrire ce que nous avons vu et remarqué, qui est la tâche que nous nous sommes imposée.

«En arrivant au pied de l'escarpement, le premier objet qui frappe la vue, ce sont des bancs de schistes ou d'ardoises bleuâtres, mêlés de larges filons de quartz qui forment la base, et les fondemens sur lesquels est élevé ce mur de pierres calcaires. Car cette roche est élevée de même à pic; ce lit d'ardoises est un peu incliné vers le couchant, ainsi que tout ce qui repose dessus; la destruction de ce lit a causé, ainsi qu'aux galeries, la chute des rochers supérieurs, et leur a occasionné cet à-plomb. Avant ces éboulements, ces couches schisteuses devoient être découvertes à une grande hauteur, être exposées aux injures du tems et des saisons, se détruire et se décomposer plus aisément. Peut-être que l'enveloppe calcaire les couvroient entièrement, et que ces schistes n'ont commencé à se détruire qu'après la ruine de la pierre calcaire. Actuellement ces schistes sont enterrés et couverts; ce n'est qu'en peu d'endroits qu'on les apperçoit; appuyés soutenus et couverts par ces immenses débris en talus, ce sont des contre forts qui les aiderons à supporter plus longtemps les prodigieuses masses sous lesquelles ces schistes sont ensevelis. Nous allons placer par ordre les différentes substances, telle qu'elle se présentent en montant.

«1. Base de schiste ou d'ardoise feuilletée bleuâtre, traversé, de larges filons de quartz. On ne voit, on ne peut estimer son épaisseur dont partie est enterrée.

«2. Immédiatement dessus pose la pierre calcaire, elle est d'une grain fin, serré, couleur grise-jaunâtre, ainsi que toute le reste.

«3. Des filons de différentes épaisseurs, d'un spath calcaire jaunâtre.

«4. Quelques petits filons ou renules de schiste pur.

«5. De la pierre calcaire d'un grain plus grossier.

«6. D'autres couches d'un grain plus fin.

«7. Couches de pierres calcaires mêlées d'une quantité suffisante de sable pour faire feu avec le briquet, sans cesser de faire effervescence avec les acides.

«8. De petits filons ou couches ondoyantes de spath.

«9. De la pierre calcaire dans laquelle sont déposés des espèces de noyaux oblongs, quelques fois par couches, mais sans suite, composés d'un sable fin de couleurs grisâtre, plus blanc que la pierre calcaire, très-durs, faisant feu au briquet, et sans effervescence avec les acides.

«10. On retrouve encore des couches minces sablonneuses mêlées de parties calcaires.

«11. D'autres de pierre calcaire compacte et d'une épaisseur considérable.

«12. Alternativement de moins compactes. Dans l'une de ces couches il y a de la pyrite vitriolique décomposé, qui teint en jaune les parties du rochers sur lesquels a flué la décomposition martiale.

«13. Quelques filons de spath jaunâtre, entremêlés de veines de schiste pur, ne faisant pas effervescence.

«14. De la pierre calcaire.

«15. Des schistes mêlés de parties calcaires.

«16. De la pierre calcaire pure.

«17. De larges filons de spath calcaire jaunâtre mêlés de quartz, faisant feu au briquet, et une peu d'effervescence.

«18. De la pierre calcaire pure grise, plus foncée que dans le bas.

«19. Des couches calcaires jaunâtres.

«20. Enfin tout le haut n'est que pierre calcaire grise et dénaturée. Cette partie supérieure du monte est fort étendue. Tout ce qui est sur le local qui va en pente assez douce vers le milieu, n'a pas été assujetti à de roulis et à des frottemens, il n'y a que la longueur du tems qui l'ait dégradé, et lui ait imprime le caractère de la vétusté. On ne voit que des pierres calcaires, elles sont remplies de trous, de fentes, et de crevasses; beaucoup, paroissent poreuses comme de la la pierre ponce grossière; le séjour des neiges des eaux, la gelée, et l'intempérie des saisons a tout fait. On voit de tous côtés que l'eau s'y infiltre et s'y perd. L'arrangement de cette espèce de pierre par couches, facilite l'entrée des eaux dans l'intérieur de la montagne pour aller donner naissance à des sources, à des torrents, et quelquefois à d'assez fortes rivieres qui sortent du pied de ces montagnes calcaires; lors de la fonte des neiges, l'eau ne se verse point des sommets de ces sortes de montagnes comme de dessus les autres espèces de rochers qui absorbent moins les eaux. Dans le milieu de ce haut il y a un petit lac d'un grand quart de lieue de long de forme ovale, ou se rassemblent les eaux des neiges fondues; il n'y a point d'issues à ce lac, ses eaux sont absorbées, et se perdent dans l'intérieur de la montagne; il n'y avoit que peu de glace alors sur ce lac, mais il y avoit encore beaucoup de neiges aux environs; un glacier est sur la droite, se prolonge et va fermer le sommet du vallon où est Loiche; c'est le même glacier qu'on apperçoit derrière les sources chaudes. Deux aiguilles de rocher en cône, fort hautes s'élèvent au-dessus du sommet; elles sont toujours couvertes de neiges: leur ressemblance et leur proximité a donné le nom de Gemmi Jumeaux, à cette montagne—On voit à ses pieds à une profondeur immense le village de Loiche, qui paroît être tout au pied du rocher; il faut cependant une grand heure et demie pour s'y rendre, tant la hauteur diminue le point de perspective. Le chemin qui est pratiqué dans ce rocher, y a été par-tout taillé; il le contourne certains endroits, dans d'autres il est creusé de façon qu'il forme une voûte couverte, et qu'on a le rocher suspendu au-dessus de soi. Il est rare de trouver l'occasion de pouvoir examiner de détailler avec autant de facilité une montagne d'une pareille hauteur. A compter des galleries jusqu'aux glaciers de la Gemmi, ces rochers perpendiculaires et à pic ont plus de trois lieues d'étendue; ils diminuent en hauteur à mesure que le pays s'élève, et se confond dans les plus hautes alpes, qui sont surmontées d'autre masses de rochers.

«De l'autre coté du vallon, et vis-à-vis des montagnes qui forment celles de la Gemmi, est la montagne du midi, séparée par la Dala, torrent qui vient du glacier à la tête du vallon, dont les eaux paroissent avoir creusé le lit étroit et profond. Cette montagne est calcaire comme la Gemmi, et paroît en avoir fait partie: je n'ai pu vérifier nulle part si elle étoit posée sur des schistes: tout est dans un grand bouleversement sur sa pente qui est fort rapide. A environs trois quarts de lieue des bains, un sentier fort difficile, qui passe sur les décombres de cette montagne et dans des bois de sapins fort obscurs, conduit par un pente fort rapide a un rocher perpendiculaire, comme sont presque tous ceux du canton on y trouve des échelles appuyées contre; on parvient à la première, en grimpant par les avances et les saillies du rocher; d'autres roches facilitent le moyen d'arriver à la seconde; on trouve ainsi sept échelles dont quelques-unes sont fort hautes, et par lesquelles on se guide au sommet de ce rocher; on est bien surpris d'y trouver un terrain en pente, où il y a des champs labourés et des vignes qui entourent le village d'Albinien, dont les habitans ont placé ces échelles pour raccourcir le chemin qui conduit à Loiche, où ils vont vendre leurs denrées.

«Nous quittons les bains de Loiche pour nous rapprocher du Rhône: on repasse par Inden, on ne trouve ensuite que des pierres, des rochers, des escarpemens; c'est un chemin des plus mauvais jusqu'au bourg de Loiche; c'est pour éviter ce chemin qu'on a fait celui des galleries. Le bourg de Leuck, ou Loiche, est un des principaux endroits du Vallais, bâti en pierres, dans une position fort élevée et très-forte; l'art avoit encore ajouté anciennement à la force de son assiette, il y a encore d'anciens forts et des tours; toute cette hauteur est calcaire; on a la plus belle vue de ce lieu, elle s'étend sur tout le bas Vallais jusqu'au dela de Martigny; nous avons donné une foible idée de cette vue, avant d'arriver aux bains de Loiche, car les expressions manquent pour rendre ces grands tableaux. Un spectacle bien intéressant pour ceux qui étudient les changemens qui arrivent journellement à la surface du globe, est la vue du Kolebesch, montagne fort élevée en face du bourg de Leuck, et de l'autre côté du Rhône; cette montagne est calcaire ainsi que la chaîne sur la rive gauche du Rhône, du moins la partie avancée qui forme le vallon où coule ce fleuve. Des chutes, des éboulemens y ont produit de grands changemens; les eaux et les torrens qui viennent des parties élevées, ont entraîné ces débris, les ont déposés aux pieds de la montagne, et en ont formé une colline qui a plus d'une demie-lieue jusqu'au Rhône, et plus d'une grande lieue de large, en forme circulaire; elle s'étend vers le haut et le bas Vallais; la partie supérieure est couverte de prés et des pâturages; celle du côté du bas Vallais est couverte d'une forêt; elle va en pente douce; la grosseur des arbres prouve combien la formation de ce terrain est ancienne. Depuis la consolidation de ce terrain des torrens nouveaux y ont creusé un ravin large et profond, par lequel s'écoulent actuellement les eaux des montagnes, et les pierres qu'elles en arrachent. Le Rhône mine et emporte le pied de cette colline qui resserroit son cours, avec ces matériaux il va plus loin former des atterrissemens composés des matières les plus pesantes; les parties les plus fines le limon suspendu dans ces eaux servent ensuite à couvrir les anciens atterrissemens, au moyen desquels ils deviennent susceptibles de toute espèce de végétation; ses eaux finissent de s'épurer dans le lac Leman, d'ou il sort clair et limpide, ainsi que toutes les rivieres qui sortent des lacs jusqu'à ce que d'autre torrens, tombant des montagnes, viennent les troubler de nouveau.»

Here is a most satisfactory view of the structure of this country on each side of the Rhône; strata of lime-stone and schisti, almost horizontal or little inclined, compose the mountains from their most lofty summits to the deepest bottom of those valleys. Such mountains cannot have been formed in any other manner than by the waste and degradation of their horizontal strata; consequently, here we are certain, that, from the summit of the Gemmi to those upon the other side of the Rhône, all the solid substance had been hollowed out by water. Thus were formed the valleys of the Rhône, the Dala, and a multitude of others.

M. de Saussure has given us a description of a tract of alpine country of the same kind with that of the *Vallais* now considered, so far as the strata are here in a horizontal position, instead of that highly inclined situation in which those primary bodies are commonly found. It is the description of Mount-Rosa Journal de Physique, Juillet 1790.

Here the same interesting observation may be made with regard to the immense destruction which must necessarily have taken place, in the elevated mass of solid earth, by the dissolving or wearing power of running water; and this will be clearly explained by the formation of those mountains and valleys, which, while they correspond with mountains and valleys in general, have something particular that distinguishes them from most of the Alps, where the strata, being much inclined, give occasion to form ranges of peaks disposed in lines according to the directions of the inclined strata. Here on the contrary, there being no general inclination of the strata to direct the formation of the peaks, they are found without any such order. I shall give it in M. de Saussure's own words.

«En effect toutes les hautes sommités que j'avois observées jusqu'à ce jour sont ou isolées comme l'Etna, ou rangées sur des lignes droites comme le Mont-Blanc et ses cimes collaterales. Mais là je voyois le Mont Rose composé d'une suite non-interrompue de pics gigantesques presqu'égaux entr'eux, former un vaste cirque et renfermer dans leur enceinte, le village de Macugnaga, ses hameaux, ses pâturages, les glaciers qui les bordent, et les pentes escarpées qui s'élèvent jusqu'aux cimes de ces majestueux colosses.

«Mais ce n'est pas seulement la singularité de cette forme qui rend cette montagne remarquable; c'est peut-être plus encore sa structure. J'ai constaté que le Mont-Blanc et tous les hauts sommets de sa chaîne sont composés de couches verticales. Au Mont-Rose jusqu'aux cimes les plus élevées, tout est horizontal ou incliné au plus de 30 degrés.

«Enfin il se distingue encore par la matière dont il est construit. Il n'est point de granits en masse, comme le Mont-Blanc et les hautes cîmes qui l'entourent; ce sont des granits veinés et des roches feuilletées de différens genre qui constituent la masse entière de cet assemblages de montagnes, depuis bases jusqu'à ses plus hautes cimes. Ce n'est pas que l'on n'y trouve du granit en masses, mais il y est purement accidentel, et sous la forme de rognons, de filons, ou de couches interposées entre celles des roches feuilletées.

«On ne dira donc plus que les granits veinés, le *gneiss* et les autres roches de ce genre, ne sont que les débris des granits rassemblés et agglutinés au pied des hautes montagnes, puisque voilà des roches de ce genre dont la hauteur égale à très-peu-près celle des cimes granitiques les plus hautes connues, et ou l'on ferois bien embarrassé à trouver la place des montagnes de granit dont les débris out pu leur servir de matériaux; sur-tout si l'on considère la masse énorme de l'ensemble des murs d'un cirque tel que celui du Mont-Rose. En effet, ce seroit une hypothèse inadmissible que de supposer, qu'anciennement il a existé dans le vuide actuel du cirque une montagne de granit, et que ce cirque est le produit des débris de cette montagne. Car comment ne resteroit-il aucun vestige de cette montagne? On conçoit bien que sa tête auroit pu se détruire, mais son corps, la base du moins, protégée par les débris de sa tête accumulés autour d'elle qu'est ce qui auroit pu l'anéantir; d'ailleurs les parois intérieures du cirque quoique très-escarpées ne sont pourtant pas verticale; elles s'avancent de tous côtés vers l'intérieur; et le fond, le milieu même du cirque n'est point du granit, il est de la même nature que ses bords. Enfin nous avons reconnu que les montagnes qui forment la couronne du Mont-Rose se prolongent au dehors à de grandes distances en sorte que leur ensemble forme une masse incomparablement plus grande que celle qui auroit rempli le vuide intérieur du cirque.

«Il faut donc reconnoître, comme tous les phénomènes le démontrent d'ailleurs, qu'il existe de montagnes de roches feuilletées, composées des mêmes élémens que le granit, et qui sont sorties comme lui des mains de la nature sans avoir commencé par êtres elles-mêmes des granits[69].»

Here is an example the most interesting that can be imagined. Those mountains are the highest in Europe, and their lofty peaks are altogether inaccessible upon one side. They had all been formed of the same horizontal strata. How then have they become separated peaks? And how have the

[69] M. de Saussure, upon the evidence before us, might have gone farther, and maintained that the masses of granite, which here traverse the strata in form of veins and irregular blocks, had been truly of a posterior formation. But this is a subject which we shall have afterwards to consider in a particular manner; and then this example must be recollected.

valleys been hollowed out of this immense mass of elevated country?—No otherwise than as we may perceive it, upon every mountain, and after every flood. It is not often indeed, that, in those alpine regions, any considerable tract of country is to be found, where an example so convincing is exhibited. It is more common for those mountains of primary strata or schistus to rise up in ridges, which, though divided into great pyramids, may still be perceived as connected in the direction of their erected strata. These last, although affording the most satisfactory view of that mineral operation by which land, formed and consolidated at the bottom of the sea, had been elevated and displaced, are not so proper to inform us of the amazing waste of those extremely consolidated bodies, as are those where the strata have preserved their original horizontal portion. It is in this last case, that there are data remaining for calculating the*minimum* of the waste that must have been made of those mountains, by the regular and long continued operations of the atmospheric elements upon the surface of this earth.

It is the singularity of these horizontal strata in that extensive alpine mass, which seems to have engaged M. de Saussure, who has inspected so much of those instructive countries, to make a tour around those mountains, and to give us a particular description of this interesting place. Now, from this description, it is evident, that there is an immense mass of primary or alpine strata nearly in the horizontal position, which is common to all the strata at their original formation; that this horizontal mass had been raised into the highest place of land upon this globe; and that, in this high situation, it has suffered the greatest degradation, in being wasted by the hand of time, or operations of the elements employed in forming soil for plants, and procuring fertility for the use of animals. Here is nothing but a truth that may almost every where be perceived; but here that important truth is to be perceived on so great a scale, as to enable us to enlarge our ideas with regard to the natural operations of this earth, and to overcome those prejudices which contracted views of nature, and magnified opinions of the experience of man may have begotten,—prejudices that are apt to make us shut our eyes against the cleared light of reason.

Abundant more examples of this kind, were it necessary, might be given, both from this very good observator, and from M. de Luc[70].

I will now only mention one from this last author, which we find in the Journal de Physique, Juin 1792.

«Entre Francfort et Hanau, le mein est bordé sur ses deux rives, de collines dans lesquelles la *lave* se trouve enchâssée entre des *couches calcaires*. Ces *couches* sont très-remarquables par leur contenue, qui est le même au-dessus et au-dessous de la *lave*, et qu'on retrouve dans les *couches* d'une grande étendue de pays, ou, comme d'ordinaire, on voit leurs sections abruptes dans les flancs de collines, mais sans *lave*, excepté dans le lieu indiqué.»

The particular structure of those lime-stone strata, with the body of basaltes or subterraneous lava which is interposed among them, shows evidently the former connection of those two banks of the river, by solid matter, the same as that which we see left there, and in the flanks of those hills. That which is wanting, therefore, of those stratified masses, in that great extent of country, marks out to us the minimum of what has been lost, in having been worn by the attrition of travelled materials.

I would now beg leave, for a moment, to transport my reader to the other side of the Atlantic, in order to perceive if the same system of rivers wearing mountains is to be found in that new world, as we have found it in the old.

Of all the mountains upon the earth, so far as we are informed by our maps, none seem to be so regularly disposed as are the ridges of the Virginian mountains. There is in that country a rectilinear continuity of mountains, and a parallelism among the ridges, no where else to be observed, at least not in such a great degree.

At neither end of those parallel ridges is there a direct conveyance for the waters to the sea. At the south end, the Allegany ridge runs across the other parallel ridges, and shuts up the passage of the water in that direction. On

[70] Vid. Discours sur l'Histoire Naturelle de la Suisse, passim; *but more particularly under the article of* Route *du Grindle* wald à meiringen *dans le pays de Hasti:* Also Hist: de la Terre, Lettre 30. p. 45, et Lettre 31. page 68, etc.

the north, again, the parallel ridges terminate in great irregularity. The water therefore, that is collected from the parallel valley, is gathered into two great rivers, which break through those ridges, no doubt at the most convenient places, forming two great gapes in the *blue ridge*, which is the most easterly of those parallel ridges.

Now, so far as mountains are in the original constitution of a country, the ridges of those mountains must have been a directing cause to the rivers. But so far as rivers, in their course from the higher to the lower country, move bodies with the force of their rolling waters, and wear away the solid strata of the earth, we must consider rivers as also forming mountains, at least as forming the valleys which are co-relative in what is termed *mountain*. Nothing is more evident than the operation of those two causes in this mountainous country of Virginia; the original ridges of mountains, or indurated and elevated land, have directed the courses of the rivers, and the running of those rivers have modified the mountains from whence their origin is taken. I have often admired, in the map, that wonderful regularity with which those mountains are laid down, and I have much wished for a sight of that gap, through which the rivers, gathered in the long valleys of those mountains, break through the ridge and find a passage to the sea. A description of this gap we have by Mr Jefferson, in his notes on Virginia.

«The passage of the Potomac, through the Blue Ridge, is perhaps one of the most stupendous scenes in nature. You stand on a very high point of land. On your right comes up the Shenandoah, having ranged, along the foot of the mountains, an hundred miles to seek a vent. On the left approaches the Potomac, in quest of a passage also. In the moment of their junction, they rush together against the mountain, rend it asunder, and pass off to the sea.

«The first glance of this scene hurries our senses into the opinion, that this earth had been erected in time; that the mountains were formed first; that the rivers began to flow afterwards; that in this place particularly they have been dammed up by the Blue Ridge of mountains, and have formed an ocean which filled the whole valley; that, continuing to rise, they have at length broken over this spot, and have torn the mountain down from its summit to its base. The piles of rock on each hand, but particularly on the

Shenandoah, the evident marks of this disrupture and avulsion from their beds, by the most powerful agents of nature, corroborate the impression. But the distant finishing which nature has given to the picture is of a different character. It is a true contrast to the foreground. It is as placid and delightful as that is wild and tremendous. For the mountain being cloven asunder, she presents to your eye, through the cleft, a small catch of smooth blue horizon at an infinite distance in the plain country, inviting you, as it were, from the riot and tumult roaring around, to pass through the breach, and partake of the calm below. Here the eye ultimately composes itself; and that way too the road happens actually to lead. You cross the Potomac above the junction, pass along its side through the base of the mountain for three miles, its terrible precipices hanging in fragments over you, and within about twenty miles reach of Frederick town, and the fine country around it. This scene is worth a voyage across the Atlantic. Yet here, as in the neighbourhood of the natural bridge, are people who have passed their lives within half a dozen of miles, and have never been to survey these monuments of a war between the rivers and mountains, which must have shaken the earth itself to its center.»

To this description of the passage of the Potomac may be added what Mr Jefferson, in the appendix, has given from his friend Mr Thomson, secretary of Congress.

«The reflections I was led into on viewing this passage of the Potomac through the Blue Ridge were, that this country must have suffered some violent convulsion, and that the face of it must have been changed from what it probably was some centuries ago; that broken and ragged faces of the mountain on each side of the river; the tremendous rocks which are left with one end fixed in the precipice, and the other jutting out, and seemingly ready to fall for want of support; the bed of the river for several miles below obstructed, and filled with the loose stones carried from this mound; in short, every thing on which you cast your eye evidently demonstrates a disrupture and breach in the mountain, and that before this happened, what is now a fruitful vale, was formerly a great lake, or collection of water, which possibly might have here formed a mighty cascade, or had its vent to the ocean by the Susquehanna, where the Blue Ridge seems to terminate.

Besides this, there are other parts of this country which bear evident traces of a like convulsion. From the best accounts I have been able to obtain, the place where the Delaware now flows through the Kittatinny mountain, which is a continuation of what is called the North Ridge, or mountain, was not its original course, but that it passed through what is now called the Wind-gap, a place several miles to the westward, and above an hundred feet higher than the present bed of the river. This Wind-gap is about a mile broad, and the stones in it such as seem to have been washed for ages by water running over them. Should this have been the case, there must have been a lake behind that mountain; and, by some uncommon swell in the waters, or by some convulsion of nature, the river must have opened its way through a different part of the mountain, and meeting there with less obstruction, carried away with it the opposing mounds of earth, and deluged the country below with the immense collection of waters to which this new passage gave vent. There are still remaining, and daily discovered, innumerable instances of such a deluge on both sides of the river, after it passed the hills above the falls of Trenton, and reached the champaign. On the New Jersey side, which is flatter than the Pennsylvania side, all the country below Croswick hills seems to have been overflowed to the distance of from ten to fifteen miles back from the river, and to have acquired a new soil, by the earth and clay brought down and mixed with the native sand. The spot on which Philadelphia stands evidently appears to be made ground. The different strata through which they pass in digging for water, the acorns, leaves, and sometimes branches which are found above twenty feet below the surface, all seem to demonstrate this.»

How little reason there is to ascribe to extraordinary convulsions the excavations which are made by water upon the surface of the earth, will appear most evidently from the examination of that natural bridge of which mention is made above, and which is situated in the same ridge of mountains, far to the south, upon a branch of James's River. Mr Jefferson gives the following account of it.

"The natural bridge, the most sublime of nature's works, is on the ascent of a hill, which seems to have been cloven through its length by some great convulsion. The fissure, just at the bridge, is by some admeasurements 270 feet deep, by others 205; it is about 45 feet wide at the bottom, and 90 feet at the top; this of course determines the length of the bridge, and its height from the water. Its breadth in the middle is about 60 feet, but more at the ends; and the thickness of the mass at the summit of the arch about 40 feet. A part of its thickness is constituted by a coat of earth, which gives growth to many large trees. The residue, with the hill on both sides, is one solid rock of lime-stone. The arch approaches the semi-elliptical form; but the larger axis of the ellipsis, which would be the cord of the arch, is many times longer than the transverse. Though the sides of the bridge are provided in some parts with a parapet of fixed rock, yet few men have resolution to walk to them, and look over into the abyss. You involuntarily fall on your hands and feet, and creep to the parapet, and look over it. Looking down from this height about a minute gave me a violent headache. If the view from the top be painful and intolerable, that from below is delightful in the extreme. It is impossible for the emotions arising from the sublime to be felt beyond what they are here. On the sight of so beautiful an arch, so elevated, so light, and springing as it were up to heaven, the rapture of the spectator is really indescribable! The fissure, continuing narrow, deep, and straight, for a considerable distance above and below the bridge, opens a short but very pleasing view of the north mountain on one side, and blue ridge on the other, at the distance each of them of about five miles. This bridge is in the county of Rockbridge, to which it has given name, and affords a public and commodious passage over a valley, which cannot be crossed elsewhere for a considerable distance. The stream passing under it is called Cedar Creek: it is a water of James's River, and sufficient in the driest seasons to turn a grist mill, though its fountain is not more than two miles above[71]."

Thus both in what is called the Old World and the New, we shall be astonished in looking into the operations of time employing water to move the solid masses from their places, and to change the face of nature, on the earth, without defacing nature. At all times there is a terraqueous globe, for the use of plants and animals; at all times there is upon the surface of the

[71] Upon this occasion it may be observed, the most wonderful thing, with regard to cosmology, is that such remnants, forming bridges, are so rare; this therefore must be an extraordinary piece of solid rock, or some very peculiar circumstances must have concurred to preserve this monument of the former situation of things.

earth dry land and moving water, although the particular shape and situation of those things fluctuate, and are not permanent as are the laws of nature.

It is therefore most reasonable, from what appears, to conclude, that the tops of the mountains have been in time past much degraded by the decay of rocks, or by the natural operations of the elements upon the surface of the earth; that the present mountains are parts which either from their situation had been less exposed to those injuries of what is called time, or from the solidity of their constitution have been able to resist them better; and that the present valleys, or hollows between the mountains, have been formed in wasting the rock and in washing away the soil.

If this is the case, that rivers have every where run upon higher levels than those in which we find them flowing at the present, there must be every where to an observing eye marks left upon the sides of rivers, by which it may be judged if this conclusion be true. I shall now transcribe a description of a part of the *Vallais* by which this will appear. (Discours sur l'Histoire Naturelle de la Suisse.)

«Après avoir passé le village de Saint-Leonard, on commence à monter la montagne de la Platière; cette route est on ne peut plus intéressante pour le naturaliste, etc.

«On se trouve fort élevé au-dessus du Rhône quand on est sur le haut de ce chemin, dont on découvre un de plus singuliers, des plus riches, et de plus variés passages qu'on puisse imaginer. On voit sous ses pieds le Rhône serpenter dans le lit qu'il se creuse actuellement, car il change et tout prouve qu'il en a souvent changé; une quantité prodigieuse de petites isles le séparent et le coupent en une multitude de canaux et de bras; ces isles sont couvertes les unes d'arbres, d'arbustes, de pâturages, de bosquets et de verdure, d'autres de pierres, de sable, et de débris de rochers; quelques-unes sont formées ou occasionnées par un amas de troncs d'arbres entassés avec de grands sapins renversés dont les long tiges hérissées de branches droites et nues représentent des chevaux de frise, et donnent l'idée de ces abatis destinés à preserver un pays contre l'approche de l'ennemi. Du côté du bas Vallais, on suit à perte de vue le fleuve dans ses sinuosités et ses détours, on l'apperçoit également dans le haut Vallais; des avances de montagne le cachent quelquefois: il reparoît et diminue insensiblement en approchant de ces monts élevés ou il prend sa source: le fond du vallon paroît être de niveau, s'abaisser seulement d'une pente douce du côté du bas Vallais: des mamelons, des hauteurs des monticules isolés, quelquefois groupés de différentes manieres, sont répandus dans cet espace, et rappellent la vue d'une pré dévasté par les taupes; plusieurs de ces hauteurs sont surmontées des ruines d'antiques châteaux, d'eglises, et de chapelles; des villages distribués ça et là enrichissent ce fond, qui d'ailleurs est couvert de pâturages, de champs d'arbres, de bois, et de bosquets; les enclos des possessions le coupent en mille figure bizarres et irrégulières. Ces monticules avec leurs fabriques s'élèvent au-dessus de tous ces objets variés; quelques-unes se distinguent par leur côtés écroulés qui sont à pic; la blancheur de ces éboulemens contraste singulièrement avec les verts qui sont les couleurs dominantes du vallon. Au-de-la des coteaux, des montagnes s'élèvent et vont s'appuyer et s'adosser à ces masses, à ces colosses énormes de rochers à pic élevés comme des murailles et d'une hauteur prodigieuse qui forment cette barrière qui sépare le Vallais de la Savoie. Les contours du pied de ces monts forment des entrées de vallons et de vallées d'ou descendent et se précipitent des torrens qui viennent grossir les eaux du Rhône; la vue cherche à pénétrer et à s'étendre dans ces espaces, l'imagination cherche vainement des passages dans effrayantes limites, parmi ces écueils et ces rochers amoncelés, elle est arrêtée partout; de noires forêts de sapin sont suspendues parmi ces rochers blancs-jaunâtres, qui se terminent enfin par une multitude d'aiguilles et de pyramides qu'on voit percer au travers des neiges et des glaces, s'élancer dans les nues, s'y cacher et s'y perdre.

«En examinant de plus près ces mamelons répandus dans le vallon, on voit qu'ils sont composés de pierres, de sables, et de débris rapportés et amoncelés sans ordre depuis des temps dont rien ne peut fixer l'époque: on voit que les eaux du Rhône ont coulé à leurs pied, qu'il en a miné plusieurs et a occasionné leurs chutes et leurs ruines. On voit actuellement quelques mamelons qui subissent ces mêmes dégradations, et fournissent au Rhône les matériaux dont il va former plus loin ces atterissemens dont nous avons parlé. La confusion et le désordre qui se remarque dans la composition intérieure de ces mamelons prouvent qu'ils ne sont pas le produit de la mer ou des eaux qui ont travaillé successivement et lentement à la formation de la plupart des terrains; mais que le fond de ce vallon a été rempli des décombres et des débris des montagnes supérieures, qu'ils y ont été entraînés par des inondations et des débordemens subits; que les eaux du Rhône ensuite ont parcouru ce vallon qu'il a souvent changé de lit; que c'est en tournant et en circulant dans ce terrain nouvellement formé, qu'il a creusé les espaces qui sont entre ces mamelons, et que c'est en creusant le terrain qu'ils se sont élevés; leurs formes et leurs pentes allongées vers le bas Vallais, sont de nouvelles preuves que ce sont les eaux actuelles qui ont changé la surface de ce terrain, nous verrons de nouvelles preuves de ce que nous disons en avançant d'avantage vers le haut Vallais; il n'y a peut-être point d'endroit plus propre à étudier le travail des eaux que ce vallon qu'on a la facilité de voir et d'examiner sous des aspects différentes.»

Another example of the same kind, with regard to the bed of the Rhine, we have from the same author. (Discours, etc. page 259.)

«*De Richenau à Coire, Troyen, et Saint-Gal.*

«Pour aller à Coire on passe le port qui est sur le haut Rhin; en côtoyant ce fleuve, qui coule dans un fond, on entre dans une plaine de niveau, qui n'a qu'une pente très insensible de trois quarts de lieue; le fond du terrain n'est qu'un amas de pierres roulées de toutes espèces. Les deux côtés sont bordés de montagnes calcaire qui courent parallèlement entr'elles. Celle de la gauche, au pied de laquelle coule le Rhine, est très rapide et perpendiculaire à son sommet; celle qui est à droite de la plaine ou petit vallon, puisqu'il se trouve entre des montagnes, est moins haute, plus boisée, et couverte de sapins. Le vallon est aussi couvert, en partie, de très-grands et beaux pins; mais ce qu'on y voit de plus remarquable, c'est une douzaine de gros mamelons ou butes, élevées de cinquante à soixante toises, plus ou moins isolée, et à différentes distances les unes des autres; ces butes sont rondes, la plupart allongées dans le sens du vallon, et composées de débris calcaires et de sables; le fond du vallon est mêlé de plus d'espèces de galets. On ne croit pas se tromper en disant que ce vallon a été rempli de matières apportées par les eaux jusqu'à la hauteur ou sont encore actuellement les mamelons; que de nouvelles inondations ont ensuite creusé et entraîné ce qui manque de terrain à ces mamelons; que c'est en circulant autour de ces mamelons que les eaux leur ont donné la forme ronde; et surtout allongée dans le sens du vallon, et que c'est par le moyen de ces mêmes eaux que le fond actuel de cette plaine a pris ce niveau et cette pente insensible vers un pays plus ouvert qui est au-dela. On a déjà fait mention de pareils mamelons qui se trouvent dans le vallon du Vallais parcouru par le Rhône.»

These examples may also be supported by what this author observes in another place[72].

«Le vallon où est situé Meiringen, est visiblement formé par le dépôt des eaux, il est de niveau, et s'étend trois lieues en longueur jusqu'au lac de Brientz, à la suite duquel est le même terrain nivelé, qui va jusqu'au lac de Thun, dont on a parlé. Une autre observation qui concourt à favoriser ce sentiment, c'est que toutes les roches calcaires, qui entourent le vallon, sont à pic, qu'on y remarque des cavités circulaires et des enfoncemens à même hauteur et à différents points, qui constatent la fouille et le mouvement des eaux contre ces parois.»

Thus we have seen the operation of the atmospheric elements degrading mountains, and hollowing out the valleys of this earth.

The land which comes from the mineral region in a consolidated state, in order to endure the injuries of those atmospheric elements, must be resolved in time for the purposes of fertilising the surface of this earth. In no station whatever is it to be exempted from the wasting operations, which are equally necessary, in the system of this world, as were those by which it had been produced.

But with what wisdom is that destroying power disposed! The summit of the mountain is degraded, and the materials of this part, which in a manner has become useless from its excessive height, are employed in order to extend the limits of the shore, and thus increase the useful basis of our dwellings.

It is our business to trace this operation through all the intermediate steps of that progress, and thus to understand what we see upon the surface of

[72] Discours, etc. page 201.

this earth, by knowing the principles upon which the system of this world proceeds.

Chapter 11. Facts And Opinions Concerning The Natural Construction Of Mountains And Valleys

The valley of the Rhône is continued up to the mountain of St. Gothard, which may be considered as the centre of the Continent, since, from the different sides of this mountain, the water runs in all directions. To the German Sea it runs by the Rhine, to the Mediterranean by the Rhone, and to the Adriatic by the Po. Here it may be proper to take a general view of this mountainous country, or that great mass of rock or solid strata which has been either formed originally in its present shape, or has been excavated by the constant operation of water running from the summit in all the different directions.

On the one hand, it is supposed that the forming cause which had produced those mountains, in collecting their materials at the bottom of the sea, had also determined the shape in which their various ridges are at present found; on the other hand, it is supposed that the destructive causes, which operate in degrading mountains, have immediately contributed to produce their present forms, and that it is only mediately or more remotely that this shape has been determined by mineral operations and the constitution of the solid parts, which thus oppose the wearing operations of the surface with different degrees of hardness and solidity. Whether natural appearances correspond with the one or the other of those two different suppositions, every person who has the opportunity of making such an examination, and has sufficient knowledge of the subject to judge from his observation, will determine for himself.

I will here give the opinion of a person who has had great opportunities for this purpose, who is an intelligent as well as an attentive observator, and who has had particularly this question in his view. It is from 'Tableaux de la Suisse'[73].

[73] «Discours sur l'Histoire Naturelle de la Suisse.»

«Quand nous nous sommes trouvé sur ces points élevés, nous avons toujours considéré le total des montagnes prises ensemble, leurs situations respectives, les unes par rapport aux autres; afin de reconnoître, s'il y avoit quelque chose de constant dans leurs position; rien n'est plus varié. Dans la grande chaîne de montagnes qui sépare le canton de Berne du Vallais d'un côté, et les Alpes qui séparent le Vallais de la Savoie de l'autre, en considérant le course du Rhône sous differens points de vue, on n'a point vu que les angles saillans de ces très hautes montagnes fussent opposés aux angles rentrans des montagnes qui sont vis-à-vis; Le fameux vallon qui est sur le haut du Saint-Gothard, le point le plus élevé de l'Europe, contredit également cette observation, aussi que les positions de la plus grande partie des montagnes qui forment son vaste circuit. Le vallon de Scholenen, qui a plus de huit lieues, et dans lequel la Reusse coule du sommet du Saint-Gothard jusqu'au lac de Lucerne, offre à peine quelques exemples d'angles rentrans opposés à des angles saillans. Les nombreux vallons que nous avons constamment traversés ceux qui conduisent au Grindelwald, et celui qui mène au pays de Hasli qui sont sous nos yeux, n'établirent pas d'avantage cette correspondance d'angles saillans et angles rentrans, qu'on regarde comme si constante. Dans les montagnes basses, du troisième et quatrième ordre, ou inférieures, on remarque plus souvent cette correspondance, encore n'est-elle pas constante: les eaux ordinaires ont formé ces vallons; mais si on veut donner une théorie générale, c'est assurement dans les plus hautes montagnes qu'il faut prendre ses exemples. Ce qui se trouve au-dessous de ces points les plus élevés, a pris sa forme de la disposition même des plus hauts sommets.»

M. de Saussure, in his second volume of *Voyages dans les Alpes*, gives the strongest confirmation to the theory of the gradual degradation of mountains by the means of rain.

«§ 920. Je reviens aux observations. Il en est une très importante pour la théorie de la terre, dont on peut du haut du Cramont apprécier la valeur, mieux que d'aucun autre site; je veux parler de la fameuse observation de *Bourguet* sur la correspondance des angles saillans avec les angles rentrans des vallées. J'ai a déjà dit un mot dans le 1er. volume, § 577, mais j'ai renvoyé à ce chapitre les developpemens que je vais donner.

«Ce qui avoit fait regarder cette observation comme très-importante, c'est que l'on avoit cru qu'elle pourroit servir à démontrer que les vallées ont été creusées par des courans de la mer, dans le temps où elle couvroit encore les montagnes; ou que les montagnes qui bordent ces vallées avoient été elles-mêmes formées par l'accumulation des dépôts rejetés sur les bords de ces mêmes courans.

«Mais l'inspection des vallées que l'on découvre du haut du Cramont démontre pleinement le peu de solidité de ces deux suppositions. En effet, toutes les vallées que l'on découvre du haut de cette cime sont fermées, au moins à l'une de leurs extrémités et quelques-unes à leurs deux extrémités, par des cols élevés, ou même par des montagnes d'une très-grande hauteur: toutes sont coupées à angles droits par d'autres vallées, et l'on voit enfin clairement que la plupart d'entr'elles ont été creusées, non point dans la mer, mais, ou au moment de sa retraite, ou depuis sa retraite, par les eaux des neiges et des pluies.

«On a d'abord sous ses yeux la grande vallée de l'Allée-Blanche, qui étant parallèle à la direction général de cette partie des Alpes, est du nombre de celles que je nomme*longitudinales*; et l'on voit cette vallée barrée à l'une de ses extrémités par le Col de la Seigne et à l'autre par le Col Ferret. En se retournant du côté de l'Italie, on voit plusieurs vallées à-peu-près parallèles à celle-là, comme celle de la Tuile, celle du Grand Saint Bernard, qui toutes aboutissent, par le haut, à quelque Col très-élevé, et par le bas, à la Doire, où elles viennent se jeter vis-à-vis de quelque montagne qui leur correspond de l'autre côté de cette vallée.

«Si l'on considère ensuite cette même vallée de la Doire, qui descend de Courmayeur à Yvrée, on la verra barrée par le Mont-Blanc et par la chaîne centrale, qui la coupent à angles droits dans la partie supérieure. On verra cette même vallée s'ouvrir, dans un espace de sept ou huit lieues, deux ou trois inflexions tout-à-fait brusques; et on la verra enfin coupée à angles droits par une quantité de vallées qui viennent y verser leurs eaux, et qui sont elles mêmes coupées par d'autres, dont elles reçoivent aussi le tribut. Or quand on réfléchit à la largeur et à l'étendue des courans de la mer, peut-on concevoir que ces sillons étroits, barrés, qui se coupent en échiquier à de très-petites distances, aient pu être creusés par de semblables courans.

«L'observation de la correspondance des angles, fut-elle aussi universelle qu'elle l'est peu, ne prouveroit donc autre chose, sinon que les vallées sont nées de la fissure et de l'écartement des montagnes, ou qu'elles ont été creusées par les torrens et les rivières qui y coulent actuellement. On voit un grand nombre de vallées naître, comme je l'ai fait voir au Bon-Homme, § 767, sur les flancs d'une montagne; on les voit s'élargir et s'approfondir a proportion des eaux qui y coulent; un ruisseau qui sort d'une glacier, ou qui sort d'une prairie, creuse un sillon, petit d'abord, mais qui s'agrandit successivement à mesure que ses eaux grossissent, par la réunion d'autres sources ou d'autres torrens.

«Il n'est même pas nécessaire, pour se convaincre de la vérité da ces faits, de gravir sur le Cramont. Il suffit de jeter les yeux sur la premiere carte que l'on trouvera sous la main, des Pyrénées, de l'Apennin, des Alpes, ou de quelqu'autre chaîne de montagnes que ce puisse être. On y verra toutes les vallées indiquées par le cours des rivieres; on verra ces rivieres et les vallées dans lesquelles elles coulent, aboutir par une de leurs extrémités au sommet de quelque montagne ou de quelque col élevé. Les replis tortueux d'un grand fleuve, indiqueront une vallée principale, dans laquelle des torrens ou des rivieres qui indiquent d'autres vallées moins considérables, viennent aboutir, sous des angles plus ou moins approchans de l'angle droit. Or ces rivieres qui viennent de droite et de gauche se jeter dans la vallée principale, ne s'accordent pas pour se jeter par paires dans le même point du fleuve; elles sont comme les branches d'un arbre qui s'implantent alternativement sur son tronc, et par conséquent, chaque petite vallée se jette dans la vallée principale vis-à-vis d'une montagne. Et de plus on verra aussi sur les cartes que même les plus grandes vallées ont presque toutes des étranglemens qui forment des écluses, des fourches, des défilés.

«Je ne prétends cependant pas que l'érosion des eaux pluviales, des torrens et des rivieres, soit l'unique cause de la formation des vallées: le redressement des couches des montagnes nous force à en admettre une autre, dont je parlerai ailleurs; j'ai voulu seulement prouver, ici que la correspondance des angles, lorsqu'elle a lieu dans les vallées, ne prouve point que ces vallées soient l'ouvrage des courans de la mer.»

The place to which M. de Saussure here remits us is where he afterwards, in describing the *Val d'Aoste*, makes the following observation.

«(§ 960.) Au-dela de Nuz, les montagnes qui bordent au midi la vallée, et dont on voit d'ici très-bien la structure, sont composées de grandes couches appliquées les unes contre les autres, et terminées par des cimes aigues, escarpées contre le midi, elles tournent ainsi le dos à la vallée, dont la direction est toujours à 10 degrés de l'est par nord. Celles de la gauche que nous côtoyons, et qui sont de nature schisteuse, tournent aussi le dos à la vallée en s'élevant contre le nord. Je crois pouvoir conclure de là, que cette vallée est une de celles dont la formation tient à celle des montagnes mêmes, et non point à l'érosion des courans de la mer ou des rivières. Les vallées de ce genre, paroissent avoir été formées par un affaissement partiel des couches des montagnes, qui ont consenti, dans la direction qu'ont actuellement ces vallées.»

Here I would beg leave to differ a little from this opinion of M. de Saussure, at least from the manner in which it is expressed; for perhaps at bottom our opinions upon this subject do not differ much.

M. de Saussure says that the formation of this valley depends upon the mountains themselves, and not upon the erosion of the rivers. I agree with our author, so far as the mountains may have here determined the shape and situation of the valley; but, so far as this valley was hollowed out of the solid mass of our earth, there cannot be the least doubt that the proper agent was the running water of the rivers. The question, therefore, comes to this, How far it is reasonable to conclude that this valley had been hollowed out of the solid mass. Now, according to the present theory, where the strata consolidated at the bottom of the sea are supposed to be erected into the place of land, we cannot suppose any valley formed by another agent than the running water upon the surface, although the parts which are first to be washed away, and those which are to remain longest, must be determined by a concurrence of various circumstances, among which this converging declivity of the strata in the bordering mountains, doubtless, must be enumerated.

With regard to any other theory which shall better explain the present shape of the surface of the earth, by giving a cause for the changed position of the strata originally horizontal, I cannot form a judgment, as I do not understand by what means strata, which were formed horizontally, should have been afterwards inclined, unless it be that of a power acting under those strata, and first erecting them in relation to the solid globe on which they rested.

Besides, in supposing this valley original, and not formed by the erosion of the rivers, What effect should we ascribe to the transport of all those materials of the Alps, which it is demonstrable must have travelled through this valley? Whether is it more reasonable to suppose, on the one hand, that the action and attrition of all the hard materials, running for millions of ages between those two mountains, had hollowed out that mass which originally intervened; or, on the other, that this valley had been originally formed in its present shape, while thousands of other valleys have been hollowed out of the solid mass?

But to put this question out of doubt, with regard to this very valley of the river *Doire*, M de Saussure has given us the following decisive fact, § 881: «Immédiatement au-dessus de cette source, est un rocher qui répond si précisément à un autre rocher de la même nature, situé de l'autre côté de la vallée de Courmayeur, qu'on ne sauroit douter qu'ils n'aient été anciennement unis par une montagne intermédiaire, détruite par les ravages du temps.»

Now, to see how little the situation of the strata influences the shape of the valleys, I shall transcribe the two paragraphs immediately following that which has given occasion to the present discussion.

«Un peu au-dela de Nux, la vallée cesse d'être large et plane, comme elle étoit dans le environs de la cité; elle devient étroite et très variée; là stérile et sauvage, ici couverte de vergers et de prairies arrosées par la Doire.

«§ 961. Les couches des montagnes à notre gauche, qui depuis la cité avoient constamment couru à l'est et monté au nord, paroissent changer à un quart de lieue du village de Chambaise, qui est à une lieue et un quart de Nux. Elles montent d'abord au sud-est, et peu plus loin droit au sud, tandis que l'autre côté de la vallée elles paroissent monter à l'est.»

In every mountain, and in every valley, the solid parts below have contributed in some manner to determine the shape of the surface of the earth; but in no place is the original shape of the earth, such as it had first appeared above the sea, to be found. Every part of the land is wasted; even the tops of the mountains, over which no floods of water run, are degraded. But this wasting operation, which affects the solid rock upon the summit of the mountain, operates slowly in some places, compared with that which may be observed in others. Now, it is in the valleys that this operation is so perceptible; and it is in the valley that there is such a quick succession of things as must strike the mind of any diligent observer; but this is the reason why we must conclude, that at least all the valleys are the operation of running water in the course of time. If this is granted, we have but to consider the mountains as formed by the hollowing out of the valleys, and the valleys as hollowed out by the attrition of hard materials coming from the mountains. Here is the explanation of the general appearance of mountain and valley, of hill and dale, of height and hollow; while each particular shape must have its dependence, consequently its explanation, upon some local circumstance.

But, besides the general conformation of mountains and valleys, there may be also, in the forms of mountains, certain characters depending upon the species of substances or rocks of which they are composed, and the general manner in which those masses are wasted by the operations of the surface. Thus there is some character in the external appearance of a hill, a mountain, or a ridge of hills and mountains; but this appearance is generally attended with various circumstances, or is so complicated in its nature, as to be always difficult to read; and it is but seldom that it affords any very particular information; although, after knowing all the state and circumstances of the case, I have always found the appearances most intelligible, and strictly corresponding with the general principle of atmospheric influence acting upon the particular structure of the earth below.

M. de Saussure has given us an observation of this kind, in describing the mountains through which the Rhône has made its way out of the Alps, at the bottom of the Vallée.

«§. 1061. Plus loin le village de *Juviana* ou Envionne on voit des rochers qui ont une forme que je nomme *moutonnée*; car on est tenté de donner des noms à des modifications qui n'en ont pas, et qui ont pourtant un caractère propre. Les montagnes que je désigne par cette expression sont composées d'un assemblage de têtes arrondies, couvertes quelquefois de bois, mais plus souvent d'herbes, ou tout au plus de brousailles. Ces rondeurs contiguës et répétées forment en grand l'effet d'une toison bien fournie, ou de ces perruques que l'on nommé aussi *moutonnées*. Les montagnes qui se présentent sous cette forme, sont presque toujours de rochers primitives, ou au moins des stéatites; car je n'ai jamais vu aucune montagne de pierre à chaux ou d'ardoise revêtir cette apparence. Les signes qui peuvent donner quelque indice de la nature des montagnes, à de grandes distances et au travers des plantes qui le couvrent, sont en petit nombre, et méritent d'être étudiés et consacrés par des termes propres.»

When philosophers propose vague theories of the earth, theories which contain no principle for investigating either the general disorder of strata or the particular form of mountains, such theories can receive no confirmation from the examination of the earth, nor can they afford any rule by which the phenomena in question might be explained. This is not the case when a theory presents both the efficient and final cause of those disorders in bodies which had been originally formed regular, and which shows the use as well as means for the formation of our mountains. Here illustration and confirmation of the theory may be found in the examination of nature; and natural appearances may receive that explanation which the generalization of a proper theory affords.

The particular forms of mountains depend upon the compound operation of two very different causes. One of these consists in those mineral operations by which the strata of the earth are consolidated and displaced, or disordered in the production of land above the sea; the other again consists in those meteorological operations by which this earth is rendered a habitable world. In the one operation, loose materials are united, for the purpose of resisting the dissolving powers which act upon the surface of the earth; in the other, consolidated masses are again dissolved, for the purpose of serving vegetation and entertaining animal life. But, in fulfilling those purposes of a habitable earth, or serving that great end, the land above the level of the sea is wasted, and the materials are transported to the bottom of the ocean from whence that consolidated land had come. At present we only want to see the cause of those particular shapes which are found among the most elevated places of our earth, those places upon which the wasting powers of the surface act with greatest energy or force.

In explaining those appearances of degraded mountains variously shaped, the fact we are now to reason upon is this; first, that in the consolidated earth we find great inequality in the resisting powers of the various consolidated bodies, both from the different degrees of consolidation which had taken place among them, and the different degrees of solubility which is found in the consolidated substances; and, secondly, that we find great diversity in the size, form, and positions of those most durable bodies which, by resisting longer the effects of the wearing operations of the surface, must determine the shape of the remaining mass. Now so far as every particular shape upon the surface of this earth is found to correspond to the effect of those two causes, the theory which gave those principles must be confirmed in the examination of the earth; and so far as the theory is admitted to be just, we have principles for the explanation of every appearance of that kind, whether from the forming or destroying operations of this earth, there being no part upon the surface of this earth in which the effect of both those causes must not more or less appear.

But though the effects of those two causes be evident in the conformation of every mountainous region, it is not always easy to analyse those effects so as to see the efficient cause. Without sections of mountains their internal structure cannot be perceived, if the surface which we see be covered with soil as is generally the case. It is true, indeed, that the solid bodies often partially appear through that covering of soil, and so far discover to us what is to be found within; but as those solid parts are often in disorder, we cannot, from a small portion, always judge of the generality. Besides, the solid parts of mountains is often a compound thing, composed both of stratified and injected bodies; it is therefore most precarious, from a portion which is seen, to form a judgment of a whole mass which is unexplored. Nevertheless, knowing the principles observed by nature both in the construction and degradation of mountains, and cautiously inferring nothing farther than the data will admit of, some conclusion may be formed, in reasoning from what is known to what is still unknown.

It is with this view that we are now to consider the general forms of mountains, such as they appear to us at a certain distance, when we have not the opportunity of examining them in a more perfect manner. For, though we may not thus learn always to understand that which is thus examined, we shall learn, what is still more interesting, viz. that those mountains have been formed in the natural operations of the earth, and according to physical rules that may be investigated.

We are to distinguish mountains as being either on the one hand soft and smooth, or on the other hand as hard and rocky. If we can understand those two great divisions by themselves, we shall find it easy to explain the more complex cases, where these two general appearances partially prevail. Let us therefore examine this general division which we have made with regard to the external character of mountains.

The soft and smooth mountains are generally formed of the schisti, when there is any considerable extent of such alpine or mountainous region. The substance is sufficiently durable to form a mountain, or sufficiently strong, in its natural state, to resist the greatest torrent of water; at the same time this fissible substance generally decays so completely, when exposed to the atmosphere, as to leave no salient rock exposed by which to characterise the mountain.

Of this kind are the schisti of Wales, of Cumberland, of the isle of Man, and of the south of Scotland. I do not say absolutely, that there is no other kind of material, besides the schisti which gives this species of mountain, but only that this is generally the case in alpine situations. It may be also formed of any other substance which has solidity enough to remain in the form of mountains, and at same time not enough to form salient rocks. Such, for example, is the chalk hills of the Isle of Wight and south of England. But these are generally hills of an inferior height compared with our alpine schisti, and hardly deserve the term of mountain.

This material of our smooth green mountains may be termed an argillaceous schistus; it has generally calcareous veins, and is often fibrous in its structure resembling wood, instead of being slatey, which it is in general. There is however another species of schistus, forming also the same sort of mountain; it is the micaceous quartzy schistus of the north of Scotland. Now it must be evident that the character of those mountains arises from there being no part of those schisti that resists the influence of the atmosphere, in exfoliating and breaking into soil; and this soil is doubtless of different qualities, according to the nature of those schisti from which the soil is formed.

Such mountains are necessarily composed of rounded masses, and not formed of angular shapes. They are covered with soil, which is more or less either stoney or tender, sterile or fertile, according to the materials which produce that soil. The fertile mountains are green and covered with grass; the sterile mountains again are black, or covered with heath in our climates.

Thus we have a general character of smooth and rounded mountains; and also a distinction in that general character from the produce of the soil indicating the nature of the solid materials, as containing, either on the one hand calcareous and argillaceous substances, or, on the other, as only containing those that are micaceous and siliceous.

With regard again to the other species of mountain, which we have termed rocky, we must make a subdistinction of those which are regular, and those in which there is no regularity to be perceived. It must be plain that it is only of those which have regularity that we can form a theory. It is this, that the regularity in the shape of those mountains arises from the rock of the mountain being either on the one hand an uniform solid mass, or on the other hand a stratified mass, or one formed upon some regular principle distinguishable in the shape. In the first of these, we have a conical or pyramidal shape, arising from the gradual decay of the rock exposed to the destructive causes of the surface, as already explained in this chapter. In the second, again, we find the original structure of the mass influencing the present shape in conjunction with the destructive causes, by which a certain regularity may be observed. Now, this original shape is no other than that of beds or strata of solid resisting rock, which may be regularly disposed in a mountain, either horizontally, vertically, or in an inclined position; and those solid beds may then affect the shape of the mountain in some regular or distinguishable manner, besides the other parts of its shape which it acquires upon the principle of decay.

In distinguishing, at a distance, those regular causes in the form of mountains, we may not be able to tell, with certainty, what the substance is of which the mountain is composed; yet, with regard to the internal structure of that part of the earth, a person of knowledge and experience in the subject may form a judgment in which, for coming at truth, there is more than accident; there is even often more than probable conjecture. Thus, a horizontal bed of rock forms a table mountain, or such as M. Bouguer found in the valley of the Madelena. An inclined rock of this kind forms a mountain sloping on the one side, and having a precipice upon the upper part of the other side, with a slope of fallen earth at the bottom; such as the ridges observed by M. de Saussure from the top of the Cramont, having precipices upon one side, which also had a respect to certain central points, an observation which draws to more than the simple structure of the mountain. Were it vertical, again, it would form a rocky ridge extended in length, and having its sides equally sloped, so far as the other circumstances of the place would permit.

Therefore, whether we suppose the mountains formed of a rock in mass, or in that of regular beds, this must have an influence in the form of this decaying surface of the earth, and may be distinguished in the shape of mountains. It is but rarely that we find mountains formed altogether of rock, although we often find them of the other sort, where little or nothing of rock is to be seen. But often also we find the two cases variously compounded. This is the source of the difficulty which occurs in the reading of the external characters of mountains; and this is one of the causes of irregularity in the form of mountains, by which there is always some degree of uncertainty in our judgment from external appearances.

We may form another distinction with regard to the structure of mountains, a distinction which depends upon a particular cause, and which will afford an explanation of some other appearance in the surface of the earth.

Mountains in general may be considered as, being either on the one hand associated, or on the other insulated; and this forms a distinction which may be explained in the theory, and afford some ground for judging of the internal structure from the external appearance.

The associated mountains are formed by the wearing down of the most decayable, or softer places, by the collected waters of the surface; consequently there is a certain similarity, or analogy, of the mountains formed of the same materials, and thus associated. The highest of those mountains should be near the center of the mass; but, in extensive masses of this kind, there may also be more than one center. Nor are all the associated mountains to be of one kind, however, to a certain extent, similarity may be expected to prevail among them.

It must now be evident, that when we find mountains composed of very different materials, such as, *e.g.* of granite, and of lime-stone or marl, and when the shape of those mountains are similar, or formed upon the same principle, such as, *e.g.* the pyramidal mountains of the Alps, we are then to conclude, as has already been exemplified (chap. 9. page 306.) that those consolidated masses of this earth had been formed into the pyramidal mountains in the same manner. We have there also shown that this principle of formation is no other than the gradual decay of the solid mass by gravity and the atmospheric influences. Consequently, those pyramidal mountains, though composed of such different materials, may, at a certain distance, where smaller characteristic distinctions may not be perceivable, appear to be of the same kind; and this indeed they truly are, so far as having their general shape formed upon the same principle.

We come now to treat of insulated mountains. Here volcanos must be mentioned as a cause. By means of a volcano, a mountain may be raised in a plain, and a volcanic mountain might even rise out of the sea. The formation of this species of mountain requires not the wearing operations of the earth which we have been considering as the modifier of our alpine regions. This volcanic mountain has a conical shape, perhaps more from the manner of its formation which is accretion, than from the wasting of the surface of the earth. It is not, however, of this particular specie of mountain that I mean to treat, having had no opportunity of examining any of that species.

The genus of mountain which we are now considering, is that of the eruptive kind. But there is much of this eruptive matter in the bowels of the earth, which, so far as we know, never has produced a volcano. It is to this species of eruption that I am now to attribute the formation of many insulated mountains, which rise in what may be termed low countries, in opposition to the highlands or alpine situations. Such is Wrekin in Shropshire, which some people have supposed to have been a volcano. Such are the hundred little mountains in the lowlands of this country of Scotland, where those insulated hills are often called by the general term *Law*; as, for example, North Berwick Law.

When masses of fluid matter are erupted in the mineral regions among strata which are to form our land; and when those elevated strata are, in the course of time, wasted and washed away, the solid mass of those erupted substances, being more durable than the surrounding strata, stand up as eminences in our land. Now these often, almost always, form the small insulated mountains which are found so frequently breaking out in the lowlands of Scotland. They appear in various shapes as well as sizes; and they hold their particular form from the joint operation of two different causes; one is the extent and casual shape of the erupted mass; the other is the degradation of that mass, which is wasted by the influences of the atmosphere, though wasted slower than the strata with which it was involved.

When the formation of this erupted mass has been determined by the place in any regular form, which may be distinguished in the shape of a mountain, it gives a certain character which is often not difficult to read. Thus, our whin-stone, interjected in flat beds between the regular strata, often presents its edge upon, or near the summit of our insolated mountains and eminences. They are commonly in the form of inclined planes; and, to a person a little conversant in this subject, they are extremely distinguishable in the external form of the hill.

We have a good example of this in the little mountain of Arthur's Seat, by this town of Edinburgh. This is a peaked hill of an irregular erupted mass; but on the south and north sides of this central mass, the basaltic matters had been forced also in those inclined beds among the regular strata. On the north side we find remarkable masses of whin-stone in that regular form among the strata, and lying parallel with them. The most conspicuous of these basaltic beds forms the summit of the hill which is called Salisbury Craig. Here the bed of whin-stone, more than 60 or 80 feet thick, rises to the west at an angle of about 40 degrees; it forms the precipicious summit which looks to the west; and this is an appearance which is distinguishable upon a hundred other occasions in the hills and mountains of this country.

Rivers make sections of mountains through which they pass. Therefore, nothing is more interesting for bringing to our knowledge the former state of things upon the surface of this earth, than the examination of those valleys which the rivers have formed by wearing down the solid parts of alpine countries. We have already seen that the wide extensive valley of the Rhône, between Loiche and Kolebesche, as well as the whole extensive circus of the Rosa mountains, has on each side mountains of the same substances, the strata of which are horizontal; consequently, here the valley must have been hollowed out of the solid rock; for there is no natural operation by which those opposite mountains of horizontal strata could have been formed, except in the continuation of those beds. We are therefore to conclude, that the solid strata between those ridges of lofty mountains had been continuous.

The most perfect confirmation which this theory could receive, would be to find that those ridges of mountains, which the Rhône divides in issuing from the Alps into the plain, had been also united, in forming one continued mass of solid rocks. But the observations of M. de Saussure, who has most carefully examined this subject, will leave no room to doubt of that fact.

This view of the entry to the valley of the Rhône is too interesting not to give it here a place. It follows immediately after that which we have last transcribed.

«Ces montagnes que j'allai sonder au haut des prairies qui les séparent de la grande route, sont composées d'un mélange très ressemblant au précédent, et ce sont-là, les derniers rochers primitifs que l'on rencontre en sortant des Alpes par cette vallée. Le village de Juviana, dont ils occupent les derrières, est encore à une lieue de St Maurice.

«§ 1062. A l'extrémité de ces rochers, on voit une grande ravine, ou plutôt une vallée ouverte du nord au midi, dans laquelle coule le torrent de St. Barthelemi. Cette vallée termine les montagnes primitives que je viens de décrire: au-delà commencent les montagnes calcaires. Cependant le pied de la montagne primitive, coupé par le torrent, est demeuré engagé sous les premières couches de la montagne calcaire.

«Au travers de cette vallée, on voit de hautes montagnes couverte de neige, situées derriere celles qui bordent notre route. La plus haute et la plus remarquable de ces montagnes se nomme la *Dent* ou *l'Aiguille du Midi*. De l'autre côté du Rhône, on voit une autre cime aussi très-élevée, qui se nomme la *Dent* ou *l'Aiguille de la Morele*. Ces deux hautes cimes ont entr'elles une correspondance de hauteur, de forme, et même de matière tout-à-fait singulière. L'une et l'autre présentent leurs escarpemens à la vallée du Rhône. Leurs cimes crénelées sont de la même couleur brune. Sous ces cimes brunes, on voit de part et d'autre une bande grise, qui paroît horizontale, et au-dessous de cette bande grise, le rocher, dans l'une comme dans l'autre, reprend sa couleur jaunâtre. Ces montagnes sont sûrement secondaires, les bandes grises paroissent être de pierre à chaux, et les jaunes de schiste argilleux et de grès, à en juger du moins à cette distance, car je ne les ai point observées de plus près. Elles paroissent aussi appartenir à des chaînes secondaires qui passent derrière les chaînes primitives, que nous avons observées sur les bords du Rhône, et quoique les bandes jaunes et grises que l'on y observe, semblent horizontales, je ne doute point que les couches mêmes, dont ces bandes sont les sections, ne descendent en arriere avec assez de rapidité; le escarpemens de ces montagnes en font une preuve à-peu-près certaine.

«Ces hautes montagnes auroient-elles été anciennement liées entr'elles par des intermédiaires de la même nature, que couvroient, et les primitives que nous avons observées, et toute cette vallée dans laquelle coule aujourd'hui le Rhône? Je me garderois bien de l'affirmer, mais je ferois tenté de le croire.

«§ 1063. Depuis la vallée dont je viens de parler, et qui termine au couchant les montagnes primitives, celles qui suivent jusques à St. Maurice, sont de nature calcaire à couches épaisses et suivies. Ces couches s'élèvent contre les primitives que nous avons côtoyées; et celles qui en sont les plus voisines paroissent fort tourmentées; ici fléchies, là rompues. Après une interruption, ces rochers sont suivis d'autres rochers, aussi calcaires, coupés à pic du côté de la vallée, et composés de grandes assises horizontales. Ces rochers forment une enceinte demi-circulaire, qui vient presque se joindre à ceux qui bordent la rive droite du Rhône, et former ainsi l'entrée de cette vallée, dont le fleuve ne sort que par une issue très-étroite.

«La ville de St. Maurice est ainsi renfermée par cette enceinte de rochers, dont les bancs épais, bien suivis, séparés par des cordons de verdure, et couronnés par des forêts, avec un hermitage niché entre ces bancs, présente une aspect singulier et pittoresque.

«§ 1064. Les rochers correspondans de l'autre côté du Rhône, ou sur la rive droite de ce fleuve sont aussi calcaires. La montagne qui domine cette rive, un peu au-dessus de St. Maurice, est composée de couches contournées, froissées et repliées de la maniere la plus étrange. Ce qu'il y a encore de remarquable, c'est que ces couches ainsi repliées en ont d'autres à côté d'elles qui sont planes, presque verticales, et d'autres sous elles, qui sont horizontales. Il faudroit avoir observé de près ce singulier rocher, et avoir déterminé comment et jusqu'à quel point ces couches sont unies entr'elles pour former les conjectures sur leur origine. Car la vallée est trop large pour que l'on puisse en juger avec précision d'une rive à l'autre.

«On voit avec peine que cette large vallée soit aussi peu cultivée; elle est presque partout couverte, ou de marais, ou de débris des montagnes voisines.

«§ 1065. Avant de quitter cette vallée, je jetterai un coup-d'oeil général sur la singulière suite de rochers qui composent la chaîne que nous venons d'observer.

«Les deux extrémités sont calcaires, avec cette différence, que celle qui est la plus près de Martigny est mêlée de mica, tandis que celle de St Maurice n'en contient point. Entre ces calcaires sont refermées des rochers que l'on regarde comme primitives; et au milieu de ces roches on trouve des ardoises et des poudingues. On fait que ce dernier genre est ordinairement classé parmi les montagnes tertiaires, ou de la formation la plus récente. Mais ces poudingues-ci, qui ne contiennent aucun fragment de pierre calcaire, qui ne sont même point unis par un gluten calcaire, ne sont vraisemblablement pas postérieures à la formation des montagnes calcaires, ou du moins ils ne doivent point être confondus avec ces grès et ces poudingues de formation nouvelle, qui entrent dans la composition des montagnes du troisième ordre.

«Quant aux ardoises que se trouvent interposées au milieu de ces grès et de ces poudingues, § 1054, elles sont de nature argilleuse, et dans l'ordre des pierres que l'on nomme secondaires.

«Ces ardoises, de même que toutes les pierres de ces montagnes, ont leurs couches dans une situation verticale: mais nous avons vu qu'il y a lieu de croire qu'elles ont été anciennement horizontales.»

It is singularly fortunate that such remarkable appearances, as are found in the rocks of this place, had called the attention of M. de Saussure to investigate a subject so interesting to the present theory; and it is upon this, as well as on many other occasions, that the value of those observations of natural history will appear. They are made by a person eminent for knowledge; and they are recorded with an accuracy and precision which leaves nothing more to be desired.

From *Martigny* to *St. Maurice*, about three leagues, there is a most interesting valley of the Rhône, through which this river makes its way from the *Vallais*, or great valley above, among those mountains which seem to have shut up the *Vallais*, and through which the river must pass in running to the lake. M. de Saussure found some singular masses, which attracted his attention, in examining the structure of the rocks on the left side of this little valley. Like a true philosopher, and accurate naturalist, he desired to compare what was to be observed in the other side of this valley of the

Rhône, which he had found so singular and so interesting on that which he had examined. Accordingly, in Spring 1785, he made a journey for that purpose. In this survey he found the most perfect correspondence between the two sides of this valley, so far as rocks of the same individual species, and precisely in the same order, are found upon the one side and upon the other.

This author, after describing those particular appearances, sums up the evidence which arises from this comparison of the two sides of the valley; and he here gives an example of just reasoning, of accuracy, and impartiality, which, independent of the subject, cannot be read without pleasure and approbation. But when it is considered, that here is a matter of the highest importance to the present theory, or to any other system of geology, no less than a demonstration that the rocks, of which the mountains on both sides of the valley of the Rhône are formed, are the same, and must have been originally continued in one mass, the following observations of our author will be most acceptable to every person who inclines to read upon this subject.

«§ 1079. On voit par cet exposé, que bien que la vallée du Rlione ait dans ce trajet près d'une lieue de largeur moyenne, les montagnes qui la bordent sont en general du même genre, et dans la même situation sur l'une et l'autre rive.

«Il y a cependant trois différences que je dois exposer et apprécier en peu de mots.

«La plus importante est dans ces couches de pierre calcaire, § 1073, que j'ai trouvées sur la rive droite, et que je n'ai point vue sur la gauche. Mais il est possible qu'elles y soient, et qu'elles m'ayent échappé, masquées par des débris ou par d'autre causes accidentelles; cette supposition est d'autant plus possible, que l'épaisseur de ces couches n'est que de quelques pieds. D'ailleurs il arrive souvent, que des filons, tel que paroît être celui dont je parle, ne s'étendent pas à de grandes distances, quoique la nature de la montagne demeure la même. Enfin ce qui diminue l'importance de cette différence, c'est que ces couches calcaires se trouvent dans le voisinage de l'ardoise qui passe, comme la pierre calcaire, pour une pierre de nature secondaire, et qui alterne très-fréquemment avec elle.

«Une autre difference que l'on aura pu remarquer, c'est que sur la rive droite, je n'ai point trouvé de petrosilex pur et en grandes masses, comme sur la rive gauche dans les environs de la cascade. Mais cette différence ne me frappe pas non plus beaucoup; parce qu'au lieu de petrosilex, j'ai trouvé sur la rive droite des roches composées en très-grande partie de feldspath. Or je regarde le pétrosilex et le feldspath comme des pierres de la même nature. Leur dureté est à-très-peu-près la même; leur densité la même, leur fusibilité la même; l'analyse chymique démontre dans l'un et dans l'autre les mêmes principes, la terre siliceuse, la terre argilleuse et le fer; et de plus ces ingrédiens s'y trouvent à très-peu-près dans les mêmes proportions. Il ne reste donc de différence que dans la couleur et dans l'agrégation des élémens. Or on fait que ces qualités accidentelles tiennent souvent à des causes qui peuvent être purement locales.

«La troisième différence, celle qui se trouve dans la direction de quelques-unes des couches, je l'ai déjà indiquée, § 1075. et il semble inutile de répéter, que quand des couches formées originairement dans une situation horizontale, ont été redressées par des opérations violentes de la nature, il n'y a pas lieu de s'étonner qu'elles n'aient pas exactement la même position dans tout l'espace qu'elles occupent.

«Les différences ne sont donc pas très-significantes, et les ressemblances sont au contraire du plus grand poids. Ce qui leur donne à mon gré la plus grande force, c'est la rareté des pierres dont ces montagnes sont composées, ces espèces de porphyres à base de pétrosilex, ces rochers feuilletées mélangées de feldspath et de mica; c'est encore la correspondance de l'ordre dans lequel elles se suivent; ces bancs de poudingues séparés par des ardoises sur une rive comme sur l'autre; leur situation également ou à-peu-près telle. Viola de grandes et fortes analogies et qui ne permettent pas de douter que ces montagnes, produites dans le même temps et par les mêmes causes, n'aient été anciennement unies.»

Having thus shown, that the Rhône had in the course of time hollowed out its way from the central mountain of the *St. Gothard* through the extensive valley of the *Vallais* we may still further trace the marks of its operation in the more open country towards the lake. It is an observation which M. de Saussure made in his way from the valley of the Rhône to Geneva.

«§ 1090. La grande route de Bex à Villeneuve suit toujours le fond de la vallée du Rhône, en côtoyant les montagnes qui bordent la droite ou le coté oriental de cette vallée. Ces montagnes sont en général de nature calcaire, mais on voit à leur pied, jusques auprès de la ville d'Aigle, située à une lieue et demi de Bex, la continuation des collines de gypse qui renferment les sources salées.

«§ 1091. A l'opposite de ces collines, au couchant de la grande route, on voit sortir du fond plat de la vallée deux collines allongées dans le sens de cette même vallée. Ces collines sont l'une et l'autre d'une pierre calcaire dure et escarpées presque de tous les côtes. L'une la plus voisine de Bex, ou la plus méridionale, se nomme *Charpigny*, l'autre *Saint Tryphon.*

«Il paroît évident que ces rochers isolés au milieu de cette large vallée sont de noyaux plus dures et plus solides qui ont résisté aux causes destructrices par lesquelles cette vallée à été creusé. Ils ne sont cependant pas exactement de la même nature, et surtout pas de la même structure; car celui de *Saint Tryphon* est composé de couches régulières, horizontales ou à-peu-près telles, tandis que celui de *Charpigny* a les siennes très-inclinées et souvent dans un grand désordre.»

In M. de Saussure's Journey to the Alps, we have now seen a description of the shape that had been given to things, by those operations in which strata had been consolidated and elevated above the sea; nothing but disorder and confusion seems to have presided in those causes, by which this mass of continent had been exposed to the sight of men; and nature, it would appear, had nothing in view besides the induration, the consolidation, and the elevation of that mass into the snowy regions of the atmosphere. From the descriptions now given, we see the operation of the waters upon the surface of the earth; we perceive a regular system of mountains and valleys, of rivulets and rivers, of fertile hills and plains, of all that is valuable to the life of man, and that which is still more valuable to man than life, viz. the knowledge of order in the works of nature, and the perception of beauty in the objects that surround him.

Let us now turn our view to distant regions, and see the effect of causes which, being general, must be every where perceived.

Chapter 12. The Theory Illustrated, By Adducing Examplesfrom The Different Quarters Of The Globe

The system which we investigate is universal on this earth; it hangs upon, the growth of plants, and life of animals; it cannot have one rule in Europe, and another in India, although there may be animals and plants, the constitutions of which are properly adapted to certain climates, and not to others. The operation of a central fire, in making solid land on which the breathing animals are placed, and the influences of the atmosphere, in making of that solid land loose soil for the service of the vegetable system, are parts in the economy of this world which must be every where distinguishable. But this the reader is not to take upon my bare assertion; and I would wish to carry him, by the observations of other-men, to all the quarters of the globe.

Mr Marsden, without pretending to be a natural historian, gives us a very good picture of the water-worn surface of Sumatra. History of Sumatra, page 20.

"Along the western coast of the island, the low country, or space of land which extends from the sea shore to the foot of the mountains, is intersected and rendered uneven to a surprising degree, by swamps, whose irregular and winding course may in some places be traced in a continual chain for many miles till they discharge themselves either into the sea, or some neighbouring lake, or the fens that are so commonly found near the banks of the larger rivers, and receive their over flowings in the rainy monsoons. The spots of land, which these swamps incompass, become so many islands and peninsulas, sometimes flat at the top, and often mere ridges; having in some places, a gentle declivity, and in others descending almost perpendicularly to the depth of an hundred feet. In few parts of the country of Bencoolen or of the northern districts adjacent to it, could a tolerable level space of four hundred yards be marked out: about Soogeylamo in particular, there is not a plain to be met with of the fourth part of that extent. I have often from an elevated situation, where a wider range was subjected to the eye, surveyed with admiration the uncommon face which nature assumes, and made enquiries and attended to conjectures on the causes of those inequalities. Some chose to attribute them to the successive concussions of earthquakes, through a course of centuries. But they do not seem to be the effect of such a cause. There are no abrupt fissures; the hollows and swellings are for the most part smooth and regularly sloping, so as to exhibit not unfrequently, the appearance of an amphitheatre, and they are clothed with verdure from the summit to the edge of the swamp. From this latter circumstance, it is also evident that they are not, as others suppose, occasioned by the falls of heavy rains that deluge the country for one half of the year. The most summary way for accounting for this extraordinary unevenness of the surface were to conclude, that in the original construction of our globe, Sumatra was thus formed by the same hand which spread out the sandy plains of Arabia, and raised up the Alps and Andes beyond the regions of the clouds." Our author then, after reprobating this idea, endeavours to explain the appearance here examined by the constant though imperceptible operation of springs. The present purpose is not so much concerning the explanation of those appearances, as to inquire if these be the general appearances of things over all the surface of the earth.

The general appearance here is that of land washed away upon the surface by water, which has every where left the marks of its operation in the shape of the ground. As for any particulars in the shape of this water-worn surface, this can only be explained in knowing the nature of the soil and solid parts, and the circumstances of the operation in which they have been wasted.

If the shape of the land here described by Mr Marsden has been produced by means of water, it must be by water moving from a higher to a lower place; and, in that respect, it is the same operation which every where prevails, in producing similar effects, although it is not every where that this effect comes to be the object of our notice. It is therefore so necessary to illustrate, in giving a diversity of cases. But it is not every case that can be understood as belonging to this rule; for, though the shape of every part has been modified by the operation of this cause, it is not every where that this relation of cause and effect is immediately perceived. There must be a certain regularity in the parts to be described, and a certain conformity wish those in which we have no doubt, or in which we certainly acknowledge the efficacy of the cause.

In America, this system of swamps and savannas are to be found upon a large scale; but for this very reason, they are not so remarkable to men. Man only sees a system of things, so far as that system is more immediately within the reach of his perception; for, without having prepared *media*, by which he may compare things that are distant either in their nature or their place, How could he judge those things to be connected in a system? It is in this manner that, seeing only the small part of an extended system of things, he sees no system in it, and, consequently he cannot give any scientifical description of the subject.

There is another case in which men of science, or systematising men, are apt to fall into delusion: it is not from any deficiency of seeing effects, and knowing general causes; it is from the misapplication of known causes to effects which are perceived. We have a remarkable example of this in the view which M. de Bouguer has taken of a singular appearance which he met with, perhaps more interesting to the present Theory than almost any other of which we know. (Voyage au Pérou, page 89.)

«Une particularité qui a attiré souvent mon attention dans toutes ces contrées, c'est que toutes les montagnes aupres desquelles je passois, et qui sont au pied et au dehors de la grande Cordelière, me paroissoient avoir eu une origine toute différente de celles que j'avois vues auparavant. Les lits de différentes terres et le plus souvent de rochers dont elles étoient formées, n'étoient pas inclinés de divers côtés, comme dans les autres: ils étoient parfaitement horizontaux, et je les voyois quelquefois se répandre fort loin dans les différentes montagnes. La plupart de celle-ci ont deux ou trois cent toises de hauteur, et elles sont presque toutes inaccessibles; elles sont souvent escarpées comme des murailles: c'est ce qui permet de mieux voir leurs lits horizontaux dont elles présentent l'extrémité. Le spectacle qu'elles fournissent n'est pas riant, mais il est rare et singulier. Lorsque le hazard a voulu que quelqu'une fût ronde, et qu'elle se trouvât absolument détachée des autres; chacun de ses lits est devenu comme un cylindre très-plat, ou comme un cône tronqué qui n'a que très-peu de hauteur; et ces différens lits placés les uns au-dessus des autres, et distingués par leurs couleurs et par les divers talus de leur contour, ont souvent donné au tout la forme d'ouvrage artificiel et fait avec la plus grande régularité. Il est une de ces montagnes à environ une lieue de Honda sur le bord du Guali et sur le chemin de Mariquita, qui est exposée à la vue de tous les voyageurs; mais je sens que si j'en donnois ici une représentation, il faudroit que je comptasse sur le credit que doit naturellement avoir le rapport de quelqu'un qui n'a aucun intérêt d'altérer la vérité, et qui a en toute sa vie le plus grand éloignement pour le mensonge. On voit dans ces pays là les montagnes y prendre continuellement l'aspect d'anciens et somptueux édifices, de chapelles, de dômes, de châteaux; quelquefois ce sont des fortifications formées de longues courtines munies de boulevarts. Il est difficile lorsqu'on observe tous ces objets et la manière dont leurs couches se répondent, de douter que le terrain ne se soit abaissé tout autour. Il paroît que ces montagnes dont la base étoit plus solidement appuyée, sont restées comme des espèces de témoins ou de monumens qui indiquent la hauteur qu'avoit anciennement le sol.»

There are but two ways in which those appearances may be explained; one of these is that which M. Bouguer has adopted; the other, again, belongs to the present Theory, which represents the action of running water upon the surface of the earth as instrumental in producing its particular forms, and thus forming many natural appearances upon the surface of the earth. The first of these, viz. that a mass of solid land, in such a shape as that here described, should remain while all around it sinks, is an opinion which, however possible it may be, is not supported, I believe, by any example in nature; the last again, viz. that the parts around those insulated masses, and those that had intervened between the corresponding mountains, have been carried away by the natural operation of the rivers, is not only the most easy to conceive, but is also, so far as those operations are concerned, conform to every appearance upon the surface of the globe. It is not necessary to go to South America, and the rivers of the Cordeliers, for examples to illustrate that which every one may see performed almost at his own door; but it is there that an example has occurred, which, though it has imposed upon an eminent philosopher, cannot properly be employed in support of any other theory but the present. Our author proceeds:

«Je ne connois les environs de l'Orénoque que par relation, mais je sçais qu'en plusieurs endroits les montagnes y sont également formées de couches horizontales, et qu'elles ont souvent en haut des plateformes qui sont exactement de niveau. On ne trouve à ce que je crois rien de semblable au Pérou malgré la variété presque infinie qui y est répandue. Toutes les couches y vont en s'inclinant autour de chaque sommet, en se conformant à la pente des collines.»

It would appear that it is a rare thing to find a great extent of indurated strata in a horizontal position. Now, this circumstance is necessary in affording the appearances here considered; those particular appearances, therefore, are only to be found more partially in other places, where the strata are inclined. If here, therefore, where the strata are horizontal, and where the spaces between the summits of those mountains had evidently been as solid as the masses which remain, we find mountains formed by the waste of land, and a system of rivers forming valleys amidst these mountains, Have we not reason to conclude, that in other mountainous regions, where the regular position of the strata has been broken and confounded, and where the same system of river and valley universally is found, the form of the surface has been produced upon no other principle than that of the natural waste of the solid mass, and the washing down of the heights for the formation of the fertile plains?

Nothing can tend more to illustrate the Theory than a proper comparison of the Old World with that which is called the New. It is not that we are to expect to see the operation of a longer time, upon the one of those continents, compared with the other; we equally lose all measure of time, in tracing the operations of nature on either continent. But in those operations there is rule to be observed; and the question is, If the same order of things may be perceived in all the quarters of the globe?

This is a question which the learned, even, in their closet, may be able to decide. They have but to look at the maps to be convinced that every where the process of nature, in forming habitable countries, is uniform; and that the system of what is called the watering those countries with rivers, is universally the same; a system which is now considered as giving us a view of the operations of water wearing down the land which it has fertilized, and shaping the surface of the earth so as to make it on the whole most useful.

There cannot be a doubt of the effects of those natural operations which belong to the surface of the earth, and which affect more powerfully the surfaces of the mountains; the only question is with regard to the general amount of those operations, and to the particular occasions which may have concurred in producing those effects. These questions can only be resolved in making particular observations. A general theory may thus be formed, of those operations by which the surface of the earth above the level of the sea has been changed, and will continue to be so as long as it remains a surface exposed to the influence of those agents which must be acknowledged in this place.

Naturalists, who have examined the various parts of the earth, almost all agree in this, that great effects have been produced by water moving upon the surface of the earth; but they often differ with respect to the cause of that motion, and also as to the time or manner in which the effect is brought about. Some suppose great catastrophes to have occasioned sudden changes upon the surface, in having removed immense quantities of the solid body, and in having deposited parts of the removed mass at great distances from their original beds. Others again, in acknowledging the natural operations which we see upon the surface of the earth, have only supposed certain occasions in which the consequence of those natural operations have been extremely violent, in order to explain to themselves appearances which they know not how to reconcile with the ordinary effects of those destructive causes.

The theory of the earth which I would here illustrate is founded upon the greatest catastrophes which can happen to the earth, that is, in being raised from the bottom of the sea, and elevated to the summits of a continent, and in being again sunk from its elevated station to be buried under that mass of water from whence it had originally come. But the changes which we are now investigating have no farther relation to those great catastrophes, except in so far as these great operations of the globe have put the solid land in such a situation as to be affected by the atmospheric influences and operations of the surface.

The water from the atmosphere, collected upon the surface of the earth, forms channels to itself in running towards the sea or lower ground; and it is these channels, increasing in their size as they are diminished in number by the uniting of their waters, that give so clear a prospect of the operations of time past, and prove the theory of the land being in a continual state of decay, and necessarily wasted for the purpose of this world. Every description, therefore, of a river and its valleys, from its sources in the mountains to its mouth where it delivers those waters to the sea, is interesting to the present theory, which is the generalization of those facts by which the end or intention of nature is to be observed. M. Reboul, in a Memoir read to the Academy of Sciences at Paris in 1788, has given a very distinct view of the *Vallée du Gave Béarnois dans les Pyrénées*; there are many things interesting in this memoir; and I shall now endeavour to avail myself of it.

«Le torrent qui porte le nom de Gave de Pau parcourt depuis sa source près des limites de l'Espagne, jusqu'à la petite ville de Lourde, une vallée qui se dirige du sud au nord sur une longueur d'environ dix lieues. Cet espace, qui forme son lit dans l'intérieur des Pyrénées, ressemble moins à une vallée dans la majeure partie de son étendue, qu'à une entaille étroite et profonde, dont les flancs sont souvent coupés à pic d'une hauteur effrayante, et dont le fond est toujours couvert d'une eau écumeuse. Cette long coupure se termine, ainsi que plusieurs de ses branches, aux sommets les plus élevés des Pyrénées, et elle reçoit les eaux qui distillent sans cesse de leur neiges durcies. Sa division géographique est en deux vallées, dont l'une plus voisine de la plain est appelée Lavedan, et dont l'autre ne fait que partie de la contrée qui porte le nom de Barèges.»

From the summit of that ridge of mountains which run from the Atlantic to the Mediterranean, the vallies of the principal rivers run from the south northward towards the plain of France; from this again they turn westward in order to find their way to the sea. The mountains, which then separate these rivers from the plain, are composed of schistus and great collections of water-worn gravel which had come from the mountains of the Pyrénées.

Upon this occasion Mr Reboul observes: «Les ruines amoncelées et la grand quantité de cailloux roulés qui forment ces digues naturelles, invitent sans doute à penser que ce sont les torrens eux-mêmes qui ont comblé leur lit et obstrué leur passage, mais on ne peut concevoir que cet effet ait pu avoir lieu que dans des tems très-reculés, et avant l'entière excavation des vallées. Peut-être paroîtra-t-il naturel d'imaginer que les masses out été produites par le conflit des eaux qui se précipitoient des montagnes et des flots de la mer, lorsqu'elle recouvroit encore les plaines, etc.

«Je ne fatiguerai point le lecteur du dénombrement inutile de tous les bancs pierreux de ces substances qui se succèdent le long de la vallée, et prenant seulement le résultat de mes observations, je me bornerai à dire que depuis Lourde jusqu'à Luz, les parois de la gorge sont alternativement composées de matières argilleuses et calcaires, quelquefois sous la forme de couches diversement inclinées, mais plus souvent fissiles, montrant de feuillets de différentes grandeurs et d'un tissu plus ou moins compacte. Ces schistes hétérogènes sont presque toujours entassés et superposés dans la même montagne, mais en plusieurs endroits un seul genre prédomine, etc. L'espèce d'uniformité qui semble exister dans la composition de ces masses, ne se trouve nullement dans leurs disposition; on chercheroit en vain dans leurs couches une direction et une inclinaison générale et constante, on pourroit tout au plus hazarder à ce sujet de légères conjectures; mais si l'ordre primitif de ces montagnes est dérobé à l'oeil de l'observateur, on trouve à chaque pas des indices certains, des marques évidentes de la manière dont il a été altéré ou détruit.

«Je reconnus d'abord que les mêmes cailloux, les mêmes débris de marbre et d'ardoise qui couvraient le fond de la vallée, et que le Gave entraîne et remplace sans cesse, se trouvent aussi à plusieurs toises au-dessus de son niveau. Je voyois quelquefois les sédimens fluviatiles recouverts et ensevelis sous des grandes masses de pierre feuilletée adhérente à la montagne; levant ensuite les yeux, j'observai que de l'un ou de l'autre côté du torrent, les flancs des montagnes étoient souvent couverts et comme plaqués de semblables masses de schiste, dont les couches et les feuillets offroient toujours des directions contraires à celles des schistes de même nature, auxquels ils étoient adossés. Les eaux du torrent, qui ont sans doute renversé ces couches sur elles-mêmes, y ont déposé des marques de leur passage; elles ont abandonné, engagé sous ces débris mêmes, à des grandes hauteurs, des blocs énormes de granit que le voyageur surpris voit pendre sur sa tête; de pareils blocs arrondis et usés couvrent le fond de la vallée, et opposent quelquefois au torrent une digue qui le fait jaillir et retomber en écume; enfin j'ai suivi les traces de ce courant aux différentes hauteurs des parois du canal où il coule aujourd'hui à plusieurs centaines de toises de profondeur. Il a dû les parcourir toutes successivement en creusant et rétrécissant sont lit et augmentant sa vitesse.

«Les crêtes des sommités qui forment les bords les plus élevés de la gorge, sont escarpées dans la direction du courant. J'ai aperçu quelquefois des portions de montagnes séparées de la crête, ou du sommet principal, et dont les eaux semblent en avoir fait des espèces d'îles, en creusant autour d'elles un fossé profond, où l'on voit fort bien les angles saillans de l'île correspondre aux angles rentrans de la montagne, etc.

«Dans la partie de la vallée où s'observent ces phénomènes, on marche toujours entre deux montagnes resserrées, dont les nuage dérobent souvent les cimes, mais par-tout où les eaux de quelque torrent considérable viennent se réunir à celles du Gave, il s'est formé un bassin d'une étendue moyenne, qui ne fut d'abord vraisemblablement qu'une grande mare d'eau semblable à ces lacs qui existent encore dans le sein des Pyrénées et des Alpes. Ainsi on voit, à une lieu avant Argelès, les montagnes s'écarter, se replier en un vaste circuit, et entourer, comme d'une muraille stérile et ruineuse, des prairies arrosées par mille canaux et par le brouillard des cascades; des coteaux, où l'on voit s'élever, parmi les vergers et les bois, des villages ornés de marbre, des châteaux majestueux et les délicieuses habitations de quelques moines fortunés.

«Le penchant qui borde ce vallon du côté de l'est n'est creusé que par quelques ravins très-inclinés, dont les eaux se précipitent en écume et disparoissent, avant d'arriver au bas de la montagne, sous l'ombre des bois et d'une foule d'habitations rustiques: mais le penchant de l'ouest, plus profondément excavé par les torrens, présentent les issues de trois autres vallées, dont les deux principales vont prendre leurs origine aux limites de l'Espagne; l'autre, plus voisine de la plaine, est à-peu-près dirigée de l'est à l'ouest. Elles s'appelle *Estrem de Sales*, et joint ses eaux à celles du Gave un peu au-dela de l'extrémité intérieure de ce grand bassin qu'elle a concouru à former. C'est au centre du bassin, auprès du village d'Argelés, que le Gave d'Azun arrive avec fracas, et c'est à son extrêmité supérieure que le Gave de Cautrês s'y précipite en sortant d'une gorge dont l'aspect frappe d'étonnement et d'horreur. Le cours de ces deux Gaves est auprès de leur embouchure oblique à celui du Gave principal; mais ils se replient ensuite vers le centre de la chaîne et deviennent presque parallèles. Auprès de Luz se découvre un autre bassin où se joignent les eaux du Gave à celles du torrent de la Lise, qui n'a creusé qu'un ravin, et à celles du Bastan qui descend d'un vallon très-évasé dans la direction de l'est à l'ouest, où se trouvent les eaux minérales de Barèges. Ce nouveau bassin n'offre que le spectacles d'une vaste prairie bordée de montagnes prodigieuses. Je n'entreprendrai point de rien ajouter ici touchant ces diverses branches de la vallée du Gave Béarnois; chacune d'elles exigeroit une description détaillé, soit à cause de son étendue, soit à cause de la variété de ses phénomènes.

«De Luz à Gavarnie le Gave se trouve de nouveau resserré dans une gorge étroite où les montagnes paroissent encore s'élever et les abîmes s'enfoncer; ses eaux ne coulent plus qu'en cascades bruyantes, et quelquefois le voyageur, qui les voit écumer sous ses pieds du haut du sentier tracé sur la montagne, entend à peine un murmure lointain. On y remarque de nouveau les phénomènes, décrit ci-devant, des pierres feuilletées renversées de leur première direction, des bancs entiers courbés et brisés dans leur chûte, des débris granitiques arrondis par les eaux, déposès à de très-grandes hauteurs dans le fond des ravins où le courant n'existe plus, etc.

«A Gèdre le Gave reçoit les eaux de Héas, lieu devenu célèbre et enrichi par la dèvotion Espagnole. A peine a-t-on passé le torrent, que le granit commence à paroître. Le Gave roule ses eaux sur cette base qu'il entame difficilement: aussi son lit est-il plus large et la gorge moins profonde: le granit se montre enterré sous de grandes montagnes calcaires. Du côté de l'ouest il est presque toujours recouvert de ces masses qu'on distingue de loin à leur teinte grise et blanchâtre mêlée de sillons d'un rouge peu foncé. A l'est les montagnes calcaires laissent le granit à découvert, et lui demeurent comme adossées. Celles qui leur succèdent offrent des marques, effrayantes de décrépitude; leurs crêtes sont démantelées, et leurs flancs sont lésardés et hérissés de rochers suspendus. Le fond de la vallée semble enseveli sous les débris de cette montagne à demi écroulées. On trouve, parmi les ruines, des blocs de plusieurs milliers de pieds cubes. Le Gave les couvre quelquefois de ses eaux, se précipite dans les intervalles qu'ils laissent entr'eux, et renaît comme sous une voûte affaissée. Plusieurs de ces lambeaux affectent sur leurs plans la forme de parallélogrammes et de rectangles; mais ceux que l'on voit encore attachés au corps de la montagne, sont pour la plupart pyramidaux, et sa crête est formée d'une suite de ces pyramides granitiques. Toutefois on ne peut pas se refuser à voir que le granit est ici disposé en couches très-distinctes qui paroissent surmontées dans quelques points des sommités, de bancs calcaire. La direction de ces couches granitiques n'est pas constante dans toute la masse; elles semblent s'incliner vers le sud-ouest du côté de Gavernie, et vers le nord-est du côté de Gèdre. Quoique leurs substance soit mêlées de plusieurs roches hétérogènes, elle est généralement composées de quartz, de feld-spath, et de mica; mais ces deux substances y sont dans un état frappant de décomposition, et semblent quelquefois réduites en chaux de fer.

«Au-delà de leurs débris, dont l'amas est désigné par le montagnards sous le nom de *Peyrade* et sous celui de *Catios* par les gens du monde, le granit est de nouveau surmonté de substances calcaires. Il sort de base aux pics coniques de Caumelie et de Pimené. Cette base forme elle-même une vaste montagne qu'on appelle *Allans*; ses roches, d'un granit ferrugineux et sombre, sont entourées d'une couronne blanchâtre et calcaire, où végètent quelque sapins épars: Gavarnie est à ses pieds.

«C'est à une légère distance de ce village, que se termine la vallée du Gave Béarnois, ou plutôt qu'elle prend naissance avec le torrent qui l'a formée. On apperçoit de loin les vastes sommets et les champs élevés de neige et de glace d'où ses eaux se précipitent; on reconnoît ensuite qu'ils ne forment qu'une montagne ou plutôt une masse énorme par sa hauteur et son volume, composée d'une même matière, et qui, placée sur une base vers laquelle on n'a cessé de monter pendant l'espace de dix lieues, s'élève tout-à-coup de sept à huit cens toises, et domine au loin toutes les montagnes qui l'entourent. Les différens sommets dont elle est couronnée se présentent sous mille formes bizarres; ce sont des pyramides irrégulières et de vastes cylindres, ou de cônes tronqués près de leur base, qui ressemblent assez à des tours écrasées. Les crêtes, qui sont formées du prolongement de ces sommités, sont autant de murailles inaccessibles bordées d'un long tas de ruines ou d'un large fossé de neige glacée, et quelquefois interrompues par de brèches profondes. On ne peut apercevoir tous ces objets du fond de la vallée, et il faut s'élever sur quelque hauteur voisine, telle que le sommet de Bergons, ou celui de Pimené, pour embrasser toutes les parties de ce vaste tableau. En remontant vers les sources du Gave, qui en occupe le centre, on pénètre par un coupure peu profonde dans une prairie de forme ovale assez régulière bordée à l'est et à l'ouest par des hauteurs plantées de sapins et de hêtres, et au sud par un amas de rochers écroulés, et par les sommets que je viens de décrire. Le Gave y serpente sur un lit de sable et de cailloux, et reçoit les eaux qui descendent, en écumant, des hauteurs voisines; il se fraie un chemin vers cette prairie parmi les débris entassées qui la bornent au sud, et qui la séparent d'une autre bassin non moins vaste, où le torrent commence son cours, et où la montagne s'élève tout autour en un rempart inaccessible.

«On peut prendre une idée légère et imparfaite de cette majestueuse enceint, en se la figurant comme un amphithéâtre moins remarquable par la vaste étendue de son arêne que par la hauteur prodigieuse de ses murs qui, par-tout bordés de parties saillantes, d'échancrures profondes, et hérissés de rochers dont la ruine est prochaine, se sont entièrement écroulés du côté du nord; elle-est couronnée vers le sud par deux sommets cylindriques recouverts d'une croûte épaisse de neige durcie, et que leur forme a fait nommer tour de marbre. Au-dessous se succèdent, en forme de gradins, de vastes platte bandes d'une neige qui ne disparoît jamais, et qui ne cesse point de se fondre insensiblement. Les eaux produites par cette stillation continuelle se divisent en sept ou huit petits torrens qui naissant sous ces lits de glace, et roulent sur le penchant rapide de la montagne ou jaillissent en cascades, quand elle se trouve coupée a pic. L'un de ces torrens venant du côté de l'est et dont le volume surpasse celui de tous les autres ensemble, se précipite du haut d'un rocher qui s'avance en saillie, et tombe avec un bruit horrible à plus de 1200 pieds de profondeur. Ses eaux, divisées dans les airs et réduites comme en poussiere, forment autour de la cascade un brouillard suspendu qui dérobe aux yeux du spectateur tout son volume et la vitesse de sa chute. L'arène ou se réunissent toutes ces eaux et où commence le Gave, est de forme irrégulière; sa surface inégale offre tantôt de grands plateaux de neige, des blocs de rochers écroulés et d'autre débris atténué et réduits à l'état terreux où végètent de belles plantes que le soleil éclaire à peine. Le Gave, en tombant sur les amas de neige, y a creusé un gouffre au fond duquel le soleil avant son déclin peint le cercle coloré de l'iris. Les eaux disparoissent sous la neige et renaissent ensuite comme sous un pont étroit ou sou la voûte d'un aqueduc; elles serpentent, se replient à travers les ruines amoncelées, et surmontent les obstacles qui s'opposent à leur sortie.

«Si l'aspect magnifique et la beauté sauvage de cette enceinte sont difficiles à représenter, sa structure n'en est pas moins facile à saisir; et dans ce lieu, qui semble fait pour le tourment du peintre de la nature, elle se découvre sans peine au yeux de l'observateur et de l'historien. *La grande enceinte de la cascade de Gavarnie*, dit M. d'Arcet, *fut un lac autrefois: l'aspect des lieux fait naître naturellement cette idée. Dans la suite les rochers qui la fermoient sur le devant, s'étant détruits, les eaux se sont écoulées et perdues*.

«On ne peut se refuser à croire avec M. d'Arcet, que l'enceinte des cascades de marbre n'ait été autrefois un lac. Le nombre et l'étendue de ces amas d'eau diminuent tous les jours dans les Pyrénées comme dans tout pays de montagnes; les eaux qui viennent s'y rendre en exhaussent le fond par les cailloux et les débris terreux qu'elles y entraînent, et celles qui s'écoulent en abaissent le niveau, en creusant insensiblement le canal par lequel elles sortent. Ainsi la marche lente et progressive de la nature sans l'intermède des accidens et de révolutions, suffit pour combler ces vastes creuse où les eaux se sont amassées, ou pour ouvrir des issues qui ne leur permettent plus d'y séjourner. Le nombre de ces lacs abandonnés et perdus n'est guère au-dessous de celui de lacs encore existans. Les naturels du pays ont appris eux-mêmes à distinguer ces monumens naturel; ils ont saisi leur structure semblable à celle d'un vaisseau évasé et coupé dans ses parois d'une ou de plusieurs entailles profondes, et les ont tous désignés par le mot *oule*, qui dérive du mot Latin*olla*, et signifie chez eux marmite; comparaison aussi juste que peu noble et bien digne de ces observateurs froids, mais exacts, également dépourvue de prévention et d'enthousiasme. Ces *oules* se trouvent souvent placées aux extrêmité supérieurs des vallées, à l'origine des torrens qui les remplissoient autrefois. En effect, ceux-ci naissent communément sous quelque vaste amas de neige, ou s'écoulent d'un réservoir qui rassemble les eaux des hauteurs voisines. Le nombre de ces lacs augmente à mesure qu'on s'élève, et c'est une observation générale, que ceux des vallées sont pour la plupart comblés ou perdus, et que ceux des montagnes, surtout de celle de granit, sont presque tous conservés. J'ai dit précédemment, d'après l'observation de M. d'Arcet, que l'enceinte des cascades présentoit la forme d'un réservoir entr'ouvert et épuisé, et qu'elle étoit précédée d'un autre bassin dont l'aspect est moins sauvage et la forme plus régulière. Tout porte à penser que celui-ci a été aussi long-tems rempli d'eau, ou plutôt il résulte d'un examen détaillé de ces lieux, que le deux bassins ne faisoient autrefois qu'un seul et immense réservoir, où les eaux étoient retenues à deux ou trois cens toises d'élévation au-dessus du sol où elles coulent aujourd'hui. Les rochers qui séparent le premier bassin de l'enceinte des cascades, ne sont, comme je l'ai déjà remarqué, qu'un vaste amas de débris; mais ces débris ne ressemblent point à ceux d'une muraille renversée sur elle-même, ou d'une digue rompue par l'effort des eaux. Il est au contraire aisé de se convaincre qu'ils ont été détachés de cette partie de la montagne qui bord l'enceinte du côté de l'est, et sur laquelle sont les sommets les plus élevés de toute cette masse. On voit encore sur ses flancs déchirés pendre d'énormes quartiers de roche prêts à s'écrouler. Ceux qui sont déjà tombés ont demeuré entassés les uns sur les autres. L'amas qu'ils ont formé est adossé à la montagne dont ils faisoient jadis partie, et s'incline jusqu'aux parois opposée de l'enceinte. Le torrent qui la traverse se trouve ainsi rejeté du côté de l'ouest, et le lit qu'il a creusé suit les contours de cet amas de débris. Un tems a donc existé auquel les deux enceintes dont j'ai parlé, étant remplies d'eau, ne formoient qu'un seul lac vaste et profond; et peut-être la même révolution qui les a séparées a-t-elle changé tout-à-fait leur forme et causé l'entière dispersion de leurs eaux; car si l'on considère que l'enceinte du bassin de la prairie est entièrement détruite du côté du nord et de la vallée, on doit se convaincre que les eaux ne l'ont point corrodée lentement, mais qu'elles l'ont entrouverte et emportée par un effort violent et subit. Or à quelle cause peut-on mieux attribuer le mouvement rapide et le choc qui dut les agiter, qu'à la chute instantanée de plusieurs milliers de toises cubes de rocher. Je me représente alors ce lac paisible et élevé changé en une mer courroucée, ses eaux bouleversées jusqu'au fond de ses abîmes jaillir au-dessus des sommets voisins, et retombant sur elles mêmes ébranler de leur poids et de leur chute la barrière qui les retenoit, cette barrière trop foible enfin renversée et ses débris transportés au loin.

«M. d'Arcet, dans son discours sur les Pyrénées, a présagé la même révolution pour le lac d'Escoubons le plus considérable de ceux qui dominent les bains de Barèges, et on ne peut douter que si quelqu'éboulement considérable vient hâter et accroître l'effet de cette débâcle inévitable, ces régions élevées subiront un nouveau déluge dont les hommes et les troupeaux seront la victime, qui ensevelira plusieurs villages, et inondera les tanières des bêtes fauves.»

M. Reboul has here imagined to himself the former existence of an immense deep lake, which, no doubt, is a thing that may have been, like many others which actually exist. But then he likewise supposes a particular revolution of things, in which one side of that stony circuit, forming the bason of the lake, had been destroyed while the water was discharged. It is this last hypothesis which appears to me to be a thing altogether inadmissible, according to the natural order of things.

In order to see this, it must be considered, that the side of the bason, which has disappeared, must have been either of similar materials to those which we see now remaining, or it must be supposed as composed of loose materials, such as had been more soft, or of those that might be easily dissolved and washed away by the water. If this last had been the state of things, there would not have been occasion for any violent catastrophe, as M. Reboul has supposed; the natural overflowing of the lake had been sufficient to wear the mound by which the water had been detained, and to carry away those materials so as one side might disappear. If, again, this mound had been formed of rock, like what remains of those mountains, in that case, the catastrophe, which this author has suggested as the cause of that destruction, would have been ineffectual to procure that end; for, though such a *débacle* might have carried away a great mass of loose materials, it could not have moved a mound of solid rock.

That of which we have here undoubted information, and that which I am labouring to generalise by comparing similar phenomena, such as are to be found over all the earth, is this, That the natural operations of the atmospheric elements decompose the solid rocks, break down the consolidated strata, waste and wash away those loosened materials of the mountains, and thus excavate the valleys, as the channels by which an indefinite quantity of materials are to be transported to the sea for the construction of future continents. It is this operation of nature which we see performed, more or less, every day, which some natural philosophers have such difficulty in admitting at all, and which others overlook in seeking for some wonderful operation to produce the effect in a shorter time. The prodigious waste that evidently appears, in many places, to have been made of the solid land, and the almost imperceptible effects of the present agents which appear, have given, occasion to those different opinions concerning that which has already happened, or that natural history by which we are to learn the system of this world. The object which I have in view, is to show, first, that the natural operations of the earth, continued in a sufficient space of time, would be adequate to the effects which we observe; and, secondly, that it is necessary, in the system of this world, that these wasting operations of the land should be extremely slow. In that case, those different opinions would be reconciled in one which would explain, at the same time, the apparent permanency of this surface on which we dwell, and the great changes that appear to have been already made.

Now if, in the indefinite course of time, (which we cannot refuse to nature, and which is only to be traced in those effects), the chymical and mechanical operations of the surface are capable of diminishing the mass of land above the level of the sea, (of which fact the appearances here so well described by M. Reboul, and those which are every where else to be observed, leave no room to doubt); and, if the wise system, of a world sustaining plants and animals, requires the long continuance of a continent above the surface of the sea, What reason have we to look out for any other causes, besides those which naturally arise from that constitution of things? And, Why refuse to see, in this constitution of things, that wisdom of contrivance, that bountiful provision, which is so evident, whether we look up into the great expanse of boundless space, where luminous bodies without number are placed, and where, in all probability, still more numerous bodies are perpetually moving and illuminated for some great end; or whether we turn our prospect towards ourselves, and see the exquisite mechanism and active powers of things, growing from a state apparently of non-existence, decaying from their state of natural perfection, and renovating their existence in a succession of similar beings to which we see no end.

We have been comparing similar operations of nature in different countries; but at present we have something farther in our view than to compare the distant regions of the earth. We want to see if it be the same system that is observed in the higher regions of the globe as in the lower. We shall thus have investigated the subject as far as we can go.

The high region of the Andes and Cordeliers affords an opportunity of deciding that question. It is there that we find a habitable country raised above the rest of the earth. It is there that nature, in elevating land, has proceeded upon a larger scale. Here, therefore, in the operations of water upon the surface of the earth, we are to look for effects proportioned to the cause.

Let us cast our eye upon the southern continent of the new world; there is not, from the one end to the other, any great river that flows to the sea upon the west side. A ridge of mountains, at no great distance from the coast, divides the water of this continent; a small part runs to the west; the most part runs to the east; and forms a country which, for fertile plains and navigable rivers, has not its equal upon the globe.

But let us observe the course of the rivers; while confined by the ridges of the Andes and Cordeliers; they run either south or north, and are thus for some time constrained to take a course very different from that which they are afterwards to pursue. It is while thus retained within the ridges of the

Andes that those rivers water plains which they had formed; and it is here that we find countries so much elevated above the rest of the world, that, under the direct rays of the sun, their inhabitants are made to suffer from the cold.

It is the collection of those waters running from south to north, and descending from an enormous height, that have formed in the plain those appearances that struck so much the French philosopher, as to make him give us a detail, which, though out of his line, is extremely interesting in the natural history of the earth.

It is in the valley of the Madelena that M. Bouguer found those grand relicts of the wasted strata; but we are now to take a view of a country situated high above the level of that valley. It is that of Santa Fée de Bogota; a fertile plain estimated at 1600 toises, almost about two miles above the level of the sea; and which pours its water into the valley of the Madelena about a degree above Honda, which is mentioned by M. Bouguer as giving so fine an example of those water-worn rocks. The extreme singularity in the situation of this country, and at the same time the perfect similarity which is here to be observed of this country with all the rest of the earth, as the work of water, will excuse my transcribing from M. le Blond, *(Journal de Physique,* Mai 1786) what I judge to be interesting to my readers.

«Si un observateur attentif parcourt les plaines immenses de l'Amérique méridionale, s'il monte les fleuves rapides et profonds qui les traversent, et les inondent, et s'il franchit les montagnes prodigieuses que l'action des eaux détruit, il apercevra bientôt qu'un développement successif et inévitable de ce nouveau continent tend à l'agrandir dans tous les sens, et rendra peut-être un jour sa surface égale à celle de notre hémisphère.

«Il est des sites dans les montagnes des Cordillères ou des obstacles plus ou moins puissant retardent cette même dégradation: la plaine de Santa Fée de Bogota est entre ces sites celui qui m'a paru le mieux caractérisé et le plus frappant. Il sera l'objet de ce Memoire: on verra avec surprise qu'un pays sain, agréable, abondant, et fertile aujourd'hui, étoit autrefois le plus dépourvu et le plus misérable du monde, ou l'Indien malheureux n'avoit pour tout bien que des rivieres sans poissons, des oiseaux en petit nombre, un quadrupéde ou deux, et quelques légumes; on sera étonné d'apprendre qu'une temperature froide environnée d'un climat brûlant, fut une barrière insurmontable pour presque tous les animaux et les plantes des pays chauds. La nature agresse et avare de ses dons sembloit en rejeter l'homme, et vouloir y être en quelque sorte séparée du reste du monde par des rochers énormes, coupés verticalement, qu'on ne parvient à franchir qu'avec des difficultés étranges à travers un brouillard humide et ténébreux, qui persuade au voyageur fatigué qu'il travers la région des nues.

«Arrivé au haut de ces montagnes, un nouveau ciel, un nouvel ordre de choses se présentent; ce ne sont plus ces insectes degoûtans et insupportables qui le fatiguoient sans relâche; ces reptiles venimeux, dont il redoutoit la morsure; ces bêtes féroces toujours prêts à le dévorer; enfin, cette, chaleur suffocante des lieux bas qu'il vient de quitter; l'air qu'il respire rafraîchit et le vivifie; il s'arrête, et ce qui l'environne l'étonné et le ravit; s'il regarde au-dessous de lui, tout est éclipsé par des nuages, dont la surface égale mouvante lui représente une mer qu'habite le silence et que termine son horison; s'il jette la vue sur la plaine qui se perd devant lui, les nues qu'il croyait sous ses pieds, roulent majestueusement sur sa tête; de nouvelles montagnes s'élèvent de toutes parts, et forment un nouveau monde qui paroît indépendant du premier.

«Pour donner une idée exacte de ce pays singulier, j'ai cru devoir transporter le spectateur à la capitale, où de là comme d'un centre, il pût observer plus commodément les phénomènes que j'ai à lui presenter.

«La ville de Santa Fée de Bogota, capital du nouveau royaume de Grenade, a environ 4 degrés de latitude N. et 304 de longitude, prise de l'île de Fer, est située au pied et sur le penchant d'une montagne escarpée qui la couvre à l'est; elle domine une plaine de douze lieues de largeur sur une longueur indéterminée et très considérable, qui présente toute l'année le riant tableau des plus belles campagnes de l'Europe: les coteaux toujours verts où les troupeaux bondissent, les prairies couverts de bétail, les champs bien cultivés, les maisons de campagne agréables, les hameaux, les villages, les vergers, les jardins, montrent à la fois, les fleurs du printemps et les fruits de l'automne, que l'abondance des pluies ou les sécheresses retardent ou avancent quelquefois mais dont l'éternelle durée bien loin d'inspirer le plaisir, et d'offrir l'attrait piquant de la nouveauté qui fait le charme de ces saisons dans nos climats, amène bientôt l'indifférence pour une beauté toujours le même, pour des agrémens qui ne changent pas.

«Ce climat est d'ailleurs si étrange et tellement constitué, que quand on est au soleil, on se trouve bientôt incommodé de sa chaleur; est on à l'ombre? on se sent pénétré d'un air subtil et froid qui transit.

«A trois lieues à-peu-près à l'ouest de la ville, passe la rivière de Bogota qui, après avoir reçu les eaux de toute la plaine, la rivière de Serrefuela et les torrens qui se précipitent de la chaîne de montagnes, dirige son cours paisible vers Tekendama à sept ou huit lieues au sud-est à-peu-près; c'est-là que ces eaux rassemblées coulent entre une suite de rochers granitiques, dont le plain incliné accélère leurs vitesse; elles n'offrent bientôt plus qu'un courant rapide, étroit et profond qui, au moment de sa chûte, rejaillit sur un rocher placé plus bas que son lit, d'où il tombe dans une abîme dont on n'a pu jusqu'ici mesurer la profondeur; c'est la cataracte ou saut de Tékendama.

«Des trous pratiqués dans le roc par les anciens aux endroits les plus commodes pour voir toute l'étendue de cette chûte prodigieuse, donnent le moyen d'observer sans risque la continuation des rochers qui s'avancent à droite et à gauche et annoncent par leurs hauteur qu'avant le passage que les eaux semblent avoir forcé, la plain de Santa Fée n'étoit alors qu'un lac d'une très-grand étendue: une tradition constante du pay, mais peu vraisemblable, porte que les Indiens ont creusé cette espèce de canal.

«Il y a quelques-uns de ces trous d'où l'on voit confusément le lieu où finit cette chûte d'eau effroyable; la rivière qui en provient n'offre plus qu'un foible ruisseau, dont le cours presqu'insensible se perd parmi les plantes qui croissent sur ses bords; ainsi disparoissent dans l'éloignement les masses les plus énormes: quelques espèces de perroquets et d'autres oiseaux de pays chauds, qui habite cette vallée profonde et inabordable de ce côté, s'élèvent assez quelquefois pour pouvoir être remarqués d'en-haut; mais le froid subit de ces montagnes qu'ils craignent, est une obstacle invincible qu'ils ne franchissent jamais: pour jouir commodément de ce point de vue, à la fois admirable et effrayant, il faut choisir un jour calme et serein, entre sept à huit heures du matin.

«Il est necessaire de prendre un long détour et cheminer pendant toute une journée, presque toujours à travers des rochers et des précipices, pour parvenir au pied de cette cataracte; on est alors étrangement surpris de voir que cette rivière à peine sensible d'en haut, soit encore un torrent prodigieux, dont la chute en cascades dans une angle de 45 degrés, offre pendant l'espace d'une grande demie lieue des amas de rochers entassés au hazard, que frappe et détruit sans relâche le plus bruyant conflict des eaux; c'est après cet espace que le courant, devenu plus paisible permet encore de comparer la rivière de Bogota à ce qu'est la Seine dans l'été.

«Un phénomène bien extraordinaire et qui sert en même tems à donner la plus haute idée de l'étendue prodigieuse de cette cataracte, c'est que sa chute commence dans un pays très-froid où il gèle souvent pendant la nuit, et finit dans un autre où la chaleur, égale à nos beaux jours d'été, offre la végétation prompte et facile de toutes les plantes des pays chauds: seroit-ce le passage subit de l'air du chaud au froid qui occasionneroit ces gelées blanches, à-peu-près comme celles qui ont lieu dans nos climats aux approche de l'hiver et à l'entrée du printemps? car on en éprouve rarement dans la plane.

«Une autre particularité remarquable de ce pays, c'est le défaut de poisson dans toutes les rivières qui l'arrosent: on en trouve cependant dans celle de Bogota où les autres rivières viennent se rendre; mais c'est une seule espèce très-peu abondante, que les Espagnols appellent el Capitan, ou le capitaine; la plus grande longueur de ce poisson est d'environ un pied, sur six pouces de grosseur; il vit dans les eaux troubles et vaseuses de cette rivière, et jamais dans les eaux claires; il est gras et excellent à manger: son genre est celui de la*mustelle fluviatile de France* et le *Gades* de Linné.

«Il est certain cependant que les poissons de toutes les sortes abondent dans les grandes rivières de l'Amérique méridionale et notamment dans celle de la Magdelaine; ne pourroit-on pas supposer d'après cela, que puisque toute communication des eaux de tout le pays élevé de Santa Fée est interrompue avec cette dernière par le saut de Tekendama, ces mêmes eaux n'ont pu en être peuplées comme celle-ci paroissent avoir été, au moins en partie, par la mer. Ce même défaut de poisson se remarque dans la plus part de lacs et des rivières des Cordillères, probablement par une cause semblable; il n'y en a point dans les deux lacs assez étendus qui sont près de la ville d'Hyvarra dans la province de *Quito*, non plus que dans les rivières de la province de Pastos.

«On peut objecter qu'une temperature toujours froide comme celle de Santa Fée, joint à la limpidité et la rapidité des torrens des Cordillères, suffisent pour écarter les poissons, de même que cela arrive dans plusieurs rivières de l'Europe.

«Cette objection seroit vraie pour la plupart des torrens des Cordillères, mais on observera que la rivière de Bogota quoique froide, est presque stagnante dans bien des endroits, et coule toujours sur de la vase qui en rend les eaux bourbeuses; il est à présumer que, s'il étoit possible d'y tranporter des poissons de nos rivières, ils y réussiroient aussi bien que les autres productions de l'Europe qui se sont naturalisées dans ce pays. Quant à la température constante froide de ces eaux, qui pourroient paroître s'opposer au développement des oeufs du poisson qui habite les rivières des pays chauds, on y respondra par le fait suivant.

«A vingt lieues environ au nord de Santa Fée à la même élévation et à la même température, est un grand lac où l'on trouve des îles habitées, et qui en a paru assez grand pour être indiqué dans les cartes géographiques, si on en savoit les dimensions; c'est le lac de Chiquinquira assez poissonneux pour y faire des pêches abondantes, parce que la rivière qui en sort n'est pas interrompue par des sauts dans son cours jusqu'à la rivière de la Magdelaine; cependant les espèces de poissons qu'on trouve dans ce lac ne sont pas aussi variées que dans cette grande rivière, sans doute à cause de la rapidité du courant, que le poisson ne remonte pas également bien.

«Lorsqu'on gravit sur les montagnes escarpées qui dominent la ville de Santa-Fée, on ne rencontre, depuis leur base jusqu'à leurs sommets, terminés par des rochers de granité, que des bruyère, des fougères, quelques plantes sauvages, etc. et pas un arbre qu'on puisse seulement appeler un boisson excepté dans quelques gorges à l'abri de courans d'air, où l'on en voit quelques-uns dont les plus grands, n'égale pas nos prunières; cette végétation engourdie paraît être due au froid vif et continuel qu'il fait sur ces montagnes; car plus on monte, moins elle se développe, et enfin finit par cesser tout-à-fait: on remarque à la moitié de la hauteur d'une de ces montagnes (à une demi-lieue à peu-près de la ville) une mine de charbon de terre en filon que renferme une rocher entrouvert, dans une situation verticale[27], les torrens y roulent de l'or.»

Footnote 27: (return) Here is an evidence that those vertical strata, now elevated into the highest stations upon the earth; had been formed originally of the spoils of the land, and deposited at the bottom of the sea.

«Si l'on descend dans la plaine, si l'on remonte sur les collines, toutes à-peu-près de la même hauteur qui sont entièrement séparées des montagnes voisines, et situées dans la direction ou courant des rivières, on remarque aisément qu'elle sont les restes d'une plaine antérieure que les eaux ont dégradée. Au lieu de ces forêts, et de ces boissons qui surchargent bientôt nos campagnes lorsque la main de l'homme cesse de les cultiver, un gazon touffu couvre la plaine et les collines de Santa-Fée d'une verdure agréable sans nul arbrisseau qui puisse en altérer l'uniformité, où les graminée, le plantain, le scorçonnaire, le trèfle, le marrube, la pimprenelle, le pourpier, la patience, le chardon, le raifort, le cresson, la chicorée sauvage, la jonquille, la marguerite, le fraisier, la violette, le serpolet, le thym, et mille autres plantes d'Europe et particulières à ce pays, offrent les variétés les plus piquantes par la beauté des fleurs et l'odeur de leurs parfums; des rochers qu'entourent le rosier ou la ronce, et quelques cavernes que le hazard presente sur ces mêmes collines, en rendent l'aspect pittoresque et délicieux.»

Here is a picture of a country such as we might find in Europe; only it is placed under the line, and elevated above the highest of the frozen summits of the European Alps. We may observe that the same order of things obtains here as in every other place upon the surface of this earth; mountains going into decay; plains formed below from the ruins of the mountains; these plains ruined again, and hills formed in their place; rivers wearing rocks and breaking through the obstacles which had before detained their waters; and a gradual progress of soil from the summits of the continent to the border at the sea, over the fertile surface of the land, successively destroyed and successively renewed.

Here are to be observed two states of country along side of each other, the plain of the Bogota, and the Valley of the Madalena. The courses of the two rivers show the direction of those ridges of mountains which had been raised from the deep; they run south and north, as do those valleys which they drain. At this place we find the valley of the river Cauca, and the valley of the Magdalena parallel to each other, and also to this high plain of the Bogota. Now the waters of this high country, instead of running northward to the sea, as do those of the two valleys below, run both from the south and north until, uniting together, they proceed westward, break the rampard of granite rocks at Tekendama, and fall at once from the high plain down into the valley of the Madalena. Those water formed plains which we perceive subsisting at unequal levels immediately adjoining to each other, while they present us with a view of the degradation of the elevated earth, at the same time illustrate the indefinite duration of a continent; for, we judge not of the progress of things from the actual operations of the surface, which are too slow for the life of man, and too vague for the subject of his history, but from the state of things which we contemplate with a scientific eye, and from the nature of things which we know to be in rule.

In like manner the horizontal situation of the solid strata in the mountains of that low country, while those of the high country are more or less inclined, afford the most instructive view of the internal operations of the globe, by which the Andes had been raised from the bottom of the sea, and of the external operations of the earth by which mountains are formed by the wasting of the elevated surface.

With this description of those high plains upon the north side of the line, let us compare what D. Ulloa has said upon the same subject in describing the continuation of that high country to the south. I shall give it from the best French translation.

It is after describing a cut or narrow ravine in the solid rock with perpendicular sides, about forty yards deep, in which a rivulet runs and the road passes.

«Cette excavation est, en petit, une modèle des vastes *Quebradas* ou profondeurs, et fait comprendre leur origine: elles ne pouvoient être que semblables à celle-ci: tout s'y est passé de même, ou plus tôt ou plus tard. Les flancs en ont été plus ou moins perpendiculaires, jusqu'au moment où ils se sont affaissées, et ont formé des plains inclinés, lorsque l'eau faisant de plus profondes excavations, eut miné la base qui les soutenoit. Ne pouvant plus alors persévérer dans leur premier état, les terrains ont croulé, et ont pris l'inclinaison qu'ils ont conservée depuis. La même chose arrivera nécessairement à ce passage de *Conaïca* lorsqu'avec le laps du tems, les effets des pluies, de gelées, des rayons solaires, auront fait tomber en ruine ces parois, quoique de roche rive; car ses agens puissans font sentir leur énergie aux corps les plus durs. Ainsi les bords du *Chapilancas*perdront insensiblement la régularité de leur distance, de leurs côtés rentrans et saillans, après l'avoir peut-être conservée plus long tems que d'autres excavations, parce que c'est une pierre dure, qui n'est mêlée d'aucune veine de terre movible. Nous pouvons le croire sans hésiter; car ce n'est que le seul frottement de l'eau qui a excavé ce lit jusqu'à la profondeur qu'il a. Mais le tems, qui réduit les roches les plus dures en sablon, ira toujours en élargissant la partie inférieure, par son action continuelle et insensible: aussi voit-on ce ruisseau rouler de petites pierres qui se détachent sous les eaux, comme on en apperçoit dans la plaine où il les entraîne, en sortant de la montagne, pour se décharger dans une terrain plus spatieux.

«Que ce canal ait été excavé à cette profondeur par l'effet continuel du frottement des eaux, ou qu'il a été ouvert par une secousse de tremblement de terre qui fit fendre la montaigne, de sorte que le ruisseau qui couloit d'un autre côté, se soit jetté de celui-ci. il est certain que cette ouverture profonde est postérieure à l'arrangement que les terrains eurent après le déluge; et que c'est ainsi que ces énormes *Quebradas* de la partie méridionale de l'Amérique, se sont formées avec le tems, par le frottement du cours rapide des eaux. En effet, on observe que la force avec laquelle s'écoulent toutes les eaux de cette partie du globe, suffit pour arracher des roches d'une masse extraordinaire. C'est pourquoi l'on voit en certaines parages des marques évidentes de leurs excavations profondes au milieu même des lits de ces eaux. Ce sont des cubes d'une grandeur énorme, qui n'ont pu être détachés avec la même facilité que les parties contiguës. La rivière *d'Iscutbaca*, qui coule près d'une hameau de même nom, nous présente dans son lit une de ces masses, dont la forme est précisément celle d'une cube. Lorsque l'eau est basse, ce cube s'élève à sept ou huit *varas* au-dessus du courant: chaque côté porte douze *varas* de face. Mais ces masses, et autres moindres de différentes formes, qui se voient dans les eaux, ne peuvent être arrivées à cet état, sans que l'eau les ait dégarnies peu-à-peu des pierres, des sables que les envelopoient, et qu'elle a arrachés de tous côtés pour les laisser isolées; or elles se maintiendrons dans cette position, jusqu'à ce que les eaux, cavant de plus en plus, rencontrent enfin à la base des veines de matières friables et dissolubles, qu'elles pénétreront et qu'elles emporteront, en détruisant l'assiette sur laquelle posent ces masses jusqu'alors *inamovibles*. Une crue d'eau considérable, et qui ne laissera plus paroître qu'une *varas* de cette masse, pourra dans ce tems-là l'arracher, et la faire rouler; mais ce mouvement, et les chocs qu'elle éprouvera de la part d'autres masses moins grosses, suffiront pour en briser les parties saillantes, et la réduire en parties moins volumineuses, qui rouleront avec plus de facilité; et qui par cette seul cause diminueront encore. C'est à cette cause qu'on doit attribuer ces quantités prodigieuses de pierres répandues ça et là sur les bords de ces eaux, de même que ces roches enormes qu'on y voit détachées, et que jamais les forces humaines n'auroient pu mettre en mouvement.

«Mais pour donner une idée quelconque de la profondeur de ces excavations, relativement au terrain ou au sol habitable de la partie haute de l'Amérique, il est à propos de rapporter quelques expériences.

«Guancavelica est une bourgade, ou un corps municipal, situé dans une de ces profondeurs, formées par différentes suites d'éminences. Le mercure du baromètre y descend, et s'arrête à dix-huit pouces une ligne et demie. Sa plus grande variation y est de 1-1/4 à 1-3/4. Sa hauteur est donc de 1949 toises, ou 4536-2/3 *varas* au-dessus du niveau de la *mer*. Au haut du mont où se trouve la mine de mercure, mont qui est habitable par-tout, et qui est immédiatement surmonté par d'autres, autant qu'il s'élève au-dessus de Guancavelica, le mercure descend et s'arrête à 16 pouces 6 lignes. Sa hauteur est donc de 2337-2/3 toises, ou de 5448 varas au-dessus du niveau de la mer. Ainsi les eaux ont encore fait cet autre excavation comme il est facile de le voir par des indices manifestes. On remarque en effet dans la partie voisine de leur lit, des roches détachées, toutes semblables à celles qui sont au milieu des eaux; ce qui prouve que les eaux ont été au même niveau à une époque beaucoup plus ancienne, et qu'elles ont excavé le sol, a force d'en arracher les parties agrégées.

«Ces terrains sont couverts par un si grand nombre de courans, qu'il n'en est aucun ou l'on n'en aperçoive, soit dans des ravins, soit entre des montagnes. J'ai observé que la superficie des terrains qui en avoisine les lits, est plus unie aux confluens, où plusieurs de ces courans se réunissent. Cela vient de ce que l'éminence, qui se trouve au confluent, paroît avoir été diminuée à la partie où elle a du former une pointe saillante, à mesure que les eaux l'ont rongée de l'un ou de l'autres côté, en continuant leurs excavation. Ces surfaces planes sont comme par étages, les unes plus hautes que les autres, et se sont insensiblement formées, selon que l'eau s'est plus ou moins arrêtée à différente hauteur, pendent qu'elle creusoit ces lits. On observe, au contraire, que les bords élevés dans ces courans, n'ont presque point de largeur dans les endroits où l'eau a pu suivre son cours très-directement. C'est cependant sur ces bords étroits et escarpées que se trouvent pratiqués les chemins par où l'on passe. Le danger y est très grand: car à peine un animal peut-il poser le pied. Toutes les fois que le courant fait un détour, la surface des bords a plus de largeur; cependant moins que lorsque plusieurs se réunissent. Un voit facilement pourquoi. L'eau forcée de se détourner, s'éloigne plus de la rive que quand elle va en ligne droite, et ronge ainsi le côté saillant sur lequel elle fait son détour, et qui en devient comme le centre.

«On peut conclure de ce que je viens de dire, à quelle élévation est la partie haute ou montagneuse de l'Amérique, relativement à la partie basse, et qu'il y a des excavations extrêmement profondes; car elles ont, comme je l'ai déjà dit, 1769-2/3 varas perpendiculaires, ou même d'avantages: cependant elles ont assez de surface pour devenir le local de nombre d'habitations fort peuplées, qui en tirent tous les produits nécessaires à la vie. Parmi ces *Quebradas*, il en est de plus étendues ou de moins profondes que les autres. Or, c'est en ceci que cette partie du monde se distingue de toutes les autres.

«Mais il est indifférent pour mes vues que ces vastes ouvertures soient l'effet des courans d'eau, ou de toute autre cause. Ce que je me propose, est uniquement de montrer qu'elles sont d'autant plus profondes et plus vastes, que ces terrains sont immensément hauts.»

M. Monnet considers the natural operations of water, upon the surface of the earth, as truly forming the shape of that surface; but he draws some very different conclusions from those which I have formed. It is in his *Nouveau Voyage Minéralogique, fait dans cette partie du Hainault connue sou le nom de Thiérache.* Journal de Physique, Aoust 1784.

«Il ne faut pas s'attendre à trouver dans ce pays des hautes montagnes qui frappent la vue de loin; c'est seulement un pays dont l'élévation est générale sur tout ce qui l'entoure, et est coupé profondément par des vallées ou ravin, ouvrage des eaux, qui, la comme ailleurs, ont use et coupé peu-à-peu les terrains et les roches les plus dures, pour s'ouvrir un passage; et peut-être pourroit-on dire; si la diminution des eaux n'étoit pas trop sensible, qu'un jour ce pays offrira des montagnes hautes est escarpées comme tant d'autres, après que les eaux auront creusé, pendant des milliers de siècles, ses gorges, ses ravins, et diminué la largeur des masses de terrain qui sont entr'eux.

«Quant à present, on ne peut y voir que de petites montagnes, ou plutôt des bosses de terre, avec des platures plus ou moins considérables à leurs sommets, avec de côtés coupées plus ou moins obliquement, ou plus ou moins droites. Ce qu'on y trouve de singulier c'est que ces petites montagnes sont presque toutes plus basses que les plaines qui les avoisinent, encore ne sont elles que dans la partie calcaire.

«La plus profonde tranchée de ce pays est, sans contredit, celle ou coule la Meuse, qui, malgré la dureté des roches d'ardoise et de quartz au travers desquelles elle passe, a coupé le terrain depuis Charleville jusqu'â Givet, à une très-grande profondeur. Dans cette distance, on voit presque par-tout les côtés coupées presque à pic sur la rivière, de deux à trois cents pieds de hauteur perpendiculaire; et comme c'est une règle générale, que plus les côtés sont coupées droites, moins elles sont distantes l'une de l'autre, on conçoit que le canal de la Meuse, dans cette étendue de terrain, doit être fort étroit, eut égard à beaucoup d'autres où il coule un bien moindre volume d'eau. Cela n'empêche pas qu'on n'y aperçoive des marques de la règle général que fait l'eau, et n'y ait taillé des angles saillans et des angles rentrans, qui sont très-grands en certains endroits. Nous verrons que Revin et Fumai, deux lieux principaux des bords de la Meuse, sont situés sur deux de plus grandes de ces ouvertures où se trouvent des platures assez vaste pour permettre, outre un emplacement considérable pour les maisons, l'établissement de beaucoup de jardins, et même des pièces à grain et des prairies. Aussi, quand on arrive sur la tranchée de la Meuse, les lieux et les terrains cultivés qu'on voit dans son fond, paroissent comme séparés sous les autres et comme dans un autre pays.

«Les autres coupures ou ravins de ce pays, quoique moins profonds, offrent cependant cette singularité, remarquée déjà ailleurs, que leurs grandeurs et profondeur ne sont point du tout proportionnées au volume de l'eau qui y coule.

«Le massif sur lequel est situé Beaumont, est coupé presque perpendiculairement à l'ouest, sud-ouest et cette coupe en fait de ce côté-là un rempart inaccessibles, ayant plus de 100 pieds de hauteur. Quand j'ai considéré cette grande coupe, et le détour que fait la petite rivière qui coule au bas de ce massif, je n'ai pus me refuser à croire qu'il n'y avoit en là un bien plus grande courant d'eau, qui a battu et miné ce massif, en s'y brisant avec force; car on ne peut supposer, avec quelque vraisemblance, que cet ouvrage ait été fait par le volume d'eau qui y coule actuellement: et il ne faut pas s'étonner de ce disparate; par-tout vous le trouverez; ce qui démontre évidemment que la quantité d'eau diminue insensiblement, et que la partie solide de notre globe augmente à proportion que la partie liquide diminue; et s'il faut encore étendre ce principe, j'ajouterai, que par-tout vous verrez les bornes de la mer et des rivières reculées; par-tout vous trouverez d'anciens courans d'eau desséchés, et même des rivières considérables, à en juger par les collines ondulées qu'on voit encore. Mais cette partie essentielle de la minéralogie qui est effrayante par les conséquences qu'elle presente, et qui peut influer sur le système général du monde, sera étendue un jour dans un autre memoire, où je décrirai d'anciens cours de rivières de la France, qui n'existent plus. J'espère fair voir alors, appuyé par les faits que me fournira l'histoire, que les rivières et les fleuves actuels ont été plus volumineux qu'ils ne le sont maintenant, et qu'il existoit en France un grande nombre de vastes lacs, comme dans l'Amérique Septentrionale, et dont à peine il nous reste des traces aujourd-hui.»

This opinion of M. Monnet, concerning the diminution of water upon the earth, does not follow necessarily from those appearances which he has mentioned. The surface of the earth is certainly changed by the gradual operations of the running water, and it may not be unfrequent, perhaps, to find a small stream of water in places where a greater stream had formerly run; this will naturally happen upon many occasions, as well as the opposite, by the changes which are produced upon the form of the surface. Likewise the conversion of lakes into plains is a natural operation of the globe, or a consequence of the degradation of the elevated surface of the earth, without there being any reason to suppose that the general quantity of running water upon the land diminishes, or that the boundaries of the various seas are suffering any permanent removal.

Whether we examine the Alps in the Old World, or the Andes in the New, we always find the evidence of this proposition, That the exposed parts of the solid earth are decaying and degraded; that these materials are hauled from the heights to be travelled by the waters over the surface of the earth; and that the surface of the earth is perpetually changing, in having materials moved from one place and deposited in another. But these changes follow rules, which we may investigate; and, by reasoning according to those rules or general laws, upon the present state of things, we may see the operation of those active principles or physical causes in very remote periods of this mundane system, and foresee future changes in the endless progress of time, by which there is, for every particular part, a succession of decay and renovation.

Chapter 13. The Same Subject Continued

The Chevalier de Dolomieu, in his most indefatigable search after natural history and volcanic productions, has given us the description of some observations which are much calculated to put this subject in a conspicuous point of view. I give them here as examples of the operation of water wasting the land and forming valleys in a system where every thing is tending to the wisest end or purpose; but they are no less interesting as proper to give us a view of the mineral operations of the globe. That therefore which, according to the order of the subject, ought to be cited in another part of this work, is here necessarily mixed in the narrative of this natural historian.

There is, upon this occasion, such a connection of the facts by which the mineral operations of the earth, either consolidating the materials deposited at the bottom of the sea, or elevating land by the power of subterraneous heat, are to be understood, and of those by which the operations of the surface are to be explained, that while they cannot be separated in this narration, they throw mutual light upon each other. It is in his Mémoire sur les Volcans éteints du Val di Noto en Sicile. Journal de Physique, Septembre 1784.

«Je trouvai les premiers indices de ces volcans, en allant de Syracuse à Sortino, à une lieue de cette ville, au fond du profond vallon qui y conduit. Quelques morceaux de laves entraînés et arrondis par les eaux m'annoncèrent d'avance que j'allois entrer dans un pay volcanique. Mon attention se fixa bientôt après sur un courant de laves que je vis sortir d'une montagne calcaire qui étoit sur ma droite, il étois coupé par une vallon dont les eaux couloient sur un sol calcaire, et alloit se perdre dans le massif également calcaire qui étoit sur ma gauche. Je passai en suite alternativement sur des matières calcaires et volcaniques, pour arriver à Sortino, ville baronale bâtie sur une montagne calcaire qui domine la vallon, et qui lui presente des escarpemens de plus de 200 toises d'élévation, dans lesquels les banc de pierres dure sont horizontaux, et exactement parallèles.»

Here, it is to be observed, are horizontal beds remaining, which give a measure of what had been abstracted by some cause, which is our present subject of investigation. The Chevalier proceeds:

«Les environs de Sortino m'offrirent des phénomènes et des singularités dont l'explication me parut difficile, et qui tinrent pendant longtemps mon esprit en suspens. Je vis d'abord les matières volcaniques ensevelies sous des bancs horizontaux de pierres calcaires, très-coquillières, contenant surtout une infinité de madréporites, quelques-uns d'un volume énorme. Je vis ensuite des hauteurs dont les sommets seuls étoient volcaniques, et les noyaux calcaires, sans que les laves qui couronnoient ces sommets eussent communication avec aucun courant, et eussent d'autre étendue que le plateau qu'elles recouvroient. Ces laves n'avoient pu être formées où je les voyois; elles étoient venues d'ailleurs; mais d'où et comment? etc. Je me déterminai à consulter les montagnes les plus hautes, qui étoient à quelque distance. J'en vis de loin plusieurs dont la forme étoit à peu-près conique, et dont les sommets étoient pointus; elles étoient vers le nord, ou nord-ouest de Sortino, dans la direction de l'Etna, qui terminoit mon horizon, à une distance de 13 ou 14 lieues, etc.

«La montagne Saint-George, une des plus hautes de tout le canton du sommet de laquelle je pouvois prendre une idée topographique de tous le pays, qui domine tout ce qui entoure, à l'exception de quelques pics calcaires qui lui sont au sud; (tel que celui de la montagne de Boujuan); cette montagne, dis-je, dont la forme est conique, et qui est isolée par des vallées, dont le sol lui étoit sur-abaissé de 3 ou 400 toises, a sa base calcaire. Sur cette première assise repose une couche volcanique, ensuite une autre tranche volcanique calcaire, à laquelle succède un sommet formé d'une lave dure. Une autre montagne auprès du fief de la Copodia, également conique, est toute volcanique, à l'exception d'une couche de pierre calcaire dure et blanche, qui la tranche à moitié hauteur parallèlement à sa base. Quelques montagnes où les couches volcaniques ou calcaires sont plus ou moins nombreuses. La montagne de Pimalia est volcanique à sa base et calcaire à son sommet; et enfin la montagne isolée sur laquelle est bâtie la ville de

Carientini est moitié calcaire et moitié volcanique: mais ici la division des deux substances se fait par un plan verticale, etc. Après être arrivé à cette limite des volcans, dont je poursuivois le foyer, je pris du côté de l'est; je suivis jusqu'à Melilli les hauteurs qui accompagnent la vallée de Lentini, et qui dominent la plaine d'Auguste; et cheminant à mi côté je vis déboucher du milieu des montagnes calcaires, qui, réunies par leur base, ne forme qu'une même groupe, sous le nom de monts Hybleens, *Colles Hyblei*, plusieurs courans de lave qui se terminent comme s'ils avoient été coupés sans avoir eu le temps de descendre dans la vallée, et de s'incliner pour en prendre la pente. Plusieurs de ces courans sont cristallisés en basaltes prismatiques; on en voit de très-belles colonnes au-près de Melilli. Au delà de cette ville jusqu'à Syracuse, on ne voit plus de traces de volcans, et les escarpemens en face du golfe d'Auguste n'offrent qu'un massif calcaire en bancs horizontaux, etc.

«Je revins a Sortino, et en allant visiter l'emplacement de l'ancienne Erbessus, connue maintenant sous le nom de Pentarica, je traversai deux gorges d'une extrême profondeur, dont les encaissemens, taillés presque à pic, ont plus de 600 pieds d'élévation, etc.»

The Chevalier then found, in the mountain of Santa Venere, an extinct volcano; and proceeds in his Memoir to give some explanation for those appearances, as follows:

«Je ne pus pas douter que cette montagne ne fût le volcan que je cherchois, et qui avoit répandus ses laves à une très-grande distance autour de lui, sur-tout dans la partie de l'est; mais il me restoit à résoudre le problème de la formation des montagnes isolées et coniques, mi-parties volcaniques et calcaires, qui ne tiennent à aucune courant, et qui sembloient n'avoir aucune relation directe avec mon volcan. L'étude de la montagne Santa-Venere, et des pays circonvoisins, m'apprit que ce volcan s'étoit élevé au milieu de la mer qui alors occupoit nos continens, que sa tête seule s'étoit soulevée au-dessus du niveau des eaux. Je fus convaincu que, lorsqu'il répandoit autour de lui des torrens de matières enflammées, la mer entassoit des dépôts calcaires; que chaque nouvelle éruption trouvoit un sol plus élevé, sur lequel elle se répandoit; que bientôt les nouvelles matières volcaniques étoient ensevelies sous de nouveaux dépôts, et qu'ainsi, par l'entassement successif et régulier des produit du feu et des dépôts de l'eau, s'étoit formé un énorme massif, á sommet aplati et horizontal. Ce massif occupoit tout le centre du Val di Noto, recouvroit de plusieurs centaines de toises le sol sur lequel s'étoit répandu les premières laves, et fut divisé, morcelé et dégradé par les courans ou par le ballottement des eaux, lors de la grande débâcle du de la catastrophe qui changea l'emplacement des mers. Les vallons et les gorges qui se formèrent au milieu de ce massis, séparèrent les laves de la montagne à qui elles appartenoient, coupèrent les courans, et façonnèrent, avec les débris de ce massif des montagnes de toutes les formes, mais la majeure partie conique, ainsi qu'on peut le voir journellement, lorsque, dans un terrain argilleux et submergé l'eau, se retirant avec précipitation, excave par-tout où elles trouve moins de resistance, creuse les premiers sillons qu'elle a tracés et forme des petits cônes, dont les sommets sont à la hauteur du sol sur lequel reposoient les eaux. Les parties où les laves avoient coulé successivement dans la même direction, les unes au-dessus des autres, ont donné naissance aux montagnes dans lesquelles les couches volcaniques et calcaires se succèdent parallèlement. Celles sur lesquelles aucunes laves ne se sont portées, n'ont produit que des montagnes totalement calcaires que se trouvent entremêlées avec les autres. Celles enfin sur lesquelles le hazard ou des circonstances locales out entasse de préférence, et dans le même lieu, les matières que vomissoit le volcan, sans laisser le temps au dépôt des eaux de se mêler avec elles, ont produit quelques petites montagnes presque entièrement volcanique, où les cendres sont agglutinées par une pâte calcaire, etc. Cette théorie rend raison de tous le phénomènes et de toutes les singularités qui s'observent dans le mélange des produits du feu et des dépôts de l'eau, et une infinité de preuves de differens genres, mais qui seroient étrangères à ce Memoire, concourent à démontrer, l'existence d'un ancien plateau qui étoit élevé de plusieurs centaines de toises au-dessus du sol actuel des vallées et du niveau de la mer, qui couvroit non seulement le Val *di Noto*, mais encore toute la Sicile, et dont les débris ont formé toutes les montagnes actuellement existantes, à l'exception de l'Etna.»

It is not the explanation here given by the Chevalier de Dolomieu, of the manner in which this great mass of land was formed in the sea, that is concerned with the subject at present under our examination, but certain facts set forth in the Memoir, and a certain conclusion which is there endeavoured to be drawn from those interesting facts[74]. This will be understood by considering; first, it is on all hands acknowledged, that the stratified matter of the globe was successively deposited in the bottom of the sea; secondly, it is also agreed, that this great mass of Sicily, formed originally under the sea, was afterwards placed in the atmosphere, whether by the retreat of the sea or by the elevation of the land; and now, lastly, we are of one mind with respect to the present shape of things, as having been produced by the wasting away of great part of that mass which had been once continued all over the island, as high at least as the tops of the mountains, *i.e.* about a mile above the level of the sea; we only differ in the time and agents which have been employed in this Operation.

On the one hand, the Memoir now before us represents this great effect as belonging to an unknown cause, so far as we are ignorant of that grand *débacle* or *catastrophe* which changed the situation of the sea. On the other hand, the Theory now proposed explains this operation, of forming those conical mountains of Sicily, and hollowing out its valleys, by known causes, and by employing powers the most necessary, the most constant, and the most general, that act upon the surface of the earth.

But, besides explaining this change of land and water by an unknown cause, our author has here employed, for the removing of this mass of solid rock, powers which appear to me no ways adequate to the end proposed. The running of water upon the soft mud left by a river, given here as an example, corresponds indeed in some respects with the form of valleys; for, water acts upon the same principle, whether it makes a channel through the subtile sediment of a river, or through the travelled materials of a valley. But it is not here that there is any difficulty in conceiving the rivers of Sicily to have shaped the mountains and the valleys; it is in removing the masses of

[74] In the first part of this work, the distinction has been made of true volcanic productions, and those which are so frequently confounded with them; these last, though the creatures of subterranean fire, and bodies which have been made to flow in a fluid state, are clearly different from those masses of lava which have issued from a volcano, as has been there described. I would only here observe, that, according to this Theory, these bodies, which the Chevalier de Dolomieu here represented as lava and volcanic production, must be considered as unerupted lavas, which had been made to flow among the strata of the earth, where other at the bottom of the sea, or during those operations by which this land was erected above the level of the ocean.

solid rock, which covered the whole surface of this land in successive strata, that any doubt could occur in ascribing the actual appearances of things to the natural operations of the earth; but it is here particularly that the retreat of the sea, in whatever manner supposed to be done, is altogether incompetent for the purpose which is now considered. I flatter myself, that when the Chevalier de Dolomieu, who has employed his uncommon talents in examining and elucidating the effects of fire in the bowels of those burning mountains, shall consider and examine the effects of time upon the surface of the earth, he will be ready to adopt my opinion, that there is no occasion to have recourse to any unknown cause, in explaining appearances which are every where to be found, although not always attended with such remarkable circumstances as those with which his labours have enriched natural history.

It may be proper to give a view of the operations of nature upon the Apennines. It is from an account of a journey into the province of Abruzzo, by Sir William Hamilton. Phil. Trans. 1786.

The road follows the windings of the Garigliano, which is here a beautiful clear trout stream, with a great variety of cascades and water-falls, particularly a double one at Isola, near which place CICERO had a villa; and there are still some remains of it, though converted into a chapel. The valley is extensive, and rich with fruit trees, corn, vines, and olives. Large tracts of land are here and there covered with woods of oak and chestnut, all timber trees of the largest size. The mountains nearest the valley rise gently, and are adorned with either modern castles towns, and villages, or the ruins of ancient ones. The next range of mountains, rising behind these, are covered with pines, larches, and such trees and shrubs as usually abound in a like situation; and above them a third range of mountains and rocks, being the most elevated part of the Apennine, rise much higher, and, being covered with eternal snow, make a beautiful contrast with the rich valley above mentioned; and the snow is at so great a distance as not to give that uncomfortable chill to the air which I have always found in the narrow valleys of the Alps and the Tyrol.

Having thus examined the alpine countries both of the Old World and the New, it remains to observe some river in a more low or level country emptying itself into a sea that does not communicate with the ocean. The Wolga will now serve for this purpose; and we shall take our facts from the observations of those men of science who were employed by their enlightened Sovereign to give the natural as well as the economical history of her dominions.

Russia may be considered as a square plain, containing about 40 degrees of longitude, and 20 of latitude, that is, between the 47° and 67° degrees. The east side is bounded by the Oural mountains, running in a straight line from north to south. The west is bounded by Poland. The south reaches to the Caspian and Black Seas, as does the north to the Polar Ocean.

The greatest part of the water which falls upon this extensive country is delivered into the Caspian by the river Wolga; and this water runs from the east and west sides, gathered in two great rivers, the Kama and the Oka. The water thus gathered from the two opposite extremities of this great kingdom meet in the middle with the Wolga, which receives its water from the north side. We thus find the water of this great plain running in all directions to its centre. Had this been the lowest place, here would have been formed a sea or lake. But this water found a lower place in the bed of the Caspian; and into this bason it has made its way, in forming to itself a channel in the great plain of the Wolga.

Our present purpose is to show that this channel, which the Wolga has cut for itself, had been once a continued mass of solid rock and horizontal strata, which in the course of time has been hollowed out to form a channel for those waters. These waters have been traversing all that plain, and have left protuberances as so many testimonies of what had before existed; for, we here find the horizontal strata cut down and worn away by the rivers.

M. Pallas gives us very good reason to believe that the Caspian Sea had formerly occupied a much greater extent than at present; there are the marks of its ancient banks; and the shells peculiar to the Caspian Sea are found in the soil of that part of its ancient bottom which it has now deserted, and which forms the low saline *Steppe*. He also makes it extremely probable that the Caspian then communicated with the Euxine or Black Sea, and that the breaking through of the channel from the Euxine into the

Mediterranean had occasioned the disjunction of those seas which had been before united, as the surface of the Caspian is lowered by the great evaporation from that sea surrounded with dry deserts.

However that may he, it is plain, that throughout all this great flat inland country of Russia, the solid rocks are decaying and wearing away by the operation of water, as certainly, though perhaps not so rapidly, as in the more mountainous regions of the earth.

If there is so much of the solid parts worn and washed away upon the surface of this earth, as represented in our Theory; and if the rivers have run so long in their present courses, it may perhaps be demanded, Why are not all the lakes filled up with soil; and why have not the Black and Caspian Seas become land or marshy ground, with rivers passing through them to the ocean? Here is a question that may be considered either as being general to all the lakes upon the earth, or as particular to every lake which should thus find a proper explanation in the Theory. With regard to the last of these, the question has already been considered in this view, when the particular case of the Rhône was taken as an example; and now we are only to consider the question as general to the globe, or so far as belonging to the Theory, without particularising any one case.

It must be evident, that the objection to the Theory, here supposed to be made, is founded necessarily upon this, that the solid basis of our continent, on whose surface are found the lakes in question, is preserved without change, because, otherwise, the smallest variation in the basis may produce the most sensible effects upon the surface; and in this manner might be produced dry land where there had been a lake, or a lake where none had been before. But, as the present Theory is founded upon no such principle of stability in the basis of our land, no objection, to the wasting operations of the surface of the earth, can be formed against our Theory, from the consideration of those lakes, when the immediate cause of them should not appear.

The natural tendency of the operations of water upon the surface of this earth is to form a system of rivers every where, and to fill up occasional lakes. The system of rivers is executed by wearing and wasting away the surface of the earth; and this, it must be allowed, is perfect or complete, at least so far as consistent with another system, which would also appear to be in nature. This is a system of lakes with which the rivers are properly connected. Now, as there are more way than one by which a lake may be formed, consistent with the Theory, the particular explanation of every lake must be left to the natural history of the place, so far as this shall be found sufficient for the purpose.

There are many places which give certain appearances, from which it is concluded, by most intelligent observators, that there had formerly existed great lakes of fresh water, which had been drained by the discharge of those waters through conduits formed by some natural operation; and those naturalists seem to be disposed to attribute to some great convulsion, rather than to the slow operation of a rivulet, those changes which may be observed upon the surface of the earth. Let us now examine some of those appearances, in order to connect them with that general system of moving water which we have been representing as every where modifying the surface of the earth on which we dwell.

It is the P. Chrysologue De Gy, who gives the following description. Journal de Physique, Avril 1787.

«La principaute de Porrentrui l'emporte encore en ce genre sur le reste du Jura à ce qu'il paroît. On pourra en juger sur les circonstances locales que je vais rapporter. Une partie de cette principauté est divisée en quatre grandes vallées, d'environs quatre lieues de long, sur trois quarts-d'heure ou une heure de large, séparées par autant de chaînes de montagnes fort élevés et large en quelques endroits d'une lieue et demie. Les extrémités de chacune de ces vallées sont plus élevées que le milieu, et on ne peut pas en sortir par ces extrémités sans beaucoup monter. Mais ces vallées ont des communications entr'elles par une pente assez douce à travers ces masses énormes de montagnes qui les separent, et qui sont coupées au niveau du milieu des vallées sur 300, 400, 500 toises de hauteur et dans toute leur largeur. On pourroit assez justement comparer ces vallées à des berceaux posés les uns à côté des autres, dont les extrémités, remplies en talus, seroient plus élevés que les cotés, et dont ces côtés seroient coupés jusqu'au fond, pour laisser une passage de l'un à l'autre. Je connois sept à huit passages semblables à travers ces hautes montagnes, dans une quarré d'environ quatre à cinq lieues; et dont quatre aboutissent à la vallée de Mouthier-Grand-Val. Ces passages sont évasés dans le dessus, d'environ une demi-lieue par endroits; mais leurs parois, en talus, se rejoignent dans le fond où coule un ruisseau. On a pratiqué des routes sur quelques-uns de ces talus, mais les roches sont quelquefois si resserrées et si escarpées, qu'on a été obligé de construire un canal sur le ruisseau, pour y faire passer la route. C'est-là que l'on voit à son aise, la nature de ces rochers primitives, leur direction, leur inclinaison, et tous leurs autres accidens qui demanderaient chacun une dissertation particulière trop longue pour le moment, et il faut les avoir vues pour se faire une juste idée des sentimens de grandeur, de surprise, et d'admiration qu'elles inspirent, et que l'on ne peut pas exprimer par des paroles. Cependant, les sources de ruisseaux, ou si l'on veut des rivières qui traversent ces montagnes, sont beaucoup plus basses que les sommités des montagnes elles-mêmes, ces sources ne font donc pas la cause de ces effets merveilleux. Il a fallu un agent plus puissant pour creuser ces abîmes.»

M. de la Metherie has taken a very enlightened view of the country of France; and has given us a plan of the different ridges of mountains that may be traced in that kingdom, (Journal de Physique, Janvier 1787). Now there is a double purpose in natural history to which such a plan as this may be applied; viz. first, to trace the nature of the solid parts, on which the soil for vegetation rests; and, secondly, to trace the nature of the soil or cultivated surface of the earth, on which depends the growth of plants.

With regard to the first, we may see here the granite raising up the strata, and bringing them to the light, where they appear on each side of those centrical ridges. What M. de la Metherie calls *Monts Secondaires*, I would call the proper strata of the globe, whether primary or secondary; and the *Monts Granit*, I would consider as mineral masses, which truly, or in a certain sense, are secondary, as having been made to invade, in a fluid state, the strata from below, when they were under water; and which masses had served to raise the country above the level of the ocean.

But this is not the subject here immediately under consideration; we are now tracing the operations of rivers upon the surface of the earth, in order to see in the present state of things a former state, and to explain the apparent irregularity of the surface and confusion of the various mineral bodies, by finding order in the works of nature; or a general system of the globe, in which the preservation of the habitable world is consulted.

For this last purpose also the mineral map of M. de la Metherie is valuable. It gives us a plan of the valleys of the great rivers, and their various branches, which, however infinitely ramified, may be considered as forming each one great valley watered, or rather drained, by its proper river. But the view I would now wish to take of those valleys, is that of habitable and fertile countries formed by the attrition of those rivers; and to perceive the operation of water wearing down the softer and less solid parts, while the more hard and solid rocks of the ridges, as well as scattered mountains, had resisted and preserved a higher station.

In this map, for example, let us suppose the first and second ridge of our author's plan to be joined at the mouth of the Loire, and retain the water of that river, as high as the summit of its surrounding ridges; this great valley of the Loire, which at present is so fine and fertile a country, would become a lake; in like manner as the proper valley of the Rhône, above St Maurice, would be drowned by shutting up that gap of the mountains through which the Rhône passes in order to enter the plain of Geneva.

This is the view that P. Chrysologue takes of those small valleys formed between the ridges of the Jura. But this is not perhaps the just view of the subject; for though by closing the gap by which the Loire or Rhône, passes through the inclosing ridge, the present country above would certainly be overflowed by the accumulated waters, yet it is more natural to suppose, that the great gap of the Loire, or the Rhône, had been formed gradually, in proportion as the inclosed country had been worn down and transported to the sea. We have but to consider, that the attrition of those transported materials must have been as necessary for the hollowing out of those gaps in the solid rock of the obstructing mountains, as the opening of those gaps may have been for the transporting of those materials to the sea. But it is perhaps impossible, from the present appearance of things, to see what revolutions may have happened to this country in the course of its degradation; what lakes may have been formed; what mountains of softer materials may have been levelled; and what basons of water filled up and obliterated.

This general view of the valley of the Loire, and all its branches, is perhaps too extensive to be admitted in this reasoning from effect to cause; we must approximate it by an intermediate step, which will easily be acknowledged as entering within the rule. It is in Forrez, near the head of the Loire. There we find the plain of Mont Brison, 40,000 toises or 22 miles long and half as wide, surrounded by a ridge of granite mountains on every side. Here the river, which is a small branch of the Loire, enters at the upper end of the plain (as M. de Bournon has described) [75] «Par une gorge très étroite et tortueuse,» and goes out in like manner at the under End.

Those French philosophers, who have seen this plain, have little doubts of this having been a lake, that is to say, they easily admit of the original continuity of those ridges of mountains in which the gaps are now found, through which the river passes. But upon those principles it must be evident, that the river has hollowed out that plain, at the same time that it had formed the gaps in those ridges of the granite mountains. The only solid part, or original stratum, which M. de Bournon has described as having seen in this plain, is a decomposing *grès* or sandstone; but there is reason to suppose, that there had been both calcareous and argillaceous or marly strata filling the hollow of that space which is inclosed by the granite mountains; consequently, no difficulty in conceiving that the river, which must wear away a passage through those mountains, should also hollow out the softer materials within, and thus form the plain, or rather a succession of plains, in proportion as the level of the water had been lowered with the wearing mountains.

If we are allowed to make this step, which I think can hardly be refused, we may proceed to enlarge our view, by comprehending, first, the Vallais of the Rhône, secondly, the countries of the Seine and Rhône, above the mountains through which those two rivers in conjunction have broke, below Lyons; and, lastly, that country of the Rhône and Durance which is almost inclosed by the surrounding mountains, meeting at the mouth of the Rhône.

[75] Journal de Physique, Mai 1787.

But this reasoning will equally apply to the countries of the Garonne, the Loire, and the Seine.

One observation more may now be made with regard to the courses of great rivers, and the fertile countries which they form in depositing the travelled soil; it is this. That though those rivers have hollowed out their beds and raised their banks; though they are constantly operating in forming fertile soil in one place and destroying it in another; and though, in many particular situations, the fertile countries, formed at the mouths of those rivers, are visibly upon the increase, yet the general progress of those operations is so slow, that human history does not serve to give us information almost of any former state of things. The Nile will serve as an example of this fact.

The river Nile, which rises in the heights of Ethiopia, runs an amazing tract through desert countries, and discharges its waters near the bottom of the Mediterranean sea, fertilizes a long valley among barren countries with which it is surrounded, and thus lays the foundation of a kingdom, which, from its situation and the number of people it can maintain and easily bring together for any manner of action, is perhaps the strongest that can well be imagined. Accordingly, it has been of old a great kingdom, that is to say, a powerful state within itself; and has left monuments of this power, which have long been the admiration of the world. The most ancient Grecian Histories mention these monuments as being no better known, with regard to their dates and authors, than they are at this day.

The conclusion here meant to be drawn is this, that, in a period of time much more ancient than the most ancient periods in human history, Egypt had been a country formed and watered by the Nile in like manner as it is at present; that though continual changes are making in this as well as in every other river, yet, on the whole, no sensible alteration can be discerned within the compass of human experience, consequently, it is only by considering, in a scientific manner, the nature of things, and making allowances for operations which have taken place in time past, that any competent judgment can be formed of the present shape and condition of countries, or of any particular place upon the surface of this earth, so far as regards its date, its causes, or its future state. Nothing, almost, but the kingdom of

Egypt would have formed those stupendous monuments of art and labour; and nothing but the present state of Egypt, fertilised by the Nile, could have formed that powerful kingdom which might execute those works.

Thus there is a system of mountains and valleys, of hills and plains, of rivulets and rivers, all of which are so perfectly connected, and so admirably proportioned, in their forms and quantities, like the arteries and veins of the animal body, that it would be absurd to suppose any thing but wisdom could have designed this system of the earth, in delivering water to run from the higher ground; or that any thing could have formed this beautiful disposition of things but the operation of the most steady causes; operations which, in the unlimited succession of time, has brought to our view scenes which seem to us to have been always, or to have been in the original construction of this earth.

To suppose the currents of the ocean to have formed that system of hill and dale, of branching rivers and rivulets, divided almost *ad infinitum*, which assemble together the water poured at large upon the surface of the earth, in order to nourish a great diversity of animals calculated for that moving element, and which carry back to the sea the superfluity of water, would be to suppose a systematic order in the currents of the ocean, an order which, with as much reason, we might look for, in the wind. The diversity of heights upon the surface of the earth, and of hardness and solidity in the masses of which the land is formed, is doubtless governed by causes proper to the mineral kingdom, and independent either of the atmosphere or sea; but the form and structure by which the surface of the earth is fitted peculiarly to the purpose of this living world, in giving a fertility which sustains both plants and animals, is only caused by those powers which work upon the surface of the earth,—those powers, the operation of which men in general see with indifference every day, sometimes with horror or apprehension.

The system of sustaining plants and animals upon a surface where fertility abounds, and where even the desert has its proper use, is to be perceived from the summit of the mountain to the shore within the region of the sea; and although we have principally taken the Alps, or alpine situations, for particular examples, in illustrating this operation of the waters upon the surface of the earth, it is because the effects are here more obvious to every inquirer, and not because there is here to be acknowledged any other principle than that which is to be found on all the surface of the earth, a principle of generation in one sense, and of destruction in another.

We may also find in this particular, a certain degree of confirmation to another part of the same theory; a part which does not come so immediately within our view, and concerning which so many contradictory hypotheses have been formed. Naturalists have supposed a certain original construction of mountains, which constitution of things, however, they never have explained; they have also distinguished those which have evidently been formed in another manner, that is to say, those the materials of which had been collected in the ocean. Now, here are two things perfectly different; on the one hand original mountains formed by nature, but we know not how, endued with solidity, but not differing in this respect from those of a posterior formation; on the other hand, secondary mountains, formed by the collection of materials in the sea, therefore, not having solidity as a quality inherent in their constitution, but only occasional or accidental in their nature. If, therefore, it be the natural constitution of things upon the surface of this earth to indurate and become solid, however originally formed loose and incoherent, we should thus find an explanation of the consolidation of those masses which had been lately formed of the loose materials of the ocean; if, on the contrary, we find those pretended primitive mountains, those bodies which are endued with hardness and solidity, wasting by the hand of time, and thus wearing in the operations natural to the surface of the earth, Where shall we find the consolidating operations, those by which beds of shells have been transformed into perfect marble, and siliceous bodies into solid flint? or how reconcile those opposite intentions in the same cause?

Nothing can be more absurd than to suppose a collection of shells and corals, amassed about the primitive mountains of the earth, to become mountains equally solid with the others, upon the removal of the sea; it would be inconsistent with every principle of sound reasoning to suppose those masses of loose materials to oppose equal resistance to the wasting and destroying operations of the surface of the earth, as do those pretended primitive masses, which might be supposed endued with natural hardness and solidity; yet, consult the matter of fact, and it does not appear that there is any difference to be perceived. There are lofty mountains to be found both of the one kind and the other; both those different masses yield to the wasting operations of the surface; and they are both carried away with the descending waters of the earth.

It is not here meant to affirm, that a mass of marble, which is a calcareous substance, opposes equal resistance, whether to the operations of dissolution or attrition, as a mass composed of granite or of quartz; it is only here maintained that there are in the Alps lofty mountains of marble, as there are in other places lower masses of granite and its accompanying schistus. But that which is particularly to be attended to here is this: In all countries of the earth, whether of primitive masses or those of secondary formation, whether uniform and homogeneous, or compound and mixed of those two different kinds of bodies, the system is always the same, of hills and valleys, lakes and rivers, ravines and streams: no man can say, by looking into the most perfect map, what is primary or what secondary in the constitution of the globe. It is the same system of larger rivers branching into lesser and lesser in a continued series, of smaller rivers in like manner branching into rivulets, and of rivulets terminating at last into springs or temporary streams. The principle is universal; and, having learned the natural history of one river, we know the constitution of every other upon the face of the earth.

Thus all the surface of this earth is formed according to a regular system of heights and hollows, hills and valleys, rivulets and rivers, and these rivers return the waters of the atmosphere into the general mass, in like manner as the blood, returning to the heart, is conducted in the veins. But as the solid land, formed at the bottom of the sea or in the bowels of the earth, could not be there constructed according to that system of things which we find so widely pursued upon the surface of the globe, it must be by wasting the solid parts of the land that this system of the surface has been formed, in like manner as it is by the operations of the sea that the shape of the land is determined, upon the shore.

Thus it has been shown, that the general tendency of the operations natural to the surface of the globe is to wear the surface of the earth, and waste the land; consequently that, however long the continents of this earth may be supposed to last, they are on the whole in a constant state of diminution and decay; and, in the progress of time, will naturally disappear. Hence confirmation is added to that mineral system of the earth, by which the present land is supposed to have acquired solidity and hardness; and according to which future land is supposed to be preparing from the materials of the sea and former continents; which land will be brought to light in time, to supply the place of that which necessarily wastes, in serving plants and animals. But what is here more particularly to the purpose is this; that we find an explanation of that various shape and conformation which is to be observed upon the surface of this earth, as being the effect of causes which are constant and unremitting in their operation, which are widely adapted to the end or absolutely necessary in the system of this world, and which, in the indefinite course of time, become unlimited in their effect, or powerful in any conceivable degree.

It is not sufficient for establishing the present theory, to refute that most unscientific hypothesis, adopted by some eminent philosophers, of mountains and valleys being the effect of currents in the ocean; it is necessary to see what is their proper cause, and to show that by no other cause known could the general effect, which is of such importance in the system of this world, be actually produced. It is for this reason that we have endeavoured to show that there is a general, an universal system of river and valley, which renders the surface of this earth a sort of organized body destined to a purpose which it perfectly fulfils.

But to see the full force of this argument, taken from that order of things which is perceived in that system of valley and river all over the earth, let us examine, first, what would be the effect, in the constitution of this world, of bodies of land formed upon no such system; and, secondly, what would be the effect of the natural constitution of this world and meteorological operations of the atmosphere, if continued for a sufficient length of time, upon a mass of land without any systematic form.

For this purpose we shall take for example a portion of this earth, which is the best known to us, that is the south-western part of Europe, in order to compare its present state, which so perfectly fulfils the purpose of this world, with that in which no order of valley and of rivers should be fund.

Let us begin at the summit, which is the Mont-Blanc. At present the water, falling from the heavens upon this continent, is gathered into a system of rivers which run through valleys, and is delivered at last into the Adriatic, the Mediterranean, the Atlantic, and the German Seas; all the rest of this continent, except some lakes and marshes, is dry land, properly calculated, for the sustenance of a variety of plants and animals, and so fulfils the purpose of a habitable earth. Now, destroy that system of river and valley, and the whole would become a mixture of lakes and marshes, except the summits of a few barren rocks and mountains. No regular channels for conveying the super-abundant water being made, every thing must be deluged, and nothing but a system of aquatic plants and animals appear. A continent of this sort is not found upon the globe; and such a constitution of things, in general, would not answer the purpose of the habitable world which we possess. It is therefore necessary to modify the surface of such a continent of land, as had been formed in the sea, and produced, by whatever means, into the atmosphere for the purpose of maintaining that variety of plants and animals which we behold; and now we are to examine how far the proper means for that modification is to be found necessarily in the constitution of this world.

If we consider our continent as composed of such materials as may decay by the influence of the atmosphere, and be moved by water descending from the higher to the lower ground, as is actually the case with the land of our globe, then the water would gradually form channels in which it would run from place to place; and those channels, continually uniting as they proceed to the sea or shore, would form a system of rivers and their branchings. But this system of moving water must gradually produce valleys, by carrying away stones and earthy matter in their floods; and those valleys would be changing according to the softness, and hardness, destructability or indestructability of the solid parts below. Still however the system of valley and river would be preserved; and to this would be added the system of mountains, and valleys, of hills and plains, to the formation of which the unequal wearing down of the solids must in a great measure contribute.

Here therefore it is evident, *first*, that the great system upon the surface of this earth, is that of valleys and rivers; *secondly*, that no such system could arise from the operations of the sea when covering the nascent land; *thirdly*, that this system is accomplished by the same means which, are employed for procuring soil from the decaying rocks and strata; and, *lastly*, that however this system shall be interrupted and occasionally destroyed, it would necessarily be again formed in time, while the earth continued above the level of the sea. Whatever changes take place from the operation of internal causes, the habitable earth, in general, is always preserved with the vigour of youth, and the perfection of the most mature age. We cannot see man cultivate the field, without perceiving that system of dry land provided by nature in forming valleys and rivers; we cannot study the rocks and solid strata of the earth, those bulwarks of the field and shore, without acknowledging the provident design of nature in giving as much permanency to our continent, as is consistent with sufficient fertility; and we cannot contemplate the necessary waste of a present continent, without perceiving the means for laying the foundation of another. But the evidence of those truths is not open to a vulgar view; *media* are required, or much reasoning; and between the first link and the last, in this chain, what a distance, from the wasting of hard bodies upon the surface of the earth, to the formation of a solid rock at the bottom of the sea.

Chapter 14. Summary Of The Doctrine Which Has Been Now Illustrated

The system of this earth appears to comprehend many different operations; and it exhibits various powers co-operating for the production of those effects which we perceive. Of this we are informed by studying natural appearances; and in this manner we are led to understand the nature of things, in knowing causes.

That our land, which is now above the level of the sea, had been formerly under water, is a fact for which there is every where the testimony of a multitude of observations. This indeed is a fact which is admitted upon all hands; it is a fact upon which the speculations of philosophers have been already much employed; but it is a fact still more important, in my opinion, than it has been ever yet considered. It is not, however, as a solitary fact that any rational system may be founded upon this truth, That the earth had been formerly at the bottom of the sea; we must also see the nature and constitution of this earth as necessarily subsisting in continual change; and we must see the means employed by nature for constructing a continent of solid land in the fluid bosom of the deep. It is then that we may judge of that design, by finding ends and means contrived in wisdom, that is to say, properly adapted to each other.

We have now given a theory founded upon the actual state of this earth, and the appearances of things, so far as they are changing; and we have, in support of that theory, adduced the observations of scientific men, who have carefully examined nature and described things in a manner that is clear and intelligible. We are now to take a review of the principle points on which this theory hangs; and to endeavour to point out the importance of the subject, and the proper manner of judging with regard to a theory of the earth, how far it is conform to the general system of nature, which has for object a world.

If it should be admitted, that this earth had been formed by the collection of materials deposited within the sea, there will then appear to be certain things which ought to be explained by a theory, before that theory be received as belonging to this earth. These are as follows:

First, We ought to show how it came about that this whole earth, or by far the greatest part in all the quarters of the globe, had been formed of transported materials collected together in the sea. It must be here remembered, that the highest of our mountainous countries are equally formed of those travelled materials as are the lowest of our plains; we are not therefore to have recourse to any thing that we see at present for the origin of those materials which actually compose the earth; and we must show from whence had come those travelled materials, manufactured by water, which were employed in composing the highest places of our land.

Secondly, We must explain how those loose and incoherent materials had been consolidated, as we find they are at present. We are not here to allow ourselves the liberty, which naturalists have assumed without the least foundation, of explaining every thing of this sort by *infiltration*, a term in this case expressing nothing but our ignorance.

Thirdly, The strata are not always equally consolidated. We often find contiguous strata in very different states with respect to solidity; and sometimes the most solid masses are found involved in the most porous substance. Some explanation surely would be expected for this appearance, which is of a nature so conclusive as ought to attract the attention of a theorist.

Fourthly, It is not sufficient to show how the earth in general had been consolidated; we must also explain, how it comes to pass that the consolidated bodies are always broken and intersected by veins and fissures. In this case, the reason commonly given, that the earth exposed to the atmosphere had shrunk like moist clay, or contracted by the operation of drying, can only show that such naturalists have thought but little upon the subject. The effect in no shape or degree corresponds to that cause; and veins and fissures, in the solid bodies, are no less frequent under the level of the sea, than on the summits of our mountains.

Fifthly, Having found a cause for the fracture and separation of the solid masses, we must also tell from whence the matter with which those chasms are filled, matter which is foreign both to the earth and sea, had been introduced into the veins that intersect the strata. If we fail in this particular, What credit could be given to such hypotheses as are contrived for the explanation of more ambiguous appearances, even when those suppositions should appear most probable?

Sixthly, Supposing that hitherto every thing had been explained in the most satisfactory manner, the most important appearances of our earth still remain to be considered. We find those strata that were originally formed continuous in their substance, and horizontal in their position, now broken, bended, and inclined, in every manner and degree; we must give some reason in our theory for such a general changed state and disposition of things; and we must tell by what power this event, whether accidental or intended, had been brought about.

Lastly, Whatever powers had been employed in preparing land, while situated under water, or at the bottom of the sea, the most powerful operation yet remains to be explained; this is the means by which the lowest surface of the solid globe was made to be the highest upon the earth. Unless we can show a power of sufficient force, and placed in a proper situation for that purpose, our theory would go for nothing, among people who investigate the nature of things, and who, founding on experience, reason by induction from effect to cause.

Nothing can be admitted as a theory of the earth which does not, in a satisfactory manner, give the efficient causes for all these effects already enumerated. For, as things are universally to be acknowledged in the earth, it is essential in a theory to explain those natural appearances.

But this is not all. We live in a world where order every where prevails; and where final causes are as well known, at least, as those which are efficient. The muscles, for example, by which I move my fingers when I write, are no more the efficient cause of that motion, than this motion is the final cause for which the muscles had been made. Thus, the circulation of the blood is the efficient cause of life; but, life is the final cause, not only for the circulation of the blood, but for the revolution of the globe: Without a central luminary, and a revolution of the planetary body, there could not have been a living creature upon the face of this earth; and, while we see a living system on this earth, we must acknowledge, that in the solar system we see a final cause.

Now, in a theory which considers this earth as placed in a system of things where ends are at least attained, if not contrived in wisdom, final causes must appear to be an object of consideration, as well as those which are efficient. A living world is evidently an object in the design of things, by whatever Being those things had been designed, and however either wisdom or folly may appear in that design. Therefore the explanation, which is given of the different phenomena of the earth, must be consistent with the actual constitution of this earth as a living world, that is, a world maintaining a system of living animals and plants.

Not only are no powers to be employed that are not natural to the globe, no action to be admitted of except those of which we know the principle, and no extraordinary events to be alledged in order to explain a common appearance, the powers of nature are not to be employed in order to destroy the very object of those powers; we are not to make nature act in violation to that order which we actually observe, and in subversion of that end which is to be perceived in the system of created things. In whatever manner, therefore, we are to employ the great agents, fire and water, for producing those things which appear, it ought to be in such a way as is consistent with the propagation of plants and life of animals upon the surface of the earth. Chaos and confusion are not to be introduced into the order of nature, because certain things appear to our partial views as being in some disorder. Nor are we to proceed in feigning causes, when those seem insufficient which occur in our experience.

Animal life being thus considered as an object in the view of nature, we are to consider this earth as being the means appointed for that end; and then the question is suggested, How far wisdom may appear in the constitution of this earth, as being *means* properly adapted to the system of animal life, which is evidently the end. This is taking for granted, that there is a known system of the earth which is to be tried—how far properly adapted to the end intended in nature. But, it is this very system of the earth which is here the subject of investigation; and, it is in order to discover the *true system* that we are to examine, by means of final causes, every theory which pretends to show the nature of that system, or to assign efficient causes to physical events.

Here then we have a rule to try the propriety of every operation which should be acknowledged as in the system of nature, or as belonging to the theory of this earth. It is not necessary that we should see the propriety of every natural operation; our natural ignorance precludes us from any title to form a judgment in things of which we are not properly informed; but, no suppositions of events, or explanations of natural appearances, are to be admitted into our Theory, if the propriety of those alledged operations is not made to appear. We are now to make an application.

This earth, which is now dry land, was under water, and was formed in the sea. Here is a matter of fact, and not of theory, so far as it can be made as evident as any thing of which we have not seen the immediate act or execution. But the propriety of this matter of fact is only to be perceived in making the following acknowledgment, That the origin of this earth is necessarily placed in the bottom of the sea. In supposing any other origin to this habitable earth, we would see the impropriety of having it covered with water, or drowned in the sea. But, being formed originally at the bottom of the sea, if we can explain the phenomena of this earth by natural causes, we will acknowledge the wisdom of those means, by which the earth, thus formed at the bottom of the sea, had been perfected in its nature, and made to fulfil the purpose of its intention, by being placed in the atmosphere.

If the habitable earth does not take its origin in the waters of the sea, the washing away of the matter of this earth into the sea would put a period to the existence of that system which forms the admirable constitution of this living world. But, if the origin of this earth is founded in the sea, the matter which is washed from our land is only proceeding in the order of the system; and thus no change would be made in the general system of this world, although this particular earth, which we possess at present, should in the course of nature disappear.

It has already been our business to show that the land is actually wasted universally, and carried away into the sea. Now, What is the final cause of this event?—Is it in order to destroy the system of this living world, that the operations of nature are thus disposed upon the surface of this earth? Or, Is it to perpetuate the progress of that system, which, in other respects, appears to be contrived with so much wisdom? Here are questions which a Theory of the Earth must solve; and here indeed, must be found the most material part by far of any Theory of the Earth. For, as we are more immediately concerned with the operations of the surface, it is the revolutions of that surface which forms, for us, the most interesting subject of inquiry.

Thus we are led to inquire into the final cause of things, while we investigate an operation of such magnitude and importance, as is that of forming land of sea, and sea of land, of apparently reversing nature, and of destroying that which is so admirably adapted to its purpose. Was it the work of accident, or effect of an occasional transaction, that by which the sea had covered our land? Or, Was it the intention of that Mind which formed the matter of this globe, which endued that matter with its active and its passive powers, and which placed it with so much wisdom among a numberless collection of bodies, all moving in a system? If we admit the first, the consequence of such a supposition would be to attribute to chance the constitution of this world, in which the systems of life and sense, of reason and intellect, are necessarily maintained. If again we shall admit, that there is intention in the cause by which the present earth had been removed from the bottom of the sea, we may then inquire into the nature of that system in which a habitable earth, possessed of beauty, arranged in order, and preserved with economy, had been formed by the mixture and combination of the different elements, and made to rise out of the wreck of a former world.

In examining the structure of our earth, we find it no less evidently formed of loose and incoherent materials, than that those materials had been collected from different parts, and gathered together at the bottom of the sea. Consequently, if this continent of land, first collected in the sea, and then raised above its surface, is to remain a habitable earth, and to resist the moving waters of the globe, certain degrees of solidity or consolidation must be given to that collection of loose materials; and certain degrees of hardness must be given to bodies which were soft or incoherent, and consequently so extremely perishable in the situation where they now are placed.

But, at the same time that this earth must have solidity and hardness to resist the sudden changes which its moving fluids would occasion, it must be made subject to decay and, waste upon the surface exposed to the atmosphere; for, such an earth as were made incapable of change, or not subject to decay, could not afford that fertile soil which is required in the system of this world, a soil on which depends the growth of plants and life of animals,—the end of its intention.

Now, we find this earth endued precisely with that degree of hardness and consolidation, as qualifies it at the same time to be a fruitful earth, and to maintain its station with all the permanency compatible with the nature of things, which are not formed to remain unchangeable.

Thus we have a view of the most perfect wisdom, in the contrivance of that constitution by which the earth is made to answer, in the best manner possible, the purpose of its intention, that is, to maintain and perpetuate a system of vegetation, or the various race of useful plants, and a system of living animals, which are in their turn subservient to a system still infinitely more important, I mean, a system of intellect. Without fertility in the earth, many races of plants and animals would soon perish, or be extinct; and, without permanency in our land, it were impossible for the various tribes of plants and animals to be dispersed over all the surface of a changing earth. The fact is, that fertility, adequate to the various ends in view, is found in all the quarters of the world, or in every country of the earth; and, the permanency of our land is such, as to make it appear unalterable to mankind in general, and even to impose upon men of science, who have endeavoured to persuade us that this earth is not to change. Nothing but supreme power and wisdom could have reconciled those two opposite ends of intention, so as both to be equally pursued in the system of nature, and both so equally attained as to be imperceptible to common observation, and at the same time a proper object for the human understanding.

We thus are led to inquire into the efficient causes of this constitution of things, by which solidity and stability had been bestowed upon a mass of loose materials, and by which this solid earth, formed first at the bottom of the sea, had been placed in the atmosphere, where plants and animals find the necessary conditions of their life.

Now, we have shown, that subterraneous fire and heat had been employed in the consolidation of our earth, and in the erection of that consolidated body into the place of land. The prejudices of mankind, who cannot see the steps by which we come at this conclusion, are against the doctrine; but, prejudice must give way to evidence. No other Theory will in any degree explain appearances, while almost every appearance is easily explained by this Theory.

We do not dispute the chymical action and efficacy of water, or any other substance which is found among the materials collected at the bottom of the sea; we only mean to affirm, that every action of this kind is incapable of producing perfect solidity in the body of earth in that situation of things, whatever time should be allowed for that operation, and that whatever may have been the operations of water, aided by fire, and evaporated by heat, the various appearances of mineralization, (every where presented to us in the solid earth, and the most perfect objects of examination), are plainly inexplicable upon the principle of aqueous solution. On the other hand, the operation of heat, melting incoherent bodies, and introducing softness into rigid substances which are to be united, is not only a cause which is proper to explain the effects in question, but also appears, from a multitude of different circumstances, to have been actually exerted among the consolidated bodies of our earth, and in the mineral veins with which the solid bodies of the earth abound.

The doctrine, therefore, of our Theory is briefly this, That, whatever may have been the operation of dissolving water, and the chymical action of it upon the materials accumulated at the bottom of the sea, the general solidity of that mass of earth, and the placing of it in the atmosphere above the surface of the sea, has been the immediate operation of fire or heat melting and expanding bodies. Here is a proposition which may be tried, in applying it to all the phenomena of the mineral region; so far as I have seen, it is perfectly verified in that application.

We have another proposition in our Theory; one which is still more interesting to consider. It is this, That as, in the mineral regions, the loose or incoherent materials of our land had been consolidated by the action of heat; so, upon the surface of this earth exposed to the fluid elements of air and water, there is a necessary principle of dissolution and decay, for that consolidated earth which from the mineral region is exposed to the day. The solid body being thus gradually impaired, there are moving powers continually employed, by which the summits of our land are constantly degraded, and the materials of this decaying surface travelled towards the coast. There are other powers which act upon the shore, by which the coast is necessarily impaired, and our land subjected to the perpetual incroachment of the ocean.

Here is a part of the Theory with which every appearance of the surface may be compared. I am confident that it will stand the test of the most rigid examination; and that nothing but the most inconsiderate judgment may mistake a few appearances, which, when properly understood, instead of forming any subject of objection to the Theory, will be found to afford it every reasonable support or confirmation.

We have now seen, that in every quarter of the globe, and in every climate of the earth, there is formed, by means of the decay of solid rocks, and by the transportation of those moveable materials, that beautiful system of mountains and valleys, of hills and plains, covered with growing plants, and inhabited by animals. We have seen, that, with this system of animal and vegetable economy, which depends on soil and climate, there is also a system of moving water, poured upon the surface of the earth[76], in the most beneficial manner possible for the use of vegetation, and the preservation of our soil; and that this water is gathered together again by running to the lowest place, in order to avoid accumulation of water upon the surface, which would be noxious.

[76] See Dissertations upon Subjects of Natural Philosophy, Part I.

It is in this manner that we first have streams or torrents, which only run in times of rain. But the rain-water absorbed into the earth is made to issue out in springs, which run perpetually, and which, gathering together as they run, form rivulets, watering valleys, and delighting the various inhabitants of this earth. The rivulets again are united in their turn, and form those rivers which overflow our plains, and which alternately bring permanent fertility and casual devastation to our land. Those rivers, augmenting in their volume as they unite, pour at last their mighty waters into the ocean; and thus is completed that circulation of wholesome fluids, which the earth requires in order to be a habitable world.

Our Theory farther shows, that in the ocean there is a system of animals which have contributed so materially to the formation of our land. These animals are necessarily maintained by the vegetable provision, which is returned in the rivers to the sea, and which the land alone or principally produces. Thus we may perceive the mutual dependence upon each other of those two habitable worlds,—the fluid ocean and the fertile earth.

The land is formed in the sea, and in great part by inhabitants of that fluid world. But those animals, which form with their *exuviae* such a portion of the land, are maintained, like those upon the surface of the earth, by the produce of that land to which they formerly had contributed. Thus the vegetable matter, which is produced upon the surface of the earth in such abundance for the use of animals, and which, in such various shapes, is carried by the rivers into the sea, there sustains that living system which is daily employed to make materials for a future land.

Here is a compound system of things, forming together one whole living world; a world maintaining an almost endless diversity of plants and animals, by the disposition of its various parrs, and by the circulation of its different kinds of matter. Now, we are to examine into the necessary consequence of this disposition of things, where the matter of this active world is perpetually moved, in that salutary circulation by which provision is so wisely made for the growth and prosperity of plants, and for the life and comfort of its various animals.

If, in examining this subject, we shall find that there is nothing in the system but what is necessary, that is, nothing in the means employed but what the importance of the end requires; if we shall find that the end is steadily pursued, and that there is no deficiency in the means which are employed; and if it shall be acknowledged that the end which is attained is not idle or insignificant, we then may draw this conclusion, That such a system is in perfect wisdom; and therefore that this system, so far as it is found corresponding properly with natural appearances, is the system of nature, and not the creature of imagination.

Let us then take a cursory view of this system of things, upon which we have proceeded in our theory, and upon which the constitution of this world seems to depend.

Our solid earth is every where wasted, where exposed to the day. The summits of the mountains are necessarily degraded. The solid and weighty materials of those mountains are every where urged through the valleys, by the force of running water. The soil, which is produced in the destruction of the solid earth, is gradually travelled by the moving water, but is constantly supplying vegetation with its necessary aid. This travelled soil is at last deposited upon the coast, where it forms most fertile countries. But the billows of the ocean agitate the loose materials upon the shore, and wear away the coast, with the endless repetitions of this act of power, or this imparted force. Thus the continent of our earth, sapped in its foundation, is carried away into the deep, and sunk again at the bottom of the sea, from whence it had originated.

We are thus led to see a circulation in the matter of this globe, and a system of beautiful economy in the works of nature. This earth, like the body of an animal, is wasted at the same time that it is repaired. It has a state of growth and augmentation; it has another state, which is that of diminution and decay. This world is thus destroyed in one part, but it is renewed in another; and the operations by which this world is thus constantly renewed, are as evident to the scientific eye, as are those in which it is necessarily destroyed. The marks of the internal fire, by which the rocks, beneath the sea are hardened, and by which the land is produced above the surface of the sea, have nothing in them which is doubtful or ambiguous. The destroying operations again, though placed within the reach of our examination, and evident almost to every observer, are no more acknowledged by mankind, than is that system of renovation which philosophy alone discovers.

It is only in science that any question concerning the origin and end of things is formed; and it is in science only that the resolution of those questions is to be attained. The natural operations of this globe, by which the size and shape of our land are changed, are so slow as to be altogether imperceptible to men who are employed in pursuing the various occupations of life and literature. We must not ask the industrious inhabitant, for the end or origin of this earth: he sees the present, and he looks no farther into the works of time than his experience can supply his reason. We must not ask the statesman, who looks into the history of time past, for the rise and fall of empires; he proceeds upon the idea of a stationary earth, and most justly has respect to nothing but the influence of moral causes.

It is in the philosophy of nature that the natural history of this earth is to be studied; and we must not allow ourselves ever to reason without proper data, or to fabricate a system of apparent wisdom in the folly of a hypothetical delusion.

When, to a scientific view of the subject, we join the proof which has been given, that in all the quarters of the globe, in every place upon the surface of the earth, there are the most undoubted marks of the continued progress of those operations which wear away and waste the land, both in its height and width, its elevation and extention, and that for a space of duration in which our measures of time are lost, we must sit down contented with this limitation of our retrospect, as well as prospect, and acknowledge, that it is in vain to seek for any computation of the time, during which the materials of this earth had been prepared in a preceding world, and collected at the bottom of a former sea.

The system of this earth will thus appear to comprehend many different operations, or it exhibits various powers co-operating for the production of those appearances which we properly understand in knowing causes. Thus, in order to understand the natural conformation of this country, or the particular shape of any other place upon the globe, it is not enough to see the effects of those powers which gradually waste and wear away the surface, we must also see how those powers affecting the surface operate, or by what principle they act.

Besides, seeing those powers which are employed in thus changing the surface of the earth, we must also observe how their force is naturally augmented with the declivity of the ground on which they operate. Neither is it sufficient to understand by what powers the surface is impaired, for, it may be asked, why, in equal circumstances, one part is more impaired than another; this then leads to the examination of the mineral system, in which are determined the hardness and solidity, consequently, the permanency of those bodies of which our land is composed; and here are sources of indefinite variety.

In the system of the globe every thing must be consistent. The changing and destroying operations of the surface exposed to the sun and influences of the atmosphere, must correspond to those by which land is composed at the bottom of the sea; and the consolidating operations of the mineral region must correspond to those appearances which in the rocks, the veins, and solid stones, give such evident, such universal testimony of the power of fire, in bringing bodies into fusion, or introducing fluidity, the necessary prelude to solidity and concretion.

Those various powers of nature have thus been employed in the theory, to explain things which commonly appear; or rather, it is from things which universally appear that causes have been concluded, upon scientific principles, for those effects. A system is thus formed, in generalising all those different effects, or in ascribing all those particular operations to a general end. This end, the subject of our understanding, is then to be considered as an object of design; and, in this design, we may perceive, either wisdom, so far as the ends and means are properly adapted, or benevolence, so far as that system is contrived for the benefit of beings who are capable of suffering pain and pleasure, and of judging good and evil.

But, in this physical dissertation, we are limited to consider the manner in which things present have been made to come to pass, and not to inquire concerning the moral end for which those things may have been calculated. Therefore, in pursuing this object, I am next to examine facts, with regard to the mineralogical part of the theory, from which, perhaps, light may be thrown upon the subject; and to endeavour to answer objections, or solve difficulties, which may naturally occur from the consideration of particular appearances.