Theory of the Earth, Volume 2 (of 4) eBook

Theory of the Earth, Volume 2 (of 4) by James Hutton

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PART II.

FARTHER INDUCTION OF FACTS AND *OBSERVATIONS, RESPECTING THE GEOLOGICAL PART* OF THE *THEORY*.

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.

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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 I.

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 meme presque partout, les couches descendent tout droit du haut de la montagne jusques a son pied: mais au dessus de Collonge le sommet

arrondi en dos d’ane presente des couches qui descendent de part et d’autre, au sud-est vers les Alpes, et au nord-ouest vers notre vallee; avec cette difference, que celles qui descendent vers les Alpes parviennent jusques au bas; au lieu que celles qui nous regardent sont coupees a pic, a une grande hauteur.

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“Ces deux inclinaisons ne sont pas les seules que l’on observe dans le bancs du mont Saleve, ils en ont encore une troisieme; ils sont releves vers le milieu de la longueur de la montagne, et descendent de la vers ses extremites. Cette pente, qui sur le Grand Saleve n’est pas bien sensible, devient tres remarquable au Petit Saleve, et meme tres rapide a son extremite. Les dernieres couches au nord au dessus d’Etrembieres descendent vers le nord-nord-est, sous un angle de 40 au 50 degres.

“On verra, dans le cours de cet ouvrage, combien le montagnes calcaires ont frequemment cette forme.

“Sec. 235. Outre ces grandes couches qui constituent le corps de la montagne, et qui peuvent en general etre mises dans la classe des couches horizontales, on en trouve d’autres dont l’inclinaison est absolument differente. Elles sont situes au bas de Grande Saleve du cote qui regarde notre vallee; on les voit appliquees contre les tranches inferieures des bancs horizontaux ou tres-inclinees en appui contre la montagne.

“Ces couches s’elevent en quelques endroits, par exemple, entre Veiry et Crevin, a peu-pres a la moitie de la hauteur du Grande Saleve. Celles qui touchent immediatement la montagne, sont le plus inclinees; on en voit la de verticales et meme quelque fois de renversees en sens contraire, qui sont soutenues par le plus exterieures. Celle ci font avec l’horizon un angle de 60 a 65 degres. Ces couches sont souvent tres etendues, bien suivies, et continues a de tres-grandes distances. Leur assemblage forme une epaisseur considerable au pied de la montagne. Elles ont cependant ete rompues, et manquent meme totalement dans quelques places. Cela meme donne la facilite 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 boisee par exemple au dessous de la croisette, le chemin qui de ce hameau descend au village de Collonge, passe sur les couches inclinees, comme celles que je viens de decrire.”

In Sec. 237, the description is continued.

“En suivant le pied de la montagne entre le Coin et Crevin, on voit reparaitre nos couches verticales ou tres inclinees qui vis a vis du Coin, ont ete detruites comme je viens de le dire. Ces couches la ou elles sorte que l’on peut comparer toutes les couches de la montagne a celles d’un jeu de cartes ploye 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 chaines dont il est compose, a mesure qu’ils s’eloignent de la haute ligne orientale perdent graduellement de leur hauteur et de leur continuite; le plus occidentales ne forment pas, comme la premiere, des chaines de montagnes elevee et non interrompues; ce sont des monticules allonges il est vrai, mais isoles ou qui du moins ne sont unis que par leurs bases.

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“Sec. 338. Leur structure n’est pas la meme dans toute l’etendue du Jura. La forme primitive la plus generale ressemble cependant a celles de la haute chaine; c’est-a-dire, que ce sont de voutes, composees et remplies d’arcs concentriques.

“C’est surtout entre Pontarlier et Besancon, que l’on rencontre des collines qui ont regulierement cette structure. La grande route traverse de larges vallees, dans lesquelles les couches sont horizontales; mais ces vallees sont separees par des chaines peu elevees dont le couches arquees montent jusques au haut de la montagne, et descendent ensuite du cote oppose. On en voit aussi de la meme forme dans la Prevote de Moutier Grand Val. La birs traverse des rochers qui offrent a decouvert la construction interieure des montagnes; les couches de roc forment dans cet endroit des voutes elevees l’une sur l’autre en suivant le contour exterieur de la montagne.—*Dict. Geog. de la Suisse, tom.* 2. *p.* 150.

“D’autres fois le sommet de la montagne est plus aigu que n’est celui d’une voute, et les couches paralelles entr’elles, mais inclinees a l’horizon en sens contraire, presentent dans leur section, la form d’un chevron ou d’un lambda [Greek: L].

“Sec. 339. Mais cette meme structure presente frequemment une singularite remarquable. Ce sont des bancs perpendiculaires a l’horizon qui occupent a-peu-pres le milieu ou le coeur de la montagne et qui separent les couches d’une des faces de celles de la face opposee.

“J’ai observe plusieurs montagnes secondaires, et du Jura et d’ailleurs, et surtout un grande nombre de montagne primitive, dont la structure est la meme[1].”

[Footnote 1: 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.]

“Sec. 340. Les couches perpendiculaires a l’horizon, que l’on rencontre frequemment dans le Jura ont presque toutes leurs plans diriges du nord-nord-est au sud-sud-ouest, suivant la direction generale de cette chaine de montagne. Cette observation est d’une assez grande importance parce qu’elle exclut ou rend du moins improbable l’idee d’un bouleversement.

“J’ai cru pendant long-temps que toutes les couches devoient avoir ete formees dans une situation horizontale, ou peu inclinee a l’horizon, et que celles que l’on rencontre dans une situation perpendiculaire, ou tres-inclinees, avoient ete mises dans cet etat par quelque revolution; mais a force de rencontrer des couches dans cette situation, de les voir dans de montagnes bien conservees, et qui ne paroissoient point avoir subi de bouleversement, et d’observer une grande regularite dans la forme et dans la direction

de ces couches; je suis venu a penser que la nature peut bien avoir aussi forme de ces bancs tres-inclines, et meme perpendiculaire a la surface de la terre.”

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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.

“Sec. 242. Dans quelques endroits du Jura, on voit des especes de demi-cirques formes par des rochers dont le couches sont de portions de la surface d’un meme cone et tendent a un centre commun eleve au dessus de l’horizon.

“Ainsi aupres de Pontarlier, *etc*.

“Sec. 343. Mais il est bien plus frequent de voir des montagnes dont les couches ont la forme d’une demi-voute, et qui vues de profil presentent, comme notre montagne de Saleve, un pente douce d’une cote, et des escarpemens de l’autre.

“Plusieurs vallees du Jura sont situees entre deux chaine de montagnes qui ont cette forme, et qui se presentent reciproquement leur faces escarpees. On croit meme apercevoir quelque correspondance, entre les couches de ces montagnes opposees, et l’on diroit qu’elles furent anciennement unies, et que la partie intermediaire a ete detruite, ou que la montagne s’est fendue du haut en bas, et que ses deux moities se sont ecartees pour faire place a la vallee qu’elles renferment.

“Sec. 346. Pour resumer en peu de mots les idees que je me forme de la structure du Jura; je dirai que je crois qu’il est compose de differentes chaines a-peu-pres paralleles entr’elles, et a celles des Alpes, mais tirant un peu plus du nord au midi: que la chaine la plus elevee et la plus voisine des Alpes, a eu originairement la forme d’une dos d’ane dont les pentes partent du faite, recouvrent les flancs, et descendent jusques au pieds de la montagne: que les chaines suivantes du cote de l’ouest, sont composees de montagnes graduellement moins elevees et moins etendues; que les couches de ces montagnes ont generalement la forme de voutes entieres ou de moitie de voutes; et qu’elles viennent mourir dans des plaines, qui ont pour base des bancs calcaires tout a fait horizontaux de la meme nature que ceux du mont Jura, et qui furent peut-etre 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.

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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.

"Sec. 287. Les pentes rapides des bancs dont est forme le mole, les directions variees de ces memes bancs sont aussi conformes a une observation generale et importante, que le montagnes secondaires sont d'autant plus irregulieres et plus inclinees qu'elles s'approchent plus des primitives.

"A la verite, quelque montagnes calcaires meme a de grandes distances des primitives ont ca et la des couches inclinees et meme quelquefois verticales; mais ces exception locales n'empechent pas qu'il ne soit vrai qu'en general, les bancs calcaires, que l'on trouve dans les plaines qui sont eloignees des hautes montagnes, ont leurs bancs ou horizontaux ou peu inclines; tandis, qu'au contraire, les montagnes qui s'approchent, du centre des grands chaines, n'ont que tres-rarement des couches horizontales, et presentent presque par-tout des couches fortement et diversement inclinees."

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.

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“Sec. 360, a. Le rocher dont j’ai parle (Sec. 354) qui touche celui de la Dole, et qui porte le nom de Vouarne, est d’une structure singuliere. Les bancs dont il est compose sont escarpes, les uns en montant contre le nord-est sous un angle de 40 a 50 degres; les autres en s’elevant contre le sud-est.

“Sec. 361. En avant de ce rocher, du cote l’est, on en voit un autre d’une structure tres remarquable. Il a la forme d’un chevron aigu ou d’un lambda [Greek: L]. on le nomme, sans doute a cause de sa forme, le Rocher de fin Chateau. Les bancs dont il est compose sont tres inclines a l’horizon, et s’appuient reciproquement contre leurs sommites respectives. Les planches que l’on dresse en appui les unes contre les autres pour les faire secher, peuvent donner une idee de la situation de les bancs. Cette forme n’est pas rare dans ces rochers calcaires; mais elle est bien plus frequente encore, et plus decidee dans le rochers primitifs, comme nous le verrons dans la suite.

“Le rocher de fin chateau presente dans cette forme meme une circonstance tres-remarquable; c’est que l’intervalle que les jambes du lambda [Greek: L] laissent entr’elles, est rempli par des couches perpendiculaires a l’horizon. On diroit que ces couches chassees en haut par une force souterraine, ou souleve de part et d’autre, des bancs qui sont demeures appuyes contre elles. Nous avons deja vu des rochers de cette forme, Sec. 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 dela de Contamine on passe sous les ruines du chateau de Faucigny, bati sur le sommet d’un rocher escarpe, qui fait partie de la base du mole. Tant qu’on est immediatement au dessous de ce rocher on ne demele pas bien sa structure; mais apres l’avoir passe, on peut voir a l’aide d’une lunette, qu’il est compose de couches perpendiculaires a l’horizon, et dirigees 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 a l’angle droits ceux des premiers.

“A une bonne demi-lieue de ce chateau on observe, comme au pied du Mont Saleve, une masse de rochers, dont les couches minces, presque perpendiculaires a l’horizon, sont adossees aux escarpemens de couches epaisses 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 a l’horizon et appuyees contre le corps meme de la montagne. Et quoique le Brezon se termine a une petite demi-lieue de la

Bonne Ville, cependant ses couches qui sont appuyees contre le pied de la chaine meridionale, et qui tournent ainsi le dos a l'Arve, continuent de regner jusques au village de Siongy pendant l'espace de pres de deux lieues. Elles sont a la verite coupees par une petite vallee a l'extremite du pied du Brezon, mais elles recommencent au de la de cette coupure.

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“Sec. 446. Cette petite vallee, qui s’ouvre au pied du Brezon, est etroite et tortueuse; les angles saillans engrenees dans les angles rentrans y sont extremement sensibles. Elle conduit au village de Brezon, qui est situe derriere la montagne de ce nom.

“Au dessus de ce village sont de grands et beaux paturages avec des chalets qui ne sont habites qu’en ete, et que l’on nomme les Granges de Solaison. C’est la que j’allois coucher quand je visitois le Brezon et les montagnes voisines. Les granges de Solaison sont dominees, au sud-est par le monts Vergi, chaine calcaire tres elevee, dont j’ai aussi parcouru les sommets qui se voyent des environs de Geneve, sur la droite du mole.

“Cette chaine court du nord-est au sud-ouest, et vient se terminer derriere les montagnes qui bordent notre route a droite.

“Sec. 447. On peut, des environs de Siongy, observer la structure de la derniere montagne de cette chaine; elle est tres remarquable. Les couches horizontales au sommet se courbent presqu’a angles droits, et descendent de la perpendiculairement du cote du nord-ouest. On diroit qu’elles ont ete ployees par une violent effort; on les voit separees et eclatees en divers endroits.

“Sec. 449. Le mole se termine a la jonction du Giffre avec l’Arve; ses dernieres couches descendent avec rapidite dans le lit de cette petite riviere,

“Les montagnes qui suivent le mole, et qui forment apres lui le cote septentrional de la vallee de l’Arve, sont basses et indifferentes, une seule est remarquable par sa forme pyramidale, et par ses couches qui convergent a son sommet, et lui donnent la forme d’un chevron.

“Sec. 450. La ville meme de Cluse est batie sur le pied d’une montagne, dont la structure est tres extraordinaire; on en juge mieux a une certain distance que de la ville meme.

“Cette montagne de forme conique emoussee, ou plutot parabolique, est pour ainsi dire coiffee d’une bande de rochers, qui du haut de sa tete descendent a droite et a gauche jusques a son pied. Ces rochers nuds sont relevees par le fond de verdure dont le reste de montagne est couverte. Ils sont composes de plusieurs bandes paralleles entr’elles; les exterieures sont blanches et epaisses, les interieures sont brunes et plus minces. Le corps meme de la montagne, dont on appercoit ca et la les rochers au travers du bois, qui les couvre, paroi compose de couches irregulieres et diversement inclinees. On pourroit soupconner que cette bande n’est que le reste d’une espece de callote qui vraisemblablement couvroit autrefois toute la montagne.

“Sec. 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 passe avant de traverser l’Arve. On

distingue d’ici le profil des couches de ces rochers; et on reconnoit qu’elles sont presque perpendiculaires a l’horizon.

“Ces couches sont adossees a d’autres couches calcaires et verticales comme elles, mais qui sont la continuation de couches a-peu-pres horizontales: on diroit qu’une force inconnue a ploye a angles droits l’extremite de ces couches, et les a ainsi contrainte a prendre une situation verticale.

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“Sec. 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 tres epais, et composes d’une pierre calcaire grise; qu’au dessus cette pierre grise on en voit une autre de couleur brune, dont les couches font tres minces; mais qui par leur repetition forment une epaisseur considerable.

“Ces couches de pierres a feuillets minces, continuent jusques a Sallanches et au de la; et sont renfermees par dessus et par dessous entre des bancs de pierre grise compacte et a couches epaisses. Quelquefois la pierre grise qui sert de base, ou comme disent les mineurs, de plancher a la brune, s’enfonce et alors celle-ci paroit a fleur de terre; ailleurs cette pierre grise se releve et porte la brune a une grande hauteur.

“Cette pierre brune et feuilletee est comme la grise de nature calcaire; mais un melange d’argile, et peut-etre un peu de matiere grasse ou phlogistique lui donnent sa couleur brune et la disposent a se rompre en fragmens angulaires et a cotes plans.

“Ce genre de pierre est fort sujet a avoir ses couches flechies ou ondees en forme de S de Z ou de C. Pres 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 extremement tourmentees. On comprend que ce vide et ce remplacement, se sont faits dans le temps meme 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 superieures du rocher de la cascade, et forment des arcs concentriques, tournes en sens contraire; en sorte que la totalite de ces couches a la forme d’une S, dont la partie superieure se recourbe fort en arriere.

“Le rocher de la cascade, represente par la planche IV. est tout calcaire; les couches, qui sont au dessous des lettres d et e, sont composees de ce roc gris compact dont les bancs, comme nous l’avons vu plus haut, sont ordinairement epais, mais les couches exterieures entre e et f, sont du roc brun a couches minces, dont nous avons aussi parle. Ces meme couches minces se voyent encore a l’intersection de perpendiculaire qui passent par lettres a et e.

“Ici dont c’est le roc gris qui est renferme entre deux bancs de roc brun au lieu qu’aupres de la caverne, c’etoit le roc brun, qui etoit resserre entre deux bancs de roc gris; mais cette difference n’est pas ce qu’il y a de plus difficile a expliquer; c’est la forme arquee 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 exterieures de ce rocher, a donc pour corde une ligne d’environ 800 pieds: dans toute cette etendue, ces couches de meme que les interieures sont suivies sans interruption.

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“Je dois cependant avertir, qu’en avant du rocher de la cascade a la hauteur de la lettre a, et au dessous, on voit des couches detachees des circulaires, et independantes d’elles; ce sont de plans inclines en appui contre le corps de la montagne, semblables a ceux que j’ai observe au pied du mont Saleve, et d’une formation vraisemblablement plus recente que le corps meme de la montagne.

“Mais derriere ces plans, on voit les couches arquees, 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 meme 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.

“Sec. 473. Il s’agiroit a present de dire quelle force a pu donner a ces couches cette situation; comment elles out pu etre retroussees de facon que les plus basses soient devenues les plus elevees?

“La premiere idee qui se presente est celle des eaux souterrains. Ce qui pourroit meme faire soupconner que ces couches ont ete reellement relevees par une force souterraine c’est que, sur la droite du rocher qu’elles forment, il y a un vide ou il manque a 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 reculee. Sur la droite de ce vide ces couches recommencent sur la ligne de celles qui sont recourbees; on les voit coupees a pic de leur cote, avec les memes couleurs, la meme epaisseur, mais dans une situation horizontale.

“J’ai observe dans plus d’une montagne des couches ainsi retroussees, aupres desquelles on voit le vide qu’elles paroissent avoir laisse en se repliant sur elles memes.

“Dans l’ober Hasli la vallee 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 rapprochee de notre cascade, et qui presente aussi ce phenomene, est situee derriere elle au nord-est entre le village de Seiz et les granges des Fonds. Cette montagne porte le nom d’Anterne. Elle est plus elevee que celle du Nant d’Arpenaz, ses couches forment des arcs concentriques plus grands et plus recourbes encore, et l’on voit de meme a leur droite un vide qu’elles semblent avoir laisse en se levant et se repliant sur la gauche.

“Mais malgre ces observations, ce n’est pas sans peine que j’ai recours a ces agens presque sur-naturelles, sur-tout quand je n’apercois aucun de leurs vestiges; car cette montagne et celle d’alentour ne laissent apercevoir aucune trace du feu. Je laisse donc cette question en suspens; j’y reviendrai plus d’une fois, et meme avant la fin de ce chapitre.

“Il faut a present jetter un coup-d’oeil sur les montagnes de l’autre cote de l’Arve.

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“Sec. 474. Vis-a-vis de la cascade de l’autre cote de la riviere, on voit un chaine de montagnes extremement elevees, qui presentent leurs escarpemens au dessus de Sallenche, et contre le Mont Blanc. Leurs couches descendent par consequent vers la vallee du Reposoir, situee a leur pied au nord-ouest.

“Mais au pied des escarpemens de cette meme chaine, on voit une rangee de bases montagnes paralleles a sa direction, inclinees en appui contre ses escarpemens et qui descendent en pente douce vers Sallenche; de meme encore une fois qu’au mont Saleve.

“Sec. 475. De la cascade jusques a St Martin, on voit frequemment a sa gauche des couches singulierement contournees, et toujours dans cette espece 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 a une demi-lieue de la cascade. Elles representent des arcs dont les convexites se regardent a peu pres comme dans un X; mais avec des plans situes obliquement entre les deux convexites, et des couches planes et horizontales immediatement au-dessus de l’arc de la gauche.

“Ces diverses couches sont si bien suivies dans tous leurs contours, et si singulierement entrelacees que j’ai peine a croire qu’elles ayent ete formees dans une situation horizontale, et qu’ensuite des bouleversemens leur ayent donne ces positions bizarres.

“Deja il faudroit supposer que ces bouleversemens se sont faits dans un tems ou ces couches etoient encore molles et parfaitement flexibles, car on n’y voit rien de rompu, leurs courbures, meme les plus angulaires, sont absolument entieres.

“Ensuite il faudroit, que ces couches, dans cet etat de mollesse, eussent ete froissees et contournees d’une maniere tout-a-fait etrange, et presqu’impossible a expliquer en detail. D’ailleurs des explosions souterraines rompent, dechirent, et ne soulevent pas avec le menagement qu’exigeroit la conservation de continuite de toutes ces parties.

“La crystallization peut seul, a mon avis, rendre raison de ces bizarreries; nous voyons, comme je l’ai deja dit, des albatres formes 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[2].”

[Footnote 2: 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;

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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.]

“Je ne repugnerois donc pas a croire que le rocher de la cascade a pu etre forme dans la situation dans laquelle il se presente; si ce vuide a 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 a ces formes bizarres, n’establissoient 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 a grains mediocres, et dont la structure n’a rien de distinct; mais au-dessus de ces granits on trouve des roches feuilletees quartzeuses melangees de mica et de feldspath genre moyenne entre le granit veine et la roche feuilletee ordinaire. Leurs couches courent du nord au sud, comme la vallee de Valorsine, et font avec l’horizon un angle de 60 degres, en s’appuyant au couchant contre cette meme vallee. Ces roches continuent dans la meme situation jusques a ce qu’apres une demi-heure de marche, on les perd de vue sous la verdure qui tapisse une petite plaine, situee au milieu des bois, et qui se nomme le *plan des Cebianes*.

“Sec. 689. De-la, en montant obliquement du cote du sud, on rencontre de grands blocs d’un schiste gris ou de couleur de lie-de-vin, quelquefois meme d’un violet decide, qui renferment une grande quantite de cailloux etrangers, les uns angulaires, les autres arrondis, et de differentes grosseurs, depuis celle d’un grain de sable jusqu’a celle de la

tete. Je fus curieux de voir ces poudingues dans leur lieu natal; je montai droit en haut pour y arriver; mais la quel ne fut pas mon etonnement de trouver leur couches dans une situation verticale!

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“Sec. 690. On comprendra sans peine la raison de cet etonnement si l’on considere qu’il est impossible que ces poudingues aient ete formees dans cette situation.

“Que des particules de la plus extreme tenuite, 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 albatres, les agathes, et meme dans les crystallizations artificielles. Mais qu’une pierre toute formee, de la grosseur de la tete, se soit arretee au milieu d’une parois verticale, et ait attendu la 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 demontree, que ces poudingues ont ete formes dans une position horizontale, ou a peu-pres telle, et redresses, ensuite apres leurs endurcissement. Quelle est la cause qui les a redresses? c’est ce que nous ignorons encore; mais c’est deja un pas, et un pas important, au milieu de la quantite prodigieuse de couches verticales que nous rencontrons dans nos Alpes, que d’en avoir trouve quelques-unes dont on soit parfaitement sur qu’elles ont ete formees dans une situation horizontale.

“Sec. 691. La nature meme de la matiere qu’enveloppe les cailloux de ces poudingues rend ce fait plus curieux et plus decisif. Car si c’etoit une pate informe et grossiere, on pourroit croire que ces cailloux et la pate qui les lie ont ete jetes pele-mele dans quelques crevasses verticales, ou la partie liquide c’est endurcie par le dessechement. Mais bien loin de-la, le tissu de cette pate est d’une finesse admirables; c’est une schiste, dont les feuillets elementaires sont excessivement minces, meles de mica, et parfaitement paralleles aux plans qui divisent les couches de la pierre. Ces couches memes sont tres-regulieres, bien suives et de differentes epaisseurs, depuis une demi pouce jusques a plusieurs pieds. Celles qui sont minces contiennent peu et quelquefois point de cailloux etrangers, et on observe quelques alternatives de ces couches minces sans cailloux et des couches epaisses qui en contiennent. La couleur du fond de ce schiste varie beaucoup; il est ici gris, la verdatre, le plus souvent violet ou rougeatre; on en voit aussi qui est marbre de ces differentes couleurs. Ses couches sont dirigees du nord au sud exactement comme celles des roches granitoides qui sont au-dessous, Sec. 688. mais l’inclinaison du schiste est beaucoup plus grande, ses couches sont souvent tout-a-fait verticales, et lorsqu’elles ne le sont pas, elles montent de quelques degres du meme cote que les roches dont je viens de parler; c’est-a-dire, du cote de l’ouest.

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“Sec. 692. Les cailloux enclaves dans ce schiste sont, comme je l’ai dite, de differentes grandeurs, depuis celle du grain de sable, jusques a 6 ou 7 pouces de diametre; ils appartiennent tous a la classe des roches que j’appelle primitives; je n’y ai cependant pas vu de granit en masse; seulement des granits feuilletes, des roches feuilletees, melangees de quartz et de mica; des fragmens meme de quartz pur; mais absolument aucun schiste purement argileux, ni aucune pierre calcaire, rien qui fit effervescence avec l’eau-forte, et la pate meme 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 meme ont la forme rhomboidale qu’affectent si frequemment les roches de ce genre. Dans les parties de la pierre ou ces cailloux etrangers sont entasses en tres-grand nombre, les elemens du schiste n’ont pas eu la liberte de s’arranger et de former des feuillets paralleles; mais par-tout ou 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.

“Sec. 693. Les bancs de ces schistes poudingues forment dans la montagne une epaisseur d’environ cent toises, comptees de l’est a 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 a fond de quartz, ou de feldspath blanc, confusement cristallise, avec des veines noires de mica ou de schorl en petites lames. Ces veines, qui penetrent tout au travers de la pierre, sont la section des couches dont elle est composee; on les voit, ici planes et paralleles, entr’elles; la en zig-zags, renfermes entre de plans parfaitement paralleles; accident dont les etoffes tout-a-la-fois rayees et chinees donnent encore le dessin. Ces anfractuosites des couches sont-elles un effect de la crystallization, ou bien d’un mouvement de pression qui a refoule des couches planes lorsqu’elles etoient encore flexibles, apres 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.

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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 general des couches de ces rochers et des ardoises qui les separent, est donc du midi au nord, ou plus exactement du sud-sud-ouest au nord-nord-est; mais cette direction est coupee a 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 a la raison de ce fait, on peut l’attribuer a de boulversemens, et c’est ce qui me paroit le plus vraisemblable. On pourroit cependant supposer qu’il existoit au milieu de ces couches une grande fissure, qui a ete remplie par des couches transversales. Mais il faudroit pour cela que ce remplissage se fut fait dans le temps meme de la formation de ce montagne, puisque les ardoises et les pyramides quartzeuses, donc la direction est transversales, sont precisement de la meme nature que les autres; et il faudrait encore supposer, qu’elles ont ete formees dans la situation tres-inclinee qu’on leur voit aujourd’hui; supposition que l’on aura quelque peine a admettre.”

In this second volume, M. de Saussure gives us a general view with regard to the mountains which border the valley of the Rhone, p. 543.

“Sec. 1095. Cette suite de montagnes calcaire que nous avons cotoyee depuis St Maurice jusques a Chillon, ne presente presque nulle part des couches regulieres et horizontales: elles sont presque par-tout inclinees, flechies, et paroissent avoir ete tourmentees par des causes violentes: car de simples affaissemens ne suffisent pas a mon gre pour rendre raison de toutes leurs formes. Leurs escarpemens sont aussi assez irregulierement situes; la plus grande partie d’entr’eux paroit cependant tournee du cote de la vallee du Rhone.

“La suite des montagnes qui correspond a celle-ci sur la rive gauche du Rhone et du lac est aussi calcaire, et a-peu-pres aussi irreguliere. La plupart de ces montagnes, celles surtout qui sont les plus voisines du lac, sont escarpees, et du cote du lac et de celui du Rhone. Les vallees qui les separent paroissent les diviser en chaines paralleles au lac, qui courent du nord-est au sud-ouest. Les plus voisines du lac sont escarpees contre lui, comme je viens de le dire, tandis que les plus eloignees du lac, ou les plus proches du centre des Alpes, sont inclinees contre ces memes Alpes. *Le Val de lie* separe ces deux ordres de montagnes: cette vallee riche et fertile a la forme d’un berceau; les deux chaines qui la bordent s’elevent en pente douce de son cote, 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.

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“Mais ce dont on peut etre certain, c’est que, si les montagnes qui bordent ces deux rives de la vallee du Rhone, 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 vallees qui les separent ne se correspondent pas non plus. Ce defaut de correspondance me paroit encore reveiller l’idee 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.

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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.

CHAP. II.

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.

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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 placee au point le plus eleve du passage, on a trois quarts de lieue, ou une petite heure de route, dans laquelle on traverse des gres, des breches calcaires, des pierres calcaires simples de couleur grise, d’autres calcaires bleuatres et des ardoises: ces alternatives se repetent a plusieurs reprises. Parmi ces gres on en trouve qui renferment des cailloux roules, 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 gres m’out paru remarquables par leur ressemblance avec des roches feuilletees; ils sont compactes meles de mica; un suc quartzeux remplit tous les interstices de leurs grains, et leur donne une durete et une solidite singuliers; il n’y a personne, qui en voyant des morceaux detaches de cette pierre, ne la prit pour une roche feuilletee; mais quand on la trouve dans le lieu de sa formation, et qu’on voit les gradations qui la lient avec des gres indubitables, par exemple avec ceux qui renferment des cailloux roules, on ne peut plus douter de sa nature. Ces couches sont en general inclinees de 30 degres en descendant au sud-est.”

Our author would here make a distinction of the *roche feuilletee* and the *gres*; 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 tres-beaux gres du meme genre; ils ne ressembloient cependant pas autant a 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 gres de cette nature renfermes entre des bancs de pierre calcaire. Cependant plus ces gres s’eloignent de la roche primitive, qui forme la base de la montagne, et moins ils sont solides et quartzeux jusqu’a ce qu’enfin les plus eleves 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.

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Our author proceeds, (p. 181,) Sec. 765, “Le haut du passage du Bon-Homme, au pied de la croix est d’ardoises minces melees de feuillets de quartz. En descendant au Chapiu, on trouve ces memes ardoises alternant avec des couches de gres mince feuillete, mele de mica, puis des calcaires simples, puis des breches calcaires qui renferment des fragmens calcaires a angles vifs. Toutes ces couches descendent au sud-est suivant la pente de la montagne, mais avec un peu plus de rapidite.

“Comme cette montagne est absolument degarnie d’arbres, on y voit d’un coup-d’oeil les progres de l’action des eaux. Des sillons a peine visibles dans le haut, s’elargissent et s’approfondissent graduellement vers le bas, ou ils forment enfin des ravines profondes, que l’on pourrait presque nommer des vallees. 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 extremement singulier. Lorsque je passai la, le 13 Juillet 1774, tous les enfoncemens de ces neiges etoient couverts de la poudre rouge que j’ai decrite Sec. 646.

“Vers la bas de la descente, on trouve des chalets que je m’etonnai de voir construits en pierres de taille, d’une forme tres reguliere; je demandai la raison de cette recherche, peu commune dans les montagnes, et j’appris que c’etoit la nature qui avoit fait tous les frais de cette taille. Effectivement je trouvai un peu plus bas une profonde ravine, creusee par les eaux dans des couches d’un beau gres qui se divise de lui-meme, et que l’on voit dans sa position originelle actuellement divise en grands parallelepipedes rectangles. Est-ce une retraite operee par le dessechement, ou n’est-ce pas plutot l’affaissement successif des couches qui les a divisees de cette maniere? C’est ce que je ne deciderai 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 gres rectangulaires, que j’avois observes la veille descendoient jusqu’au bas de la montagne; j’y trouvai effectivement des gres mais a couches minces, et qui ne se divisoient point avec regularite; en revanche, je vis des couches de ce gres ployees et reployees en zig-zags, comme celles que j’avois rencontrees aux contamines, Sec. 755, et ces couches ondees etoient aussi renfermees entre de couches planes et paralleles. Ce phenomene est bien plus rare dans les gres, que dans les roches feuilletees proprement dites.”

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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:

“Sec. 776. Tout pres du sommet du Col, on rencontre de beaux bancs de gres jaunatre qui sortent de dessous la pierre calcaire, et qui pourtant ne font aucune effervescence avec les acides.

“Sec. 777. Je mis deux heures et trois quarts a monter depuis le hameau du Glacier jusqu’au haut du Col, d’ou l’on descend a la croix du Bon-Homme. J’envoyai mes mulets m’attendre a 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 donne a cette sommite, qui n’avoit point de nom, celui de *Cime des Fours*, a cause du passage qu’elle domine. De grandes plaques de neige couvroient en divers endroits la route que j’avois a faire pour y aller; le roc se montroit cependant assez pour que l’on put reconnoitre sa nature.

“Sec. 778. Je traversai d’abord des couches des gres qui etoient la continuation de celles dont je viens de parler, Sec. 776. Je trouvai ensuite des bancs d’une espece de poudingue grossier, dont le fond etoit ce meme gres rempli de cailloux arrondis. Quelques uns de ces bancs se sont decomposes, et les eaux out entraine les parties de sable qui lioient les cailloux, en sorte que ceux-ci sont demeures libres et entasses exactement comme au bord d’un lac ou d’une riviere. Il etoit si etrange de marcher a cette hauteur sur des cailloux roules, que Pierre Balme en temoigna son etonnement, meme avant, que j’en parlasse. On auroit ete tente de croire qu’une cascade tombant anciennement de quelque rocher plus eleve, detruit des-lors par le temps, avoit arrondi ces cailloux, si on n’en trouvoit pas de semblables encore enclaves dans les couches regulieres du gres qui compose le haut de cette montagne.

“Sec. 779. Quoique depuis long-temps je ne doute plus que les eaux n’aient couvert et meme forme ces montagnes, et qu’il y en ait meme des preuves plus fortes que l’existence de ces cailloux roules, 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 etonnement. Si en marchant sur ces cailloux, et en les observant, j’oubliois pour un moment le lieu ou j’etois, je me croyois au bord de notre lac; mais, pour peu que mes yeux s’ecartassent a droite ou a gauche, je voyois au-dessous de moi des profondeurs immenses; et ce contraste avoit quelque chose qui tenoit d’un reve; je me representois alors avec une extreme vivacite les eaux remplissant toutes ces profondeurs, et venant battre et arrondir a 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’etoient retirees. Mais il fallut m’arracher a ces grandes speculations et employer plus utilement mon temps a l’exacte observation de ces singuliers phenomenes.”

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The fact here worthy of observation is the effect of time in decomposing this *gres*, 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.

“Sec. 780. Tous les bancs de gres que l’on voit sur cette montagne ne renferment pas des cailloux roules; il y a des alternatives irregulieres, de bancs de gres pur, et de bancs de gres mele de cailloux. Les plus eleves n’en contiennent point. Le plus haut de ceux qui en renferment est un banc bien suivi d’un pied d’epaisseur, et qui monte de 30 degres au nord-nord-ouest.

“Quelques-uns de ces bancs, remplis de cailloux, offrent une particularite bien remarquable; on voit a leur surface exterieure, exposee a l’air, une espece de reseau forme par des veines noires solides, et saillantes de deux ou trois pouces au-dessus de la surface de la pierre; les mailles de ce reseau sont quelquefois irregulieres, mais ce sont pour la plupart des quadrilateres obliquangles, dont les cotes ont huit a dix pouces de longueur. Comme ces pierres ont toutes un tendance a se partager en rhomboides, il paroit qu’il y a eu anciennement des fentes qui divisoient les bancs en parties de cette forme; et que ces fentes ont ete remplies par du sable qui a ete cimente 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 ronge la surface de ces bancs, les mailles du reseau sont demeurees saillantes.

“Les cailloux arrondis, qui out ete long-temps exposes a l’air, out aussi pris par dehors une teinte noiratre ferrugineuse, mais ceux qui sont encore renfermes dans les bancs de gres ont comme lui une couleur jaunatre. Je n’en trouvai la aucun qui ne fut de nature primitive, et la plupart etoient de feldspath gris ou roux tres-dur, et confusement crystallise. Ce sont donc des pierres qui n’ont point naturellement une forme arrondie; et qui, par consequent, ne tiennent celle qu’elles ont ici, que du roulement, et du frottement des eaux.

“Tous ces gres font effervescence avec l’eau-forte, mais les parties du reseau ferrugineux en font beaucoup moins que le fond meme du gres. De meme si l’on compare entr’eux les gres 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 coherence.

“Sur la cime meme de la montagne, ces gres sont recouverts par une ardoise grise, luisante, qui s’exfolie a l’air. Et si l’on redescend de cette meme cime par le nord-est, du cote oppose au passage des Fours, on retrouvera des bancs d’un gres parfaitement semblable, et qui se divisent la d’eux-memes en petits fragmens parallelepipedes.

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“Du haut de cette cime, elevee de 1396 toises au-dessus de la mer, on a une vue tres entendue. Au nord et au nord-ouest les vallees de Mont Joie, de Passy, de Sallanches; au couchant la haut cime calcaire dont j’ai parle, Sec. 759; au sud les montagnes qui s’etendent depuis le Chapiu jusqu’au Col de la Seigne; a l’est, ce meme Col que l’on domine beaucoup. Sur la droite de ce col, on voit du cote de l’Italie la chaine du Cramont, et plusieurs autres chaines qui lui sont paralleles, tourner tous leurs escarpemens contre la chaine centrale, de meme qu’on voit du cote de la Savoye, les chaines du Reposoir, de Passy, de Servoz, tourner en sens contraire leurs escarpemens contre cette meme chaine. Car c’est-la une des vues tres etendues sur les deux cotes opposes des Alpes; puisque l’on decouvre d’ici les montagnes de Courmayeur et de l’Allee Blanche, qui sont du cote meridional de la chaine, et celles du Faucigny et de la Tarentaise, qui sont du cote septentrional. Or les sites d’ou l’on jouit tout a-la-fois de ces deux aspects sont tres rares; parce que les hautes cimes de la chaine centrale sont presque toutes inaccessibles, et les cols par lesquels on la traverse sont presque tous tortueux, etroite, et ne presentent pour la plupart que de vues tres bornees.”

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,

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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.)

“Sec. 918. Mais la chaine centrale n’est pas la seule primitive qu’il y ait de ce cote des Alpes. Du haut du Cramont en se tournant du cote de l’Italie, on voit un entassement de montagnes qui s’etendent aussi loin que peut aller la vue. Parmi ces montagnes on en distingue un au sud-ouest qui est extrememement elevee: son nom est *Ruitor*: elle se presente au Cramont a-peu-pres pres sous le meme aspect que le Mont-Blanc a Geneve; sa cime est couverte de neiges, un grand glacier descend de sa moyenne region, 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 chaine de montagnes moins elevees, mais primitives comme elle, et qui passent au-dessus du val de Cogne. On voit de la cime du Cramont des montagnes secondaires situees entre le Cramont et cette chaine primitive, et on reconnoit que les couches de ces montagnes s’elevent contre cette chaine en tournant le dos a la chaine centrale.

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“Sec. 939. L’inclinaison du Cramont et de la chaine contre le Mont-Blanc, n’est donc pas un phenomene qui n’appartienne qu’a cette seule montagne; il est commun a toutes les montagnes primitives, dont c’est une loi generale 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 premiere fois, cette observation alors nouvelle, que j’ai verifie ensuite sur un grand nombre d’autres montagnes, non pas seulement dans la chaine des Alpes, mais encore dans diverses autres chaines, comme je le ferai voir dans le IVe. volume. Les preuves multipliees que j’en avois sous les yeux au moment ou je l’eus faite, et d’autres analogues que ma memoire me rappela d’abord, me firent soupconner son universalite, et je la liai immediatement aux observations que je venois de faire sur la structure du Mont-Blanc et de la chaine primitive dont il fait partie. Je voyois cette chaine composee de feuillets que l’on pouvoit considerer comme des couches; je voyois ces couches verticales dans le centre de cette chaine et celles des secondaires presque verticales dans le point de leur contact avec elles, le devenir moins a de plus grandes distances, et s’approcher peu-a-peu de la situation horizontale a mesure qu’elles s’eloignoient de leur point d’appui. Je voyois ainsi les nuances entre les primitives et les secondaires, que j’avois deja observees dans la matiere dont elles sont composees, s’etendre aussi a la forme et a la situation de leurs couches; puisque les sommites secondaires que j’avois la sous les yeux se terminoient en lames piramidales aigues et tranchantes, tout comme le Mont-Blanc, et les montagnes primitives de la chaine. Je conclus de tout ces rapports, que, puisque les montagnes secondaires avoient ete formees dans le sein des eaux, il falloit que les primitives eussent aussi la meme origine. Retracant alors dans ma tete la suite des grandes revolutions qu’a subies notre globe, je vis la mer, couvrant jadis toute la surface du globe, former par des depots et des crystallisations successives, d’abord les montagnes primitives puis les secondaires; je vis ces matieres s’arranger horizontalement par couches concentriques; et ensuite le feu ou d’autres fluides elastiques renfermes dans l’interieur du globe, soulever et rompre cette ecorce, et faire sortir ainsi la partie interieure et primitive de cette meme ecorce, tandis que ses parties exterieures ou secondaires demeuroient appuyees contre les couches interieures. Je vis ensuite les eaux se precipiter dans les gouffres creves et vides par l’explosion des fluides elastiques; et ces eaux, en courant a ces gouffres, entrainer a de grandes distances ces blocs enormes que nous trouvons epars dans nos plaines. Je vis enfin apres la retraite des eaux les germes des plantes et des animaux, fecondes par l’air nouvellement produit, commencer a se developper, et sur la terre abandonnee par les eaux, et dans les eaux memes, qui s’arreterent dans les cavites de la surface.

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“Telles font les pensees que ces observations nouvelles m’inspirerent en 1774. On verra dans le IVe. volume comment douze ou treize ans d’observations et de reflections continuelles sur ce meme sujet auront modifie ce premier germe de mes conjectures; je n’en parle ici qu’historiquement, et pour faire voir qu’elles sont les premieres idees que le grande spectacle du Cramont doit naturellement faire eclore dans une tete qui n’a encore epouse aucun systeme.”

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.

[3] “On s’embarque a Fluelen a une demi-lieue d’Altorf sur le lac des quatre Waldstoett ou cantons forestiers; les bords de ce lac sont des rochers souvent a pic et d’une tres grande elevation et la profondeur de ses eaux proportionnee. Ces roches sont toutes calcaires, et souvent remarquables par la position singuliere de leurs couches. A une demi-lieue environ de Fluelen, sur la droite, des couches de six pouces environ d’epaisseur sont deposees en zig-zags comme une tapisserie de point-d’hongrie; a une lieue et demie a cote de couches bien horizontales, de quatre a cinq pieds d’epaisseur il y en a de contournees de forme circulaire et d’elliptiques. Il seroit difficile de se faire une idee de la formation de pareilles couches, et d’expliquer comment les eaux ont pu les deposer ainsi.”

[Footnote 3: Discours sur l’Hist. Nat. de la Suisse, page CLV.]

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.

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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 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 cone, je n’ai vu qu’un terrain compose de ces debris, et cultive en vignes. Mais apres l’avoir depasse, j’ai trouve la coupe verticale d’une colline a couches pierreuses, si reguliers, que je les ai prises au premier coup d’oeil pour de la pierre a chaux. L’esprit de nitre m’a detrompe: c’est une pierre sableuse tres compacte, dont les couches, qui n’ont souvent que quelques pouces d’epaisseur, s’elevent par une pente insensible vers le cone volcanique qu’elle recouvrent de ce cote la sans aucune apparence de desordre. Ces couches qui sont visiblement des depots de la mer, quoique je n’y ai pas trouve de corps marins, ont ete formees depuis que le cone s’etoit eleve.”

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.

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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 la ont ete formes par des depots de la mer: Les corps marin qu’ils renferment en font foi. Des lors ils ont du avoir dans leur origine la seule position que la mer put leur donner; l’horizontale ou legerement inclinee. Leur couches sont aujourd’hui rompues, et leur inclination n’est plus celle de depots immediats de la mer. Les collines, auxquelles elle appartenoient, sont en meme tems entourees de volcans anciens; et il est naturel d’en conclure, que c’est a 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 cotes n’est rien, quand on considere le prodigieuse excavation qui ont du 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 Mineralogique, *etc*. Journal Physique, Aoust, 1784.)

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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 presentent assez communement perpendiculaire, tandis que les grands bancs d’ardoises, ceux qu’on exploite, sont, comme nous l’avons dit, couches sur une ligne de 15 a 20 degres. J’ai parle des montagnes de marbre qui sont derriere Givet, et de celles sur la quelle est situe Charlemont. J’ai fait voir que bien loin que les bancs de marbre, qui forment la montagne du Givet, soient horizontaux comme on seroit tente de le croire, d’apres les principes de quelques naturalistes systematiques, qui pensent que tous les bancs de pierres calcaires ne sauroient etre autrement; j’ai fait voir, dis-je, que ces bancs sont presque perpendiculaire a l’horizon; et de plus, qu’ils sont tellement colles les uns contre les autres, qu’a 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’a 18 ou 20 toises d’epaisseur dans une etendue dont on ne connoit pas encore les bornes. L’un de ces *filons* fait avec l’horizon un angle de 25 degres; c’est l’inferieur: l’autre s’eleve de 45 degres: et leur distance etant peu considerable, leurs plans doivent se rencontrer dans un point qui n’est pas fort eloigne des mines. Leurs *directions* sont aussi differentes: celle du *filon* de 35 degres est a 61/2 *heures*; et celle du *filon* de 45 degres est a 5_h._-1/2: tellement qu’ils se croisent a l’endroit ou est perce le puits des pompes.

“On est embarrasse d’expliquer l’etat de cette montagne par des secousses. Il faut au moins supposer que la montagne entiere a ete culbutee, et encore reste-t-il a comprendre, comment s’est soutenue cette grande piece qui separe les filons, et qui, en supposant vuides les espaces de ceux-ci, se trouveroit absolument en l’air.

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“Ce phenomene important a l’histoire des montagnes, je veux dire ces intersections des *filons*, est tres frequent dans les mines et tres remarque par les mineurs. Il arrive souvent que des *filons*, qui sont a la meme *heure*, c’est-a-dire, qui ont des *directions* semblables vers l’horizon, ont une chute ou inclinaison differente, et telle que leurs deux plans se coupent a une certaine profondeur. Si le mineur ne s’en appercoit pas assez tot, et que des le commencement de son exploitation, il n’etanconne pas fortement partout ou il enleve les *filons*, tout son ouvrage peut etre ecrase par l’enfoncement de la piece qui les separoit. Cette piece meme a un nom chez le mineurs; ils la nomment *Bergkiel*, c’est-a-dire coin de la matiere de la montagne: et quand deux filons sont voisins l’une de l’autre, le geometre souterrain en etudie l’inclinaison pour juger a l’avance s’il y aura un *Bergkiel*; et qu’en ce cas la mineur prenne ses precautions, en conservant des appuis naturels dans la gangue, ou s’en faisant d’artificiels, a mesure qu’il s’enfonce. Or si, en elevant les filons, ce coin se trouve sans appui; comment s’est-il soutenu avant que les filons fussent formes?

“Voila une question forte embarrassante. Mais peut-etre n’a-t-on pas fait assez d’attention jusqu’ici a la mauvaise gangue, qui se trouve etre de la meme nature que la montagne. Peut-etre trouveroit on par la, qu’en meme tems que les fentes se font faites, il y est tombe des pieces des cotes, qui ont empeche la reunion 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 a les connoitre.

“Ce peu d’inclinaison des *filons* du Rammelsberg rappelleroit l’idee des *couches* formees de depots successifs, s’ils etoient paralleles. Mais leur manque de parallelisme en tout sens exclut cette explication. Car dans toutes les montagnes qui doivent leur formation aux depots des eaux, les *couches* sont paralleles; et l’on sent bien qu’elles doivent l’etre.

“La nature des *filons* du *Rammelsberg* est aussi differente de celle de *Claustbat* que l’est leur situation. C’est un massif compacte, et presque partout le meme, de mineral de *plomb* et *argent* pauvre, penetre de *pyrite* sulphureuse. Ils sont traverses en plusieurs endroits par de *Ruscheln*, qui ont fait glisser le toit vers le *mur*; tellement que malgre l’epaisseur de ces *filons*, on crut une fois en avoir trouve la fin. Ils sont aussi coupes dans leur interieur, en sens differens, par d’autres plus petits *filons*, composes de matieres tres differentes; surtout d’une *pyrite cuivreuse* dure et pauvre, et que par cette raison on ne tente pas de separer.

“En mettant a part ces petits *filons* particuliers, ainsi que les Ruscheln, dus probablement les uns et les autres a des causes posterieures a celles qui ont produit les filons principaux, la masse compacte de ceux-ci reveille beaucoup l’idee d’une matiere fondue; en meme tems qu’on seroit fort embarrasse a concevoir, d’ou viendroit cette matiere, si distincte de toute autre, lorsqu’on voudroit l’attribuer a l’eau.

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“Cette idee, que je dois a Mr. de Redden, perfectionnee par l’etude des phenomenes, donnera peut-etre un jour le mot de toutes ces enigmes.”

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.

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CHAP. III.

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

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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.

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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.

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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.

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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.

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Vol. 1. (page 163.) “Les tranches nues et escarpees des grandes couches du petit et surtout du grande Saleve, presentent presque partout les traces les plus marquees du passage des eaux, qui les ont rongees et excavees, on voit sur ces rochers, des sillons a peu pres horizontaux, plus ou moins larges et profonds; il a de 4 a 5 pieds de largeur, et d’une longueur double ou triple, sur 1 ou 2 pieds de profondeur. Tous ces sillons ont leur bords termines des courbures arrondies; telles que les eaux ont coutume de les tracer. Je dis qu’ils sont a peu pres horizontaux, parce qu’ils sont par fois inclines de quelques degres, 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 ete traces par les eaux des pluies; car celles-ci forment des excavations, ou perpendiculaires a l’horizon ou dirigees suivant la plus grande inclinaison des faces des rochers; au lieu que celles la font tracees presqu’horizontalement sur de faces tou-a-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*, Sec.236. “La ou ces couches manquent, il est aise de voir qu’elles ont ete detruites par le tems; les couches meme horizontales, contres lesquelles elles out appuyees, ont souffert en bien des endroits des alterations considerables.

“Un peintre qui voudroit monter son imagination, et se faire des grandes idees des ravages du tems sur de grands objects, devroit aller au pied de Saleve, a l’extremite des ces grands rochers, au-dessus du coin, hameau fort eleve de la paroisse de Collonge.

“On voit la des rochers tailles a pic a la hauteur de plusieurs centaines de pied avec des faces, ici planes et uniformes, la partagees et sillonnes par les eaux.

“La base de ces rochers est couverte de debris et de fragmens enormes, confusement entasses; un de ces debris soutenu fortuitement par d’autres est demeure, et paroit de pres un obelisque quadrangulaire d’une hauteur prodigieuse; de plus loin on reconnoit que sa sommite est une arrete tranchante, et qu’il a la forme d’un coin; et c’est peut-etre cette forme qui a donne son nom au hameau qu’il domine.

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“L’Angle meme de la montagne est partage par une fente qui le traverse de part en part. Cette profonde fissure merite qu’on la voye, et meme qu’on la penetre. Elle est tortueuse, et dans quelques endroits si etroite, qu’a peine un homme peut il y passer. Quand vous y etes engages vous trouvez des places ou les sinuosites du rocher vous cache le ciel, plus loin elles le laissent apercevoir par echappees; ailleurs vous voyez des blocs de rochers engages dans la crevasse, et suspendus au-dessus de votre tete.”

In his route from Contamine to Bonneville, he observes, page 365, “Enfin vis-a-vis la Bonne-ville, ces memes escarpemens des bases du mole, presentent une grande echancrure, qui paroit etre le vuide qu’a laisse une montagne qui s’est anciennement ecroulee; ses debris sont encore entasses au-dessous de l’echancrure. Il paroit meme qu’elle etoit plus elevee que ses voisines, j’en juge par leur couches qui montent a droite et a gauche, contre le vuide qu’elle a laisse.

“Sec. 493. En suivant la route de servez, on voit sur sa gauche la continuation des rocs escarpes qui couronnent les montagnes situees au-dessus de Passy. Un de ces rochers est si eleve, et en meme tems si mince que l’on a peine a concevoir qu’il puisse se tenir debout et resister aux orages.

“C’est aupres de cette sommite elevee qu’etoit situee une montagne qui s’eboula en 1751, avec un fracas si epouvantable, et une poussiere si epaisse et si obscure, que bien de gens crurent que c’etoit 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 meme de Monetier, ou cette grande echancrure qui separe le grand Saleve du petit, et dans le fond de laquelle est renferme le joli vallon de Monetier, paroit avoir ete formee par un courant semblable, qui descendant des Alpes par la vallee 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 detacher et emporter la piece enorme qui manque en cet endroit a 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.

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“Le faite de la montagne, battu de tous cotes par les vents, et par les pluies, a souffert des alterations les plus grandes: ici les couches du cote du lac ont ete detruites, et laissent voir les sommites des couches opposees, dont les escarpemens paroissent tourner contre ce meme lac; la, ce font les couches du cote de la vallee de Mijoux, qui out ete emportees, et la montagne en pente uniforme de notre cote, est escarpee du cote de celle vallee; plus loin, le faite entier a ete enleve, et la on voit des abaissemens ou des gorges comme aux Faucilles, a St. Serge, *etc*.

“Les flancs et la base de La montagne ont aussi ete degrades par les torrens que produisent la pluie et les neiges fondues, qui ont forme 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 vallee de Chamouni, de l’Arve qui l’arrose dans toute la longueur, d’une soule de villages et de hameaux entoures d’arbres et de champs bien cultives. Au moment ou l’on arrive au Montanvert, la scene change; et au lieu de cette riante et fertile vallee, on se trouve presqu’au bord d’un precipice, dont le fond est une vallee beaucoup plus large et plus

etendue, remplie de neige et de glace, et bordee de montagnes colossales, qui etonnent par leur hauteur et par leurs formes, et qui effraient par leur sterilite et leurs escarpements.”

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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.)

“Apres une bonne demi-heure de marche sur le glacier, nous traversons une arrete de glace chargee de terre, de sable et de debris de rocher. J’ai parle dans le 1er. vol. de ces arretes paralleles a la longueur de glaciers, que l’on voit souvent dans le milieu de leur largeur, ou a des distances plus ou moins grandes de leurs bords. J’ai fait voir qu’elles sont produites par des debris qui du haut des montagnes, roulent sur le glacier, et qui entraines par la glace sur laquelle ils reposent suivent comme elle une direction oblique en descendant tout-a-la-fois vers le milieu et vers le bas de la vallee.

“Dix minutes apres, nous traversames une seconde arrete plus haute que la premiere, et nous jugeames que sous ces debris la glace etoit de 20 ou 25 pieds plus elevee que dans les endroits ou l’air et les rayons du soleil agissent librement sur elle. On rencontre une troisieme arrete a vingt minutes de la seconde, et la quatrieme, qui est la derniere, la suit de tres-pres.

“Ici nous nous trouvons au point ou le glacier des bois se divise, comme je l’ai dit, Sec. 611, en deux grandes branches, dont l’une tourne a droite vers le Mont-Blanc, et prend le nom de glacier de *Tacul*, et l’autre a gauche se nomme le glacier de *Lechaud*. Il seroit, sans doute, plus interessant de suivre celle de la droite, et de s’approcher ainsi du Mont-Blanc; ses pentes de neige et de glace, qui se presentent a nous, semblent meme n’etre point absolument inaccessibles: mais ce sont des apparences trompeuses; des glaciers entrecoupes de profondes crevasses masquees ca et la par des couches minces de neige les approches de cette redoutable montagne, quoique peut-etre en choisissant une annee ou il seroit tombe beaucoup de neige, et en prenant le temps ou 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 vallee, et apres deux heures de marche sur le glacier des bois, nous en sortons au pied de celui du Talefre, c’est-a-dire, a l’endroit ou celui-ci vient verser sa glace dans celui-la qui a change de nom, et qui s’appelle ici le *glacier de Lechaud*.

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“La vue du glacier du Talefre est ici majestueuse et terrible. Comme la pente par laquelle il descend est extremement rapide, les glacons se pressant mutuellement, se dressent, se relevent, et presentent des tours, des pyramides diversement inclinees, qui semblent pretes a ecraser le voyageur temeraire qui oseroit s’en approcher.

“Pour parvenir au sommet de ce glacier, ou il est moins incline et par cela meme moins inegal, nous gravissons le rocher qui est a la gauche du cote du couchant. Ce rocher se nomme *le Couvercle*; il est domine par une cime inaccessible, qui, suivant l’usage du pays, est decoree du nom *aiguille*, et, en prenant le nom du glacier le plus proche, s’appelle *l’aiguille du Talefre*.

“La pente, par laquelle on gravit le couvercle, est excessivement rapide; on suit une espece de sillon creuse 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 a ce passage le nom *d’egralets* ou de petits degres. Ce passage n’est cependant point dangereux, parce que le roc, qui est un granit tres-coherent, permet d’assurer toujours solidement les mains et les pieds; mais la rapidite le rend un peu effrayant a la descente.

“Lorsqu’on est au haut des egralets, on suite un pente beaucoup moins rapide; on marche tantot sur du gazon, tantot sur de grandes tables de granit, et on arrive ainsi au bord du plan du glacier du Talefre. On nomme le *plan* d’un glacier la partie elevee et a-peu-pres horizontale dans laquelle on peut le traverser.

“Nous avions mis une heure et un quart a monter du glacier de Lechaud au plan de celui du Talefre. Nous fumes tentes de nous reposer un moment avant d’entrer sur celui-ci. Tout nous invitoit a choisir cette place, un beau gazon arrose par un ruisseau qui sortoit de dessous la neige et qui rouloit son eau crystalline sur un sable argente, et ce qui etoit plus seduisant encore, une vue d’une etendue et d’une beaute dont une description ne peut donner qu’une bien foible idee.

“Sec. 631. En effet comment peindre, a 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’ame du lecteur cette impression melee d’admiration et de terreur qu’inspirent ces immenses amas de glaces entoures et surmontes de ces rochers pyramidaux plus immenses encore; le contraste de la blancheur des neiges avec la couleur obscure des rochers, mouilles par les eaux que ces neiges distillent, la purete de l’air, eclat de la lumiere du soleil, qui donne a tous ces objets une nettete et une vivacite extraordinaires; le profond et majestueux silence qui regne dans ces vastes solitudes, silence qui n’est trouble que de loin en loin par le fracas de quelque grand rocher de granit ou de glace qui s’ecroule du haut de quelque montagne; et la nudite meme de ces rochers eleves, ou l’on ne decouvre ni animaux,

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ni arbustes, ni verdure. Et quand on se rappelle la belle vegetation, et les charmans paysages que l'on a vus le jours precedens dans le basses vallees, on est tente de croire qu'on a ete subitement transporte dans un autre monde oublie par la nature, ou sur une comete dans son aphelie. La vue du Montanvert ne donne de celle-ci qu'une idee tres-imparfaite; la on ne voit qu'un seul glacier, au lieu que d'ici vous voyez les trois grands glaciers des Bois, de Lechaud et du Tacul, sans compter un grand nombre d'autres moins considerables qui, comme celui du Talefre, 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 feuilletees, interposees entre ces granits, des *gneufs*, par exemple, ou des roches de corne; comme elles etoient plus tendres que les granits, leurs parties faillantes ont ete detruites par les injures de l'air, et il ne reste plus que leurs bases, caches au fond des gorges qui separent 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.

CHAP. IV.

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[4].

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[Footnote 4: Tableaux de la Suisse Discours, *etc*. p. 113. Route d'Altorf au St. Gothard.]

"Nous allons donner les observations que nous avons faites, en montant le Saint Gothard par le cote septentrional, et nous terminerons ce que nous avons a 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 roulees, dont la plus grande partie est amenee par le Schechen, torrent qui descend de la vallee du meme 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 variete de pierres d'especes differentes et de connoitre d'avance les rochers qui composent les montagnes qu'on va parcourir; nous repetons ici que toutes les pierres arrondies ont pris cette forme par le roulis qu'elles ont essuyees dans les torrens, en se precipitant avec les eaux qui les ont amenees: plus nous avons parcouru de montagnes, plus nous nous sommes confirmes que cette observation etoit vraie et exact. Si on a la constance de suivre une espece 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 a toutes les substances qui restent en place; on verra qu'a mesure qu'elles s'eloignent de leur premiere position leurs angles et leurs parties saillantes se detruisent, et qu'elles finissent par prendre la forme ronde ou approchante, en raison de leurs durete et du chemin qu'elles auront parcouru. Nous renvoyons a ce sujet ce qui a ete dit vers le commencement de ces observations, en parlant du Trient. Nous ajoutons seulement qu'il n'y a guere d'espece de pierres roulees dans les montagnes, dont nous n'ayons pas trouve 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 entoure de tres-hautes montagnes, des vallons aboutissent de tous cotes dans ses environs, parce-que c'est le lieu le plus bas ou les eaux vont se jetter dans le lac de Wahlasthall ou de Lucerne, a l'extremite duquel Altorf est situe; le vallon est assez couvert dans le bas, il est cultive dans quelques parties, et il y a des arbres fruitiers; c'est sur-tout aux environs de Birglen qu'on rencontre beaucoup de pierres roulees et des rochers amenes par les eaux.

"Les rochers sont de pierre calcaire, et continuent jusqu'a Silenen a deux lieues d'Altorf; les montagnes sont fort hautes et fort escarpees des deux cotes du vallon, de beaux pres sont dans le bas; quelque arbres fruitiers et sur-tout des noyers sont a mi-cote, et entre les rochers, des forets de sapins. Avant d'arriver a Silenen, on appercoit le glacier de Tittlis; il est sur le territoire d'Engelberg, et on trouve encore quelques hetres; derriere les montagnes boisees il s'en eleve d'autre nues et arides. Des points et des vues admirables par la degradation des montagnes et pour le sauvage, s'offrent de toutes parts. Des chalets, des habitations isolees, sont situes au pied des plus affreux rochers qui les menacent d'une ruine prochaine. L'habitant y vit sans crainte, entoure de son pre et de son petit bien dont il est tranquille possesseur.

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“La chaleur concentree dans ce vallon y fait murir differentes productions peu recherchees; a la verite, 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 entoure de fort hautes montagnes, qu’on commence a monter ce qu’on nomme le Saint Gothard general: le chemin devient plus roide, la Reuss y est plus resserres et roule ses eaux dans un lit fort profond et tres-escarpe, des torrens des cascades, tombent de differens endroits des deux cotes de ce vallon et de belles forets de sapin, ou il y a des arbres prodigieux pour la hauteur, varient les points de vues; on s’eleve 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 cote du vallon, sur la gauche de la Reuss, est une usine ou on fabriquoit de l’alum et du vitriol, les travaux ont cesse, ces etablissemens 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 creusee un lit a des profondeurs incroyables; il n’y a point d’endroit ou l’on puisse mieux voir cet etonnant travail des eaux que sur le pont du Pfaffensprung, a une demi-lieue de Vassen; il est a 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 reflexion qu’on y revient, On voit la progression et le travail successif de l’eau du haut jusqu’en bas; la roche a des sinuosites ou des angles arrondis, rentrans et faillans, alternativement de chaque cote, et dont saillans sont opposes aux rentrans, de facon 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, mele de beaucoup de quartz; le lit de la Reuss est rempli de granits, mais qui viennent des montagnes superieures. Au-dessus du pont, dont nous venons de faire mention, on rencontre un passage des plus pittoresques, compose de moulins, de scieries, de chutes d’eau, domines par le village de Vassen, et entoures de montagnes fort extraordinaire. Une roche argileuse sur un plan incline, s’est detachee de la hauteur, et a emporte un pont et un moulin.

“On monte beaucoup apres avoir passe Vassen; ces environs sont d’une variete etonnante pour la beaute et la singularite des paysages. Des nappes d’eau, des cascades qui se precipitent de roches en roches, forment dix et quinze chutes avant de se perdre dans les sapins qui contrastent avec la blancheur des eaux toutes reduites en ecume. Des maisons d’une construction particuliere, placees contre les rochers pour les mettre a l’abri des avalanches, des poutres jetees sur differentes

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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 precipices, 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 occupes que de leurs craintes et des terreurs paniques; c'est en effet une grande privation de ne pas sentir les beautes de la nature, elle devient un malheur reel quand ce plaisir se trouve remplace par des angoisses et de la frayeur. Un tableau d'un autre genre nouveau, et pour lequel les expressions manquent, est une foret rasee et abattue par une avalanche, il y a quelques annees, ces sapins de plus de cent pied de long, ont eu le tems de perdre leurs feuilles et de permettre a la vue de passer a travers cette enorme quantite de bois et de branches entre lacees de mille manieres bizarres, et d'apercevoir des rocs epars, des eaux qui circulent autour, et tombent quelque fois en cascades. C'est une spectacle qui devient effrayant quand on pense a la force et a la violence du moyen qui a pu occasionner un pareil effet. On recueille dans ce canton la resine des melezes. Quoique Vassen soit deja fort eleve, on y cultive encore quelque jardinage, et il y a aussi quelque cerisiers sauvages. Il y a environ cinq-lieues jusqu'a Altorf.

"Apres avoir passe Vassen, on trouve cinq ou six superbes cascades formees par la Reuss. Elle fait un bruit a etourdir: la chaleur qu'il faisoit, avoit procure une abondante fonte de neige, et l'eau avoit beaucoup augmente depuis le matin. Des bouleaux, des sapins, et des melezes, groupes ensemble, formoient des contrastes agreables par la variete et le melange des differens verts. Les chemins sont faits a grand frais et avec beaucoup de soin; on a jette des arcades en differens endroits pour joindre les rochers, et faire passer les chemins par-dessus; on entend mugir la Reuss sous ses pieds elle ecume par-tout, il faut etre accoutume a ce spectacle pour n'en pas etre effraye. Les rochers de droite et de gauche sont par-tout a pic et d'une granit, qui est jaunatre dans differens endroits; dans d'autres, il est decompose, passant a l'etat d'argile; c'est le felds-path qui subit le premiere ce changement. Des quartiers de rochers des parties de montagnes sont epars; des chalets, des habitations solitaires sont place aux environs des endroits ou il y a quelque paturage. Il y a un de ces rochers qui est une belle masse de granit, appellee la Pierre du Diable; on n'oublie pas de la faire remarquer, parce qu'il y a un conte populaire a son sujet que de graves auteurs nous ont conserve. Le vallon se retrecit beaucoup avant d'arriver a Gestinen.

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“On a eleve par-tout de murailles a de tres-grandes hauteur pour faire le chemin. Tout ce travail, vu le local, est incroyable pour la difficulte; de gros blocs de granits sont ranges sur les bords du chemin pour servir de barrieres dans les endroits les plus dangereux. Ces passages sont si etroit qu’il faut peu de chose pour les interrompre. Le pont du Diable est d’une seul arche a plein ceintre de quatre toises d’ouverture deux et demie de large, et de douze toises d’elevation au-dessus de l’eau; le fracas et la rapidite avec laquelle l’eau passe sous ce pont, ne permettent gueres qu’on la considere tranquillement de dessus le pont, on est toujours tente de s’en eloigner.—La distance depuis Gestinen jusqu’a Teufelsbruck ou pont du Diable, qui est environ deux lieues, suffit pour prouver ce que nous disons; cette vallee, qu’on nomme Schollenen, offre a chaque pas des difficultes vaincues, des rochers franchis, des intervalles combles par des murailles, ou il a fallu employer des montagnes de pierres.

“Les chemins sont paves partout mieux que dans beaucoup de villes; des chevaux et des mulets charges les frequentent toute l’annee; et dans quels pays ces grands travaux ont-ils ete executes? Dans un veritable chaos de rochers et montagnes dont partie sont bouleverses, et l’autre paroit prete a s’ecrouler sur le passant, qui ne voit sous ses pieds que des ecueils, des gouffres et des precipices, au fond desquels roule un torrent ecumant et furieux. Si les rochers sont menacans, les avalanches sont encore plus dangereuses dans ce redoutable passage; il n’y a point d’annee qu’il ne perisse des hommes et des betes de somme; on fait voir un endroit ou une avalanche transporta a plus de cent toises au-dela de la Reuss, dix-neuf chevaux et mulets charges ainsi que leurs conducteurs; dans d’autres endroits des quartiers de rochers prodigieux qui ont ete deplaces et transportes de meme.

“Apres avoir passe le pont du Diable, le chemin tourne a gauche, puis a droite, pour monter une rampe assez rapide, tres-bien pavee, qui conduit a une ouverture dans le rocher, c’est le seul passage qui se presente, nomme Urner-Loch, trou du pays d’Urner ou Urseren; un rocher fort eleve est sur la gauche, et les cascades de la Reuss a droite; l’entree du passage est obscure, c’est une galerie souterraine pratiquee dans le roc, haute de neuf pieds environ de facon qu’un homme peut y passer a cheval, de onze pieds de large et trente-deux toises de long; on a pratique 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 ete ouverte; le chemin passoit auparavant en dehors sur une espece de pont qui tournoit le rocher, et se trouvoit exactement suspendu et fort mal assure au-dessus des cascades de la Reuss; de frequens accidens, de grands frais pour reconstruire et entretenir ce pont, souvent entraine par les eaux, ont necessite l’ouverture de ce passage.

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“En sortant de ce passage obscur, on est surpris d’entrer dans une plaine ouverte, riante et couverte de verdure, et de voir couler a cote 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 leve entre deux decorations, dont l’une representoit le chaos et le bouleversement de la nature, et l’autre celle de la nature naissante et paree des premiers et des plus simples ornemens; cette plaine est unie, de forme ovale, couverte d’un vaste gazon et de paturages, 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 isoles et solitaires sont repandus ca et la a l’entree du vallon: a gauche est le village d’In-der-Matt bati en pierres, et a neuf; dans le fond celui de hospital et situe sur le penchant d’un coteau, il est domine par une grosse tour: les montagnes du St. Gothard servent de fond au tableau, elles sont trop eloignees pour laisser apercevoir leur aridite; des montagnes nues, couvertes d’une verdure legere sans arbres et sans buissons, bordent les deux cotes du vallon: enfin tout paroit jeune et d’une creation nouvelle au premier coup d’oeil, qui met le spectateur dans l’etat ou est un homme a son reveil apres un reve epouvantable, ou il n’a vu que des objets effrayans; il se trouve heureux et content d’etre en surete et hors des dangers qui le menacoient, tant les impressions de son reve lui sont encore presentes.

“Ce vallon offre des remarques interessantes pour l’histoire naturelle, sa position, sa forme, et son nivellement ne laissent aucun doute que cet emplacement n’ait ete le sejour des eaux; en examinant les bords du lit de la Reuss, on reconnoit 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, a la meme hauteur, et a mi-cote, sur la gauche, on trouve de la pierre ollaire. Voila encore une de ces circonstances ou il seroit interessant de connoitre la hauteur exacte de cette pierre calcaire, et de pouvoir comparer son niveau avec d’autres que nous avons deja observe etre aussi deposees au pied des montagnes dans de petits vallons fort eleves, analogues a celui dont il est question. Quelque secousse aura rompu l’enceinte de rocher qui fermoit ce bassin: l’ecoulement des eaux aura acheve de creuser ce passage, ou 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 regle certaine: le vallon qui descend du Saint Gothard a 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 etre creuse dans le granit, il y a tout a cote sans interruption, et formant la meme masse de rocher,

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de la pierre schisteuse micacee, melee de quartz, dont les couches sont perpendiculaire, se fendent et tombent par morceaux, qui ont la forme de poutres ou de bois equarris. Cette espece de roche est aussi haute que celle de granit, et composee, dans des proportions differentes, des memes parties integrantes que le granit; n'a-t-elle pas ete apposee et formee contre celle de granit, qui assurement doit etre plus ancienne, puisqu'elle est enveloppee par la roche schisteuse[5]?

[Footnote 5: 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 moitie de largeur, peut occasionner bien des reflexions; nous avons ete oblige 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 defendu de toucher sous peine de la vie. Il est reserve contre les avalanches; ce sont les seules arbres qu'on voie sur les hauteurs environnantes; derriere ce bois on appercoit un glacier d'ou descend un torrent qui va se jetter dans la Reuss; il amene, ainsi que les autres qui descendent de ce cote, des pierres schisteuses micacees, melees de quartz, de meme nature que celle qui est a cote du passage souterrain. On monte par un beau chemin au village de Hospital, qui depend aussi du pays d'Urseren: tout ce canton est renomme pour ces excellens fromages. Il n'y a que des paturages et point d'autre culture. Le bois, qui est de premiere necessite dans un pays aussi froid, aussi eleve et toujours entoure de neige, y manque totalement, on est oblige de l'aller chercher dans la vallee de Schollenen, et on traine sur la neige le bois de charpente. Le village de Hospital est situe sur des roches schisteuses melees de mica et de quartz, elles sont bleues, verdatres, et grises. C'est a Hospital qu'est la rencontre de differens chemins pour passer le Saint-Gothard; il y en a un qui venant du Vallais, passe a cote du glacier du Rhone 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 etre d'apres le grand chemin que nous venons de decrire, qui conduit de la Suisse en Italie.

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“Sur la droite du village de Hospital est un vallon que nous avons visite jusqu’au village de Zum-d’Orff, a une grand demi-lieue. Il y regne aussi une couche de pierre calcaire a meme 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 a de pierre ollaire; une masse enorme de cette espece, sous laquelle on travailloit depuis long-tems pour en tirer de quoi faire des poeles, ayant perdu son equilibre, est tombee sur le cote. Les rochers qui dominent, sont des rochers schisteuse micacees avec du quartz. Ce dernier village fait aussi partie de la vallee d’Urseren, c’est le pays habite le plus eleve de l’Europe; les habitons sont forts et robustes; les montagnes de ce canton etant nues, arides, et fort rapide, les avalanches y sont frequentes.

“C’est au sortir de Hospital qu’on monte veritablement le Mont Saint Gothard: le chemin est escarpe, pave, et bien entretenu. Par un vallon a droite descend le Garceren, torrent qui vient des glaciers; son eau est blanchatre, se jette dans la Reuss, et en trouble la limpidite; les rochers sont de plus en plus depouilles, secs et arides, on trouve les derniers buissons, des aulnes rabougris. La Reuss tombe de rocher en rocher, des blocs et des quartiers enormes, qui remplissent son lit, lui barrent souvent le passage; ses eaux s’elancent par-dessus quand elle ne peut le contourner; on ne voit enfin que des rochers, des abymes et des precipices; on marche neanmoins en surete au milieu de ce desordre de la nature; les chemins sont bien paves, et assez larges pour que deux chevaux ou deux mulets charges puissent y passer de front. Sur un rocher a droite, a une lieue de Hospital environ, on trouve tailles dans le roc les limites entre le pays d’Urseren, et la partie Italienne ou vallee de Livenen; ainsi tout sommet du St. Gothard appartient a la partie Italienne, qui est actuellement sujette du canton d’Uri. On parvient enfin sur un terrain plus uni, et une espece de plateau, c’est le haut du Saint Gothard; a une demi-lieue sur la droite, entre des rochers forts hauts, forts escarpes et a pic, est une espece d’entonnoir, ou se rassemblent les eaux des neiges fondues; elles y forment le petit lac de Luzendro, gele le trois quarts de l’annee, 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 regarde comme la seconde source de la Reuss; le Rhone prend sa source dans la partie opposee du meme glacier. Le haut du Saint Gothard est un vrai vallon, puisque des cimes, des pyramides, des montagnes prodigieuses, composees toutes de rochers, s’elevent au-dessus, et l’entourent de tous cotes. L’espace qui est entre ces rochers a une forme a-peu-pres circulaire; il paroit avoir ete un fond qui a ete eleve et comble jusqu’au point ou il est par les debris des montagnes qui le dominent, et qui s’y amoncelent encore actuellement

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sous nos yeux; il a une espece de niveau qui va un peu en pente du cote du midi, et du cote du Nord par lesquels se fait l'ecoulement des eaux fournies par la fonte des neiges, dont la Reuss et le Tessin sont les canaux. Des masses etonnantes de rochers remplissent la surface de ce vallon: elles y sont placees dans une desordre qui ne ressemble point aux positions des rochers actuels, et autorise a croire qu'elles y ont ete jetees et culbutees au hazard. Ces masses isolees sont toutes de granit, compose de quartz, de feldspath, et de mica verdatre; le chemin qui traverse ce vallon tourne autour de ces masses. Il faut que les pics eleves qui bordent ce vallon ayent ete beaucoup plus hauts qu'ils ne le sont actuellement pour avoir pu fournir a combler cette etendue, 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 acces plus facile, et des rampes moins rapides pour s'elevent comme par degres a cette hauteur, qui composent enfin ces montagnes de seconde et de troisieme formation, ne doivent leur existence qu'aux debris 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'ecoulement d'eaux, quelque petit qu'il soit, qui n'entraine en descendant des montagnes, des terres, des graviers, ou des sables, pour les porter plus bas. Les grands torrens, les fleuves, les rivieres, gonfles par les fontes subites des glaces et des neiges, entrainent des rochers entieres, 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 debris de cette espece de trituration qui troublent les eaux, et dont le depot eleve insensiblement les bords des rivieres, forme le limon fecondant 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 a faconner, ne resistent point au tems et aux intemperies des saisons; leur superficie se denature et se decompose souvent au point de ne pas les reconnoitre: des lichens, des petites mousses s'insinuent dans leur tissu, l'eau y penetre, et la gelee separe leurs parties; s'ils se trouvent place sur une pente de facon a pouvoir etre entraine par les eaux, la plus grosse masse est bientot reduite a peu de chose, apres avoir parcouru un plan incline; quels changemens ne doit pas avoir opere cette marche constante de la nature. A quel point n'est elle pas rendu meconnoissable la superficie du globe que nous habitons. Pour peu qu'on reflechisse que les montagnes fournissent continuellement aux plaines, et que celle-ci ne rendent

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rien aux montagnes, on pourra se faire quelque idee des changemens que la revolution des siecles a du operer. Aussi n'est ce que sur les hautes montagnes qu'on appercoit encore parmi leurs vastes debris, les materiaux qui ont servi et servent aux creations nouvelles que la nature opere journellement, qu'ils sont grands, qu'ils sont majestueux ces antiques debris! 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 Pyrenees (Essai sur la Mineralogie des Monts Pyrenees) page 76.

"La vallee d'Aspe est arrosee dans toute sa longueur, par le Gave, qui prend sa source vers les frontieres d'Espagne: dans les temps de pluie et d'orage, cette riviere est coloree en rouge par des terres composees de schiste rougeatre, qui s'eboulent: des montagnes de Gabedaille et de Peyrenere: au reste les eaux du Gave profondement encaissees dans leur lit ne peuvent plus contribuer a la fecondite des plaines qu'elles ont formees.

"On observe, en suivent cette riviere que lorsque les montagnes courent parallelement, les angles faillans qu'elles forment correspondent aux angles rentrans; cette regle generale sert a etablir que les vallees des Pyrenees, qu'il faudroit plutot 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 demontre avoir ete creusees par les courans de la mer, ou les supposer formees par les torrens qui se precipitent des montagnes?

"Ne croyez pas, dit M. d'Arcet, en faisant mention des vallees des Pyrenees, que les eaux aient pris ces routes parce qu'elles les ont trouvees frayees anterieurement a leur cours; ce sont les eaux meme d'en-haut, qui, se ressemblant peu-a-peu, se sont ouvert de force ces passages: elles se sont creuse ces lits dans le temps passes, comme elles les creusent encore tous les jours. *Voyez la Discours sur l'Etat Actuel de Pyrenees, p.*. 10.

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(p. 86.) “Les pierres que les eaux du Val de Canfrac entrainent, sont rarement usees 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 Pyrenees; le sol des environs de Jacia, plus eleve que celui des plaines du cote de la France, s’oppose a ce qu’elles soient emportees a d’assez grandes distances, et avec la rapidite necessaire pour recevoir, par un long frottement, une figure arrondie: on ne voit point de pierres roulees dans les plaines qui entourent cette ville, les bancs calcaires ne sont couverts que d’une croute de terre peu epaisse; un telle formation differe de celle qu’on observe au pied des monts Pyrenees, du cote de la France, ou le sol de plusieurs contrees est compose des debris que les rivieres y ont deposes[6]; une partie de l’Egypte, selon Herodote, a ete pareillement formee des matieres que le Nil y a apportees; Aristotle la nomme l’ouvrage du fleuve: c’est pourquoi les Ethiopiens se vantoient que l’Egypte leur etoit redevable de son origine. Les habitans de Pyrenees pourroient dire la meme chose de presque toutes les contrees situees le long de la chaine septentrionale, depuis l’ocean jusqu’a la Mediterranee, et qui forment cette espace d’isthme qui separe les deux mers: c’est ainsi que la nature change continuellement la surface de notre globe; elle eleve les plaines, abaisse les montagnes; et l’eau est principal agent qu’elle emploie pour operer ces grandes revolutions; il ne faut que du temps, pour que le mot de Louis XIV. a son petit-fils, se realise. La posterite pourra dire un jour; *il n’y a plus de Pyrenees*. On concoit combien cette epoque est eloignee de nous. M. Gensanne a trouve, par des observations qu’il pretend non equivoques, que la surface de ces montagnes baisse d’environ dix pouces par siecle; ainsi, en les supposant seulement de quinze cens toises au-dessus du niveau de la mer, et toujours susceptibles du meme degre d’abaissement, il s’ecoulera un million d’annees avant leur destruction totale.”

[Footnote 6: 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.

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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.]

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 Rhone that formed the lake of Geneva; for, had the lake subsisted in its present state, while the Rhone 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

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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 Rhone 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.

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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 a ces *angles saillans et rentrans alternativement opposes*, qui lorsque Mr. Bourguet les annonca, 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 phenomene pretendu demonstratif.

"Lorsqu'on voyage dans les vallees, on va ordinairement en tournoyant; et quand un angle saillant oblige a courber la route, on trouve assez souvent un angle rentrant qui lui fait face, et la vallee conserve a peu pres la meme largeur. M. Bourguet ayant fait cette remarque, et considerant que les bords opposes d'une riviere qui serpente, offrent la meme opposition des angles saillans et rentrans, en conclut en general, que les montagnes avoient ete formees par les courans de la mer.

"Si toutes les montagnes, et les *Alpes* par exemple, avoient tous les autres caracteres qu'exige une telle formation celui-la sans doute ne paroitroit pas les contredire; et l'on ne peut meme disconvenir, qu'au premier coup d'oeil, ces zig-zags ne ressemblent beaucoup aux effets des eaux courantes. Cependant ce caractere appartient bien plus aux eaux qui se frayent une route, qu'a celles qui font des depots. Un riviere qui creuse son lit, se detourne a la rencontre d'un obstacle, et ronge le cote oppose; c'est ce qui produit ses meandres. Mais on ne voit point les memes causes de zig-zags dans les courans au sein de la mer; a moins qu'il n'y ait deja des montagnes.

"En effet si l'on considere les montagnes et les collines qui par leurs couches et les corps etrangers qu'elles renferment, montrent sans equivoque qu'elles sont l'ouvrage des eaux, on les trouvera le plus souvent rangees sans ordre. Quelquefois elles ne paroissent que des monceaux poses ca et la; comme dans une grand partie du *Piemont*. Ou si elles sont sous la forme de chaines continues, on y trouve peu de parallelisme, c'est-a-dire de ces angles rentrans opposes aux angles saillans: tel est le Jura.

"Mais si les courans de la mer ont trouve des montagnes toutes faites, et qu'ils les ayent traversees, dans quelque sens que ce soit; ils se sont fraye des routes dans les endroits ou la resistance etoit moindre, et ont ronge les bords de leurs canaux a la maniere des rivieres. On doit donc y trouver du parallelisme.

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“Si maintenant on considere la chaine des *Alpes*, on verra qu’elle repond fort bien a cet effet naturel. Quoique ces montagnes forment une chaine dans leur ensemble, leurs parties superieures ne montrent aucune sorte d’arrangement particulier, aucune trace de zig-zags: c’est dans le fond des grandes vallees, ou dans les coupures qui servent a l’ecoulement des eaux, que ce parallelisme des cotes opposes se remarque; quoiqu’avec bien des exceptions. Et ce qu’il y a de plus important a considerer, c’est que ces grandes vallees ou les angles saillans et rentrans forment l’engrenement le plus sensible, coupent ordinairement la chaine en travers, au lieu de la suivre; ce qui annonce plutot destruction qu’edification.

“Ainsi *les angles saillans et rentrans alternativement opposes dans les vallees des montagnes*, peuvent bien contribuer a prouver qu’elles ont ete toutes sous les eaux de la *mer*; mais non que la mer les ait toutes faites. C’est ici donc un nouvel exemple de la necessite de considerer attentivement les idees qui paroissent le plus naturelles au premier coup d’oeil: car cet apercu etoit bien un de ceux qu’on est tente d’admettre sans examiner autre chose que la verite 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 chaine exterieure des *Alpes* evidemment d’origine *marine*, a cependant des caracteres qui la distinguent de la plupart des autres montagnes de la meme classe; et ces caracteres semblent annoncer plus d’antiquite. 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 couronnees de pics que les *Alpes primordiales*; et ces *pics*, etant par *couches*, montrent des restes d’anciens sommets qui devoient avoir une grande etendue. Ce qui, joint a quelques derangemens dans leurs couches, paroit indiquer que ces montagnes ont ete exposees plus longtemps que la plupart des autres montagnes *secondaires*, aux revolutions qu’essuyoit le fond de la *mer*; et qu’elles en sont sorties deja fort alterees.”

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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.

CHAP. V.

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.

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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.

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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.

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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.

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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[7].

[Footnote 7: Discours sur l’Histoire Naturelle de la Suisse, p. 27.]

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“Nous avons dit precedemment que c’etoit entre Orfiere et Liddes que nous avions vu les derniers granites roules, 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 composes de granites, et quoiqu’on ne puisse aborder jusqu’a leur plus grande elevation, on peut juger de leurs especes, par les masses qui s’en precipitent. D’ou peuvent donc provenir ces masses roulees de granites qui se trouvent jetes et repandus sur le penchant et au bas de ce mont? Il y a peut-etre quelque montagne ou rocher de granite que nous n’avons pas ete a portee de voir: il faudroit plus d’un mois pour faire un pareil examen et parcourir les montagnes environnantes, et faute de pouvoir parvenir a 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 reellement voir et observer. Beaucoup de vallons sont combles a des hauteurs prodigieuses, par les amas et les debris provenant des montagnes superieures: ils cessent d’etre des vallons, pour former ou faire partie de montagnes. Ces deplacement et des bouleversemens, changeant la direction et le courant des torrens, entrainent dans des parties bien opposees des debris 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 egalement des exemples de masses de rochers roules de differentes especes dont il n’existoit pas de rochers pareils, dans toutes les parties elevees environnantes, a plusieurs lieues, a plusieurs journees de chemin, et souvent totalement inconnus dans les pays d’alentour. Si nous avons remarque les meme especes de rochers faisant corps, et attaches au sol, a une ou plusieurs lieues de distance; nous avons vu souvent que des montagnes plus hautes etoient entre ces masses roulees et les rochers, d’ou on auroit pu supposer qu’elles ont ete arrachees: il repugne a croire que des masses, d’un poids prodigieux, ayent ete transportees et roulees en travers d’un vallon profond, pour remonter et passer de l’autre cote d’une montagne. Nous abandonnons, a ceux qui travaillent dans le cabinet, a l’arrangement du globe, la recherche des moyens que la nature a employe pour produire de pareils effets. Nous nous contenterons, ainsi que nous avons promis, de rendre compte de ce que nous avons vu et observe, et d’engager ceux qui auront la facilite de faire des remarques analogues de constater leurs observations en indiquant toujours les lieux fidelement, ainsi que nous le faisions pour la Suisse.”

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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.

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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 degages et sortis entierement des masses qui forment les montagnes, posent immediatement sur le granit friable ou sur d’autres blocs durs qui eux-memes sont sur le granit friable.

“Quoique la plupart des blocs de granit dur, que l’on observe sur toute l’etendue de ce terrain granitique, soient entierement sortis et degages de la masse de pierre qui forme la montagne, on en rencontre cependant qui ne sont pas encore tout-a-fait degages. Et c’est ici l’observation essentielle qui conduit directement a l’explication du phenomene de l’arrangement, de l’entassement, et de *l’amoncellement* des blocs d’une maniere simple et absolue.

“On voit sur la surface du terrain des portions de blocs durs qui semblent sortir peu a peu, et se degager de la masse de granit friable; celui-ci se decompose et se reduit en poussiere tout autour de cette masse dure que les causes de decomposition du granit friable semblent respecter.

“Quelques-uns de ces blocs durs, sortans de la montagne granitique, sont deja considerable; on distingue qu’ils n’y tiennent plus que par une tres-petite partie; d’autres commencent a paroitre se degager, ils ne *saillent*, ils ne sortent encore que de quelque pieds, et meme de quelques pouces. Enfin, en examinant soigneusement et attentivement toute la surface de ce terrain granitique, on appercoit tous les intermediaires entre un bloc de granit dur contenu et enchasse dans la masse totale du granit friable et un bloc entierement degage.

“Ces observations, suivies avec attention, ne laissent aucun doute que les blocs de granit que l’on observe sur toute l’etendue de ce terrain granitique, n’aient fait autrefois partie d’une couche considerable de granit decomposable qui couvroit ces montagnes et exhaussoit leur sol; que cette couche, dont il semble impossible d’apprecier la hauteur, malgre les blocs considerable qui restent et qui attestent son existence, a ete decomposee par l’air et l’intemperie des saisons; que la poussiere, le sable resultans de cette decomposition, ont ete entraines par les eaux, et deposes a divers points de la surface de la globe; et que ces blocs ont ete peu-a-peu degages de la couche, ainsi qu’il s’en degage 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.

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“C’est apres avoir quitte le terrain volcanique, c’est dans le terrain granitique que j’ai trouve des blocs enormes de granit, qui ont fixe mon attention.

“Toute l’etendue du terrain granitique que j’ai traversee, se trouve presque couverte de ces masses; les uns sur les sommets des montagnes les plus elevees, les autres sur la pente et dans les vallees. Plusieurs de ces masses sont arrangees les uns sur les autres avec un art inimitable, les autres sont isolees et eparses.

“Peu de ces masses m’ont presente un spectacle plus beau et plus imposant que celles que l’on rencontre a 6 heures de marche de S. Flour, a une petite demi heure avant d’arriver a la Garde.

“La, sur le sommet d’une montagne, est un amas considerable de blocs de granit, etonnans par leur volume et leur nombre. La grande route passe a travers, et circule autour de ces masses que les constructeurs des chemins n’ont pas ose attaquer.

“Le voyageur est penetre d’admiration en voyant l’ordre et l’arrangement symetrique 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 poses purement et simplement les uns sur les autres, et forment une colonne isolee; le plus gros sert de base, et les autres, graduellement plus petits, son poses dessus. On voit jusqu’a trois de ces blocs immediatement l’un sur l’autre.

“D’autres fois, le bloc qui sert de base est beaucoup plus petit que celui qui le couvre immediatement; et s’arrangement de ces deux blocs presente l’aspect d’un champignon.

“Plus souvent plusieurs blocs separes les uns des autres, forment la base, et un ou plusieurs blocs sont poses immediatement dessus, sans ordre constant, tantot inclines, mais toujours d’une maniere stable et fixe, propre a resister aux plus grands efforts.

“Enfin, par fois, des masses plus petites placees 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.

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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.

CHAP. VI.

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.

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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.

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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.

[8]"Les pluies et les rosees forment partout ou elles sejournent, des depots qui sont la premiere source de toute *vegetation*. Ces depots sont toujours meles des semences des *mousses*, que l’air charie continuellement, et auxquelles se joignent bientot les semences presque aussi abondantes des *gramens*, qui sont l’herbe dominante de nos prairies. Ainsi partout ou la pluie a forme quelque petit depot, il croit de la mousse ou des *gramens*. Ceux-ci demandent un peu plus de *terre vegetale* pour croitre, ils germent, et se conservent principalement dans les intervalles et les creux des pierres: mais la *mousse* croit bientot sur la surface la plus unie. Il n’est aucune pierre long-temps exposee a l’air, qui soit parfaitement polie; l’action de l’air, du soleil, des eaux, des gelees, detruiroit ce poli quand il existeroit. Le moindre creux alors recoit un depot de la pluie, et nourrit un brin de *mousse,* ces brins poussent des racines; et de nouveaux jets autour d’eux, qui contribuent a arreter l’eau de la pluie et de la rosee, et par ce moyen a arreter les depots Nourriciers.”

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[Footnote 8: Histoire de la Terre, Tom. 2. page 26.]

“Quand la mousse a multiplie ses filets, les depots s’augmentent plus rapidement encore; les brins de la *mousse,* en sechant et pourrissant, en forment eux-memes; car leur substance n’etoit que ces memes depots faconnes: d’autres semences charriees 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’humidite necessaire pour produire leurs premieres racines: celles-ci s’entrelassent dans la *mousse*, ou elles se conservent a l’abri du soleil, et sont alors autant de petites bouches qui pompent les sucs, que l’air, les pluies, et les rosees y deposent. Ces premieres plantes sont foibles, quelque fois meme elles ne parviennent pas a leur perfection: mais elles ont contribue a fixer la *terre vegetable*. En sechant et se decomposant, elles se transforment en cette *terre*, qui tombe au fond de la *mousse*, et qui prepare ainsi de la nourriture pour de nouvelles plantes qui alors prosperent et fructifient.

“Nous connoissons peu encore ce que c’est que cette *terre vegetable*, ce depot des pluies ou en general de l’air. Cependant, en rassemblant les phenomenes, on peut conjecturer, que la plupart des corps terrestres sont susceptibles d’etre changes en cette substance, et qu’il ne s’agit pour cette transformation que de les decomposer. J’entends par la une telle division de leurs parties, que devenant presque des elemens, elles puissent etre intimement melees a l’eau, et pompees avec elle par les tuyaux capillaires des plantes. En un mot, il semble suffisant qu’une matiere puisse entrer en circulation dans les vegetaux, pour qu’elle serve a en developper le tissu, et qu’elle y prenne la figure et les qualites que chacun de ces laboratoires est propres a produire.

“Nous pouvons accelerer de bien des manieres la transformation des matieres terrestres en *terre vegetable*. La fermentation, la calcination, une plus grande exposition a l’air, differens melanges, rendent propres a la vegetation, des matieres qui ne l’etoient par elles-memes: voila ce que peuvent nos soins. Mais l’air travaille sans cesse et en mille manieres. Son simple frottement sur tous les corps, en enleve des particules si attenuees que nous ne les reconnoissons plus. La *poussiere* de nos appartemens en est peut-etre un exemple. De quelque nature que soient les corps dont elle se detache, c’est une poudre grisatre qui semble etre partout la meme. La formation de la *terre vegetable* a probablement quelque rapport a celle-la. Toute la surface de la terre, les rocs les plus durs, les sables et les graviers les plus arides, les metaux meme, eprouvent l’action *rongeante* de l’air et leurs particules attenuees, decomposees, recomposees de mille manieres, sont probablement la source principal de la vegetation. *L’air* lui-meme ainsi que *l’eau*, s’y combinent:

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beaucoup d'observations et d'experiences nous prouvent que ces deux fluides fournissent leur propre substance aux parties solides des vegetaux, et par consequent a la *terre vegetable* qui les produit et qu'ils deposent. Quantite de plantes se nourrissent de *l'eau* seule, et nous laissant cependant en se sechant, un residu de matiere 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 elasticite primitive, par divers procedes: et avant la multitude d'experiences qui se sont de nos jours sur cet objet interessant de la physique, le Dr. Hales avoit montre, que les vegetaux renferment une tres-grande quantite *d'air*, qui s'y trouve sans ressort et comme matiere constituante.

"Voila donc probablement les sources ou la nature puise peu a peu la *terre vegetable* dont elle recouvre la surface de nos continens. Ce sont les particules, peut-etre, de tous les corps tant solides que fluides, extraites ou fixees par des procedes qui les rapprochent de leurs premiers elemens, et leur font prendre a nos yeux une meme apparence. Ces particules sont ainsi rendues propres a circuler dans les semences des plantes, a en etendre le tissu a y prendre toutes les proprietes qui caracterisent chaque espece, et a les conserver tant que la plante existe. Ces memes particules, apres la destruction des plantes, prennent le caractere general de *terre vegetable*, c'est-a-dire de provision toute faite pour la vegetation.

"Les plus petits recoins des montagnes, qui peuvent arreter l'eau de la pluie, sont certainement fertilises; ce ne sont pas seulement les grandes surfaces plates, ni les pentes; ce sont meme les faces escarpees des rochers les plus durs. S'il s'y fait quelque crevasse, un arbre s'y etablit bientot; et souvent il contribue, par l'accroissement de ses racines, a accelerer la chute du lambeau de rocher qui l'avoit recu. S'il y a quelque petite terrasse, ou seulement quelque partie saillante grande comme la main, elle est bientot gazonnee. Les plus petites sinuosites se peuplent de plantes; et les surfaces les plus unies, celles memes qui sont tournees vers la bas, recoivent au moins quelqu'une de ces *mousses* plates, nommes *lichen* par les botanistes, qui ne font en apparence que passer une couleur sur la pierre. Mais cette couche est ecaillee, et elle loge bientot de petites plantes dans ses replis; de celles qui veulent l'ardeur du soleil, si le rocher est au midi, ou la fraicheur 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 variete de ces petites plantes, qui font les delices des botanistes, et l'une des sources les plus abondantes ou la medicine puise les secours reels qu'elle fournit a l'humanite.

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“Quelle richesse dans les ressources de la nature! La pesanteur n’est pas plus prete a entrainer les pierres qui se detachent des montagnes, que l’air a fournir de semences celles qui se fixent: et des qu’une fois elles sont recouvertes de plantes, elles sont certainement fixees pour toujours, du moins contre les injures de l’air. Le fait meme nous l’annonce. Si ces ravins ou ces terreins quelconques, tendoient encore a rouler ou a se degrader, en un mot a se detruire de quelque maniere que ce fut, ils ne le recouvriroient, ni de *mousses* ni d’aucune autre plante. La premiere vegetation est due a quelque depot de *terre vegetable*; et les pluies ou l’air n’en forment que lentement; le moindre mouvement la detruite. Le terrein est donc bien certainement fixe quand il se recouvre de plantes; et s’il s’y accumule de la *terre vegetable*, c’est un signe bien evident que rien ne l’attaque plus: car elle seroit la premiere emportee si quelque cause exterieure 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’epaisseur de la couche de *terre vegetable* qui couvre les montagnes, et qui les garantit ainsi de plus en plus de cette destruction a laquelle on les croit exposes: les pluies en un mot, au lieu de les degrader comme on se l’imagine y accumuleront leurs depots. Tel est l’agent simple qu’employe si admirablement le Createur pour la conservation de son ouvrage.”

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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 a V.M. les causes qui garantissent de destruction exterieure 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 deja parvenus a cet etat permanent. Tout roc nud est attaque par l’air et les meteores, et il tend a se detruire quelle que soit sa durete. Mais ce seroit peu que cette destruction exterieure; elle pourroit meme 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’interieur.

“Il n’est presque point de rocher qui offre a l’air une seule masse compacte; ils sont ou crevasses, ou formes par couches; et l’eau s’insinue toujours dans ces fentes. Quand cette eau vient a se geler, elle agit comme un coin pour ecarter les pieces entre lesquelles elle se trouve. V.M. seroit etonnee de la grandeur des masses que cette cause peut mouvoir: elle agit exactement comme la poudre a canon dans les mines; detachant toutes les pieces exterieures qui commencent a se separer, et en decouvrant 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 separer les rochers deja crevasses, qui se trouvent a l’exterieur des faces escarpees. Le petit moellon qui s’y accumule, les depots des pluies, les plantes qui y croissent, les alternatives de l’humidite et de la secheresse, les vicissitudes de la chaleur, les vents meme, sont autant de causes continuellement agissantes quand la *pesanteur* les seconde. Les rochers escarpes se detruisent donc par de continuels eboulemens.

“Mais toutes ces matieres qui tombent, ne sont pas perdues pour les montagnes; il s’en perd meme bien peu. Elles s’arretent au pied des rochers dont elles sont successivement detachees; et la elles s’entassent, s’elevant en forme de *talus* contre ces rochers eux-memes.”

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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.

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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 arrete d'abord l'effet de ces deux grandes causes causes de destruction de montagnes, la *pesanteur* et les *eaux*: la vegetation ensuite arrete 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[9].

[Footnote 9: 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.]

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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 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 eboulement)* 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

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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.

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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[10]. 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.

[Footnote 10: An Account of the Ganges and Burrampooter Rivers, by James Rennel, Esquire. Philosophical Transactions, 1781.]

CHAP. VII.

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.

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“Des montagnes basses (comme le *Jura*, qui est bas comparativement aux Alpes) sont bientot fixees par ce moyen. Il ne se fait presque qu’un seul *talus* depuis leur sommet jusques dans les basses vallees, ou sur la plaine. Aussi l’etat de ces montagnes est-il deja presqu’entierement *fixe*: on y voit tres peu de rochers nuds qui s’eboulent, excepte, aupres des *rivieres*. C’est dans ces lieux-la que l’ouvrage tarde le plus a se finir. Le bas des *talus* est mine par l’eau; leur surface s’eboule donc, pour ainsi dire, sans cesse, et laisse a decouvert les rochers des sommets, qui par la continuent aussi a *s’ebouler*. Mais les vallees s’elargissent enfin; et les *talus* s’eloignant ainsi des *rivieres*, commencent a eprouver 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 etendue, il ne souffre plus aucun changement ruineux: la *vegetation* le recouvre presque partout. Les bas sont cultives de toute sorte de maniere suivant leur exposition; les sommets sont couverts de pelouses, qui forment les paturages les plus precieux. Cette gazonade s’etend 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 etat est presque partout tel que je viens d’avoir l’honneur de la descrire a V.M. J’ai sur-tout observe avec attention les lits des *torrens* qui, en descendent pour se rendre dans les lacs de *Geneva*, de *Neufchatel* et de *Bienne*, ainsi que dans l’Aar et dans le Rhin: et hormis ceux de ces *torrens* qui viennent des gorges ou les terrains sont encore escarpes, ils ne roulent plus que l’ancien gravier qu’ils out apporte autrefois.

“Mais il n’en est pas ainsi des *Alpes*, des *Pyrenees*, et des autres montagnes, qui, comme celles-la, sont beaucoup plus elevees, ou qui sans l’etre davantage ont ete livrees aux influences de l’air dans un desordre plus grand. Dans ce genre de montagnes il reste encore a la *vegetation* de bien grandes conquetes a faire.

“Ces montagnes ne sont pas telles que V.M. pourroit se les figurer naturellement; il faut y etre monte pour s’en former une juste idee. Ce sont des montagnes sur d’autres montagnes. De pres on ne voit que les parties inferieures; de loin tout se confond; il faut donc etre arrive sur une des premieres *terrasses* pour voir les secondes; sur celles-ci pour les troisiemes; et ainsi de suite.

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“La plupart de ces *terrasses* successives sont de grandes plaines, dominees par des rochers qui s’eboulent, et forment des *talus*. Si dans la succession des siecles, les *eboulemens* de ces bandes de rochers en amphitheatre finissoient sans emporter les plaines qu’ils soutiennent, et que les *torrens* eussent creuse leur lit pendant ce tems la a quelque distance des *talus* tout seroit fini par cette premiere operation. Mais il y a peu de hautes montagnes ou les arrangemens soient si simples: souvent ces bandes empietent les unes sur les autres en *s’eboulant*, et alors le repos est bien differe.

“Supposons que ces *terrasses* soient etroites, et que leurs murs, c’est-a-dire les rochers qui les soutiennent, soient fort eleves. Les *terrasses* alors ne suffiront pas pour recevoir les *eboulemens* qui doivent se faire sur elles car le dessus de chacune d’elles s’etrecit de plus en plus par la destruction du rocher qui la soutient. Il pourra donc arriver que ce talus, s’etant etendu jusqu’au bord de la terrasse, se trouve reposer sur une base qui s’eboule encore; et meme cela arrive tres souvent; de sorte qu’a chaque retrecissement de la base, le *talus* lui-meme s’eboule. Ainsi deux *talus*, qui etoient peut-etre deja en pleine vegetation par la lenteur des eboulemens des rochers qui les formoient, pourront etre fort recules a cet egard; le *talus* superieur, parce que la surface fertilisee glissera en bas; et le *talus* inferieur, parce que la sienne sera ensevelie sous de nouveaux decombres.

“Les montagnes qui sont dans ce cas seront proportionnellement plus abaissees que les autres; parce que leurs *talus* se confondant ainsi et devenant par la fort etendus demeureront longtemps a 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 ou les terrasses subsisteront encore apres que tous les rochers se seront *eboules*, les eaux etant recues par reprises, perdront beaucoup de leur rapidite. Elles se rassembleront dans les enfoncemens des petites vallees superieures, elles s’y formeront des lits qu’elles ne rongeront presque point; et la *vegetation* 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

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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

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of the proposition. “L’etat des *montagnes* sera *fixe*, partout ou les *rivieres* seront arrivees au point de n’emporter pas plus de limon hors de leur enceinte, que l’air et les pluies n’y deposeront de *terre vegetable*, et voila enfin quel sera le repos, l’etat permanent de la surface de notre globe. Car alors il y aura compensation entre les destructions et les reparations simultanees, et les montagnes surement 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.

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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[11].

[Footnote 11: 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.]

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.

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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 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.[12]

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[Footnote 12: 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.]

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.

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“Voici la designation des matieres qui furent trouvees en partant de la surface.

51 pieds, meles *de sable tourbeux*, de fable *des dunes pur* et *d’argile* ou limon.

22.——de meme *sable des dunes pur*, et *d’argile* bleuatre.

14.——du meme *sable* pur.

87 pieds.—Ou rien encore n’indiquoit la presence de la mer.

55.——de *sable marin*, et *de limon*, meles l’un et l’autre de *coquilles* dans plusieurs couches.

142 pieds.—Soit la plus grande profondeur, ou s’est manifestee la *presence* de la mer.

49.——*Argille* dure sans melange de coquilles, soit que ce soit une couche *argilleuse continentale,* ou les premiers depots des fleuves; ce qu’il est difficile de Determiner.

191 pieds.

13.——Sable mele de pierres; qui est enfin surement le *sol* vierge continental.

28.——Sable pur; continental encore; car j’ai remarque partout dans la *Geest*, que c’est dans la couche superieure, a une petite profondeur que se trouvent les pierres; au-dessous le *sable* est pur.232 pieds.—C’est a cette profondeur, ou dans la masse de ces deux dernieres couches, que se trouva l’eau douce, et par consequent 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[13].

[Footnote 13: 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.]

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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 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.

CHAP. VIII.

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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.

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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.

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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.

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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 Rhone aux environs de Lyon, et sur la longueur de quarante lieues, et de plus, des montagnes entieres, dans le meme pays, sont formes de pierres dont on ne trouve les analogues que dans la Suisse. Ce fait presqu’incomprehensible est accompagne de beaucoup de circonstances qui meritent d’etre detaillees dans un discours plus longue que celui-ci. Il y a cependant une que je ne peux pas m’empecher de rapporter ici, comme une suite de ce que je viens de dire.

“Dans cette grand catastrophe, a laquelle j’attribue le transport de ces matieres alpines, il se fit de grandes echancrures 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 cinquieme aux environs du village de Grange, trois lieues plus bas que Bienne, et une sixieme a quatre a cinq lieues plus bas que Soleure, a l’endroit dit la cluse. Cette derniere est la plus profonde, et se trouve de niveau avec les eaux de l’Aar. Beaucoup de ces matieres etrangeres au Jura, ont passe par ces echancrures, et sans doute, par bien d’autres et se sont repandues, dans plusieurs de ces vallees. J’en ai vu un suite bien marquee qui a passe par Jougue, par Saint-Antoine, part Mont Perreux, les Grangettes, les Granges Friards, Oye, et qui est allee jusqu’aux plaines de Pontarlier. Cette suite est en ligne droite vis-a vis l’echancrure de Jougue, et la direction de la vallee qui est au bas de ce village. On en trouve quelques morceaux a Metabiefs, mais je n’en ai point vu aux Longevilles, ni a Roche-Jean. Il y en a au-dessus de Saint-Croix ou d’autres ont pu passer aussi pour aller de meme aux environs de Portarlier. Il y en a dans le val de Mousthier-Travers jusqu’au dessus de village de Butte; elles ont meme passe les roches de Saint-Sulpice du cote des Verrieres de Suisse, ou l’on a ete oblige d’en faire sauter de gros blocs avec de la poudre pour degager la grande route; il y en a dans les vallees de Tavannes, et de Delemont; on en trouve bien plus loin, j’en ai vu pres de Roulans, et je ne douterois pas que les pierres meulieres de Moissez et des environs n’eussent la meme origine.”

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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 Sec. 717).

“Dans le haut des vallees entourees de hautes montagnes, on ne voit point de cailloux roulees, qui soient etrangers a la vallee meme dans laquelle on les trouve; ceux que l’on y rencontre ne sont jamais que les debris des montagnes voisines. Dans le plaines au contraire, et a l’embouchure des vallees, qui aboutissent aux plaines et meme assez haut sur les pentes des montagnes qui bordent ces plaines, on trouve des cailloux et des blocs que l’on diroit tombes du ciel, tant leur nature differe 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.

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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 interessantes qu’offrent les rives de Chilea, on remarque au dessous de la fonderie, des collines de petunt-fe blanc comme la neige, parseme de mica argentin de la plus grande tenuite. Dans le voisinage de ce petunt-fe est une argile micacee, qui en est peut-etre une decomposition: on essaya en ma presence d’en faire de la poterie qui avoit tous les caracteres 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.

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I shall give an example concerning the situation in which this stream gold is found in Peru (Voyage au Perou, par M. Bouguer, page 49.)

“Cette Cordeliere occidentale contient beaucoup d’or de meme que le pied de l’orient, et celui d’une autres chaine tres-longue qui s’en detache un peu au sud de Popayan, et qui apres avoir passe par Santa Fe de Bogota, et par Merida, va se terminer vers Caracas sur la mer du nord; outre que l’or en paillettes occupe toujours des postes assez bas a l’egard du reste de la Cordeliere, on ne peut aussi jamais le decouvrir qu’en enlevant presque toujours deux couches de differentes terres qui le cachent. La premiere, qui est de la terre ordinaire, a trois ou quatre pieds d’epaisseur et quelquefois dix ou douze. On trouve souvent au dessous une couche moins epaisse qui tire sur le jaune, et plus bas est une troisieme qui a une couleur violette, qui a souvent trois ou quatre pieds d’epaisseur, mais qui n’a aussi quelquefois qu’un pouce, et c’est cette troisieme dans laquelle l’or est mele. Au dessous la terre change encore de couleur, elle devient noire comme a la surface du sol, et elle ne contient aucun metal. D’ailleurs on ne creuse pas indistinctement par tout. On se determine a chercher en certains endroits plutot qu’en d’autres par la pente de terrain. On agit comme si l’or avant que d’avoir ete couvert par les deux couches superieures, avoit ete charrie par des eaux courantes. On s’est assure aussi que les terres une fois *lavees* ou depouillee de leurs richesses n’en produisent point d’autres; ce qui prouve que l’or y avoit ete comme depose.”

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.

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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.

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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[14].

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[Footnote 14: M. de Lamblardie, *ingenieur des ponts et chaussees*, 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.]

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 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.

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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

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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[15].

[Footnote 15: Observations sur la Physique, *etc*. Juliet 1786.]

“Autant l’interieur du petit bourg de Porto-venere et les rochers qui l’environnent sont a l’abri des tempetes, autant les parties exterieures sont exposees aux coups de mer les plus violens, lorsqu’elles sont en proie au deux terribles vents d’Afrique et a celui du sud-est. Ce dernier en particulier souleve les flots avec tant de violence et a une telle hauteur contre les ecueils qui servent de defense a ce petit terrain, que la mer semble menacer de l’engloutir. J’ai ete le temoin d’un de ces orages, et quoique je fusse a l’abri de tout danger, je ne pourroit vous representer l’horreur que me fit eprouver ce spectacle. J’ai voulu prendre avec exactitude la hauteur moyenne de l’elevation des flots dans les plus violens coups de vent; et quand je vous en parlerai vous serez etonne de leur force et de l’etendue de leurs effets. Les rochers qui sont a la partie meridionale de Porto-venere se rongent et se detruisent peu-a-peu de meme 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 opposee est deserte et inaccessible couverte de precipices, de ruines et d’horreurs; les autres parties du rivage sont renfermees par la riviere du ponent et par celle

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du levant, de meme que celles qui s'approchent des cotes de Provence. Il me paroit que la mer a beaucoup gagne sur le terre dans ces parages; et pour parler seulement de Palmarin, la plus grande, et la plus remarquable des trois isles que j'ai nommees, je crois etre suffisamment fonde pour conclure que la meme pente facile et longue qu'on observe du cote de la terre avoit aussi existe du cote de la mer; mais que cette derniere avoit ete detruite par les orages, qui se sont succedes pendant le cours de siecles. La vue reflechie de ces trois isles me force a les regarder comme ayant ete autre fois reunies, et formant une isle seule par leur reunion, ou plutot comme une presqu'ile attenante a 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 Memoire 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 isle continue a etre devoree par la mer, elle l'attaque dans toutes les parties de son contour, ou elle trouve peu de resistance, et elle ne cesse de creuser, principalement, tous les escarpemens du nord. Il paroit, par les vestiges des antiquites qui sont sur la pointe dite *di Nevola*, que sous l'Empire de Cesar cette isle avoit encore une etendue plus considerable. Il s'y fait journellement des eboulemens; on peut prevoir qu'elle diminuera progressivement, qu'elle se divisera, et que dans les temps a venir elle sera reduite aux rochers de laves qui la supportent, et qui seuls peuvent resister, pendant une longue suite de siecles, a tous les efforts des flots; ce ne sera

surement pas la seule terre que le temps et la mer auront devoree, et que les vicissitudes de la nature ont fait disparoitre avant que l’histoire en ait pu constater l’existence.”

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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 reunion de deux matieres aussi differentes 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 densite sa durete; son odeur fetide annonce une origine ancienne; elle n'est point formee par un depot de nouvelle date; elle differe des pierres calcaires-coquilliere qui recouvrent les volcans du Padouan et du Vicentin, et de celles qui se sont meles avec les produits du feu dans les volcans eteintes de la Sicile: les laves ici reposent sur elle: elle paroit donc anterieure a l'epoque des irruptions qui ont eleve les isles ponces. Par sa nature elle est semblable aux pierres du Mont Circe, et a celles de l'interieure de l'Apennin; il semble que cette portion de montagne calcaire, abstraction faite des matieres volcaniques qui lui sont reunies, a appartenu a quelqu'unes des montagnes qui dependent de la chaine qui traverse l'Italie; car il n'est pas possible que ni elle ni le Mont Circe ayent ete formes seules et isoles ainsi que nous les voyons. Mais quand ont-ils ete detachees? etoient-ils deja isoles lorsque les feux ont commence la formation des isles ponces? ou seroit-ce la meme revolution qui les auroit separes du continent, et qui a opere le desordre que nous voyons dans ces isles 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.

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“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.

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“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.”

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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[16].

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[Footnote 16: 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.]

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 already given, is by no means required in order to confirm a theory founded upon appearances which leave no manner of doubt.

CHAP. IX.

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.

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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.

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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.

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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.

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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[17].

[Footnote 17: Voyage dans les Alpes, tom. 2.]

Sec. 910. “Le premier objet de mon etude fut le Mont Blanc. Il se presente 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’a sa cime, et il semble avoir ecarte et rejete sur ses epaules son manteau de neiges et de glaces pour laisser voir a decouvert la structure de son corps. Taille presqu’a pic dans une hauteur perpendiculaire de 1600 toises, les neiges et les glaces ne peuvent s’arreter que dans un petit nombre d’echancrures, et il montre partout a nud le roc vif dont il est compose.

“Sa forme paroit etre celle d’une pyramide, qui presente au sud-est du cote du Cramont une de ses faces. L’arrete droite de cette pyramide du cote du sud-ouest, monte au sommet, en faisant avec l’horison un angle de 23 a 24 degres. L’arrete gauche du cote du nord-est, monte au meme sommet sous un angle de 23 a 24 degres, en sorte que l’angle au sommet est d’environ 130 degres.

“Cette pyramide paroit elle meme composee de grands feuillets triangulaires ou pyramidaux. Trois de ces grands feuillets ont leurs bases dans l’Allee-Blanche, et forment ensemble tout l’avant corps de la base de la pyramide. Chacun de ces feuillets, vu de l’Allee-Blanche, paroit une grande montagne, je les ai decrits dans le chapitre precedent sous le noms de Mont-Peteret, Mont-Rouge, et Mont-Broglia, Sec. 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-memes composes de grandes feuilles pyramidales; on voit que les injures du temps ont detruit la pointe du Mont-Rouge, tandis que celles des deux autres pyramides sont demeurees entieres.

“Ces trois feuillets ne s’elevent pas jusqu’a la moitie de la hauteur du Mont-Blanc; d’autres feuillets plus petits, situes derriere et au-dessus d’eux, et places sur deux lignes principales qui convergent au sommet, achevent 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 mesure plusieurs, dont l’angle au sommet n’etoit que de 70 degres. Tous, absolument tous, ont leurs plans paralleles a l’Allee-Blanche, et par consequent diriges du nord-est au sud-ouest.

“Sec. 911. Quant a la matiere dont est composee cette grande et haute montagne, toute sa cime et toute sa base, tant au centre que du cote du nord-est, sont indubitablement de granit; mais le cote sud-ouest de la base, ou le Mont-Broglia que nous avons vu de pres, Sec. 834, est d’une pierre moins dure, melangee de schorl, de feldspath, de mica, de quartz gras et de pyrites.

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“On voit tres-bien du haut du Cramont que cette partie de la base n’est point du granit; sa couleur est d’un brun rougeatre, elle ne se termine point par des arretes vives et nettes, n’est point composee de grandes tables planes. Ce font cependant des feuillets pyramidaux, mais petits et presses les unes contre les autres; a mesure qu’ils s’approchent du sommet, et par cela meme du coeur de la montagne, ils perdent leur couleur rouge, leurs angles deviennent plus vifs, leurs tables plus grandes et plus planes, et enfin pres de la cime, et a la cime meme, ce sont de vrais granits parfaitement caracterises. On peut donc conclure, que le corps entier du Mont-Blanc, et meme ces bases avancees du cote de l’Italie, sont toutes de granit, excepte la base de l’arrete exterieure du cote du sud-ouest.

“Sec. 912. La montagne qui touche le Mont-Blanc du cote du nord-est, et qui, vue de Geneve, forme en quelque maniere le premiere escalier en descendant de la cime, est aussi composee de tables de granit qui paroissent dirigees du nord-est au sud-ouest. Mais la sommite qui suit celle-ci en tirant toujours au nord-est, et qui forme le second escalier, paroit avoir quelques feuillets tournans autour de son corps pyramidal, comme les feuillets d’un artichaux, et comme j’ai depeint l’aiguille du Midi, *tome* I. *pl.* 6. En tirant plus encore au nord-est, on reconnoit les Jorasses que nous avons vues du haut du Talefre, Sec. 637, elles paroissent d’ici, apres le Mont-Blanc et ses escaliers, les sommites les plus elevees de toute cette chaine, et elles semblent resulter de l’assemblage de plusieurs suites de feuillets pyramidaux convergents vers leur sommet. En general toutes les cimes elevees que l’on peut distinguer dans cette chaine, depuis le Mont-Blanc jusqu’au col Ferret, sont soutenues par des augives composees d’une ou de plusieurs suites de feuillets pyramidaux appuyes les uns contre les autres; les exterieures ont leurs bases dans le fond de la vallee, et les interieures remontent par degres jusqu’au haut des cimes. Les deux escaliers du Mont-Blanc sont les seules sommites qui n’aient pas des augives de ce genre.

“Sec. 913. Je demande a present quelle idee on peut se faire de l’origine de ces feuillets plans et de toutes ces pyramides grandes et petites qui resultent de leur assemblage, si on ne les considere pas comme les restes ou les noyaux les plus durs des couches qui out resiste aux ravages du temps, tandis que les parties intermediaires, qui les lioient entr’elles, out ete detruites par ces memes ravages.

“Mais jusqu’a quel point la crystallization a-t-elle contribue a determiner ces formes pyramidales? doit-on considerer le Mont-Blanc ou telle autre de ces aiguilles, comme un enorme crystal? C’est une question de theorie que j’examinerai ailleurs. Quant a present je me contenterai de conclure, que la face meridionale de la chaine centrale des Alpes est, comme la face septentrionale de cette meme chaine, composee, pour la plus grande partie, de couches de granit a-peu-pres verticales, et dirigees pour la plupart du nord-est au sud-ouest.”

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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.

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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.

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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.

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“Sec.. 639. J’ai deja plusieurs fois nomme cette montagne, qui est situee immediatement au-dessus du Prieure de Chamouni, du cote du nord-ouest: elle est liee par sa base avec les Aiguilles-rouges, dont j’ai aussi parle dans le premier volume. Mais sa cime est nue, isolee, arrondie sur les derrieres, et coupee a pic du cote de Chamouni. C’est a tous egards une des montagnes les plus interessantes pour un naturaliste.

“J’y montai pour la premiere fois en 1760, et je ne crois pas qu’aucun naturaliste l’eut visitee avant moi; j’y retournai l’annee suivante; j’y allai encore en 1767, et j’y montai enfin pour la derniere fois en 1781, afin de verifier mes anciennes observations, et de me mettre en etat d’en donner une description plus exacte.

“Sec. 640. On peut du Prieure monter au sommet du Breven et redescendre dans le meme jour, mais c’est une course penible, car il faut au moins cinq heures pour monter, et la pente est extremement rapide. On peut cependant faire a mulet le premier tiers de cette montee. 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, nomme *Plianpra*, qui, en partant du Prieure, est aux deux tiers de la hauteur totale de la montagne.

“En montant a Plianpra, on fait pres des trois quarts du chemin sur des debris tombes et roules du haut de la tete du Breven. La colline meme sur laquelle est bati le village du Prieure n’est composee que des debris de cette montagne; ces debris ont debouche par une gorge que nous traversons en montant, et se versant ensuite a droite et a gauche, ils ont pris la forme d’un cone, dont le sommet est au milieu de cette gorge. Les collines de ce genre et de cette forme se rencontrent bien frequemment dans les vallees bordees par de hautes montagnes.

“Ces debris, qui ne viennent pas seulement de la tete du Breven, mais de ses flancs et de sa base, sont des roches feuilletees melangees de quartz, de mica et de feldspath dans toutes les proportions imaginables. De ces differentes proportions naissent differens degres de durete, depuis le granit feuillete le plus dur jusques a la roche micacee la plus tendre.

“Sec. 641. Les rochers au pied desquels on passe avant de gravir la montee rapide et herbee qui aboutit a Plianpra, sont composes d’une roche feuilletee assez dure, dont les couches bien paralleles aux veines interieures de la pierre, suivent la direction de l’aiguille aimantee et sont tres-inclinees a l’horison.

“Le chalet de Plianpra est situe au milieu d’une assez grande prairie en pente douce du cote de la vallee de Chamouni, et dominee du cote oppose par les rocs nus qui forment les sommites de la chaine du Breven. Du bord de cette prairie, on a une tres-belle vue du Mont-Blanc, de la vallee de Chamouni et des glaciers qui y aboutissent. Ces memes objets se presentent avec bien plus d’eclat de la cime du Breven; cependant la vue de

Plianpra meriteroit bien que ceux qui n’auroient pas la force ou le courage d’aller jusques a la cime, montassent du moins jusque la pour s’en former une idee.

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“Comme je ne voulois monter sur le Breven que lendemain, j’employai le reste de la journee a observer les environs du chalet. J’examinai surtout avec soin des rochers situes a une demi-lieue au nord au-dessus du chalet, qui de loin paroissent colores en rouge, comme plusieurs sommites de cette chaine: c’est par cette raison qu’elle porte le nom *d’Aiguilles-rouges*.

“Sec. 642. Je trouvai que c’etoient encore des granits veines, melanges de quartz, de feldspath, de mica et de fer qui colore la pierre en se decomposant au-dehors: cette teinte penetre meme quelquefois assez avant dans l’interieur. Ces rochers sont divises par couches bien distinctes, a-peu-pres verticales, et dans la direction de l’aiguille aimantee, comme celles que j’avois observees au-dessous du chalet. Ces couches sont coupees par des fentes a-peu-pres perpendiculaires a leurs plans, et qui sont pour la plupart paralleles a l’horison, de maniere que ces rochers se trouvent ainsi divises en grandes pieces de forme a-peu-pres rhomboidale. Les veines memes interieures de la pierre sont aussi tres-bien prononcees, et exactement paralleles a ses couches; observation generale 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 inegal des parties du rocher. Ces veines sont dessinees sur le fond blanc de la pierre des feuillets minces de mica noiratre; elles sont tantot planes, tantot ondees, mais toujours regulieres et paralleles entr’elles, excepte la ou il se rencontre des noeuds; encore reprennent-elles leur direction apres en avoir fait le tour. Comme le mica s’y trouve en petite quantite, la pierre est dure, et ne se brise qu’a grands coups de marteau. Lorsqu’on l’observe de pres dans sa cassure, on voit que les petites lames ou ecailles de mica sont constamment couchees dans le sens des veines de la pierre. Ces memes ecailles n’ont presque aucune adherence entr’elles, en sorte que les feuillets dont la pierre est composee, n’adherent entr’eux que par les points ou il ne se trouve point de mica.

“Sec. 643. Je me demandois a moi-meme, en observant cette pierre, s’il etoit possible qu’elle eut ete formee dans cette situation verticale; si ces ecailles incoherentes auroient pu venir s’attacher a ces murs verticaux, et si le mouvement des eaux, clairement indique par le tissu feuillete de la pierre, n’auroit pas du les detacher et les faire tomber a mesure qu’elles se formoient. Je me demandois encore, si les fentes qui coupent ces feuillets, perpendiculairement a leurs plans, ne dateroient point d’un tems ou ces couches auroient ete horisontales, et n’auroient point ete produites alors par le poids et l’affaissement inegal 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 ete si frequent, si regulier, *etc*. *etc*. Je reserve 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 theorie des observations si minutieuses en apparence.

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“En faisant ces reflexions, je retournai au chalet de Plianpra ou je passai la nuit sur de la paille que j’avois fait etendre aupres du feu, parce que la soiree etoit extremement fraiche.

“Sec. 645 On commence a monter par de jolis sentiers peu inclines, pratiques le long d’un grand rocher semblable a ceux que j’avois observes la veille. On a ensuite le choix de monter, ou par des pentes couvertes de rocailles un peu fatigantes, ou par des gazons extremement rapides. Ceux-ci paroissent d’abord plus agreables et moins penibles; cependant ces gazons sont si serres et si glissans, qu’ils en deviennent dangereux, au moins pour ceux qui n’ont pas l’habitude des montagnes. Ces rocailles sont debris de roches feuilletees, semblables a celles que l’on rencontre en montant du Prieure a Plianpra.

“Sec. 646. B. Au bout d’une heure de marche, on arrive au pied d’un rocher assez escarpe, qu’il faut escalader pour parvenir a la cime de la montagne. C’est une roche micacee, mais qui contient cependant assez de quartz pour avoir de la consistance. Elle se separe par feuillets si decides, que sans employer d’autre instrument que mes mains, j’en detachai une dalle, qui avoit sept pieds de hauteur sur quatre de largeur, et a peine un pouce dans sa plus grande epaisseur.

“J’avois quelque desir de descendre de-la au pied des grandes tables verticales qui composent la tete du Breven, pour les observer de pres et comparer ainsi leur base avec leur cime; mais de cet endroit la chose est impossible, la pente est d’une telle rapidite qu’une pierre mediocrement grosse, que je mis en mouvement, roula avec beaucoup de vitesse, en entraina d’autres, celles-ci d’autres, et elles formerent enfin un torrent de pierres qui se precipita avec un fracas mille fois repete par les grands rochers du Breven.

“Comme donc je ne pouvois pas descendre, je montai par le passage ordinaire, qui est une espece de couloir ou de cheminee ouverte, adossee a un rocher presqu’a 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’a un demi-quart de lieue plus au nord, on trouve un autre passage extremement commode, qui mene au meme but, et qu’il faut par consequent toujours preferer.

“Ce rocher une fois escalade, on monte par une pente douce, sans danger et sans fatigue, jusqu’au sommet du Breven.

“Sec. 646. C. En montant le long du bord, du cote de Chamouni, j’eus un plaisir inexprimable a contempler les magnifiques tables de granit dont est composee toute la tete de cette montagne. Car bien que les ecailles du mica noiratre dont cette roche est melangee, soient paralleles entr’elles et lui donnent ainsi quelque ressemblance avec une roche feuilletee, cependant la quantite de quartz et de feldspath qui entrent dans sa composition, son extreme durete, le peu de disposition qu’elle a a 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[18]; et le parfait parallelisme de ces feuillets avec les faces des grandes tables, ou des grandes divisions du rocher, demontre que ces tables sont des couches, et non des parties separees par des fissures accidentelles.”

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[Footnote 18: “La denomination de *granit veine* que j’ai, a ce que je crois, employee le premier, a paru tres-heureuse a quelques naturalistes, et a, au contraire, souverainement deplu a quelques autres. Un de ces derniers pretend que ce que je nomme granit veine n’est qu’un amas de gravier graniteux, et par consequent une espece de gres grossier. Mais je voudrois que ceux qui de bonne foi pourroient croire que j’aie commis une erreur aussi grossiere et aussi frequemment repetee, observassent les granits du Breven; et j’en enverrais volontiers a 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 empatees les unes avec les autres, comme dans les granits en masse; que leur coherence est aussi grande que dans ces derniers granits, et que cette roche n’en differe absolument, comme je l’ai deja dit, que par le parallelisme qu’observent entr’elles les lames rares de mica dont elle est melangee: je suis persuade qu’ils reconnoitroient qu’elle a tous les caracteres essentiels du ranit, qu’elle doit avoir la meme origine, et qu’en un mot elle est au granit proprement dit, ce qu’une pierre calcaire feuilletee est a une pierre calcaire dans laquelle on ne distingue point de feuillets.”]

“L’extreme regularite de ces tables acheve de demontrer que ce sont de veritables couches. Leurs plans qui sont ici a decouvert dans une hauteur perpendiculaire de plus de 500 pieds, sont parfaitement suivis, comme tailles au ciseau, diriges tous comme l’aiguille aimantee, et verticaux, a quelques degres pres dont ils s’appuyent contre le corps de la montagne. On s’assure en montant que cette structure est celle de la montagne entiere; on voit les profils d’une infinite de ces couches, on passe sur les sommites de ces tranches verticales, et on les voit se prolonger dans cette meme direction tout au travers de la montagne. Or je demande si un naturaliste qui aura observe cet ensemble et ces details pourra regarder cette montagne comme le produit du concours fortuit de grains de sable agglutines entr’eux.

“Ces tables sont coupees un peu obliquement a leurs plans par des fentes dont la plupart sont a-peu-pres horizontales et d’autres tres-inclinees a l’horizon. La pierre se trouve ainsi tres-frequemment coupee en parallelepipedes obliquangles. Ces memes fentes rendent raison, d’une observation que j’avois faite en 1776. En examinant avec une bonne lunette, depuis une fenetre du Prieure, les faces verticales des couches de la sommite du Breven, j’avois remarque un grand dieze [Illustration] bien nettement ecrit sur la face de la montagne, je le vis de pres en 1781, et je reconnus qu’il etoit forme par quatre de ces fentes qui se coupoient obliquement.

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“Sec. 647. La cime de la montagne est une pointe mousse, coupee a pic du cote de la vallee de Chamouni et arrondie de tous les autres cotes. Cette tete est entierement couverte de debris et de blocs confusement entasse. On est etonne de trouver la ces debris, car cette cime est absolument isolee, et separee par de larges et profondes vallees des sommites qui la surpassent en hauteur: il semble que ces debris n’aient pu tomber que du ciel; mais quand on les examine avec soin, on voit qu’ils sont du meme genre de pierre que la montagne elle meme; et que tous leurs angles font vifs, leurs faces planes et leur forme souvent rhomboidale. On reconnoit donc par la que les parties superieures de la montagne, qui sont plus exposees aux injures de l’air et qui ne sont pas assujetties par des masses situees au-dessus d’elles, se delitent et se separent. Je trouvai cependant sur la cime une pierre d’une espece differente; c’etoit une roche composee de schorl noir en aiguilles, de quartz et de grenats; sa forme etoit exactement rhomboidale. Mais ce genre de pierre se rencontre assez souvent en filons dans les roches feuilletees et dans les granits veines; il est donc vraisemblable que le filon auquel ce fragment avoit appartenu s’est detruit avec la partie superieure du rocher, du moins n’en ai-je pu trouver aucun indice dans la partie solide de la montagne.

“L’admirable regularite des couches de cette cime elevee merite l’attention des amateurs de la geologie, et la vue qu’elle presente dedommageroit seule de la peine d’y monter.

“Sec. 648. Mon but principal dans la premiere course que je fis au Breven etoit de prendre de la une idee juste des glaciers de la vallee de Chamouni, de leur forme, de leur position, et de l’ensemble des montagnes sur lesquelles ils sont situes. Comme cette montagne est postee a-peu-pres au milieu de la vallee de Chamouni, en face du Mont-Blanc et vis-a-vis des principaux glaciers qui en descendent, c’etoit certainement un des meilleurs observatoires que l’on put choisir dans cette intention. J’y montai par le jour le plus beau et le plus clair; c’etoit mon premier voyage dans les hautes Alpes, je n’etois point encore accoutume a ces grands spectacles; en sorte que cette vue fit sur moi une impression qui ne s’effacera jamais de mon souvenir.

“On decouvre tout-a-la-fois et presque dans un seul tableau les six glaciers qui vont se verser dans la vallee 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 eleve. On voit ces etendues immenses de neige et de glaces, dont, malgre leur distance, on a peine a soutenir l’eclat, ces beaux glaciers qui s’en detachent comme autant de fleuves solides qui vont entre de grandes forets de sapins, descendre en replis tortueux, et se verser au fond de la vallee de Chamouni; les yeux fatigues de l’eclat de ces neiges et de ces glaces se reposent delicieusement ou sur ces forets, dont le verd fonce contraste avec la blancheur des glaces qui les traversent, ou dans la fertile et riante vallee qu’arrosent les eaux qui decoulent de ces glaciers.”

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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.

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The summit of the granite pyramids of Mont-Blanc, the summit of the Breven, that of the Saleve[19], 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.

[Footnote 19: See Part II. chap. 30.]

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.

CHAP. X.

The Theory illustrated with a view of the Valleys 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.

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(M. Bourrit[20], *Nouvelle Description des Alpes*.) “Saint-Maurice est entre le Rhone et une montagne; “Quoique la situation de Saint-Maurice paroisse l’exposer au malheur d’etre un jour ensevelie sous les ruines des montagnes, cependant on ne vit pas ici avec moins de securite qu’ailleurs: ce qu’il y a de plus a craindre, c’est la submersion du pays; ce malheur pourrait arriver si l’une ou l’autre des montagnes qui forment la gorge, venoit a tomber soit par un tremblement de terre, soit par des affaissemens considerables: cette gorge etant etroite, le Rhone ne pourroit plus s’ecouler il s’etendroit necessairement au large, bientot toute la vallee jusqu’a Martigni, Sion meme, rentreroit sous les eaux qui l’ont autrefois couvert, et tout ce pays ne formeroit plus qu’un lac, a moins que le Rhone ne se fit jour sous les rochers renverses, comme il passe au travers de ceux qui semblent lui disputer le passage a cinq-lieues au-dessous de Geneve.”

[Footnote 20: M. Bourrit, *etc*.]

“Avant de penetrer dans le Vallais, il convient d’en donner une idee generale: il forme cette partie des Alpes connue sous le nom d’Alpes Pennines; il contient non-seulement les plus hautes montagnes des Alpes, mais encore la plus longue vallee qui il y ait en Europe, puis qu’elle a trente-quatre lieues depuis Saint-Maurice jusqu’a-la source du Rhone, qui la traverse dans toute cette etendue: sa largeur est depuis demi-lieu jusqu’a une lieue et demie; sa direction suit le soleil. Outre cette vallee, il y en a d’autres qui y viennent aboutir dans diverses directions: celle-ci sont enclavees dans les deux chaines de montagnes qui bordent la grande vallee; quelques-unes remontent a quatre lieues et meme a six, dans les sinuosites que forment les rochers qui bordent les deux cotes 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 depot pour les marchandises qui vont et viennent d’Italie. Le chateau a cote de cette ville est situe 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 a l’Hospice situe sur ce mont; a une demie-lieue on commence a monter insensiblement; le chemin est beau et peut se faire en voiture jusqu’au bourg Saint-Pierre.

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“Le vaste base de ces monts accumules n’est qu’un compose des debris des montagnes superieures; on rencontre ici des granits roules, composes de quartz, de feld-spath, et de mica; des graviers et des sables provenant de la decomposition 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 a portee de la vue et qui forme cette gorge sont absolument de pierres micacees par lits et par couches, ou schisteuses melees de gros et petits rognons, de filons et de veines de quartz; elles font en general toutes feu avec le briquet. Le chemin et la Drance qu’on passe et repasse plusieurs fois, occupent tout le fond de la vallee qui devient fort etroite. On rencontre des pierres schisteuses, quartzeuses et sablonneuses, seules sans melange d’autre especes.

“Saint-Branchier, bon village, est situe entre des montagnes tres-hautes et tres-escarpees composees des memes especes des pierres schisteuses micacees que les precedentes; elles sont de couleur bleuatre, vue en grandes masses et inclinees a l’horison; cette inclinaison suivant la meme direction de ce cote ci de la Drance, et les couches se correspondant l’une a l’autre, on voit que ce torrent s’y est creuse un passage. En avancant, on trouve de l’ardoise feuilletee bleue avec des veines de spath calcaire, ensuite une grande quantite de granits et de pierres calcaires roulees, sans que les montagnes environnantes changent d’especes; les montagnes a l’est sont bien cultivees, rapportent differentes sortes de grains, avant et apres avoir passe orsiere; on retrouve de l’ardoise entre ce village et Liddes et les derniers granits roules.

“La Drance est ici fort resserree et tres encaissee; ce n’est pas sans fremir qu’on s’appercoit, quand on est sur deux morceaux de bois jetes d’une roche a l’autre, appelles ici pont, qu’on a un gouffre de plus de trois cent pieds au dessous de soi, il faut etre sur cette espece de pont pour s’en apercevoir et distinguer les differents sinuosites tracees sur chaque cote de cette roche du haut jusqu’en bas; ce sont autant de preuves des differentes hauteurs ou l’eau a passe avant de parvenir a sa profondeur actuelle.

“La dernier village qu’on rencontre, avant d’arriver au Saint-Bernard, est le bourg Saint-Pierre, on mont insensiblement jusqu’a ce village, et on ne peut plus se servir de voitures pour aller au-dela. 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 quantite des rochers dont toute cette partie est couverte que par la difficulte de les entretenir ou de les renouveler chaque annee, parce que les torrens et les avalanches les detruiroient; de plus on ne pourroit y travailler que trois ou quatre mois de l’annee, les huit ou neuf autres mois le pays, au dela du bourg, etant presque toujours couvert de neige. La truite ne remonte pas au-dela du bourge Saint-Pierre, elle se trouve arretee par

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les cascades et chutes trop considerables de la Vassoree qui va se jetter dans la Drance. Ce torrent sort encaisse et resserre dans le lit qu'il s'est creuse, provient d'un glacier qu'on rencontre en montant le Saint-Bernard qui porte le meme nom. L'entree du valais est fermee et defendue de ce cote par le lit de la Vassoree; c'est le fosse le plus profond et le plus escarpe qui existe. Des ouvrage creneles et une porte sont places a l'entree du bourg Saint-Pierre, nous avons donne un dessin de la chute de ce torrent, on voit le travail des eaux dans le rocher qu'il a mine et ou il s'est ouvert un passage.

"On compte trois lieues de ce bourg a l'Hospice, sur le haut du Saint-Bernard; c'est le passage le plus frequente pour communiquer du Bas-Vallais en Italie par le Piemont et la vallee d'Aost; le transport des marchandises ne se fait qu'a dos de mulets et de chevaux; c'est du produit de ces transports que vivent la plupart des habitans qui sont des deux cotes 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 entasses les uns sur les autres, entre lesquels on passe par mille detours, en suivant les petits vallons qu'ils forment. Des torrents des eaux y roulent et s'y precipitent de tous cotes; on voit dans ces bas, de bois de sapins meles de quelques pins et puis des melezes; ils diminuent insensiblement, leurs vegetation est moins vigoureuse, les arbres sont plus rares les derniers qu'on rencontre sont des melezes a 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 melezes et les aulnes, est un sureau sans fruit. Les paturages, l'herbe et le gazon suivent la meme progression. Ce n'est-que dans quelques endroits, d'ou les eaux n'on pas entraine une restant de terre vegetale, qu'il se voit un gazon fin, menu et serre; de petites fleurs, aussi bases que ces gazons, nuancees des plus belles et des plus vives couleurs, y forment des groupes de la plus grande beaute; des mousses non moins curieuses que variees, couvrent et colorent quelques parties de rochers; le reste n'offre a l'oeil que d'enormes masses de rochers, entrecoupes de fentes, de crevasses; des pierres culbutees et amoncelees dans les fonds, qui font en partie couverts de neige.

"A une demie lieue de l'Hospice dans une vallon assez large pour une pareille hauteur, nomme les Envers des Foireuse, on rencontre une enorme quantite de pierre roulees 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 elevee du groupe de montagnes, qui forment le grand Saint Bernard. La sont des neiges et des glaciers de cette partie, fournit aussi la Drance qui va se jetter dans le Rhone au dessous

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de Martigny. On ne voit de ces pierres roulees qu'en cet endroit, elles viennent directement des glaciers, elles ont ete charriees par les eaux qui en viennent, et ne peuvent avoir pris leur forme que par les meme causes, dont nous avons parle ci-devant dans l'observation faite en Savoie sur les pierres roulees; elles sont toutes, ainsi que les rochers au-dessus, d'ou-elles proviennent, composees de parties micacees-argilleuses, plus ou moins melees de partie de rognons, de veines et de filons de quartz, par lits et par couches irregulieres, plus ou moins epaisses. Les parties micacees de ces pierres sont variees de differentes nuances, tirant sur le gris, le bleu, le verd, et le jaune; ces nuances sont quelquefois melees. Tous les rochers composans ce cote de montagne tourne au nord, sont de la meme espece. Nous n'y avons pas vu un seul granit, c'est-a-dire, une pierre composee de petites masses irregulieres de quartz, melees et agglutinees, avec des parties micacees argilleuses, et quelquefois melanges de feldspath. Parmi ces pierres, il y en a quelques-unes provenant du meme filon, qui contiennent de la pyrite cuivreuse dans un filon de quartz.

"Nous avons dit precedement que c'etoit entre Orfiere et Liddes que nous avions vu des derniers granites roules, 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'a leurs plus grands elevation, on peut juger de leurs especes, par les masses qui s'en precipitent.

"(Page 35.) Malgre la chaleur qu'il avoit fait le jour de l'arrivee au Saint-Bernard, la nuit fut froide; le lendemain (31 Juillet) le haut de la montagne etoit enveloppe de nuages epais, mais tranquilles, il n'y avoit point d'agitation dans l'air on assuroit qu'il faisoit beau au-dessous de ce sommet; nous fumes visiter le revers meridional de la montagne qui conduit au val d'Aost; apres une demie heure de marche, nous fumes hors de cet atmosphere sombre et humide, le soleil etoit chaud, le ciel pur et serein: on voyoit dans le lointain les sommets des plus hautes montagnes enveloppes dans les nuages comme le Saint-Bernard: les sommets les plus a portee etoient decouverts et eclaires par le soleil; ces rochers termines en pointe, en pyramides et en aiguilles, sembloient s'elancer dans la region pure de l'ether: des vallons profonds, des ecueils, et des precipices effrayants les entouraient. Toutes ces masses sont, comme dans la partie opposee de la montagne, des pierre schisteuses, argilleuses et micacees: le plupart schisteuses, c'est-a-dire par feuillets, par lits ou par couches differemment inclinees, le toute mele de veines et de parties quartzeuses, de couleurs variees, mais les verdatres dominent: il y a de plus sur la hauteur de ce revers des masses et des blocs prodigieux, sans melange, de quartz blanc et grenu a sa superficie, lesquels, au premier coup-d'oeil, paroissoient etre de marbre de Carare; a quelque distance c'est un chaos immense de blocs de pierres de toutes grandeurs, jetes, culbutes, entasses dans la plus grand confusion; c'est la meme espece de pierre micacee; il faut que des sommets, des rochers prodigieux se soient ecroules pour avoir produit un pareil desordre qui ressemble a la destruction d'un mond.

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“(Page 40.) On trouve aux environs du couvent quelques schistes argilleux ou ardoises grises feuilletees detruites a moitie. On ne voir nulle part de ces ardoises sur pied ou formant des masses attachees au sol; il faut que les couches ou les lits de ces ardoises, qui avoient ete formes et places sur ces hauts, ayent ete detruits et renverses par le temps.

“Enfin toute cette montagne, une des plus hautes des Alpes Poenines, qui conserve des neiges et de glaces permanentes, est composee en general de pierres et de roches schisteuses, dont les couches et les lits sont plus on moins sensibles et inclines, et d’une grande durete. Leurs parties constituantes sont un mica argilleux dont les lames ou les parties sont plus ou moins grandes et brillantes et diversement colorees: elles sont traversees de filons et de veines meles 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 etoient isoles et roules. Quelqu’un qui aura plus de temps, plus de loisir, decouvrira peut-etre d’ou ces masses proviennent[21].”

[Footnote 21: 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.]

We have here a picture of one of those valleys which branch from, or join the main valley of the Rhone. In this subordinate valley, there is the most evident marks of the operations of water hollowing out its way, in flowing 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.

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In taking this view of the mountains on each side which supply the water of the Rhone, 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 Rhone, 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 Rhone, 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 Rhone pour visiter les bains de Loiche, afin de ne pas revenir sur nos pas. De Sierre on passe par Clare et Salge, en laissant le Rhone sur la droite; tout ce terrain est calcaire et fort pierreux. A Faren (villages qui ne font point sur les cartes) on commence a 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 composes de quartz, de feld-spath, et de mica, d’ou viennent-ils? On ne voit que des roches calcaires et point de montagne plus elevee au-dessus; on passe par un bois de pins, on parvient enfin a un escarpement a pic, dont on n’a point d’idee pour la hauteur; on reste stupefait de voir le gouffre qu’on a devant soi, et on ne prevoit pas trop comment on parviendra dans ce fond, ou la vue a peine a distinguer la Dala, gros torrent qui y precipite ses eaux. On a taille a grands frais un sentier tortueux dans cette roche toute calcaire; On a eu soin de garnir le cote scabreux du sentier avec des pierres ou des garde fou, pour rendre ce passage moins effrayant; ces precautions ne peuvent guerir de la crainte de voir tomber d’enormes quartiers de rochers suspendus au-dessus de soi, ils sont fendus et crevasses partout, et menacent de se precipiter a chaque instant; on ne peut meme s’empecher de remarquer qu’il y en a qui sont tombes nouvellement! Ce sont des mineurs Tiroliens qui ont fait cet ouvrage, ainsi que le passage du Mont-Gemmi.

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“Quand on est descendu au tiers environ de cet enorme fond, on passe sur les decombres de cette vaste montagne, et par un bois de pins et de sapins; la vue ne perce pas dans ce fond tenebreux, on entend plutot le bruit du torrent qu’on ne l’appercoit. Ayant eu occasion de voir et d’examiner par la suite ces bas et le pied de cette etonnante 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 feuilletees sans melange, que ce lit est detruit et se detruit dans differens endroits, qu’il est incline et affaisse dans d’autres, et que c’est la destruction qui a occasionne la chute d’une partie de cette montagne; elle est par-tout a pic de ce cote, et a subi successivement ces renversements qui paroissent plus anciens les unes que les autres, car ces debris sont plus ou moins couverts de bois, d’arbres, et de productions vegetales.

“On continue la route a mi cote au travers de ces debris. Le sommet de ces montagnes eclaires par le soleil, etoit peint de rouge, de jaune, de blanc, de bleu, et de noir, dans les endroits ou les eaux avoient coule par-dessus, ils ressemblent de loin a des murailles, des tours, des forts, et des fortifications de differentes formes placees pour se defendre contre des ennemis qui viendroient par les airs. Les neiges qu’on appercoit dans differents endroits, produisent des chutes d’eau, des cascades, dont partie se reduit en vapeurs avant d’atteindre le bas: le haut des montagnes qu’on voit de l’autre cote de ce vallon, est egalement 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 sejour des neiges et sont partie de la Gemmi.

“Une de plus haute montagnes du Vallais, et situee sur une terrain tres-eleve, est la Gemmi; elle fait partie de la grande chaine qui separe le Canton de Berne du Vallais. Elle est remarquable, a cause de l’importance du chemin qu’on y a pratique, des grandes difficultes qu’il a fallu surmonter, et qu’elle est la seule communication entre les deux Cantons. Nous parlerons de ce chemin, apres avoir decrit la nature de ce prodigieux rocher. La Gemmi est la partie la plus haute de cette chaine qui commence aux galleries; elle est en general calcaire. On commence a monter insensiblement en sortant de Loiche; on traverse beaucoup de paturages; on voit quelques champs de seigle qui etoient encore sur pied et a moitie verts, des bosquets et de petits bois de sapins. Des masses considerables des rochers, des monceaux de pierres entassees 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 forme des pierres et des sables qui tombent des hauts et produisent, a la longue, des talus formes en pain de sucre, adosses contre les parties escarpees; les plus grosses pierres

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roulent et se precipitent plus bas, servent de point d'appui aux nouveaux materiaux qui s'y arretent, augmentent la hauteur des talus, en elargissant les basis, et finissent par devenir des montagnes tres considerables qui ont augmente en raison de la quantite des debris qu'ont pu fournir les parties plus elevees; c'est ce qu'on nomme montagnes de troisieme formation, composees des ruines de celles qui dominent ces talus; ces eboulemens sont ordinairement plus fertiles, plus couverts de vegetaux, d'arbres et de forets, sur-tout s'ils sont composes de differentes especes de debris. Nous avons deja vu que les montagnes calcaires sont elles-memes 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 ete arranges et formes successivement; quelle est donc la base primitive sur laquelle sont appuyees et reposent ces masses qui etonnent l'imagination, a quelle profondeur faudra-t-il l'aller chercher? Si nous concevons la formation et la maniere dont se sont accrues et elevees ces troisiemes montagnes, pouvons-nous imaginer comment se sont arrangees celles qui sont si elevees au-dessus d'elles, ce tout que rien ne domine. C'est en examinant en considerant ces grands spectacles que ces reflections nous viennent; nous nous arretons, pour continuer a decrire ce que nous avons vu et remarque, qui est la tache que nous nous sommes imposee.

"En arrivant au pied de l'escarpement, le premier objet qui frappe la vue, ce sont des bancs de schistes ou d'ardoises bleuatres, meles de larges filons de quartz qui forment la base, et les fondemens sur lesquels est eleve ce mur de pierres calcaires. Car cette roche est elevee de meme a pic; ce lit d'ardoises est un peu incline vers le couchant, ainsi que tout ce qui repose dessus; la destruction de ce lit a cause, ainsi qu'aux galeries, la chute des rochers superieurs, et leur a occasionne cet a-plomb. Avant ces eboulements, ces couches schisteuses devoient etre decouvertes a une grande hauteur, etre exposees aux injures du tems et des saisons, se detruire et se decomposer plus aisement. Peut-etre que l'enveloppe calcaire les couvroient entierement, et que ces schistes n'ont commence a se detruire qu'apres la ruine de la pierre calcaire. Actuellement ces schistes sont enterres et couverts; ce n'est qu'en peu d'endroits qu'on les appercoit; appuyes soutenus et couverts par ces immenses debris en talus, ce sont des contre forts qui les aiderons a supporter plus longtemps les prodigieuses masses sous lesquelles ces schistes sont ensevelis. Nous allons placer par ordre les differentes substances, telle qu'elle se presentent en montant.

"1. Base de schiste ou d'ardoise feuilletee bleuatre, traverse, de larges filons de quartz. On ne voit, on ne peut estimer son epaisseur dont partie est enterree.

"2. Immediatement dessus pose la pierre calcaire, elle est d'une grain fin, serre, couleur grise-jaunatre, ainsi que toute le reste.

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“3. Des filons de differentes epaisseurs, d’un spath calcaire jaunatre.

“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 melees d’une quantite 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 deposes des especes de noyaux oblongs, quelques fois par couches, mais sans suite, composes d’un sable fin de couleurs grisatre, plus blanc que la pierre calcaire, tres-durs, faisant feu au briquet, et sans effervescence avec les acides.

“10. On retrouve encore des couches minces sablonneuses melees de parties calcaires.

“11. D’autres de pierre calcaire compacte et d’une epaisseur considerable.

“12. Alternativement de moins compactes. Dans l’une de ces couches il y a de la pyrite vitriolique decompose, qui teint en jaune les parties du rochers sur lesquels a flue la decomposition martiale.

“13. Quelques filons de spath jaunatre, entremeles de veines de schiste pur, ne faisant pas effervescence.

“14. De la pierre calcaire.

“15. Des schistes meles de parties calcaires.

“16. De la pierre calcaire pure.

“17. De larges filons de spath calcaire jaunatre meles de quartz, faisant feu au briquet, et une peu d’effervescence.

“18. De la pierre calcaire pure grise, plus foncee que dans le bas.

“19. Des couches calcaires jaunatres.

“20. Enfin tout le haut n’est que pierre calcaire grise et denaturee. Cette partie superieure du monte est fort etendue. Tout ce qui est sur le local qui va en pente assez douce vers le milieu, n’a pas ete assujetti a de roulis et a des frottemens, il n’y a que la

longueur du tems qui l'ait degrade, et lui ait imprime le caractere de la vetuste. 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 grossiere; le sejour des neiges des eaux, la gelee, et l'intemperie des saisons a tout fait. On voit de tous cotes que l'eau s'y infiltre et s'y perd. L'arrangement de cette espece de pierre par couches, facilite l'entree des eaux dans l'interieur de la montagne pour aller donner naissance a des sources, a des torrents, et quelquefois a 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 especes 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 a ce lac, ses eaux sont absorbees, et se perdent dans

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l’interieur 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 ou est Loiche; c’est le meme glacier qu’on appercoit derriere les sources chaudes. Deux aiguilles de rocher en cone, fort hautes s’elevent au-dessus du sommet; elles sont toujours couvertes de neiges: leur ressemblance et leur proximite a donne le nom de Gemmi Jumeaux, a cette montagne—On voit a ses pieds a une profondeur immense le village de Loiche, qui paroit etre 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 pratique dans ce rocher, y a ete par-tout taille; il le contourne certains endroits, dans d’autres il est creuse de facon qu’il forme une voute couverte, et qu’on a le rocher suspendu au-dessus de soi. Il est rare de trouver l’occasion de pouvoir examiner de detailler avec autant de facilite une montagne d’une pareille hauteur. A compter des galleries jusqu’aux glaciers de la Gemmi, ces rochers perpendiculaires et a pic ont plus de trois lieues d’etendue; ils diminuent en hauteur a mesure que le pays s’eleve, et se confond dans les plus hautes alpes, qui sont surmontees d’autre masses de rochers.

“De l’autre cote du vallon, et vis-a-vis des montagnes qui forment celles de la Gemmi, est la montagne du midi, separee par la Dala, torrent qui vient du glacier a la tete du vallon, dont les eaux paroissent avoir creuse le lit etroit et profond. Cette montagne est calcaire comme la Gemmi, et paroit en avoir fait partie: je n’ai pu verifier nulle part si elle etoit posee 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 decombres 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 echelles appuyees contre; on parvient a la premiere, en grimpant par les avances et les saillies du rocher; d’autres roches facilitent le moyen d’arriver a la seconde; on trouve ainsi sept echelles 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, ou il y a des champs laboures et des vignes qui entourent le village d’Albinien, dont les habitans ont place ces echelles pour raccourcir le chemin qui conduit a Loiche, ou ils vont vendre leurs denrees.

“Nous quittons les bains de Loiche pour nous rapprocher du Rhone: 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 eviter ce chemin qu’on a fait celui des galleries. Le bourg de Leuck, ou Loiche, est un des principaux endroits du Vallais, bati en pierres, dans une position

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fort elevee et tres-forte; l’art avoit encore ajoute anciennement a 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’etend sur tout le bas Vallais jusqu’au dela de Martigny; nous avons donne une foible idee de cette vue, avant d’arriver aux bains de Loiche, car les expressions manquent pour rendre ces grands tableaux. Un spectacle bien interessant pour ceux qui etudient les changemens qui arrivent journellement a la surface du globe, est la vue du Kolebesch, montagne fort elevee en face du bourg de Leuck, et de l’autre cote du Rhone; cette montagne est calcaire ainsi que la chaine sur la rive gauche du Rhone, du moins la partie avancee qui forme le vallon ou coule ce fleuve. Des chutes, des eboulemens y ont produit de grands changemens; les eaux et les torrens qui viennent des parties elevees, ont entraine ces debris, les ont deposes aux pieds de la montagne, et en ont forme une colline qui a plus d’une demie-lieue jusqu’au Rhone, et plus d’une grande lieue de large, en forme circulaire; elle s’etend vers le haut et le bas Vallais; la partie superieure est couverte de pres et des paturages; celle du cote du bas Vallais est couverte d’une foret; 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 creuse un ravin large et profond, par lequel s’ecoulent actuellement les eaux des montagnes, et les pierres qu’elles en arrachent. Le Rhone mine et emporte le pied de cette colline qui resserroit son cours, avec ces materiaux il va plus loin former des atterrissemens composes des matieres les plus pesantes; les parties les plus fines le limon suspendu dans ces eaux servent ensuite a couvrir les anciens atterrissemens, au moyen desquels ils deviennent susceptibles de toute espece de vegetation; ses eaux finissent de s’epurer dans le lac Leman, d’ou il sort clair et limpide, ainsi que toutes les rivieres qui sortent des lacs jusqu’a 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 Rhone; 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 Rhone, all the solid substance had been hollowed out by water. Thus were formed the valleys of the Rhone, 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.

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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 sommites que j'avois observees jusqu'a ce jour sont ou isolees comme l'Etna, ou rangees sur des lignes droites comme le Mont-Blanc et ses cimes collaterales. Mais la je voyois le Mont Rose compose d'une suite non-interrompue de pics gigantesques presqu'egaux entr'eux, former un vaste cirque et renfermer dans leur enceinte, le village de Macugnaga, ses hameaux, ses paturages, les glaciers qui les bordent, et les pentes escarpees qui s'elevent jusqu'aux cimes de ces majestueux colosses.

"Mais ce n'est pas seulement la singularite de cette forme qui rend cette montagne remarquable; c'est peut-etre plus encore sa structure. J'ai constate que le Mont-Blanc et tous les hauts sommets de sa chaine sont composes de couches verticales. Au Mont-Rose jusqu'aux cimes les plus elevees, tout est horizontal ou incline au plus de 30 degres.

"Enfin il se distingue encore par la matiere dont il est construit. Il n'est point de granits en masse, comme le Mont-Blanc et les hautes cimes qui l'entourent; ce sont des granits veines et des roches feuilletees de differens genre qui constituent la masse entiere de cet assemblages de montagnes, depuis bases jusqu'a 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 interposees entre celles des roches feuilletees.

"On ne dira donc plus que les granits veines, le *gneiss* et les autres roches de ce genre, ne sont que les debris des granits rassembles et agglutines au pied des hautes montagnes, puisque voila des roches de ce genre dont la hauteur egale a tres-peu-pres celle des cimes granitiques les plus hautes connues, et ou l'on ferois bien embarrasse a trouver la place des montagnes de granit dont les debris out pu leur servir de materiaux; sur-tout si l'on considere la masse enorme de l'ensemble des murs d'un cirque tel que celui du Mont-Rose. En effet, ce seroit une hypothese inadmissible que de supposer, qu'anciennement il a existe dans le vuide actuel du cirque une montagne de granit, et que ce cirque est le produit des debris de cette montagne.

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Car comment ne resteroit-il aucun vestige de cette montagne? On concoit bien que sa tete auroit pu se detruire, mais son corps, la base du moins, protegee par les debris de sa tete accumules autour d'elle qu'est ce qui auroit pu l'aneantir; d'ailleurs les parois interieures du cirque quoique tres-escarpees ne sont pourtant pas verticale; elles s'avancent de tous cotes vers l'interieur; et le fond, le milieu meme du cirque n'est point du granit, il est de la meme nature que ses bords. Enfin nous avons reconnu que les montagnes qui forment la couronne du Mont-Rose se prolongent au dehors a de grandes distances en sorte que leur ensemble forme une masse incomparablement plus grande que celle qui auroit rempli le vuide interieur du cirque.

"Il faut donc reconnoitre, comme tous les phenomenes le demontrent d'ailleurs, qu'il existe de montagnes de roches feuilletees, composees des memes elemens que le granit, et qui sont sorties comme lui des mains de la nature sans avoir commence par etres elles-memes des granits[22]."

[Footnote 22: 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.]

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 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.

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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[23].

[Footnote 23: Vid. Discours sur l'Histoire Naturelle de la Suisse, passim; *but more particularly under the article of Route du Grindle* wald a meiringen *dans le pays de Hasti:* Also Hist: de la Terre, Lettre 30. p. 45, et Lettre 31. page 68, *etc*.]

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 borde sur ses deux rives, de collines dans lesquelles la *lave* se trouve enchassee entre des *couches calcaires*. Ces *couches* sont tres-remarquables par leur contenue, qui est le meme au-dessus et au-dessous de la *lave*, et qu'on retrouve dans les *couches* d'une grande etendue de pays, ou, comme d'ordinaire, on voit leurs sections abruptes dans les flancs de collines, mais sans *lave*, excepte dans le lieu indique."

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.

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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 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

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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.

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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

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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[24]."

[Footnote 24: 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.]

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 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.)

"Apres avoir passe le village de Saint-Leonard, on commence a monter la montagne de la Platiere; cette route est on ne peut plus interessante pour le naturaliste *Etc*.

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“On se trouve fort eleve au-dessus du Rhone quand on est sur le haut de ce chemin, dont on decouvre un de plus singuliers, des plus riches, et de plus varies passages qu’on puisse imaginer. On voit sous ses pieds le Rhone serpenter dans le lit qu’il se creuse actuellement, car il change et tout prouve qu’il en a souvent change; une quantite prodigieuse de petites isles le separent et le coupent en une multitude de canaux et de bras; ces isles sont couvertes les unes d’arbres, d’arbustes, de paturages, de bosquets et de verdure, d’autres de pierres, de sable, et de debris de rochers; quelques-unes sont formees ou occasionnees par un amas de troncs d’arbres entasses avec de grands sapins renverses dont les long tiges herissees de branches droites et nues representent des chevaux de frise, et donnent l’idee de ces abatis destines a preserver un pays contre l’approche de l’ennemi. Du cote du bas Vallais, on suit a perte de vue le fleuve dans ses sinuosites et ses detours, on l’appercoit egalement dans le haut Vallais; des avances de montagne le cachent quelquefois: il reparoit et diminue insensiblement en approchant de ces monts eleves ou il prend sa source: le fond du vallon paroit etre de niveau, s’abaisser seulement d’une pente douce du cote du bas Vallais: des mamelons, des hauteurs des monticules isoles, quelquefois groupes de differentes manieres, sont repandus dans cet espace, et rappellent la vue d’une pre devaste par les taupes; plusieurs de ces hauteurs sont surmontees des ruines d’antiques chateaux, d’eglises, et de chapelles; des villages distribues ca et la enrichissent ce fond, qui d’ailleurs est couvert de paturages, de champs d’arbres, de bois, et de bosquets; les enclos des possessions le coupent en mille figure bizarres et irregulieres. Ces monticules avec leurs fabriques s’elevent au-dessus de tous ces objets varies; quelques-unes se distinguent par leur cotes ecroules qui sont a pic; la blancheur de ces eboulemens contraste singulierement avec les verts qui sont les couleurs dominantes du vallon. Au-de-la des coteaux, des montagnes s’elevent et vont s’appuyer et s’adosser a ces masses, a ces colosses enormes de rochers a pic eleves comme des murailles et d’une hauteur prodigieuse qui forment cette barriere qui separe le Vallais de la Savoie. Les contours du pied de ces monts forment des entrees de vallons et de vallees d’ou descendent et se precipitent des torrens qui viennent grossir les eaux du Rhone; la vue cherche a penetrer et a s’etendre dans ces espaces, l’imagination cherche vainement des passages dans effrayantes limites, parmi ces ecueils et ces rochers amonceles, elle est arretee partout; de noires forets de sapin sont suspendues parmi ces rochers blancs-jaunatres, qui se terminent enfin par une multitude d’aiguilles et de pyramides qu’on voit percer au travers des neiges et des glaces, s’elancer dans les nues, s’y cacher et s’y perdre.

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“En examinant de plus pres ces mamelons repandus dans le vallon, on voit qu’ils sont composes de pierres, de sables, et de debris rapportes et amonceles sans ordre depuis des temps dont rien ne peut fixer l’epoque: on voit que les eaux du Rhone ont coule a leurs pied, qu’il en a mine plusieurs et a occasionne leurs chutes et leurs ruines. On voit actuellement quelques mamelons qui subissent ces memes degradations, et fournissent au Rhone les materiaux dont il va former plus loin ces atterissemens dont nous avons parle. La confusion et le desordre qui se remarque dans la composition interieure de ces mamelons prouvent qu’ils ne sont pas le produit de la mer ou des eaux qui ont travaille successivement et lentement a la formation de la plupart des terrains; mais que le fond de ce vallon a ete rempli des decombres et des debris des montagnes superieures, qu’ils y ont ete entraines par des inondations et des debordemens subits; que les eaux du Rhone ensuite ont parcouru ce vallon qu’il a souvent change de lit; que c’est en tournant et en circulant dans ce terrain nouvellement forme, qu’il a creuse les espaces qui sont entre ces mamelons, et que c’est en creusant le terrain qu’ils se sont eleves; leurs formes et leurs pentes allongees vers le bas Vallais, sont de nouvelles preuves que ce sont les eaux actuelles qui ont change la surface de ce terrain, nous verrons de nouvelles preuves de ce que nous disons en avancant d’avantage vers le haut Vallais; il n’y a peut-etre point d’endroit plus propre a etudier le travail des eaux que ce vallon qu’on a la facilite de voir et d’examiner sous des aspects differentes.”

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 a Coire, Troyen, et Saint-Gal.*

“Pour aller a Coire on passe le port qui est sur le haut Rhin; en cotoyant ce fleuve, qui coule dans un fond, on entre dans une plaine de niveau, qui n’a qu’une pente tres insensible de trois quarts de lieue; le fond du terrain n’est qu’un amas de pierres roulees de toutes especes. Les deux cotes sont bordes de montagnes calcaire qui courent parallelement entr’elles. Celle de la gauche, au pied de laquelle coule le Rhine, est tres rapide et perpendiculaire a son sommet; celle qui est a droite de la plaine ou petit vallon, puisqu’il se trouve entre des montagnes, est moins haute, plus boisee, et couverte de sapins. Le vallon est aussi couvert, en partie, de tres-grands et beaux pins; mais ce qu’on y voit de plus remarquable, c’est une douzaine de gros mamelons ou butes, elevees de cinquante a soixante toises, plus ou moins isolee, et a differentes distances les unes des autres; ces butes sont rondes, la plupart allongees dans le sens du vallon, et composees de debris calcaires et de sables; le fond du vallon est mele de plus d’especes de galets. On ne croit pas se tromper en disant que ce vallon a ete rempli de matieres apportees par

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les eaux jusqu'a la hauteur ou sont encore actuellement les mamelons; que de nouvelles inondations ont ensuite creuse et entraine ce qui manque de terrain a ces mamelons; que c'est en circulant autour de ces mamelons que les eaux leur ont donne la forme ronde; et surtout allongee dans le sens du vallon, et que c'est par le moyen de ces memes 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 deja fait mention de pareils mamelons qui se trouvent dans le vallon du Vallais parcouru par le Rhone."

These examples may also be supported by what this author observes in another place[25].

[Footnote 25: Discours, *etc*. page 201.]

"Le vallon ou est situe Meiringen, est visiblement forme par le depot des eaux, il est de niveau, et s'etend trois lieues en longueur jusqu'au lac de Brientz, a la suite duquel est le meme terrain nivele, qui va jusqu'au lac de Thun, dont on a parle. Une autre observation qui concourt a favoriser ce sentiment, c'est que toutes les roches calcaires, qui entourent le vallon, sont a pic, qu'on y remarque des cavites circulaires et des enfoncemens a meme hauteur et a differents 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 this earth, by knowing the principles upon which the system of this world proceeds.

CHAP. XI.

Facts and Opinions concerning the Natural Construction of Mountains and Valleys.

The valley of the Rhone 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.

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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'[26].

[Footnote 26: "Discours sur l'Histoire Naturelle de la Suisse."]

"Quand nous nous sommes trouve sur ces points eleves, nous avons toujours considere le total des montagnes prises ensemble, leurs situations respectives, les unes par rapport aux autres; afin de reconnoitre, s'il y avoit quelque chose de constant dans leurs position; rien n'est plus varie. Dans la grande chaine de montagnes qui separe le canton de Berne du Vallais d'un cote, et les Alpes qui separent le Vallais de la Savoie de l'autre, en considerant le course du Rhone sous differens points de vue, on n'a point vu que les angles saillans de ces tres hautes montagnes fussent opposes aux angles rentrans des montagnes qui sont vis-a-vis; Le fameux vallon qui est sur le haut du Saint-Gothard, le point le plus eleve de l'Europe, contredit egalement 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 a peine quelques exemples d'angles rentrans opposes a des angles saillans. Les nombreux vallons que nous avons constamment traverses ceux qui conduisent au Grindelwald, et celui qui mene au pays de Hasli qui sont sous nos yeux, n'etablirent pas d'avantage cette correspondance d'angles saillans et angles rentrans, qu'on regarde comme si constante. Dans les montagnes basses, du troisieme et quatrieme ordre, ou inferieures, on remarque plus souvent cette correspondance, encore n'est-elle pas constante: les eaux ordinaires ont forme ces vallons; mais si on veut donner une theorie generale, 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 eleves, a pris sa forme de la disposition meme des plus hauts sommets."

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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.

“Sec. 920. Je reviens aux observations. Il en est une tres importante pour la theorie de la terre, dont on peut du haut du Cramont apprecier 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 vallees. J’ai a deja dit un mot dans le 1er. volume, Sec. 577, mais j’ai renvoye a ce chapitre les developpemens que je vais donner.

“Ce qui avoit fait regarder cette observation comme tres-importante, c’est que l’on avoit cru qu’elle pourroit servir a demontrer que les vallees ont ete creusees par des courans de la mer, dans le temps ou elle couvroit encore les montagnes; ou que les montagnes qui bordent ces vallees avoient ete elles-memes formees par l’accumulation des depots rejetes sur les bords de ces memes courans.

“Mais l’inspection des vallees que l’on decouvre du haut du Cramont demontre pleinement le peu de solidite de ces deux suppositions. En effet, toutes les vallees que l’on decouvre du haut de cette cime sont fermees, au moins a l’une de leurs extremites et quelques-unes a leurs deux extremites, par des cols eleves, ou meme par des montagnes d’une tres-grande hauteur: toutes sont coupees a angles droits par d’autres vallees, et l’on voit enfin clairement que la plupart d’entr’elles ont ete creusees, 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 vallee de l’Allee-Blanche, qui etant parallele a la direction general de cette partie des Alpes, est du nombre de celles que je nomme *longitudinales*; et l’on voit cette vallee barree a l’une de ses extremites par le Col de la Seigne et a l’autre par le Col Ferret. En se retournant du cote de l’Italie, on voit plusieurs vallees a-peu-pres paralleles a celle-la, comme celle de la Tuile, celle du Grand Saint Bernard, qui toutes aboutissent, par le haut, a quelque Col tres-eleve, et par le bas, a la Doire, ou elles viennent se jeter vis-a-vis de quelque montagne qui leur correspond de l’autre cote de cette vallee.

“Si l’on considere ensuite cette meme vallee de la Doire, qui descend de Courmayeur a Yvree, on la verra barree par le Mont-Blanc et par la chaine centrale, qui la coupent a angles droits dans la partie superieure. On verra cette meme vallee s’ouvrir, dans un espace de sept ou huit lieues, deux ou trois inflexions tout-a-fait brusques; et on la verra enfin coupee a angles droits par une quantite de vallees qui viennent y verser leurs eaux, et qui sont elles memes coupees par d’autres, dont elles recoivent aussi le tribut. Or quand on reflechit a la largeur et a l’etendue des courans de la mer, peut-on concevoir que ces sillons etroits, barres, qui se coupent en echiquier a de tres-petites distances, aient pu etre creuses par de semblables courans.

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“L’observation de la correspondance des angles, fut-elle aussi universelle qu’elle l’est peu, ne prouveroit donc autre chose, sinon que les vallees sont nees de la fissure et de l’ecartement des montagnes, ou qu’elles ont ete creusees par les torrens et les rivieres qui y coulent actuellement. On voit un grand nombre de vallees naitre, comme je l’ai fait voir au Bon-Homme, Sec. 767, sur les flancs d’une montagne; on les voit s’elargir 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 a mesure que ses eaux grossissent, par la reunion d’autres sources ou d’autres torrens.

“Il n’est meme pas necessaire, pour se convaincre de la verite 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 Pyrenees, de l’Apennin, des Alpes, ou de quelqu’autre chaine de montagnes que ce puisse etre. On y verra toutes les vallees indiquees par le cours des rivieres; on verra ces rivieres et les vallees dans lesquelles elles coulent, aboutir par une de leurs extremites au sommet de quelque montagne ou de quelque col eleve. Les replis tortueux d’un grand fleuve, indiqueront une vallee principale, dans laquelle des torrens ou des rivieres qui indiquent d’autres vallees moins considerables, 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 vallee principale, ne s’accordent pas pour se jeter par paires dans le meme point du fleuve; elles sont comme les branches d’un arbre qui s’implantent alternativement sur son tronc, et par consequent, chaque petite vallee se jette dans la vallee principale vis-a-vis d’une montagne. Et de plus on verra aussi sur les cartes que meme les plus grandes vallees ont presque toutes des etranglemens qui forment des ecluses, des fourches, des defiles.

“Je ne pretends cependant pas que l’erosion des eaux pluviales, des torrens et des rivieres, soit l’unique cause de la formation des vallees: le redressement des couches des montagnes nous force a 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 vallees, ne prouve point que ces vallees 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.

“(Sec. 960.) Au-dela de Nuz, les montagnes qui bordent au midi la vallee, et dont on voit d’ici tres-bien la structure, sont composees de grandes couches appliquees les unes contre les autres, et terminees par des cimes aigues, escarpees contre le midi, elles tournent ainsi le dos a la vallee, dont la direction est toujours a 10 degres de l’est par nord. Celles de la gauche que nous cotoyons, et qui sont

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de nature schisteuse, tournent aussi le dos a la vallee en s'elevant contre le nord. Je crois pouvoir conclure de la, que cette vallee est une de celles dont la formation tient a celle des montagnes memes, et non point a l'erosion des courans de la mer ou des rivieres. Les vallees de ce genre, paroissent avoir ete formees par un affaissement partiel des couches des montagnes, qui ont consenti, dans la direction qu'ont actuellement ces vallees."

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, Sec. 881: “Immediatement au-dessus de cette source, est un rocher qui repond si precisement a un autre rocher de la meme nature, situe de l’autre cote de la vallee de Courmayeur, qu’on ne sauroit douter qu’ils n’aient ete anciennement unis par une montagne intermediaire, detruite par les ravages du temps.”

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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 vallee cesse d’etre large et plane, comme elle etoit dans le environs de la cite; elle devient etroite et tres variee; la sterile et sauvage, ici couverte de vergers et de prairies arrosees par la Doire.

“Sec. 961. Les couches des montagnes a notre gauche, qui depuis la cite avoient constamment couru a l’est et monte au nord, paroissent changer a un quart de lieue du village de Chambaise, qui est a 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 cote de la vallee elles paroissent monter a 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.

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M. de Saussure has given us an observation of this kind, in describing the mountains through which the Rhone has made its way out of the Alps, at the bottom of the Vallee.

“Sec.. 1061. Plus loin le village de *Juviana* ou Envionne on voit des rochers qui ont une forme que je nomme *moutonnee*; car on est tente de donner des noms a des modifications qui n’en ont pas, et qui ont pourtant un caractere propre. Les montagnes que je designe par cette expression sont composees d’un assemblage de tetes arrondies, couvertes quelquefois de bois, mais plus souvent d’herbes, ou tout au plus de brousailles. Ces rondeurs contigues et repetees forment en grand l’effet d’une toison bien fournie, ou de ces perruques que l’on nomme aussi *moutonnees*. Les montagnes qui se presentent sous cette forme, sont presque toujours de rochers primitives, ou au moins des steatites; car je n’ai jamais vu aucune montagne de pierre a chaux ou d’ardoise revetir cette apparence. Les signes qui peuvent donner quelque indice de la nature des montagnes, a de grandes distances et au travers des plantes qui le couvrent, sont en petit nombre, et meritent d’etre etudies et consacres 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.

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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.

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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

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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.

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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.

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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 Rhone, 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.

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The most perfect confirmation which this theory could receive, would be to find that those ridges of mountains, which the Rhone 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 Rhone 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 separent de la grande route, sont composees d’un melange tres ressemblant au precedent, et ce sont-la, les derniers rochers primitifs que l’on rencontre en sortant des Alpes par cette vallee. Le village de Juviana, dont ils occupent les derrieres, est encore a une lieue de St Maurice.

“Sec. 1062. A l’extremite de ces rochers, on voit une grande ravine, ou plutot une vallee ouverte du nord au midi, dans laquelle coule le torrent de St. Barthelemi. Cette vallee termine les montagnes primitives que je viens de decrire: au-dela commencent les montagnes calcaires. Cependant le pied de la montagne primitive, coupe par le torrent, est demeure engage sous les premieres couches de la montagne calcaire.

“Au travers de cette vallee, on voit de hautes montagnes couverte de neige, situees 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 cote du Rhone, on voit une autre cime aussi tres-elevee, 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 meme de matiere tout-a-fait singuliere. L’une et l’autre presentent leurs escarpemens a la vallee du Rhone. Leurs cimes crenelees sont de la meme couleur brune. Sous ces cimes brunes, on voit de part et d’autre une bande grise, qui paroit horizontale, et au-dessous de cette bande grise, le rocher, dans l’une comme dans l’autre, reprend sa couleur jaunatre. Ces montagnes sont surement secondaires, les bandes grises paroissent etre de pierre a chaux, et les jaunes de schiste argilleux et de gres, a en juger du moins a cette distance, car je ne les ai point observees de plus pres. Elles paroissent aussi appartenir a des chaines secondaires qui passent derriere les chaines primitives, que nous avons observees sur les bords du Rhone, et quoique les bandes jaunes et grises que l’on y observe, semblent horizontales, je ne doute point que les couches memes, dont ces bandes sont les sections, ne descendent en arriere avec assez de rapidite; le escarpemens de ces montagnes en font une preuve a-peu-pres certaine.

“Ces hautes montagnes auroient-elles ete anciennement liees entr’elles par des intermediaires de la meme nature, que couvroient, et les primitives que nous avons observees, et toute cette vallee dans laquelle coule aujourd’hui le Rhone? Je me garderois bien de l’affirmer, mais je ferois tente de le croire.

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“Sec. 1063. Depuis la vallee dont je viens de parler, et qui termine au couchant les montagnes primitives, celles qui suivent jusques a St. Maurice, sont de nature calcaire a couches epaisses et suivies. Ces couches s’elevent contre les primitives que nous avons cotoyees; et celles qui en sont les plus voisines paroissent fort tourmentees; ici flechies, la rompues. Apres une interruption, ces rochers sont suivis d’autres rochers, aussi calcaires, coupes a pic du cote de la vallee, et composes de grandes assises horizontales. Ces rochers forment une enceinte demi-circulaire, qui vient presque se joindre a ceux qui bordent la rive droite du Rhone, et former ainsi l’entree de cette vallee, dont le fleuve ne sort que par une issue tres-etroite.

“La ville de St. Maurice est ainsi renfermee par cette enceinte de rochers, dont les bancs epais, bien suivis, separes par des cordons de verdure, et couronnes par des forets, avec un hermitage niche entre ces bancs, presente une aspect singulier et pittoresque.

“Sec. 1064. Les rochers correspondans de l’autre cote du Rhone, 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 composee de couches contournees, froissees et repliees de la maniere la plus etrange. Ce qu’il y a encore de remarquable, c’est que ces couches ainsi repliees en ont d’autres a cote d’elles qui sont planes, presque verticales, et d’autres sous elles, qui sont horizontales. Il faudroit avoir observe de pres ce singulier rocher, et avoir determine comment et jusqu’a quel point ces couches sont unies entr’elles pour former les conjectures sur leur origine. Car la vallee est trop large pour que l’on puisse en juger avec precision d’une rive a l’autre.

“On voit avec peine que cette large vallee soit aussi peu cultivee; elle est presque partout couverte, ou de marais, ou de debris des montagnes voisines.

“Sec. 1065. Avant de quitter cette vallee, je jetterai un coup-d’oeil general sur la singuliere suite de rochers qui composent la chaine que nous venons d’observer.

“Les deux extremites sont calcaires, avec cette difference, que celle qui est la plus pres de Martigny est melee de mica, tandis que celle de St Maurice n’en contient point. Entre ces calcaires sont refermees 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 classe parmi les montagnes tertiaires, ou de la formation la plus recente. Mais ces poudingues-ci, qui ne contiennent aucun fragment de pierre calcaire, qui ne sont meme point unis par un gluten calcaire, ne sont vraisemblablement pas posterieures a la formation des montagnes calcaires, ou du moins ils ne doivent point etre confondus avec ces gres et ces poudingues de formation nouvelle, qui entrent dans la composition des montagnes du troisieme ordre.

“Quant aux ardoises que se trouvent interposees au milieu de ces gres et de ces poudingues, Sec. 1054, elles sont de nature argilleuse, et dans l’ordre des pierres que l’on nomme secondaires.

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“Ces ardoises, de meme 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 ete 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 Rhone, 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 Rhone, 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 Rhone 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.

“Sec. 1079. On voit par cet expose, que bien que la vallee du Rlione ait dans ce trajet pres d’une lieue de largeur moyenne, les montagnes qui la bordent sont en general du meme genre, et dans la meme situation sur l’une et l’autre rive.

“Il y a cependant trois differences que je dois exposer et apprecier en peu de mots.

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“La plus importante est dans ces couches de pierre calcaire, Sec. 1073, que j’ai trouvees 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 echappe, masquees par des debris ou par d’autre causes accidentelles; cette supposition est d’autant plus possible, que l’epaisseur de ces couches n’est que de quelques pieds. D’ailleurs il arrive souvent, que des filons, tel que paroit etre celui dont je parle, ne s’etendent pas a de grandes distances, quoique la nature de la montagne demeure la meme. Enfin ce qui diminue l’importance de cette difference, 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 tres-frequemment avec elle.

“Une autre difference que l’on aura pu remarquer, c’est que sur la rive droite, je n’ai point trouve de petrosilex pur et en grandes masses, comme sur la rive gauche dans les environs de la cascade. Mais cette difference ne me frappe pas non plus beaucoup; parce qu’au lieu de petrosilex, j’ai trouve sur la rive droite des roches composees en tres-grande partie de feldspath. Or je regarde le petrosilex et le feldspath comme des pierres de la meme nature. Leur durete est a-tres-peu-pres la meme; leur densite la meme, leur fusibilite la meme; l’analyse chymique demontre dans l’un et dans l’autre les memes principes, la terre siliceuse, la terre argilleuse et le fer; et de plus ces ingrediens s’y trouvent a tres-peu-pres dans les memes proportions. Il ne reste donc de difference que dans la couleur et dans l’agregation des elemens. Or on fait que ces qualites accidentelles tiennent souvent a des causes qui peuvent etre purement locales.

“La troisieme difference, celle qui se trouve dans la direction de quelques-unes des couches, je l’ai deja indiquee, Sec. 1075. et il semble inutile de repeter, que quand des couches formees originairement dans une situation horizontale, ont ete redressees par des operations violentes de la nature, il n’y a pas lieu de s’etonner qu’elles n’aient pas exactement la meme position dans tout l’espace qu’elles occupent.

“Les differences ne sont donc pas tres-significantes, et les ressemblances sont au contraire du plus grand poids. Ce qui leur donne a mon gre la plus grande force, c’est la rarete des pierres dont ces montagnes sont composees, ces especes de porphyres a base de petrosilex, ces rochers feuilletees melangees de feldspath et de mica; c’est encore la correspondance de l’ordre dans lequel elles se suivent; ces bancs de poudingues separes par des ardoises sur une rive comme sur l’autre; leur situation egalement ou a-peu-pres telle. Viola de grandes et fortes analogies et qui ne permettent pas de douter que ces montagnes, produites dans le meme temps et par les memes causes, n’aient ete anciennement unies.”

Having thus shown, that the Rhone 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 Rhone to Geneva.

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“Sec. 1090. La grande route de Bex a Villeneuve suit toujours le fond de la vallee du Rhone, en cotoyant les montagnes qui bordent la droite ou le cote oriental de cette vallee. Ces montagnes sont en general de nature calcaire, mais on voit a leur pied, jusques aupres de la ville d’Aigle, situee a une lieue et demi de Bex, la continuation des collines de gypse qui renferment les sources salees.

“Sec. 1091. A l’opposite de ces collines, au couchant de la grande route, on voit sortir du fond plat de la vallee deux collines allongees dans le sens de cette meme vallee. Ces collines sont l’une et l’autre d’une pierre calcaire dure et escarpees presque de tous les cotes. L’une la plus voisine de Bex, ou la plus meridionale, se nomme *Charpigny*, l’autre *Saint Tryphon.*

“Il paroit evident que ces rochers isoles au milieu de cette large vallee sont de noyaux plus dures et plus solides qui ont resiste aux causes destructrices par lesquelles cette vallee a ete creuse. Ils ne sont cependant pas exactement de la meme nature, et surtout pas de la meme structure; car celui de *Saint Tryphon* est compose de couches regulieres, horizontales ou a-peu-pres telles, tandis que celui de *Charpigny* a les siennes tres-inclinees et souvent dans un grand desordre.”

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.

CHAP. XII.

The Theory illustrated, by adducing examples from 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.

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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 Soogey-lamo 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.

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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 Perou, page 89.)

“Une particularite qui a attire souvent mon attention dans toutes ces contrees, c’est que toutes les montagnes aupres desquelles je passois, et qui sont au pied et au dehors de la grande Cordeliere, me paroissoient avoir eu une origine toute differente de celles que j’avois vues auparavant. Les lits de differentes terres et le plus souvent de rochers dont elles etoient formees, n’etoient pas inclines de divers cotes, comme dans les autres: ils etoient parfaitement horizontaux, et je les voyois quelquefois se repandre fort loin dans les differentes montagnes. La plupart de celle-ci ont deux ou trois cent toises de hauteur, et elles sont presque toutes inaccessibles; elles sont souvent escarpees comme des murailles: c’est ce qui permet de mieux voir leurs lits horizontaux dont elles presentent l’extremite. Le spectacle qu’elles fournissent n’est pas riant, mais il est rare et singulier. Lorsque le hazard a voulu que quelqu’une fut ronde, et qu’elle se trouvat absolument

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detachee des autres; chacun de ses lits est devenu comme un cylindre tres-plat, ou comme un cone tronque qui n'a que tres-peu de hauteur; et ces differens lits places les uns au-dessus des autres, et distingues par leurs couleurs et par les divers talus de leur contour, ont souvent donne au tout la forme d'ouvrage artificiel et fait avec la plus grande regularite. Il est une de ces montagnes a environ une lieue de Honda sur le bord du Guali et sur le chemin de Mariquita, qui est exposee a la vue de tous les voyageurs; mais je sens que si j'en donnois ici une representation, il faudroit que je comptasse sur le credit que doit naturellement avoir le rapport de quelqu'un qui n'a aucun interet d'alterer la verite, et qui a en toute sa vie le plus grand eloignement pour le mensonge. On voit dans ces pays la les montagnes y prendre continuellement l'aspect d'anciens et somptueux edifices, de chapelles, de domes, de chateaux; quelquefois ce sont des fortifications formees de longues courtines munies de boulevarts. Il est difficile lorsqu'on observe tous ces objets et la maniere dont leurs couches se repondent, de douter que le terrain ne se soit abaisse tout autour. Il paroit que ces montagnes dont la base etoit plus solidement appuyee, sont restees comme des especes de temoins 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'Orenoque que par relation, mais je scais qu'en plusieurs endroits les montagnes y sont egalement formees de couches horizontales, et qu'elles ont souvent en haut des plateformes qui sont exactement de niveau. On ne trouve a ce que je crois rien de semblable au Perou malgre la variete presque infinie qui y est repandue. Toutes les couches y vont en s'inclinant autour de chaque sommet, en se conformant a la pente des collines."

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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.

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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 *Vallee du Gave Bearnois dans les Pyrenees*; 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 pres des limites de l’Espagne, jusqu’a la petite ville de Lourde, une vallee qui se dirige du sud au nord sur une longueur d’environ dix lieues. Cet espace, qui forme son lit dans l’interieur des Pyrenees, ressemble moins a une vallee dans la majeure partie de son etendue, qu’a une entaille etroite et profonde, dont les flancs sont souvent coupes a pic d’une hauteur effrayante,

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et dont le fond est toujours couvert d'une eau ecumeuse. Cette long coupure se termine, ainsi que plusieurs de ses branches, aux sommets les plus eleves des Pyrenees, et elle recoit les eaux qui distillent sans cesse de leur neiges durcies. Sa division geographique est en deux vallees, dont l'une plus voisine de la plain est appelee Lavedan, et dont l'autre ne fait que partie de la contree qui porte le nom de Bareges."

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 Pyrenees.

Upon this occasion Mr Reboul observes: "Les ruines amoncelees et la grand quantite de cailloux roules qui forment ces digues naturelles, invitent sans doute a penser que ce sont les torrens eux-memes qui ont comble leur lit et obstrue leur passage, mais on ne peut concevoir que cet effet ait pu avoir lieu que dans des tems tres-recules, et avant l'entiere excavation des vallees. Peut-etre paroitra-t-il naturel d'imaginer que les masses out ete produites par le conflit des eaux qui se precipitoient des montagnes et des flots de la mer, lorsqu'elle recouvroit encore les plaines, *etc*.

"Je ne fatiguerai point le lecteur du denombrement inutile de tous les bancs pierreux de ces substances qui se succedent le long de la vallee, et prenant seulement le resultat de mes observations, je me bornerai a dire que depuis Lourde jusqu'a Luz, les parois de la gorge sont alternativement composees de matieres argilleuses et calcaires, quelquefois sous la forme de couches diversement inclinees, mais plus souvent fissiles, montrant de feuillets de differentes grandeurs et d'un tissu plus ou moins compacte. Ces schistes heterogenes sont presque toujours entasses et superposes dans la meme montagne, mais en plusieurs endroits un seul genre predomine, *etc*. L'espece d'uniformite 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 generale et constante, on pourroit tout au plus hazarder a ce sujet de legeres conjectures; mais si l'ordre primitif de ces montagnes est derobe a l'oeil de l'observateur, on trouve a chaque pas des indices certains, des marques evidentes de la maniere dont il a ete altere ou detruit.

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“Je reconnus d’abord que les memes cailloux, les memes debris de marbre et d’ardoise qui couvraient le fond de la vallee, et que le Gave entraine et remplace sans cesse, se trouvent aussi a plusieurs toises au-dessus de son niveau. Je voyois quelquefois les sedimens fluviatiles recouverts et ensevelis sous des grandes masses de pierre feuilletee adherente a la montagne; levant ensuite les yeux, j’observai que de l’un ou de l’autre cote du torrent, les flancs des montagnes etoient souvent couverts et comme plaques de semblables masses de schiste, dont les couches et les feuillets offroient toujours des directions contraires a celles des schistes de meme nature, auxquels ils etoient adosses. Les eaux du torrent, qui ont sans doute renverse ces couches sur elles-memes, y ont depose des marques de leur passage; elles ont abandonne, engage sous ces debris memes, a des grandes hauteurs, des blocs enormes de granit que le voyageur surpris voit pendre sur sa tete; de pareils blocs arrondis et uses couvrent le fond de la vallee, et opposent quelquefois au torrent une digue qui le fait jaillir et retomber en ecume; enfin j’ai suivi les traces de ce courant aux differentes hauteurs des parois du canal ou il coule aujourd’hui a plusieurs centaines de toises de profondeur. Il a du les parcourir toutes successivement en creusant et retrecissant sont lit et augmentant sa vitesse.

“Les cretes des sommites qui forment les bords les plus eleves de la gorge, sont escarpees dans la direction du courant. J’ai apercu quelquefois des portions de montagnes separees de la crete, ou du sommet principal, et dont les eaux semblent en avoir fait des especes d’iles, en creusant autour d’elles un fosse profond, ou l’on voit fort bien les angles saillans de l’ile correspondre aux angles rentrans de la montagne, *etc*.

“Dans la partie de la vallee ou s’observent ces phenomenes, on marche toujours entre deux montagnes resserrees, dont les nuage derobent souvent les cimes, mais par-tout ou les eaux de quelque torrent considerable viennent se reunir a celles du Gave, il s’est forme un bassin d’une etendue moyenne, qui ne fut d’abord vraisemblablement qu’une grande mare d’eau semblable a ces lacs qui existent encore dans le sein des Pyrenees et des Alpes. Ainsi on voit, a une lieu avant Argeles, les montagnes s’ecarter, se replier en un vaste circuit, et entourer, comme d’une muraille sterile et ruineuse, des prairies arrosees par mille canaux et par le brouillard des cascades; des coteaux, ou l’on voit s’elever, parmi les vergers et les bois, des villages ornes de marbre, des chateaux majestueux et les delicieuses habitations de quelques moines fortunes.

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“Le penchant qui borde ce vallon du cote de l’est n’est creuse que par quelques ravins tres-inclines, dont les eaux se precipitent en ecume 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 profondement excave par les torrens, presentent les issues de trois autres vallees, dont les deux principales vont prendre leurs origine aux limites de l’Espagne; l’autre, plus voisine de la plaine, est a-peu-pres dirigee de l’est a l’ouest. Elles s’appelle *Estrem de Sales*, et joint ses eaux a celles du Gave un peu au-dela de l’extremite interieure de ce grand bassin qu’elle a concouru a former. C’est au centre du bassin, aupres du village d’Argeles, que le Gave d’Azun arrive avec fracas, et c’est a son extremite superieure que le Gave de Cautres s’y precipite en sortant d’une gorge dont l’aspect frappe d’etonnement et d’horreur. Le cours de ces deux Gaves est aupres de leur embouchure oblique a celui du Gave principal; mais ils se replient ensuite vers le centre de la chaine et deviennent presque paralleles. Aupres de Luz se decouvre un autre bassin ou se joignent les eaux du Gave a celles du torrent de la Lise, qui n’a creuse qu’un ravin, et a celles du Bastan qui descend d’un vallon tres-evase dans la direction de l’est a l’ouest, ou se trouvent les eaux minerales de Bareges. Ce nouveau bassin n’offre que le spectacles d’une vaste prairie bordee de montagnes prodigieuses. Je n’entreprendrai point de rien ajouter ici touchant ces diverses branches de la vallee du Gave Bearnois; chacune d’elles exigeroit une description detaille, soit a cause de son etendue, soit a cause de la variete de ses phenomenes.

“De Luz a Gavarnie le Gave se trouve de nouveau resserre dans une gorge etroite ou les montagnes paroissent encore s’elever et les abimes s’enfoncer; ses eaux ne coulent plus qu’en cascades bruyantes, et quelquefois le voyageur, qui les voit ecumer sous ses pieds du haut du sentier trace sur la montagne, entend a peine un murmure lointain. On y remarque de nouveau les phenomenes, decrit ci-devant, des pierres feuilletees renversees de leur premiere direction, des bancs entiers courbes et brises dans leur chute, des debris granitiques arrondis par les eaux, deposes a de tres-grandes hauteurs dans le fond des ravins ou le courant n’existe plus, *etc*.

“A Gedre le Gave recoit les eaux de Heas, lieu devenu celebre et enrichi par la devotion Espagnole. A peine a-t-on passe le torrent, que le granit commence a paroitre. 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 enterre sous de grandes montagnes calcaires. Du cote de l’ouest il est presque toujours recouvert de ces masses qu’on distingue de loin a leur teinte grise et blanchatre melee de sillons d’un rouge peu fonce. A l’est les montagnes calcaires laissent le granit a decouvert,

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et lui demeurent comme adossees. Celles qui leur succedent offrent des marques, effrayantes de decrepitude; leurs cretes sont demantelees, et leurs flancs sont lesardes et herisses de rochers suspendus. Le fond de la vallee semble enseveli sous les debris de cette montagne a demi ecroulees. On trouve, parmi les ruines, des blocs de plusieurs milliers de pieds cubes. Le Gave les couvre quelquefois de ses eaux, se precipite dans les intervalles qu'ils laissent entr'eux, et renait comme sous une voute affaissee. Plusieurs de ces lambeaux affectent sur leurs plans la forme de parallelogrammes et de rectangles; mais ceux que l'on voit encore attaches au corps de la montagne, sont pour la plupart pyramidaux, et sa crete est formee d'une suite de ces pyramides granitiques. Toutefois on ne peut pas se refuser a voir que le granit est ici dispose en couches tres-distinctes qui paroissent surmontees dans quelques points des sommites, 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 cote de Gavernie, et vers le nord-est du cote de Gedre. Quoique leurs substance soit melees de plusieurs roches heterogenes, elle est generalement composees de quartz, de feld-spath, et de mica; mais ces deux substances y sont dans un etat frappant de decomposition, et semblent quelquefois reduites en chaux de fer.

"Au-dela de leurs debris, dont l'amas est designe par le montagnards sous le nom de *Peyrade* et sous celui de *Catios* par les gens du monde, le granit est de nouveau surmonte de substances calcaires. Il sort de base aux pics coniques de Caumelie et de Pimene. Cette base forme elle-meme une vaste montagne qu'on appelle *Allans*; ses roches, d'un granit ferrugineux et sombre, sont entourees d'une couronne blanchatre et calcaire, ou vegetent quelque sapins epars: Gavarnie est a ses pieds.

"C'est a une legere distance de ce village, que se termine la vallee du Gave Bearnois, ou plutot qu'elle prend naissance avec le torrent qui l'a formee. On appercoit de loin les vastes sommets et les champs eleves de neige et de glace d'ou ses eaux se precipitent; on reconnoit ensuite qu'ils ne forment qu'une montagne ou plutot une masse enorme par sa hauteur et son volume, composee d'une meme matiere, et qui, placee sur une base vers laquelle on n'a cesse de monter pendant l'espace de dix lieues, s'eleve tout-a-coup de sept a huit cens toises, et domine au loin toutes les montagnes qui l'entourent. Les differens sommets dont elle est couronnee se presentent sous mille formes bizarres; ce sont des pyramides irregulieres et de vastes cylindres, ou de cones tronques pres de leur base, qui ressemblent assez a des tours ecrasees. Les cretes, qui sont formees du prolongement de ces sommites, sont autant de murailles inaccessibles bordees d'un long tas de ruines ou d'un large fosse de neige glacee, et quelquefois interrompues par de breches profondes. On ne peut apercevoir

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tous ces objets du fond de la vallee, et il faut s'elever sur quelque hauteur voisine, telle que le sommet de Bergons, ou celui de Pimene, pour embrasser toutes les parties de ce vaste tableau. En remontant vers les sources du Gave, qui en occupe le centre, on penetre par un coupure peu profonde dans une prairie de forme ovale assez reguliere bordee a l'est et a l'ouest par des hauteurs plantees de sapins et de hetres, et au sud par un amas de rochers ecroules, et par les sommets que je viens de decrire. Le Gave y serpente sur un lit de sable et de cailloux, et recoit les eaux qui descendent, en ecumant, des hauteurs voisines; il se fraie un chemin vers cette prairie parmi les debris entassees qui la bornent au sud, et qui la separent d'une autre bassin non moins vaste, ou le torrent commence son cours, et ou la montagne s'eleve tout autour en un rempart inaccessible.

"On peut prendre une idee legere et imparfaite de cette majestueuse enceint, en se la figurant comme un amphitheatre moins remarquable par la vaste etendue de son arene que par la hauteur prodigieuse de ses murs qui, par-tout bordes de parties saillantes, d'echancrures profondes, et herisses de rochers dont la ruine est prochaine, se sont entierement ecroules du cote du nord; elle-est couronnee vers le sud par deux sommets cylindriques recouverts d'une croute epaisse de neige durcie, et que leur forme a fait nommer tour de marbre. Au-dessous se succedent, en forme de gradins, de vastes platte bandes d'une neige qui ne disparoit 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 coupee a pic. L'un de ces torrens venant du cote de l'est et dont le volume surpasse celui de tous les autres ensemble, se precipite du haut d'un rocher qui s'avance en saillie, et tombe avec un bruit horrible a plus de 1200 pieds de profondeur. Ses eaux, divisees dans les airs et reduites comme en poussiere, forment autour de la cascade un brouillard suspendu qui derobe aux yeux du spectateur tout son volume et la vitesse de sa chute. L'arene ou se reunissent toutes ces eaux et ou commence le Gave, est de forme irreguliere; sa surface inegale offre tantot de grands plateaux de neige, des blocs de rochers ecroules et d'autre debris attenue et reduits a l'etat terreux ou vegetent de belles plantes que le soleil eclaire a peine. Le Gave, en tombant sur les amas de neige, y a creuse un gouffre au fond duquel le soleil avant son declin peint le cercle colore de l'iris. Les eaux disparoissent sous la neige et renaissent ensuite comme sous un pont etroit ou sou la voute d'un aqueduc; elles serpentent, se replient a travers les ruines amoncelees, et surmontent les obstacles qui s'opposent a leur sortie.

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“Si l’aspect magnifique et la beaute sauvage de cette enceinte sont difficiles a representer, sa structure n’en est pas moins facile a saisir; et dans ce lieu, qui semble fait pour le tourment du peintre de la nature, elle se decouvre 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 naitre naturellement cette idee. Dans la suite les rochers qui la fermoient sur le devant, s’etant detruits, les eaux se sont ecoulees et perdues*.

“On ne peut se refuser a croire avec M. d’Arcet, que l’enceinte des cascades de marbre n’ait ete autrefois un lac. Le nombre et l’etendue de ces amas d’eau diminuent tous les jours dans les Pyrenees comme dans tout pays de montagnes; les eaux qui viennent s’y rendre en exhaussent le fond par les cailloux et les debris terreux qu’elles y entrainent, et celles qui s’ecoulent en abaissent le niveau, en creusant insensiblement le canal par lequel elles sortent. Ainsi la marche lente et progressive de la nature sans l’intermede des accidens et de revolutions, suffit pour combler ces vastes creuse ou les eaux se sont amassees, ou pour ouvrir des issues qui ne leur permettent plus d’y sejourner. Le nombre de ces lacs abandonnes et perdus n’est guere au-dessous de celui de lacs encore existans. Les naturels du pays ont appris eux-memes a distinguer ces monumens naturel; ils ont saisi leur structure semblable a celle d’un vaisseau evase et coupe dans ses parois d’une ou de plusieurs entailles profondes, et les ont tous designes par le mot *oule*, qui derive du mot Latin *olla*, et signifie chez eux marmite; comparaison aussi juste que peu noble et bien digne de ces observateurs froids, mais exacts, egalement depourvue de prevention et d’enthousiasme. Ces *oules* se trouvent souvent placees aux extremite superieurs des vallees, a l’origine des torrens qui les remplissoient autrefois. En effect, ceux-ci naissent communement sous quelque vaste amas de neige, ou s’ecoulent d’un reservoir qui rassemble les eaux des hauteurs voisines. Le nombre de ces lacs augmente a mesure qu’on s’eleve, et c’est une observation generale, que ceux des vallees sont pour la plupart combles ou perdus, et que ceux des montagnes, surtout de celle de granit, sont presque tous conserves. J’ai dit precedemment, d’apres l’observation de M. d’Arcet, que l’enceinte des cascades presentoit la forme d’un reservoir entr’ouvert et epuise, et qu’elle etoit precedee d’un autre bassin dont l’aspect est moins sauvage et la forme plus reguliere. Tout porte a penser que celui-ci a ete aussi long-tems rempli d’eau, ou plutot il resulte d’un examen detaille de ces lieux, que le deux bassins ne faisoient autrefois qu’un seul et immense reservoir, ou les eaux etoient retenues a deux ou trois cens toises d’elevation au-dessus du sol ou elles coulent aujourd’hui. Les rochers qui separent le premier bassin de l’enceinte

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des cascades, ne sont, comme je l'ai deja remarque, qu'un vaste amas de debris; mais ces debris ne ressemblent point a ceux d'une muraille renversee sur elle-meme, ou d'une digue rompue par l'effort des eaux. Il est au contraire aise de se convaincre qu'ils ont ete detaches de cette partie de la montagne qui bord l'enceinte du cote de l'est, et sur laquelle sont les sommets les plus eleves de toute cette masse. On voit encore sur ses flancs dechires pendre d'enormes quartiers de roche prets a s'ecrouler. Ceux qui sont deja tombes ont demeure entasses les uns sur les autres. L'amas qu'ils ont forme est adosse a la montagne dont ils faisoient jadis partie, et s'incline jusqu'aux parois opposee de l'enceinte. Le torrent qui la traverse se trouve ainsi rejete du cote de l'ouest, et le lit qu'il a creuse suit les contours de cet amas de debris. Un tems a donc existe auquel les deux enceintes dont j'ai parle, etant remplies d'eau, ne formoient qu'un seul lac vaste et profond; et peut-etre la meme revolution qui les a separees a-t-elle change tout-a-fait leur forme et cause l'entiere dispersion de leurs eaux; car si l'on considere que l'enceinte du bassin de la prairie est entierement detruite du cote du nord et de la vallee, on doit se convaincre que les eaux ne l'ont point corrodee lentement, mais qu'elles l'ont entrouverte et emportee par un effort violent et subit. Or a quelle cause peut-on mieux attribuer le mouvement rapide et le choc qui dut les agiter, qu'a la chute instantanee de plusieurs milliers de toises cubes de rocher. Je me represente alors ce lac paisible et eleve change en une mer courroucee, ses eaux bouleversees jusqu'au fond de ses abimes jaillir au-dessus des sommets voisins, et retombant sur elles memes ebranler de leur poids et de leur chute la barriere qui les retenoit, cette barriere trop foible enfin renversee et ses debris transportes au loin.

"M. d'Arcet, dans son discours sur les Pyrenees, a presage la meme revolution pour le lac d'Escoubons le plus considerable de ceux qui dominent les bains de Bareges, et on ne peut douter que si quelqu'eboulement considerable vient hater et accroitre l'effet de cette debacle inevitable, ces regions elevees subiront un nouveau deluge dont les hommes et les troupeaux seront la victime, qui ensevelira plusieurs villages, et inondera les tanieres des betes 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.

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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 *debacle* 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.

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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.

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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 Fee 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’Amerique meridionale, 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 detruit, il apercevra bientot qu’un developpement successif et inevitable de ce nouveau continent tend a l’agrandir dans tous les sens, et rendra peut-etre un jour sa surface egale a celle de notre hemisphere.

“Il est des sites dans les montagnes des Cordilleres ou des obstacles plus ou moins puissant retardent cette meme degradation: la plaine de Santa Fee de Bogota est entre ces sites celui qui m’a paru le mieux caracterise et le plus frappant. Il sera l’objet de ce Memoire: on verra avec surprise qu’un pays sain, agreable, abondant, et fertile aujourd’hui, etoit autrefois le plus depourvu et le plus miserable du monde, ou l’Indien malheureux n’avoit pour tout bien que des rivieres sans poissons, des oiseaux en petit nombre, un quadrupede ou deux, et quelques legumes; on sera etonne d’apprendre qu’une temperature froide environnee d’un climat brulant, fut une barriere 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 etre en quelque sorte separee du reste du monde par des rochers enormes, coupes verticalement, qu’on ne parvient a franchir qu’avec des difficultes etranges a travers un brouillard humide et tenebreux, qui persuade au voyageur fatigue qu’il travers la region des nues.

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“Arrive au haut de ces montagnes, un nouveau ciel, un nouvel ordre de choses se presentent; ce ne sont plus ces insectes degoutans et insupportables qui le fatiguoient sans relache; ces reptiles venimeux, dont il redoutoit la morsure; ces betes feroces toujours prets a le devorer; enfin, cette, chaleur suffocante des lieux bas qu’il vient de quitter; l’air qu’il respire rafraichit et le vivifie; il s’arrete, et ce qui l’environne l’etonne et le ravit; s’il regarde au-dessous de lui, tout est eclipse par des nuages, dont la surface egale mouvante lui represente 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 tete; de nouvelles montagnes s’elevent de toutes parts, et forment un nouveau monde qui paroit independant du premier.

“Pour donner une idee exacte de ce pays singulier, j’ai cru devoir transporter le spectateur a la capitale, ou de la comme d’un centre, il put observer plus commodement les phenomenes que j’ai a lui presenter.

“La ville de Santa Fee de Bogota, capital du nouveau royaume de Grenade, a environ 4 degres de latitude N. et 304 de longitude, prise de l’ile de Fer, est situee au pied et sur le penchant d’une montagne escarpee qui la couvre a l’est; elle domine une plaine de douze lieues de largeur sur une longueur indeterminee et tres considerable, qui presente toute l’annee le riant tableau des plus belles campagnes de l’Europe: les coteaux toujours verts ou les troupeaux bondissent, les prairies couverts de betail, les champs bien cultives, les maisons de campagne agreables, les hameaux, les villages, les vergers, les jardins, montrent a la fois, les fleurs du printemps et les fruits de l’automne, que l’abondance des pluies ou les secheresses retardent ou avancent quelquefois mais dont l’eternelle duree bien loin d’inspirer le plaisir, et d’offrir l’attrait piquant de la nouveaute qui fait le charme de ces saisons dans nos climats, amene bientot l’indifference pour une beaute toujours le meme, pour des agremens qui ne changent pas.

“Ce climat est d’ailleurs si etrange et tellement constitue, que quand on est au soleil, on se trouve bientot incommode de sa chaleur; est on a l’ombre? on se sent penetre d’un air subtil et froid qui transit.

“A trois lieues a-peu-pres a l’ouest de la ville, passe la riviere de Bogota qui, apres avoir recu les eaux de toute la plaine, la riviere de Serrefuela et les torrens qui se precipitent de la chaine de montagnes, dirige son cours paisible vers Tekendama a sept ou huit lieues au sud-est a-peu-pres; c’est-la que ces eaux rassemblees coulent entre une suite de rochers granitiques, dont le plain incline accelere leurs vitesse; elles n’offrent bientot plus qu’un courant rapide, etroit et profond qui, au moment de sa chute, rejaillit sur un rocher place plus bas que son lit, d’ou il tombe dans une abime dont on n’a pu jusqu’ici mesurer la profondeur; c’est la cataracte ou saut de Tekendama.

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“Des trous pratiques dans le roc par les anciens aux endroits les plus commodes pour voir toute l’etendue de cette chute prodigieuse, donnent le moyen d’observer sans risque la continuation des rochers qui s’avancent a droite et a gauche et annoncent par leurs hauteur qu’avant le passage que les eaux semblent avoir force, la plain de Santa Fee n’etoit alors qu’un lac d’une tres-grand etendue: une tradition constante du pay, mais peu vraisemblable, porte que les Indiens ont creuse cette espece de canal.

“Il y a quelques-uns de ces trous d’ou l’on voit confusement le lieu ou finit cette chute d’eau effroyable; la riviere 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’eloignement les masses les plus enormes: quelques especes de perroquets et d’autres oiseaux de pays chauds, qui habite cette vallee profonde et inabordable de ce cote, s’elevent assez quelquefois pour pouvoir etre remarques d’en-haut; mais le froid subit de ces montagnes qu’ils craignent, est une obstacle invincible qu’ils ne franchissent jamais: pour jouir commodement de ce point de vue, a la fois admirable et effrayant, il faut choisir un jour calme et serein, entre sept a huit heures du matin.

“Il est necessaire de prendre un long detour et cheminer pendant toute une journee, presque toujours a travers des rochers et des precipices, pour parvenir au pied de cette cataracte; on est alors etrangement surpris de voir que cette riviere a peine sensible d’en haut, soit encore un torrent prodigieux, dont la chute en cascades dans une angle de 45 degres, offre pendant l’espace d’une grande demie lieue des amas de rochers entasses au hazard, que frappe et detruit sans relache le plus bruyant conflict des eaux; c’est apres cet espace que le courant, devenu plus paisible permet encore de comparer la riviere de Bogota a ce qu’est la Seine dans l’ete.

“Un phenomene bien extraordinaire et qui sert en meme tems a donner la plus haute idee de l’etendue prodigieuse de cette cataracte, c’est que sa chute commence dans un pays tres-froid ou il gele souvent pendant la nuit, et finit dans un autre ou la chaleur, egale a nos beaux jours d’ete, offre la vegetation 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 gelees blanches, a-peu-pres comme celles qui ont lieu dans nos climats aux approche de l’hiver et a l’entree du printemps? car on en eprouve rarement dans la plane.

“Une autre particularite remarquable de ce pays, c’est le defaut de poisson dans toutes les rivieres qui l’arrosent: on en trouve cependant dans celle de Bogota ou les autres rivieres viennent se rendre; mais c’est une seule espece tres-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 riviere, et jamais dans les eaux claires; il est gras et excellent a manger: son genre est celui de la *mustelle fluviatile de France* et le *Gades* de Linne.

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“Il est certain cependant que les poissons de toutes les sortes abondent dans les grandes rivieres de l’Amerique meridionale et notamment dans celle de la Magdelaine; ne pourroit-on pas supposer d’apres cela, que puisque toute communication des eaux de tout le pays eleve de Santa Fee est interrompue avec cette derniere par le saut de Tekendama, ces memes eaux n’ont pu en etre peuplees comme celle-ci paroissent avoir ete, au moins en partie, par la mer. Ce meme defaut de poisson se remarque dans la plus part de lacs et des rivieres des Cordilleres, probablement par une cause semblable; il n’y en a point dans les deux lacs assez etendus qui sont pres de la ville d’Hyvarra dans la province de *Quito*, non plus que dans les rivieres de la province de Pastos.

“On peut objecter qu’une temperature toujours froide comme celle de Santa Fee, joint a la limpidite et la rapidite des torrens des Cordilleres, suffisent pour ecarter les poissons, de meme que cela arrive dans plusieurs rivieres de l’Europe.

“Cette objection seroit vraie pour la plupart des torrens des Cordilleres, mais on observera que la riviere 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 a presumer que, s’il etoit possible d’y tranporter des poissons de nos rivieres, ils y reussiroient aussi bien que les autres productions de l’Europe qui se sont naturalisees dans ce pays. Quant a la temperature constante froide de ces eaux, qui pourroient paroitre s’opposer au developpement des oeufs du poisson qui habite les rivieres des pays chauds, on y respondra par le fait suivant.

“A vingt lieues environ au nord de Santa Fee a la meme elevation et a la meme temperature, est un grand lac ou l’on trouve des iles habitees, et qui en a paru assez grand pour etre indique dans les cartes geographiques, si on en savoit les dimensions; c’est le lac de Chiquinquira assez poissonneux pour y faire des peches abondantes, parce que la riviere qui en sort n’est pas interrompue par des sauts dans son cours jusqu’a la riviere de la Magdelaine; cependant les especes de poissons qu’on trouve dans ce lac ne sont pas aussi variees que dans cette grande riviere, sans doute a cause de la rapidite du courant, que le poisson ne remonte pas egalement bien.

“Lorsqu’on gravit sur les montagnes escarpees qui dominent la ville de Santa-Fee, on ne rencontre, depuis leur base jusqu’a leurs sommets, termines par des rochers de granite, que des bruyere, des fougeres, quelques plantes sauvages, *etc*. et pas un arbre qu’on puisse seulement appeler un boisson excepte dans quelques gorges a l’abri de courans d’air, ou l’on en voit quelques-uns dont les plus grands, n’egale pas nos prunieres; cette vegetation engourdie parait etre due au froid vif et continuel qu’il fait sur ces montagnes; car plus on monte, moins elle se developpe, et enfin finit par cesser tout-a-fait: on remarque a la moitie de la hauteur d’une de ces montagnes (a une demi-lieue a peu-pres 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.”

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[Footnote 27: 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 a-peu-pres de la meme hauteur qui sont entierement separees des montagnes voisines, et situees dans la direction ou courant des rivieres, on remarque aisement qu’elle sont les restes d’une plaine anterieure que les eaux ont degradee. Au lieu de ces forets, et de ces boissons qui surchargent bientot nos campagnes lorsque la main de l’homme cesse de les cultiver, un gazon touffu couvre la plaine et les collines de Santa-Fee d’une verdure agreable sans nul arbrisseau qui puisse en alterer l’uniformite, ou les graminee, le plantain, le scorconnaire, le trefle, le marrube, la pimprenelle, le pourpier, la patience, le chardon, le raifort, le cresson, la chicoree sauvage, la jonquille, la marguerite, le fraisier, la violette, le serpolet, le thym, et mille autres plantes d’Europe et particulieres a ce pays, offrent les varietes les plus piquantes par la beaute 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 memes collines, en rendent l’aspect pittoresque et delicieux.”

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.

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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 modele des vastes *Quebradas* ou profondeurs, et fait comprendre leur origine: elles ne pouvoient etre que semblables a celle-ci: tout s’y est passe de meme, ou plus tot ou plus tard. Les flancs en ont ete plus ou moins perpendiculaires, jusqu’au moment ou ils se sont affaissees, et ont forme des plains inclines, lorsque l’eau faisant de plus profondes excavations, eut mine la base qui les soutenoit. Ne pouvant plus alors perseverer dans leur premier etat, les terrains ont croule, et ont pris l’inclinaison qu’ils ont conservee depuis. La meme chose arrivera necessairement a ce passage de *Conaica* lorsqu’avec le laps du tems, les effets des pluies, de gelees, des rayons solaires, auront fait tomber en ruine ces parois, quoique de roche rive; car ses agens puissans font sentir leur energie aux corps les plus durs. Ainsi les bords du *Chapilancas* perdront insensiblement la regularite de leur distance, de leurs cotes rentrans et saillans, apres l’avoir peut-etre conservee plus long tems que d’autres excavations, parce que c’est une pierre dure, qui n’est melee d’aucune veine de terre movible. Nous pouvons le croire sans hesiter; car ce n’est que le seul frottement de l’eau qui a excave ce lit jusqu’a la profondeur qu’il a. Mais le tems, qui reduit les roches les plus dures en sablon, ira toujours en elargissant la partie inferieure, par son action continuelle et insensible: aussi voit-on ce ruisseau rouler de petites pierres qui se detachent sous les eaux, comme on en appercoit dans la plaine ou il les entraine, en sortant de la montagne, pour se decharger dans une terrain plus spatieux.

“Que ce canal ait ete excave a cette profondeur par l’effet continuel du frottement des eaux, ou qu’il a ete ouvert par une secousse de tremblement de terre qui fit fendre la montaigne, de sorte que le ruisseau qui couloit d’un autre cote, se soit jette de celui-ci. il est certain que cette ouverture profonde est posterieure a l’arrangement que les terrains eurent apres le deluge; et que c’est ainsi que ces enormes *Quebradas* de la partie meridionale de l’Amerique, se sont formees avec

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le tems, par le frottement du cours rapide des eaux. En effet, on observe que la force avec laquelle s'ecoulent 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 evidentes de leurs excavations profondes au milieu meme des lits de ces eaux. Ce sont des cubes d'une grandeur enorme, qui n'ont pu etre detaches avec la meme facilite que les parties contigues. La riviere *d'Iscutbaca*, qui coule pres d'une hameau de meme nom, nous presente dans son lit une de ces masses, dont la forme est precisement celle d'une cube. Lorsque l'eau est basse, ce cube s'eleve a sept ou huit *varas* au-dessus du courant: chaque cote porte douze *varas* de face. Mais ces masses, et autres moindres de differentes formes, qui se voient dans les eaux, ne peuvent etre arrivees a cet etat, sans que l'eau les ait degarnies peu-a-peu des pierres, des sables que les envelopoient, et qu'elle a arraches de tous cotes pour les laisser isolees; or elles se maintiendrons dans cette position, jusqu'a ce que les eaux, cavant de plus en plus, rencontrent enfin a la base des veines de matieres friables et dissolubles, qu'elles penetreront et qu'elles emporteront, en detruisant l'assiette sur laquelle posent ces masses jusqu'alors *inamovibles*. Une crue d'eau considerable, et qui ne laissera plus paroitre qu'une *varas* de cette masse, pourra dans ce tems-la l'arracher, et la faire rouler; mais ce mouvement, et les chocs qu'elle eprouvera de la part d'autres masses moins grosses, suffiront pour en briser les parties saillantes, et la reduire en parties moins volumineuses, qui rouleront avec plus de facilite; et qui par cette seul cause diminueront encore. C'est a cette cause qu'on doit attribuer ces quantites prodigieuses de pierres repandues ca et la sur les bords de ces eaux, de meme que ces roches enormes qu'on y voit detachees, et que jamais les forces humaines n'auroient pu mettre en mouvement.

"Mais pour donner une idee quelconque de la profondeur de ces excavations, relativement au terrain ou au sol habitable de la partie haute de l'Amerique, il est a propos de rapporter quelques experiences.

"Guancavelica est une bourgade, ou un corps municipal, situe dans une de ces profondeurs, formees par differentes suites d'eminences. Le mercure du barometre y descend, et s'arrete a dix-huit pouces une ligne et demie. Sa plus grande variation y est de 1-1/4 a 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 ou se trouve la mine de mercure, mont qui est habitable par-tout, et qui est immediatement surmonte par d'autres, autant qu'il s'eleve au-dessus de Guancavelica, le mercure descend et s'arrete a 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 detachees, toutes semblables a celles qui sont au milieu des eaux; ce qui prouve que les eaux ont ete au meme niveau a une epoque beaucoup plus ancienne, et qu'elles ont excave le sol, a force d'en arracher les parties agregees.

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“Ces terrains sont couverts par un si grand nombre de courans, qu’il n’en est aucun ou l’on n’en apercoive, soit dans des ravins, soit entre des montagnes. J’ai observe que la superficie des terrains qui en avoisine les lits, est plus unie aux confluens, ou plusieurs de ces courans se reunissent. Cela vient de ce que l’eminence, qui se trouve au confluent, paroit avoir ete diminuee a la partie ou elle a du former une pointe saillante, a mesure que les eaux l’ont rongee de l’un ou de l’autres cote, en continuant leurs excavation. Ces surfaces planes sont comme par etages, les unes plus hautes que les autres, et se sont insensiblement formees, selon que l’eau s’est plus ou moins arretee a differente hauteur, pendent qu’elle creusoit ces lits. On observe, au contraire, que les bords eleves dans ces courans, n’ont presque point de largeur dans les endroits ou l’eau a pu suivre son cours tres-directement. C’est cependant sur ces bords etroits et escarpees que se trouvent pratiques les chemins par ou l’on passe. Le danger y est tres grand: car a peine un animal peut-il poser le pied. Toutes les fois que le courant fait un detour, la surface des bords a plus de largeur; cependant moins que lorsque plusieurs se reunissent. Un voit facilement pourquoi. L’eau forcee de se detourner, s’eloigne plus de la rive que quand elle va en ligne droite, et ronge ainsi le cote saillant sur lequel elle fait son detour, et qui en devient comme le centre.

“On peut conclure de ce que je viens de dire, a quelle elevation est la partie haute ou montagneuse de l’Amerique, relativement a la partie basse, et qu’il y a des excavations extremement profondes; car elles ont, comme je l’ai deja dit, 1769-2/3 varas perpendiculaires, ou meme d’avantages: cependant elles ont assez de surface pour devenir le local de nombre d’habitations fort peuplees, qui en tirent tous les produits necessaires a la vie. Parmi ces *Quebradas*, il en est de plus etendues 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 indifferent 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 immensement 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 Mineralogique, fait dans cette partie du Hainault connue sou le nom de Thierache.* Journal de Physique, Aoust 1784.

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“Il ne faut pas s’attendre a trouver dans ce pays des hautes montagnes qui frappent la vue de loin; c’est seulement un pays dont l’elevation est generale sur tout ce qui l’entoure, et est coupe profondement par des vallees ou ravin, ouvrage des eaux, qui, la comme ailleurs, ont use et coupe peu-a-peu les terrains et les roches les plus dures, pour s’ouvrir un passage; et peut-etre pourroit-on dire; si la diminution des eaux n’etoit pas trop sensible, qu’un jour ce pays offrira des montagnes hautes est escarpees comme tant d’autres, apres que les eaux auront creuse, pendant des milliers de siecles, ses gorges, ses ravins, et diminue la largeur des masses de terrain qui sont entr’eux.

“Quant a present, on ne peut y voir que de petites montagnes, ou plutot des bosses de terre, avec des platures plus ou moins considerables a leurs sommets, avec de cotes coupees 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 tranchee de ce pays est, sans contredit, celle ou coule la Meuse, qui, malgre la durete des roches d’ardoise et de quartz au travers desquelles elle passe, a coupe le terrain depuis Charleville jusqu’a Givet, a une tres-grande profondeur. Dans cette distance, on voit presque par-tout les cotes coupees presque a pic sur la riviere, de deux a trois cents pieds de hauteur perpendiculaire; et comme c’est une regle generale, que plus les cotes sont coupees droites, moins elles sont distantes l’une de l’autre, on concoit que le canal de la Meuse, dans cette etendue de terrain, doit etre fort etroit, eut egard a beaucoup d’autres ou il coule un bien moindre volume d’eau. Cela n’empeche pas qu’on n’y apercoive des marques de la regle general que fait l’eau, et n’y ait taille des angles saillans et des angles rentrans, qui sont tres-grands en certains endroits. Nous verrons que Revin et Fumai, deux lieux principaux des bords de la Meuse, sont situes sur deux de plus grandes de ces ouvertures ou se trouvent des platures assez vaste pour permettre, outre un emplacement considerable pour les maisons, l’etablissement de beaucoup de jardins, et meme des pieces a grain et des prairies. Aussi, quand on arrive sur la tranchee de la Meuse, les lieux et les terrains cultives qu’on voit dans son fond, paroissent comme separes sous les autres et comme dans un autre pays.

“Les autres coupures ou ravins de ce pays, quoique moins profonds, offrent cependant cette singularite, remarquee deja ailleurs, que leurs grandeurs et profondeur ne sont point du tout proportionnees au volume de l’eau qui y coule.

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“Le massif sur lequel est situe Beaumont, est coupe presque perpendiculairement a l’ouest, sud-ouest et cette coupe en fait de ce cote-la un rempart inaccessibles, ayant plus de 100 pieds de hauteur. Quand j’ai considere cette grande coupe, et le detour que fait la petite riviere qui coule au bas de ce massif, je n’ai pus me refuser a croire qu’il n’y avoit en la un bien plus grande courant d’eau, qui a battu et mine ce massif, en s’y brisant avec force; car on ne peut supposer, avec quelque vraisemblance, que cet ouvrage ait ete fait par le volume d’eau qui y coule actuellement: et il ne faut pas s’etonner de ce disparate; par-tout vous le trouverez; ce qui demontre evidemment que la quantite d’eau diminue insensiblement, et que la partie solide de notre globe augmente a proportion que la partie liquide diminue; et s’il faut encore etendre ce principe, j’ajouterai, que par-tout vous verrez les bornes de la mer et des rivieres reculees; par-tout vous trouverez d’anciens courans d’eau desseches, et meme des rivieres considerables, a en juger par les collines ondulees qu’on voit encore. Mais cette partie essentielle de la mineralogie qui est effrayante par les consequences qu’elle presente, et qui peut influer sur le systeme general du monde, sera etendue un jour dans un autre memoire, ou je decrirai d’anciens cours de rivieres de la France, qui n’existent plus. J’espere fair voir alors, appuye par les faits que me fournira l’histoire, que les rivieres et les fleuves actuels ont ete plus volumineux qu’ils ne le sont maintenant, et qu’il existoit en France un grande nombre de vastes lacs, comme dans l’Amerique Septentrionale, et dont a 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.

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CHAP. XIII.

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 Memoire sur les Volcans eteints du Val di Noto en Sicile. Journal de Physique, Septembre 1784.

“Je trouvai les premiers indices de ces volcans, en allant de Syracuse a Sortino, a une lieue de cette ville, au fond du profond vallon qui y conduit. Quelques morceaux de laves entraines et arrondis par les eaux m’annoncerent d’avance que j’allois entrer dans un pay volcanique. Mon attention se fixa bientot apres sur un courant de laves que je vis sortir d’une montagne calcaire qui etoit sur ma droite, il etois coupe par une vallon dont les eaux couloient sur un sol calcaire, et alloit se perdre dans le massif egalement calcaire qui etoit sur ma gauche. Je passai en suite alternativement sur des matieres calcaires et volcaniques, pour arriver a Sortino, ville baronale batie sur une montagne calcaire qui domine la vallon, et qui lui presente des escarpemens de plus de 200 toises d’elevation, dans lesquels les banc de pierres dure sont horizontaux, et exactement paralleles.”

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 phenomenes et des singularites dont l’explication me parut difficile, et qui tinrent pendant longtemps mon esprit en suspens. Je vis d’abord les matieres volcaniques ensevelies sous des bancs horizontaux de pierres calcaires, tres-coquillieres, contenant sur-tout une infinite de madreporites, quelques-uns d’un volume enorme. Je vis ensuite des hauteurs dont les sommets

seuls etoient volcaniques, et les noyaux calcaires, sans que les laves qui couronnoient ces sommets eussent communication avec aucun courant,

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et eussent d'autre etendue que le plateau qu'elles recouvroient. Ces laves n'avoient pu etre formees ou je les voyois; elles etoient venues d'ailleurs; mais d'ou et comment? *etc*. Je me determinai a consulter les montagnes les plus hautes, qui etoient a quelque distance. J'en vis de loin plusieurs dont la forme etoit a peu-pres conique, et dont les sommets etoient pointus; elles etoient vers le nord, ou nord-ouest de Sortino, dans la direction de l'Etna, qui terminoit mon horizon, a 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 idee topographique de tous le pays, qui domine tout ce qui entoure, a 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 isolee par des vallees, dont le sol lui etoit sur-abaisse de 3 ou 400 toises, a sa base calcaire. Sur cette premiere assise repose une couche volcanique, ensuite une autre tranche volcanique calcaire, a laquelle succede un sommet forme d'une lave dure. Une autre montagne aupres du fief de la Copodia, egalement conique, est toute volcanique, a l'exception d'une couche de pierre calcaire dure et blanche, qui la tranche a moitie hauteur parallelement a sa base. Quelques montagnes ou les couches volcaniques ou calcaires sont plus ou moins nombreuses. La montagne de Pimalia est volcanique a sa base et calcaire a son sommet; et enfin la montagne isolee sur laquelle est batie la ville de Carientini est moitie calcaire et moitie volcanique: mais ici la division des deux substances se fait par un plan verticale, *etc*. Apres etre arrive a cette limite des volcans, dont je poursuivois le foyer, je pris du cote de l'est; je suivis jusqu'a Melilli les hauteurs qui accompagnent la vallee de Lentini, et qui dominent la plaine d'Auguste; et cheminant a mi cote je vis deboucher du milieu des montagnes calcaires, qui, reunies par leur base, ne forme qu'une meme groupe, sous le nom de monts Hybleens, *Colles Hyblei*, plusieurs courans de lave qui se terminent comme s'ils avoient ete coupes sans avoir eu le temps de descendre dans la vallee, et de s'incliner pour en prendre la pente. Plusieurs de ces courans sont cristallises en basaltes prismatiques; on en voit de tres-belles colonnes au-pres de Melilli. Au dela de cette ville jusqu'a 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 extreme profondeur, dont les encaissemens, tailles presque a pic, ont plus de 600 pieds d'elevation, *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:

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“Je ne pus pas douter que cette montagne ne fut le volcan que je cherchois, et qui avoit repandus ses laves a une tres-grande distance autour de lui, sur-tout dans la partie de l’est; mais il me restoit a resoudre le probleme de la formation des montagnes isolees et coniques, mi-parties volcaniques et calcaires, qui ne tiennent a aucune courant, et qui sembloient n’avoir aucune relation directe avec mon volcan. L’etude de la montagne Santa-Venere, et des pays circonvoisins, m’apprit que ce volcan s’etoit eleve au milieu de la mer qui alors occupoit nos continens, que sa tete seule s’etoit soulevee au-dessus du niveau des eaux. Je fus convaincu que, lorsqu’il repandoit autour de lui des torrens de matieres enflammees, la mer entassoit des depots calcaires; que chaque nouvelle eruption trouvoit un sol plus eleve, sur lequel elle se repandoit; que bientot les nouvelles matieres volcaniques etoient ensevelies sous de nouveaux depots, et qu’ainsi, par l’entassement successif et regulier des produit du feu et des depots de l’eau, s’etoit forme un enorme massif, a 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’etoit repandu les premieres laves, et fut divise, morcele et degrade par les courans ou par le ballottement des eaux, lors de la grande debacle du de la catastrophe qui changea l’emplacement des mers. Les vallons et les gorges qui se formerent au milieu de ce massis, separerent les laves de la montagne a qui elles appartenoient, couperent les courans, et faconnerent, avec les debris 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 submerge l’eau, se retirant avec precipitation, excave par-tout ou elles trouve moins de resistance, creuse les premiers sillons qu’elle a traces et forme des petits cones, dont les sommets sont a la hauteur du sol sur lequel reposoient les eaux. Les parties ou les laves avoient coule successivement dans la meme direction, les unes au-dessus des autres, ont donne naissance aux montagnes dans lesquelles les couches volcaniques et calcaires se succedent parallelement. Celles sur lesquelles aucunes laves ne se sont portees, n’ont produit que des montagnes totalement calcaires que se trouvent entremelees avec les autres. Celles enfin sur lesquelles le hazard ou des circonstances locales out entasse de preference, et dans le meme lieu, les matieres que vomissoit le volcan, sans laisser le temps au depot des eaux de se meler avec elles, ont produit quelques petites montagnes presque entierement volcanique, ou les cendres sont agglutinees par une pate calcaire, *etc*. Cette theorie rend raison de tous le phenomenes et de toutes les singularites qui s’observent dans le melange des produits du feu et des depots de l’eau, et une infinite de preuves de differens genres, mais qui seroient etrangeres a ce Memoire, concourent a demontrer, l’existence d’un ancien plateau qui etoit eleve de plusieurs centaines de toises au-dessus du sol actuel des vallees et du niveau de la mer, qui couvroit non seulement le Val *di Noto*, mais encore toute la Sicile, et dont les debris ont forme toutes les montagnes actuellement existantes, a l’exception de l’Etna.”

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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[28]. 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.

[Footnote 28: 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.]

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 *debacle* 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

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the rivers of Sicily to have shaped the mountains and the valleys; it is in removing the masses of 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 deg. and 67 deg. 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.

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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 Rhone 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.

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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 a ce qu’il paroit. On pourra en juger sur les circonstances locales que je vais rapporter. Une partie de cette principaute est divisee en quatre grandes vallees, d’environs quatre lieues de long, sur trois quarts-d’heure ou une heure de large, separees par autant de chaines de montagnes fort eleves et large en quelques endroits d’une lieue et demie. Les extremites de chacune de ces vallees sont plus elevees que le milieu, et on ne peut pas en sortir par ces extremites sans beaucoup monter. Mais ces vallees ont des communications entr’elles par une pente assez douce a travers ces masses enormes de montagnes qui les separent, et qui sont coupees

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au niveau du milieu des vallees sur 300, 400, 500 toises de hauteur et dans toute leur largeur. On pourroit assez justement comparer ces vallees a des berceaux poses les uns a cote des autres, dont les extremites, remplies en talus, seroient plus eleves que les cotes, et dont ces cotes seroient coupes jusqu'au fond, pour laisser une passage de l'un a l'autre. Je connois sept a huit passages semblables a travers ces hautes montagnes, dans une quarre d'environ quatre a cinq lieues; et dont quatre aboutissent a la vallee de Mouthier-Grand-Val. Ces passages sont evases dans le dessus, d'environ une demi-lieue par endroits; mais leurs parois, en talus, se rejoignent dans le fond ou coule un ruisseau. On a pratique des routes sur quelques-uns de ces talus, mais les roches sont quelquefois si resserrees et si escarpees, qu'on a ete oblige de construire un canal sur le ruisseau, pour y faire passer la route. C'est-la que l'on voit a son aise, la nature de ces rochers primitives, leur direction, leur inclinaison, et tous leurs autres accidens qui demanderaient chacun une dissertation particuliere trop longue pour le moment, et il faut les avoir vues pour se faire une juste idee 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 rivieres qui traversent ces montagnes, sont beaucoup plus basses que les sommites des montagnes elles-memes, ces sources ne font donc pas la cause de ces effets merveilleux. Il a fallu un agent plus puissant pour creuser ces abimes."

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.

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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 Rhone, above St Maurice, would be drowned by shutting up that gap of the mountains through which the Rhone 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 Rhone, 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 Rhone, 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)[29] "Par une gorge tres etroite et tortueuse," and goes out in like manner at the under End.

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[Footnote 29: Journal de Physique, Mai 1787.]

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 *gres* 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 Rhone, secondly, the countries of the Seine and Rhone, above the mountains through which those two rivers in conjunction have broke, below Lyons; and, lastly, that country of the Rhone and Durance which is almost inclosed by the surrounding mountains, meeting at the mouth of the Rhone. 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.

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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.

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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.

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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.

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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.

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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.

CHAP. XIV.

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.

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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.

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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.

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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.

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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

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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.

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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.

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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[30], 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.

[Footnote 30: 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.

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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.

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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.

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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.

END OF VOLUME SECOND.