with the best remembrances of Andw. Ramsay

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PASSAGES

IN THE

HISTORY OF GEOLOGY:

BEING

An Inaugural Lecture

AT

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BY

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GEOLOGY in its widest sense may be defined to be the history of the Earth, animate and inanimate, as far as it can be traced by investigating those relics of the past that form the existing surface of the globe,—an extended field requiring for elucidation the aid of many sciences, which, of themselves, may often be pursued as distinct if not independent subjects.

To place the events of this complicated history in clear chronological succession is, therefore, the business of Geological Science; and, as in the story of the human race there are two orders of history, one contenting itself with a simple detail of events, the other embracing a wider scope, and by an analysis of these events endeavouring to arrive at just conceptions of the nature of the physical and moral influences whence they originated; so in Geology, the philosophical inquirer will not be content with a dry detail of isolated facts; but, engrafting on his inquiry a similar analysis, he will endeavour to form true and lawful conclusions as to the nature of the secondary causes that gave rise to the phenomena he contemplates. Such is the *object* of Geology, which, like every other physical science, combines observation of facts with consequent inductive reasoning.

The first step in this inquiry is to mark the varied appearances in the solid crust of the earth. The second is to compare these with what is present to our view in the living world.

For the first he must observe the nature of rocks, their composition, their crystalline character, their stratification, their division into spreading formations of varied extent and thickness, their included organic remains, their dislocation, their regular disposition, their not unfrequent most obvious disturbance and distortion, and their fragmentary condition. For the second step he must study the action of earthquakes and volcanos, and their effects far and near by land and in the neighbouring seas. He must watch the process of atmospheric disintegration, the wasting power of rains, which, gathering into brooks and torrents as they descend into the plains, unite at length into great rivers, bearing in their course to the parent sea vast loads of matter, won from the many lands through which they flow. An observation of lines of coast will instruct him in the destructive action of the sea, which, never at rest, undermines by the ceaseless grinding of its breakers the cliffs that overhang its margin, bearing away its spoils, to be re-deposited in remoter deeps. He must call to his aid the hydrographer, who will tell him of the form of the bed of the sea and the nature of its soundings. Distinct perceptions of the phenomena of life, whether terrestrial or aquatic, must be entertained. The accomplished botanist can alone compare the forms of an extinct flora with our existing vegetation; to the comparative anatomist must be referred the relations of animals that once peopled the earth with their existing analogies; and he who dredges in the sea-deeps can alone reveal the secrets of the ocean, and bring to light the organisms that people its dark waters. Even Meteorology is not without its reference to our subject, for the laws that regulate climate now, may have affected it in all time past, and governed the diffusion of life on the face of the world. Chemistry must do more than analyse the mere composition of isolated specimens of earths, rocks, minerals, and shells; for Chemistry alone can divulge the reason of many of their modes of occurrence; and who can foresee how far it may yet aid in explaining the conditions under which rocks were formed, and the relation of these conditions in connexion with climatal and other arrangements to the development of the life of the time? Without these aids but a small part of the story of the world could be interpreted. It is possible to conceive an untenanted world undergoing many revolutions; locally, successions in time might of themselves be deciphered, yet without the history of life who could explain the synchronic succession of distant deposits? And, inasmuch, as the phenomena of life form a loftier subject than the mere study of inorganic matter, without this history superadded, meagre indeed would be the detail of a Geology destitute of life. These form the *nature* of the inquiries necessary for the successful determination of the *object* proposed in the pursuit of Geological Science.

I shall now, by a concise analysis of the progress of Geological investigation, endeavour to ascertain how far this object has been attained. For this purpose I shall deal simply with a few of the greater names in Geology, (considering them as the exponents of the state of Geological Science in their day); generally disregarding the host of writers who, by detached observations and minor theories, sometimes right and sometimes wrong, yet by the spirit of inquiry they aroused, did not labour utterly in vain. It would be vain in the space of an hour, even in this manner, to attempt to do justice to the entire subject; I shall, therefore, principally restrict myself to a time ending with the labours of Hutton; leaving for a future opportunity a more particular account of the history of those whose work more immediately bore on the doctrines of Werner, and the great discovery of William Smith.

I will not here discuss the fabled doctrines of early Cosmogonies, nor do more than advert to the mass of floating information respecting the gradual revolutions that the earth has undergone, which may be found in the doctrines of the Pythagoreans, and scattered in the pages of Herodotus, Aristotle, Strabo, and Pliny. The mutability of the relations of sea and land, the excavating power of water, the elevating action of earthquakes, the bursting forth and extinction of volcanos, the union of islands with, and their separation from, the mainland, by the gradual invasion of the sea, all come within the scope of their philosophies. They taught, that no form of matter is destined for ever to remain unchanged. Yet catastrophes are not universal, but local and intermittent; and though the progress of change is almost unnoted because of its slowness and the shortness of life, still, in the illimitable lapse of time, the entire result is not the less certain. The great geographer Strabo distinctly attributes the occurrence of marine exuviæ on mountains to the upheaval of ancient bottoms of the sea, and especially insists on the necessity of accounting for their situation and for all other terrestrial changes by the agency of causes constantly in action, such as volcanos, earthquakes, and gradual elevations of continents above, and their depression beneath, the waters.* His classification of islands is very remarkable. "Some islands," he says, as quoted by Humboldt, "are fragments of the Continent; others have arisen from the sea—an event that still happens at the present day: for the islands of the great ocean have probably been lifted from its bosom, those that lie off promontories have probably been detached from the mainland."† Here then are unconsciously recognised the principles on which are built many of the greater problems of modern Physical Geology: first, the principle of local elevation, and second, that of aqueous degradation; for to the combined

* For a concise account of the opinions of Strabo, see Lyell's "Principles of Geology," Book I. Chap. 2.

† Cosmos, London, 1845, p. 445.

action of these are owing the configuration of all existing land, and the deposition of formations in all geological time.

In connexion with the subject of the formation of islands by separation from the main land, I must here be permitted to advert to two direct applications of the subject, that, many hundreds of years afterwards, have been made to elucidate what was once one of the most obscure problems of geology. In the year 1715, some large teeth were dug up in the North of Ireland, respecting which Mr. Francis Nevile wrote "a Letter to the Right Rev. St. George, Lord Bishop of Clogher."* In the pages immediately succeeding, are some "Remarks upon the aforesaid Letter and Teeth, by Thomas Molyneux, M.D., and R.S.S., and addressed to his Grace the Lord Archbishop of Dublin."† Disregarding the "hint" given by Nevile "of their being human or gigantick," as "contradictory to comparative anatomy and all natural history," he at once, by comparison, identifies them with the teeth of elephants, and concludes "that these remains must be cotemporaries with remote ages when the surface of this terraqueous globe might, in the earliest ages of the world, after the deluge, but before all records of our oldest histories, *differ widely from its present geography, as to the distribution of the ocean and dry land.*" He then draws the same inference with regard to "that other vast large stately animal the moose-deer," which he conceives once to have wandered by land "from North America," mistaking the remains of the Cervus Megaceros for those of the North American elk; "and," continues he, with wonderful sagacity, "how can we suppose that birds of shortest flight, the various sorts of poisonous serpents, and of offensive creeping vermin, with all the various tribes of smaller insects, could possibly be found in islands, unless they had been

* Phil. Trans., vol. xxix. p. 367. † Id. p. 370.

stocked with those inhabitants when the intercourse between them and the Continent was free and open?" Strange inconsistency, to suppose that such mighty changes could have taken place (even had the species not been extinct) in the little space of time that has elapsed since the Noachian deluge! The important general truth, as it were, divined in the above quotation, has been admirably speculated upon by Mr. Lyell in his "Principles of Geology,"* and its absolute workings have lately been clearly established by my colleague in the Geological Survey, Professor Edward Forbes, who, following out the subject far beyond what, long after the time of Molyneux, was ever dreamed of, has shown that the "existing Fauna and Flora of the British Isles" travelled hither at "several distinct points of time," dependent on the union or separation of our islands with the mainland.†

To return to the writers of antiquity :—

Standing altogether apart from fabled Cosmogonies, there is dimly foreshadowed in their writings the *germ* of much that has of late years raised Geology to the high rank it occupies among the sciences—I mean the close observation of existing phenomena of change, and their application to time past and future. Unrestricted by the dictates of a mistaken orthodoxy they knew no limit to time, and thus, almost in the spirit of prophecy, the Stagyrite dared to assert that even as rivers and continents had heretofore sprung up and disappeared, so those that now are, must also slowly pass away. The high acumen displayed by Strabo in the application of the theory of upheaval, to account for the occurrence of marine shells at a distance from the sea, is all the more wonderful when we consider that the inference

* Seventh Ed. pp. 663 to 670. At page 301 Mr. Lyell quotes Verstegan's "Antiquities of the English Nation," to show that so early as 1605 the opinion was entertained that the noxious animals of our country passed from the Continent, when England was joined by an isthmus to the mainland.

† Memoirs of the Geological Survey of Great Britain, vol. i. p. 336.

was supported by the most slender portion of what now constitutes the mass of Geological evidence. Knowing nothing of the absolute Geological mechanism of the earth, yet deeming the laws of nature for ever unchangeable,—marking well the present, and looking into the future, these men saw in the world an endless circle of mutability which, in the language of Hutton, gave "no vestige of a beginning, no trace of an end;" a marvellous inference, by those who knew not that the events, marking that wondrous history, are recorded on tables of stone by the finger of him who cannot lie.

After the destruction of the Roman empire a long period of European darkness elapsed. It was not till the beginning of the sixteenth century that the subject first began to arouse attention in Italy. For the history of the early struggles of Geology, let me refer you to the graphic pages of Mr. Lyell's great work, the "Principles of Geology." Truth and strange delusion, mingled in strong and ingenious minds, for centuries strove for the mastery,—delusions haply not greater than some that now agitate the Geological world; for, even as we regard the history of the past, those that follow may, from a higher point, look back and smile at the track of our devious wanderings. In these pages you will find the record of those keen spirits who proved that what we now term organic remains were "sports of nature," the results of a "plastic virtue latent in the earth," of the fermentation of a certain incomprehensible "materia pinguis," or "fatty matter," of "the tumultuous movements of terrestrial exhalations," or of "an internal principle" without a name. The idea could not be tolerated, that earthly creatures had ever been, of which there remained no living examples, or that the "eternal mountains" did not stand as they appeared when first creation dawned. If, however, we examine the processes by which bolder yet more sober reasoners arrived at their conclusions, it cannot be denied that they were at least equal to, and often in advance of, the knowledge and temper of the times. Of such inquirers, among the most remarkable were Fracastoro, the immortal painter Leonardo da Vinci, Fabio Colonna, Steno and Hook; and in later times, Vallisneri, Lazzaro Moro, Generelli and Raspe.

Of all these none deserves a higher place than Nicolaus Steno, whose treatise "De Solido intra Solidum naturaliter contento," published in 1669, displays an originality and logical method of Geological reasoning in few points surpassed till the advent of the illustrious Hutton, in the middle of last century. An English edition appeared in 1671, entitled "Prodromus to a Dissertation concerning Solids naturally contained within Solids," &c. He had previously dissected a shark, and published the results at Florence, in a work called "Musculi Descriptio Geometrica." Amid other anatomical investigations, (says the writer of a notice in the "Philosophical Transactions" for 1667,)* "examining withal whether the *Glossopteræ* be the *Teeth* of this creature, or stones produced by the earth; in which controversie he takes their part who maintain, that those, and divers other substances found in the earth, are parts of the bodies of animals, and endeavours to prove that such sorts of earth may be the sediments of water, and such bodies the parts of animals carried down together with these sediments, and in progress of time rendered of a stony hardness."

Arguments drawn from similar comparisons respecting the identity of structure exhibited by sharks' teeth and the "Glossopteræ dug up in Malta," had forty-one years before been strongly urged by Fabio Colonna, whose reasonings to prove that such exuviæ did not vegetate in the matrix are almost equally powerful with those subsequently employed by Steno. He shows that the buried specimens possess the same internal structure with those fresh from the life; and that the former *are frequently*

* Vol. ii. pp. 627, 628.

broken, "and that, not with an uniform fracture, but different in every one." "Nature," says Ray, in describing the investigations of Colonna, "never made teeth without a jaw, nor shells without an animal inhabitant, nor single bones—no, not in their own proper element, much less in a strange one." Further, he shows the distinction that ought to be drawn between crystals infiltered into cavities, and buried organic remains; in which latter case the "Tophus," as he calls it, or matrix, takes its impression from the contained body, proving that the latter was hardened before the formation of the former.*

In his "Prodromus," Steno contrasts the more reasonable opinions of the ancients with those that generally obtained in his own day—the only difficulty of old being "how marine bodies came to be left in places remote from the sea," whereas in his time "they almost all busied themselves about the origin of the said bodies;" the advocates of a plastic virtue employing "their wit in extolling the powers of nature, as able to produce anything whatever."† To settle this point he found it necessary to "comply with the laws of an analysis;" and revolving the subject in all its bearings, he "found the matter reduced to this, that we were to examine *every solid naturally included in a solid;* * * * viz., Whether it was produced in the same place where it is found." Arguing *à priori* he laid down certain propositions:—

First. "If a solid body be anywhere encompassed by another solid body, THAT, of the two, first was hardened, which, in the mutual contact, doth express on its superfice the proprieties of the superfice of the other." This is not necessarily an invariable rule, since (to select a familiar example) selenite is frequently formed in massive deposits of clay by the mutual decomposition of carbonate of lime

* Ray's "Miscellaneous Discourses," London, 1692, pp. 109 to 114.

† Prod. London, 1671, p. 11.

and sulphuret of iron.* It is, however, strictly true in the case of "Plants, and their parts, bones and shells of animals * * * already hardened, when the matter of the earths and stones containing them was yet fluid; and, consequently, that these earths or stones are so far from having produced the bodies contained in them, that *they were not there existent, when those bodies were there produced.*"

Secondly. "If a solid body be everywhere like another solid, not only as to surface, but also in the inner constitution and frame of its parts and particles, then it will also be like it as to the manner and place of its production, excepting those conditions of place, which are often found in a place and are no advantage or disadvantage to the production of a body." From this he infers "that the *beds* of the earth" (strata) "agree with those beds which turbid waters let fall," and "that those bodies, which being digged out of the earth, are altogether like the parts of plants and animals, were produced in the same manner and place, in which the very parts of plants and animals are produced." Assuming, after the fashion of his time, an original fluid menstruum "that overwhelmed all," from which the oldest rocks were formed, he correctly infers the derivative origin of beds containing *fragments* of other rocks and possessed of organic remains. He recognises the agency of rivers in the embedding of terrestrial exuviæ, of water in smoothing inequalities by the spreading abroad of sediment, and of volcanos in producing beds of ashes, pumice, and other igneous substances, wherever they may be found, even though no other visible trace of a volcano, as ordinarily understood, should appear. He hints at the various conditions necessary to account for the production of different kinds of strata, and vaguely anticipates Hutton

* The opinion of Steno that selenites were always formed before the surrounding matrix, is well refuted by Dr. Plot, in his "Natural History of Oxfordshire," Oxford, 1677, p. 83.

in the idea that they are consolidated by volcanic heat.* He adduced the doctrine of superposition as indicative of succession in time, and with rare sagacity inferred the original limitation of strata; for, says he, "wherever there are seen any marked sides of beds (meaning stratified escarpments) there is either to be sought for, a continuation of the same beds, or there must be found out another solid body, which kept the matter of the beds from falling asunder." He then asserts the original general horizontality of strata, and nearly approaching some modern tenets, ascribes the subsequent *dislocation* and *contortion* of these masses to the joint agencies of upheaval and depression, "by the occasion of which, the beds of the earth may change their scite two ways:—

"The first is, a violent excussion of the beds upwards, whether that be caused by a sudden ascension of underground exhalations, or by a forcible elision of air occasioned by other huge neighbouring ruines * * *. The other is, a spontaneous falling down of the upper beds, when the lower matter or foundation being withdrawn, the upper bodies have begun to crack; whence, according to the variety of cavities and crevices, there follows a various scituation of the broken beds; forasmuch as some remain parallel to the horizon, others become perpendicular to it; most make oblique angles with it; some are bowed into arches, being made up of a tough matter: and this change may happen either in all beds imminent to cavities, or in some lower ones, the upper beds being left entire."† These changes, together with volcanic eruptive accumulations, are, he affirms, "the chief original of mountains, and prepare," in flaws and fissures, "a receptacle for most minerals."

In a further portion of the essay, he anatomises the structure of recent shells, and demonstrates its similarity to that of those "under ground," "that are so like to

* Prod. pp. 40, 41. † Prod. pp. 44, 45.

those lately described as an egg is to an egg," and therefore concludes that "these shells were once the parts of animals living in a fluid." He then reasons back through the different stages of alteration that fossils have undergone, from partial decomposition to entire replacement of particles, or the complete removal of the original matter, the cast alone remaining, quaintly denominating these "aerial shells." The same argument he applies to the entombment of fossil mammals; and in reference to objections raised on account of their frequent size, (for they were generally believed to be the bones of buried giants) he remarks with a whimsical and semi-satirical mixture of truth and error, "1st. In our own age there have been men with very long faces. 2nd. It is certain that there were once men of a monstrous bigness. 3rd. Often those are believed to be humane bones that are bones of other animals. 4th. It is the same thing to ascribe to Nature the production of bones truly fibrous, and to say, that Nature can produce the hand of a man without the rest of a man." He further maintained that Tuscany had been twice under water, and as dry land had existed twice with a level, and twice with an irregular surface. He illustrated this proposition with six singular diagrams, (probably the first attempts to explain Geological phenomena by sections,) thus strangely anticipating a species of research which has begun of late years to assume a definite shape—I mean the application of Geology to the elucidation of problems in physical geography.

Even from the height we have now attained, it is impossible to look back on the period when, surrounded by ignorance, prejudice, and error, the genius of one man penetrated so deeply into the mysteries of nature, and propounded them to the world in terms so clear and explicit.

From the time of Steno to the advent of Raspe, Werner, and Hutton, but little actual progress was made towards a right understanding of the economy of the world. The works of the whole list of Geologists exhibit a constant oscillation between truth and error. At one time the tide of opinion goes forward with Hook, Ray, Vallisneri, and Moro; or recedes with Quirini, Plot, and Lister. Thinking men maintained that what we now term fossils, were the mere freaks of a prolific Nature; and ever and anon there flashed across the Geological horizon men like Burnet and Whiston, who traced the progress of events from times

> "where eldest Night
> And Chaos, ancestors of Nature, hold
> Eternal anarchy,"

through all the phases of first creation, absolute dissolution at the deluge, and subsequent less perfect reconstruction; men who scrupled not to call in the aid of "an auxiliar comet's tail;"* dreamers of miraculous dreams, and seers of unevidenced visions. Time will not permit me to do more than hint at these marvels; but it may not be uninteresting to notice more particularly the style of reasoning which learned men indulged in who were contemporary with Hook. "I have," says Lister, "I think, demonstrated that the rock cochlites were no shells."† In 1667 the

* Raspe, alluding to Whiston, "Account of some German Volcanos," London, 1776, p. 22.

† Phil. Trans. vol. xiv. p. 742. In the year 1683, Martin Lister, M.D., delivered to the Royal Society "An Ingenious Proposal for a new sort of Maps of Countrys, together with Tables of Sands and Clays," &c. This was the first proposal for a geological map. "Something more," says he, "might be comprehended from the whole, and from every part, than I can possibly foresee." Phil. Trans. vol. xiv. p. 739. I shall in a future essay, dealing more immediately with the progress of that branch of geology that ended in the discoveries of Smith, fully consider this paper, and also the much more remarkable "History of Pembrokeshire," by George Owen, of Henllys, Lord of Kemes, written in the reign of Queen Elizabeth, and published in the "Cambrian Register." Neither of them seem to have had distinct ideas of the underground continuity of strata; but Owen approaches nearer this than Lister.

learned Dr. Plot published his "Natural History of Oxfordshire." He seems to have had a faint idea of the structure of limited portions of the earth's surface; "for," says he, alluding to the succession of strata in a sinking on Shotover hill, "the earth is here as at most other places—I think I may say, of a *bulbous nature*, several folds of divers colours and consistencies, still including one another, not unlike the several coats of a tulip root or onyon."* He maintained, with Stillingfleet,† the non-universality of the deluge. He therefore denied that shells had been brought by this means to the tops of mountains; and again, even allowing its universality, he declares that the tranquil increase of the waters precludes the idea of miscellaneous bodies having been violently transported and scattered abroad on the face of the earth.

Thus, by fair reasoning, having got rid of one dogma, he seized upon and stoutly advocated another, almost more impossible than the first. Treating of "stones in the forms of shell-fish,"—because the flood did not move them, because many living species are not found among them, because many resemble no living species, and because it cannot be determined whether others are animals or plants —"upon mature deliberation," says he, "I must confess I am inclined rather to the opinion of Mr. Lister, that they are *lapides sui generis*, than to theirs (Hook and Ray) that they are thus formed in an animal mould."‡

This point gained, and disregarding the clear distinction that had been drawn by Steno between organic remains and crystalline and other minerals, he launches into a lengthy description of stones; and for the edification of the vulgar, describes them as related to the greater and lesser

* Nat. Hist. of Oxfordshire, p. 56.

† The "Origines Sacræ" of Bishop Stillingfleet was published in 1662. He was, as far as I am aware, the first author who openly declared against the universality of the Noachian Deluge. "Stillingfleet's Works," London, 1790, vol. ii., pp. 337 to 339.

‡ Nat. Hist. of Oxfordshire, p. 112.

heavenly bodies, to the inferior heavens, the inferior air, the fresh water and the sea,—confounding therein the manner of formation of selenites, stalagmites, stalactites, marcasites,* echini, belemnites, corals and chalk flints; and sometimes discovering wondrous "imitations" of the heads of horses, human feet, and other members unnecessary to particularise. Yet one marvellous thing he did find, which he doubted not was part of the thigh bone of a mighty giant. Dwelling on this subject with evident delight, he enumerates all the famous giants from the times of the sons of Anak; and is satisfied that "'tis possible enough these bones from Cornwell might be the bones of a man or woman;" for, "if we look abroad amongst the present barbarous nations of both Indies, where they still live according to nature, and do not debauch her with the sensual delights of the more civilised world, we shall find (if the relations either of English or Hollanders be of any credit) that there are now men and women adequate to them in stature, several having been seen, especially about the Straights of Magellan, of ten, and one near the River Plate, by Thomas Turner, twelve foot high." With such strange minglings of impossible physics, theology, and travellers' tales, did early Geologists sometimes amuse and bewilder their readers.

A few years later Hook and Ray somewhat stemmed the retrograding tide, and in some points advanced the science beyond its previous bounds. One important step made by Hook was the admission that existing knowledge afforded no sufficient data on which to found a true theory of the earth, and he strongly insists that it is alone by the united and long continued efforts of many, that we can hope "to find out the truth or the real effect as it is in its constitution or state of being;" † and, continues he, "when this

* Iron pyrites.

† Posthumous Works (A Discourse of Earthquakes), p. 279.

mighty collection is made, what will be the use of so great a pile? Where will be found the architect that shall contrive and raise the superstructure that is to be made of them, that shall fit every one for its proper use? Till which be found they will indeed be but a heap of confusion." Acting on this admission, he himself sets the example of collecting and recording past evidences of Geological change within historical times.

Disdaining as "fantastical and groundless," the opinions attributing the origin of fossils to "celestial influence," and "vegetative or plastic vertue inherent in the parts of the earth where they were made," he, by a variety of arguments similar to those employed by Steno, proves that fossil shells, fish, and wood, are really the remains of the organisms they represent,* and that they were accumulated at the bottom of the sea. Like Steno and Hutton, he partly attributes the consolidation of strata "to some kind of fiery exhalations arising from subterraneous eruptions or earthquakes," but with greater correctness he assigns the principal share to the influence of infiltrations and internal decomposition, or to "a very long continuation of these bodies under a great degree of cold and compression."† The rocks thus formed were shattered and elevated by earthquakes and volcanic eruptions, and became dry land. To prove the power of earthquakes, he gives an admirable *resumé* of their effects, from "the relation of the sad catastrophe of those four cities, Sodom, Gomorrha, Zeboim, and Adma," down to his own time, recognising their influence, both in elevations, and "in the depression or sinking of the parts of the earth's surface below the former level;" ‡ "for," says he, "'tis very probable that whatsoever an earthquake raises up in great part of the earth in one place, it suffers another to sink in another

* Posthumous Works (A Discourse of Earthquakes), p. 318.
† Id. p. 290. ‡ Id. p. 298.

place."* "The universality of this active principle" accounts for the occurrence of marine remains at any distance from the sea. "Nothing is made by nature so fixt as to be unmoveable, some sink at one time, some at another. And, as in great cities, now this house, now that house, hangs tottering on props; so in the great face of the earth, now this part fails, now that."† He invokes the same agency to account for *the extinction of species, and for the production of varieties;* "for since we find that there are some kinds of animals and vegetables peculiar to certain places, and not to be found elsewhere, if such a place have been swallowed up, 'tis not improbable that those animal beings may have been swallowed up with them." And again, "'tis not to be doubted that alterations of this nature may cause a very great change in the shape and other accidents of an animated body."‡ Indeed Hook seems almost, as if by inspiration, to have divined the idea of succession in species, believing "that there have been many other species of creatures in former ages, of which we can find none at present; and that it is not unlikely also but that there may be divers new kinds now, which have not been from the beginning;" § "and," says he, speaking of these "records of antiquity which nature has left as monuments and hieroglyphic characters of preceding transactions, * * * though it must be granted that it is very difficult to read them, and to raise a *chronology* out of them, and to state the intervals of the times wherein such or such catastrophes and mutations have happened, yet 'tis not impossible."||

By the agency of earthquakes and volcanos he strove to account for the kind of irregularities that mark the earth's surface, seeing in the action of water only a degrading and smoothing influence, which it certainly is, though not

* Posthumous Works (A Discourse of Earthquakes), p. 320.

† Quoted by Hook from Seneca, p. 111.

‡ Posthumous Works (A Discourse of Earthquakes), p. 327.

§ Id. p. 291. || Id. p. 411.

in the precise sense he intended; for while the waves and the rain for ever strive to restore the land to the sea, yet, in the very exercise of this levelling power, both united, go far to produce many of the more obvious asperities that form such characteristic features of the continents we inhabit. "*The former principle* (earthquakes), *seems to be that which generates hills* and holes, cliffs and caverns, and all manner of asperity and irregularity on the surface of the earth, *and this* (the influence of water) *is that which endeavours to reduce them back again to their pristine regularity*, by washing down the tops of hills, and filling up the bottoms of pits, which is indeed consonant to all the other methods of nature, in working with contrary principles of heat and cold, driness, and moisture, light and darkness, &c., by which there is, as it were, a continual circulation. Water is rais'd in vapours into the air by one quality, and precipitated down in drops by another, the rivers run into the sea, and the sea again supplies them. In the circular motion of all the planets, there is a direct motion which makes them endeavour to *recede* from the sun or center, and a magnetic or attractive power that keeps them *from* receding. Generation creates and death destroys; winter reduces what summer produces; the night refreshes what the day has scorcht, and the day cherishes what the night benumb'd. The air impregnates the ground in one place, and is impregnated by it in another. All things almost circulate, and have their vicissitudes. We have multitudes of instances of the washing of the tops of hills, and of the filling or increasing of the plains or lower grounds, of rivers continually carrying along with them great quantities of sand, mud, or other substances from higher to lower places: of the seas washing cliffs away, and wasting the shores: of land floods carrying away with them all things that stand in their way, and covering those lands with mud which they overflow, levelling ridges and filling ditches. Tides and currents in the sea act, in all probability, what floods and rivers do on land; and storms effect that on the sea-coasts that great land floods do on the banks of rivers." *

In this eloquent passage we find the entire idea that animated the glowing address of Generelli, when sixty-one years later he delivered to the Academicians at Cremona his beautiful exposition of the doctrines of Moro, striving strongly to explain all terrestrial phenomena, "without violence, without fictions, without hypothesis, without miracles."†

Hook approached nearer than his successors to the grand generalities of Hutton; for, while yielding free scope to all subterranean influences, he rose far above the gross error of Moro, that the stratified rocks were of volcanic origin, rapidly accumulated on the third day (or perhaps epoch) of creation. Yet wide as were Hook's views, with reluctance we cannot but regard them as vague foreshadowings of truths, like the words of a prophet, dimly comprehending what he spoke; for forced by the physico-theological necessity of accounting for the deluge, and of confining entire and perfect revolutions in the economy of the world within the narrow space of a few thousand years, he is driven to conclusions only less extravagant than the wild visions of Burnet, and built upon foundations equally insecure. An extraordinary earthquake may have changed the centre of terrestrial gravity, and altered the rapidity of the diurnal revolution, so that though the Antediluvians lived more days than we do, their lives may not have been actually longer. In early youth the earth was soft and pliable, and earthquakes were more powerful "in breaking, raising, overturning, and otherwise changing the superficial parts of the earth * * * before the fuels of these subterraneous fires were much spent."

* Posthumous Works (A Discourse of Earthquakes), pp. 312, 313.

† Lyell's "Principles," 7th ed., p. 39.

But now "it doth wax old, almost in the same manner as animals and vegetables do."* Age hath made it hard and stony, for "this effect of petrifaction is a symptom of old age." The days of its youth have gone by, "when it had a much smoother and more succous skin than now it hath, when it more abounded with spirituous substances, when all its powers were more strong and vegete, and when those scars, roughness, and stiffness were not in being." †

I will not stay to analyse the opinions of Ray. In summing up the arguments for and against the effect of earthquakes, the destruction, without renovation, of the whole land of the world by aqueous degradation, the original animated organisation of "formed stones," and the physical cause of the flood, he so cautiously expresses himself, that, even though distinctly leaning to the side of truth, he still leaves a gap for the timid to fall back on the stronghold of popular error.‡ Nor will I now attempt to discuss the writings of Woodward. In the whole circle of Geology (a bold assertion) it would probably be impossible to find a more diligent collector, or a more unphilosophical observer and reasoner. In the Preface to his Essay towards a Natural History of the Earth, he declares that the "terrestrial globe was taken all to pieces and dissolved at the Deluge, and that the present earth consists and was formed out of that promiscuous mass of sand, earth, shells, and the rest, falling down again and subsiding from the water, * * * * and these marine bodies are now formed, lodged in the strata according to the order of their gravity." And again, "the antediluvian corals were like all other solid stony bodies, then in solution in that water, and might concrete again, and form true corals there, as well as in the sea-water," § by which he

* Hook's Posthumous Works, p. 325. † Id. p. 427.

‡ Miscellaneous Discourses concerning the Dissolution and Changes of the World, London, 1692.

§ Letters relating to the Method of Fossils, pp. 81, 82, London, 1728.

meant to express that no fossil corals were formed in the sea in the ordinary course of nature; but rather that they were dissolved by the Deluge, and re-concreted before its close.

The remarkable paper by Michell, published in 1760,* forms the first attempt to systematise a theory of earthquakes. This talented exposition has not (as far as I am aware) been entirely superseded till the publication of the views of Mr. Mallet, in a paper remarkable alike for soundness of reasoning, and elegance and vigour of style.†

It would be foreign to my present purpose to review Michell's theory, and I only notice it because of the comparative clearness of his perception of the frequent relation of strata to the forms of mountain chains. He insists on the varying structure of interstratified rocks, and the comparative uniformity of individual strata for many miles: but strata being frequently shattered, and raised in ridges, of which the tops have been cut off, "it will follow that we ought to meet with the same kind of earths, stones, and minerals, appearing at the surface, in long narrow slips, and lying parallel to the greatest rise of any long ridges of mountains; and so in fact we find them." This admirable description, which is quite distinct from the principles proposed by Lister (1683), involves great part of the *theory* of Geological mapping, and the construction of sections. Of the latter, as illustrations to his paper, he gives three well-drawn hypothetical examples.

The Italian successors of Steno advanced but few new truths of which his theory does not contain the germ. Vallisneri sketched the extent of the Italian strata, the nature of their characteristic organic remains, and the dependence of springs on their *order and dislocation.*

* Phil. Trans., vol. li. p. 566.

† Proc. of the Royal Irish Academy, vol. xxi. part i.

To explain the origin of such strata and their dislocations, Moro, though in an extravagant manner, applied the machinery of earthquakes and volcanos; and Generelli,* outstripping his age, boldly asserted, that in the operations of nature there is an enduring constancy of cause and effect, ensuring the grand result that the wasting degradation of continents is for ever repaired by counteracting forces equally slow in operation.

Thus far in Italy had Geology advanced a hundred years ago. As yet special inquiries respecting the actual relations of formations to each other were unknown. The progress that had been made over Europe resulted, not so much from patient and continuous observation, as from abstract reasonings on the simple facts, that many rocks contained the remains of marine and fresh-water animals, that these rocks are arranged in layers once horizontal, and subsequently dislocated and disturbed. It is singular to observe how acutely the soundest reasoners argued while confining themselves to matters of observation, and how suddenly they wandered from the truth when the narrow theology of the time barred the way to further progress. Then, like Burnet, they felt "we must often tread unbeaten paths, and make a way where we do not find one;" and the minds that, disdaining the aid of imaginary agents, could grasp the problem that the machinery constructed by the Author of Nature is equal to maintain the balance of terrestrial creation, yielded to the now self-evident contradiction that the stupendous changes visible on the face of the world had all taken place in the little space of six thousand years.

It would appear to be an inseparable concomitant of the imperfection of our nature, that, in the whole history of mind, there is never, however slowly, an uninterrupted onward progress; and thus with the mass error is often for a time more powerful than truth. Men, too, will not

* Lyell's "Principles," 7th ed., pp. 37 to 40.

have venerable prejudices disturbed,—they mistake them for conviction, and care not to inquire; or if they *can* examine, and if they *do* attempt to judge, old warpings of the judgment still count as arguments of truth, and conviction is delayed. Yet, as in the history of social civilisation, no great mechanical discovery has ever been permanently lost, so in the history of mind, discovered truths may be obscured, but they are not extinguished, and diffusedly floating in the atmosphere of thought, the minds of men by degrees and unawares drink in their influence. "Thou hearest the sound thereof, but canst not tell whence it cometh and whither it goeth." In the history of Science we often find grand truths unproved, but divulged to the master minds of an age, distinctly expressed and yet faintly understood; tempting the historian of after years to attribute to men larger or more precise perceptions than they in reality possessed. Such are the shadowy grandeurs of the doctrines of the Pythagoreans, and the dim ideas of infinite terrestrial change taught by Aristotle and Strabo. Such were the ideas of Steno on the bounds of ancient seas, and recurring modifications of terrestrial outlines; and of such a character the opinions of Hook, when he hinted at the extinction and new creation of species, and taught the doctrine of the disappearance of continents equal in magnitude to our own. As such too, at a later period, must we regard the remarkable inference of Molyneux, when, on data more than half erroneous, he yet comprehended the truth of the great law that regulates the transmission of species in space; and of such a nature perhaps, even now, are our own gropings respecting the internal structure of the globe and the nature of its heat, the origin and first birth-place of species, and perhaps sometimes their absolute relations with what we believe to be their living analogues.

When such a state of things has for long prevailed, a man at length appears, who grasps the scattered materials strewed around, and unites the whole into a stately and proportionable structure. Such a man was Dr. James Hutton.

In the year 1788, he produced the first sketch of his celebrated " Theory of the Earth," on the occasion of the institution of the Royal Society of Edinburgh. His Geological studies began while prosecuting the practice of agriculture in Norfolk, and after more than thirty years of careful investigation, he gave the results to the world, first in the " Transactions of the Royal Society of Edinburgh," and afterwards in 1795, in a separate more extended work in two volumes. A third unpublished volume probably still remains in manuscript. This work is not more remarkable for the boldness of the views it enunciates, than for the singularly cumbrous obscurity and diffuseness of its style, so that it is no light task to gather from its pages the opinions of the gifted author. Sensible of this defect, his friend and pupil, Professor Playfair, drew up his celebrated "Illustrations of the Huttonian Theory," with the view of explaining Dr. Hutton's " Theory of the Earth " in a manner more popular and perspicuous than is done in his own writings."*

Hutton divides the " Mineral Kingdom " into two parts, stratified and unstratified. Stratified rocks of all ages he shows to be derived from pre-existing organic or inorganic bodies, "*from the ruins of former continents*, from the dissolution of rocks, or the destruction of animal or vegetable bodies." † This deduction (now an axiom in Geology), at once destroyed the long-received cosmical doctrine of primitive strata, and well entitled Dr. Hutton to state that, " in tracing back the natural operations which have succeeded each other, and mark to us the course of time past, we come to a period in which we cannot see any further; not the *beginning*, but ' the limit of our retrospective view of those operations which have come to pass in time, and

* Playfair's Works, Edinburgh, 1822, vol. i. p. 17. † Id. p. 32.

have been conducted by supreme intelligence.'"* When, therefore, Hutton spoke of primitive strata, "he only meant to describe them as more ancient than any other strata now existing, but not as more ancient than any that ever had existed." †

The principle which guided this style of reasoning is clearly set forth when, speaking of Pallas' account of the structure of the Ural chain, he insists that there is no "clear and distinctive mark of primitive, secondary, and tertiary mountains, further than one stratum may be considered as either prior or posterior to another stratum, according to the order of superposition in which they are found." ‡ The force of such arguments became apparent in his own day, in the discovery by himself and Sir James Hall of fossils in Scotland, Cumberland, and Wales, in strata till then styled primitive, because of the supposed absence of the relics of life.

In all respecting the derivative nature of stratified rocks, Hutton's reasonings are truly admirable. He proves by arguments now familiar, that the retreat of the sea cannot account for the position of fossiliferous strata so high above its level, and demonstrates the original horizontality of beds and their subsequent disturbance, by arguments resembling many of those employed by Steno one hundred years before.§ Early in the 18th century, Mr. Strachey pointed out the unconformity of the overlying rocks with the coal measures of Somersetshire;‖ and at a later date De Luc described analogous appearances on the Hartz. But Hutton was the first to understand, that this not only implied disturbance previous to the deposition of the overlying rocks, but also that it bespeaks in certain cases denudation by the very sea in which these rocks were deposited.¶

* Theory of the Earth, Edinburgh, 1795, vol. i. p. 223.

† Playfair's Works, vol. i. p. 30. ‡ Theory of the Earth, vol. i. p. 348.

§ Playfair's Works, vol. i. pp. 58 to 63. Steno's "Prodromus," London, 1671, pp. 23, 37, and 42 to 45.

‖ Phil. Trans., 1719, 1725, vols. xxx, xxxi.

¶ Playfair's Works, vol. i. p. 66. Theory of the Earth, vol. i. p. 449.

The agency that Hutton invoked to consolidate strata formed by aqueous action was that of subterranean heat. This theory he pushed to an unwarrantable extreme; for it is now more than questionable if subterranean heat, in any way but what may be termed accidental cases, has any influence on the first ordinary consolidation of strata. His attempted refutation of arguments in favour of other means of consolidation, is almost altogether erroneous;* and, indeed, in the instance of the consolidation of limestone (which he was wont to attribute to the action of heat under pressure so great that it hindered the escape of its carbonic acid), it had been shown in 1750, by Vitaliano Donati, that, in the bed of the Adriatic, limestone in process of formation was already consolidated at less than a foot beneath the surface.

To expansion, consequent on subterranean heat, Hutton more correctly attributed the phenomena of disruption and upheaval. In the powers that can "demolish cities in an instant, and split asunder rocks and solid mountains,"† he saw the instrument that raises continents from the depths of the ocean. "If," said he, "these strata are cemented by the heat of fusion, and erected with an expansive power acting below, we may expect to find every species of fracture, dislocation, and contortion in those bodies, and every degree of departure from a horizontal towards a vertical position," and "matter" (of igneous origin) "foreign to the strata may have been thus introduced into the fractures and separations of those indurated masses." The origin of trap dykes is thus correctly referred to these operations.‡ We have seen that the idea of the

* Playfair's Works, vol. i. pp. 35 to 47.

† Theory of the Earth, vol. i. p. 140.

‡ Raspe, in his "Account of some German Volcanos," London, 1776, p. 35, instances an Amygdaloidal-trap Dyke intersecting Limestone "on the Krazenberg." Describing certain calcareous rocks in the valley of Cassell, he says, "These beds have probably been shaken and split by earthquakes, which have raised and brought them to their present inclinations to the

elevation of continents, through the agency of earthquakes, was as old as the days of Aristotle and Strabo; and in forms more or less expanded had been inculcated by many succeeding writers. Hutton, far outstripping all his purely Geological predecessors, scrupled not to apply this principle (in connexion with that of denudation), as the essential and ordinary means in the economy of the world, by which the balance of land and sea has been preserved in all traceable time,—a principle undeviating in its average intensity;—"for," says he, "these operations of the globe *remain at present with undiminished activity, or in the fulness of their power*." *

This passage of itself seems to go far to establish Hutton's claim to the authorship of the idea, based on purely geological grounds, that, as far as it is possible, "In the dark backwards and abysm of time," to trace the course of events, there were no intermittent crises of action, no sudden and overwhelming convulsions of general application, but the progress of change was as gradual as that which now obtains, and as calm and certain in its effects. The world is a "machine," endued "with those moving powers, by which its operations, diversified almost *ad infinitum*, are performed."† "Time is to nature endless and as nothing," and the progress of things upon the globe cannot be limited *by time*, which must proceed in a continual succession." ‡ The "expansive power" which elevates the land "is to be reasonably concluded *as accompanying* those operations

horizon," p. 6. He seems to have had higher notions of the antiquity of the earth than he ventured to inculcate. Referring to the same strata, "I am not inclined," said he, "to lose myself in a nearer examination of their antiquity, which my readers are desired to fix as they please, according to the wants or the advantages of that system of chronology which they have a mind to or are convinced of," p. 16. For a full account of his opinions, which were beyond his time, see his "Specimen Historiæ Naturalis Globi Terraquei," 1763; and the work on Volcanos, above quoted.

* Theory of the Earth, vol. i. p. 141.

† Id. p. 12.

‡ Id. p. 15.

which we have found natural to the globe."* "*We suppose a due proportion of land and water to be always preserved* upon the surface of the globe, for the purpose of a habitable world such as this which we possess. *We thus also allow time and opportunity for the translation of animals and plants to occupy the earth.*"† Furthermore he answers in the affirmative the questions whether "these powerful operations of subterraneous heat," have "always been," whether "they are proper to every part of the globe, and *continual in the system of this earth.*" "A volcano is not made on purpose to frighten superstitious people into fits of piety and devotion, nor to overwhelm devoted cities with destruction; a volcano should be considered as a spiracle to the subterranean furnace, in order to prevent the unnecessary elevation of land, and fatal effects of earthquakes; and one may rest assured that they in general wisely answer the end of their intention, without being in themselves an end, for which nature had exerted such amazing power, and excellent contrivance."‡

Reasoning from the present visible evidences of the action of subterranean heat, Hutton shows in what modern lavas resemble ancient igneous rocks, and in certain respects how far they differ. He points out the occasional induration of rocks in contact with them, the charring of coal, and other analogous phenomena, and clearly distinguishes between subaërial and subaqueous lavas.§ But Hutton's most remarkable achievement in working out his theory of igneous rocks was the determination of the true nature of granite. In the first draft of the "Theory of the Earth," published in the first volume of the "Transactions of the Royal Society of Edinburgh," from internal evidence, he saw reason to consider granite as a body "*consolidated by*

* Theory of the Earth, vol. i. p. 122.

† This is evidently the same idea as that entertained by Molyneux (already quoted), less distinctly and fully expressed.

‡ Theory of the Earth, vol. i. p. 146. § Id. pp. 148, 149.

heat, and which had at least *in some parts* been in the state of perfect fusion."* At the same time he had not perfectly decided "whether it was not rather a body transfused from the subterraneous regions, and made to break and invade the strata, in the manner of our whinstone or trapp, and of porphyries, into which the whinstone often graduates." † Having chanced to mention the subject to the Duke of Athol, Dr. Hutton and Mr. Clerk of Eldin were invited by his Grace to his hunting-seat at Blair during the shooting season, "where," says Hutton, (strange contrast to the treatment of modern savans in Glen Tilt), "we were entertained with the utmost elegance and hospitality." Here in the bend of the Tilt he found "the most perfect evidence that the granite had been made to break the Alpine strata, and invade the country in a fluid state." ‡ "No less," says Playfair, "than six large veins of red granite in the course of a mile were seen traversing the black micaceous schistus," a sight that so "filled him with delight," that "the guides who accompanied him were convinced that it must be nothing less than the discovery of a vein of silver or gold, that could call forth such strong marks of joy and exultation."§ From this discovery Hutton drew the important conclusion that granite hitherto considered "as being the original or primitive part of the earth, is now found to be posterior to the Alpine schistus." ||

In the work by Raspe already noticed, much sagacity is exhibited in the discrimination of the characteristics of ancient igneous rocks. He, like Hutton, asserts "that eruptions of smelted substances may be produced even at and under the very bottom and level of the sea." ¶ He proves elsewhere the igneous origin of "basaltes,"** and describes

* Trans. R. S. Edin. vol. iii. p. 77. † Id. p. 78. ‡ Id. p. 79.

§ Playfair's Works (Life of Hutton), vol. iv. p. 75.

|| Trans. R. S. Edin. vol. iii. p. 81.

¶ Raspe on some German Volcanos, pp. 46, 50.

** Phil. Trans., vol. lxi.

in the Habichwald the occurrence of ancient volcanic "sand, ashes, brimstone, slags and lavas." Like Hutton he also clearly attributes the dislocation of strata to the operation of earthquakes, and speculates on the details of the manner of accumulation of the volcanic rocks of the Habichwald, bursting through and overwhelming marine strata, in the midst of which the volcanic hills rose as islands. But, unlike Hutton, his views are bounded by the district he so well illustrates; nor does he attempt from this local description to draw any conclusions bearing on the general economy of the earth. Hutton therefore far outstripped him and all his predecessors; when uniting the theory of volcanos and subterranean heat with that of expansion, he declared them to be "continual in the system of the earth,"* and joined to the incessant operation of aqueous degradation, forming "a system of beautiful economy in the works of nature" to the end, that "this earth, like the body of an animal, *is wasted at the same time that it is repaired.*" †

The theory of Hutton that, while strata were being formed from the disintegrated materials of ancient continents, an underground work of consolidation was going on through the agency of fire, seems of itself irresistibly to lead to the doctrine of what is now styled metamorphism. He was fully convinced of frequent oscillation of level. "Parts of the land may often sink in a body below the level of the sea, and parts again may be restored, without waiting for the general circulation of land and water, which proceeds with all the certainty of nature, but which advances with an imperceptible progression." ‡ Again, reasoning on the depression, beneath the sea, of land that had been long above the waters, "that land," says he, "which had for millions of ages past sustained plants and animals, would again be placed at the bottom of the sea,

* Theory of the Earth, vol. i. p. 144.

† Id. vol. ii. p. 562.

‡ Id. vol. i. p. 196.

and strata of every different species might be deposited again upon that mass;" and on being restored to the upper air, "with the new superincumbent strata," the inferior mass must have undergone a double course of mineral changes and displacement; *consequently the effect of subterranean heat or fusion must be more apparent in the mass, and the marks of its original formation more and more obliterated*."* "If," he continues, "on examining our land, we shall find a mass of matter which had been evidently formed originally in the ordinary manner of stratification, but which is now extremely distorted in its structure, and displaced in its position,—which is also extremely consolidated in its mass, and variously changed in its composition,—which, therefore, *has the marks of its original or marine composition extremely obliterated*, and many subsequent veins of melted mineral matter interjected; we should then have reason to suppose that here were masses of matter which, *though not different in their origin from those that are gradually deposited at the bottom of the ocean, have been more acted upon by heat and the expanding power; that is to say, have been changed in a greater degree by the operations of the mineral region.* If this conclusion shall be thought reasonable, then here is an explanation of all the peculiar appearances of the Alpine schistus masses of our land, *those parts which have been erroneously considered as primitive in the constitution of the earth*." Here, then, are the rudiments of the theory of metamorphic action clearly expressed. It remained for subsequent inquirers, with more extended observation and knowledge, fully to work it out in all its consequences.

Hutton's exposition of the principles of disintegration, of the waste of land by the action of running water, and the destructive effects of the sea on coasts, is scarcely less admirable. Still he was not warranted in attributing the

* Theory of the Earth, vol. i. pp. 374. 375.

formation of all valleys to the erosive influence of streams and rivers; for it cannot be doubted that many of the principal features of our continents are partly due to the effects of ancient marine denudations. No sooner, says his theory, does the land raise its head above the waters, than air, water, and the vicissitudes of heat and cold, unite to disintegrate the solid masses. Descending by the aid of gravity, in brooks, torrents, and rivers to the sea, the loosened materials by the power of attrition, aid in promoting a system of universal decay. The "powerful artillery with which the ocean assails the bulwarks of the land," forms the irregular outline of coasts, dependent on the relative strength of the rocks opposed to the force of the waves. This, with the progressing insulation of bluffs and promontories in the descriptions of Playfair, rise vividly before us.

Summing up an argument respecting the proportional waste and reproduction of land, he draws the following most pregnant inference:—"We are certain that all the coasts of the present continents are wasted by the sea, and constantly wearing away upon the whole; but this operation is so extremely slow, that we cannot form a measure of the quantity in order to form an estimate. Therefore the present continents of the earth, which we consider as in a state of perfection, would, in the natural operations of the globe, require a time indefinite for their destruction.

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

It is impossible, in the fragment of an hour, fully to

* Theory of the Earth, vol. i. p. 195.

analyse the theory of the earth as propounded by Hutton. The whole work is pregnant with powerful and original thought. What though he erred in his theory of mineral veins, and in the manner of the consolidation of strata, in other respects, there is scarcely a large problem in the whole circle of modern Physical Geology, of which the germ or more enlarged development may not be discovered in his writings. Disregarding all minor points, I claim for Hutton the first distinct enunciation of the following great principles in Geology:—

1st,—That in the whole traceable history of the world the course of events has never been disturbed by universal paroxysmal catastrophes, but that the course of change has ever been similar to that which guides our experience of the ordinary economy of nature.

2nd,—That we know of no set of igneous rocks (whether granite or others), that can be proved to be of generally older origin than the earliest stratified deposits, but that *they may often be proved* to be of posterior origin.

3rd,—That the stratified masses which constitute most of the visible surface of the earth were formed from the waste of pre-existing rocks, mingled with organic exuviæ.

4th,—That such land-derived strata afford a measure of the amount of pre-existing continents destroyed, to afford materials for their formation. But having no measure of time comparable to these epochs, it is impossible to estimate their duration.

5th,—That there may be a progressive formation of new rocks in the bottom of the sea, contemporaneous with great and repeated alterations of the lower strata, that approach the regions of internal heat.

6th,—That all strata being derivative, and a machinery existing and having always existed, (as far as observation can discover,) capable alike of erecting and destroying rocks, in the whole course of *visible* nature, " we find no vestige of a beginning—no trace of an end."

As yet the connexion of organic life with the succession of strata was not understood. Primary and secondary rocks were, however, words of vague but familiar import. In the writings of Hutton there is established a clearer principle of stratigraphical succession ; for, in showing *how* strata were formed, he demonstrated a law of succession altogether independent of organic life, and to which the subsequent wonderful discovery of Smith afforded the perfect key. Enough had been done by one man to establish a name lasting as the science he adorned. When we speak of Hutton, who remembers his little errors of detail? like the spots in the sun they are lost in the splendour of his generalisations, and we cannot cease to wonder and admire how, from the old chaos of Geological speculation, one mind elicited so much of admirable order and completeness. "As it stands at present," says Playfair, "though *true* it must still be imperfect * * * *. Ages may be required to fill up the bold outline which Dr. Hutton has traced with so masterly a hand ; to detach the parts more completely from the general mass ; to adjust the size and position of the subordinate members; and to give to the whole piece the exact proportion and true colouring of Nature." * This in fact, since his death, has constituted the progress of Physical Geology,—a filling up of his grand outline,—a perfecting of the machine of which he left far more than the sketch.

He loved to generalise and unite his doctrines with the visible operations of the living world ; seeing in everything an "*intention* of that mind which formed the matter of the globe." † "Thus," says he, "everything is in a state of change ; the rock and solid strata 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

* Playfair's Works, vol. i. p. 149.

† Theory of the Earth, vol. ii. p. 551.

of the sea, an agitation which is essential to the purpose of a living world. Without these operations, which wear and waste the coast, there would not be wind and rain, and without these operations, which waste and wear 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 slow and sure destruction of the present land, are operations necessary in the system of this world." *

On the 26th of March, 1795, Dr. Hutton died, at the age of sixty-nine. He had inherited a small property from his father; and was in early life apprenticed in Edinburgh to a Writer to the Signet. Forsaking this for the study of medicine, in 1749 he took the degree of Doctor of Medicine at Leyden. He afterwards applied himself to the study of agriculture and the cultivation of his paternal acres in Berwickshire. No sooner, however, had he brought his farm to a state of high cultivation, than the pursuit lost its charm. He removed to Edinburgh, where, though partner in a successful chemical establishment, he devoted his time exclusively to scientific pursuits. Here he formed not the least brilliant light of that constellation of literary and scientific men who then adorned the Scottish metropolis; and amid such men as Dr. Black, Adam Ferguson, Sir George Clerk, Mr. Clerk of Elden, Sir James Hall, Adam Smith, Hume, Robertson, and Playfair, Hutton occupied a prominent position. "It was always true of Dr. Hutton," says Playfair, "that to an ordinary man he appeared to be an ordinary man." This unobtrusive simplicity formed, indeed, one of the great charms of his character; yet among men of his own stamp, his nervous and enthusiastic temperament shone strongly forth. In conversation he was earnest and animated, and often in the unrestrained

* Theory of the Earth, vol. ii. pp. 236, 237.

society of friends at the Oyster Club, he indulged in a vein of rich and racy humour. In argument, characterised alike by boldness and caution, the love of truth is in him for ever conspicuous. Contrasting him with his friend Dr. Black, Playfair remarks, "One would say Dr. Black dreaded nothing so much as error, and that Dr. Hutton dreaded nothing so much as ignorance; that the one was always afraid of going beyond the truth, and the other of not reaching it,"—a characteristic remark, strongly indicative of the vigorous spirit of him, who, with a rare grasp of mind, collected and sifted the isolated facts that then constituted our science, and when many were still found wanting, by an admirable union of correct observation and profundity of thought, filled up the wide blanks, and united the scattered fragments into a stately structure, to which later architects, labouring at the same pile, have scarcely added more than a few extraneous ornaments.

The labours of Hutton constituted one great epoch in Geology; the investigations of Smith formed another. On the latter I cannot now enter, but must reserve for a future opportunity the story of the long series of struggles ending in that great original discovery which opened to our view the wondrous history of the succession of animated beings IN TIME.

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