CHAPTER XXVI.

On the stratified rocks usually called 'primary'—Proofs from the disposition of their strata that they were originally deposited from water—Alternation of beds varying in composition and colour—Passage of gneiss into granite—Alteration of sedimentary strata by trappean and granitic dikes—Inference as to the origin of the strata called 'primary'—Conversion of argillaceous into hornblende schist—The term 'Hypogene' proposed as a substitute for primary—'Metamorphic' for 'stratified primary' rocks—No regular order of succession of hypogene formations—Passage from the metamorphic to the sedimentary strata—Cause of the high relative antiquity of the visible hypogene formations—That antiquity consistent with the hypothesis that they have been produced at each successive period in equal quantities—Great volume of hypogene rocks supposed to have been formed since the Eocene period—Concluding remarks.

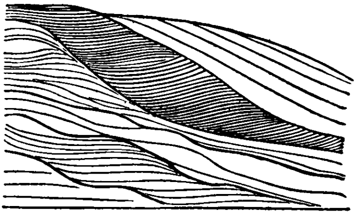
ON THE STRATIFIED ROCKS CALLED 'PRIMARY.'

We stated in the last chapter, that the rocks usually termed 'primary' are divisible into two natural classes, the stratified and the unstratified. The propriety of the term stratified, as applied to the first-mentioned class, will not be questioned when the rocks so designated are carefully compared with strata known to result from aqueous deposition.

Mode of stratification.—If we examine gneiss, which consists of the same materials as granite, or mica-schist which is a binary compound of quartz and mica, or clay-slate, or any other member of the so-called primary division, we find that it is made up of a succession of beds, the planes of which are, to a certain extent, parallel to each other, but which frequently deviate from parallelism in a manner precisely analogous to that exhibited by sedimentary formations of all ages. The resemblance is often carried farther, for in the crystalline series we find beds composed of a great number of layers placed diagonally, as we have shown to be the case in the

Crag and other formations*. This disposition of the layers

No. 89.



Lamination of clay-slate, Montagne de Seguinat, near Gavarnie, in the Pyrenees.

is illustrated in the accompanying diagram, in which I have represented carefully the stratification of a coarse argillaceous schist, which I examined in the Pyrenees, part of which approaches in character to a green and blue roofing slate, while part is extremely quartzose, the whole mass passing downwards into micaceous schist. The vertical section here exhibited is about three feet in height, and the layers are sometimes so thin that fifty may be counted in the thickness of an inch. Some of them consist of pure quartz.

The stratification now alluded to must not be confounded with that fissile texture sometimes observed in the older rocks, by virtue of which they divide in a direction different both from the general planes of stratification and from the planes of those transverse layers of which a single stratum may be made up.

Another striking point of analogy between the stratification of the crystalline formations and that of the secondary and tertiary periods is the alternation in each of beds varying greatly in composition, colour, and thickness. We observe, for instance, gneiss alternating with layers of black hornblende-schist, or with granular quartz or limestone, and the interchange of these different strata may be repeated for an indefinite number of times. In like manner, mica-schist alternates with chlorite-schist, and with granular limestone in thin layers.

As we observe in the secondary and tertiary formations

* See above, p. 173.

strata of pure siliceous sand alternating with micaceous sand and with layers of clay, so in the 'primary' we have beds of pure quartz rock alternating with mica-schist and clay-slate. As in the secondary and tertiary series we meet with limestone alternating again and again with micaceous or argillaceous sand, so we find in the 'primary' gneiss and mica-schist alternating with pure and impure granular limestones.

Passage of gneiss into granite—If, then, reasoning from the principle that like effects have like causes, we attribute the stratification of gneiss, mica-schist, and other associated rocks, to sedimentary deposition from a fluid, we encounter this difficulty, that there is often a transition from gneiss, one of the stratified series, into granite, which, as we have shown, is of igneous origin. Gneiss is composed of the same ingredients as granite, and its texture is equally crystalline. It sometimes occurs in thick beds, and in these the rock is often quite undistinguishable, in hand specimens, from granite; yet the lines of stratification are still evident. These lines imply deposition from water, while the passage into granite would lead us to infer an igneous origin. In what manner can we reconcile these apparently conflicting views? The Huttonian hypothesis offers, we think, the only satisfactory solution of this problem. According to that theory, the materials of gneiss were originally deposited from water in the usual form of aqueous strata, but these strata were subsequently altered by their proximity to granite, and to other plutonic masses in a state of fusion, until they assumed a granitiform texture. The reader will be prepared, by what we have said of granite, to conclude, that when voluminous masses of melted rock have been for ages in an incandescent state, in contact with sedimentary deposits, they must produce some alteration in their texture, and this alteration may admit of every intermediate gradation between that resulting from perfect fusion, and the slightest modification which heat can produce.

The geologist has been conducted, step by step, to this theory by direct experiments on the fusion of rocks in the laboratory, and by observation of the changes in the composition and texture of stratified masses, as they approach or come in contact with igneous veins and dikes. In studying the latter class of phenomena, we have the advantage of examining the condition of the rock at some distance from the dike where it has escaped the influence of heat, and its state where it has been near to, or in contact with, the fused mass. The changes thus exhibited may be regarded as the results of a series of experiments, made on a great scale by nature under every variety of condition, both as relates to the mineral ingredients of the rocks, the intensity of heat or pressure, the celerity or slowness of the cooling process, and other circumstances.

Strata altered by volcanic dikes—Plas Newydd.—We shall select a few examples of these alterations in illustration of our present argument. One of the most interesting is the modification of strata in the proximity of a volcanic dike near Plas Newydd, in Anglesea, described by Professor Henslow. The dike is 134 feet wide, and consists of basalt (dolerite of some authors), a compound of felspar and augite. Strata of shale and argillaceous limestone, through which it cuts perpendicularly, are altered to a distance of thirty, or even in some places to thirty-five feet, from the edge of the dike. The shale, as it approaches the basalt, becomes gradually more compact, and is most indurated where nearest the junction. Here it loses part of its schistose structure, but the separation into parallel layers is still discernible. In several places the shale is converted into hard porcellanous jasper. In the most hardened part of the mass the fossil shells, principally *Productæ*, are nearly obliterated, yet even here their impressions may frequently be traced. The argillaceous limestone undergoes analogous mutations, losing its earthy texture as it approaches the dike, and becoming granular and crystalline. But the most extraordinary phenomenon is the appearance in the shale of numerous crystals of analcime and garnet, which are distinctly confined to those portions of the rock affected by the dike*. Garnets have been observed, under very analogous circumstances, in High Teesdale, by Professor Sedgwick, where they also occur in shale and limestone, altered by a basaltic dike. This discovery is most interesting, because garnets often abound in mica-schist, and we see in the instances above cited, that they did not previously exist in the shale and limestone, and that they have evidently been produced by heat in rocks in which the marks of stratification have not been effaced.

Stirling Castle.—To select another example : we find in the rock of Stirling Castle, a calcareous sandstone fractured and forcibly displaced by a mass of green-stone, which has evidently invaded the strata in a melted state. The sandstone has been indurated, and has assumed a texture approaching to hornstone near the junction. So also in Arthur's Seat and Salisbury Craig, near Edinburgh, a sandstone is seen to come in contact with greenstone, and to be converted into a jaspideous rock †.

Antrim.—In the north of Ireland, in several parts of the county of Antrim, chalk, with flints, is traversed by basaltic dikes. The chalk is converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dike, being greatest at that point, and thence gradually decreasing till it becomes evanescent. 'The extreme effect,' says Dr. Berger, 'presents a dark brown crystalline limestone, the crystals running in flakes as large as those of coarse *primitive* limestone; the next state is saccharine, then fine-grained and arenaceous; a compact variety having a porcellanous aspect, and a bluish-grey colour succeeds; this, towards the outer edge, becomes yellowish-white, and insensibly graduates into the unaltered chalk. The flints in the altered chalk usually assume a grey yellowish colour ‡.' All

* Trans. of Cambridge Phil. Soc., vol. i. p. 406.

† Illust. of Hutt. Theory, § 253 and 261. Dr. Macculloch, Geol. Trans., 1st series, vol. ii. p. 305.

‡ Dr. Berger, Geol. Trans., 1st series, vol. iii. p. 172.

traces of organic remains are effaced in that part of the limestone which is most crystalline.

As the carbonic acid has not been expelled, in this instance, from that part of the rock which must be supposed to have been melted, the change must have taken place under considerable pressure; for we know, by the experiments of Sir James Hall, that it would require the weight of about 1700 feet of sea-water, which would be equivalent to the pressure of a column of liquid lava 600 feet high, to prevent this acid from being given off.

Another of the dikes of the north-east of Ireland has converted a mass of red sandstone into hornstone *. By another, the slate-clay of the coal-measures has been indurated, and has assumed the character of flinty slate †; and in another place the slate-clay of the lias has been changed into flinty slate, which still retains numerous impressions of ammonites ‡. One of the greenstone dikes of the same country passes through a bed of coal, which it reduces to a cinder for the space of nine feet on each side §.

The secondary sandstones in Sky are converted into solid quartz in several places where they come in contact with veins or masses of trap; and a bed of quartz, says Dr. Macculloch, has been found near a mass of trap, among the coal-strata of Fife, which was in all probability a stratum of ordinary sandstone subsequently indurated by the action of heat ||.

Alterations of strata in contact with granite.—Having selected these from innumerable examples of mutations caused by volcanic dikes, we may next consider the changes produced by the contiguity of plutonic rocks. To some of these we have already adverted, when speaking of granite veins, and endeavouring to establish the igneous origin of granite. We mentioned that the main body of the Cornish granite sends forth veins through the killas of that country ¶, a coarse argillaceous schist, which is converted into hornblende-schist

* Rev. W. Conybeare, Geol. Trans., 1st series, vol. iii. p. 201.

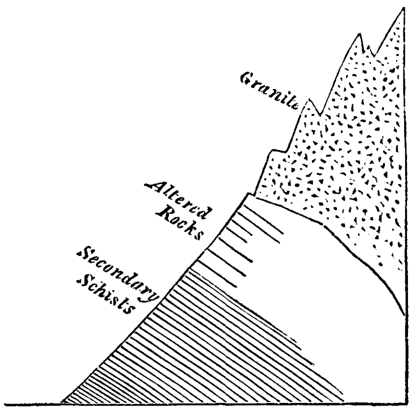
† Ibid., p. 205. ‡ Ibid. p. 213, and Playfair, Illust. of Hutt. Theory, § 253.

§ Ibid., p. 206. || Syst. of Geol., vol. i. p. 206. ¶ See diagram, No. 87.

near the contact with the veins. These appearances are well seen at the junction of the granite and killas in St. Michael's Mount, a small island nearly 300 feet high, situated in the bay, at the distance of about three miles from Penzance.

In the department of the Hautes Alpes, in France, near Vizille, M. Elie de Beaumont traced a black argillaceous limestone, charged with belemnites to within a few yards of a mass of granite. Here the limestone begins to put on a

No. 90.



Junction of granite with Jurassic or oolite strata in the Alps, near Champoleon.

granular texture, but is extremely fine-grained. When nearer the junction it becomes grey and has a saccharoid structure. In another locality, near Champoleon, a granite composed of quartz, black mica, and rose-coloured felspar, is observed partly to overlie the secondary rocks, producing an alteration which extends for about thirty feet downwards, diminishing in the inferior beds which lie farthest from the granite. (See woodcut No. 90.) In the altered mass the argillaceous beds are hardened, the limestone is saccharoid, the grits quartzose, and in the midst of them is a thin layer of an imperfect granite. It is also an important circumstance, that near the point of contact both the granite and the secondary rocks become metalliferous, and contain nests and small veins of blende, galena, iron, and copper pyrites. The stratified rocks become harder and more crystalline, but the granite, on the contrary, softer and less perfectly crystallized near the junction *.

It will appear from sections described by M. Hugi, that some of the secondary beds of limestone and slate, which are in a similar manner overlaid by granite, have been altered into gneiss and mica-schist †. Some of these altered sedimentary formations are supposed, by M. Elie de Beaumont, to be of the age of the lias of England, and others to be even as modern as the jurassic or oolite formations.

We can scarcely doubt, in these cases, that the heat communicated by the granitic mass reduced the contiguous strata to semi-fusion, and that on cooling slowly the rock assumed a crystalline texture. The experiments of Gregory Watt prove, distinctly, that a rock need not be perfectly melted in order that a re-arrangement of its component particles should take place, and that a more crystalline texture should ensue. We may easily suppose, therefore, that all traces of shells and other organic remains may be destroyed, and that new chemical combinations may arise, without the mass being so fused as that the lines of stratification should be wholly obliterated.

In allusion to the passage from granite to gneiss before described, Dr. Macculloch remarks, that 'in numerous parts of Scotland, where the leading masses of gneiss are schistose, evenly stratified, and scarcely ever traversed by granite veins, they become contorted and irregular as they approach the granite; assuming also the granitic character, and becoming intersected by veins, numerous in proportion to the vicinity of the mass. The conclusion,' he adds, 'is obvious; the fluid granite has invaded the aqueous stratum as far as its influence could reach, and thus far has filled it with veins, disturbed its regularity and generated in it a new mineral character, often absolutely confounded with its own. And if the more remote beds, and those alternating with other rocks, are not thus

* Elie de Beaumont, Sur les Montagnes de l'Oisans, &c., Mem. de la Soc. d'Hist. Nat. de Paris, tome v.

† Natur. Historische Alpenreise, Soleure, 1830.

affected, it is not only that it has acted less on those, but that, if it had equally affected them, they never could have existed, or would have been all granitic and venous gneiss*.

According to these views, gneiss and mica-schist may be nothing more than micaceous and argillaceous sandstones altered by heat, and certainly, in their mode of stratification and lamination, they correspond most exactly. Granular quartz may have been derived from siliceous sandstone, compact quartz from the same. Clay-slate may be altered shale, and shale appears to be clay which has been subjected to great pressure. Granular marble has probably originated in the form of ordinary limestone, having in many instances been replete with shells and corals now obliterated, while calcareous sands and marls have been changed into impure crystalline limestones.

Associated with the rocks termed primary we meet with anthracite, just as we find beds of coal in sedimentary formations, and we know that, in the vicinity of some trap dikes, coal is converted into anthracite. 'Hornblende schist,' says Dr. Macculloch, 'may at first have been mere clay, for clay or shale is found altered by trap into Lydian stone, a substance differing from hornblende-schist almost solely in compactness and uniformity of texture†.' 'In Shetland,' remarks the same author, 'argillaceous schist (or clay-slate), when in contact with granite, is sometimes converted into hornblende-schist, the schist becoming first siliceous, and ultimately, at the contact, hornblende-schist ‡.'

This theory, if confirmed by observation and experiment, may enable us to account for the high position in the series usually held by clay slate relatively to hornblende-schist, as also to gneiss and mica-schist, which so commonly alternate with hornblende-schist. For we must suppose the heat which alters the strata to proceed, in almost all cases, from below upwards, and to act with greatest intensity on the inferior strata. If, therefore, several sets of argillaceous strata or shales be superimposed upon each other in a vertical series of beds in the same

* Syst. of Geol., vol. ii. p. 145. † Ibid., vol. i. p. 210. ‡ Ibid., p. 211

district, the lowest of these will be converted into hornblende-schist, while the uppermost may continue in the condition of clay-slate.

The term 'Hypogene' proposed for Primary.—If our readers have followed us in the train of reasoning explained in this and the preceding chapter, they must already be convinced that the popular nomenclature of Geology, in reference to the so called 'primary' rocks, is not only imperfect, but in a great degree founded on a false theory; inasmuch as some granites and granitic schists are of origin posterior to many secondary rocks. In other words, some *primary* formations can already be shown to be newer than many *secondary* groups—a manifest contradiction in terms.

Yet granite and gneiss, and the families of stratified and unstratified rocks connected with each, belong to one great natural division of mineral masses, having certain characters in common, and it is therefore convenient that the class to which they belong should receive some common name—a name which must not be of chronological import, and must express, on the one hand, some peculiarity equally attributable to granite and gneiss (to the plutonic as well as the *altered* rocks), and which, on the other, must have reference to characters in which those rocks differ both from the volcanic and from the *unaltered* sedimentary strata. We propose the term 'hypogene' for this purpose, derived from ὑπο, *subter*, and γινομαι, *nascor*, a word implying the theory that granite and gneiss are both *nether-formed* rocks, or rocks which have not assumed their present form and structure at the surface. It is true that gneiss and all stratified rocks must have been deposited originally at the surface, or on that part of the surface of the globe which is covered by water; but according to the views explained in this and the foregoing chapter, they could never have acquired their crystalline texture, unless acted upon by heat under pressure in those regions, and under those circumstances where the plutonic rocks are generated.

The term 'Metamorphic' proposed for stratified primary.—

We divide the hypogene rocks, then, into the unstratified, or plutonic, and the *altered* stratified. For these last the term 'metamorphic' (from μετα, *trans*, and μορφη, *form*) may be used. The last-mentioned name need not, however, be often resorted to, because we may speak of hypogene *strata*, hypogene *limestone*, hypogene *schist*, and this appellation will suffice to distinguish the formations so designated from the plutonic rocks. By referring to the table (No. I.) at the close of this chapter, the reader will see the chronological relation which we conceive the two classes of hypogene rocks to bear to the strata of different ages.

No order of succession in hypogene formations.—When we regard the tertiary and secondary formations simply as mineral masses uncharacterized by organic remains, we perceive an indefinite series of beds of limestone, clay, marl, siliceous sand, sandstone, coal, and other materials, alternating again and again without any fixed or determinate order of position. The same may be said of the hypogene formations, for in these a similar want of arrangement is manifest, if we compare those occurring in different countries. Gneiss, mica-schist, hornblende-schist, quartz rock, hypogene limestone, and the rest, have no invariable order of superposition, although, for reasons above explained, clay-slate must usually hold a superior position relatively to hornblende schist.

We do not deny, that in a particular mountain-chain, a chronological succession of hypogene formations may be recognized, for the same reason that in a country of limited extent there is an order of position in the secondary and tertiary rocks, limestone predominating in one part of the series, clay in another, siliceous sand in a third, and so of other compounds. It is probable that a similar prevalence of a regular order of arrangement in the hypogene series throughout certain districts, led the earlier geologists into a belief, that they should be able to fix a definite order of succession for the various members of this great class throughout the world, That expectation has not been realized; yet was it more reasonable than the doctrine of the universality of certain rocks which were admitted to be of sedimentary origin; for there is certainly a remarkable identity in the mineral character of the hypogene formations, both stratified and unstratified, in all countries; although the notion of a uniform order of succession in the different groups must be abandoned.

The student may, perhaps, object to the views above given of the relation of the sedimentary and metamorphic rocks, on the ground that there is frequently, indeed usually, an abrupt passage from one to the other. This phenomenon, however, admits of the same explanation as the fact, that the beds of lakes and seas are now frequently composed of hypogene rocks. In these localities the hypogene formations have been brought up to the surface and laid bare by denudation. New sedimentary strata are thrown down upon them, and in this manner the two classes of rocks, the aqueous and the hypogene, come into immediate contact, without any gradation from one to the other. As we suppose the plutonic and metamorphic rocks to have been uplifted at all periods in the earth's history, so as to have formed the bottom of the ocean and of lakes, by the same operations which have carried up marine strata to the summits of lofty mountains, we must suppose the juxtaposition of the two great orders of rocks now alluded to, to have been a necessary result of all former revolutions of the globe.

But occasionally a transition is observable from strata containing shells, and displaying an evident mechanical structure, to others which are partially altered, and from these again we sometimes pass insensibly into the hypogene series. Some of the argillaceous-schists in Cornwall are of this description, being undistinguishable from the hypogene schists of many countries, and yet exhibiting, in a few spots, faint traces of organic remains. In parts of Germany, also, there are schists which, from their chemical condition, are identical with hypogene-schists, yet are interstratified with greywacke, a rock probably modified by heat, but which contains casts of shells, and often displays unequivocal marks of being an aggregate of fragments of pre-existing rocks.

Those geologists who shrink from the theory, that all the hypogene strata, so beautifully compact and crystalline as they are, have once been in the state of the ordinary mud, clay, marl, sand, gravel, limestone, and other deposits now forming beneath the waters, resort, in their desire to escape from such conclusions, to the hypothesis, that *chemical causes* once acted with intense energy, and that by their influence more crystalline strata were precipitated; but this theory appears to us to be as mysterious and unphilosophical as the doctrine of a 'plastic virtue,' introduced by the earlier writers to explain the origin of fossil-shells and bones.

Relative age of the visible hypogene rocks.—We shall now return to the subject already in part alluded to at the close of the last chapter—the relative age of the hypogene rocks as compared to the secondary. How far are they entitled in general to the appellation of 'primary,' in the sense of being anterior in age to the period of the carboniferous strata, in which last we include the greywacke and many of the rocks commonly called transition? It is undoubtedly true that we can rarely point out metamorphic or plutonic rocks which can be proved to have been formed in any secondary or tertiary period. We can, in some instances, demonstrate, as we have already shown, that there are granites of posterior origin to certain secondary strata, and that *secondary* strata have sometimes been converted into the *metamorphic*. But examples of such phenomena are rare, and their rarity is quite consistent with the theory, that the hypogene formations, both stratified and unstratified, have been always generated in equal quantities during periods of equal duration.

We conceive that the granite and gneiss, formed at periods more recent than the carboniferous era, are still for the most part concealed, and those portions which are visible can rarely be shown, by geological evidence, to have originated during secondary periods. It is very possible, for example, that considerable tracts of hypogene strata in the Alps may be altered oolite, altered lias, or altered secondary rocks inferior to the lias; but we can scarcely ever hope to substantiate the fact, because, whenever the change of texture is complete, no characters remain to afford us any insight into the probable age of the mass. Where granite happens to have intruded itself in such a manner as partially to overlie a mass of lias or other strata, as in the case before alluded to (diagram No. 90, p. 371), we may prove that *fossilliferous* strata have become gneiss, mica-schist, clay-slate, or granular marble; but if the action of the heat upon the strata had been more intense, the same inferences could not have been drawn. It might then have been supposed that no Alpine hypogene strata were newer than the carboniferous period.

The metamorphic strata of Scotland are certainly in great part older than the carboniferous, which are found incumbent upon them in an unaltered state; but it appears that secondary deposits as new, or newer than the lias, have come in contact, in the Western Islands, with granite, and have there assumed the hypogene texture.

A considerable source of difficulty and misapprehension, in regard to the antiquity of the metamorphic rocks, may arise from the circumstance of their having been deposited at one period, and having assumed their crystalline texture at another. Thus, for example, if an Eocene granite should invade the lias and superinduce a hypogene structure, to what period shall we refer the altered strata? Shall we say that they are metamorphic rocks of the Eocene or Liassic eras? They assumed their stratified form when the animals and plants of the lias flourished; they became metamorphic during the Eocene period. It would be preferable in such instances, we think, to consider them as hypogene strata of the Eocene period, or of that in which they were altered; yet it would rarely be possible to establish their true age. We should know the granite, to which the change of texture was due, to be newer than the lias which it penetrated; but there would rarely be any date to show that it might not have been injected at the close of the Liassic period, or at some much later era.

The metamorphic rocks must be the oldest, that is to say, they must lie at the bottom of each series of superimposed strata, because the influence of the volcanic heat proceeds from below upwards; but the hypogene strata of one country may be, and frequently are, of a very different age from those of another. The greater part, however, of the visible hypogene rocks are, we believe, more ancient than the carboniferous formations. In the latter, we frequently discover pebbles of hypogene rocks, namely, granite, gneiss, mica-schist, and clay-slate; and the carboniferous rocks often rest unchanged upon the hypogene. According to our views of the operations of earthquakes, we ought not to expect plutonic and metamorphic rocks of the more modern eras to have reached the surface generally, for we must imagine many geological periods to elapse before a mass which has put on its particular form far below the level of the sea, can have been upraised and laid open to view above that level. Beds containing marine shells sometimes appear at the height of two or three miles in the principal mountain-chains, but they always belong to formations of considerable antiquity; still more should we be prepared to find the hypogene rocks now in sight to be of high relative antiquity, since, in order to be brought up to view, they must probably have risen from a position far inferior to the bottom of the ocean.

We shall endeavour to elucidate the cause of the great age of the plutonic and metamorphic rocks, *now in sight*, by a familiar illustration. Suppose two months to be the usual time required for passing from some tropical country to our island, and that an annual importation takes place of a certain tropical species of insect, the ordinary term of whose life is two months, and which can only be reared in the climate of that equatorial country. It is evident that no living individuals could ever be seen in England except in extreme old age. The young may come annually into the world in great numbers, but in order to see them, we must travel to lands near the equator.

In like manner, if the hypogene rocks can only originate at great depths in the regions of subterranean heat, and if it requires many geological epochs to raise them to the surface, they must be very ancient before they make their appearance in the superficial parts of the earth's crust. They may still be forming in every century, and they may have been produced in equal quantities during each successive geological period of equal duration; but in order to see them in a nascent state, slowly consolidating from a state of fusion, or semi-fusion, we must descend into the 'fuelled entrails' of the earth, into the regions described by the poets, where for ages the land has

> ——— ever burn'd
> With solid, as the lake with liquid fire.

As the progress of decay and reproduction by aqueous agency is incessant on the surface of the continents, and in the bed of the ocean, while the hypogene rocks are generated below, or are rising gradually from the volcanic foci, thus there must ever be a remodelling of the earth's surface in the time intermediate between the origin of each set of plutonic and metamorphic rocks, and the protrusion of the same into the atmosphere or the ocean. Suppose the principal source of the Etnean lavas to lie at the depth of ten miles, we may easily conceive that before they can be uplifted to the day several distinct series of earthquakes must occur, and between each of these there might usually be one or more periods of tranquillity. The time required for so great a development of subterranean elevatory movements might well be protracted until the deposition of a series of sedimentary rocks, equal in extent to all our secondary and tertiary formations, had taken place. We conceive, therefore, that the relative age of the *visible* plutonic and metamorphic rocks, as compared to the unaltered sedimentary strata, must always be determined by the relations of two forces,—the power which uplifts the hypogene rocks, and that aqueous agency which degrades and renovates the earth's surface; or, in other words, it must depend on the quantity of aqueous action which takes place between two periods, that when the heated and melted rocks are cooled and consolidated in the nether regions, and that when the same emerge to the day.

Volume of hypogene rocks supposed to have been formed since the Eocene period.—If we were to indulge in speculations on the probable quantity of hypogene formations, both stratified and unstratified, which may have been formed beneath Europe and the European seas since the commencement of the Eocene period, we should conjecture, that the mass has equalled, if not exceeded in volume, the entire European continents. The grounds of this opinion will be understood by reference to what we have said of the causes which may have upheaved part of Sicily to a great height above the level of the sea since the beginning of the Newer Pliocene period*. If the theory which, in that instance, attributes the disturbance and upheaving of the superficial strata to the action of subterranean heat be deemed admissible, the same argument will apply with no less force to every other district, elevated or depressed, since the commencement of the tertiary period.

But we have shown, in our remarks on the map of Europe, in the second volume, that the conversion of sea into land, since the Eocene period, embraces an area equal to the greater part of Europe, and even those tracts which had in part emerged before the Eocene era, such as the Alps, Apennines, and other mountain-chains, have risen to the additional altitude of from 1000 to 4000 feet since that era. We have also stated the probability of a great amount of subsidence and the conversion of considerable portions of European land into sea during the same period—changes which may also be supposed to arise from the influence of subterranean heat.

From these premises we conclude, that the liquefaction and alteration of rocks by the operation of volcanic heat at suc-

* See above, p. 107.

cessive periods, has extended over a subterranean space equal at least in area to the present European continent, and often through a portion of the earth's crust 4000 feet or more in thickness.

The principal effect of these volcanic operations in the nether regions, during the tertiary periods, or since the existing species began to flourish, has been to heave up to the surface hypogene formations of an age anterior to the carboniferous. We imagine that the repetition of another series of movements, of equal violence, might upraise the plutonic and metamorphic rocks of many of the secondary periods; and if the same force should still continue to act, the next convulsions might bring up the *tertiary* and *recent* hypogene rocks, by which time we imagine that nearly all the sedimentary strata now in sight would either have been destroyed by the action of water, or would have assumed the metamorphic structure, or would have been melted down into plutonic and volcanic rocks.

At the close of this chapter the reader will find a table of the chronological relations of the principal divisions of rocks according to the views above set forth. The sketch is confessedly imperfect, but it will elucidate our theory of the connexion which may exist between the hypogene rocks of different periods, and the alluvial, volcanic, and sedimentary formations. A second table is added, containing the names of some of the principal groups of sedimentary strata mentioned in this work, arranged in their order of superposition.

Concluding Remarks.—In our history of the progress of geology, in the first volume, we stated that the opinion originally promulgated by Hutton, 'that the strata called *primitive* were mere altered sedimentary rocks,' was vehemently opposed for a time, the main objection to the theory being its supposed tendency to promote a belief in the past eternity of our planet. Previously the absence of animal and vegetable remains in the so-called primitive strata, had been appealed to, as proving that there had been a period when the planet was uninhabited by living beings, and when, as was also inferred, it was uninhabitable, and, therefore, probably in a nascent state.

The opposite doctrine, that the oldest visible strata might be the monuments of an antecedent period, when the animate world was already in existence, was declared to be equivalent to the assumption, that there never was a beginning to the present order of things. The unfairness of this charge was clearly pointed out by Playfair, who observed, 'that it was one thing to declare that we had not yet discovered the traces of a beginning, and another to deny that the earth ever had a beginning.'

We regret, however, to find that the bearing of our arguments in the first volume has been misunderstood in a similar manner, for we have been charged with endeavouring to establish the proposition, that 'the existing causes of change have operated with absolute uniformity from all eternity *.'

It is the more necessary to notice this misrepresentation of our views, as it has proceeded from a friendly critic whose theoretical opinions coincide in general with our own, but who has, in this instance, strangely misconceived the scope of our argument. With equal justice might an astronomer be accused of asserting, that the works of creation extend throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view, and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows that it must occupy a minute and infinitessimal point in infinite space. So, if in tracing back the earth's history, we arrive at the monuments of events which may have happened millions of ages

* Quarterly Review, No. 86, Oct. 1830, p. 464.

before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitessimal portion of eternity.

It has been argued, that as the different states of the earth's surface, and the different species by which it has been inhabited, have had each their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that as we admit the creation of man to have occurred at a comparatively modern epoch—as we concede the astonishing fact of the first introduction of a moral and intellectual being, so also we may conceive the first creation of the planet itself.

We are far from denying the weight of this reasoning from analogy; but although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings.

In vain do we aspire to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also, the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time or space, we discover everywhere the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe that has been suited to the accommodation of myriads of living creatures, but that many former states also have been equally adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates have varied; so it appears that the species have been changed, and yet they have all been so modelled, on types analogous to those of existing plants and animals, as to indicate throughout a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to us inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.