CHAPTER II.

Arrangement of the materials composing the earth's crust—The existing continents chiefly composed of subaqueous deposits—Distinction between sedimentary and volcanic rocks—Between primary, secondary, and tertiary—Origin of the primary—Transition formations—Difference between secondary and tertiary strata—Discovery of tertiary groups of successive periods—Paris basin—London and Hampshire basins—Tertiary strata of Bordeaux, Piedmont, Touraine, &c.—Subapennine beds—English crag—More recent deposits of Sicily, &c.

GENERAL ARRANGEMENT OF THE MATERIALS COMPOSING THE EARTH'S CRUST.

When we examine into the structure of the earth's crust (by which we mean the small portion of the exterior of our planet accessible to human observation), whether we pursue our investigations by aid of mining operations, or by observing the sections laid open in the sea cliffs, or in the deep ravines of mountainous countries, we discover everywhere a series of mineral masses, which are not thrown together in a confused heap, but arranged with considerable order; and even where their original position has undergone great subsequent disturbance, there still remain proofs of the order that once reigned.

We have already observed, that if we drain a lake, we frequently find at the bottom a series of recent deposits disposed with considerable regularity one above the other; the uppermost, perhaps, may be a stratum of peat, next below a more compact variety of the same, still lower a bed of laminated shell marl, alternating with peat, and then other beds of marl, divided by layers of clay. Now if a second pit be sunk through the same continuous lacustrine deposit, at some distance from the first, we often meet with nearly the same series of beds, yet with slight variations; some, for example, of the layers of sand, clay, or marl may be wanting, one or more of

them having thinned out and given place to others, or sometimes one of the masses, first examined, is observed to increase in thickness to the exclusion of other beds. Besides this limited continuity of particular strata, it is obvious that the whole assemblage must terminate somewhere; as, for example, where they reach the boundary of the original lake-basin, and where they will come in contact with the rocks which form the boundary of, and, at the same time, pass under all the recent accumulations.

In almost every estuary we may see, at low water, analogous phenomena where the current has cut away part of some newly-formed bank, consisting of a series of horizontal strata of peat, sand, clay, and, sometimes, interposed beds of shells. Each of these may often be traced over a considerable area, some extending farther than others, but all of necessity confined within the basin of the estuary. Similar remarks are applicable, on a much more extended scale, to the recent delta of a great river, like the Ganges, after the periodical inundations have subsided, and when sections are exposed of the river-banks and the cliffs of numerous islands, in which horizontal beds of clay and sand may be traced over an area many hundred miles in length, and more than a hundred in breadth.

Subaqueous deposits. The greater part of our continents are evidently composed of subaqueous deposits; and in the manner of their arrangement we discover many characters precisely similar to those above described; but the different groups of strata are, for the most part, on a greater scale, both in regard to depth and area, than any observable in the new formations of lakes, deltas, or estuaries. We find, for example, beds of limestone several hundred feet in thickness, containing imbedded corals and shells, stretching from one country to another, yet always giving place, at length, to a distinct set of strata, which either rise up from under it like the rocks before alluded to as forming the borders of a lake, or cover and conceal it. In other places, we find beds of pebbles, and sand, or of clay of great thickness. The different formations composed of these materials

usually contain some peculiar organic remains; as, for example, certain species of shells and corals, or certain plants.

Volcanic rocks. Besides these strata of aqueous origin, we find other rocks which are immediately recognized to be the products of fire, from their exact resemblance to those which have been produced in modern times by volcanos, and thus we immediately establish two distinct orders of mineral masses composing the crust of the globe—the sedimentary and the volcanic.

Primary rocks. But if we investigate a large portion of a continent which contains within it a lofty mountain range, we rarely fail to discover another class, very distinct from either of those above alluded to, and which we can neither assimilate to deposits such as are now accumulated in lakes or seas, nor to those generated by ordinary volcanic action. The class alluded to, consists of granite, granitic schist, roofing slate, and many other rocks, of a much more compact and crystalline texture than the sedimentary and volcanic divisions before mentioned. In the unstratified portion of these crystalline rocks, as in the granite for example, no organic fossil remains have ever been discovered, and only a few faint traces of them in some of the *stratified* masses of the same class; for we should state, that a considerable portion of these rocks are divided, not only into strata, but into laminæ, so closely imitating the internal arrangement of well-known aqueous deposits, as to leave scarcely any reasonable doubt that they owe this part of their texture to similar causes.

These remarkable formations have been called *primitive*, from being supposed to constitute the most ancient mineral productions known to us, and from a notion that they originated before the earth was inhabited by living beings, and while yet the planet was in a nascent state. Their high relative antiquity is indisputable; for in the oldest sedimentary strata, containing organic remains, we often meet with rounded pebbles of the older crystalline rocks, which must therefore have been consolidated before the derivative strata were formed out of

their ruins. They rise up from beneath the rocks of mechanical origin, entering into the structure of lofty mountains, so as to constitute, at the same time, the lowest and the most elevated portions of the crust of the globe.

Origin of primary rocks. Nothing strictly analogous to these ancient formations can now be seen in the progress of formation on the habitable surface of the earth, nothing, at least, within the range of human observation. The first speculators, however, in Geology, found no difficulty in explaining their origin, by supposing a former condition of the planet perfectly distinct from the present, when certain chemical processes were developed on a great scale, and whereby crystalline precipitates were formed, some more suddenly, in huge amorphous masses, such as granite; others by successive deposition and with a foliated and stratified structure, as in the rocks termed gneiss and mica-schist. A great part of these views have since been entirely abandoned, more especially with regard to the origin of granite, but it is interesting to trace the train of reasoning by which they were suggested. First, the stratified primitive rocks exhibited, as we before mentioned, well-defined marks of successive accumulation, analogous to those so common in ordinary subaqueous deposits. As the latter formations were found divisible into natural groups, characterized by certain peculiarities of mineral composition, so also were the primitive. In the next place, there were discovered, in many districts, certain members of the so-called primitive series, either alternating with, or passing by intermediate gradations into rocks of a decidedly mechanical origin, containing traces of organic remains. From such gradual passage the aqueous origin of the stratified crystalline rocks was fairly inferred; and as we find in the different strata of subaqueous origin every gradation between a mechanical and a purely crystalline texture; between sand, for example, and saccharoid gypsum, the latter having, probably, been precipitated originally in a crystalline form, from water containing sulphate of lime in solution, so it was imagined that, in a

former condition of the planet, the different degrees of crystallization in the older rocks might have been dependent on the varying state of the menstruum from which they were precipitated.

The presence of certain crystalline ingredients in the composition of many of the primary rocks, rendered it necessary to resort to many arbitrary hypotheses, in order to explain their precipitation from aqueous solution, and for this reason a difference in the condition of the planet, and of the pristine energy of chemical causes, was assumed. A train of speculation originally suggested by the observed effects of aqueous agents, was thus pushed beyond the limits of analogy, and it was not until a different and almost opposite course of induction was pursued, beginning with an examination of volcanic products, that more sound theoretical views were established.

Granite of igneous origin. As we are merely desirous, in this chapter, of fixing in the reader's mind the leading divisions of the rocks composing the earth's crust, we cannot enter, at present, into a detailed account of these researches, but shall only observe, that a passage was first traced from lava into other more crystalline igneous rocks, and from these again to granite, which last was found to send forth dikes and veins into the contiguous strata in a manner strictly analogous to that observed in volcanic rocks, and producing at the point of contact such changes as might be expected to result from the influence of a heated mass cooling down slowly under great pressure from a state of fusion. The want of stratification in granite supplied another point of analogy in confirmation of its igneous origin; and as some masses were found to send out veins through others, it was evident that there were granites of different ages, and that instead of forming in all cases the oldest part of the earth's crust, as had at first been supposed, the granites were often of comparatively recent origin, sometimes newer than the stratified rocks which covered them.

Stratified primary rocks. The theory of the origin of the other crystalline rocks was soon modified by these new views

respecting the nature of granite. First it was shown, by numerous examples, that ordinary volcanic dikes might produce great alterations in the sedimentary strata which they traversed, causing them to assume a more crystalline texture, and obliterating all traces of organic remains, without, at the same time, destroying either the lines of stratification, or even those which mark the division into laminæ. It was also found, that granite dikes and veins produced analogous, though somewhat different changes; and hence it was suggested as highly probable, that the effects to which small veins gave rise, to the distance of a few yards, might be superinduced on a much grander scale where immense masses of fused rock, intensely heated for ages, came in contact at great depths from the surface with sedimentary formations. The slow action of heat in such cases, it was thought, might occasion a state of semi-fusion, so that, on the cooling down of the masses, the different materials might be re-arranged in new forms, according to their chemical affinities, and all traces of organic remains might disappear, while the stratiform and lamellar texture remained.

May be of different ages. According to these views, the primary strata may have assumed their crystalline structure at as many successive periods as there have been distinct eras of the formation of granite, and their difference of mineral composition may be attributed, not to an original difference of the conditions under which they were deposited at the surface, but to subsequent modifications superinduced by heat at great depths below the surface.

The strict propriety of the term primitive, as applied to granite and to the granitiform and associated rocks, thus became questionable, and the term primary was very generally substituted, as simply expressing the fact, that the crystalline rocks, as a mass, were older than the *secondary*, or those which are unequivocally of a mechanical origin and contain organic remains.

Transition formations. The reader may readily conceive, even from the hasty sketch which we have thus given of the supposed origin of the stratified primary rocks, that they may

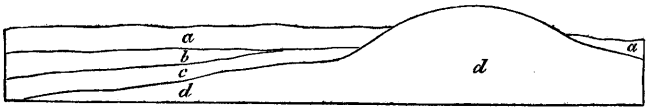
occasionally graduate into the secondary; accordingly, an attempt was made, when the classification of rocks was chiefly derived from mineral structure, to institute an order called *transition*, the characters of which were intermediate between those of the primary and secondary formations. Some of the shales, for example, associated with these strata, often passed insensibly into clay slates, undistinguishable from those of the granitic series; and it was often difficult to determine whether some of the compound rocks of this transition series, called greywacke, were of mechanical or chemical origin. The imbedded organic remains were rare, and sometimes nearly obliterated; but by their aid the groups first called transition were at length identified with rocks, in other countries, which had undergone much less alteration, and wherein shells and zoophytes were abundant.

The term transition, however, was still retained, although no longer applicable in its original signification. It was now made to depend on the identity of certain species of organized fossils; yet reliance on mineral peculiarities was not fairly abandoned, as constituting part of the characters of the group. This circumstance became a fertile source of ambiguity and confusion; for although the species of the transition strata denoted a certain epoch, the intermediate state of mineral character gave no such indications, and ought never to have been made the basis of a chronological division of rocks.

Order of succession of stratified masses. All the subaqueous strata which we before alluded to as overlying the primary, were at first called secondary; and when they had been found divisible into different groups, characterised by certain organic remains and mineral peculiarities, the relative position of these groups became a matter of high interest. It was soon found that the order of succession was never inverted, although the different formations were not coextensively distributed; so that, if there be four different formations, as *a*, *b*, *c*, *d*, in the annexed diagram (No. 1), which, in certain localities, may be seen in vertical superposition, the uppermost or newest of them,

a, will in other places be in contact with *c*, or with the lowest

No. 1.



of the whole series, *d*, all the intermediate formations being absent.

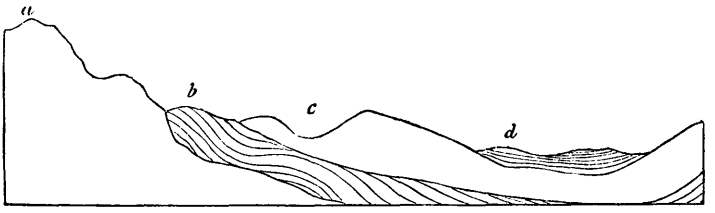
Tertiary formations. After some progress had been made in classifying the secondary rocks, and in assigning to each its relative place in a chronological series, another division of sedimentary formations was established, called *tertiary*, as being of newer origin than the secondary. The fossil contents of the deposits belonging to this newly-instituted order are, upon the whole, very dissimilar from those of the secondary rocks, not only all the species, but many of the most remarkable animal and vegetable forms, being distinct. The tertiary formations were also found to consist very generally of detached and isolated masses, surrounded on all sides by primary and secondary rocks, and occupying a position, in reference to the latter, very like that of the waters of lakes, inland seas, and gulfs, in relation to a continent, and, like such waters, being often of great depth, though of limited area. The imbedded organic remains were chiefly those of marine animals, but with frequent intermixtures of terrestrial and freshwater species so rarely found among the secondary fossils. Frequently there was evidence of the deposits having been purely lacustrine, a circumstance which has never yet been clearly ascertained in regard to any secondary group.

We shall consider more particularly, in the next chapter, how far this distinction of rocks into secondary and tertiary is founded in nature, and in what relation these two orders of mineral masses may be supposed to stand to each other. But before we offer any general views of this kind, it may be useful to present the reader with a succinct sketch of the principal

points in the history of the discovery and classification of the tertiary strata.

Paris Basin. The first series of deposits belonging to this class, of which the characters were accurately determined, were those which occur in the neighbourhood of Paris, first described by MM. Cuvier and Brongniart*. They were ascertained to fill a depression in the chalk (as the beds *d*, in diagram No. 2, rest upon *c*), and to be composed of different materials, some-

No. 2.



a, Primary rocks.
b, Older secondary formations. *c*, Chalk.
d, Tertiary formation.

times including the remains of marine animals, and sometimes of freshwater. By the aid of these fossils, several distinct alternations of marine and freshwater formations were clearly shown to lie superimposed upon each other, and various speculations were hazarded respecting the manner in which the sea had successively abandoned and regained possession of tracts which had been occupied in the intervals by the waters of rivers or lakes. In one of the subordinate members of this Parisian series, a great number of scattered bones and skeletons of land animals were found entombed, the species being perfectly dissimilar from any known to exist, as indeed were those of almost all the animals and plants of which any portions were discovered in the associated deposits.

We shall defer, to another part of this work, a more detailed account of this interesting formation, and shall merely observe in this place, that the investigation of the fossil contents of these beds forms an era in the progress of the science. The

* Environs de Paris, 1811.

French naturalists brought to bear upon their geological researches so much skill and proficiency in comparative anatomy and conchology, as to place in a strong light the importance of the study of organic remains, and the comparatively subordinate interest attached to the mere investigation of the structure and mineral ingredients of rocks.

A variety of tertiary formations were soon afterwards found in other parts of Europe, as in the south-east of England, in Italy, Austria, and different parts of France, especially in the basins of the Loire and Gironde, all strongly contrasted to the secondary rocks. As in the latter class many different divisions had been observed to preserve the same mineral characters and organic remains over wide areas, it was natural that an attempt should first be made to trace the different subdivisions of the Parisian tertiary strata throughout Europe, for some of these were not inferior in thickness to several of the secondary formations that had a wide range.

But in this case the analogy, however probable, was not found to hold good, and the error, though almost unavoidable, retarded seriously the progress of geology. For as often as a new tertiary group was discovered, as that of Italy, for example, an attempt was invariably made, in the first instance, to discover in what characters it agreed with some one or more subordinate members of the Parisian type. Every fancied point of correspondence was magnified into undue importance, and such trifling circumstances, as the colour of a bed of sand or clay, were dwelt upon as proofs of identification, while the difference in the mineral character and organic contents of the group from the whole Parisian series was slurred over and thrown into the shade.

By the influence of this illusion, the succession and chronological relations of different tertiary groups were kept out of sight. The difficulty of clearly discerning these, arose from the frequent isolation of the position of the tertiary formations before described, since, in proportion as the areas occupied by them are limited, it is rare to discover a place where one

set of strata overlap another, in such a manner that the geologist might be enabled to determine the difference of age by direct superposition.

ORIGIN OF THE EUROPEAN TERTIARY STRATA AT SUCCESSIVE PERIODS.

We shall now very briefly enumerate some of the principal steps which eventually led to a conviction of the necessity of referring the European tertiary formations to distinct periods, and the leading data by which such a chronological series may be established.

London and Hampshire Basins.—Very soon after the investigation, before alluded to, of the Parisian strata, those of Hampshire and of the Basin of the Thames were examined in our own country. Mr. Webster found these English tertiary deposits to repose, like those in France, upon the chalk or newest rock of the secondary series. He identified a great variety of the shells occurring in the British and Parisian strata, and ascertained that, in the Isle of Wight, an alternation of marine and fresh-water beds occurred, very analogous to that observed in the basin of the Seine*. But no two sets of strata could well be more dissimilar in mineral composition, and they were only recognized to belong to the same era, by aid of the specific identity of their organic remains. The discordance, in other respects, was as complete as could well be imagined, for the principal marine formation in the one country consisted of blue clay, in the other of white limestone, and a variety of curious rocks in the neighbourhood of Paris had no representatives whatever in the south of England.

Subapennine Beds.—The next important discovery of tertiary strata was in Italy, where Brocchi traced them along the flanks of the Apennines, from one extremity of the peninsula to the other, usually forming a lower range of hills, called by him the Subapennines†. These formations, it is true, had

* Webster in Englefield's Isle of Wight and Geol. Trans., vol. ii. p. 161.
† Conch. Foss. Subap., 1814.

been pointed out by the older Italian writers, and some correct ideas, as we have seen, had been entertained respecting their recent origin, as compared to the inclined secondary rocks on which they rested*. But accurate data were now for the first time collected, for instituting a comparison between them and other members of the great European series of tertiary formations.

Brocchi came to the conclusion that nearly one-half of several hundred species of fossil shells procured by him from these Subapennine beds were identical with those now living in existing seas, an observation which did not hold true in respect to the organic remains of the Paris basin. It might have been supposed that this important point of discrepancy would at once have engendered great doubt as to the identity, in age, of any part of the Subapennine beds to any one member of the Parisian series; but, for reasons above alluded to, this objection was not thought of much weight, and it was supposed that a group of strata, called 'the upper marine formation,' in the basin of the Seine, might be represented by all the Subapennine clays and yellow sand.

English Crag.—Several years before, an English naturalist, Mr. Parkinson, had observed, that certain shelly strata, in Suffolk, which overlaid the blue clay of London, contained distinct fossil species of testacea, and that a considerable portion of these might be identified with species now inhabiting the neighbouring sea†. These overlying beds, which were provincially termed 'Crag,' were of small thickness, and were not regarded as of much geological importance. But when duly considered, they presented a fact worthy of great attention, viz., the superposition of a tertiary group, inclosing, like the Subapennine beds, a great intermixture of recent species of shells, upon beds wherein a very few remains of recent or living species were entombed.

Mr. Conybeare, in his excellent classification of the English

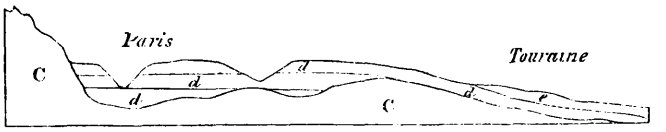
* See vol. i. p. 51, for opinions of Odoardi, in 1761.

† Geol. Trans., vol. i. p. 324. 1811.

strata*, placed the crag as the uppermost of the British series, and several geologists began soon to entertain an opinion that this newest of our tertiary formations might correspond in age to the Italian strata described by Brocchi.

Tertiary Strata of Touraine.—The next step towards establishing a succession of tertiary periods was the evidence adduced to prove that certain formations, more recent than the uppermost members of the Parisian series, were also older than the Subapennine beds, so that they constituted deposits of an age intermediate between the two types above alluded to. Mr. Desnoyers, for example, ascertained that a group of marine strata in Touraine, in the basin of the Loire (*e*, diagram No. 3), rest upon the uppermost subdivision of the

No. 3.



C, Chalk and other secondary formations.
d, Tertiary formation of Paris basin.
e, Superimposed marine tertiary beds of the Loire.

Parisian group *d*, which consists of a lacustrine formation, extending continuously throughout a platform which intervenes between the basin of the Seine and that of the Loire. These overlaying marine strata, M. Desnoyers assimilated to the English crag, to which they bear some analogy, although their organic remains differ considerably, as will be afterwards shown.

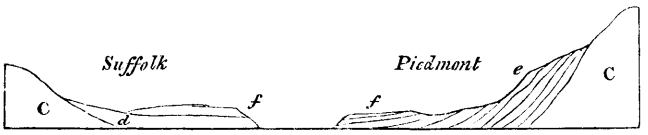
A large tertiary deposit had already been observed in the south-west of France, around Bordeaux and Dax, and a description of its fossils had been published by M. de Basterot†. Many of the species were peculiar, and differed from those of the strata now called Subapennine; yet these same peculiar and characteristic fossils reappeared in Piedmont, in a series of

* Outlines of the Geology of England and Wales, 1822.

† Mem. de la Soc. d'Hist. Nat. de Paris, tome ii., 1825.

strata inferior in position to the Subapennines (as *e* underlies *f*, diagram No. 4.)

No. 4.



C, Chalk and older formations.
d, London clay, (old tertiary).
e, Tertiary strata of same age as beds of the Loire.
f, Crag and Subapennine tertiary deposits.

This inferior group, *e*, composed principally of green sand, occurs in the hills of Mont Ferrat, and beds of the same age are seen in the valley of the Bormida. They also form the hill of the Superga, near Turin, where M. Bonelli formed a large collection of their fossils, and identified them with those discovered near Bordeaux and in the basin of the Gironde.

But we are indebted to M. Deshayes for having proved, by a careful comparison of the entire assemblage of shells found in the above-mentioned localities, in Touraine, in the south-east of France, and in Piedmont, that the whole of these three groups possess the same zoological characters, and belong to the same epoch, as also do the shells described by M. Constant Prevost, as occurring in the basin of Vienna*.

Now the reader will perceive, by reference to the observations above made, and to the accompanying diagrams, that one of the formations of this intervening period, *e*, has been found superimposed upon the highest member of the Parisian series, *d*; while another of the same set has been observed to underlie the Subapennine beds, *f*. Thus the chronological series, *d*, *e*, *f*, is made out, in which the deposits, originally called tertiary, those of the Paris and London basins, for example, occupy the lowest position, and the beds called 'the Crag,' and 'the Subapennines,' the highest.

Tertiary Strata newer than the Subapennine.—The fossil

* Sur la Constitution, &c. du bassin de Vienne, Journ. de Phys., Nov. 1820.

remains which characterize each of the three successive periods above alluded to, approximate more nearly to the assemblage of *species* now existing, in proportion as their origin is less remote from our own era, or, in other words, the recent species are always more numerous, and the extinct more rare, in proportion to the low antiquity of the formations. But the discordance between the state of the organic world indicated by the fossils of the Subapennine beds and the actual state of things is still considerable, and we naturally ask, are there no monuments of an intervening period ?—no evidences of a gradual passage from one condition of the animate creation to that which now prevails, and which differs so widely ?

It will appear, in the sequel, that such monuments are not wanting, and that there are marine strata entering into the composition of extensive districts, and of hills of no trifling height, which contain the exuviæ of testacea and zoophytes, hardly distinguishable, as a group, from those now peopling the neighbouring seas. Thus the line of demarcation between the actual period and that immediately antecedent, is quite evanescent, and the newest members of the tertiary series will be often found to blend with the formations of the historical era.

In Europe, these modern strata have been found in the district around Naples, in the territory of Otranto and Calabria, and more particularly in the Island of Sicily ; and the bare enumeration of these localities cannot fail to remind the reader, that they belong to regions where the volcano and the earthquake are now active, and where we might have anticipated the discovery of emphatic proofs, that the conversion of sea into land had been of frequent occurrence at very modern periods.