## CHAPTER XVII.

Eocene period — Fresh-water formations — Central France — Map — Limagne d'Auvergne—Sandstone and conglomerate—Tertiary Red marl and sandstone like the secondary 'new red sandstone'—Green and white foliated marls—Indusial limestone—Gypseous marls—General arrangement and origin of the Travertin—Fresh-water formation of the Limagne—Puy en Velay—Analogy of the strata to those of Auvergne—Cantal—Resemblance of Aurillac limestone and its flints to our upper chalk—Proofs of the gradual deposition of marl—Concluding Remarks.

### EOCENE FRESH-WATER FORMATIONS.

We have now traced back the history of the European formations to that period when the seas and lakes were inhabited by a few only of the existing species of testacea, a period which we have designated *Eocene*, as indicating the *dawn* of the present state of the animate creation. But although a small number only of the living species of animals were then in being, there are ample grounds for inferring that all the great classes of the animal kingdom, such as they now exist, were then fully represented. In regard to the testacea, indeed, it is no longer a matter of inference, for 1400 species of this class have been obtained from that small number of detached Eocene deposits which have hitherto been examined in Europe.

The celebrated Paris basin, the position of which was pointed out in the former part of this volume, (see wood-cut, p. 16) first presents itself, and seems to claim our chief attention when we treat of the phenomena of this era. But in order more easily to explain to the student the peculiar nature and origin of that group, it will be desirable, first, to give a brief sketch of certain deposits of Central France, which afford many interesting points of analogy, both in organic remains and mineral composition, and where the original circumstances under which the strata were accumulated may more easily be discerned.

*Auvergne.*—We allude to the lacustrine basins of Auvergne, Cantal, and Velay, the site of which may be seen in the

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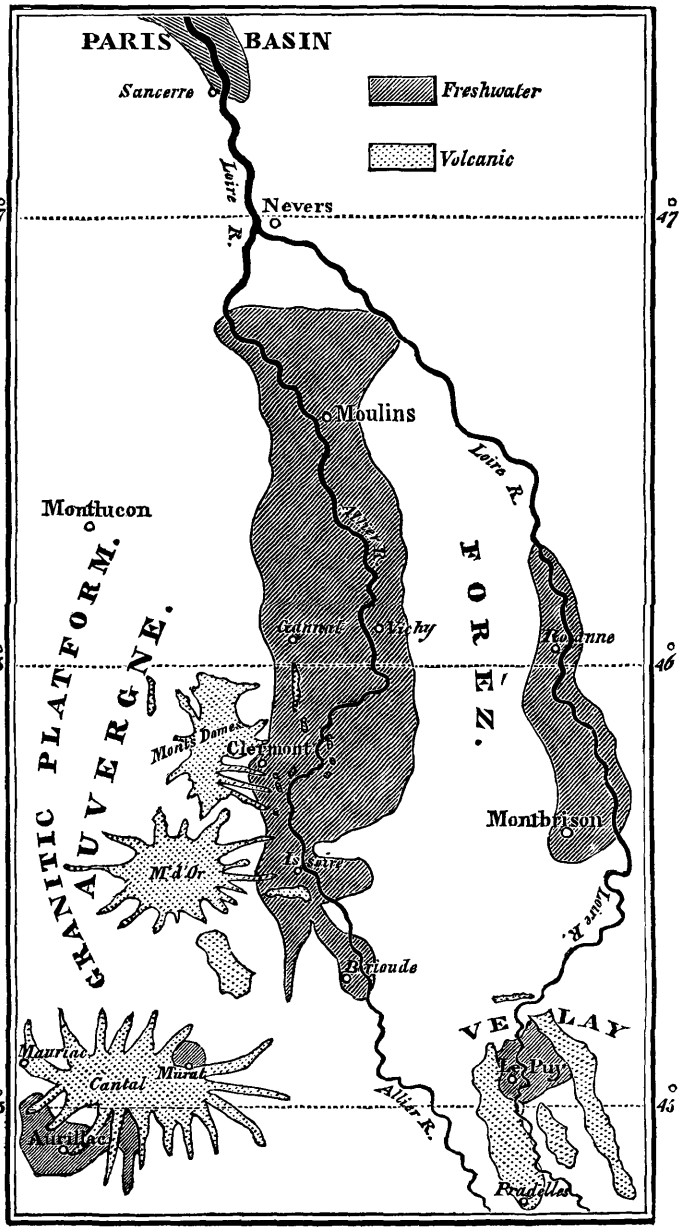


annexed Map *. They appear to be the monuments of ancient lakes which may have resembled in geographical distribution some of those now existing in Switzerland, and may like them have occupied the depressions in a mountainous country, and have been each fed by one or more rivers and torrents. The country where they occur is almost entirely composed of granite, and different varieties of granitic schist, with here and there a few patches of secondary strata much dislocated, and which have probably suffered great denudation. There are also some vast piles of volcanic rock, (see the Map,) the greater part of which are newer than the fresh-water strata, often resting upon them, whilst a small part were evidently of contemporaneous origin. Of these igneous rocks we shall treat more particularly in the nineteenth chapter, and shall first turn our attention exclusively to the lacustrine beds.

The most northern of the fresh-water groups is situated in the valley-plain of the Allier, which lies within the department of the Puy de Dome, being the tract which went formerly by the name of the Limagne d'Auvergne. It is inclosed by two parallel primitive ranges,—that of the Forèz, which divides the waters of the Loire and Allier, on the east, and that of the Monts Domes, which separates the latter river from the Sioule, on the west †. The average breadth of this tract is about 20 miles, and it is for the most part composed of nearly horizontal strata of sand, sandstone, calcareous marl, clay, limestone, and some subordinate groups, none of which observe a fixed and invariable order of superposition. The ancient borders of the lake, wherein the fresh-water strata were accumulated, may generally be traced with precision, the granite and other ancient rocks rising up boldly from the level country. The precise junction, however, of the lacustrine and granitic beds is rarely seen, as a small valley usually intervenes between them. The fresh-

* The following account of the fresh-water formations of Central France is the result of observations made in the summer of 1828, in company with Mr. Murchison.

† Scrope, Geology of Central France, p. 15.

water strata may sometimes be seen to retain their horizontality within a very slight distance of the border-rocks, while in some places they are inclined, and in a few instances vertical. The principal divisions into which the lacustrine series may be separated are the following: 1st, Sandstone, grit, and conglomerate. 2ndly, green and white foliated marls. 3dly, limestone or travertin, oolite, &c. 4thly, gypseous marls.

1. *Sandstone and conglomerate.*—Strata of sand and gravel, sometimes bound together into a solid rock, are found in great abundance around the confines of the lacustrine basin, containing, in different places, pebbles of all the ancient rocks of the adjoining elevated country, namely, granite, gneiss, mica-schist, clay-slate, porphyry, and others. But the arenaceous strata do not form one continuous band around the margin of the basin, being rather disposed like the independent deltas which grow at the mouths of torrents along the borders of existing lakes *.

At Chamalieres, near Clermont, we have an example of one of these littoral groups of local extent where the pebbly beds slope away from the granite as if they had formed a talus beneath the waters of the lake near the steep shore. A section, of about 50 feet in vertical height, has been laid open by a torrent, and the pebbles are seen to consist throughout of rounded and angular fragments of granite, quartz, primary slate, and red sandstone, but without any intermixture of those volcanic rocks which now abound in the neighbourhood. Partial layers of lignite and pieces of wood are found in these beds, but no shells, a fact which probably indicates that testacea could not live where the turbid waters of a stream were frequently hurrying down uprooted trees, together with sand and pebbles, or, that if they existed, they were triturated by the transported rocks.

There are other localities on the margin of the basin where quartzose grits are found, composed of white sand bound together by a siliceous cement.

* See vol. i. chap. xiv. p. 249; and 2nd. Ed. p. 286.

Occasionally, when the grits rest on granite, as at Chamalieres before mentioned, and many other places, the separate crystals of quartz, mica, and felspar, of the disintegrated granite, are bound together again by the silex, so that the granite seems regenerated in a new and even more solid form, and thus so gradual a passage may sometimes be traced between a crystalline rock and one of mechanical origin, that we can scarcely distinguish where one ends and the other begins.

In the Puy de Jussat, and the neighbouring hill of La Roche, are white quartzose grits, cemented into a sandstone by calcareous matter, which is sometimes so abundant as to form imbedded nodules. These sometimes constitute spheroidal concretions six feet in diameter, and pass into beds of solid limestone resembling the Italian travertins, or the deposits of mineral springs.

In the hills above mentioned, we have the advantage of seeing a section continuously exposed for about 700 feet in thickness. At the bottom are foliated marls, white and green, about 400 feet thick, and above, resting on the marls, are the quartzose grits before mentioned with the associated travertins. This section is observed close to the confines of the basin, so that the lake must here have been filled up near the shore with fine mud, before the coarse superincumbent sand was introduced. There are other cases where sand is seen below the marl.

2. *Red marl and sandstone.*—But the most remarkable of the arenaceous groups is a red sandstone and red marl, identical in all their characters with the secondary *new red sandstone* and marl of England. In the latter, the red ground is sometimes variegated with light greenish spots, and the same may be seen in its tertiary counterpart of fresh-water origin at Coudes, on the Allier. The marls are sometimes of a purplish-red colour, as at Champheix, and are accompanied by a reddish limestone, like the well-known 'cornstone,' which is associated with the old red sandstone of English geologists. The red sandstone and marl of Auvergne have evidently been derived from the

degradation of gneiss and mica-schist, which are seen *in situ* on the adjoining hills, decomposing into a soil very similar to the tertiary red sand and marl. We also find pebbles of gneiss, mica-schist, and quartz, in the coarser sandstones of this group, clearly pointing to the parent rocks from which the sand and marl were derived. The red beds, although destitute of organic remains, pass upwards into strata containing Eocene fossils, and are certainly an integral part of the lacustrine formation.

3. *Green and white foliated marls.*—A great portion of what we term clay in ordinary language, consists of the same materials as sandstone, but the component parts are in a finer state of subdivision. The same primary rocks, therefore, of Auvergne, which, by the partial degradation of their harder parts, gave rise to the quartzose grits and conglomerates before mentioned, would, by the reduction of the same into powder, and by the decomposition of their felspar, mica, and hornblende, produce aluminous clay, and, if a sufficient quantity of carbonate of lime was present, calcareous marl. This fine sediment would naturally be carried out to a greater distance from the shore, as are the various finer marls now deposited in Lake Superior *. And, as in the American lake, shingle and sand are annually amassed near the northern shores, so in Auvergne the grits and conglomerates before mentioned were evidently formed near the borders.

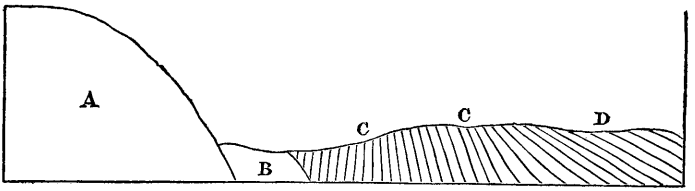
The entire thickness of these marls is unknown, but it certainly exceeds, in some places, 700 feet. They are for the most part either light-green or white, and usually calcareous. They are thinly foliated, a character which frequently arises from the innumerable thin plates or scales of that small animal called *cypris*, a genus which comprises several species, of which some are recent, and may be seen swimming rapidly through the waters of our stagnant pools and ditches. This animal resides within two small valves like those of a bivalve shell, and it moults its integuments annually, which the conchiferous

* See vol. i. chap. xiii.

molluscs do not. This circumstance may partly explain the countless myriads of the shells of cypris which were shed in the Eocene lakes, so as to give rise to divisions in the marl as thin as paper, and that too in stratified masses several hundred feet thick. A more convincing proof of the tranquillity and clearness of the waters, and of the slow and gradual process by which the lake was filled up with fine mud, cannot be desired. We may easily suppose that, while in the deep and central parts of the basin, this fine sediment was thrown down, gravel, sand, and rocky fragments were hurried into the lake near the shore, and formed the group first described.

Not far from Clermont the green marls, containing the cypris in abundance, approach to within a few yards of the granite which forms the borders of the basin. The annexed section occurs at Champradelle, in a small ravine north of La petite Baraque, and above the bridge.

No. 57.




*Vertical strata of marl near Clermont.*

A, Granite. C, Green marl, vertical and inclined.
B, Space of 60 feet in which no section is seen. D. White marl.

The occurrence of these marls so near the ancient margin may be explained by considering that, at the bottom of the ancient lake in spaces intermediate between the points where rivers and torrents entered, no coarse ingredients were deposited, but finer mud only was drifted by currents. The *verticality* of some of the beds in the above section bears testimony to considerable local disturbance subsequent to the deposition of the marls, but such inclined and vertical strata are very rare.

4. *Limestone, travertin, &c.*—Both the preceding members of the lacustrine deposit, the marls and grits, pass occasionally

into limestone. Sometimes only concretionary nodules abound in them; but these, by an additional quantity of calcareous matter, unite, as already noticed (p. 229), into regular beds.

On each side of the basin of the Limagne, both on the east at Gannat, and on the west at Vichy, a white oolitic limestone is quarried. At Vichy, the oolite resembles our Bath stone in appearance and beauty, and, like it, is soft when first taken from the quarry, but soon hardens on exposure to the air. At Gannat, the stone contains land-shells and bones of quadrupeds, resembling those of the Paris gypsum. In several places in the neighbourhood of Gannat, at Marculot among others, this stone is divided by layers of clay.

At Chadrat, in the hill of La Serre, the limestone is pisolitic, and in this and other respects resembles the travertin of Tivoli. It presents the same combination, of a radiated and concentric structure, and the coats of the different segments of spheroids have the same undulating surface. (See wood-cut No. 5, chap. xii. vol. i.)

*Indusial limestone.*—There is another remarkable form of fresh-water limestone in Auvergne, called 'indusial,' from the cases, or *indusiæ*, of the larvæ of Phryganea, great heaps of which have been encrusted, as they lay, by hard travertin, and formed into a rock. We may often see, in our ponds, some of the living species of these insects, covered with small fresh-water shells, which they have the power of fixing to the outside of their tubular cases, in order, probably, to give them weight and strength. It appears that, in the same manner, a large species which swarmed in the Eocene lakes of Auvergne, was accustomed to attach to its dwelling the shells of a small spiral univalve of the genus *Paludina*. A hundred of these minute shells are sometimes seen arranged around one tube, part of the central cavity of which is still occasionally empty, the rest being filled up with thin concentric layers of travertin. When we consider that ten or twelve tubes are packed within the compass of a cubic inch, and that some single strata of this limestone are six feet thick, and may be

traced over a considerable area, we may form some idea of the countless number of insects and mollusca which contributed their integuments and shells to compose this singularly constructed rock. It is unnecessary to suppose that the Phryganeæ lived on the spots where their cases are now found; they may have multiplied in the shallows near the margin of the lake, and their buoyant cases may have been drifted by a current far into the deep water.

The calcareous strata of the Limagne, like the other members of the lacustrine formation, are for the most part horizontal, or inclined at a very slight angle, but instances of local dislocation are sometimes seen. At the town of Vichy, for example, the strata dip at an angle of between 30 and 40 degrees; in an ancient quarry behind the convent of Celestines, and near the hot spring at the same place, the beds of limestone are seen first inclined at an angle of 80°, and then vertical.

5. *Gypseous marls.*—More than 50 feet of thinly-laminated gypseous marls, exactly resembling those in the hill of Montmartre, at Paris, are worked for gypsum at St. Romain, on the right bank of the Allier. They rest on a series of green cypriferous marls which alternate with grits, the united thickness of this inferior group being seen, in a vertical section on the banks of the river, to exceed 250 feet.

*General arrangement and origin of the fresh-water formations of Auvergne.*—The relations of the different groups above described cannot be learnt by the study of any one section, and he who sets out with the expectation of finding a fixed order of succession may perhaps complain that the different parts of the basin give contradictory results. The arenaceous division, the marls and the limestone, may all be seen in some localities to alternate with each other, yet it can by no means be affirmed that there is no order of arrangement. The sands, sandstone, and conglomerate, constitute in general a littoral group; the foliated white and green marls a contemporaneous central deposit, and the limestone is for the most part subordinate to the newer portions of the above groups.

We never meet with calcareous rocks covered by a considerable thickness of quartzose sand or green marl, and the uppermost marls and sands are more calcareous than the lower. From the resemblance of the Eocene limestones of Auvergne to the Italian travertins, we may conclude that they were derived from the waters of mineral springs,—such springs as now exist in Auvergne, and which rising up through the granite precipitate travertin. They are sometimes thermal, but this character is by no means constant.

We suppose that, when the ancient lake of the Limagne first began to be filled with sediment, no volcanic action had produced lava and scoriæ on any part of the surface of Auvergne. No pebbles, therefore, of lava were transported into the lake,—no fragments of volcanic rocks imbedded in the conglomerate. But at a later period, when a considerable thickness of sandstone and marl had accumulated, eruptions broke out, and lava and tuff were alternately deposited, at some spots, with the lacustrine strata. Of this we shall give proofs in the 19th chapter. It is not improbable that cold and thermal springs, holding different mineral ingredients in solution, increased in number during the successive convulsions attending this development of volcanic agency, and thus carbonate and sulphate of lime, silex, and other minerals, were produced. Hence these minerals predominate in the uppermost strata. The subterranean movements may then have continued until they altered the relative levels of the country and caused the waters of the lakes to be drained off, and the farther accumulation of regular fresh-water strata to cease. The occurrence of these convulsions anterior to the Miocene epoch, and prolonged during a succession of after-ages, may explain why no fresh-water formations more recent than the Eocene are now found in this country.

We may easily conceive a similar series of events to give rise to analogous results in any modern basin, such as that of Lake Superior, for example, where numerous rivers and torrents are carrying down the detritus of a chain of mountains into the

lake. The transported materials must be arranged according to their size and weight, the coarser near the shore, the finer at a greater distance from land; but in the gravelly and sandy beds of Lake Superior no pebbles of modern volcanic rocks can be included, since there are none of these at present in the district. If the igneous action should break out in that country and produce lava, scoriæ, and thermal springs, the deposition of gravel, sand, and marl, might still continue as before; but in addition, there would then be an intermixture of volcanic gravel and tuff, and rocks precipitated from the waters of mineral springs.

Although the fresh-water strata of the Limagne approach generally to a horizontal position, the proofs of local disturbance are sufficiently numerous and violent to allow us to suppose great changes of level since the Eocene period. We are unable to assign a northern barrier to the ancient lake, although we can still trace its limits to the east, west, and south, where they were formed of bold granitic eminences. But we need not be surprised at our inability to restore the physical geography of the country after so great a series of volcanic eruptions. It is by no means improbable that one part of the district may have been moved upwards bodily, while the others remained at rest, or even suffered a movement of depression.

*Puy en Velay.*—In the department of the Haute Loire, a fresh-water formation, very analogous to that of Auvergne, is situated in the basin of the Loire, and is exposed in the valley in which stands the town of Le Puy. Since the deposition of the lacustrine strata, there have been so many volcanic eruptions in this country, and such immense quantities of lava and scoriæ poured out upon the surface, that the aqueous rocks are almost buried and concealed. We are indebted, however, to the researches of M. Bertrand de Doue for having distinctly ascertained the succession of strata, and we have had opportunities of verifying his observations during a visit to Le Puy.

In this basin we find, as in Auvergne, two great divisions, consisting of grits and marls; the former composed of quartzose

grit, sometimes granitiform, reddish and mottled sands and conglomerates, all evidently derived from the degradation of granitic rocks, and resembling exceedingly the arenaceous group of the Limagne before described. This formation is almost confined to the borders of the basin, and was evidently a littoral deposit. The other member of the formation, the *marls*, are more or less calcareous, and are associated with limestone and gypsum, which last is worked for agricultural uses, and exactly resembles that of Paris.

The analogy in the mineral character of the Velay and Paris basins is rendered more complete by the presence in both of silex in regular beds. In the limestone I found gyrogonites, or seeds of the Chara, of the same species as those most common in the Paris basin; and M. Bertrand de Doue has discovered the bones of several mammiferous animals of the same genera as those which characterize the basins of Auvergne and Paris *. The shells also of this formation correspond specifically with those of Eocene formations in other parts of France.

The sand and conglomerate of the fresh-water basin of Velay is entirely free from volcanic pebbles, agreeing in this respect with the analogous group of the Limagne; but the fact is the more striking in Velay, because the masses of trachyte, clinkstone, and other igneous rock now abounding in that country, have an aspect of extremely high antiquity, and constitute a most prominent feature in the geological structure of the district. Yet the non-intermixture of volcanic products with the lacustrine sediment, is just what we should expect when we have ascertained that the imbedded organic remains of those strata are Eocene; whereas the lavas belong in part, if not entirely, to the Miocene period †.

*Cantal.*—Near Aurillac, in Cantal, another series of fresh-water strata occurs, which resembles, in mineral character and organic remains, those of Auvergne and Velay already described. The leading feature of this group, as distinguished

* Descrip. Géognos. des Env. du Puy en Velay, 1823.

† See above, p. 219, and below, Chap. xix.

from the two former, is the immense abundance of silex associated with the calcareous marls and limestone, which last, like the limestone of Auvergne, constitutes an upper member of the fresh-water series.

The formation of the Cantal may be divided into two groups, the lowest composed of gravel, sand, and clay, such as might have been derived from the wearing down and decomposition of the granitic schists of the surrounding country; the upper system consisting of siliceous and calcareous marls, contains subordinately gypsum, silex, and limestone—deposits such as the waters of springs charged with carbonate and sulphate of lime, and with silica, may have produced.

*Fresh-water limestone and flints resembling chalk.*—To the English geologist, the most interesting feature in the Cantal is the resemblance of the fresh-water limestone, and its accompanying flint, to our upper chalk, a resemblance which, like that of the red sandstone of Auvergne to our secondary 'new red,' is the more important, as being calculated to put the student upon his guard against too implicit a reliance on lithological characters as tests of the relative ages of rocks. When we approach Aurillac from the west, we pass over great heathy plains, where the sterile mica-schist is barely covered with vegetation. Near Ytrac, and between La Capelle and Viscamp, we begin to see the surface strewed over with loose broken flints, some of them black in the interior, but with a white external coating, others stained with tints of yellow and red, and looking precisely like the flint gravel of our chalk districts. When heaps of this gravel have thus announced our approach to a new formation, we arrive at length at the escarpment of the lacustrine beds. At the bottom of the hill we see strata of clay and sand resting on mica-schist; and above, in the quarries of Belbet, Leybros, and Bruel, a white limestone, in horizontal strata, the surface of which has been hollowed out into irregular furrows, since filled up with broken flint, marl, and vegetable mould. We recognize in these cavities, filled with dark mould and flint gravel, an exact counterpart to

the appearances so frequently presented on the furrowed surface of our white chalk. Proceeding onwards from these quarries, along a road made of the white limestone, which reflects as glaring a light in the sun, as do our roads composed of chalk, we reach, at length, in the neighbourhood of Aurillac, hills of limestone and calcareous marl, in horizontal strata, separated in some places by regular layers of flint in nodules, the coating of each nodule being of an opaque white colour, like the exterior of the flinty nodules of our chalk. In these last the hard white substance has been ascertained to consist, in some instances, wholly of siliceous matter, and sometimes to contain a small admixture of carbonate of lime *, and the analysis of those of the Cantal would probably give the same results. The Aurillac flints have precisely the appearance of having separated from their matrix after the siliceous and calcareous matter had been blended together. The calcareous marl sometimes occupies small sinuous cavities in the flint, and the siliceous nodule, when detached, is often as irregular in form as those found in our chalk.

By what means, then, can the geologist at once decide that the limestone and silex of Aurillac are referrible to an epoch entirely distinct from that of the English chalk? It is not by reference to position, for we can merely say of the lacustrine beds, as we should have been able to declare of the true chalk had it been present, that they overlie the granitic rocks of this part of France. It is by reference to the organic remains that we are able to pronounce the formation to belong to the Eocene tertiary period. Instead of the marine Alcyonia of our cretaceous system, the silicified seed-vessels of the Chara, a plant which grows at the bottom of lakes, abound in the flints of Aurillac, both in those which are *in situ* and those forming the gravel. Instead of the Echinus and marine testacea of the chalk, we find in the marls and limestones the shells of the Planorbis, and other lacustrine testacea, all of

* Phillips, Geol. Trans. First Series, vol. v. p. 22.—Outlines of Geology, p. 95.

them, like the gyrogonites, agreeing specifically with species of the Eocene type.

*Proofs of the gradual deposition of marl.*—Some sections of the foliated marls in the valley of the Cer, near Aurillac, attest, in the most unequivocal manner, the extreme slowness with which the materials of the lacustrine series were amassed. In the hill of Barrat, for example, we find an assemblage of calcareous and siliceous marls, in which, for a depth of at least 60 feet, the layers are so thin that thirty are sometimes contained in the thickness of an inch; and when they are separated we see preserved in each the flattened stems of Charæ, or other plants, or sometimes myriads of small *paludinæ* and other fresh-water shells. These minute foliations of the marl resemble precisely some of the recent laminated beds of the Scotch marl lakes, and when divided may be compared to the pages of a book, each containing a history of a certain period of the past. The different layers may be grouped together in beds from a foot to a foot and a half in thickness, which are distinguished by differences of composition and colour, the latter being white, green, and brown. Occasionally there is a parting layer of pure flint, or of black carbonaceous vegetable matter, one inch thick, or of white pulverulent marl. We find several hills in the neighbourhood of Aurillac composed of such materials for the height of more than 200 feet from their base, the whole sometimes covered by rocky currents of trachytic or basaltic lava *.

*Concluding remarks.*—So wonderfully minute are the separate parts of which some of the most massive geological monuments are made up! When we desire to classify, it is necessary to contemplate entire groups of strata in the aggregate; but if we wish to understand the mode of their formation, and to explain their origin, we must think only of the minute subdivisions of which each mass is composed. We must bear in mind how many thin, leaf-like seams of matter, each con-

* Lyell and Murchison, sur les Dépôts Lacust. Tertiaires du Cantal, &c. Ann. des Sci. Nat., Oct. 1829.

taining the remains of myriads of testacea and plants, frequently enter into the composition of a single stratum, and how great a succession of these strata unite to form a single group! We must remember, also, that volcanos like the Plomb du Cantal, which rises in the immediate neighbourhood of Aurillac, are equally the result of successive accumulation, consisting of reiterated flows of lava and showers of scoriæ; and we have shown, when we treated of the high antiquity of Etna, how many distinct lava-currents and heaps of ejected substances are required to make up one of the numerous conical envelopes whereof a volcano is composed.—Lastly, we must not forget that continents and mountain-chains, colossal as are their dimensions, are nothing more than an assemblage of many such igneous and aqueous groups, formed also in succession during an indefinite lapse of ages, and superimposed upon each other.