

## CHAPTER XV.

Miocene period—Marine formations—Faluns of Touraine—Comparison of the Faluns of the Loire and the English Crag—Basin of the Gironde and Landes—Fresh-water limestone of Saucats—Position of the limestone of Blaye—Eocene strata in the Bordeaux basin—Inland cliff near Dax—Strata of Piedmont—Superga—Valley of the Bormida—Molasse of Switzerland—Basin of Vienna—Styria—Hungary—Volhynia and Podolia—Montpellier.

### MIOCENE FORMATIONS—MARINE.

HAVING treated in the preceding chapters of the older and newer Pliocene formations, we shall next consider those members of the tertiary series which we have termed Miocene. The distinguishing characters of this group, as derived from its imbedded fossil testacea, have been explained in the fifth chapter (p. 54). In regard to the relative *position* of the strata, they underlie the older Pliocene, and overlie the Eocene formations, when any of these happen to be present.

The area covered by the marine, fresh-water, and volcanic rocks of the Miocene period, in different parts of Europe, can already be proved to be very considerable, for they occur in Touraine, in the basin of the Loire, and still more extensively in the south of France, between the Pyrenees and the Gironde. They have also been observed in Piedmont, near Turin, and in the neighbouring valley of the Bormida, where the Apennines branch off from the Alps. They are largely developed in the neighbourhood of Vienna and in Styria; they abound in parts of Hungary; and they overspread extensive tracts in Volhynia and Podolia.

Shells characteristic of the Miocene strata are found in all these countries, figures of some of which are given in Plate 2 in this volume. They characterize the period, because they are either wanting or extremely rare in the Eocene or Pliocene formations.

We shall now proceed to notice briefly some of the countries

before enumerated as containing monuments of the era under consideration.

*Touraine.*—We have already alluded to the proofs of superposition adduced by M. Desnoyers, to show that the shelly strata provincially called ‘the Faluns of the Loire’ were posterior to the most recent fresh-water formation of the basin of the Seine. Their position, therefore, shows that they are of newer origin than the Eocene strata,—more recent, at least, than the uppermost beds of the Paris basin. But an examination of their fossil contents proves also that they are referrible to that type which distinguishes the Miocene period. When three hundred of the Touraine shells were compared with more than eleven hundred of the Parisian species, there were scarcely more than twenty which could be identified; and, on the other hand, the fossil shells of the Touraine beds agree far less with the testacea now inhabiting our seas than does the group occurring in the older Pliocene strata of northern Italy.

The Miocene strata of the Loire have been observed to repose on a great variety of older rocks between Sologne and the sea, in which line they are seen to rest successively upon gneiss, clay-slate, coal-measures, Jura limestone, greenstone, chalk, and lastly upon the upper fresh-water deposits of the basin of the Seine. They consist principally of quartzose gravel, sand, and broken shells. The beds are generally incoherent, but sometimes agglutinated together by a calcareous or earthy cement, so as to serve as a building-stone. Like the shelly portion of the crag of Norfolk and Suffolk, the *faluns* and associated strata are of slight thickness, not exceeding seventy feet. They often bear a close resemblance to the crag in appearance, the shells being stained of the same ferruginous colour, and being in the same state of decay; serving in Touraine, just as in Norfolk and Suffolk, to fertilize the arable land. Like the crag, also, they contain mammiferous remains, which are not only intermixed with marine shells, but sometimes encrusted with *serpulæ*, *flustra*, and *balani*. These

terrestrial quadrupeds belong to the genera Mastodon, Rhinoceros, Hippopotamus, &c., the assemblage, considered as a whole, being very distinct from those of the Paris gypsum.

I examined several detached patches of the Touraine beds, where they rest on primary strata in the environs of Nantes, particularly one locality at Les Cleons, about eight miles south-east of that town, and was struck with the evidence afforded by them of the emergence of large intervening tracts of granitic schist since the Miocene era, which we might otherwise have supposed to have been raised at a very remote epoch. It is probable that these patches of tertiary deposits were originally local, having been thrown down wherever the set of the tides and currents permitted an accumulation to take place.

The faluns and contemporary strata of the basin of the Loire may be considered generally as having been formed in a shallow sea, into which a river, flowing perhaps from some of the lands now drained by the Loire, introduced from time to time fluviatile shells, wood, and the bones of quadrupeds, which may have been washed down during floods. Some of these bones have precisely the same black colour as those found in the peaty shell-marl of Scotland; and we might imagine them to have been dyed black in *Miocene peat* which was swept down into the sea during the waste of cliffs, did we not find the remains of cetacea in the same strata, bones, for example, of the lamantine, morse, sea-calf, and dolphin, having precisely the same colour.

*Comparison of the Faluns of the Loire and the English Crag.*—The resemblance which M. Desnoyers has pointed out as existing between the English *crag* and the French *faluns* is one which ought by no means to induce us to ascribe a contemporaneous origin to these two groups, but merely a similarity of geographical circumstances at the respective periods when each was deposited. In every age, where there is land and sea, there must be shores, shallow estuaries, and rivers; and near the sea-coasts banks of marine shells and corals may accumulate. It must also be expected that rivers will drift in

fresh-water shells, together with sand and pebbles, and occasionally, perhaps, sweep down the carcasses of land quadrupeds into the sea. If the sand and shells, both of the 'crag' and the 'faluns' have each acquired the same ferruginous colour, such a coincidence would merely lead us to infer that, at each period, there happened to be springs charged with iron, which flowed into some part of the sea or basin of the river, by which the sediment was carried down into the sea.

Even had the French and English strata which we are comparing shared a greater number of mineral characters in common, that identity could not have justified us in inferring the synchronous date of the two groups, where the discordance of fossil remains is so marked. The argument which infers a contemporaneous origin from correspondence of mineral contents, proceeds on the supposition that the materials were either washed down from a common source, or from different sources into a common receptacle. If, according to the latter hypothesis, the crag and the faluns were thrown down in one continuous sea, the testacea could not have been so distinct in two very contiguous regions, unless we assume that the laws which regulated the geographical distribution of species were then distinct from those now prevailing. But if it be said that the two basins may have been separated from each other, as are those of the Mediterranean and Red Sea, by an isthmus, and that distinct assemblages of species may have flourished in each, as in the example above-mentioned is actually the case\*, we may reply that such narrow lines of demarcation are extremely rare now, and must have been infinitely more so in remoter tertiary epochs, because there can be no doubt that the proportion of land to sea has been greatly on the increase in European latitudes during the more modern geological eras.

In the *fuluns*, and in certain groups of the same age, which occur not far to the west of Orleans, M. Desnoyers has discovered the following mammiferous quadrupeds. *Palæothe-*

\* See above, chap. x.

*rium magnum*, *Mastodon angustidens*, *Hippopotamus major*, and *H. minutus*, *Rhinoceros leptorhinus*, and *R. minutus*, *Tapir gigas*, *Anthracotherium* (small species), *Sus*, *Equus* (small species), *Cervus*, and an undetermined species of the Rodentia.

The first species on this list is common to the Paris gypsum, and is therefore an example of a land quadruped common to the Miocene and Eocene formations, an exception perfectly in harmony with the results obtained from the study of fossil shells\*.

*Basin of the Gironde and district of the Landes.*—A great extent of country between the Pyrenees and the Gironde is overspread by tertiary deposits which have been more particularly studied in the environs of Bordeaux and Dax, from whence about 600 species of shells have been obtained. These shells belong to the same type as those of Touraine.—See Appendix I.†

Most of the beds near Dax, whence these shells are procured, consist of incoherent quartzose sand, mixed for the most part with calcareous matter, which has often bound together the sand into concretionary nodules. A great abundance of fluviatile shells occur in many places intermixed with the marine; and in some localities microscopic shells are in great profusion.

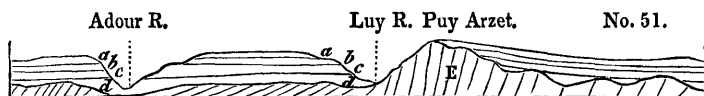
The tertiary deposits in this part of France are often very inconstant in their mineralogical character, yet admit generally of being arranged in four groups, which are enumerated in the explanation of diagram No. 51.

In some places the united thickness of these groups is considerable, but in the country between the Pyrenees and the valley of the Adour around Dax, the disturbed secondary rocks

\* For further details respecting the basin of the Loire, see M. Desnoyers, *Ann. des Sci. Nat.*, tome xvi. pp. 171 and 402, where full references to other authors are given.

† M. de Basterot has given a description of more than 300 shells of Bordeaux and Dax, and figures of the greater number of them. *Mém. de la Soc. d'Hist. Nat. de Paris*, tome ii.

are often covered by a thin pellicle only of tertiary strata, which rests horizontally on the chalk and does not always conceal it.



*Tertiary strata overlying chalk in the environs of Dax.*

- |                                   |                               |
|-----------------------------------|-------------------------------|
| a, Siliceous sand without shells. | c, Sand and marl with shells. |
| b, Gravel.                        | d, Blue marl with shells.     |
| E, Chalk and volcanic tuff.       |                               |

In the valleys of the Adour and Luy, sections of all the members of the tertiary series are laid open, but the lowest blue marl, which is sometimes 200 feet thick, is not often penetrated. On the banks of the Luy, however, to the south of Dax, the subjacent white chalk is exposed in inclined and vertical strata. In the hill called Puy Arzet the chalk, characterized by its peculiar fossils, is accompanied by beds of volcanic tuff, which are conformable to it, and which may be considered as the product of submarine eruptions which took place in the sea wherein the chalk was formed.

About a mile west of Orthès, in the Bas Pyrenees, the blue marl is seen to extend to the borders of the tertiary formation, and rises to the height probably of six or seven hundred feet. In that locality many of the marine Miocene shells preserve their original colours. This marl is covered by a considerable thickness of ferruginous gravel, which seems to increase in volume near the borders of the tertiary basin on the side of the Pyrenees.

In an opposite direction, to the north of Dax, the shelly sands often pass into calcareous sandstone, in which there are merely the casts of shells as at Carcares, and into a shelly breccia resembling some rocks of recent origin which I have received from the coral reefs of the Bermudas.

*Fresh-water limestone at Saucats.*—Associated with the Miocene strata near Bordeaux, at a place called Saucats, is a

compact fresh-water limestone, of slight thickness, which is perforated on the upper surface by marine shells, for the most part of extinct species. It is evident that the space must have been alternately occupied by salt and fresh water. First, a lagoon may have been formed, in which the water may have become fresh; then a barrier of sand, by which the sea was excluded for a time, may have been breached, whereby the salt water again obtained access.

*Eocene strata in the Bordeaux basin.*—The relations of some of the members of the tertiary series, in the basin of the Gironde, have of late afforded matter of controversy. A limestone, resembling the calcaire grossier of Paris, and from 100 to 200 feet in thickness, occurs at Pauliac and Blaye, and extends on the right bank of the Gironde, between Blaye and La Roche. It contains many species of fossils identical with those of the Paris basin. This fact was pointed out to me by M. Deshayes before I visited Blaye in 1830; but although I recognized the mineral characters of the rock to be very different from those of the Miocene formations in the immediate neighbourhood of Bordeaux, I had not time to verify its relative position. I inferred, however, the inferiority of the Blaye limestone to the Miocene strata, from the order in which each series presented itself as I receded from the chalk and passed to the central parts of the Bordeaux basin.

Upon leaving the white chalk with flints, in travelling from Charente by Blaye to Bordeaux, I first found myself upon overlying red clay and sand (as at Mirambeau); I then came upon the tertiary limestone above alluded to, at Blaye; and lastly, on departing still farther from the chalk, reached the strata which at Bordeaux and Dax contain exclusively the Miocene shells.

The occurrence both of Eocene and Miocene fossils in the same basin of the Gironde, had been cited by M. Boué as a fact which detracted from the value of zoological characters as a means of determining the chronological relations of tertiary

groups. But on farther inquiry, the fact, on the contrary, has furnished additional grounds of confidence in these characters.

M. Ch. Desmoulins replied, in answer to M. Boué's objections, that the assemblage of Eocene shells are never intermixed with those found in the 'moellon,' as he calls the sandy calcareous rock of the environs of Bordeaux and Dax; and M. Dufrénoy farther stated, that the hills of limestone which border the right bank of the Gironde, from Marmande as far as Blaye, present several sections wherein the Parisian (or Eocene) limestone is seen to be separated from the shelly strata called 'faluns,' or 'moellon,' by a fresh-water formation of considerable thickness. It appears, therefore, that as the marine faluns of Touraine rest on a fresh-water formation, which overlies the marine calcaire grossier of Paris, so the marine Miocene strata of Bordeaux are separated from those of Blaye by a fresh-water deposit\*.

The following diagram, therefore, will express the order of position of the groups above alluded to.

No. 52.



*a*, Red clay and sand.

*b*, Limestone like calcaire grossier, sometimes alternating with green marl and containing Eocene shells.

*c*, Fresh-water formation, same as that of the department of Lot and Garonne.

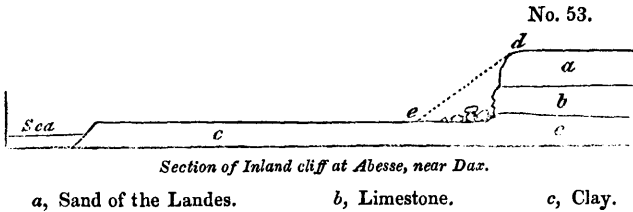
*d*, Tertiary strata of the Landes, with Miocene fossils.

*Inland cliff near Dax.*—A few miles west from Dax, and at the distance of about twelve miles from the sea, a steep bank is seen running in a direction nearly north-east and south-west, or parallel to the contiguous coast. This steep declivity, or *brae*, which is about 50 feet in height, conducts us from the higher platform of the Landes to a lower plain which extends to the sea. The outline of the ground might suggest to every geologist the opinion, that the bank in question was once

\* Bulletin de la Soc. Géol. de France, tome ii. p. 440.



a sea-cliff, when the whole country stood at a lower level



relatively to the sea. But this can no longer be regarded as matter of conjecture. In making excavations recently for the foundation of a building at Abesse, a quantity of loose sand, which formed the slope *d, e*, was removed, and a perpendicular cliff exposed about 50 feet in height. The bottom of this cliff consists of limestone, *b*, which contains shells and corals of Miocene species, and is probably a calcareous form of the division *c* (diagram No. 51, p. 207). Immediately below this limestone is the clay *c* (probably *d*, diagram No. 51, p. 207), and above it the usual tertiary sand *a* of the department of the Landes. At the base of the precipice are seen large, partially-rounded, masses of rock, evidently detached from the stratum *b*. The face of the limestone is hollowed out and weathered into such forms as are seen in the calcareous cliffs of the adjoining coast, especially at Biarritz, near Bayonne\*. It is evident that, when the country was at a somewhat lower level, the sea advanced along the surface of the argillaceous stratum *c*, which, by its yielding nature, favoured the waste and undermining of the more solid superincumbent limestone *b*. Afterwards, when the country had been elevated, part of the sand *a* fell down, or was drifted by the winds, so as to form the talus *d, e*, which masked the inland cliff until it was artificially laid open to view.

The situation of this cliff is interesting, as marking one of the pauses which intervened between the successive movements of elevation whereby the marine tertiary strata of this country

\* This spot was pointed out to me by the proprietor of the lands of Abesse in 1830.

were upheaved to their present height, a pause which allowed time for the sea to advance and strip off the upper beds *a*, *b*, from the denuded clay *c*.

*Hills of Mont Ferrat and the Superga.*—The late Signor Bonelli of Turin was the first who remarked that the tertiary shells found in the green sand and marl of the Superga near Turin differed, as a group, from those generally characteristic of the Subapennine beds. The same naturalist had also observed, that many of the species peculiar to the Superga were identical with those occurring near Bordeaux and Dax. The strata of which the hill of the Superga is composed, are inclined at an angle of more than 70 degrees. They consist partly of fine sand and marl, and partly of a conglomerate composed of primary boulders, which forms a lower part of the series, and not, as represented by M. Brongniart by mistake \*, an unconformable and overlying mass †. This same series of beds is more largely developed in the chain of Mont Ferrat, especially in the basin of the Bormida. The high road which leads from Savona to Alessandria intersects them in its northern descent, and the formation may be well studied along this line at Carcare, Cairo, and Spinto, at all which localities fossil shells occur in a bright green sand. At Pianà, a conglomerate, interstratified with this green sand, contains rounded blocks of serpentine and chlorite schist, larger than those near the summit of the Superga, some of the blocks being not less than nine feet in diameter.

When we descend to Aqui, we find the green sand giving place to bluish marls, which also skirt the plains of the Tanaro at lower levels. These newer marls are associated with sand, and are nearly horizontal, and appear to belong to the older Pliocene Subapennine strata ‡. The shells which characterize the latter, abound in various parts of the country near Turin; but that region has not yet been examined with sufficient care to enable us to give exact sections to illustrate the superpo-

\* Terrains du Vicentin, p. 26.

† I examined the Superga in company with Mr. Murchison in 1828.

‡ See section, wood-cut No. 4, p. 21.

sition of the Miocene and older Pliocene beds. It is, however, ascertained, that the highly-inclined green sand, which comes immediately in contact with the primary rocks, is the oldest part of the series\*.

*Molasse of Switzerland.*—If we cross the Alps, and pass from Piedmont to Savoy, we find there, at the northern base of the great chain and throughout the lower country of Switzerland, a soft green sandstone, much resembling some of the beds of the basin of the Bormida, above described, and associated in a similar manner with marls and conglomerate. This formation is called, in Switzerland, ‘molasse,’ said to be derived from ‘mol,’ ‘soft,’ because the stone is easily cut in the quarry. It is of vast thickness, but shells have so rarely been found in it that they do not supply sufficient data for correctly determining its age. M. Studer, in his treatise on the ‘molasse,’ enumerates some fossil shells found near Lucerne, agreeing, apparently, with the testacea of the Subapennine hills. The correspondence in mineral character between the green sand of Piedmont and that of Switzerland can in nowise authorise us to infer identity of age, but merely to conclude that both have been derived from the degradation of similar ancient rocks.

Until the place of the ‘molasse’ in the chronological series of tertiary formations has been more rigorously determined, the application of this provincial name to the tertiary groups of other countries must prove a source of ambiguity, and we regret that the term has been so vaguely employed by M. Boué.

*Styria, Vienna, Hungary, &c.*—Of the various groups which have hitherto been referred to the Miocene era, none are so important in thickness and geographical extent as those which are found at the eastern extremity of the Alps, in what have been termed the basins of Vienna and Styria, and which spread thence into the plains of Hungary. The collection of shells formed by M. Constant Prevost, in the neighbourhood of

\* We trust that MM. Pareto, Passini, Sismonda, and La Marmora, will devote their attention to the relative position of the several groups of tertiary strata in Piedmont, by instituting a comparison between their respective organic remains.

Vienna, and described by him in 1820\*, were alone sufficient to identify a great part of the formations of that country with the Miocene beds of the Loire, Gironde, and Piedmont. The fossil remains subsequently procured by that indefatigable observer M. Boué have served to show the still greater range of the same beds through Hungary and Transylvania.

It appears from the recently published memoirs of Professor Sedgwick and Mr. Murchison †, that the formations in Styria may be divided into groups corresponding to those adopted by M. Partsch for the Vienna beds; the basin of Vienna exhibiting nearly the same phenomena as that of Styria. These regions have evidently formed, during the Miocene period, two deep bays of the same sea, separated from each other by a great promontory connected with the central ridge of the eastern Alps.

The English geologists, above mentioned, describe a long succession of marine strata intervening between the Alps and the plains of Hungary, which are divisible into three natural groups, each of vast thickness, and affording a great variety of rocks. All these groups are of marine origin, and lie in nearly horizontal strata, but have a slight prevailing easterly dip, so that, in traversing them from west to east, we commence with the oldest and end with the youngest beds. At their western extremity they fill an irregular trough-shaped depression, through which the waters of the Mur, the Raab, and the Drave, make their way to the lower Danube ‡. They here consist of conglomerate, sandstone, and marls, some of the marls containing marine shells. Beds also of lignite occur, showing that wood was drifted down in large quantities into the sea. In parts of the series there are masses of rounded siliceous pebbles resembling the shingle banks which are forming on some of our coasts.

The second principal group is characterized by coralline

\* Journal de Physique, Novembre, 1820.

† Geol. Trans., Second Series, vol. iii. p. 301.

‡ Ibid., p. 382.

and concretionary limestone of a yellowish white colour : it is finely exposed in the escarpments of Wildon, and in the hills of Ehrenhausen, on the right bank of the Mur\*. This coralline limestone is not less than 400 feet thick at Wildon, and exceeds, therefore, some of the most considerable of our secondary groups in England, as, for example, the 'Coral Rag †.'

Beds of sandstone, sand, and shale, and calcareous marls, are associated with the above-mentioned limestone.

The third group, which occurs at a still greater distance from the mountains, is composed of sandstone and marl, and of beds of limestone, exhibiting here and there a perfectly oolitic structure. In this system fossil shells are numerous.

It is by no means clear that the coralline limestones of the second group, are posterior in origin to all the beds of the first division ; they may possibly have been formed at some distance from land, while the head of the gulf was becoming filled up with enormous deposits of gravel, sand, and mud, which may, in that quarter, have rendered the waters too turbid for the fullest development of testaceous and coralline animals.

In regard to the age of the formations above described, we may observe that the middle group, both in the basins of Styria and Vienna, belongs indisputably to the Miocene period, for the species of shells are the same as those of the Loire, Gironde, and other contemporary basins before noticed. Whether the lowest and uppermost systems are referrible to the same, or to distinct tertiary epochs, is the only question. We cannot doubt that the accumulation of so vast a succession of beds required an immense lapse of ages, and we are prepared to find some difference in the species characterizing the different members of the series ; nevertheless, all may belong to different subdivisions of the Miocene period. Professor Sedgwick and Mr. Murchison have suggested that the inferior, or first group, which comprises the strata between the Alps and the coralline

\* Geol. Trans., Second Series, vol. iii. p. 385.

† Ibid., p. 390.

limestone of Wildon, may correspond in age to the Paris basin ; but the list of fossils which they have given, seems rather to favour the supposition, that the deposit is of the Miocene era. They enumerate four characteristic Miocene fossils,—*Mytilus Brardii*, *Cerithium pictum*, *C. pupæforme*, and *C. plicatum*,—and if there are some few of the associated shells common to the Paris basin, such a coincidence is no more than holds true in regard to all the European Miocene formations.

On the other hand, the third or newest system, which overlies the coralline limestone, contains fossils which do not appear to depart so widely from the Miocene type as to authorize us to separate them. They appear to agree with the tertiary strata of a great part of Hungary and Transylvania, which will be seen, by the tables of shells in Appendix I., to be referrible to the Miocene period.

*Volhynia and Podolia.*—We may expect to find many other districts in Europe composed of Miocene strata, and there appears already to be sufficient evidence that the marine deposits of the platform of Volhynia and Podolia were of this era. The fossils of that region, which is bounded by Galicia on the west, and the Ukraine on the east, and comprises parts of the basins of the Bog and the Dniester, has been investigated by Von Buch, Eichwald, and Du Bois, and the latter has given excellent plates of more than one hundred fossil shells of the country, which M. Deshayes finds to agree decidedly with the fossils of the Miocene period\*.

The formation consists of different rocks, sand and sandstone, clay, coarse limestone, and a white oolite, the last of which is of great extent.

*Montpellier.*—The tertiary strata of Montpellier contain many of the Dax and Bordeaux species of shells, so that they are probably referrible to the Miocene epoch ; but in the catalogue given by M. Marcel de Serres, many *Pliocene* species, similar to those of the Subapennine beds, are enumerated.

\* *Conch. Foss. du Plateau Wolhyni-Podo*, par F. du Bois. Berlin, 1831.

This subject requires fuller investigation, and it would be highly interesting if the Montpellier beds should be found to indicate a passage from the fossils of the Miocene type to those of the older Pliocene. We are fully prepared for the discovery of such intermediate links, and we have endeavoured to provide a place for them in the classification proposed in the fifth chapter\*.

\* Page 57.

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