CHAPTER XXIII.

Secondary formations—Brief enumeration of the principal groups—No species common to the secondary and tertiary rocks—Chasm between the Eocene and Maestricht beds—Duration of secondary periods—Former continents placed where it is now sea—Secondary fresh-water deposits why rare—Persistency of mineral composition why apparently greatest in older rocks—Supposed universality of red marl formations—Secondary rocks why more consolidated—Why more fractured and disturbed—Secondary volcanic rocks of many different ages.

SECONDARY FORMATIONS.

As we have already exceeded the limits originally assigned to this work, it is not our intention to enter, at present, upon a detailed description of the formations usually called 'Secondary,' the elucidation of which might well occupy another volume. By 'secondary,' we mean those stratified rocks older than the tertiary, which contain distinct organic remains, and which sometimes pass into the strata called 'Primary,' to be described in our concluding chapters.

The observations which we are about to offer have chiefly for their object to show that the rules of interpretation adopted by us for the tertiary formations, are equally applicable to the phenomena of the secondary series. This last has been divided into several groups, and we shall briefly enumerate some of the principal of these for the convenience of reference, without pretending to offer to the student a systematic classification, founded on a full comparison of fossil remains.

PRINCIPAL SECONDARY GROUPS. (*Descending Series.*)

1. *Strata from the chalk of Maestricht to the lower green-sand inclusive.*

The number of species of testacea already procured from the different members of this division amount to about 1000. The principal subdivisions are the Maestricht beds, the chalk with and without flints, the upper green-sand, the gault, and the lower green-sand. The first of these groups is seen at St. Peter's Mount, Maestricht, reposing upon the upper flinty chalk of England and France. It is characterized by a peculiar assemblage of organic remains, perfectly distinct from those of the tertiary period. M. Deshayes, after a careful comparison, and after making drawings of more than 200 species of the Maestricht shells, has been unable to identify any one of them with the numerous tertiary fossils in his collection. On the other hand, there are several shells which are decidedly common to the calcareous beds of Maestricht and the white chalk. The names of twelve of these, communicated by M. Deshayes, will be found in Appendix II., p. 60.

But the fossils of the Maestricht beds extend not merely into the white chalk of the French geologists, but into their 'green-sand,' which appears to correspond very nearly with the upper green-sand of the English geologists. A list of five species of shells, common to the Maestricht beds and the upper green-sand of France, will be found in Appendix II., p. 60.

It will be seen by the above lists, that the belemnite, one of the cephalopodes not found in any tertiary formation, occurs in the Maestricht beds; an ammonite has also been discovered in this group by Dr. Fitton, and is now in the collection of the Geological Society of London.

That gigantic species of reptile, the Mososaurus of Maestricht, has also been found by Mr. Mantell in the English chalk.

2. *The Wealden, or the strata from the Weald clay to the Purbeck limestone inclusive.*

The numerous fossil-shells of this group are referrible to fresh-water genera, which are associated with many remains of fluviatile and terrestrial reptiles and land-plants. We believe that no species, whether animal or vegetable, in this group, has been distinctly identified with any found either in the super-incumbent marine beds of the first division, or in the subjacent rocks of the group No. 3, which are also of marine origin.

3. *Oolite, or Jura limestone formation.*

This division, in which we do not include the lias, contains a great number of subordinate members, several of which may relate, perhaps, to periods as important as our subdivisions of the great tertiary epoch. The shells, even of the uppermost part of the series, appear to differ entirely from the species found in the division No. 1.

4. *The Lias.*

The shells of the argillaceous limestone, termed lias, and other associated strata, differ considerably from those of the preceding group, as do the greater number of species of vertebrated animals.

5. *Strata intervening between the Lias and the Carboniferous group.*

The formations which are referrible to the interval which separated the great coal formations from the division last mentioned, are very various, and some of them, like the new red sandstone, contain few organic remains. One group, however, belonging to this period, the Muschelkalk of the Germans, which has no precise equivalent among the English strata, contains many organic remains belonging to species perfectly distinct from the fossils of the lias, and equally so from those of the carboniferous era next to be mentioned.

6. *Carboniferous group, comprising the coal-measures, the mountain limestone, the old red sandstone, the transition limestone, the coarse slates and slaty sandstones called graywacke by some writers, and other associated rocks.*

The mountain and transition limestones of the English geologists contain many of the same species of shells in common, and we shall therefore refer them for the present to the same great period; and, consequently, the coal, which alternates in some districts with mountain limestone, and the old red sandstone which intervenes between the mountain and transition limestones, will be considered as belonging to the same period. The coal-bearing strata are characterized by several hundred species of plants, which serve very distinctly to mark the vegetation of part of this era. Some of the rocks, termed graywacke in Germany, are connected by their fossils with the mountain limestone.

With this group we shall conclude our enumeration for the present; for although other divisions may hereafter be requisite, we are not aware that any antecedent periods can yet be established on the evidence of a distinct assemblage of fossil remains. Traces of organization undoubtedly occur in rocks more ancient than the transition limestone, and its associated sandstones, called graywacke; but we cannot refer them to a distinct geological period, according to the principles laid down in this work, until we have obtained data for determining the specific characters of a considerable number of fossil remains.

In reviewing the above groups we may first call the reader's attention to the important fact stated on the authority of M. Deshayes, that no species of fossil shells has yet been found common to the secondary and tertiary formations*. This marked discordance in the organic remains of the two series is not confined to the testacea, but extends, so far as a careful comparison has yet been instituted, to all the other departments of the animal kingdom, and to the fossil plants. I am informed by M. Agassiz, whose great work on fossil fish is anxiously looked for by geologists, that after examining about 500 species of that class, in formations of all ages, he could discover no one common to the secondary and tertiary rocks; nay, all the secondary species hitherto known to him, belong to

* M. Deshayes assures me that he has seen no tertiary shells in the Gosau beds, supposed by some geologists to be intermediate between the secondary and tertiary formations; but that some of the most characteristic species of Gosau occur in the green-sand beneath the chalk, at Mons in Belgium.

genera distinct from those established for the classification of tertiary and recent fish.

Chasm between the Eocene and Maestricht formations.—There appears, then, to be a greater chasm between the organic remains of the Eocene and Maestricht beds, than between the Eocene and Recent strata; for there are some living shells in the Eocene formations, while there are no Eocene fossils in the newest secondary group. It is not improbable that a greater interval of time may be indicated by this greater dissimilarity in fossil remains. In the 3rd and 4th chapters we endeavoured to point out that we have no right to expect, even when we have investigated a greater extent of the earth's surface, that we shall be able to bring to light an unbroken chronological series of monuments from the remotest eras to the present; but as we have already discovered a long succession of deposits of different ages, between the tertiary groups first known and the *recent* formations, so we may, perhaps, hereafter detect an equal, or even greater series, intermediate between the Maestricht beds and the Eocene strata.

Duration of secondary periods.—The different subdivisions of the secondary group No. 1, extending from the chalk of Maestricht to the lower green-sand inclusive, may, perhaps, relate to a lapse of ages as immense as the united tertiary periods, of which we have sketched the eventful history in this volume. Such a conjecture, at least, seems warranted, if we can form any estimate of the quantity of time, by comparing the amount of vicissitude in animal life which has occurred during its lapse.

Position of former continents.—The existence of sea as well as land, at every geological period, is attested by the remains of terrestrial plants imbedded in the deposits of all ages, even the most remote. We find fluviatile shells not unfrequently in the secondary strata, and here and there some fresh-water formations; but the latter are less common than in the tertiary series. For this fact we have prepared the reader's mind, by the views advanced in the third chapter respecting the different circumstances under which we conceive the secondary and tertiary strata to have originated. We have there hinted, that the former may have been accumulated in an ocean like the Pacific, where coralline and shelly limestone are forming, or in a basin like the bed of the western Atlantic, which may have received for ages the turbid waters of great rivers, such as the Amazon, and Orinoco, each draining a considerable extent of continent. The *tertiary* deposits, on the other hand, may have been accumulated during the growth of a continent, by the successive emergence of new lands, and the uniting together of islands. During such changes, inland seas and lakes would be caused, and afterwards filled up with sediment, and then raised above the level of the waters.

That the greater part of the space now occupied by the European continent was sea when some of the secondary rocks were produced, must be inferred from the wide areas over which several of the marine groups are diffused; but we do not suppose that the quantity of land was less in those remote ages, but merely that its position was very different. In the above tabular view of the secondary rocks, we have shown that immediately below the division No. 1, or 'the chalk and green-sand,' is placed a fresh-water formation called, in the south-east of England, the Wealden. This group has been ascertained to extend from west to east (from Lulworth Cove to the boundary of the Lower Boulonnois) about 200 English miles, and from north-west to south-east (from Whitchurch to Beauvais), about 220 miles, the depth or total thickness of the beds, where greatest, being about 2000 feet *.

Now these phenomena most clearly indicate, that there was a constant supply in this region, for a long period, of a considerable body of fresh water, such as might be supposed to have drained a continent, or a large island, containing within it a lofty chain of mountains. Dr. Fitton, in speaking of these appearances, recalls to our recollection that the delta of the newly-discovered Quorra, or Niger, in Africa, stretches into the interior

* Fitton's Geology of Hastings, p. 58.

for more than 170 miles, and occupies, it is supposed, a space of more than 300 miles along the coast, thus forming a surface of more than 25,000 square miles, or equal to about one half of England *.

Now if this modern 'delta,' or, in other words, that part of the bed of the Atlantic which has been converted into land by matter deposited immediately at the river's mouth, be so extensive, how much larger may be the space over which the same kind of sediment may be distributed by the action of the tides and currents! If, then, groups like the Wealden may be formed near the mouths of great rivers, others, like the lias, may be produced by the wider dispersion of similar materials over larger submarine areas. For we may conceive that the Niger may carry out the remains of land plants, and the carcasses and bones of fluviatile reptiles, into places where they may be swept away by currents and afterwards mingled far and wide with the marine shells and corals of the Atlantic.

The reader will remember that we stated, in the first volume†, that the common crocodile of the Ganges frequents both fresh and salt water, the same species being sometimes seen far inland, many hundred miles from the sea, and at the same time swarming on the sand-banks in the salt and brackish water beyond the limits of the delta.

If we are asked where the continent was placed from the ruins of which the Wealden strata were derived, we are almost tempted to speculate on the former existence of the Atlantis of Plato, which may be true in geology, although fabulous as an historical event. We know that the present European lands have come into existence almost entirely since the deposition of the chalk, and the same period may have sufficed for the disappearance of a continent of equal magnitude, situated farther to the west.

Secondary fresh-water deposits why rare.—If there were extensive tracts of land in the secondary period, we may presume that there were lakes also; yet we are not aware of any

* Fitton's Geology of Hastings, p. 58, who cites Lander's Travels.

† Page 243; Second Edition, p. 279.

pure lacustrine formations interstratified with rocks older than the chalk. Perhaps their absence may be accounted for by the adoption of the theoretical views above set forth; for if the present ocean coincides for the most part with the site of the ancient continent, the places occupied by lakes must have been submerged. It should also be recollected, that the area covered by lakes, at any one time, is very insignificant in proportion to the sea, and, therefore, we may expect that, after the earth's surface has undergone considerable revolutions in its physical geography, the lacustrine strata will be concealed, for the most part, under superimposed marine deposits.

Persistency of mineral character.—In the same manner as it is rare and difficult to find ancient lacustrine strata, so also we can scarcely expect to discover newer marine groups preserving the same lithological characters continuously throughout wide areas. The chalk now seen stretching for thousands of miles over different parts of Europe, has become visible to us by the effect, not of one, but of many distinct series of movements. Time has been required, and a succession of geological periods, to raise it above the waves in so many regions; and if calcareous rocks of the Eocene or Miocene periods have been formed, preserving an homogeneous mineral composition throughout equally extensive regions, it may require convulsions as numerous as all those which have occurred since the origin of the chalk, to bring them up within the sphere of human observation. Hence the rocks of more modern periods may appear of partial extent, as compared to those of remoter eras, not because there was any original difference of circumstances throughout the globe when they were formed, but because there has not been sufficient time for the development of a great series of subterranean volcanic operations since their origin.

At the same time, the reader should be warned not to place implicit reliance on the alleged persistency of the same mineral characters in secondary rocks *. When it was first ascertained that an order of succession could be traced in the principal

* See some remarks on this subject, vol. i. p. 90, and Second Edition, p. 102.

groups of strata above enumerated by us, names were given to each, derived from the mineral composition of the rocks in those parts of Germany, England or France, where they happened to be first studied. When it was afterwards acknowledged that the zoological and phytological characters of the same formations were far more persistent than their mineral peculiarities, the old names were still retained, instead of being exchanged for others founded on more constant and essential characters. The student was given to understand, that the terms chalk, green-sand, oolite, red marl, coal, and others, were to be taken in a liberal and extended sense; that chalk was not always a cretaceous rock, but, in some places, as on the northern flanks of the Pyrenees, and in Catalonia, a saliferous red marl. Green-sand, it was said, was rarely green, and frequently not arenaceous, but represented in parts of the south of Europe by a hard dolomitic limestone. In like manner, it was declared that the oolitic texture was rather an exception to the general rule in rocks of the oolitic period, and that no particle of carbonaceous matter could often be detected in the true *coal* formation of many districts where it attains great thickness. It must be obvious to every one, that inconvenience and erroneous prepossessions could hardly fail to arise from such a nomenclature, and accordingly a fallacious mode of reasoning has been widely propagated, chiefly by the influence of a language so singularly inappropriate.

After the admission that the identity or discordance of mineral character was by no means a sure test of agreement or disagreement in the age of rocks, it was still thought, by many geologists, that if they found a rock at the antipodes agreeing precisely in mineral composition with another well known in Europe, they could fairly presume that both are of the same age, *until the contrary could be shown.*

Now it is usually difficult or impossible to combat such an assumption, on geological grounds, so long as we are imperfectly acquainted with the geology of a distant country, inasmuch as there are often no organic remains in the foreign stratum, and even if these abound and are specifically different from the fossils of the supposed European equivalent, it may be objected, that we cannot expect the same species to have inhabited very distant quarters of the globe at the same time.

Supposed universality of red marl.—We shall select a remarkable example of the erroneous mode of generalizing now alluded to. A group of red marl and sandstone, sometimes containing salt and gypsum, is found in England interposed between the lias and the carboniferous strata. For this reason, other red marls and sandstones, associated some of them with salt and others with gypsum, and occurring not only in different parts of Europe, but in Peru, India, the salt deserts of Asia, those of Africa, in a word, in every quarter of the globe, have been referred to one and the same period. The burden of proof is not supposed to rest with those who insist on the identity of age of all these groups, so that it is in vain to urge as an objection, the improbability of the hypothesis which would imply that all the moving waters on the globe were once simultaneously charged with sediment of a red colour.

But the absurdity of pretending to identify, in age, all the red sandstones and marls in question, has at length been sufficiently exposed, by the discovery that, even in Europe, they belong decidedly to many different epochs. We have already ascertained, that the red sandstone and red marl with which the rock-salt of Cardona is associated, may be referred to the period of our chalk and green-sand *. We have pointed out that in Auvergne there are red marls and variegated sandstones, which are undistinguishable in mineral composition, from the new red sandstone of English geologists, but which were deposited in the Eocene period ; and, lastly, the gypseous red marl of Aix in Provence, formerly supposed to be a marine secondary group, is now acknowledged to be a tertiary freshwater formation.

* I was led to this opinion when I visited Cardona in 1830, and before I was aware that M. Dufrénoy had arrived at the same conclusions. Ann. des Sci. Nat., Avril, 1831, p. 449.

Secondary rocks why more consolidated.—One of the points where the analogy between the secondary and tertiary formations has been supposed to fail is the greater degree of solidity observable in the former. Undoubtedly the older rocks, in general, are more stony than the newer; and most of the tertiary strata are more loose and incoherent in their texture than the secondary. Many exceptions, however, may be pointed out, especially in those calcareous and siliceous deposits which have been precipitated in great part from the waters of mineral springs, and have been originally compact. Of this description are a large proportion of the Parisian Eocene rocks, which are more stony than most of the English secondary groups.

But a great number of strata have evidently been consolidated *subsequently to their deposition* by a slow lapidifying process. Thus loose sand and gravel are bound together by waters holding carbonate and oxide of iron, carbonate of lime, silica, and other ingredients, in solution. These waters percolate slowly the earth's crust in different regions, and often remove gradually the component elements of fossil organic bodies, substituting other substances in their place. It seems, moreover, that the draining off of the waters during the elevation of land may often cause the *setting* of particular mixtures, in the same manner as mortar hardens when desiccated, or as the recent soft marl of Lake Superior becomes highly indurated when exposed to the air *. The conversion of clay into shale, and of sand into sandstone, may, in many cases, be attributed to simple pressure, produced by the weight of superincumbent strata, or by the upward heaving of subjacent masses during earthquakes. Heat is another cause of a more compact and crystalline texture, which will be considered when we speak of the strata termed 'primary.' All the changes produced by these various means require *time* for their completion; and this may explain, in a satisfactory manner, why the older rocks are most consolidated, without

* Vol. i. p. 226, and Second Edition, p. 259.

entitling us to resort to any hypothesis respecting an *original* distinctness in the degree of lapidification of the secondary strata.

Secondary rocks why more disturbed.—As the older formations are generally more stony, so also they are more fractured, curved, elevated, and displaced, than the newer. Are we, then, to infer, with some geologists, that the disturbing forces were more energetic in remoter ages? No conclusion can be more unsound; for as the moving power acts from below, the newer strata cannot be deranged without the subjacent rocks participating in the movement; while we have evidence that the older have been frequently shattered, raised, and depressed, again and again, before the newer rocks were formed. It is evident that if the disturbing power of the subterranean causes be exerted with *uniform* intensity in each succeeding period, the quantity of convulsion undergone by different groups of strata will generally be great in proportion to their antiquity. But exceptions will occur, owing to the partial operation of the volcanic forces at particular periods, so that we sometimes find tertiary strata more elevated and disturbed, in particular countries, than are the secondary rocks in others.

Some of the enormous faults and complicated dislocations of the ancient strata may probably have arisen from the continued repetition of earthquakes in the same place, and sometimes from two distinct series of convulsions, which have forced the same masses in different, and even opposite directions, sometimes by vertical, at others by horizontal movements.

Secondary volcanic rocks of different ages.—The association of volcanic rocks with different secondary strata is such as to prove, that there were igneous eruptions at many distinct periods, as also that they were confined during each epoch, as now, to limited areas. Thus, for example, igneous rocks contemporaneous with the carboniferous strata abound in some countries, but are wanting in others. So it is evident that the bottom of the sea, on which the oolite and its contemporary deposits were thrown down, was, for the most part, free from submarine eruptions; but at some points, as in the Hebrides, it seems that the same ocean was the theatre of volcanic action. We have mentioned in the first volume *, that as the ancient eruptions occurred in succession, sufficient time usually intervening between them to allow of the accumulation of many subaqueous strata, so also should we infer that subterranean movements, which are another portion of the volcanic phenomena, occurred separately and in succession.

* Chap. v. p. 88; and Second Edition, p. 100.