FEBRUARY 22, 1854.

Charles Lindsay, Esq., C. H. Burbidge Hamley, Esq., and James Augustus Caley, Esq., C.E., were elected Fellows,

The following communication was read :—

On the GEOLOGY of the MAYENCE BASIN.

By WILLIAM J. HAMILTON, Esq., Sec. Geol. Soc.

CONTENTS.

Introduction, p. 254.

Part I.—Extent of the Mayence Basin and stratigraphical account of its different constituent beds, p. 255.

Extent of the area occupied by the Mayence Tertiaries, p. 255.

Description of the strata, p. 257.

Basement rocks; red sandstone, &c., p. 257.

Tertiary rocks :—

I. Marine Sand and Quartz-conglomerate, p. 260.

II. Lower blue Brown-coal Clay; Cyrena-clay, p. 265.

III. Cerithium-limestone, p. 266.

IV. Littorinella-limestone, p. 268.

V. Upper blue Brown-coal Clay, p. 271.

VI. Leaf-bearing Clay, p. 272.

VII. Ossiferous Sand, p. 272.

Part II.—On the Zoological Characters and Age of the Marine Molluscos Fauna of the Mayence Basin, p. 273.

Table I. Mollusca of the Marine Sands of the Mayence Basin, p. 274.

Table II. Fossils of the Cyrena-clay, p. 280.

Table III. Fossils of the "Freshwater Limestone" of the Germans, p. 281.

Table IV. Fossils of the Cerithium-limestone, p. 282.

Table V. Fossils of the Littorinella-limestone, p. 284.

Table VI. Fossils of the Ossiferous Sand, p. 285.

Part III.—On the Ancient Geographical Character and Connection of the Sea in which the Marine Fauna of the Mayence Basin was deposited, p. 288.

Comparison with the Tertiaries of Belgium, France, Switzerland, the Vienna Basin, the Brown-coal, Magdeburg, Bavaria, and Wurtemberg, p. 289 *et seq.*

Conclusion, p. 293.

INTRODUCTION.

THE insulated position of the Mayence Basin and the abundance of its fossil remains, particularly the marine molluscos fauna, had long ago invested it with an interest for the geologist far beyond what its limited extent would have led us to anticipate; and which the investigations of the last few years, while they have made us better acquainted with its fossil contents, have not yet exhausted.

Since the time when Brongniart first called attention to the fossils of the Weisenau strata*, the geologists of Frankfort, Wiesbaden, Darmstadt, Mayence, Hanau, and other places in the neighbourhood have contributed their share towards the investigation of the peculiar features of this formation. The results, however, are not generally known in this country; and, having lately had several opportunities

* *Mémoire sur les Terrains supérieurs calcaireo-trappéens du Vicentin, et sur quelques Terrains d'Italie, de France, d'Allemagne, &c.* 4to. Paris, 1823.

of visiting some of the most interesting localities in the district, I propose in the following remarks to lay before the Society the results of my inquiries. The subject is as yet, however, far from being exhausted; many localities require a more searching examination; the fossils need a more careful and exact comparison with those of other tertiary districts; and the relations of the formations to those of the north of Germany demand further examination.

I propose in the following observations, in making which I have been indebted for many valuable suggestions to Mr. R. A. C. Austen, who accompanied me on my last visits to Hochheim and to Alzey, in the first place, to describe the physical features of the district and the stratigraphical position of the different beds; secondly, to give an account of the palæontological contents of the beds in question, with a special reference to the marine mollusca; and thirdly, I shall conclude with some remarks on the original position of this marine basin, its probable connection with a former ocean, and the means by which it has been brought into its present relative position.

PART I.

EXTENT OF THE MAYENCE BASIN AND STRATIGRAPHICAL ACCOUNT OF ITS DIFFERENT CONSTITUENT BEDS.

Extent of the area occupied by the Mayence Tertiaries.—The district to which the term Mayence Basin has been applied forms the extreme northern limit of that portion of the great valley of the Rhine, which extends in an almost N. and S. direction from the northern flanks of the Jura to the southern or south-eastern flanks of the Taunus and the Hunsrück (see Map, fig. 1). It is in fact no basin in itself, although, in one sense, the whole of the depressed Rhine Valley, bounded on the W. by the mountains of the Vosges, the Haardt, and Mont Tonnerre, and on the E. by the mountains of the Schwarzwald and of the Odenwald, might not inappropriately be so called. The general character of this valley is well exhibited in the excellent relief-maps of Bauerkeller and of Ravenstein.

The so-called Mayence basin itself stretches in a general direction from W.S.W. to E.N.E., commencing between Kreutznach and Alzey on the S. side of the Hunsrück, and extending to the N.E. or E.N.E. along the S. flank of the Taunus beyond Frankfort and Hanau into the Wetterau, a distance of from 60–70 English miles. Its western limit rests against the Carboniferous formation of the Donnersberg, and the numerous porphyritic outbursts which characterize that country; while its northern beds repose against the talc-slates and sericit-slates of the Taunus. To the S. and E., the formation gradually disappears, partly in consequence of the gentle dip of the beds in that direction, and partly owing to the abrading action of the waters of the Rhine, which now wash its low escarpments or cliffs. To the S., the tertiary formation extends beyond Neustadt to Landau, gradually thinning out, and in a few places only leaving insulated patches adhering to the flanks of the Haardt mountains, and forming steep cliffs or escarpments to the eastward, which will be more distinctly pointed out hereafter.

FIG. 1.—GEOLOGICAL MAP OF THE MAYENCE BASIN.

Table of Signs.

[This map is taken from M.F. Voltz's Geological Map of the Grand-duchy of Hesse.]

	Alluvium.		Bunter Sandstone.
	Gravels.		Lower Red Sandstone.
	Ossiferous sands.		Coal-formation.
	Littorinella limestone.		Spirifer-sandstone.
	Cerithium limestone.		Taunus rocks.
	Freshwater limestone.		Greenstone.
	Marine clays.		Porphyry.
	Marine sands & conglomerates.	.....	Outline of the formations.

Description of the Strata.—The following Tabular statement of the nomenclature of the deposits of the Mayence Basin, adopted in this paper, will facilitate a reference to the Sections.

C. Post-pliocene	{ 2. Loess. 1. Gravel.
B. Tertiary	{ 7. Ossiferous sand. 6. Upper or leaf-bearing sandstone. 5. Upper blue Brown-coal clay. 4. Littorinella-limestone. 3. Cerithium-limestone. 2. Lower blue Brown-coal clay, or Cyrena-clay. 1. Marine sand and quartz-conglomerate.
A. Carboniferous, or Lower New Red	{ Red sandstone, &c.

A. BASEMENT ROCKS.

Carboniferous, or Lower Red Sandstone.—The lowest tertiary deposit invariably rests, wherever its basis has been observed, on red and yellow micaceous sandstone, which occurs as great underlying spurs, particularly in the neighbourhood of Weinheim and Flonheim, as seen in the sections, figs. 2, 3, 4 (see page 258); it forms a portion of the Coal-measures, which are extensively developed round the base of the porphyritic mountain of the Donnersberg.

Spurs of this red sandstone must have extended from the Donnersberg eastward into the ancient sea, from the wearing away and disintegration of which rocks the marine sands appear to have been prin-

Fig. 2.—Section of the “Marine Sands,” near Flonheim.

Fig. 3.—Section of the “Marine Sands,” near Uffhofen.

Fig. 4.—Section of the “Marine Sands” and “Cyrena Clay,” resting on the Red Sandstone, at Weinheim.

cipally derived; and, although the distinction between them was at one time overlooked, these underlying sandstones are mineralogically distinct from the tertiary sands and sandstones. The former are generally thin-bedded, micaceous, and interstratified with bands of black argillaceous shale; and I have never seen or heard of any fossil remains having been found in them. Of the Sections, that of Weinheim, fig. 4, p. 258, is the most complete. In this section, A shows the Carboniferous sandstone, separated by thin bands of black argillaceous shale; in which no organic remains could be detected. In places it is much shattered, and traversed by faults and cracks. It is overlaid by the "Marine Sand" (B. 1 *a*), which is the lowest member of the tertiary formation of the district.

We have here abundant evidence that the Carboniferous or red sandstones form the base on which the marine formations of the Mayence basin were deposited; and they were penetrated in various localities by porphyritic masses previously to the deposition of the marine beds, inasmuch as the latter sometimes repose directly upon the porphyries. These marine beds also mark the commencement of the tertiary period in this district; and, appear to be confined to its north-western extremity.

One of the spurs of this red sandstone which forms the nucleus of the range of hills between Alzey and Flonheim, and is penetrated in several places by outbursts of basaltic or porphyritic rocks, extends in a N.E. direction from the Donnersberg. The prolongation of this ridge of hills in the same direction, nearly brings us to a conspicuous hill of red sandstone between Nackenheim and Nierstein on the banks of the Rhine. An excavation near the summit of the table-land near Nierstein, which I visited some years ago, brought to light, in the midst of the opening, a large mass of basalt which had penetrated the red sandstone, and was the probable cause of its upheaval (see fig. 11, page 270).

The remarkable appearance of these red cliffs between the hills of white Cerithium-limestone on either side had frequently attracted my attention. They appeared to be overlaid by the Cerithium-limestone, and I therefore determined last summer to visit the locality, expecting there to find a junction-bed between it and the overlying rocks. I was also desirous of ascertaining whether it had formed an island or at least a promontory in the tertiary sea, or whether it had been subsequently elevated. If the latter, it must have brought up the marine sands with it in a tilted position, and I might then expect a rich harvest of new species from this new locality: if an island, I hoped to find traces of the old sea-beach. I proceeded accordingly to Nackenheim, and, ascending the red sandstone hill behind the village, I found it to be principally a micaceous sandstone alternating with marly beds, the sandstone sometimes forming nodules in the marl, and the whole dipping about 10° N.N.E. In some of the ravines behind the village I found that the overlying beds consisted of thick masses of *loess* instead of limestone; neither this latter nor the marine sands appeared anywhere to overlie the red sandstone. There was, therefore, every reason to believe that the red sandstone in

question must have been an island or promontory in the tertiary sea ; on further search, I found in the valleys the "loess," resting in general directly on the red sandstone, but occasionally separated from it by a bed of shingle or gravel, in which, in a few places, I found fragments of marine bivalves, amongst which were chiefly *Pectunculus* and a single valve of *Nucula Lyellii*, thus clearly proving even here the existence of a true marine beach. Further west, or inland from the river, the red sandstone is so covered up by "loess" that there was no opportunity of finding any junction between it and the tertiary formation, except beds of small pebbly gravel, probably much more recent.

B. TERTIARY FORMATION.

The following series, in an ascending order, is given in all the German works on the Mayence basin* :—

1. Marine sand and quartz-conglomerate.
2. Lower blue brown-coal clay.
3. Freshwater limestone.
4. *Cerithium* limestone.
5. *Littorinella* limestone.
6. Upper blue brown-coal clay.
7. Upper or leaf-bearing sandstone.
8. Ossiferous sand.

The introduction of the Freshwater limestone (No. 3) into the above list appears to me an error. It tends to encourage the idea that we have here a system of alternation of marine and freshwater formations, as in the London, Hampshire, and Paris basins, an idea which the evidence does not in any way justify. I shall therefore omit it in the following description, merely stating where the land-molluscs occur which have given rise to this nomenclature.

B. 1. *Marine sand and quartz-conglomerate.* (List at p. 257.)

This is unquestionably the lowest member of the tertiary series ; it is frequently non-fossiliferous ; near Weinheim, however, some of the beds contain numerous fossils. The section (fig. 4) exhibits a bed of sand and gravel (B. 1 *a*) about a foot thick, containing a great number of Sharks'-teeth, some bones of fish, and *Ostreæ*, in many places still adhering to the underlying rock. Above this is a thin bed of fine sand (B. 1 *b*), overlaid by clays (B. 2), belonging to the blue clay of the brown-coal formation, which on the opposite hill, called the Sommerberg, contains a great abundance of *Cerithium margaritaceum* and *Cyrena subarata*.

Wherever fossils are abundant, as in the neighbourhood of Wein-

* Walckner's Geognosie, 2nd Edit. Uebersicht der geologischen Verhältnisse des Gross-Herzogthum Hessen, v. Friedr. Voltz, Mainz 1852. Uebersicht der geologischen Verhältnisse des Herzogthum's Nassau, v. Dr. Frid. Sandberger, Wiesbaden 1847. Untersuchungen über das Mainzer Tertiär Becken, v. Dr. F. Sandberger, Wiesbaden 1853 (published and received in London long after the commencement of this paper).

heim, this sand, which is there coarse and shelly, alternates with beds of hard compact limestone, also fossiliferous, although, in such cases, it is almost impossible to extract their contents. A few miles S.W. of Weinheim, between the villages of Offenheim and Beckenheim, is a good section of this marine sand, overlaid by thin beds of blue and mottled clays, close to the very edge of the basin, as shown in the neighbouring quarry (only a few paces above it) of micaceous sandstone-grit, evidently belonging to the Carboniferous system. The accompanying section, fig. 5, will show the relative

Fig. 5.—Section of the “Marine Sands” and “Cyrena Clay.”

position of these beds. This spot, which had been opened apparently as a sand-pit, offered the following section in descending order :—

	ft.	in.
Upper blue clay, with septaria	0	4
Brown clays	1	0
Second band of blue clay	0	1
Brown clay, with small nodules of phosphate of lime? .	1	1
Ferruginous clay	0	4
Lowest blue clay, with traces of vegetable matter	0	9
Ferruginous clay	0	4
Ferruginous sand	3	4
White sand, with ferruginous streaks	10	0

—the latter in fact extending to the bottom of the pit, as far as was exposed, and probably much deeper. It should be observed, that in this pit we found no fossils whatever, nor even a pebble or other extraneous matter. To the E. and S.E. the same beds are seen stretching away from the ancient shore, and increasing in thickness ; and at no great distance we found in a bank by the road-side a section nearly on the same level as the sand-pit, in which the clays abounded with *Cerithium margaritaceum*, another smaller *Cerithium*, probably *C. plicatum*, *Cyrena subarata*, and a small *Ostrea*, proving these clays to be the same as those which near Weinheim and elsewhere overlie the marine sands, and belong to the lower brown-coal formation or Cyrena-marl of the German geologists.

The lower or true marine formation extends, or rather has hitherto been observed, only over a small portion of the Mayence district. It

dips slightly to the east, and, commencing at the western extremity of the region, either soon thins out or is lost under the more recent accumulations of the tertiary period. It has never been observed in the sections or quarries near Mayence, nor does it occur on the right bank of the Rhine. It may be said to be confined to a small tract of country in the neighbourhood of Weinheim, near Alzey, and about Fürfeld, Uffhofen, Flonheim, and a few other localities in that region; it may also be occasionally traced in small patches along the hill-range to the south towards Dürkheim and Neustadt, but without fossils, with the exception of a small spot near Dürkheim, underlying the Cerithium-limestone, where I found a bed of *Pinna*, which, however, were difficult to extract. They lie in a white and incoherent sand, and the shells are generally as incoherent and friable as the sand itself, with the exception of a few small masses cemented together by a more calcareous matrix. This is, I believe, the only locality where *Pinna* has been found in this formation.

Associated with this *Pinna*-sand is a bed of red ferruginous clay, containing large septaria, but I was unable to ascertain the relative position of the two beds in consequence of the broken nature of the ground, and their not occurring in the same section. Both are, however, below the Cerithium-limestone, and the section seen near Beckenheim affords, I have no doubt, the true explanation of their occurrence, viz. that the *Pinna*-sand represents the marine sands; and the clay with septaria, the lower brown-coal formation or Cyrenamari.

The two sections of the true marine formation in the vicinity of Weinheim, near Alzey, are so much more important in respect of their fossil contents than any others in this formation, that a more detailed notice of them is perhaps necessary. The first locality, fig. 6, is on the high road, a few hundred yards to the E. of Weinheim. The rocks here form a low broken escarpment, serving as the northern boundary of a small valley, watered by the stream which flows through Alzey. On the south the ground rises gradually over the undulating hill of the Sommerberg to the general tableland of the country, which consists of the overlying Cerithium-limestone. The marine beds themselves dip very slightly to the E. and S.E., and on approaching the village of Weinheim they are seen reposing directly on a dark greenish trappean rock.

Such igneous rocks, it may be here observed, are very abundant throughout this district, particularly towards the Donnersberg, and in the direction of Kreuznach, appearing as porphyry, melaphyr, or greenstone, and frequently containing geodes of agate and tabular veins of chalcedony. Sometimes they have cut through the underlying red or carboniferous sandstone, at others they have only caused the elevation of the sedimentary rocks, but they are all anterior to the deposition of the tertiary beds.

The section, fig. 6, represents the general appearance of the beds opposite the Wirthsmühle. A hard bed of compact limestone rests rather irregularly against the trap-rock. It contains a few remains of *Ostrea*, *Pectunculus*, &c. Over it is a loose shelly sand, 3 or 4 feet

in thickness, in which the greatest number of shells is found; the lower portion in particular is almost a complete mass of such remains,

Fig. 6.—Section of the “Marine Sands” (B. 1), near Weinheim; opposite the Wirthsmühle. Height of Section about 20 feet.

6. Gravel.
5. Calcareous sand; *Pectunculus*, abundant.
4. Shelly sand. (At about this level on the opposite side of the valley, the *Cyprina rotundata* occurs; fig. 7.)
3. Hard-bedded limestone; *Pectunculus crassus*, &c.
2. Shelly sand; *Natica gigantea*, &c.
1. Compact limestone. Few *Ostrea*.

many of which are broken, while others have their valves pierced by borers, showing that they were probably already dead before they were washed into this locality. Those in the upper portion are better preserved.

This shelly sand is again overlaid by a compact hard calcareous sandstone, in which the large *Pectunculus crassus* (Phil.) is very abundant; this passes into a softer arenaceous bed, in which the *Pectunculi*, in consequence of the denudation of the intervening strata, are in immediate contact with the diluvial gravel.

The section, fig. 7, represents the beds as seen in the hollow-road,

Fig. 7.—Section of the Alternations of Sandy and Calcareous beds in the “Marine Sands,” B. 1, at the Hollow Way behind Weinheim.

9. Sandy; *Pectunculus*, very abundant.
8. Calcareous.
7. Shelly sand.
6. Calcareous.
5. Sandy; *Cyprina rotundata*.
4. Calcareous.
3. Loose sand.
2. Calcareous. *Halianassa* bones.
1. Sandy.

or pass, behind or to the north of the same hill, at a somewhat higher level. The fossil remains found here are generally the same as those

near the Wirthsmühle, but there is a more frequent alternation of soft shelly arenaceous, and hard compact areno-calcareous beds; we observed as many as four or five of these alternations. In the lowest of them, Mr. Austen found some fossil bones, but which, from the extreme hardness of the rock, it was impossible to extract. They belonged in all probability to the *Halianassa Collinii*, the remains of which are found not unfrequently in this lowest marine bed.

The remains of Mollusca were most abundant in the two upper beds, *Pectunculus arcatus* and *P. crassus* particularly abounding in the uppermost. The large *Cyprina rotundata* occurs chiefly in the sand below, in which few other fossils were found. The limestone-bed below the *Cyprina*-sand does not run continuously along the face of the scarp, but occurs in the shape of large nodules, which, from their greater resistance to the weathering action of the air and rain, project beyond the softer sands like the gigantic rafters of a building.

On the opposite or northern side of the red-sandstone ridge which separates the valley of Alzey from that of Flonheim to the N.E., the marine sands are seen in considerable thickness near Flonheim and Uffhofen, as has been already observed. Near Flonheim they are seen resting on the red sandstone in a sand-pit a little way above the town. The sand here contains but few fossils, and evidently represents a sandy beach along an open line of coast. Section fig. 2, page 258, will give an idea of this character. A depth of from 30 to 40 feet is exposed in the sand-pit, but they have dug 15 feet lower through the sand. The lowest portion (*a*) consists of a gravel of small quartz-pebbles, like that seen near Eckelsheim. (*b*) represents an Oyster-bed, amongst which Shark's-teeth are not unfrequently found; these latter indeed occur generally throughout every portion of this section. At (*c*) is the stratum in which bones have been frequently found, and on the occasion of my last visit I succeeded in extracting one, apparently a rib of *Halianassa*.

At Uffhofen are sand-pits of the same character and at nearly the same level, abounding in *Ostrea Collinii*, which form in the lower portion regular thick banks; many of these Oysters are covered with large *Balani*. Here, a few days before my last visit (July 1853), a most interesting and entire skeleton had been discovered imbedded in the soft incoherent sand, and was still lying as it had been found when we visited the spot. The lower jaw, and upwards of thirty vertebræ with their ribs, some slightly broken, were lying almost in their true position. The upper jaw and skull, having been found a short time before, had been sold to a neighbouring collector; the sand-digger, who found them, never dreaming that the remaining portions of the skeleton were then so near. From the short examination which Dr. G. Sandberger and myself could give them, there is little doubt but that they belong to the *Halianassa Collinii*, of which it is the most perfect specimen yet found*.

* I have since learned that this fine specimen has been secured by Prof. Kaup for the Museum at Darmstadt.

1854.]

HAMILTON—MAYENCE BASIN.

265

Fig. 8.—General Section across the Mayence Basin,—from Weinheim near Alzey to Flörsheim. Length about 40 miles.

Between Uffhofen and Eckelsheim, a short distance further north, these marine beds assume the character of a quartzose conglomerate or gravel, passing into a coarse incoherent sand, and the fauna is somewhat different from that of Weinheim. Here two or three species of *Ostrea*, including the peculiar form *O. rhenana*, together with two species of *Pecten*, are almost the only representatives of the numerous species found elsewhere. A single *Pectunculus* and an *Astarte* found in this sand were so soft that it was impossible even to touch them without injury; they crumbled to powder on removing the sand. The Pectens and Oysters seem to have a peculiar facility for resisting the decomposing effect of the water which percolates so easily through this loose sand.

II. Lower blue Brown-coal Clay (*Cyrenen-Mergel*), *Cyrena-marl*.

With the exception of the few hard calcareous bands intercalated in the shelly sands of Weinheim, there does not appear to have been any great change in the mineralogical character of the deposits formed at the bottom of this tertiary sea, so long as it maintained its true marine character. Finesand and gravel, derived from the disintegration of the surrounding rocks, and mixed with an abundance of broken shells in the upper portion, are the chief materials in which

the marine mollusca are found; but we here suddenly reach a totally different formation. A stiff tenacious blue clay overlies the shelly sands, and a corresponding change in the animal remains shows how the conditions of life were modified by those events which produced this change in the nature of the subaqueous deposits. These marly beds are considered by the German geologists to represent the lower brown-coal formation of the Wetterau, and are called by some the Cyrenen-Mergel or Cyrena-marl, from the abundance of *Cyrena subarata* found in it; with this are associated several species of *Cerithium*, and a few forms of littoral Gasteropods.

This formation occupies a considerable area in that portion of the Mayence basin which lies to the westward of the Rhine (see fig. 8), appearing in many of the bottoms and hollows, and even constituting low undulating hills. Here it has generally a very slight dip or inclination to the eastward; but on the opposite or eastern side of the Rhine the dip is reversed, and it only appears in a very few localities, and at a very low level. Between Hochheim and Flörsheim it occurs on the bank or in the bed of the Maine, where it contains *Cerithium margaritaceum* of a large size. Here a slight rise towards the east appears to be indicated; for in the section taken near Hanau, fig. 9, it forms the basis of the whole tertiary series, at a slight elevation above the bed of the river. This section, which is the most eastern point I had an opportunity of examining, extends from the lower to the upper blue clay, and will be subsequently described. (Hanau is about 30 miles N.E. by E. of Flörsheim.)

The principal localities where this blue clay has come under my notice, in addition to those already incidentally mentioned, are the Zeil Stück near Weinheim, where many fossils have been found, and the Sommerberg, opposite Weinheim; it also occurs abundantly on the road between Alzey and Mayence, near the village of Ensheim, where Mr. Austen and myself found *Cyrena subarata* and a small *Cerithium*; and again, on another road to Mayence, near Partenheim, where I obtained numerous *Cerithia* on a former occasion. The septarian clay near Dürkheim also evidently belongs to this formation, while to the N.W. it extends at intervals from Alzey to Kreutznach.

III. *Cerithium Limestone*. (Nos. 3 and 4 of the German list, p. 260.)

I omit the No. 3 of the German table, which is evidently only the lower portion of this limestone, into which considerable numbers of land-shells have in particular spots been drifted. The beds of which this division of the series consists are generally hard, compact, and thick-bedded. In many places, indeed, it is difficult to detect evidence of distinct stratification. They are also generally more extensively developed on the left bank of the Rhine than on the right, where the next succeeding bed, the *Littorinella*-limestone, is more abundant. It is however difficult, if not impossible, to draw any distinct line between them, except in so far as their fossil contents differ, and that the *Littorinella*-limestone is somewhat less thickly bedded, and is often interstratified with beds of marl or clay. The

two formations pass gradually into each other, and should only be looked upon as subdivisions of the great calcareous deposit, formed during the period when this lacustrine basin was passing from a brackish to a freshwater condition.

The following section, fig. 9, taken at Hochstadt, near Hanau, will show how the two formations, extending from the lower to the upper blue clay, pass into each other.

Fig. 9.—Section of the *Cyrena Clay* (B. 2.), *Cerithium* and *Littorinella* Limestones (B. 3, B. 4), and the *Upper blue Clay* (B. 5), at Hochstadt.

1. (B. 2.) Blue clay (*unterer blauer Letten*) without fossils, said to rest immediately on the red sandstone (*Bunter-Sandstein* or *rothetodte-liegende*). The pits where this blue clay had been dug out are at the foot of the hill below Hochstadt, but had all been filled up before I was there, so that I was indebted for my information to M. Roessler of Hanau, who accompanied me to the spot.

2. (B. 3.) Compact blue limestone passing into yellow. This bed is also unfossiliferous and slightly bituminous.

3. Hard limestone, occasionally nodular and concretionary, containing *Littorinella* and *Dreissena Brardii*.

4. (B. 4.) Limestone of a similar character, with numerous *Littorinellæ* and *Helices* of various species. We did not find *Dreissena* in this bed; but bones are said to have been occasionally found in the lower portion of it. It is the occurrence of these numerous *Helices*, in particular spots of this formation, which has led the German geologists to call it a freshwater limestone, but there seems to be no sufficient ground for such an assumption. No freshwater shells are found in it, neither *Planorbis*, *Limnæus*, nor *Paludina*. It is evidently a continuation of the brackish-water formation, into which land-shells have been drifted by the rivers. The abundance of these molluscs in particular spots has been accounted for by supposing them to have been deposited in those places where a great river, flowing into the brackish-water lake, impinged against particular promontories more exposed to the currents of fresh water. Supposing this ancient tertiary river to have occupied the bed of the present Main, issuing into the plain (then a lake) from the narrow defiles near Aschaffenburg, the current would naturally deposit on the opposite bank the land-shells brought down by freshets from the

Spessart, or the River Kinzig in like manner might have brought them down from the Fichtel Gebirge.

5. Alternating beds of sand and limestone; the sand is in some places slightly ferruginous, and contains fragments of shells; the limestone occasionally alternates with sandy marl, containing a small *Littorinella*; it is a kind of junction-bed with No. 4, into which it sometimes passes. The singular small round bodies, described by some naturalists as snakes'-eggs*, have been found in this part of the section.

This bed brings us to the level of the little town of Hochstadt, built on the slope of the hill. Many small pits have been opened on the ground above the town, by means of which the section can be tolerably well traced upwards. *Littorinellæ* abound in most of these beds, but the *Helices* are less frequent than below.

6. The only characteristic horizon which I observed in this upper succession of limestone beds, more or less compact or arenaceous, is a band nearly a foot thick, containing *Mytilus Faujasii*.

7. (B. 5.) The highest bed in this section which I had an opportunity of observing consists of blue clay, in which the small *Cyrena Faujasii* and a *Cerithium*, probably *C. cinctum*, are tolerably abundant.

IV. *Littorinella*-limestone. (No. 5 of the German list, page 260.)

One of the chief localities for observing the various beds of this portion of the Mayence basin, which in a general sense may be considered as the upper portion of the brackish-water limestone formation, is the district lying between the towns of Hochheim and Flörsheim on the Main. The numerous quarries opened on the slope of these hills have produced an abundant harvest to the palæontological inquirer, and have, in connection with the railway cuttings, brought to light a great variety of new forms of land-shells of the genera *Helix*, *Pupa*, *Bulimus*, *Clausilia*, and *Cyclostoma*. The valley of the Mühl-thal, leading from Biebrich to Wiesbaden, is a portion of this formation, and appears to represent its upper beds. It is moreover remarkable for containing, in addition to the molluscs found near Hochheim, a considerable number of freshwater shells.

I visited the Hochheim beds in company with Mr. Austen. The best section we obtained was at the eastern end of the line of quarries near Flörsheim, at a place called the Ziegel Hütte. The section of the lower part of this group here is remarkable for presenting on the same horizon two distinct series of beds, apparently without a fault (see fig. 10). The mass of rock in the centre consists of hard concretionary mammillated calc-sinter, made up of minute hollow stems, the interstices between which are often filled with fine sand. It looks as if the calcareous matter, the produce of springs highly charged with carbonate of lime, had been deposited on masses of Mosses or *Confervæ*, an appearance not uncommon in other parts of the formation. I particularly noticed it near Dürkheim, where the limestone also

* Quart. Journ. Geol. Soc. vol. vi. part 2. Miscell. p. 42.

appeared to be the produce of calcareous springs. To the north-west of this mass, the beds, which are nearly horizontal, are essentially calcareous, varying considerably in their degrees of hardness, and

Fig. 10.—Section of the *Cerithium* Limestone (B. 3) with *Calcsinter*, between Hochheim and Flörsheim.

sometimes passing into soft calcareous marl; while on the east or south-eastern side, they are essentially arenaceous, the stratification, especially at a short distance from the central mass, being more distinct than on the other side. On this eastern side we observed the following features in an ascending order :—

- a. Loose sand, with a few *Helices* and *Perna*, from 10 to 20 feet thick.
- b. Several bands of concretionary limestone-nodules, running through the same greenish sand.
- c. Bands of hard limestone, 6 inches thick, containing numerous casts of a small *Cerithium*.
- d. Two bands, a few inches thick, and three or four feet apart, containing *Venus incrassata*.
- e. Band containing *Perna Soldanii*.

On the north-western side the palæontological evidence is less clear, and the stratification is much less regular. Numerous *Helices* and *Cyclostomata*, particularly *C. sulcatum*, occur in patches here and there, together with *Venus incrassata* and *Perna*. The great difference in the lithological character of the two sides of the section may, I think, be accounted for in this way :—if we suppose that a large river, occupying the position of the present Maine, flowed into the lacustrine basin from the Spessart, viz. from the E. or E.S.E., the action of the water on the calcareous spring would cause the calcareous matter to be deposited on the western or further side of the spring, while the matter deposited on the eastern side consisted of the more arenaceous sediment brought down by the river itself.

Another section further westward, and nearer Hochheim, produced an abundance of small *Cerithia*, with *Mytilus socialis*, fragments of

Fig. 11.—Section from Oppenheim to the neighbourhood of Mayence. Length about 15 miles.

Perna, and a small *Neritina* and *Nerita*, underlaid by a hard compact bed of limestone without fossils. In other portions of the section, casts of *Cerithium* occur in the hard limestone.

The valley of the Mühl-thal, between Biebrich and Wiesbaden, represents the upper portion of this formation, and the *Littorinella acuta* is here so abundant as to constitute almost the entire mass of the rock in many places. With it the *Mytilus Brardii* is also abundantly found, and a few freshwater shells, as *Paludina lenta*, *Melanopsis*, *Limnæus*, and *Planorbis*, here make their first appearance, plainly indicating the diminished saltiness of the water.

Another instructive section of the calcareous portion of the Mayence tertiaries, including the *Cerithium*-limestone and the *Littorinella*-limestone, is exhibited in the quarries and other cuttings extending from the fortifications of Mayence, through the village of Weissenau, as far as Oppenheim on the left bank of the Rhine (fig. 11). The three localities of the Kästrich in Mayence, the quarries of Weissenau, and those of Oppenheim will complete our investigation of these beds.

1. Kästrich in Mayence. This section is exposed in the upper part of the town, in cutting a new road to the fortifications: it represents the upper portion of the *Littorinella*-limestone, and consists of frequent alternations of thin beds of flaggy limestone with arenaceous marly beds. Two species of *Littorinella* abound in these beds, but they are not less abundant in the arenaceous beds. On the whole, from 30 to 50 feet are exposed here.

2. Near the village of Weissenau, about one mile S.S.E. from Mayence, extensive quarries have long been opened in the limestone rocks, showing the passage downwards from the *Littorinella*-limestone to the *Cerithium*-limestone. The *Littorinella*-limestone appears to thin out gradually as the hills rise towards the S.E. The following sequence, in ascending order, will show how the beds succeed each other:—

1. Cerithium-limestone; generally compact and close-grained, containing *C. margaritaceum* and *Dreissena Brardii*, with here and there a cast of *Helix*; the lower portion of this bed is almost unfossiliferous, and seems to rest upon more marly beds. Its thickness is at least 50 feet.

2. Compact limestone, full of a small species of *Cerithium*, *Neritina*, and *Dreissena*; about 10 feet.

3. Limestone-beds, containing a large *Cerithium*, *Dreissena*, and *Cyrena Faujasii*; about 4 feet thick.

4. Alternating beds of sand and marl. The lowest sandy beds are full of *Littorinella*; I am, therefore, disposed to look upon these beds as marking here the junction between the Cerithium and Littorinella limestones. They have a thickness of about 30 feet.

5. A bed of broken fragments.

6. Alternating beds, containing *Littorinella* and *Cyrena*. The *Littorinella* generally occurs in the harder beds. Some of the *Cyrena*-beds are completely made up of casts of that shell.

7. Sand.

8. Littorinella-limestone, alternating with marls and sands. Thickness uncertain. This is the same formation as that which is seen at the Kästrich in Mayence.

9. Diluvial gravel; 2 feet.

10. Loess; 3 feet.

11. Soil.

3. Oppenheim. The lowest bed in the quarries at this place consists, like those of Weissenau, of compact limestone, containing very few fossils, and those chiefly *Cerithium*. A few bones are said to have been found here. It belongs evidently to the Cerithium-limestone. Above it are beds with *Mytilus Faujasii*, and a bivalve (*Cyrena subarata?* or *Venus incrassata*). Near the top of the section is a loose marly limestone, containing angular fragments of limestone, immediately overlying the oolitic-looking rock which in some places appears to form the upper portion of the Cerithium-kalk.

V. Upper Blue Clay. (No. 6 of the German list, page 260.)

The Littorinella-limestone is immediately overlaid by the Upper blue Clay or Upper Brown-coal Clay. I had no opportunity of observing it, except in the small section near Hochstadt (fig. 9, page 267), where it contains a small *Cerithium* and *Cyrena Faujasii*. It is, however, in some respects a very important formation, as containing the brown-coal beds of the Wetterau, the Westerwald, and the Middle Rhine, which are extensively worked and are remarkable for the interesting flora they contain. Some account of this flora will be found in the above-mentioned works of Walckner, Sandberger, and Voltz. It is, however, possible that the marly beds which overlie the Littorinella-limestone in the Mühl-thal, near Wiesbaden, are the representatives of this formation. In the second quarry from Wiesbaden, down the Mühl-thal, is a section of 10 or 12 feet of yellow, green, and dark-coloured marls, without fossils, overlying the

Littorinella-limestone. In another quarry these marls are 20 or 30 feet thick, very near the surface, overlying the Littorinella-limestone, from which it is separated by a white calcareous band.

VI. *Leaf-bearing Sandstone.* (No. 7 of the German list, page 260.)

Of the next formation in ascending order, as they are laid down by the German geologists, viz. Sandstone with impressions of leaves, I am unable to give any satisfactory account. It occurs in the neighbourhood of Wiesbaden, overlying the upper marls and clays, and overlapping the slaty metamorphic rocks of the Taunus.

VII. *Ossiferous Sand.* (No. 8 of the German list, page 260.)

This bed appears to indicate a different state of things from that belonging to the preceding beds, which it overlies unconformably, although belonging to the same general epoch, inasmuch as many of the fossil remains are the same as those found in the underlying beds. It is deposited in hollows in the pre-existing Littorinella-limestone, and is decidedly of a freshwater character. Some of the insulated patches are remarkable for the great number of Mammalian bones found in them: most of these are deposited in the museum at Mayence. One of the chief localities for these remains are the sand-pits near Eppelsheim, into which the animals or their bones would appear to have been washed from the surrounding dry ground, on which they must have lived and roamed after the drainage of the great lacustrine basin. The following section in descending order will show the superposition of the beds. It is taken from the top of the hill, distant about a mile N.W. from the village of Eppelsheim:—

1. Soil; 2 or 3 feet thick.
2. Loess; yellowish sandy loam; 4 feet.
3. Yellow gravel, with limestone boulders, and a few fragments of small bones.
4. Yellow clay, varying in thickness from 4 to 12 inches.
5. Loose sand and small gravel, containing boulders of hæmatitic ironstone; 3–4 feet.
6. Fine loose sand; about 14 feet exposed, but the bottom not visible; said by the workmen to rest on hard rock.

The Mammalian remains and teeth were said to have been found in No. 5, but little has been found of late. These sands, &c. are perfectly horizontal, but the Littorinella-limestone in the neighbourhood has been very much disturbed.

The Rhinoceros jaw which I obtained from one of the sand-diggers, was said to have come from bed No. 5.

Descending into the valley, near Bischheimer Hof, three or four miles distant to the S.E., I found the same formation of sands and clays filling up the hollow, and containing a specimen of *Mytilus Faujasii*, too soft and crumbling, however, to be extracted.

Although this Ossiferous Sand is unquestionably more recent than the underlying formations ; and although it may be difficult, from want of proper means of comparison, to fix its exact relative age, yet the great analogy between the numerous land and freshwater molluscs found in the underlying *Littorinella* and *Cerithium* limestones with those now living in the southern regions of Europe will justify us in assuming that the terrestrial and climatological conditions of life were not very different from those now existing, and that the superficial surface of the ground had already assumed its present form and configuration.

PART II.

ON THE ZOOLOGICAL CHARACTERS AND AGE OF THE MARINE MOLLUSCOUS FAUNA OF THE MAYENCE BASIN.

Having endeavoured in the preceding statements to describe the geographical position and the physical features of the various strata of the Mayence basin, with their relative succession and superposition, I now propose to allude to their palæontological contents, and to point out their analogies with the tertiary deposits of neighbouring regions, so far as they have yet been examined, with the view of ascertaining their true position in the tertiary series, and the period to which they should be referred.

Although I have succeeded during several excursions in collecting a considerable series of the fossils of this region, I could not expect to be so successful as those who, from long residence in the neighbourhood, have such constant opportunities of collecting, as the geologists of Wiesbaden, Mayence, Hanau, &c. ; and who, in extending their knowledge of the fossil contents of the *Cerithium* and *Littorinella* limestones, had the additional advantage of examining the ground during the construction of the Mayence, Wiesbaden, and Frankfort railways. I am therefore compelled to have recourse to the lists of fossils published by these observers ; amongst which I may particularly mention those of M. Walckner and of Dr. F. Sandberger, to which I am most indebted.

Although the fossil contents of the overlying brackish and freshwater formations are not without considerable interest in reference to the question of Age now immediately before us, their importance is but small, when compared with that of the underlying Marine Sands. It is the marine fauna to which we have principally to look, as the key of the whole question. Wherever this bed shall be placed, all the others follow immediately and without interruption. Their superposition is self-evident, and the gradual passage from one into the other is proved by mineralogical no less than by palæontographical evidence. In this marine sand, principally derived from the disintegration or abrasion of the previously existing and underlying red or carboniferous sandstones and shales, we have the evident commencement of a new state of things, the basis of a new formation ; we here see the first proofs of a new deposit thrown down upon a new sea-bottom, when, after a sudden change in the relative levels of land

and water, the sea rushed into the newly-made depression, forming a deep inlet or æstuary, in which, for a time, marine life alone existed, until the conditions of life being again altered, and the waters having gradually become brackish, the true marine fauna also disappeared, and was replaced by one adapted to the altered conditions of life.

How, and where, and when these changes may have taken place, are questions which must be deferred to the concluding portion of this paper. We have now to compare the fossils of the marine sand of Weinheim with those of other tertiary deposits, and to endeavour by means of such comparison to ascertain their relative age and position with regard to the other tertiary beds of Europe, as well as their absolute place in the tertiary system.

The following list of fossils in the Marine Sand of Weinheim is chiefly taken from that given by Dr. Sandberger in his last-published work.

TABLE I.

Tabular view of the Mollusca of the Marine Sands of the Mayence Basin, showing some of the other localities where they have been observed.

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
<i>Teredo anguinus</i> , Sandb., n.s.					* ?		
<i>Saxicava</i> , 3 or 4 species, undetermined							
<i>Leguminaria papyracea</i> , D'Orb.				*			
<i>Solecortus appendiculatus</i> , Desmoul....		*					
<i>Panopæa intermedia</i> , Sow.		*			*		
= <i>P. Hebertiana</i> , Bosq. (? the same)							
<i>Thracia phaseolina</i> , Kiener							
<i>Corbulomya polita</i> , A. Braun		*					
= <i>C. complanata</i> , Nyst.							
<i>Corbula pisum</i> , Sow.	*	*	*	*	*		
— <i>striata</i> , Lam.		*		*	*		
— <i>scalaris</i> , A. Braun.							
<i>Tellina donacina</i> , L. ?							
— <i>Hebertiana</i> , Bosq.		*	*				
= <i>T. Benedenii</i> .							
—, 2 species undetermined							
<i>Crassatella Bronnii</i> , Merian							
<i>Astarte plicata</i> , Merian							
—, species undetermined							
<i>Diplodonta fragilis</i> , A. Braun							
<i>Lucina Bronnii</i> , Merian		* ?					
= <i>L. squamosa</i> , Lam.							
— <i>Galeottiana</i> , Nyst			*				
— <i>lepida</i> , Bosq.		*		*		*	
— <i>uncinata</i> , Desh.		*					
— <i>tenuistria</i> , Héb.		*					
— <i>commutata</i> , Phil.							
= <i>L. divaricata</i> , var. Nyst.							
— <i>saxorum</i> , Lam.		*					

TABLE I. (*continued*).

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
<i>Cytherea incrassatoides</i> , <i>Nyst</i>		*		*			
— minima, <i>A. Braun</i>	*						
= <i>C. deltoidea</i> , <i>Lamk.</i>							
— splendida, <i>Merian</i>		*					
= <i>C. lævigata</i> , <i>Nyst.</i>							
— Bosqueti, <i>Heb.</i>		*					
? — nitidula, <i>Lamk.</i>	*						
— Goldfussiana, <i>A. Braun</i>							
<i>Cyprina rotundata</i> , <i>Braun</i>		*	*				
= <i>C. islandica</i> , <i>Lam.</i> ?							
<i>Cardita orbicularis</i> , <i>Bronn</i>	*	*	*		*		
— var. minor, <i>Sandb.</i>							
— — Omaliana, <i>Nyst.</i>		*					
— — lævicosta, <i>Sandb.</i>							
— — Kickxii, <i>Nyst.</i>		*					
— — scalaris, <i>Goldf.</i>		*				*	
— — chamaeformis, <i>Nyst.</i>			*				
<i>Cyrena ambigua</i> , <i>A. Braun</i>							
<i>Isocardia transversa</i> , <i>Nyst.</i>		*					
— cyprinoides, <i>A. Braun</i>							
<i>Cardium tenuisulcatum</i> , <i>Nyst</i>		*		*	*		
— scobinula, <i>Merian</i>		*					
— turgidum, <i>Brander</i>		*		*			
— , species uncertain							
<i>Chama exogyra</i> , <i>A. Braun</i>							
<i>Arca hiantula</i> , <i>Desh.</i>			*		*		
= <i>A. hians</i> , <i>A. Braun.</i>							
= <i>A. umbonata</i> , <i>Lamk.</i>							
— diluvii, <i>Lamk.</i>			*			*	
— multistriata, <i>De Kon.</i>		*					
= <i>A. decussata</i> , <i>Nyst.</i>							
<i>Pectunculus crassus</i> , <i>Phil.</i>		*		*		*	
= <i>P. polyodonta</i> , <i>Goldf.</i>							
— arcatus, <i>Schloth.</i>							
— angusticostatus, <i>Lamk.</i>			*	*			
— lunulatus, <i>Nyst.</i>		*					
<i>Limopsis Goldfussiana</i> , <i>Nyst</i>		*					
<i>Nucula Lyelliana</i> , <i>Bosq.</i>							
— margaritacea, <i>Lamk.</i>	*	*	*				
— placentina, <i>Lamk.</i>			*				
= <i>N. lævigata</i> , <i>Goldf.</i>							
— Deshayesiana, <i>Duch.</i>			*				
— minuta, <i>DeFr.</i>							
<i>Modiola micans</i> , <i>A. Braun</i>			*		*		
? = <i>M. sericea</i> , <i>Bronn.</i>							
<i>Mytilus Nystii</i> , <i>Kickx.</i>		*					*
<i>Perna Soldanii</i> , <i>Desh.</i>						*	*
<i>Pinna</i>		*			*		
<i>Avicula</i> ? trigonata, <i>Lamk.</i>		*					
<i>Lima subcylindrica</i> , <i>Sandb.</i>							
— , spec. undetermined							

TABLE I. (continued).

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
<i>Pecten pictus</i> , Goldf.		*					
— <i>Deshayesii</i> , Nyst		* ?					
— <i>furfuraceus</i> , A. Braun							
—, 3 species undetermined							
? <i>inæqualis</i> , A. Braun.							
? <i>decussatus</i> , Münster and Goldf.							
? <i>striatus</i> , Münster and Goldf.							
<i>Spondylus auriculatus</i> , Nyst	*						
—, sp. n.							
<i>Ostrea callifera</i> , Lamk.			*	*			
= <i>O. Collinii</i> , Merian.							
— <i>mutabilis</i> , Desh.							
— <i>flabellula</i> , Lamk.	*		*	*			
= <i>O. rhenana</i> , Merian.							
<i>Plicatula</i> , sp. (rare)							
<i>Anomia tenuistriata</i> , Desh.	*			*			
<i>Terebratula</i>							
<i>Cleodora</i> ?							
<i>Dentalium entalis</i> , Gmel.		*	*				
— <i>Kickxii</i> , Nyst			*				
— <i>fissura</i> , Lamk.		*					
<i>Patella moguntiacæ</i> , A. Braun*							
—, n. sp.							
<i>Emarginula Nystiana</i> , Bosq.			*				
—, n. sp.							
<i>Calyptræa striatella</i> , Nyst		*		*			
<i>Capulus</i> , uncertain							
<i>Crepidula</i> , uncertain							
<i>Natica gigantea</i> , A. Braun				*			
= <i>N. crassatina</i> , Lamk.							
= <i>N. maxima</i> , Grat.							
— <i>glaucinoides</i> , Sow.		*			*	*	
= <i>N. Guilleminii</i> , Payr. & Bronn.							
var. <i>β. major</i> .							
— <i>crassa</i> , Nyst			*				
— <i>Hantoniensis</i> , Sow.		*			*		
— <i>Bronni</i> , Merian							
<i>Nerita rhenana</i> , Thom							
—, sp. (major)							
<i>Neritina concava</i> , Sow.							
= <i>N. pisum</i> , Merian.							
— <i>pisiformis</i> , Fér.				*			
<i>Volvaria acutiuscula</i> , Sow.				*			
<i>Tornatella sulcata</i> , Lamk.	*			*			
— <i>simulata</i> , Brand.		*			* ?		
<i>Ringicula</i> , sp. uncert.							
<i>Pyramidella cancellata</i> , Nyst		*					
— <i>subulata</i> , Merian							
—, 2 sp. uncert.							
<i>Niso terebellata</i> , Risso				*			
<i>Eulima subulata</i> , Risso			*	*			

TABLE I. (*continued*).

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
Turbonilla elegantissima, <i>Leach</i>							
— Nystii, <i>Duch.</i>							
— lævissima, <i>Bosq.</i>		*	.				
—, sp. uncert.							
Rissoa plicata, <i>Desh.</i>		*		*			
— Duboisii, <i>Nyst</i>		*					
— succincta, <i>Nyst</i>		*					
— Michaudi, <i>Nyst</i>							
= <i>R. tumida</i> , <i>Merian</i> .							
Vermetus, sp. uncert.							
Scalaria rudis, <i>Phil.</i>					*		
— pusilla, <i>Phil.</i>							
Turritella crenulata, <i>Nyst</i>		*					
Phasianella (aff. <i>P. Prevostina</i> , <i>Bast.</i>)							
Delphinula, sp. uncert.							
Rotella nana, <i>Grat.</i>							
Phorus umbilicaris, <i>Brand.</i>	*	*					
= <i>Trochus agglutinans</i> , <i>Lamk.</i>							
Trochus fragilis, <i>Desh.</i>				*			
— rhenanus, <i>Merian</i>							
= <i>T. striatus</i> , <i>Gmel.</i>							
— bicarinatus,							
— margaritula, <i>Merian</i>							
—, 2 sp. uncert.							
Turbo, sp. uncert.							
Solarium, sp. uncert.							
Xenophora Lyelliana, <i>Bosq.</i>		*	*				
Littorina, 2 sp. uncert.							
Cerithium mutabile, <i>Lamk.</i>				*			
— subvaricosum, <i>A. Braun</i>							
— dentatum, <i>Defr.</i>				*			
— plicatum, <i>Lamk.</i>		*		*		*	
— intermedium, <i>Braun</i>							
— lima, <i>Brug.</i>		*					*
— lævissimum, <i>Schloth.</i>							
— conoidale, <i>Lamk.</i>				*			
— margaritaceum, <i>Sow.</i>		*				*	
= <i>C. elegans</i> , <i>Desh.</i>							
— abbreviatum, <i>A. Braun</i>							
— (aff. <i>C. lapidum</i> , <i>Lamk.</i>)							
—, 6 sp. undetermined							
Chenopus vittatus, <i>A. Braun</i>							
— speciosus, <i>Schloth.</i>		*				*	
= <i>C. tridactylus</i> , <i>A. Braun.</i>							
= <i>C. pes-pelecani</i> , <i>Phil.</i>							
—, sp. undeterm.							
Tritonium argutum, <i>Brand.</i>		*			*		
= <i>T. rugosum</i> , <i>Phil.</i>							
= <i>T. flandricum</i> , <i>De Kon.</i>							
—, 3 sp. undeterm.							
— anguinum, <i>Merian</i>							

TABLE I. (*continued*).

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
<i>Tritonium cerithioides</i> , <i>A. Braun</i>							
<i>Typhis cuniculosus</i> , <i>Nyst</i>		*		*	*		
— <i>scalaris</i> , <i>A. Braun</i>							
— <i>pyruloides</i> , <i>A. Braun</i>							
<i>Murex Deshayesii</i> , <i>Duch.</i>		*					
—, sp. uncert.							
— <i>affinis</i> , <i>Eichw.</i>							
<i>Fusus elongatus</i> , <i>Nyst</i>		*		*	*		
— <i>multisulcatus</i> , <i>Nyst</i>		*					
— <i>rostratus</i> , <i>Defr.</i>							
<i>Fasciolaria</i> (aff. <i>F. Lynchii</i> , <i>Grat.</i>)							
—, sp. undeterm.							
<i>Pyrula elegans</i> , <i>Lamk.</i>		*		*			
—, uncert. sp.							
<i>Pleurotoma Waterkeynii</i> , <i>Nyst</i>		*			*		
— <i>belgicum</i> , <i>Goldf.</i>		*		*			
— <i>regulare</i> , <i>van Bened.</i>		*	*				
— <i>Selysii</i> , <i>De Kon.</i>		*			*		
— <i>subdenticulatum</i> , <i>Münst.</i>		*			*		
— <i>Morrenii</i> , <i>De Kon.</i>		*			*		
— <i>scabrum</i> , <i>Phil.</i>					*		
— <i>flexuosum</i> , <i>Münst.</i>		*			*		
— <i>conoideum</i> , <i>Brand.</i>		*			*		
— <i>canaliferum</i> , <i>Merian</i>		*					
= <i>P. Borsoni</i> , var. <i>tumida</i> , <i>Bronn.</i>							
<i>Cancellaria evulsa</i> , <i>Brand.</i>		*	*		*		
— <i>Brauniana</i> , <i>Nyst</i>							
— <i>minuta</i> , <i>A. Braun</i>							
— <i>cornigera</i> , <i>A. Braun</i>							
<i>Cassidaria depressa</i> , <i>von Buch</i>		*			*		
— <i>Nysti</i> , <i>Kickx.</i>							
= <i>C. pulcherrima</i> , <i>A. Braun.</i>							
<i>Cassis belata</i> , <i>Beyrich</i>							
— <i>megapolitana</i> , <i>Beyrich</i>							
—, sp. uncert.							
<i>Buccinum cassidaria</i> , <i>Bronn</i>							
<i>Voluta Rathieri</i> , <i>Héb.</i>		*		*			
— <i>modesta</i> , <i>Merian</i>							
— <i>Schlotheimi</i> , <i>A. Braun</i>							
<i>Mitra perminuta</i> , <i>A. Braun</i>							
<i>Oliva</i> , sp. uncert.							
<i>Conus dormitor</i> , <i>Soland.</i>		*					
<i>Cypræa inflata</i> , <i>Lamk.</i>		*					
— <i>subcolumbaria</i> , <i>D'Orb.</i>		*					
<i>Bulla?</i> <i>concinna</i> , <i>Wood</i>							
= <i>B. ovulata</i> , <i>Lamk.</i>							
— <i>Bronnii</i> , <i>Merian</i>							
= <i>B. angustoma</i> , <i>Desh.</i>							
—, sp. uncert.							
<i>Serpula</i> , sp. uncert.							
<i>Spirorbis</i> , sp. uncert.							

TABLE I. (*continued*).

	Belgium.			Paris.	Magdeburg.	Vienna.	Bordeaux.
	Older than the Limburg series.	Limburg series.	Younger than the Limburg series.				
<i>Bairdia subdeltoidea</i> , <i>Münst.</i>							
— <i>arcuata</i> , <i>Münst.</i>			*	*			
<i>Cytheridea Mulleri</i> , <i>Münst.</i>		*	*	*			
<i>Cytherella tenuistriata</i> , <i>Reuss</i>							
<i>Cythere Voltzii</i> , <i>Reuss</i>							
Krebs (Crab?).....							
<i>Sphærodus</i> , sp. uncert.							
<i>Piscium</i> , 9 sp. uncert.....							
<i>Myliobates</i>							
<i>Zygobates</i>							
<i>Lamna cuspidata</i> , <i>Ag.</i>		*			*	*	
— <i>contortidens</i> , <i>Ag.</i>		*			*	*	
— <i>denticulata</i> , <i>Ag.</i>					*	*	
<i>Carcharodon angustidens</i> , <i>Ag.</i>		*				*	
<i>Notidanus primigenius</i> , <i>Ag.</i>		*				*	
<i>Crocodylus</i> , sp.							
<i>Trionyx</i> , sp.....							
<i>Emys hospes</i> , <i>von Meyer</i>							
<i>Halianassa Collinii</i> , <i>von Meyer</i>						*	
<i>Anthracotherium magnum</i> , <i>Cuv.</i>							

If from this list we direct our attention to Belgium, we find in Sir C. Lyell's paper* "On the Tertiary Strata of Belgium and French Flanders," that the fossils of the Limburg beds near Kleyn Spawen are in a very large proportion identical with those of Weinheim and its neighbourhood. The *Pectunculus*-bed at Bergh†, so called from the extraordinary number of *P. fossilis* contained in it, has its exact counterpart at Weinheim in a bed occurring, as has been already observed (p. 263), near the top of the section, containing a surprising number of *P. crassus*, Phil. and *P. arcatus*, Schloth., overlying beds of shelly sand abounding in fossil Gasteropods and Conchifers like those of the Bergh sands, *d* and *f* of fig. 2, *l. c.* p. 305. *P. crassus*, Phil., is the same as *P. fossilis*, Linn., and *P. arcatus*, Schloth., is *P. terebratularis*, Lam.

Unfortunately, the Weinheim fossils have not yet been so accurately worked out and referred to the different sandy beds in which they occur, as those of Kleyn Spawen. For the sake of comparison, therefore, we must take the whole of the lists referred to in Tables VIII. and IX. (*l. c.* pp. 304 and 312) of Sir C. Lyell's paper, in order to ascertain the resemblance between them and the Weinheim beds, as given in the above table. As far as I have been able to ascertain, it seems that about sixty species or nearly fifty per cent. are common to the two formations, many of these being very characteristic shells, such as *Nucula Deshayesiana*, *Pectunculus arcatus*,

* See Quarterly Journal Geol. Soc. vol. viii. p. 277. † *Loc. cit.* p. 305.

P. crassus, *Cyprina rotundata*, *Cytherea lævigata*, *Cardita Omaliana*, *Voluta Rathieri*, &c. Dr. Sandberger makes out no less than sixty-three species common to Weinheim and the Limburg series. A large proportion of these shells are evidently much water-worn, and many of the bivalves have been perforated by boring animals. From this it might, perhaps, have been inferred that they had been washed in with considerable violence, and drifted into particular places as dead shells. But the occurrence of Sharks'-teeth, which in some localities are very numerous, shows that this region must have been for a long time an arm or basin of the sea inhabited by marine animals until the brackish nature of the water interfered with their existence.

The beds immediately overlying the Marine Sands, while still containing many truly marine species, show a decided commencement of a brackish-water fauna, and this character increases as we ascend to the Cerithium and Littorinella limestones. The following is the list of fossils hitherto found in the Lower blue Brown-coal Clay or Cyrena-marl.

TABLE II.

Fossils of the Cyrena-marl, or blue Brown-coal Clay.

Saxicava, sp.	Littorina moguntina, <i>A. Braun.</i>
Solecurtus, sp.	Melania oviformis, <i>A. Braun.</i>
Mya pusilla, <i>A. Braun.</i>	— pernodosa, <i>Sandb.</i>
Corbulomya polita, <i>A. Braun.</i>	Cerithium incrustatum, <i>Schloth.</i>
— triangular, <i>Duch.</i>	— var. α . elongatum, <i>Sandb.</i>
Tellina faba, <i>Sandb.</i>	— — β . Meriani, <i>A. Braun.</i>
Bornia, sp.	— margaritaceum, <i>Brocchi.</i>
Cytherea Bosqueti, <i>Héb.</i>	— var. α . calcaratum, <i>Grat.</i>
— incrassata, <i>Sow.</i>	— — β . incrassatum, <i>Grat.</i>
Cyrena subarata, <i>Bronn</i> (very common).	— plicatum, <i>Lam.</i>
Cardium scobinula, <i>Merian.</i>	— var. α . crassum, <i>Sandb.</i>
Pectunculus crassus, <i>Phil.</i>	— — β . intermedium, <i>A. Braun.</i>
Nucula piligera, <i>Sandb.</i>	— — γ . Galeotti, <i>Nyst.</i>
Leda Deshayesiana, <i>Duch.</i>	— creniferum, <i>Desh.</i>
Tichogonia clavata, <i>Krauss.</i>	— abbreviatum, <i>A. Braun.</i>
Mytilus (aff. <i>M. gallo-provincialis</i> , <i>Lam.</i>)	—, sp. uncert.
— Faujasii, <i>Bronn.</i>	Chenopus tridactylus, <i>A. Braun.</i>
Avicula? trigonata, <i>Lam.</i>	Typhis cuniculosus, <i>Duch.</i>
Perna Soldanii, <i>Desh.</i>	Murex conspicuus, <i>A. Braun.</i>
Ostrea cyathula, <i>Lam.</i>	Pleurotoma belgicum, <i>Goldf.</i>
— callifera, <i>Lam.</i>	— subdenticulatum, <i>Münst.</i>
— var. β . minor.	Buccinum Cassidaria, <i>Bronn.</i>
Natica glaucinoides, <i>Sow.</i>	—, sp. incert.
Trochus rhenanus, <i>Merian.</i>	Mitra perminuta, <i>A. Braun.</i>
Littorinella Draparnaudii, <i>Nyst.</i>	Bulla? concinna, <i>Wood.</i>
— obtusata, <i>A. Braun.</i>	Planorbis pseudammonius, <i>Voltz.</i>
— acicula, <i>A. Braun.</i>	Limnæus, spec. 2 uncert.
— helicella, <i>A. Braun.</i>	Helix, sp. (aff. <i>H. lacticina</i> , <i>Ziegl.</i>)
— gibbula, <i>A. Braun.</i>	Serpula sinistrorsa, <i>Sandb.</i>
— angulata, <i>A. Braun.</i>	Balanus, sp. 2.
— lubricella, <i>A. Braun.</i>	Cytheridea Mülleri, <i>Münst.</i>
— compressuscula, <i>A. Braun.</i>	Sphærodon lens, <i>Ag.</i>
— acuta, <i>Desh.</i>	Lamna cuspidata, <i>Ag.</i>
Nematura granulum, <i>A. Braun.</i>	— contortidens, <i>Ag.</i>
Rissoa plicata, <i>Desh.</i>	Zygobates, sp.
— nitida, <i>Grat.</i>	Anthracootherium alsaticum, <i>Cuv.</i>
Scalaria (aff. <i>S. reticulata</i> , <i>Phil.</i>).	

With regard to the proper parallelism of this formation, I may quote the words of Dr. F. Sandberger, who, after giving the various localities in which each of these fossils is found, observes that "out of the whole list of twenty-eight species common to the Cyrena-marls and other tertiary deposits, eighteen are common to the Middle Limburg formation, and eight to the upper marine sand of Paris; but, as we have found a still larger number of species which these formations have in common with the sands of Weinheim, and have consequently recognized them as the equivalent of the Middle beds of Limburg, and as the Cyrena-clay is proved by its position to be newer than the sands of Weinheim, I believe that it must be paralleled with the Upper Limburg and the Septaria-clay of Northern Germany."

I have already observed that the "freshwater limestone" of the German geologists must be considered as the lowest member of the Cerithium-limestone, we must therefore take the two following lists together; No. III. being that of the so-called "freshwater limestone," and No. IV. that of the Cerithium-limestone.

TABLE III.

Fossils of the "Freshwater Limestone of the Germans." (No. 3 of the list at p. 260.)

<i>Littorinella acuta</i> , Desh.	<i>Helix osculum</i> , Thom.
<i>Neritina picta</i> , Fér.	— var. <i>α. communis</i> ,
<i>Cerithium subcorrugatum</i> , d' Orb.	— <i>affinis</i> , Thom.
— <i>submargaritaceum</i> , A. Braun.	— <i>involuta</i> , Thom.
<i>Planorbis parvulus</i> , Reuss.	— var. <i>α. communis</i> ,
<i>Limnæus Thomæi</i> , Reuss.	— <i>pupula</i> , A. Braun.
<i>Auricula minutissima</i> , A. Braun.	— var. <i>α. Coreulum</i> , A. Braun.
<i>Truncatella microceras</i> , A. Braun.	— — <i>β. paludinæformis</i> , A. Braun.
<i>Acicula subtilissima</i> , A. Braun.	— <i>stenotrypta</i> , A. Braun.
— <i>suturalis</i> , A. Braun.	<i>Helix verticilloides</i> , A. Braun, Th.
<i>Cyclostoma</i> (<i>Craspedopoma</i>) <i>utriculosum</i> , Sandb.	— var. <i>β. euryomphalos</i> , A. Braun.
— (<i>Megalomastoma</i>) <i>Dolium</i> , Thom.	— <i>hypoleios</i> , A. Braun.
— (<i>Cyclostomus</i>) <i>bisulcatum</i> , von Zieten.	— <i>β. compressa</i> , A. Braun.
— (<i>Pomatias</i>) <i>labellum</i> , Thom.	— <i>discus</i> , Thom.
<i>Vitrina intermedia</i> , Reuss.	— <i>disculus</i> , A. Braun.
<i>Helix Ramondi</i> , Brongn.	— <i>nana</i> , A. Braun.
— <i>Brauniorum</i> , Thom.	— <i>subcellaria</i> , Thom.
— <i>deflexa</i> , A. Braun.	— <i>sublucida</i> , A. Braun.
— var. <i>α. communis</i> ,	— <i>nitidulosa</i> , A. Braun.
— — <i>β. hortulana</i> , Thom.	<i>Bulimus gracilis</i> , Thom.
— — <i>γ. minor</i> ,	<i>Achatina</i> (<i>Glandina</i>) <i>subsulcosa</i> , Thom.
— <i>oxystoma</i> , Thom.	— (—) Sandbergeri, Thom.
— <i>subsulcosa</i> , Thom.	— (—) <i>lubricella</i> , A. Braun.
— <i>similis</i> , Thom.	<i>Clausilia exarata</i> , Ziegl.
— <i>Kalmitana</i> , A. Braun.	<i>Pupa variabilis</i> , Drap.
— <i>Rahtii</i> , A. Braun, Th.	— var. <i>β. gracilis</i> , Sandb.
— <i>phacodes</i> , Thom.	— <i>cylindrella</i> , A. Braun.
— <i>lapicidella</i> , A. Braun.	— <i>Dolium antiquum</i> , A. Braun.
— <i>pulchella</i> , Müll.	— <i>quadrigranata</i> , A. Braun.
— var. <i>γ. costellata</i> , A. Braun.	— <i>subdentata</i> , A. Braun.
— <i>uniplicata</i> , A. Braun.	— <i>cryptodonta</i> , A. Braun.
— <i>lepidotricha</i> , A. Braun.	— var. <i>β. lævis</i> , A. Braun.
	— (<i>Vertigo</i>) <i>trifurcata</i> , A.
	— (—), n. sp.

TABLE III. (*continued*).

Pupa (<i>Vertigo</i> didymodonta, <i>A. Braun</i> .	Snakes.
— (—) palustris, <i>Turton</i> .	Lizards, 2–3 sp.
— var. γ . minor oblonga, <i>A. Braun</i> .	Birds, 3 sp.
— trigonostoma, <i>A. Braun</i> .	Microtherium Renggeri, <i>von Meyer</i> .
— tiarula, <i>A. Braun</i> .	Rhinoceros, sp.
— acicula, <i>Sandb</i> .	Palæomeryx pygmæus, <i>von Meyer</i> .
Cypris faba, <i>Desm</i> .	Rodentia, 5 sp.
Salamander.	Carnivora, 3 sp.
Frogs, 5 sp.	Insectivora.

It may be observed, that, with scarcely an exception, only those species have been introduced into this list which have been found at Hochheim.

TABLE IV.

Fossils of the Cerithium Limestone.

Foraminifera, 2 sp.	Cerithium var. α . pustulatum,
Bryozoa.	— — forma calva,
Modiola angusta, <i>A. Braun</i> .	— var. α . plicato-granulatum,
Mytilus socialis, <i>A. Braun</i> .	— incrustatum, <i>Schloth</i> .
— ? antiquorum, <i>Sow</i> .	— var. α . elongatum,
— Faujasii, <i>Brongn</i> .	— — forma nodosa et calva,
Perna Soldanii, <i>Desh</i> .	— var. β . Meriani,
Pinna ?, sp.	—, n. sp. (aff. <i>C. Scalaroides</i> .)
Pisidium antiquum, <i>A. Braun</i> .	Fusus brevis, <i>A. Braun</i> .
Cyrena donacina, <i>A. Braun</i> .	Nassa, sp. (aff. <i>N. reticulata</i> , .)
Cytherea incrassata, <i>Sow</i> .	Cyclostoma bisulcatum, <i>von Zieten</i> .
Corbulomya donacina, <i>A. Braun</i> .	— Dolium, <i>Thom</i> .
Littorina moguntina, <i>A. Braun</i> .	— labellum, <i>Thom</i> .
Littorinella acuta, <i>Desh</i> .	Strophostoma tricarinatum, <i>M. Braun</i> .
Planorbis declivis, <i>A. Braun</i> .	Helix deflexa, <i>A. Braun</i> .
Limnæus Thomæi, <i>Reuss</i> .	— oxystoma, <i>Thom</i> .
Neritina picta, <i>Fér</i> .	— valdecarinata, <i>A. Braun</i> .
— concava, <i>Sow</i> ,	— phacodes, <i>Thom</i> .
Nerita rhenana, <i>Thom</i> .	— parvula, <i>A. Braun</i> .
Cerithium submargaritaceum, <i>A. Braun</i> .	— verticilloides, <i>A. Braun, Th</i> .
— plicatum, <i>Lam</i> .	— subcellaria, <i>Thom</i> .
— var. γ . Galeotti, <i>Nyst</i> .	— subluclida, <i>A. Braun</i> .
— — forma calva,	Balanus, sp.
— var. δ . curvuplicatum,	Cypris, sp.

The great peculiarity of list No. 3 is the very large proportion of land-shells which it contains; but these, it must be remembered, are all derived from one or two small localities. They are only sparingly found in other parts of the formation, and it may be observed that every one of the *Helices* and *Cyclostomata* found in table No. IV., which comprises the general contents of the whole formation, is also to be found in list No. III., which latter professes to give only the contents of one or two small localities near the edge of the formation, and where we might fairly expect the remains of the terrestrial fauna of the district to have accumulated on the shores and margins of the waters. The two lists must, therefore, be looked upon as contemporaneous; the one showing the terrestrial fauna washed into and found on the margin of the lake, the other the real inhabitants of the brackish water.

But to resume ;—the increasing brackishness of the water during this period is apparent from these lists, and by the greater number of land and freshwater shells which are found promiscuously dispersed throughout the whole thickness, but in general more abundantly in particular localities. These have evidently been washed into the basin by large freshwater streams, emptying themselves and their contents into the lacustrine basin, and show how the diminished saltiness of the water was in part at least occasioned. They also offer an argument in favour of our placing the whole Mayence basin higher rather than lower in the geological scale, inasmuch as amongst the land-shells we find at least four species still living in some parts of Europe, viz. *Helix pulchella* (Müll.), *Pupa palustris* (Drap.), *Pupa variabilis* (Drap.), and *Clausilia exarata* (Ziegl.).

In addition to these observations, I might also quote the comparison made by Dr. F. Sandberger between the land and freshwater molluscs of the Mayence basin and those now living, in which he has shown, that, with few exceptions, they have analogous, if not identical, representatives in those of the existing Mediterranean basin. With regard to the genus *Helix*, Dr. Sandberger observes that, amongst the numerous species of *Helix* found at Hochheim, the true Mediterranean groups of *H. verticillus* and *H. serpentina* preponderate, and amongst those found at Wiesbaden is *H. moguntina* (Desh.), an analogue of *H. splendida*. In the group of *Helix verticillus*, the fossil species *H. verticilloides* (A. Braun), *H. amplificata* (Th.), and *H. discus* (Th.) must be noticed.

The following tabular list will show some of the analogies observed by Dr. Sandberger :—

RECENT.		FOSSIL.
<i>Helix acies</i> , <i>Partsch</i>	=	<i>Helix discus</i> , <i>Thom.</i>
— <i>olivetorum</i>	=	— <i>subcellaria</i> , <i>Thom.</i>
— <i>muralis</i>		
— <i>serpentina</i> } (Italy).....	=	— <i>deflexa</i> , <i>A. Braun.</i>
— <i>globularis</i> }		
— <i>serpentina</i> , <i>Fér.</i>	=	— <i>subcarinata</i> , <i>A. Braun.</i>
— <i>lens</i>	=	— <i>phacodes</i> , <i>Thom.</i>
— <i>lenticula</i>	=	— <i>lapicidella</i> , <i>A. Braun.</i>
— <i>scabriuscula</i>	=	— <i>Rahtii</i> .
— <i>rotundata</i>	=	— <i>multicostata</i> , <i>Thom.</i>
— <i>pulchella</i>	=	— <i>pulchella</i> .
— <i>triaria</i>	=	— <i>plicatella</i> , <i>Reuss.</i>
— <i>desertorum</i>	=	{ <i>Brauniorum</i> .
		— <i>Mattiaca</i> .
— <i>obvoluta</i>	=	— <i>involuta</i> , <i>Thom.</i>
— <i>Lefeburiana</i>	=	— <i>Arnoldii</i> , <i>Thom.</i>
— <i>personata</i>	=	— <i>osculum</i> , <i>Thom.</i>
<i>Clausilia macarana</i>	=	<i>Clausilia bulimoides</i> .
— <i>exarata</i>	=	— <i>exarata</i> .

But it is unnecessary to quote any more instances*.

* Sandberger, Untersuchungen, p. 73.

TABLE V.—*Fossils of the Littorinella Limestone.*

<i>Tichogonia clavata</i> , <i>Krauss.</i>	<i>Pupa bigranata</i> , <i>Rossm.</i>
<i>Mytilus</i> ? <i>antiquorum</i> , <i>Sow.</i>	— <i>retusa</i> , <i>A. Braun.</i>
— <i>Faujasii</i> , <i>Desh.</i>	— <i>cryptodonta</i> , <i>A. Braun.</i>
<i>Cyrena Faujasii</i> , <i>Brongn.</i>	— <i>acicula</i> , <i>Sandb.</i>
— <i>lævigata</i> , <i>Goldf.</i>	— (<i>Vertigo</i>) <i>obstructa</i> , <i>A. Braun.</i>
<i>Cerithium margaritaceum</i> , <i>Brocchi.</i>	— (—) <i>quadruplicata</i> , <i>A. Braun.</i>
— <i>plicatum</i> , <i>Lamk.</i>	— (—) <i>palustris</i> , <i>Turton.</i>
— var. <i>ε. pustulatum</i> ,	— var. <i>α. major ovata</i> ,
— <i>incrustatum</i> , <i>Schloth.</i>	— var. <i>β. minor subglobosa</i> ,
— var. <i>β. Meriani</i> ,	<i>Cypris faba</i> , <i>Desm.</i>
<i>Neritina fluviatilis</i> , <i>Lam.</i>	— <i>angusta</i> , <i>Reuss.</i>
— var. <i>gregaria</i> , <i>Thom.</i>	— <i>trigonula</i> , <i>Sandb.</i> , n. sp.
<i>Littorinella acuta</i> , <i>Desh.</i>	<i>Phryganea Mombachiana</i> , <i>Höningh.</i>
— <i>inflata</i> , <i>Brard.</i>	— <i>Blumii</i> , <i>Hepp.</i>
<i>Paludina lenta</i> , <i>Sow.</i>	<i>Perca moguntina</i> , <i>Ag.</i>
<i>Melanopsis olivula</i> , <i>Grat.</i>	<i>Pisces</i> , sp.
— var. <i>α. minor</i> .	<i>Salamandra</i> , sp.
— var. <i>β. major</i> .	<i>Rana</i> , sp.
<i>Melanopsis marginata</i> , <i>A. Braun.</i>	<i>Ophidia</i> , sp.
<i>Limnæus pachygaster</i> , <i>Thom.</i>	—, eggs?
—, n. sp.	<i>Crocodylus</i> , sp.
— <i>subpalustris</i> , <i>Thom.</i>	<i>Trionyx</i> , sp.
— <i>striatellus</i> , <i>Grat.</i>	<i>Aspidonectes Gergensii</i> , <i>von Meyer.</i>
— <i>vulgaris</i> , <i>Pfeif.</i>	<i>Emys</i> , sp.
— <i>minor</i> , <i>Thom.</i>	<i>Clemmys rhenana</i> , <i>von Meyer.</i>
<i>Planorbis pseudammonius</i> , <i>Voltz.</i>	<i>Palæochelys taunica</i> , <i>von Meyer.</i>
— <i>declivis</i> , <i>A. Braun.</i>	<i>Birds</i> , sp.
— <i>dealbatus</i> , <i>A. Braun.</i>	—, eggs, 2 sp.
— <i>Kraussii</i> , <i>von Klein.</i>	<i>Hippotherium gracile</i> , <i>Kaup.</i>
<i>Ancylus Mattiacus</i> , <i>A. Braun.</i>	<i>Microtherium Renggeri</i> , <i>von Meyer.</i>
<i>Auricula antiqua</i> , <i>A. Braun.</i>	— <i>concinnum</i> , <i>von Meyer.</i>
— <i>minutissima</i> , <i>A. Braun.</i>	<i>Hyotherium medium</i> , <i>von Meyer.</i>
<i>Helix Mattiaca</i> , <i>Steining.</i>	— <i>Meissneri</i> , <i>von Meyer.</i>
— <i>sylvestrina</i> , <i>von Zietzen.</i>	<i>Rhinoceros incisivus</i> , <i>Cuvier.</i>
— <i>moguntina</i> , <i>Desh.</i>	—, sp.
— <i>α. splendideformis</i> , <i>A. Braun.</i>	<i>Tapirus Helveticus</i> , <i>von Meyer.</i>
— <i>β. communis</i> ,	<i>Palæomeryx Scheuchzeri</i> , <i>v. Meyer.</i>
— <i>γ. subcarinata</i> ,	— <i>medius</i> , <i>von Meyer.</i>
— <i>subcarinata</i> , <i>A. Braun.</i>	— <i>minor</i> , <i>von Meyer.</i>
— n. sp. (aff. <i>H. candidissima</i> ,)	— <i>pygmæus</i> , <i>von Meyer.</i>
— <i>punctigera</i> , <i>Thom.</i>	<i>Lithomys parvulus</i> , <i>von Meyer.</i>
— <i>phacodes</i> , <i>Thom.</i>	<i>Brachymys ornatus</i> , <i>von Meyer.</i>
— <i>pulchella</i> , <i>Müll.</i>	<i>Chalicomys Eseri</i> , <i>von Meyer.</i>
— var. <i>β. costellata</i> , <i>A. Braun.</i>	<i>Titanomys Visenoviensis</i> , <i>v. Meyer.</i>
— <i>osculum</i> , <i>Thom.</i>	<i>Rodentia</i> , sp.
— var. <i>β. depressa</i> ,	<i>Carnivora</i> , sp.
— var. <i>γ. globosa</i> ,	<i>Stephanodon Mombachensis</i> , <i>v. M.</i>
— <i>involuta</i> , <i>Thom.</i>	<i>Acanthodon ferox</i> , <i>von Meyer.</i>
— var. <i>β. dilatata</i> , <i>A. Braun.</i>	<i>Amphicyon dominans</i> , <i>von Meyer.</i>
— <i>stenotrypa</i> , <i>A. Braun.</i>	— <i>intermedius</i> , <i>von Meyer.</i>
— <i>verticilloides</i> , <i>A. Braun.</i>	— <i>Klipsteinii</i> , <i>von Meyer.</i>
— var. <i>γ. increscens</i> , <i>Thom.</i>	<i>Palæogale pulchella</i> , <i>von Meyer.</i>
— <i>multicostata</i> , <i>Thom.</i>	— <i>fecunda</i> , <i>von Meyer.</i>
— <i>lunula</i> , <i>Thom.</i>	<i>Erinaceus priscus</i> , <i>von Meyer.</i>
— <i>Thomæana</i> , <i>A. Braun.</i>	<i>Oxygomphus leptognathus</i> , <i>v. M.</i>
— <i>uniplicata</i> , <i>A. Braun.</i>	<i>Dimylus paradoxus</i> , <i>von Meyer.</i>
<i>Achatina subrimata</i> , <i>Reuss.</i>	<i>Talpa brachycheir</i> , <i>von Meyer.</i>
<i>Clausilia bulimoides</i> , <i>A. Braun</i> , <i>Th.</i>	<i>Sorex pusillus</i> , <i>von Meyer.</i>
<i>Pupa quadrigranata</i> , <i>A. Braun.</i>	<i>Vespertilio præcox</i> , <i>von Meyer.</i>
— <i>Rahtii</i> , <i>A. Braun.</i>	— <i>insignis</i> , <i>von Meyer.</i>

This list shows an increasing proportion of land and freshwater shells throughout the general mass, although the whole number of species is hardly so great as in the lower beds of the Cerithium-limestone. There is also a considerable change of species between the two formations, and were it not for the *Cerithia* and *Mytili*, which are still abundant, although the species are few, this might almost be looked upon as a freshwater formation. This however is not the case; moreover certain species of *Cerithia* and *Cyrena Faujasii* occur in the overlying blue clays, so that the brackish-water period must not be considered as yet concluded. Here also, as in the preceding formation, several forms of land shells make their appearance which are strictly analogous to, some even identical with, those now existing in one part or other of the Mediterranean basin.

TABLE VI.

Fossils of the Ossiferous or Bone-bearing Sand.

Fish, sp.	Macrotherium, sp.
Crocodylus, sp.	Agnotherium antiquum, <i>Kaup.</i>
Tortoise, sp.	Dorcatherium Nani, <i>Kaup.</i>
Hippotherium gracile, <i>Kaup.</i>	Palæomeryx minor, <i>v. Meyer.</i>
Chalicotherium antiquum, <i>Kaup.</i>	Cervus Bertholdi, <i>Kaup.</i>
— Goldfussii, <i>Kaup.</i>	— Partschii, <i>Kaup.</i>
Anthracotherium magnum, <i>Cuv.</i>	— anocerus, <i>Kaup.</i>
Tapirus priscus, <i>Kaup.</i>	— dicranocerus, <i>Kaup.</i>
Sus antediluvianus, <i>Kaup.</i>	— curtocerus, <i>Kaup.</i>
— palæochoerus, <i>Kaup.</i>	— nanus, <i>Kaup.</i>
— antiquus, <i>Kaup.</i>	Chalicomys Jægeri, <i>Kaup.</i>
Rhinoceros Goldfussii, <i>Kaup.</i>	Gulo diaphorus, <i>Kaup.</i>
— Schleiermacheri, <i>Kaup.</i>	Machairodus cultridens, <i>Kaup.</i>
— incisivus, <i>Cuv.</i>	Felis aphanista, <i>Kaup.</i>
— minutus, <i>Cuv.</i>	— ogygia, <i>Kaup.</i>
Mastodon longirostris, <i>Kaup.</i>	— prisca, <i>Kaup.</i>
Dinotherium giganteum, <i>Kaup.</i>	— antediluviana, <i>Kaup.</i>
— Bavaricum, <i>v. Meyer.</i>	

The isolated character of the deposits in which these osseous remains are found has been already mentioned in the former portion of this paper (page 272). It is only necessary here to observe, that the occurrence of *Anthracotherium magnum* (*Cuv.*), common to the Marine Sands, and of *Rhinoceros incisivus* (*Cuv.*), *R. minutus* (*Cuv.*), *Palæomeryx minor* (*Von Meyer*), and *Hippotherium gracile* (*Kaup.*), common to the Littorinella-limestone, proves that these ossiferous sands, although somewhat newer, do in reality belong to the same general system of tertiary deposits as the underlying formations.

I will not attempt to point out any inferences as to the nature of climate or geographical features of the then existing country, which might be drawn from the habits and characters of the mammalian animals whose remains have been here preserved; I leave it to the palæontologists and cultivators of comparative anatomy, whom we rejoice to reckon amongst our members and to see on our benches, to work out the interesting problems connected with this part

of the question; but I venture, with great diffidence, to lay before the Society the reasons which have led me to incline to the opinion that the Marine Sands of Weinheim ought to be looked upon as *Miocene* rather than *Eocene*.

I say *Miocene* rather than *Eocene*, because I am not altogether prepared to admit the correctness of these terms, in the sense of looking upon them as two subdivisions the exact boundaries of which can be accurately laid down or defined. I believe that if we could obtain sections of all the European tertiary deposits, from the nummulitic limestone up to the most recent post-pliocene formation, we should be able to make out, in one section or another, a constant unbroken sequence, without either break or interruption. I do not mean to assert that no local changes or interruptions took place during this period; on the contrary, they were probably very frequent. Animal life also was undergoing a slow but gradual change, from the earliest post-cretaceous to the existing forms, regulated according to the more or less favourable conditions under which it was placed, contemporaneously with the changes going on in the physical condition of the region; but I do not believe that these changes or disturbances were universal, or that the causes which occasioned the destruction of one species and the introduction of another operated at the same epoch in all parts of the then European seas. In process of time, as the different changes in relative height, in elevation above and depression beneath the mean level of the ocean, extended, did the change in animal life also extend, modifying it everywhere on the same general principles, again to be locally modified by the differences of soil, rocks, and sea-bottoms, until it had travelled through all the changes from the commencement to the close of the tertiary epoch.

I have said thus much to show that I do not attach any great importance abstractedly to the question as to whether the beds we are now considering should be called Upper Eocene or Lower Miocene; for although I think they contain a greater number of fossils identical with those found in other countries in formations above rather than below them, the mere name of the beds is not the real question before us. One thing however is certain, that they have a greater resemblance with the *Limburg*, and particularly with the *Kleyn Spawen* beds, than with any other known European formation. They contain also some fossils similar to those below, and others identical with those above. As however the question has been raised, whether they should be placed in the Eocene or Miocene subdivision, I will briefly state my reasons, founded on physical as well as on palæontological grounds, for the conclusion at which I have arrived.

It is well known that the author of this nomenclature founded his system on the different proportions of the fossil shells found in each formation which are identical with living species, on the assumption that, in proportion as we ascend to a higher bed, the greater is the identity between its organic contents and the existing fauna; and

although he refuses to entertain the idea of connecting these divisions with sudden and violent interruptions in the ordinary course of events, or with violent revolutions in the physical geography of the earth's surface, he cannot deny that the changes of strata are owing to physical causes and to alternate elevations and depressions occasioned by subterranean convulsions. If, then, these subdivisions of Eocene, Miocene, and Pliocene are to be considered as representing true geological horizons, it must be admitted that they depend on some external facts, some natural, but partial convulsions, which, by altering the relative levels of land and water, or by other similar causes, changed the conditions of life, causing the destruction of some then-existing species, and producing the necessary conditions for the introduction or creation of new ones. If this be not the case, the lines or divisions are made to depend on the accidental varieties of numbers, which may be owing to merely local or temporary causes, and could hardly be considered as a sufficient basis for a philosophically-established nomenclature.

It is, therefore, not unreasonable to assume, that, wherever the real line of demarcation between any two subdivisions is to be drawn, some physical change or convulsion must have occurred at no great distance, by which the conditions of life were suddenly altered, although further off no real break took place in the continuity of deposits, and there the change of species was so gradual, and almost imperceptible, that it was impossible to draw a true geological line of separation. Where, however, the sudden change did take place, there the line of demarcation can be distinctly drawn, and will thus serve as a correct guide to the separation of other beds. We have, then, no difficulty in saying, where one deposit ceases, "This is the end of the old system," and where a new deposit commences, "This is the beginning of the new system." Now, this is precisely the position we are in with regard to the Weinheim beds of the Mayence basin. They have been satisfactorily shown to be identical with the Middle Limburg beds; the Middle Limburg beds are part of a continuous series, gradually merging into those below and those above. They are called indiscriminately Upper Eocene by one author, Lower Miocene by another; and, belonging partially to both, they can yet be fully claimed by neither. With the Weinheim beds the case is very different; they can be shown, under successive modifications, clearly to belong to the same system as the beds above, but they have no relation whatever to those below. They lie unconformably on the Carboniferous Sandstone; they form the commencement of a series, the basis of the whole system. Here, then, we are enabled to say, "This is the beginning of the new system;" and we have consequently no difficulty, and ought to have no hesitation, in looking on the Middle Limburg, as well as the Weinheim beds, as the commencement of the Miocene series.

It would, I think, be inconsistent with all analogy to call a bed, which unequivocally forms the commencement of the whole tertiary system in the country, the upper bed of an old expiring series, rather

than the lowest bed of a new series; the latter being in accordance with its true position, the former supposition being at variance with the local facts, and unsupported by satisfactory evidence.

These are the principal reasons which have induced me to refer the Marine Sands of Weinheim to the Miocene rather than to the Eocene formation, and not on account of any vague numerical proportion of forms agreeing more with the recent than with the older beds. No doubt they contain many Eocene forms, but we are not to assume that all life was destroyed at each successive period of change. The old forms were doubtlessly washed into the newly created seas, dead or alive, from the pre-existing Eocene waters; besides which, many species may have lived through the change, as we find species existing through the whole tertiary period, notwithstanding the many successive changes to which they must have been exposed*.

PART III.

ON THE ANCIENT GEOGRAPHICAL CHARACTER AND CONNECTION OF THE SEA IN WHICH THE MARINE FAUNA OF THE MAYENCE BASIN WAS DEPOSITED.

One of the most interesting questions connected with the locality of the Mayence basin, and its marine fauna, is the insulated character of its position, and its probable channels of communication with the then existing ocean. The opinion generally entertained by the German geologists is, that the region occupied by these marine formations was at the period of their deposition an inland lake (*Binnen-See*), having no direct communication with the ocean, but containing a somewhat similar fauna in consequence of the saltiness of its water. The abundant occurrence of Sharks' teeth of several species, and the remains of *Halianassa Collinii* in numerous places, sufficiently disprove this hypothesis. Notwithstanding the present difference of levels between the existing sea and the marine beds of Weinheim, amounting to between 500 and 600 feet, and the complete insulation of the region, these remains are a convincing proof

* It must, however, in justice be admitted, that, if this rule is fully carried out, we must not attempt to apply too arbitrarily the nomenclature of one place to the circumstances of another, when the physical changes which have disturbed the continuity of organic life have taken place at different periods. For example, in Belgium there is no break in the Limburg beds in the continuity of deposition. In Mayence the new system begins with the equivalent of the Middle Limburg series. In another country the physical change took place at a later period, viz. after the Upper Limburg beds or their equivalents were deposited. There we find a regular sequence of beds from the London clay to the Upper Limburg, and then it suddenly ceases, until it is overlaid by diluvial deposits. Here, then, we find that the equivalent of the bed which in the first locality was shown to be the commencement of a new series, and consequently is called Miocene, proves to be in another place the termination of the old series. We have no means of avoiding the conviction which forces itself upon us, that we must call it Eocene. Thus, the same beds which I call Miocene in Mayence, may with perfect propriety be called Eocene by Prof. Forbes, in the Isle of Wight.—July 12, 1854.—W. J. H.

that the sea in which the beds in question were formed must, at the period of their deposition, have been in direct connection with a then existing ocean. The numerous remains of Sharks also show that that ocean was not exclusively an Arctic one; and even the *Halina* tells the same story, its remains having hitherto been found in the Molasse of Switzerland, and at Malta. On the other hand, the large *Cyprina rotundata*, which can hardly, if at all, be distinguished from the recent *C. islandica*, shows that we must not look exclusively to a warm or semi-tropical connection.

The numerous volcanic regions, and the evidence of igneous agency of various periods, by which this district is surrounded, point at once to the causes which produced the different changes of relative level by which this connection was broken off. I will here only allude to a few of them. The great volcanic region of the Eifel, lying to the north and north-west of the Hunsrück, which forms the N.W. boundary of our district, is one of the recent results of igneous action. The outpourings of basaltic rocks, which have elevated and broken up the Brown-coal deposits of the Westerwald, must have been active agents in modifying the physical configuration of this country. The basalts of the Fichtelgebirge, and those in the vicinity of Hanau and of Frankfort, and in the Coal-field of the Wetterau, have probably been equally effective.

Let us now look at the various tertiary deposits existing in the neighbouring countries, to see how far any connection between their areas and that of the Mayence Basin may be supposed to have existed.

I. *Belgium*.—From the evidence brought forward in the former part of this paper (page 279), there can be no doubt as to the great resemblance between the fossils of the Weinheim sands and those of the Middle Limburg beds, and particularly the so-called *Pectunculus*-bed, constituting, according to Sir C. Lyell, the upper portion of those Middle Limburg beds.

The large proportion of identical species in these two formations is alone sufficient to lead to the conviction that some connection must have existed between these two marine basins. Three species of *Lamna*, viz. *L. cuspidata*, Ag., *L. denticulata*, Ag., and *L. contertens*, Ag., also occur in these beds, which are not only found in the Limburg beds, but in those near Turin.

II. With the tertiary formations of *France*, no special direct communication appears to exist, beyond what may be traced through the tertiaries of Belgium. The two districts are here separated by a large tract of intervening mountain-ranges, consisting of jurassic, liassic, and carboniferous rocks, against which the Weinheim beds appear to have been subsequently deposited.

III. *Switzerland*.—I greatly regret not having yet had an opportunity of seeing Prof. Studer's second volume on the Geology of Switzerland, in which the fossils of the Molasse are worked out*.

* Since the above was written, the second volume of Prof. Studer's work has

The collection in the museum at Berne was not, when I visited it, completely arranged, nor were the localities given with such a degree of accuracy as to show from what portion of the Molasse the large collection of Mollusca, classed generally as belonging to it, was derived. The principal features which struck me were the great preponderance of Bivalves, and the rather more recent *facies* of the whole collection. It is well known that this formation is very generally extended over the great central valley of Switzerland, between the Alps and the Jura; it is to be traced in almost all the valleys of the Jura, forming terraces on the sides of the hills, or occupying the bottoms; and it also occurs in most of the valleys on the northern flank of the Jura, opening into the valley of the Rhine below Basle†; and a few miles from Basle, north of the Rhine, at Lörrach in Baden, is one of the best localities, according to Prof. Merian, for studying the Molasse formation, where it occurs as a kind of calcareous rock (formerly extensively quarried), and overlaid by freshwater limestone. Indeed it is said that this formation may be traced all round the basin of the ancient sea, and along the hills of Alsace, where a large species of *Ostrea* is found attached to the jurassic limestone, on which it once grew when this limestone formed the cliffs rising up from the shore of the tertiary sea.

When we look at the physical connection between the formations of the Mayence basin and the older rocks against which they are deposited, it is evident that the hills which constitute the western side of the Valley of the Upper Rhine, forming the mountains of the Haardt and the Vosges, had already assumed in a great measure their present forms and characteristic outlines before the deposition of the tertiary beds. On the western side of the Rhine the tertiary

reached England, giving the results hitherto obtained respecting the fossil contents of the Molasse. In general, however, the specimens are so imperfectly preserved, that it is difficult to make out the species accurately. Yet, from the list published by Prof. Studer, it is remarkable what a large proportion of the *Mollusca* of the older Molasse of Basle, Porrentruy, &c., are identical with the fossils of the Mayence basin. After describing these Molasse beds, and hesitating as to whether they should be referred to the Eocene or Miocene groups, showing that in some places they approach an eocene, in others a miocene *facies*, Prof. Studer observes that there is a remarkable analogy, which might almost be called identity, between the North Jura marine tertiary formation and that of the Mayence basin; not only in the rock itself, but in its organic remains, singularly like those of the Mayence basin; and, although many species are difficult to identify, some of the most characteristic, as *Halianassa* and Fishes, *Cerithia*, *Natica gigantea*, *Panopæa intermedia*, *Corbula pisum*, *Pectunculus crassus*, and *Ostrea Collinii*, are common to both formations.

† It now appears from Prof. Studer's work, that the Molasse formation must be separated into two chief divisions: 1. That of the Northern Jura; 2. That of the Interior or Mittel-land. The former is overlaid by a freshwater formation; the latter, which assumes a more recent character, is divided into two subdivisions,—the subjurassic and subalpine zones, and lies between two freshwater formations. Of these, the fauna of the Subjurassic zone has considerable resemblance with that of the Marine Molasse of Basle; while the fauna of the Subalpine zone is compared with that of Bordeaux, Vienna, and the Subapennine formation of the North of Italy.

limestones may be traced at nearly the same level, following the sinu-
osities of the valleys, and appearing as beaches of the ancient sea ;
thus agreeing with what we have already seen to be the case in the
valleys of Switzerland. On the eastern side of the Rhine, where
volcanic outbursts of a more recent period are visible, the evidence is
not so conclusive ; but even here, tertiary beds of sandstone and
Molasse can be made out in various places, as at Heppenheim, be-
tween Darmstadt and Heidelberg, and further south near Offenburg.

IV. Extending our view to the other tertiary deposits round the
district we are examining, we meet with the interesting formations of
the Vienna Basin. The general character of most of the fossil
remains,—for they are said to belong to two periods,—which have been
found in this formation, to which the name of “Tegel” has been ap-
plied by the German geologists, and a list of the chief of which has
been published by the Imperial Geological Institute of Vienna, ap-
pears to be more recent than that of the Weinheim fossils. According
to Burmeister *, these middle tertiary formations extend in Germany
down the Valley of the Danube from the Lake of Constance to
Vienna, and stretch along the base of the Carpathian Mountains.
This author considers the Tegel formation to be nearly if not quite
contemporaneous with the Molasse and Nagel-fluhe of Switzerland.

The following species are common to the lists published by the
Imperial Geological Institute and by Prof. Studer † as belonging
to the younger Molasse :—

Conus Mercati, Brocchi.
Ancillaria glandiformis, Lam.
Mitra fusiformis, Brocchi.
Columbella curta, Bellardi.
— *nassoides, Bellardi.*
Buccinum reticulatum, Grat.
— *semistriatum, Broc.*
— *mutabile, Linn.*
— *baccatum, Basterot.*
Rostellaria pes-pellicani, Lam.
Ranella marginata, Lam.
Fusus burdigalensis, Grat.
Cancellaria cancellata, Lam.
Pleurotoma asperulata, Lam.
— *pustulata, Broc.*
— *turricula, Broc.*
Cerithium margaritaceum, Lam.
— *scabrum, Desh.*

Turritella terebralis, Lam.
— *Riepellii, Partsch.*
Trochus patulus, Brocchi.
Sigaretus haliotoideus, Lam.
Natica millepunctata, Lam.
Crepidula unguiformis, Lam.
Mactra podolica, Eichwald.
Corbula revoluta, Broc.
Lucina divaricata, Lam.
Cytherea pedemontana, Agassiz.
— *erycinoides, Lam.*
— *multilamella, Lam.*
Venus plicata, Gmel.
Cardium Deshayesii, Payr.
Arca barbata, Linn.
— *diluvii, Lam.*
Pecten Solarium, Lam.

Many other identities will probably be found to exist, when the
synonyms shall have been more carefully examined. Dr. Sandberger
informs me that he was much struck, on visiting the Vienna basin
last year, with the remarkable analogies between it and the upper
portions of the Mayence basin.

V. The next tertiary deposit to which we must allude are the

* Geschichte der Schöpfung, fourth edition, p. 275.

† Geol. Switzerland, vol. ii.

Brown-coal beds, existing in numerous localities on the frontiers of Saxony and Bohemia. I am unable, however, to give any details of it; but its existence is worth mentioning in connection with the beds to which we must now allude.

VI. At Westeregeln, in the neighbourhood of Magdeburg, an interesting tertiary formation exists, abounding in fossils, which is now beginning to attract considerable attention. It is of peculiar importance with reference to the correct position of the Mayence basin, inasmuch as its exact relation to this formation appears from Dr. Sandberger's statements to have been satisfactorily made out. These sands or sandstones of Westeregeln are paralleled with the Septaria-clay of Celle, Berlin, and Mecklenburg. It is said to overlie the Brown-coal formation of the Westerwald, which is itself the uppermost of the two Brown-coal formations of the Mayence basin. It forms a portion of those tertiary formations which extend through Northern Germany, from the confines of Holland and Belgium, on the west, to the Oder, on the east, and the fossils of which are now in the course of publication by Dr. Beyrich of Berlin. It is a portion of the same great oceanic deposit which has been already observed in the vicinity of Cassel, although the exact parallelisms of age have not yet been fully worked out; but the general resemblance of the Cassel beds to those of Weinheim is sufficiently clear from the following extract of a private communication which I have received from Dr. F. Sandberger:—

“At Cassel I observed the following section, in descending order. 1st. Cassel marine beds. 2nd. Clay with calcareous nodules, containing the same fossils as the Wiesbaden beds. 3rd. Quartzose sandstones, occasionally containing leaves not yet made out. 4th. Brown-coal deposits separated by layers of clay. 5th. As the basis of the whole deposit, and immediately resting on the Muschelkalk, a bed of clay, containing the characteristic fossils of the Cyrena-marls” (the lower blue clay of Weinheim).

The following list will give some idea of the fossil contents of the Westeregeln beds. I have received it from Dr. Sandberger, and it must be understood as only giving those species which he has already received; I believe it, however, to be nearly complete.

TABLE VII.

*List of Fossils from the Magdeburg Sands hitherto received by
Dr. Sandberger.*

(Those marked with an asterisk * occur in the Weinheim beds.)

*Teredo, sp.	Astarte Henkeliussiana, <i>Nyst.</i>
Teredina Hoffmanni, <i>Phil.</i>	— vetula, <i>Phil.</i>
*Corbula striata, <i>Lam.</i>	—, sp. (aff. <i>A. gracilis</i> , Müntst.)
*— pisum, <i>Sow.</i>	Diplodonta apicalis, <i>Phil.</i>
— Henkeliussiana, <i>Nyst.</i>	Cardium porulosum, <i>Brand.</i>
Tellina donacialis, <i>Lam.</i>	*— tenuisulcatum, <i>Nyst.</i>

TABLE VII. (*continued*).

Cypricardia pectinifera, <i>Sow.</i>	Pleurotoma multicostatum, <i>Lam.</i>
Cardita (aff. <i>C. aculeata</i> , <i>Poli.</i>).	— ventricosum, <i>Lam.</i>
— Avellana, <i>Phil.</i>	— attenuatum, <i>Lam.</i>
*— orbicularis, <i>Bronn.</i>	Borsonia, n. sp.
— analis, <i>Phil.</i>	*Fusus elongatus, <i>Nyst.</i>
Crassatella intermedia, <i>Nyst.</i>	— funiculosus, <i>Lam.</i>
Pectunculus (aff. <i>P. pulvinatus</i> , <i>Lam.</i>).	— plicatellus, <i>Lam.</i>
Limopsis granulata, <i>Lam.</i>	— conjunctus, <i>Desh.</i>
Nucula Dechenii, <i>Phil.</i>	—, sp. undeterm.
Leda Galeottiana, <i>Nyst.</i>	Pyrula lævigata, <i>Lam.</i> var.
*Pinna margaritacea, <i>Lam.</i>	— clathrata, <i>Lam.</i>
*Panopæa Hebertiana, <i>Bosq.</i>	*Cancellaria evulsa, <i>Brand.</i>
Pecten Solea, <i>Desh.</i>	—, n. sp.
Ostrea ventilabrum, <i>Goldf.</i>	Typhis, sp.
—, sp. undeterm.	*Tritonium argutum, <i>Brand.</i>
Anomia orbiculata, <i>Nyst</i> (non	Chenopus, sp.
<i>Brocchi</i>).	*Cassidaria depressa, v. <i>Buch.</i>
Bulla apicina, <i>Phil.</i>	Buccinum fusiforme, <i>Desh.</i>
—, sp. undeterm.	Mitra marginata, <i>Lam.</i>
Tornatella, n. sp. (aff. <i>T. simulata</i> ,	—, sp.
<i>Brand.</i>)	Terebra, sp.
*Natica Hantoniensis, <i>Sow.</i>	Voluta semigranosa, <i>Nyst.</i>
*— glaucinoides, <i>Sow.</i>	— suturalis,
Calyptrea, sp. undeterm.	— labrosa, <i>Phil.</i>
Littorina sculpta, <i>Sow.</i>	— eximia, <i>Beyr.</i>
Scalaria, n. sp.	Cypræa sphærica, <i>Phil.</i>
Turritella, n. sp.	Marginella ovulata, <i>Lam.</i>
Planaxis, n. sp.	Terebellum, sp.
Solarium plicatum, <i>Lam.</i>	Ancillaria, n. sp.
Pleurotoma tarbidulum, <i>Nyst.</i>	— buccinoides, <i>Lam.</i>
*— conoideum, <i>Brand.</i>	Conus Allionii, <i>Michelotti.</i>
— Volgeri, <i>Phil.</i>	Dentalium acutum, <i>Héb.</i>
— uniseriale, <i>Desh.</i>	—, sp.
*— flexuosum, <i>Münst.</i>	Serpula turbinata, <i>Phil.</i>
*— Waterkeynii, <i>Nyst.</i>	Nonionina magdeburgica, <i>Phil.</i>
— granulatum, <i>Lam.</i>	Lunulites, sp.
*— Selysii, <i>De Kon.</i>	*Lamna cuspidata, <i>Ag.</i>
— var. <i>semilæve</i> , <i>Phil.</i>	*— contortidens, <i>Ag.</i>

VII. Lastly, I will only briefly allude to the freshwater deposits of *Bavaria* and of *Wurtemberg*, found in the neighbourhood of *Ulm*. These contain nearly the same land and freshwater Molluscs as the *Littorinella*-limestone of *Hochheim* and *Wiesbaden*; but I am not aware that they have ever yet been found to rest on or to be associated with the marine tertiaries. They represent great inland freshwater lakes, and are therefore not so directly connected with the objects of this memoir.

Having thus briefly laid before the Society the principal facts connected with those tertiary marine formations which are found in the nearest propinquity to the *Mayence* basin, we shall be enabled to form some opinion as to the real connection between these beds and the ancient ocean. It seems probable that at some period during the middle tertiary epoch a communication existed between what now forms the *Mediterranean* to the south, and the great northern ocean

which extended over the greater part of northern France, Belgium, Holland, and the north of Germany. The nucleus of the European Continent was then but a group of detached rocky islands, some of them consisting of long mountain-ridges or backbones, indicating the line of subsequent mountain-chains, and more or less connected by submerged reefs with each other or with other masses of land which appeared above the surface of the water. That a considerable portion of the Alpine chain has been elevated at a comparatively recent tertiary period, we know from the late investigations, amongst others, of Sir R. I. Murchison, whose elaborate paper, on the Geological structure of the Alps, Apennines, and Carpathians, not only points out the extraordinary disturbances which have occurred in the Alps, but shows that the earlier tertiary formations, the nummulitic limestone and the "Flysch," have been so tilted as to assume not only a vertical, but even an inverted position, and that, while they show a thickness of more than 8000 feet, thus proving the great length of time during which their deposition was taking place, they have been raised to the height of many thousand feet above the level of the sea. But this is not all: the same remarks apply to the Nagelfluhe and the Molasse formation, also exceeding 6000 or 8000 feet in thickness, and of a more recent date; so recent indeed, that Sir Roderick Murchison does not hesitate to refer them to the older Pliocene age; and yet they are described as having, both on the northern and southern flanks of the Alps, been raised into a vertical, and, in some places, even an inverted position. Thus, admitting even the Molasse to be of a more recent period than the Mayence beds, we have here sufficient evidence of a great portion of the North of Italy, the Alpine district, and even the Northern parts of Switzerland, having been covered by the waters of the sea, not only during the earliest, but during the most recent period of the tertiary epoch, leaving only the highest portion of the mountain-peaks as islands.

Again, to the north, we have evidence of considerable elevation and disturbance, although, perhaps, not to the same extent; nor can we be at a loss to ascertain some at least of the causes which have produced these results. The volcanic outbursts, attributable to the tertiary period, which abound in the greater part of the western and central portions of Germany, point out to us the causes of these disturbances. They belong, however, to different periods; consequently the results they have produced are local. But it is not only with phenomena of elevation that we have to do; evidence of depression is also there, and that is exactly what we should expect. Elevation in one spot is in most cases, if not always, accompanied by depression in another. The very fact of the enormous thickness to which the tertiary formations of the Alps have been accumulated, is a convincing proof, that, contemporaneously with their deposition, subsidence must also have been going on, or they could never have attained to such a thickness. The eruptive phenomena of the Eifel belonging to various ages, the basaltic outbursts of the Westerwald, the Fichtelgebirge, and the Wetterau have all contributed to bring about those

changes which first produced and then cut off the communication between the Mayence basin and the German Ocean.

The Mayence beds rest immediately on the older formations of the New Red Sandstone, the "Rothe-todte-liegende" of the Germans. We may therefore conclude, that during the Cretaceous and earlier tertiary periods this portion of the country was dry land, sloping gradually to the southward from the mountain-districts of the Hunsrück and the Taunus, until it met the southern ocean in which the "Flysch" was being deposited, off and around the group of islands which formed the nucleus of the Alpine chain, now such an impassable barrier between the Mediterranean and the North Sea. This depression or gradual sinking continued, affecting in all probability, to a certain extent, the neighbouring continent, until it reached such a point, aided to all appearance by other local depressions, as to occasion the formation of that remarkable valley of the Upper Rhine from Basle to Mayence and Bingen, and opening to the eastward round the Taunus into the German or Northern Ocean.

There, in a bay of this newly opened sea, were deposited those beds now under consideration, which, while partaking of the quasi-tropical character of the Mediterranean, also combined many forms peculiar to that ocean which had long existed to the north of the Hunsrück and the Eifel, occupying the site of Belgium and the north of France, and depositing the various forms of the Eocene period. With such a change as this, however, new conditions of life must have been introduced. The volcanic agency exerted in many places rendered these waters for a time unfit for animal life. The deposits on the various coasts were modified and changed, new river-channels were formed, while old ones were blocked up, and species which could only exist under the former circumstances necessarily disappeared, while others adapted to the new conditions were introduced.

As far as has been hitherto observed, the animal whose remains have been found in the lowest portion of the Marine Sands of the Mayence beds is the *Halianassa Collinii*, associated with the numerous teeth of one or more species of *Lamna*. Now, we do not find *Halianassa Collinii* anywhere amongst the Belgian fossils; but it has been found in a portion of the Vienna basin, in Switzerland, and, if I am not misinformed, at Malta; thus showing a connection at this period between these beds and the southern or Mediterranean ocean. But this remarkable animal, of which the perfect skeleton was lately found in the sands of Uffhofen (page 264), does not occur in the upper beds; it may thence be inferred that soon after the opening of this channel, and before the more torpid and slowly moving Molluscs had reached a distance which the Sharks, &c. had rapidly traversed, the subsidence of the Alpine region, indicated by the vast thickness of the "Flysch" beds, had ceased, and, in compliance with that law of oscillatory movement, which appears in former periods to have been so universally prevalent on the surface of our earth, had been succeeded by an upward movement, which extended so far as to cut off the connection with the Mediterranean, leaving open only that with the northern and Belgic ocean. This continued for a long

lapse of time, during which the Marine Sands of Weinheim were being deposited. But other changes accompanied this gradual elevation; as we approach the upper portion of these sands, we find *Cerithia* more abundant, indicating, if not already a brackish condition of the water, at least a diminution of depth and the presence of freshwater streams flowing into the sea at no great distance. And this is precisely what *à priori* we should expect. The closing of the communication by the Alpine range converted what had previously been an open passage, like the straits of Gibraltar, connecting one ocean with another, into a deep land-locked bay or æstuary, where the depth of water would necessarily diminish independently of any elevation, and the influence of the neighbouring streams would be constantly greater in diminishing the saline properties of the water.

But after a time, another change took place. The deposits changed from an arenaceous to an argillaceous character. The blue clay formation (Cyrenen-Mergel of Sandberger, and lower Brown-coal formation of former German writers) bears indications of important changes in the neighbourhood. Volcanic eruptions may have caused the rivers to bring down a thick and muddy sediment, which was carried to the northern point of this long narrow æstuary; or, more probably still, the partial and ever-increasing closing up of the channel leading to the North Sea may have caused those particles of clay and mud, previously carried out through the northern straits, to have been here deposited, containing in some places those accumulations of drifted vegetable matter which have contributed to the formation of the Brown-coal beds. How the closing up of the northern channel was brought about, we are not yet in a condition to explain; but it may have been occasioned by the elevation of the Fichtelgebirge, or by some of the neighbouring basaltic outbursts which I have not yet been able to examine.

At the same time a gradual, but general, elevation of the land appears to have been going on elsewhere; inasmuch as the presumed parallel beds of the Upper Limburg series were also becoming brackish, resting on the purely marine beds of the Middle Limburg formation. The analogy, however, is not complete. In Belgium the succeeding deposits maintain their marine character, whereas in the Mayence basin the blue clays are immediately succeeded by a thick deposit of calcareous matter, the fossil contents of which not only indicate the continued brackish nature of the water, but show that it was gradually losing its saline qualities, and becoming more and more fitted for the existence of freshwater molluscs. During this period, when all communication with the Northern Ocean appears to have been cut off, the calcareous beds of the *Cerithium* and *Littorinella* limestones were deposited in a great inland lake having no apparent outlet. Large streams of fresh water, flowing from the S., the W., and the S.W., the parents of the present Rhine, the Neckar, the Maine, and the Kinzig, brought down large accessions of material, to fill up the bottom of the basin, and to raise the surface of the water, imbedding in it at the same time, in particular localities, the *débris* of the terrestrial molluscs which had

lived upon their banks. These remains, in certain favourable spots, have been heaped together in such abundance as to have obtained for those formations in which they are found the name of "freshwater limestone." At the same time, on the western shores of the lake, between Kreuznach and Dürkheim, it is probable that the saline character of the water was maintained by those abundant salt-springs, which, even in the present day, issue from the neighbouring rocks, bringing health and wealth to the surrounding population, and giving evidence of that secret and subterranean activity which in one form or another has at all periods and in all places modified the crust of our globe.

We have seen that during this period calcareous rocks were deposited to a great extent in this northern portion of the upper Rhenish lake. From whence was this calcareous matter derived?—and why should it have been mainly deposited in this portion of the basin? It appears to have been owing to one, if not to both, of the following causes. It may have been deposited from local springs highly charged with calcareous matter, or it may have been derived from the material brought down by the many rivers which flowed into the lake; and its deposition in this particular spot may have been partly brought about by the greater amount of animal life living in this still brackish water, to whose existence and growth this calcareous matter was subservient; or partly, perhaps, by some chemical influence, the result of the action of the salt-springs upon the water thus charged with calcareous matter. But, that it has in some places at least owed its origin to calcareous springs of a local character, is I think sufficiently proved by the structure of the rock itself. I need only refer to fig. 10. p. 269, where the hard portion of the limestone rock, evidently formed contemporaneously with the softer and more sandy beds to the S.E., containing the intercalated beds with *Venus incrassata*, is altogether made up of a congeries of hollow pipes and stems, as if it were the remains of a mass of incrustations around the delicate fibres of mosses or confervæ. A similar structure may also be seen in many other localities, particularly along the line of limestone cliffs to the S.W., in the neighbourhood of Dürkheim and Kahlstadt; and, wherever this occurs, the limestone itself is spongy and cavernous, full of small irregular cavities, and frequently containing nuclei of a harder and more solid texture.

Other changes subsequently took place, which we can now hardly stop to consider. In some parts of this lacustrine basin the calcareous beds were covered up by morasses and forests, as in the Wetterau and the Westerwald. A description of the fossil flora of this district would be a subject of great interest, for amongst the curious relics of the period which have been rescued from the Brown-coal of the Wetterau are perfect specimens of more than one species of Vine, the fruit itself being preserved in the form of petrified raisins*. These forests and morasses were subsequently converted into

* See Official Report of the 29th Meeting of the Society of German Naturalists at Wiesbaden, 1853, p. 155.

Brown-coal, and have been convulsed, contorted, and broken up by penetrating dykes and outbursts of basaltic and other igneous rocks. Again the alternate action of subsidence was introduced, and the northern portion of this Brown-coal became submerged under the waters of the northern sea, inasmuch as we find the Brown-coal again overlaid by the marine deposits of Westeregeln and Magdeburg. But it is almost premature to enter on this question; I have not myself yet visited the locality.

We have thus faintly attempted to trace the possible history of the origin of the Mayence basin formations, and of their gradual rise until the waters in which they were deposited had reached their highest level. It only remains, in conclusion, to say a few words respecting their probable drainage and the desiccation of the Rhine Valley. Assuming that no outlet existed for its waters, the surface-level of the lake must at last have reached a height at which they would overflow the mountain-barrier by which they were enclosed. This spot appears to have been at the commencement of the narrow gorge near Bingen, by which the Rhine now escapes from the Rheingau, and flows through the most picturesque and striking scenery of Northern Europe, between Bingen and Coblenz. The formation of this gorge was in the first instance probably owing to volcanic agency. The mountain-chains of the Hunsrück and the Taunus were already partially riven asunder, and the long pent-up waters, finding at length an outlet, rushed with overwhelming force through the chasm, removing all opposing obstacles, and carrying with them a large portion of those deposits which had previously formed the bottom of the lake. The imagination is bewildered in contemplating the details of this stupendous operation; but it is not unreasonable to suppose that something similar, if not indeed of a grander character, took place during the process of cutting back this mighty channel, to what we now see in the St. Lawrence, while cutting back its channel from Lake Ontario to Lake Erie. It is vain to attempt to calculate the time which must have elapsed during this operation, when we consider the hard nature of the Devonian schists through which the waters had to cut their way; but when we add to this, that a similar lacustrine basin exists between Coblenz and Neuwied, below which again the river has cut its way through another mighty gorge, from Andernach to the Siebengebirge, we can only wonder at the countless ages which must have gone by during this comparatively small period of the tertiary epoch, itself one of the shortest of the many successive ages which the study of the crust of our globe has brought to our knowledge.