XVI.—*Notes on the Mountain Limestone and Lower Carboniferous Rocks of the Fifeshire Coast from Burntisland to St Andrews.* By the Rev. THOMAS BROWN, Edinburgh.

(Read 17th April 1860.)

Introduction.

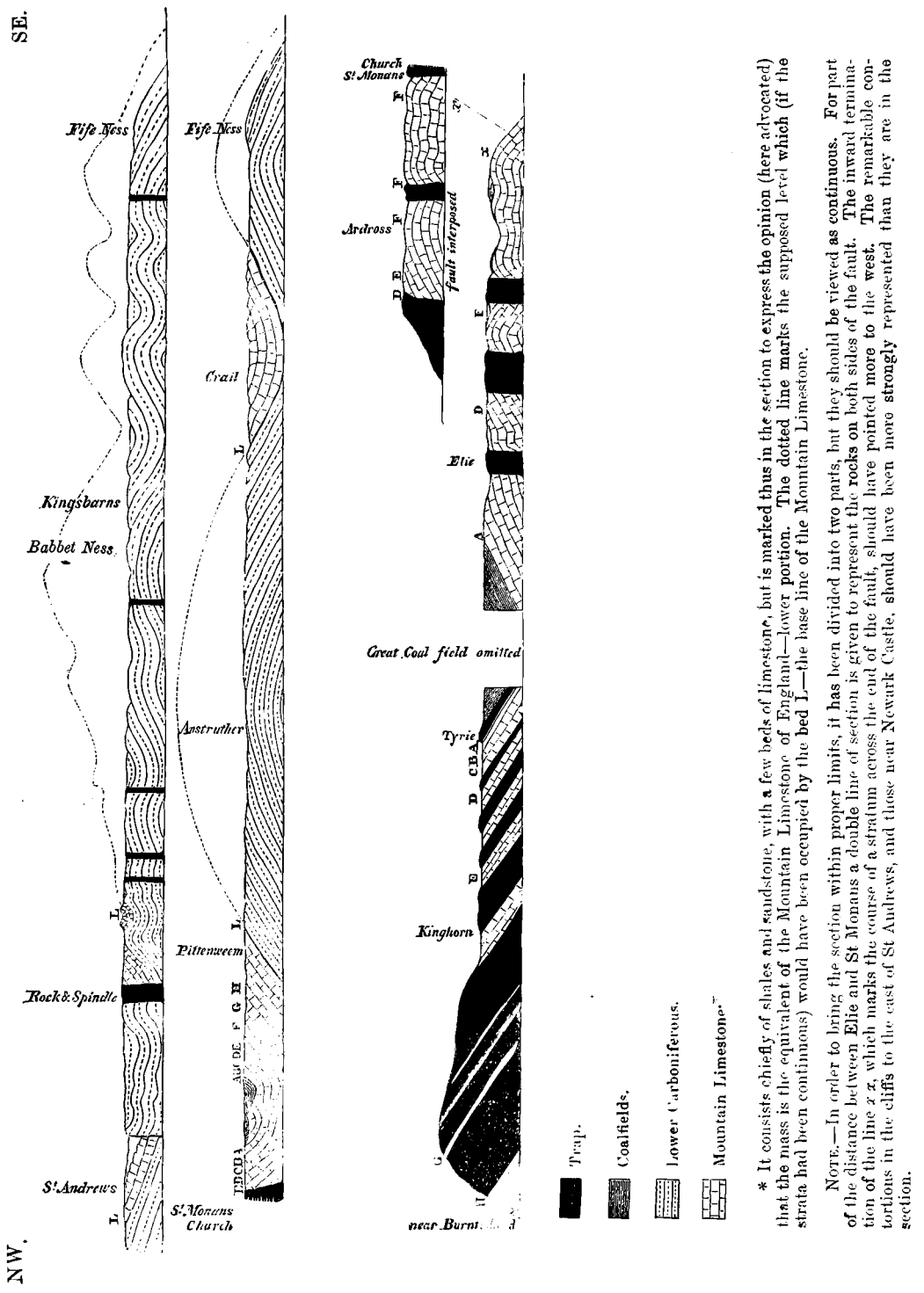
In this paper I shall first refer to the circumstances under which the following observations were made.

I had gone in the autumn of 1856 for a few weeks to Elie on the Fife coast, and was induced, as a means of relaxation and exercise in the open air, to pay some attention to the geology of the neighbourhood, resuming for a brief interval what was once a favourite pursuit. About a mile to the east of the village, I found a stratum well deserving attention—a thin bed of limestone—dipping inland a little beyond the cliff on which stands the ruined Castle of Ardross. The fossil shells which it contained were of unusual form, and beautifully preserved; there were fish remains of two or three species, and a small group of crustaceans still more remarkable. Among the fish I thought I could detect the large scales of an Irish species—the *Holoptychius Portlockii*—and among the crustaceans there were the valves of Dithyrocaris, a genus particularly characteristic of the Irish beds. At once the question arose whether these fossils might not serve as links connecting this Ardross bed with the Irish series. The point was of the more importance, that our leading geologists had been differing widely as to the true position of our Scottish coal strata in the geological scale. The lamented Professor EDWARD FORBES had assigned them a place comparatively high, while Sir RODERICK MURCHISON, with surer judgment, had taken the opposite view and put them beneath the Newcastle coal-field. If any light could be thrown on this question, it might prove of some interest to the Scottish geologist. My first object, then, was to ascertain the level on which the Ardross limestone lay among

our own strata; but this proved at first a question of unexpected difficulty. The coast near Ardross is cut up by trap in the most singular way, and the sedimentary strata are fractured and isolated into patches, in one of which the bed in question is situated. Looking into our local authorities, I found Mr MACLAREN gave no assistance, Dr ANDERSON was silent, and even Mr LANDALE, in his valuable Essay, was still more discouraging. East and west there is no lack of detail in his account of the coast; but precisely here for some distance on either side of Ardross he gives up the case as hopeless, the trap having reduced the whole to "a heap of ruins." A rapid glance at the rocks convinced me that matters were not so bad as this. At all, events the attempt to reduce these beds to order promised to give pleasant occupation for three or four idle weeks. Selecting, accordingly, a fixed point, I began at first, quite mechanically, noting each bed as it came, —its composition, thickness, dip, strike, and gathering such fossils as might serve to identify it—the results being laid down each evening in detailed sections. It ended, indeed, in my making (besides the sections) a ground plan of the coast from Elie to St Monans. And very singular it was to see how, under this treatment, the beds fell into their places, and the supposed heap of ruins became an orderly series. Through faults, convolutions, and outbursts of trap, the strata could be distinctly followed westward into the coal-basin at Earlsferry, and eastward into that of St Monans.

The position of the Ardross bed being thus determined, other questions arose. The limestone strata of Burntisland have long been a fixed point well known to geologists. Where was the level of the Ardross bed as compared with these Burntisland strata, and generally, how would the western side of the basin correspond with what I had found on the east? This led me to examine the shore from Invertiel to Burntisland, and nothing could be clearer than the general resemblance. Beds with which I had made myself familiar came up in regular order. The thick white limestone of St Monans, for example, distinguished for its abundance of Zaphrentes and similar corals, was there in position, covered by the same fossils still larger and more abundant. Going on as far as Burntisland, I found the relative position of the strata to be as shown in the section.

Another question referred to the underlying series of rocks. On the shore to the east of St Monans, I had seen the Ardross bed overlying that great mass of strata which Mr MACLAREN has termed the calciferous sandstones. What was the character and relations of this lower group? This investigation I found one of extreme interest. It led me first as far as Anstruther; then past Crail on to Fife Ness, and then to where the rocks are lost in the sand a little to the north of St Andrews. It has occupied my autumn leisure for several years—in some cases, however, only a few days being at my disposal. I beg to offer to the Society a notice of such facts as I have observed on the following points, viz.:—



* It consists chiefly of shales and sandstone, with a few beds of limestone, but is marked thus in the section to express the opinion (here advocated) that the mass is the equivalent of the Mountain Limestone of England—lower portion. The dotted line marks the supposed level which (if the strata had been continuous) would have been occupied by the bed L,—the base line of the Mountain Limestone.

NOTE.—In order to bring the section within proper limits, it has been divided into two parts, but they should be viewed as continuous. For part of the distance between Elie and St Monans a double line of section is given to represent the rocks on both sides of the fault. The inward termination of the line *x x*, which marks the course of a stratum across the end of the fault, should have pointed more to the west. The remarkable contortions in the cliffs to the east of St Andrews, and those near Newark Castle, should have been more strongly represented than they are in the section.

I. The General Course of the Strata.

The section passes along near high-water mark, the strata being supposed to be cut at right angles so as to show their real thickness only, not the space they occupy on the shore. From Fife Ness to St Andrews they are laid down in reverse, as if the spectator were looking seaward, and this is done to bring the corresponding portions of the two shores into comparison.

From Burntisland to Inverteil the great feature is the immense development of trap beds, amidst which the sedimentary strata lie conformably. The limestones G and H,* with other beds as far as Kinghorn, are estuarine, and then come the six upper marine limestones, all dipping beneath the great coal-fields.

Rising at Elie harbour in reverse order the beds are with some difficulty to be made out covered as they are at some points by sand or obscured by trap, at others as in Woodhaven almost removed by quarrying, and complicated throughout by the thirty-fathom fault, yet with patient attention the position of the whole series can be well enough traced. The fault cuts the Earlsferry coal-field in two, passes along-shore in front of Elie, goes, according to Mr Landale, through the "Taft," may be seen west of Ardross skirting *low-water* mark till it touches the bend of the coast west of Newark, where it seems to vanish.† Outside this line the beds are thrown up and carried (the field geologist well knows how) in the direction of their dip far out of the bearing of the same beds as they lie in-shore. The middle portion of the coast between Elie and St Monans, consisting of the lower beds, is estuarine. Approaching Newark, these strata become remarkably contorted, dipping into little basins, but rising at each movement into higher beds, till the six marine bands of limestone finally fold over and plunge beneath the coal-field at St Monans. Rising again to the east all trap is left behind, and the sequence of the whole beds is singularly clear as they lie exposed along the shore like the mighty pages of nature's book. Passing through the same estuarine beds the strata beyond Pittenweem rise into bold cliffs, remarkable for the depth of the shales which they display, and at that point occurs the limestone L, so important in the classification of the whole series. Eastward among the fine rocks of the Billow Ness lie the thin limestone bands of the lower series, and the shales charged with numerous vegetable remains, continuing down till the anticlinal axis is reached at the harbour of Anstruther. From Anstruther to Crail the same rocks are repeated—the depth of the whole series, however, being apparently greater and—the sandstones especially— more powerfully developed. A red colour

* Owing to the small size of the section, as given in this paper, it has been impossible to represent the separate beds of limestone, or the sub-divisions of the upper group. For the same reason it has been found difficult to give the angle of dip with anything like minute accuracy. Some of the lesser bendings of the strata are omitted—only the general results could be given.

† This point is marked in the section by the letter *x*.

from iron tinges some of the limestones, and especially the bed L, which at Pittenweem is dark gray. At Roome beyond Crail the synclinal axis is reached: the beds again show a descending series till they fold over an anticlinal close to Fife Ness. That point forms a splendid display of powerful yellow sandstone, dipping with gentle slope towards the ocean whose stormy waves it has flung back for ages.

Away to the north, and on as far as St Andrews, my examination of the coast was more rapid. In the section as it approaches Crail, and goes north of Fife Ness, I do not attempt to show the effect of the faults, but the general features of the strata will be found given with sufficient accuracy. Passing Balcomie, the lower series of rocks is well displayed; but especially from Cambo Point, on beyond Kingsbarns and down to the lowest beds at Babbet Ness, all is singularly complete and clear. At the latter point, the lowest strata of the whole coast from Burntisland to St Andrews are reached, lying considerably beneath the level of Anstruther. Passing Pitmilly Burn, the section exhibits the various bendings of these strata, till the limestone L is found on the shore near the Rock and Spindle. On to St Andrews the foldings seen in the cliffs form a striking feature of the coast, till at the Witch Lake, with its deep shale beds, the limestone L again comes into view.

The general aspect of the coast thus described will best be understood by a glance at the accompanying section. Omitting the minor foldings of the strata there are, east of the Ochills and on to Fife Ness, four great anticlinals, with their accompanying basins on either shore. The first of these basins on the coast of the Firth (not shown in this section) reaches from Alloa and Dunfermline to Aberdour. It corresponds to that on the east, in which St Andrews is situated, and whose southern margin touches the Babbet Ness. The second stretches from Aberdour to a point beyond Elie, where the axis, though obscure, is really present; and so on to Fife Ness, every anticlinal and basin on the west has its corresponding feature on the east, though not always in the same relative proportions. One marked difference, however, will be observed. Along the German Ocean the beds have been lifted to a far higher level, as is shown by the dotted line which represents the supposed level of the bed L. High above the ground on the eastern side, it is often from one to two thousand feet beneath it on the shores of the Firth.

II. The Trap Rocks.

These I did not attempt to study, but one or two points may be mentioned which came under my notice.

First, A large portion of these traps can have had nothing to do with the elevation of the other strata. On the one hand, they are so interstratified that on looking to the details one can hardly resist the inference that they were contemporaneously formed; and on the other, they have themselves been acted on much

as the other rocks by the forces of elevation. A glance at the section from Pettycur to Inverteil will show how the beds of trap and the other strata have been lifted together to the same angle of dip. Another example is still more instructive. Not far from Queensferry there is, to the east of St David's, a mass of tufaceous trap, and south of St Andrews there is a mass of sedimentary strata both contorted in a similar way. They lie in the same position on the southern rise of the great basin—which leans against the axis of Aberdour on the one shore, and Babbet Ness on the other. The force which caused these convolutions must thus have acted over a wide stretch of country, and the traps and the sedimentary strata must have yielded alike to its power.

Second, There are trap rocks evidently intrusive, and of subsequent formation, containing as they do fragments of the other strata. Every Edinburgh geologist knows well the Basalts, Tufas, and Amygdaloids of the coast from Pettycur to Inverteil. In the Huttonian and Wernerian controversy this western series was the stronghold of the Wernerians. It seems strange that their adversaries did not claim the Elie side, where the intrusive traps may be studied to singular advantage.* Perhaps the most common appearance resembles that at Edinburgh Castle—the sedimentary strata at the point of contact being fractured and bent downwards; but there is this difference, that the phenomena can be studied not in section, as at the Castle, but amid the bared rocks of the coast they are laid open as on a ground plan.

Whether these intrusive traps had anything to do with the elevation of the other strata seems extremely doubtful. For the most part they appear to penetrate the mass much as a musket bullet does a pane of glass, fracturing the portions in immediate contact, but leaving the general plane of the beds unchanged. A single example near Kinghorn is the only instance of what seems elevation resulting from the intrusion of trap. That some deep-seated force of elevation has acted over the district is indeed obvious. Starting at Fife Ness, we can trace the long, rolling undulations of the strata, as if lifted over the crests and sinking into the troughs of some gigantic sea. How vast the elevation must have been at first, and how immense the denuding agencies by which all was subsequently planed down to its present level, may be seen from the dotted line showing the supposed level of the bed L, itself very far below the coal-fields. I have seen, however, no

* It is not intended in this or the following statements to advance any theory as to the formation of these rocks, the term intrusive being merely used to indicate that the previously formed sedimentary strata must have been consolidated and fractured before these traps could have come into their present position. While on the west the two kinds of rock lie for the most part conformably interstratified, it seemed deserving of notice that on the east side of the basin, when they come into contact, there are in most cases clear traces of convulsion. A geologist holding extreme Huttonian or extreme Wernerian opinions might easily enough find on these shores not a few facts in support of his favourite views on either side, but there are still considerable difficulties in the way of any theory which shall explain and harmonise *all* the phenomena.

clear evidence to connect these intrusive traps with the deep-seated forces which produced such vast results. The question would require much closer attention than it was in my power to give; but everything seemed to support the views so ably propounded by Professor ROGERS in the Transactions of this Society.

Before entering on the sedimentary strata, it is right to state that the object of this paper is restricted properly to a single point. The petralogy of these coasts —the mineral structure of their rock-masses—I do not refer to, except incidentally. For the present, my remarks are confined to one point, a consideration of the fossils in connection with the different levels at which they occur, and the light which is thus cast on the different groups of strata in their geological relations.

III. MOUNTAIN LIMESTONE.

In regard to the classification of the rocks of this district, I have been led to deviate to a considerable extent from the views commonly held. If about 1400 feet be taken from the lower series—the calciferous sandstones of Mr MACLAREN—and added to that upper marine zone, usually termed the Mountain Limestone, then a well-defined base line is obtained for the upper division, and the two groups may be distinguished by satisfactory characters. To the whole of the upper division, I would extend the term Mountain Limestone; and to the underlying group the term Lower Carboniferous. The reasons for this arrangement I shall afterwards state. Assuming it in the meantime, the Mountain Limestone will present the three following portions, viz.:—

1. *The Six Upper* Limestones*, A *to* F.

Immediately underlying the coal-fields on the Fife coast, we find these beds with shales and sandstones intercalated. The whole body of strata is set down by Mr GEIKIE as from 150 to 200 feet thick in the Lothians; and by Mr PAGE as 200 feet thick in Fife. If the lowest bed F be included, I am disposed to put the estimate considerably higher. The Ardross limestone, to which I referred at the outset of this paper, is the bed F, the lowest of these six beds.

It is the abundance of their fossils which render these six limestones so important. As it is often difficult to know how far such lists as the following may be depended on, I may mention that all the fossils here named were collected by myself, the beds and the localities being carefully noted. With the exception of one or two of the commoner species, they will all be submitted along with this paper. The determination of fossil species is often a point of much difficulty, especially where no collection exists to which reference can be made; and I may therefore mention, that the lamented Dr FLEMING and Dr SCOULER of Glasgow, two of our highest authorities, did me the favour to examine part of my collec-

* The term *upper* is used only relatively. They form the highest portion of the strata to which this paper refers, underlying the coal-fields.

tion, and that I have submitted the whole to Mr SALTER, Palæontologist to the Government Survey, whose assistance has been of special importance, not only from his great eminence in that science, but from his familiarity with the fossils of England and Ireland. The system of nomenclature in his hands being uniform, we can employ the species here named with confidence as points of comparison with distant formations. A considerable proportion of the following list are new to Scotland. Two or three of the names are given on the authority of Dr FLEMING; the rest on that of Mr SALTER.

Fossils.

Corals.—The following seem the most common species:—

Chaetetes tumidus.
Aulophyllum fungites.
Lithostrotion junceum.
L. fasciculata.
Zaphrentis species.

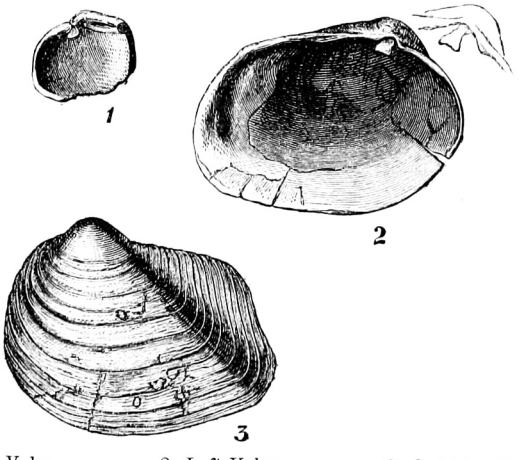
To these may be added (from the Bryozoa), the *Fenestella plebeia*, which is plentiful in all the strata.

Shells.—From the bed F at Ardross, I obtained the following, viz.:—

1. Lingula mytiloides.
2. Productus semi-reticulatus.
3. Pecten Sowerbii.
4. Edmondia unioniformis.
5. Schizodus sulcatus.
6. Nucula gibbosa.
7. Nucula attenuata.
8. Macrocheilus ovalis.
9. Bellerophon Urii.
10. Bellerophon decussatus.
11. Nautilus subsulcatus.
12. Orthoceras cylindraceus.

Along with these there were other species belonging to the following genera not yet determined, *Orthoceras*, *Schizodus*, *Arca*, *Modiola*, *Loxonema* and *Goniotites*. Of the whole perhaps the shells most characteristic of the bed are a strong handsome *Schizodus*, and a thin stiletto-like *Orthoceras*, whose long, taper form does not seem as yet to have been figured or described.

Fig. 1.



1. Right Valve. 2. Left Valve. 3. Outside of Left Valve.

Of the *Schizodus*, figures are here given from characteristic drawings furnished by Mr SALTER.

Dr FLEMING, to whom I formerly submitted this shell, considered it to be the *Anatina attenuata* of M'COY, but held that it had been erroneously referred to that genus. He possessed numerous specimens from a bed near Colinton, where it occurs in such abundance as to suggest the idea of its having been gregarious; but the specimens from Fife were in better preservation, and he intended to have them laid open and submit them to a careful examination, in order to determine the generic character. Circumstances prevented this, but it has now been made clear by Mr SALTER. The species seems to have belonged properly to the Lower Carboniferous group, rather than to the Mountain Limestone. It is common enough, indeed, in the bed F, to be characteristic of the stratum; but when met with in the lower rocks, it shows itself in a far different way, and in far greater abundance. This is seen not only at Colinton, but in a very remarkable bed south-east of Kingsbarns, where, in countless masses, it covers the surface of the rock in a state of preservation singularly fresh and beautiful. On passing up into the Mountain Limestone it occurs rather in a straggling condition, and in comparatively scanty numbers.

Passing to the five overlying beds, besides most of the shells just enumerated, we find the following:—

1. Athyris ambigua.
2. Athyris Royssii.
3. Chonetes Hardrensis.
4. Chonetes variolata.
5. Discina nitida.
6. Leptaena crenistria.
7. Productus giganteus.
8. Productus punctatus.
9. Orthis Michelini.
10. Orthis filiaria.
11. Orthis resupinata.
12. Athyris gibera.
13. Productus longispina.
14. Rhynconella pleurodon.
15. Spirifer duplicicosta.
16. Spirifer trigonalis.
17. Avicula rugosa.
18. Aviculopecten interstrialis.
19. Mytilus triangularis.
20. Nucula tumida.
21. Euomphalus carbonarius.
22. Orthoceras annulare.

Along with these there occur species of *Schizodus*, *Aviculopecten*, *Modiola*, and *Turbo*, not determined. There is also one species of *Sanguinolites*, which Mr SALTER pronounces to be new.

Crustaceans.—The bed B east of St Monan's has yielded various specimens of a species of trilobite—the *Griffithides mucronatus*; and in the bed E, near Kinghorn, I found a plate of the *Eurypterus Hibberti*.

It is the bed F at Ardross, however, which has proved most productive of these remains. They are of two kinds. *First*, Those belonging to the genus Dithyrocaris, chiefly detached valves; one specimen, however, showing distinctly the tail spines, and another the jaws. Mr SALTER, whose authority stands so high in regard to this class of fossils, has decided that the specimens belong to two species both hitherto undescribed.

The other crustaceans are of a form nearly allied to the shrimp, and closely resemble the species of Gampsonyx, described by VON MEYER, from the coal for-

mation of Saarbruck in Lorraine. The shelly covering seems to have been peculiarly thin and tender, for though the limestone is singularly favourable for their preservation, yet there is a difficulty in making out the form with sufficient distinctness for scientific description. Its resemblance to the shrimps of our shores is obvious, however, at a glance, and like them it seems to have been social in its habits; for at the only spot in which it occurred a whole swarm was laid open at once, and very remarkable it was to see these tiny forms of crustacean life lying close to each other in every imaginable attitude on the surface of the rock. For the following remarks and figure, singularly true to nature, I am indebted to Mr SALTER:—

"There can be little doubt this is of the same genus as the curious *Gampsonyx fimbriatus* of Jordan, figured so well by VON MEYER in his "Palæontographica" for 1854, Vol. VI. t. t. That species was found in the coal of Saarbruck and Salzbach, and it was regarded by VON MEYER as belonging to the Amphipod group, the only example yet known of a true Malacostracous crustacean below the New Red Sandstone. Our specimens, though crushed, show much fewer segments than the German fossil, and it is no doubt desirable to compare specimens of both. I am not clear about any appendages to the head, which appears (if that be not due to pressure) to be elongated. Seven body-rings and a minute telson are all that can be made out. But the tail appendages are very like those of a shrimp, and the body-rings not dissimilar."*

Fig. 2.

Uronectes (Gampsonyx of Jordan) socialis, n. sp.

A single remark of a general kind I may be permitted to offer. One of the most delightful passages in PALEY'S "Natural Theology" is his description of the shrimp, and the proof of the goodness of God in communicating such manifest enjoyment of life to these lower orders of being, diffusing such happiness among myriads of His creatures. When we look back into the old creations of geology with their predaceous races, covered with bony armature, and furnished with instruments of destruction so formidable, we are ready to feel as if the world must have been a scene only of darkness and terror; yet the light of God's love must have shone then as now, and perhaps the little crustacean here before us may give some indication of this truth. If PALEY can stand on our modern shores, and, amidst the social instincts of its shrimps, can point to the fulness of their enjoyment as a proof of the goodness of God, I know not why, in the little Gampsonyx of these primeval rocks, evidently not less social in its instincts, we may not read the same lesson, and feel that then of old, as now, the world which He had made bore witness that "God is love."

Fish.—These remains deserve particular attention. At Ardross I detected small

* Mr SALTER, MSS.

scales of some species of Palæoniscus, and one good specimen of an Amblypterus, which seems to be the *A. striatus*. There were teeth and scales also of a Holoptychius; some of the latter more than an inch in diameter, and their resemblance to the figures of the *H. Portlockii*, published in the Report of the Irish Survey, seemed to be complete. If the fish remains at Ardross are thus not devoid of interest, those on the west side of the basin near Kinghorn are still more important. It was in connection with these that I obtained one of the most striking proofs of the identity of the corresponding beds on the two sides of the basin. Beginning at Inverteil, or rather at Tyrie, I had traced the strata backwards and downwards through every link of the series, to that level on which the fish occur on the east. The limestone bed was there, its corals and shells agreed, but at first there seemed no trace of fish. The point was important, the opportunity for search was good, for the beds lay open, intercalated between two sheets of trap. Beginning at the top, and resolvéd that nothing should escape, I had nearly gone over the whole, when, about three inches above the lowest trap, I caught the glitter of a ganoid scale, and laying open the spot, a very slight effort disclosed a whole array of fish remains—spines, plates, teeth, scales, &c., in singular abundance. I was reminded of the famous bone-bed at Ludlow, described as resembling a mass of broken beetles. This was obviously a similar formation of the carboniferous system. About an inch in thickness, imbedded among shale with a few shells, and charged with its abundant fish remains, all disjointed, but in beautiful preservation, I could trace it, running at its own level for fifty yards, till lost at low-water mark in its course seawards. All the fish I had found at Ardross were there, with additional species; but there was one new and most noticeable feature, the abundance of Cestraciont teeth—the crushing teeth of ancient sharks. Would it not be possible to find these fossils also on the eastern side of the basin? Returning to Ardross, I sought for them in the bed F, but in vain. In the bed E, I also failed in finding them; but at last the limestone D, and especially a bed of underlying shale, yielded a considerable number of specimens. The links of connection between these beds, separated at a distance of some twenty miles, were thus made clear, and it was also established that fish remains were diffused through the lower half of these six marine limestones.

The disjointed state of the remains from the fish-bed renders it difficult to identify the species. There are head-plates and scales of *Rhizodus Hibberti*. There is a well-preserved jaw undetermined, and scales of Amblypterus. Besides these there is a spine of Ctenacanthus, which Sir P. EGERTON considers as hitherto undescribed, and among the teeth there are several fine specimens belonging to the genus Cochliodus, also marked by him as new to science.* More than by all these, however, my attention was attracted by some plates belonging to the great

* It was through the kindness of Sir R. MURCHISON that the specimens were submitted to Sir P. EGERTON, our highest authority in fossil Ichthyology.

class of tuberculated fish. I extremely regret that from the softness of the shale it has been impossible to preserve them in anything like their original completeness. When first laid open they seemed unequivocal plates of some species of Pterichthys. When submitted in their present state to Sir P. EGERTON he has marked them as "very doubtful—probably not Pterichthys." Enough, however, still remains to show that they must have belonged to the great class of tuberculated fish. At Mr SALTER'S request, I have agreed to place these specimens in the new museum here. Should they prove to have belonged to any genus allied to Pterichthys, the discovery would be one of considerable importance. The range of that great family would no longer be confined to the Devonian formation, and this point might have an important bearing on questions connected with systematic geology. Already, in England and elsewhere, these tuberculated fish have been found up to the highest beds of the Devonian system; but should their discovery at Kinghorn be confirmed, they must be held to have existed through the long period of the Lower Carboniferous group, and to have passed far up into the Mountain Limestone. It would be well, meantime, if the attention of our local geologists were directed to this bone-bed. A thorough search by those who could command the necessary time would yield results of considerable interest. Before leaving these fish remains, it is right to call attention to their position as belonging to the six upper marine limestones. In the corresponding marine formation of Yorkshire, the fish remains are few or none; and in the same marine band, as found in the Lothians, Mr GEIKIE mentions that fish remains are also absent. It will be remembered that the ganoid fish now living are found only in fresh water, and it might have been argued that their ancient congeners were also fresh-water fish. This idea might have found support from the absence of their remains from the deep marine formation of Yorkshire, and the marine beds of the Mountain Limestone in the Lothians. The Fife beds, however, at once place the whole matter in another light. At Ardross we have the remains of Rhizodus and Amblypterus intermingled with the Cephalopods and Brachiopods of the ancient seas. At Kinghorn the bone-bed gives us the remains of the whole family of carboniferous Ganoids, side by side with those of Cestraciont Sharks, and Brachiopods like the Lingula, all evidently marine.

One other fossil deserves notice—the *Serpulites carbonarius*, which is confined, so far as I observed, to the two lower beds E and F. Immediately to the west of Newark Castle, the bed F yields these remains in great abundance, and fine condition, in many cases filled with carbonate of lime.

2. *The Estuarine Strata between F and L.*

Underneath the six limestones we find a series of rocks of considerable depth, apparently 1400* feet. That they are fresh water or estuarine, is shown by the

* Since presenting this paper to the Society, I have gone over these beds to the east of St Monans

sudden disappearance of the crinoids, corals, and other marine fossils so abundant in the overlying beds. The *Cypris scoto-burdigalensis* is also found in layers so distinct, and entering so largely into the composition of the rocks, as fairly to indicate fresh water conditions. One marking feature also is the abundance of *Sphenopteris affinis*, unknown in the overlying limestones, but all along between Elie and St Monans, and farther east down as far as the bed L, it is the prevailing fossil in this the Estuarine part of the series.

The well-known Limestones of Burntisland, with their numerous fish remains, lie on this level. It is, however, to the east of St Monans and on beyond Pittenween that the series can be studied to best advantage. The very point in the descending order can be fixed where the Sphenopteris begins, and its rapid increase traced downwards through the strata. Two singular beds of limestone, obviously on the same level with those marked G and H at Pettycur, on the west, well deserve attention. They are yellow or pale-buff in colour, distinctly brecciated, often siliceous and cherty, and so much harder in structure than the sandstone, that they may be traced on the shore west of Pittenweem harbour, standing boldly up in marked outline and running seawards like tall slanting walls. In colour and structure they are quite different from the six overlying limestones. On the west side there is a bed at Pettycur marked G, which may be traced running inland through the railway cutting and sweeping round till it reappears behind the Binn, which shows at certain points much of the same colour and some tendency to the same brecciated structure, but from the absence of siliceous matter it is comparatively soft.

West of Newark there is in the coal-shale a bed with nodules of clay ironstone, containing coprolites, from which I extracted two complete specimens of fish—a species of Palæoniscus. Near the same point, close to an out-burst of intrusive trap, is a layer containing good specimens of carboniferous wood in a state of charcoal, some of the fragments being very distinct.

To this part of the series also belongs a shale-bed beyond Crail (close to the farm-servants' houses at Kilminning) containing fish remains, among which I could detect the scales of Megalichthys and Eurynotus. It was there I obtained the jaw of a small species of fish belonging to the family of Pycnodonts, with five rows of tesselated teeth. Of this family, so common in the secondary strata, only one previous example is mentioned by Professor OWEN as having been found in the palæozoic rocks, a small jaw described as occurring in the coal-field at Leeds. That found at Kilminning was upwards of 1000 feet below our Scottishcoal-fields, and is probably therefore of a still older date.

in order to ascertain the thickness of the mass of strata measured in a line perpendicular to the plane of the beds. Taking the direct distance from F to L at right angles to the general strike, and taking the average dip from a series of measurements, the result is that this mass of estuarine beds is about 1400 feet in thickness. Such measurements are of course only approximate.

3. *Limestone L. Line of lower Encrinites.*

Underlying these estuarine beds we have already referred to a thin stratum of marine limestone, seen in the cliffs of Pittenween. At various points along the coast it again occurs as shown in the section. Its fossils are numerous, and obviously, even at first sight, similar to those of beds A to F. The following kinds have been noticed :—

Crinoids.—In speaking of the upper limestones, I should have remarked that these fossils (the Crinoids) are found everywhere in great profusion in the form of detached vertebræ or fragments of stems. The bed E, west of Ardross, seems to have been a singular storehouse of these remains. Washed out by the sea, they used to lie scattered in thousands along the shore, and under the local name of Croupies were familiar as playthings to all the children of Elie. The deposit seems now to be in a great measure exhausted, and those formerly washed out are buried by the sand.

The Crinoids of this lower bed L are smaller and apparently of different species. There is among my specimens one Rhodocrinus and one Poteriocrinus, the latter showing the head, and being therefore of considerable interest. It has often been matter of surprise why the remains of Encrinites in our limestones should consist entirely of disjointed stems. "What can have become of the *heads* of all our Scottish Encrinites?" a leading naturalist once asked me, adding, that of the thousands of specimens he had seen he could find nothing but the vertebræ. The bold conjecture has, I believe, sometimes been hazarded, that our Scottish Encrinites either never had heads at all or had them of some softer substance than their English brethren, so as not to admit of preservation. This somewhat whimsical idea might perhaps have been met by asking in reply whether there were any analogy to support it; whether other Scottish productions were usually more destitute of head or more soft-headed than those of the south? But there is really no need for pushing the argument. Specimens enough will be forthcoming. Among those here produced is the small head of a Poteriocrinus taken from the bed L, the base of the Mountain Limestone, a little to the south of the Rock and Spindle.

Corals.—Of these I observed four species, two of which are undetermined. The *Chœtetes tumidus* is common, and still more so the *Fenestella plebeia.*

Shells.—Of species not observed in the upper limestones I found the following, viz. :—

1. Spirifer octoplicatus.
2. Aviculopecten arenosa.
3. Sanguinolites tricostatus.
4. Chemnitzia gracilis.

Of species already found in the beds above, there were

1. Productus semi-reticulatus.
2. Edmondia unioniformis.
3. Nucula attenuata.
4. Nucula gibbosa.
5. Bellerophon decussatus.
6. Bellerophon Urii.

Of these, the most characteristic shell at Pittenweem is the Productus; and at Crail, the Edmondia and the Bellerophons, which are abundant and large.

These three portions—the upper limestones, the estuarine beds, and the line of lower Encrinites—have now been described, and their fossils, when viewed together, form an assemblage which all will at once recognise as belonging to the Mountain Limestone. To this point I shall afterwards advert. Meantime, no one can go over the ground without feeling how singularly rich these deposits are in the remains of ancient life. Justice has perhaps hardly been done as yet in this respect to our Scottish rocks. Among the Crustaceans and fish we have seen that there are not a few additions to be made to our extinct Fauna. Of the forty named species of shells recorded in this paper, only twelve are found in Professor NICOL's list of Scottish fossils, and the specimens I have mentioned as unnamed species will probably furnish still farther additions. It should be remembered that I made no special effort to collect fossils, visited no quarries, asked no assistance, took only what came in my way. The naturalist, who should, with time at his disposal, take up this work would find his researches richly rewarded.

IV.—LOWER CARBONIFEROUS.

Along these shores there occurs a great body of strata underlying L, the line of lower Encrinites.

A distinguishing feature, which at once strikes the observer, is the great prevalence of shell-beds—limestones composed of a single species of bi-valve resembling Unio, and now placed in the genus Myalina or Anthracosia. It were much to be desired that these obscure families were dealt with by some competent naturalist, and their distinctions satisfactorily made out. Meantime, we must be content to refer to them as undetermined species of Myalina. One circumstance connected with these beds is, that they increase as we go eastwards, both in number and size. Thus, taking the axis at Anstruther, I found not more than two shell-beds to the west, only one of which is of importance, viz., that lying among the strata in front of the town. To the east of the axis there are up to bed L at least three shell-bands. The lowest sweeps round from Anstruther, running inland at Kilrenny, where it is comparatively thick. Two others were detected lying at distant intervals in the series above. Near Fife Ness these shell-bands are more fully developed, but it is towards Kingsbarns that they come out in all their force as limestones, four or five feet thick, consisting of consolidated shells piled above each other in countless myriads. They have been compared to banks of mussels, and held to indicate a shallow sea, if not estuarine conditions. There is a difficulty, however, in their extent, reaching from St Andrews far beyond Dunbar, and from Anstruther to Kingsbarns, getting ever the more fully developed. It is to be observed also that those portions of the shore, where there are on other grounds the greatest indications of estuarine conditions (as from An-

struther to Pittenweem), are exactly those in which the shell-beds are least prevalent. One is struck further also with the immense extent to which the ocean of that early time must have been pervaded by this form of life, its waters swarming with myriads of these bi-valves. It can hardly have been a shallow sea, across the bottom of which there stretched continuously layers of dead shells four or five feet in thickness, more especially when we observe that just in proportion as the accompanying beds abound in evidences of marine conditions, these bands of Myalina are the more fully developed.

Among these lower rocks may be noticed the occurrence near Caiplie of what is termed in the neighbourhood the petrified forest, a thick bed of sandstone with twelve or fifteen trunks of trees, some of them prostrate, but most showing their stumps projecting through the rock. As the bed dips at about fifteen degrees to the east, and the trees lie slanting at about seventy-five degrees west, they are nearly perpendicular to the plane of the bed, showing that they must have been growing on the spot when enveloped in the sand. Unlike those of Craigleith there is no real petrifaction; they are simply casts of the inside of the stem from which the bark has subsequently fallen away, but which show obscurely the flutings and other marks peculiar to the genus Sigillaria.

Another circumstance of great importance to the understanding of this lower series is, that at various levels it shows beds with unequivocal marine fossils. Thus there is a stratum with many specimens of Natica in the Billow Ness, and across near Caiplie it is again found with the same pretty little shell still better preserved. Again, in the axis of the anti-clinal, near Fife Ness, there occur, along with some fish remains, species of Orthoceras, Chemnitzia, and Natica, the two last very beautifully preserved. South-east of Cambo is a bed charged with shells, distinctly marine, and on the other side what appears to be the same stratum, more fully developed. A species of Schizodus especially, as formerly stated, is found in great profusion. In the neighbourhood of Caiplie also there is a shale-bed with specimens of Lingula, on a different level from that in which the Natica prevails.

Shells.—Two species may be mentioned, both carboniferous, but different from those already referred to:

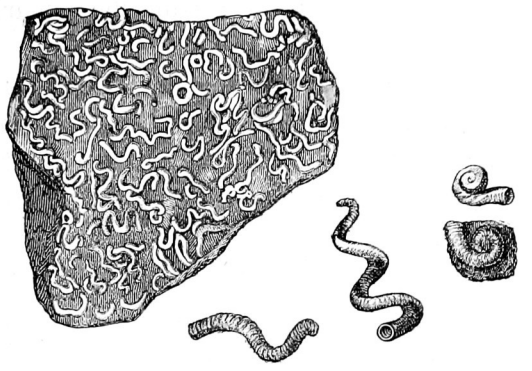
Murchisonia trilineata, from near Cambo.
Lingula marginata, near Caiplie.

Along with these occurred *Orthoceras cylindraceus*, and *Aviculopecten arenosa*. These all comparatively lie deep in the series.

One of the most interesting discoveries which I met with in this lower series is a thin stratum of reddish limestone, charged in great abundance with a little Annelid, a species of Spirorbis or Serpula. It is allied to the *Spirorbis* (*Microconchus*) *carbonarius*, but larger in size, and, instead of being folded on itself like the coil of an Ammonite, is remarkably twisted in a serpentine form.

A clear idea of it will be obtained from the following figures and specific character, with remarks, for which I am indebted to Mr SALTER :—

Fig. 3.



"*Spirorbis* (*Serpula*) *helicteres*, n. sp."

"S. ¼ uncialis, laxe spiratus; anfractibus, 4—5; quorum, 2—3 compactis, reliquis longe vagis,—omnibus compressis. Superficies rugosa, lineis incrementi rugisque irregularibus aspera, nec striata. Apertura ovata, margini haud incrassato."

"This striking fossil occurs in distinct beds, grouped hundreds together, yet without ostensible attachment to any other object than its own species. The helix formed by the compressed whorls is a very open one, and often drawn out to more than a quarter of an inch long; the first whorl or two only being discoid. The surface is roughened by lines and ridges of growth, but has no distinct striæ either longitudinal or transverse.

"*S. Archimedis* of DE KONINCK (animaux foss de Belge PC. G. f. 6), a fossil from the Carboniferous Limestone of Visè, is only slightly compressed. It is much more closely coiled, the whorls touching each other, and has close set striæ and larger plaits in the direction of the lines of growth."*

Another feature to be noticed is the marked abundance of Cyclopteris. This is especially seen among the rocks from Pittenweem eastward. Both plants occur in both portions of the series, but above the bed L Sphenopteris is the prevailing form; below L it is Cyclopteris.

V. RESULTS.—THE TWO GROUPS.

Mr MACLAREN'S classification, in his able work on the "Geology of Fife and the Lothians," has been in substance adhered to by subsequent writers. Underlying the coal-field there is first a zone of encrinal limestone, comparatively thin.

* Mr SALTER, MSS. Our fossil is imbedded in the stone, which is to a large extent made up of it; but the weathered surface often shows the fossil very beautifully, the white snake-like form charged with carbonate of lime being well relieved by the dark red of the limestone. The bed occurs among the rocks of the shore near Fife Ness, a short way to the north-west of Balcomie Sands.

Beneath this there is a large mass of strata, the calciferous sandstones of his nomenclature,—the lower carboniferous of subsequent authors. When I began these observations on the Fifeshire coast, I held to this received view, and put the strata into two groups. Down to the bed F all was marine, and marked by me as the Mountain Limestone; below F came the estuarine beds,—the lower carboniferous.

What first shook my confidence in this classification was the discovery of the marine bed L, or rather the results obtained, after a full examination of its fossils. Lying 1400 feet down among these estuarine strata, it exhibited not only the same fauna with the upper six limestones, but that fauna amply developed. Why should it not go into the same group with these upper beds?

Next came the question, whether the difference of character between Estuarine and Marine could form a safe ground for distinguishing the groups,—it might or it might not be convenient as a local arrangement, but if the groups were so formed, would the classification be of any value on a wider area when brought into comparison with the strata of other districts?

But what proved most decisive, was an examination of the great mass of strata underlying L. Studying these lower beds on to Fife Ness and northwards, it became evident that they had a character of their own by which they might be defined and recognised,—that L was really the lowest point or base line of an upper group, and that the two were separated by characters more to be depended on than the difference between a fresh-water and marine formation.

The only difficulty in assigning the bed L to the upper group is the fact that the mass of strata intercalated between F and L are Estuarine, while these two beds are Marine, but there should really be no hesitation in setting aside this character as a ground of distinction. Every epoch has its fresh-water and salt-water beds contemporaneously formed. Just as at this moment deposits are going on simultaneously in our fresh-water lakes like Loch Lomond, in our estuaries, as among the upper reaches of our Firth, as well as in the open sea, all representing the same point of time, so the fact that a mass of strata is estuarine does not in the least disconnect it with the *period* of the two limestone bands between which it is intercalated. It must be grouped along with them, so that the whole mass of the nine limestone bands from A to L, with their accompanying strata, must be associated together.

Now there cannot be any ground even for hesitation as to what portion of the geological scale this group belongs to. The fossils which we have enumerated not only as a whole, must be referred to the Mountain Limestone, but contain a large proportion of the species held to be decisive as characterising that formation. Take a list of shells like *Productus giganteus*, *P. semi-reticulatus*, *P. longispinus*, *Athyris ambigua*, *A. Royssii*, *Rhynconella pleurodon*, *Edmondia unioniformis*, *Bellerophon Urii*, *B. decussatus*,—let these and others similar not only be found, but

be the prevailing forms in a group of rocks, and any one accustomed to deal with such questions will hold the conclusion irresistible—*that* group is simply the Mountain Limestone. This is one of the best marked and most thoroughly understood portions in the whole series of ancient rocks. Powerfully developed in Yorkshire, it passes south by Bristol into Devonshire and Wales, crosses over into Ireland, where, north and south, the level of the great Scaur Limestone has been well recognised. Spreading over the kingdom, this belt of Mountain Limestone lies everywhere on the same geological horizon, and what we have here on the Fifeshire coast overlying the bed L is simply a powerful mass of strata forming a prolongation of the same great series. The limit of the group upwards I have not examined.

The question, therefore, which suggested itself on the shore at Ardross, on first looking at the limestone bed with its fossils, has been satisfactorily solved. Its place is somewhere about 1400 feet above the base of that great series which is recognised over the kingdom as the Mountain Limestone proper.

And now, in regard to the inferior group—the Lower Carboniferous—Mr GEIKIE recognising the insufficiency of the difference between the fresh-water and marine character of beds as a ground of distinction between the groups, has proposed to regard the whole carboniferous series beneath our coal-fields as the representative merely of the marine Mountain Limestone of Yorkshire.* There seems, however, reason to believe that the lower portion belongs to that antecedent period which ushered in the Mountain Limestone proper. Should this be confirmed, it will give special importance to our Scottish rocks, as casting valuable light on the obscure introductory stage of the carboniferous era. The difference of this group from the other is no doubt only one of degree, for both are carboniferous and belong to the same formation; but referring back to the details of our general description in the preceding section, the following points may be noted as distinctive of the lower series, viz.:—

1. The prevalence of Myalina beds throughout the strata below L.

2. The comparative abundance of *Sphenopteris affinis* above L, and of Cyclopteris below it. Both plants occur in both series, but their comparative abundance is markedly different.

3. The most important point is that the carboniferous fauna of the Mountain Limestone is seen only in an incipient state.

This was not for want of sea-room in which to show itself. There was room for Pectens, Modiolæ, and Schizodi, just as in the limestones above and what is not less conclusive, there was room for Gasteropods like Murchisonia, Chemnitzia, Natica, and Cephalopods, like Orthoceras. But where are the Corals, the Encrinites, the immense development of Brachiopods, all those great characteristic forms of life that make the Mountain Limestone fauna what it is. If they occur

* See his interesting work "The Story of a Boulder," p. 195.

at all it must be scantily, and we seem warranted in holding that the rocks below L exhibit that great fauna only in its feeble beginnings. Thus the bed L, marking the point where it fairly took possession of the ancient seas, forms the true base-line of the upper group.

It may confirm these views to observe that an underlying series of strata of the same kind has been found in other parts of the kingdom. In Yorkshire nothing carboniferous is seen below the Mountain Limestone, but these lower beds have been traced at Bristol, in South Wales, and still more fully in Ireland. The Calp. series in the north and the Comhoola grits in the south, with their accompanying strata, are described as occurring in a position beneath the Mountain Limestone, closely analogous to that of our lower series. In these different districts the group, while agreeing in its general features, varies according to the locality. These varying aspects should be carefully studied and compared, and when the results are fully wrought out, the effect will be to unfold many a deeply interesting page in the opening history of the great carboniferous era. It is from Fife Ness on to St Andrews that the beds are most fully developed with us, and the few details which I have endeavoured to record, will, I trust, be sufficient to show the interesting nature of the field, and the value of those results which are yet to be brought to light.