NEW SERIES, Vol. X. 1901, -2, -3.

PROCEEDINGS
OF THE
BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIV.

INDEX TO VOL. X.

NEW SERIES, Vol. X., Part I. (issued for 1901). **Price 2s.**

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

" *Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIII.

NEW SERIES, Vol. X., Part I. (issued for 1901).

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIII.

LIST OF OFFICERS
(1901).

President:

Arthur B. Prowse, M.D.

Past Presidents:

John Beddoe, M.D., F.R.S.
Prof. C. Lloyd Morgan, F.R.S., F.G.S.
Prof. Sydney Young, D.Sc., F.R.S.

Vice-Presidents:

A. E. Hudd, F.S.A.
C. K. Rudge.

Members of the Council:

E. H. Cook, D.Sc.
T. Fisher, M.D.
W. B. Gubbin, M.D.
Rev. A. C. Macpherson, M A.
A. C. Pass, J.P.
H. W. Pearson, M.Inst. C.E.
Rev. H. Pentecost, M.A.
H. C. Playne, M.A.
Rev. G. F. Whidborne, M.A.

Honorary Treasurer:

Thompson Strickland, 13, Victoria Square, Clifton.

Honorary Secretary:

S. H. Reynolds, M.A., University College, Bristol.

Honorary Reporting Secretary:

G. Brebner, University College.

Honorary Librarian:

C. K. Rudge, Ashgrove House, 145, White Ladies' Road.

Honorary Sub-Librarian:

Henry J. Charbonnier, 15, Cranbrook Road, Redland.

OFFICERS OF SECTIONS.

Botanical:

President—Cedric Bucknall, Mus. Bac., 13, Whatley Road, Clifton.
Secretary—James W. White, F.L.S., Warnham, Woodland Road, Clifton.

Chemical and Physical:

President—F. W. Stoddart, F.I.C., F.C.S., Grafton Lodge, Sneyd Park.
Secretary—L. N. Tyack, University College, Bristol.

Entomological:

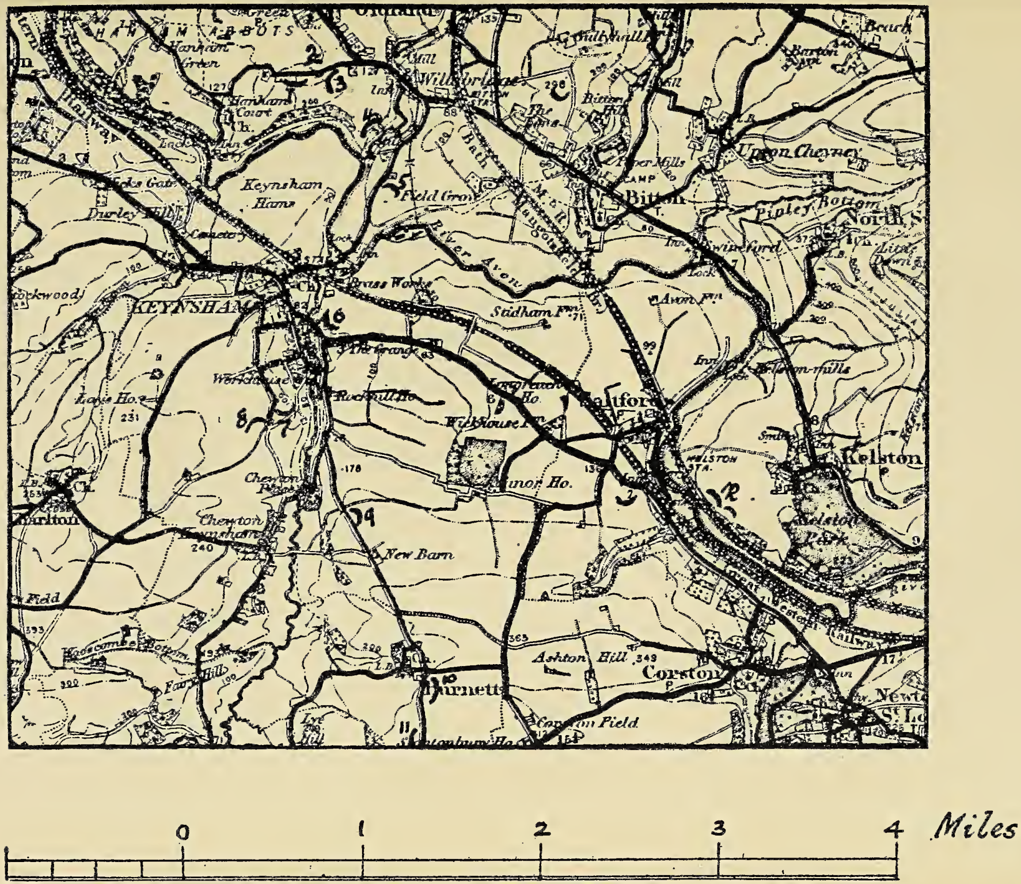
President—G. C. Griffiths, F.Z.S., F.E.S., 43, Caledonia Place, Clifton.
Secretary—Charles Bartlett, 18, Henleaze Avenue, Westbury-on-Trym.

Geological:

President—S. H. Reynolds, M.A., F.G.S., 9, Tottenham Place, Clifton.
Secretary—B. A. Baker, 11, Westbury Park, Durdham Down.

TABLE OF CONTENTS.

NEW SERIES. VOL. X. PART I.



KEYNSHAM
Keynsham Hams
Hanham Green
Hanham Court
Durley Hill
Cemetery
Brass Works
River Avon
Stidham Fm.
Field Grove
Willsbridge
Bitton
Upton Cheyney
Pipley Bottom
Swineford
Avon Fm.
The Grange
Workhouse
Rockhill Ho.
Lays Ho.
Chewton Place
Chewton Keynsham
New Barn
Manor Ho.
Saltford
Kelston
Kelston Park
Ashton Hill
Corston
Corston Field
Burnett
Fairy Hill
0
1
2
3
4
Miles

The Lower Lias of Keynsham.

By Arthur Vaughan, Esq., B.A., B.Sc., F.G.S., and J. W. Tutcher, Esq.

THE district we have examined extends from Willsbridge on the north to a mile below Burnet on the south, and from Keynsham on the west to Kelston Station on the east. Our attention has been devoted almost exclusively to the rocks of Lower Lias age; the beds immediately above and below are, at the present time, nowhere very clearly exposed, so that only their general character can be made out.

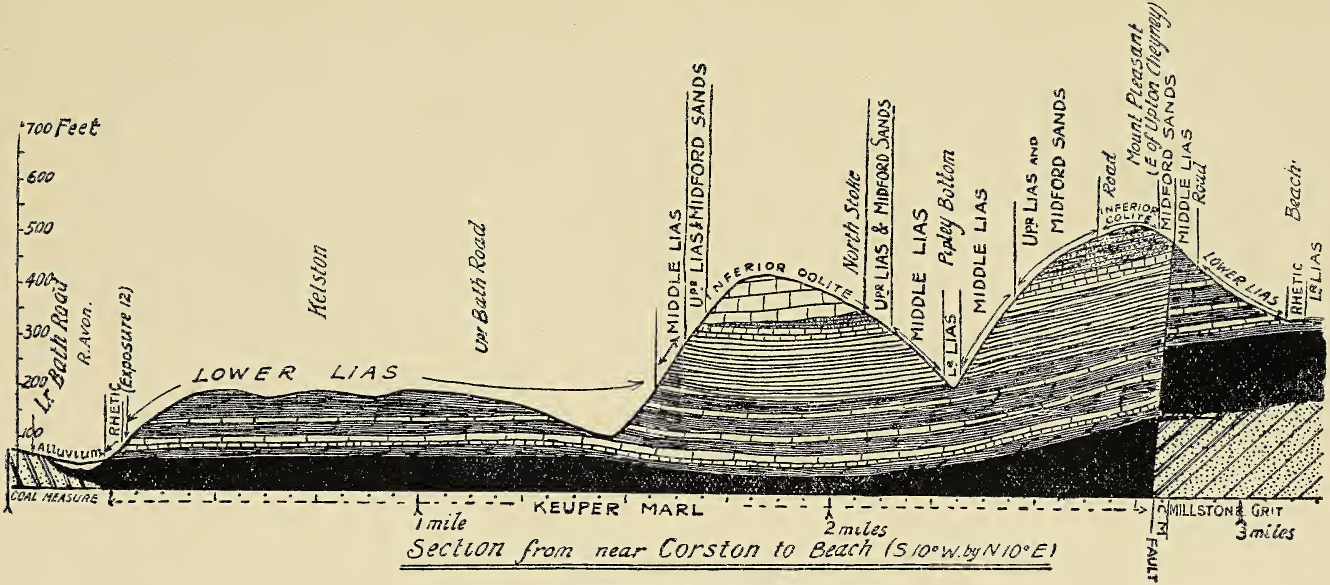
The beds immediately below can be imperfectly seen in the cutting on the Midland Railway just north of Bitton Station. This section is described by Moore[1] and exhibits a normal sequence, through the Rhetic shales, down into the Keuper marls.

The following is a broad summary of the general geological structure of the Keynsham area. The Lower Lias, with the underlying Rhetic shales and Keuper marls, rests quite unconformably upon the Coal Measures below; this capping of newer rocks is nowhere very thick, and the older rocks appear at the surface in broad areas both to north and south. To the north we have the Coal Measures of Brislington and

[1] *Q. J. G. S.*, vol. xxiii.

Warmley, and to the south those of Compton Dando and Pensford. Small patches of the Palæozoic rocks have been exposed at certain points, owing to the removal of the overlying secondaries by the Avon and its tributaries. To this cause are due a small patch of coal measures at Corston on the west bank of the Avon, south of Saltford, and a second patch in the Golden Valley, traversed by the Boyd. Viewed broadly, the dip of the secondary rocks is nowhere considerable; but, when examined in detail, the beds show numerous flexures of very varying orientation; examples of such small folds are well shown in exposure 1 (see map). The general dip is a small easterly one, which carries the Lias under the oolitic escarpment of Lansdown and Odd Down. It is on the west flank of Lansdown (as at Upton Cheyney, North Stoke and Kelston) that the connexion of the Lower Lias with the beds above it can be best made out. Two small outliers, west of the main oolitic escarpment, lie within the area which we are describing; the one, Jay Hill, just east of Bitton Station, and the other, Stantonbury Hill Camp. Both these hills are capped by Inferior Oolite, and they consequently offer opportunities for the examination of the beds intermediate between that formation and the Lower Lias which forms their base.

The lowest beds of the Lower Lias, and the Rhetic series immediately below, are exposed wherever the Avon or one of its tributaries has cut through the upper beds, and it is, consequently, in such places that the lowest beds can best be examined. Two such sections occur within our area, the first, south of Burnet on the east bank of the Chew, and the second, in the Midland Railway cutting, east of Kelston Station, on the north of the Avon. The area is intersected by three or four large faults, as well as by several smaller ones. The main faults run west and east and produce a downthrow in all cases to the south. A good instance of one



Section from near Corston to Beach (S 10° W. by N 10° E)

Vertical Exaggeration 6·6

of the larger faults is to be seen in the disused quarry marked 2 on the map, where the Lower Lias has been thrown down to the south so as to rest against the Keuper marls. A very good instance of a smaller fault is to be seen in exposure 3, where the *Arietes* beds are thrown down to the north and rest against *Angulatus* beds on the south.

The horizontal section illustrates all the most important geological features alluded to above; it shows the relation of the Lower Lias to the rocks above and below, the exposure of lower beds by the denudation of the Avon and its tributaries, and the displacement caused by one of the larger faults.

One of the matters of chief interest in the Lower Lias of Keynsham is the transition which it exhibits between the peculiarly attenuated development of that series in the Radstock area and its more normal development further north.

The Keynsham district has not attracted nearly the same amount of attention as has the neighbouring area of Radstock, which forms its southern continuation. The only detailed accounts of the Keynsham area are to be found in a paper by Moore[1] and in the Survey Memoir.[2]

To no single individual, as to Charles Moore, do we owe so much for a knowledge of the geology around Bristol; with indefatigable energy he extended his researches far and near and yet worked out each section in the most patient detail. By laborious collecting and careful horizoning, he paved the way for the very detailed zoning which is the prominent feature of all recent work.

In so far as his paper deals with the Keynsham district it had two main objects, firstly, to establish a general comparison with the neighbouring Lias areas of Somerset and South Wales, and secondly, to describe in detail many new

[1] *Loc. cit.*

[2] *Jurassic Rocks*, vol. iii.

fossil forms. His first object was achieved by a general account of the fossils found in the Lower Lias, without any need for assigning each to its exact relative position; and the second, by the careful collection and examination of specimens (chiefly of gastropods) from the rich fossil beds of the *Angulatus* and *Arietes* zones.

So far as we are able to judge, the two exposures in the area to which Moore devoted his attention are those marked 3 and 4 on our map. The difficulty of exactly fixing the localities arises partly from the absence of any map to accompany his text, and partly from the evident fact that lower beds were exposed at the time of his work.

In the Survey Memoir, the exposures described clearly include most of our sections 1 to 8, though it is again obvious, from the list of fossils, that lower beds were then exposed than are shown at the present time. There is, however, no attempt made to assign the fossils to their relative vertical positions, but merely to enumerate those of most common occurrence in the district.

The account of our work will be best introduced by a very brief statement of the few facts we have been able to gather concerning the rocks intervening between the upper clays of the Lower Lias and the limestones of the Inferior Oolite.

The mere fact that there are no stone quarries in any Lias rocks above the *Arietes* Limestone is sufficient evidence that the middle Lias contains no hard rocks at all comparable in thickness with the marlstone rock of other districts.

On the other hand, the sands of the Midford Sand Series are well shown in many places, and notably on Jay Hill, east of Bitton Station, where they are somewhat extensively worked. In the quarries on the top of this hill the sands contain several hard layers, and, in the lowest of these, badly preserved ammonites of Upper Liassic facies occur, together with abundant specimens of a small sharply ribbed *Rhyn-*

chonella which is probably closely related to the ill-defined *Rh. moorei.*

Carefully as we hunted in the banks of the steep road which leads directly from the quarry to the bottom of the hill, we found no trace of any hard bed containing Middle Lias fossils. The only hard bed we were able to discover was a compact cream-coloured limestone which has a considerable resemblance in texture to a rock found in the Upper Lias of Sodbury, but, in the absence of fossils, its horizon must remain undetermined. A doubtfully persistent band of marlstone, about 1 ft. thick, immediately below the upper Lias bed, is recorded by Moore[1] at Upton Cheyney and Kelston Village, and one of us has found loose blocks containing belemnites, etc., in the same locality. *Am. serpentinus* is recorded by Moore from the Upper Lias of Upton Cheyney.

The upper part of the sands can be examined in detail in exposures near Upton Cheyney on the north-west flank of Lansdown Hill. Here there occurs an actual Cephalopod bed in which ammonites of the *Aalensis* type are extremely common, whilst, at the very top of the sands immediately below the Inferior Oolite limestones, we have found specimens of *Am. moorei.*

The Inferior Oolite itself consists, as at Midford, of only the upper portion, namely the Upper Trigonia grit. Fossils are very plentiful and specimens of *Rh. spinosa*, costate *Trigonias* and *Lima pectiniformis*, are extremely common.

Mr. Buckman's detailed section at North Stoke[2] (a little further south on the west flank of the same hill) confirms the same general conclusions, namely that the sands are normally developed and capped by a distinct Cephalopod bed, but that

[1] Compare the general account in the Survey Memoir, pp. 212, 213.

[2] *Q.J.G.S.*, vol. lviii., p. 736.

all the lower beds of the Inferior Oolite are missing, as in the classical section at Midford.

Of the passage from the lowest beds of the Lower Lias down into the Rhetic series beneath, we have obtained no direct evidence ; the section north of Bitton Station which exhibits the junction is no longer accessible. The Cotham marble has been recorded in the G.W.R. cutting at Saltford,[1] and it is probable that this characteristic bed is present at the base of the Lias throughout the district.

Before proceeding to give a detailed account of the Lower Lias in the Keynsham district, it will be necessary to explain the system of zoning which we consider most useful for explaining the faunal sequence here and in the neighbouring areas to north and south.

It is immediately obvious that, however limited the area considered, no series of species could ever be discovered whose ranges are exactly conterminous, so that no two are ever found together, and so that no gap exists between the last appearance of one and the first entrance of the next. The very exactness of the requirements is sufficient to demonstrate the impossibility of their satisfaction. The most we can hope for is, that we may be able to find a series of species or groups, of common and general occurrence, whose periods of greatest abundance ("maxima") always succeed each other in the same definite order and such that there is neither a large interval between the times of occurrence of two successive members of the series, nor any considerable period of overlap. As an example of a bad selection of a zonal series which is apt to lead to erroneous conclusions, we take the following abstract case. Suppose three species, A, B and C, to be three selected zonal indices which, whenever they all three occur in the same locality, always have their maxima in

[1] *Q.J.G.S.*, vol. xvi., p. 399, and Wright, *Lias Ammonites*, p. 36.

the definite order A, B, C. Further, suppose that a locality is discovered in which A and C alone occur, whilst the range of C approximately starts where that of A ends. It does not necessarily follow that there was no deposit going on in this locality during the time when B was common elsewhere, but rather that A lived on longer and C started its existence earlier: the only just conclusion is that B is not valuable as a zonal unit outside the localities in which it actually occurs.

The adoption of minute *hemeræ*, represented by the ranges of very short lived species of a single genus, must also be open to very considerable objection, for the fact that their maxima succeed each other in a definite order proves little more than a uniformity in the direction of evolution; it cannot be deduced as even probable that the actual period of existence of any particular species was the same in two distant localities, nor that the ratios of the duration of existence of two successive species in one locality was the same as for another.

Groups, rather than species, are the best zonal indices for general application, whilst species are most useful for local comparisons. If to the name of a zonal group we add that of any species, we indicate a smaller sub-division of time, but, at the same time, we limit the geographical application, so that finally, when a large number of species are named as co-occurrent, we indicate merely the time during which a particular bed, to be found in a particular quarry, was laid down. These are the lines which we here follow; the zonal indices are of world-wide application, the sub-zonal indices have merely local value.

In England, the zonal series generally accepted for the Lower Lias, so far only as we are here concerned with it, consists of the following indices: *Am. planorbis* (with a subzone of *Ostrea liassica*), *Am. angulatus*, *Am. bucklandi*, *Am. turneri* (with the sub-zone of *Am. semicostatus*), *Am. obtusus*, *Am. oxynotus*.

The series of indices adopted in this paper is as follows :

Am. oxynotus	. . . .	.	=Am. oxynotus zone.
Am. arietes	Am. semi-costatus	Am. geometricus	=Am. obtusus and Am. turneri
		Am. obliquecostatus	=Am. bucklandi
	Am. bisulcatus		
Am. angulatus	Rh calcicosta		=Am. angulatus
	Ostrea irregularis		
	Echinid Beds.		
Am. psilonotus	Am. johnstoni		=Am. planorbis
	Am. planorbis		
Ostrea liassica	Sub-ammonite Beds.		
	Sun Bed		=Rhetic
	White Lias		

O. liassica zone.

Since the White Lias and the thick block which caps it (the Sun Bed) have, since the time of Moore, been almost universally regarded as part of the Rhetic, it is necessary to give reasons for including them in the Lias. This we do on account of the practical identity of the fauna contained in the Sun Bed with that in the sub-ammonite beds immediately above. The following species are common to both :—*Ostrea liassica*, *Modiola minima*, *Pleuromya crowcombeia*, *Lima valoniensis*, *Avicula fallax*, and *Cardium rheticum*. Of these species *Modiola minima* and *Avicula fallax* are found commonly in the Rhetic shales ; *Cardium rheticum* occurs abundantly in the Rhetics, but of a very distinct form, which is easily separable ; *Lima valoniensis* is very rare in Rhetic shales, but abundant in the sub-ammonite beds. The only species which links the Sun Bed with the

Rhetic series, rather than with the beds above, is a species of *Isodonta*. This view, that the White Lias is best classed with the Lias, has been already maintained by the late Edward Wilson, and for the same reasons, namely, the identity of the molluscan fauna.[1]

We consequently include all the rocks above the Cotham marble, and below those containing ammonites, in the lowest zone of the Lias as he suggests.

In accordance with custom, we accept *O. liassica* as the zonal index for these beds, since its maximum is undoubtedly in the sub-ammonite beds, where it occurs in thousands. There are, however, two objections to its adoption as a zonal index, which apply equally to all oysters, viz:—Firstly, the difficulty of definition and separation from allied oysters, and secondly, their extensive range. *O. liassica* is, in certain forms, impossible to separate from mutations of *O. irregularis*, and it ranges almost through the *Psilonotus* zone. The further objection to *O. liassica*, that it is far from common in the Sun Bed, applies only to the system of zoning advocated in this paper. We are inclined to think that *Pleuromya crowcombeia* would be a much more satisfactory index. It is easily recognized, both in the young *Pleuromya*-like form, and, when full grown, is unmistakable on account of its *Panopea*-like aspect. It is common in all the beds of the zone, including the Sun Bed, and in certain bands is extremely abundant, whilst we have never found it either in the Rhetic shale below or in the *Psilonotus* Beds above.[2]

The fact, however, that the most important character of the beds, as distinguishing them from those above, is the absence of ammonites, renders the choice of a zonal index a matter of less importance than usual.

[1] Rhetic Rocks at Pylle Hill, Bristol, *Q.J.G.S.*, vol. xlvii. p. 546.
[2] Moore notes the occurrence of this fossil with *Avicula contorta*, *Q.J.G.S.*, vol. xvii.

Am. psilonotus zone (=Zone of *Am. planorbis*).

In all the Lower Lias outcrops near Bristol, *Am. planorbis* is confined to a very limited portion of the zone, namely, to one or two beds at the very base. Were we to confine this zone to the very small thickness of rocks in which *Am. planorbis* actually occurs, the zone would be too narrow to afford either a useful or reliable unit of time measurement. Hence, by general consent, the zone is made to include an upper and larger portion from which *Am. planorbis* is absent, and which is only limited by the first occurrence of the next zonal index, *Am. angulatus*. A considerable vagueness is the necessary result; for example, if a fossil is said to be confined to the *Planorbis* zone, it is merely implied that no specimen of *Am. angulatus* has been found associated with it, but the fossil may or may not occur in association with *Am. planorbis*. The difficulty can be partially overcome by associating a nearly allied ammonite, *Am. johnstoni*, as joint zonal index. The zone is then best described as that of *Am. psilonotus*, since under this term, Quenstedt included both *Am. planorbis* and *Am. johnstoni*. The usual objection urged against this course is the fact that, in certain localities, *Am. johnstoni* is stated to be a common associate of *Am. angulatus*, and, consequently, there would be a marked overlap of zones. We cannot see that any vagueness results, but rather that the circumstances lend themselves to an added exactness of horizoning in the districts in which the overlap occurs. The objection seems to be based on the impossible striving after conterminous zonal indices. It seems to us to be preferable to have a series of overlapping indices, rather than one which admits of large gaps between its successive terms. Throughout the district from Radstock to Sodbury, we have found no overlapping of the *Psilonotus* and *Angulatus* zones, but always that there is a considerable gap between the beds in which *Am. psilonotus* occurs and those in which typical specimens of *Am. angulatus* can be found.

In the Keynsham district, exposure 12 (Kelston Station), is the only one in which the *Psilonotus* Beds are completely shown. And here, *Am. planorbis* is confined to a single bed at the base of the zone, whilst *Am. johnstoni* is extremely abundant in the limestones above. We have found no specimens of *Am. johnstoni* actually associated with *Am. planorbis*, and the same statement is true of the section near Redland, and at Stoke Gifford,[1] where the general faunal succession is almost identical with that at Kelston. At Radstock, *Am. johnstoni* is not a common fossil, but, so far as our investigations have yet gone, the same sequence holds good here also. At Sodbury,[2] *Am. planorbis* is apparently absent, whilst *Am. johnstoni* is very abundant to the very base of the zone.

Am. angulatus zone.

Am. angulatus is a somewhat unsatisfactory zonal index on account of its rarity; even fragments are uncommon, and specimens showing the earlier and later whorls in conjunction are the rarest finds in the district. As already stated, we have never found *Am. angulatus* associated with *Am. johnstoni*, either at Keynsham or in the neighbouring districts. Owing to the extreme rarity of the zonal index, it becomes necessary to select other commoner species as sub-zonal indices of at least local value.

Just above the *Psilonotus* zone, echinids are so common that this horizon may be fittingly termed the Echinid Bed. Since only a single, very badly preserved, fragmentary cast of an ammonite, whose relationship is extremely doubtful, has been found in this bed, it is very immaterial whether we assign this horizon to the *Psilonotus* or to the *Angulatus* zone. At Redland, Kelston and Sodbury similar Echinid Beds occur and, at the two first-mentioned localities, they

[1] *Q.J.S.S.*, vol. lviii. pp. 727–729.
[2] *Q.J.G.S.*, vol. lviii. p. 719.

are certainly in very close relation to the top beds of the *Psilonotus* zone.

In the variable limestones and clays above the Echinid Bed, typical specimens of *Am. angulatus* occur, and the maximum development of the species would seem to be in these beds, for, in all the quarries where fragments of *Am. angulatus* can be picked up, they are almost invariably found in association with the forms peculiar to these beds.

The most characteristic and abundant fossil, associated with *Am. angulatus* in these beds, is a very puzzling oyster which has been assigned to several species and which, in its mutations, exhibits the characters of both *Gryphea* and *Exogyra*. This fossil we have tentatively referred to *Ostrea irregularis*, and we have selected it as a sub-zonal index of at least great local importance.

Above the sub-zone of *O. irregularis*, comes a series of limestones and thin clays which we term the *Calcicosta* Beds, on account of the extreme abundance of *Rhynchonella calcicosta* in them throughout the district. This is, *par excellence*, the richest fossiliferous series in the Keynsham district, and forms a very homogeneous group both lithologically and palæontologically. Notwithstanding the remarkable homogeneity of this series of beds, it would undoubtedly be assigned to two different zones by the rigid adherent to zonal division; for the top thick bed contains abundant representatives of the bisulcate group of ammonites, whilst the lower beds contain specimens of *Am. angulatus* in considerable number. We have, however, found large adult specimens of *Am. angulatus* in the beds immediately above the top of the *Calcicosta* series, showing that there is, in the Keynsham district, a distinct overlap of the *Angulatus* and the so-called *Bucklandi* zones, though of no considerable extent.

Comparing the sequence in neighbouring districts:—In the Sodbury area to the north, the sequence is almost identical, though the lithological characters are so distinct. A thick lower series of Echinid shales is succeeded by thick shales in which *Am. angulatus* is associated with countless specimens of *Ostrea irregularis*, and these beds are capped by thin limestones in which *Rhynchonella calcicosta* occurs, though very sparingly.

In the Radstock area to the south, no specimen of *Am. angulatus* has ever been recorded, but *O. irregularis* is common, and the presence of *Lima hettangiensis* seems to point to a considerable development of the *Angulatus* zone.

Zone of Am. arietes (=zones of *Bucklandi* and *Turneri*).

Since, in the Keynsham district, *Am. semicostatus*, *Am. turneri*, and *Am. planicosta* occur in the same bed, whilst *Am. semicostatus* occurs lower down with typical specimens of *Am. bisulcatus*, we have been compelled to group the whole series together under the comprehensive zonal designation of *Am. arietes*. (By the group name, *Am. arietes*, we understand ammonites with a widely open umbilicus, a rim provided with a strong central keel flanked by deep furrows on either side, and strong, similar, simple ribs, running continuously right across the sides of the whorls.) This group name excellently covers the four ammonites usually employed as zonal indices, viz., *Am. bucklandi*, *Am. semicostatus*, *Am. turneri*, and *Am. obtusus*.

This broad division of zones has a very great practical advantage in that it requires no expert knowledge of ammonites to distinguish between members of the *Psilonotus*. *Angulatus*, *Arietes* and *Oxynotus* groups.

In order to express more definitely the ranges of species. we shall adopt two sub-zones for which we claim, at least, a local importance.

Sub-zone of Am. bisulcatus.

We use this definition for the beds above the thick top block of the *Calcicosta* series, and below the first perfect shale found in the district. This shale is well marked out palæontologically by the great abundance of *Anomia* and *Avicula*, and by the occurrence of fish fragments. It is probable that most stratigraphists would include also in this zone the top block of the *Calcicosta* series which is here grouped as the uppermost bed of the *Angulatus* zone. The argument for the inclusion of this block is often very striking, for bisulcate ammonites are in many places very abundant in it (we may especially mention exposure 7, where the upper surface of the block is, in places, almost paved with large specimens of *Am. conybeari*), and they are never wholly absent. The reasons against its inclusion seem to us stronger, for, excepting the ammonites, all the fossils it contains are identical with those found in the beds just below. *Rh. calcicosta*, small gastropods and species of *Astarte* and *Cardinia* occur in immense numbers throughout the *Calcicosta* beds, but are uncommon above.

(We attach little importance to the very rare occurrence of *Am. angulatus* in the beds immediately above the top of the *Calcicosta* beds, for these beds are, in every respect, typical members of the *Bisulcatus* zone.)

It is also possible that the perfect shale with the hard bed immediately above it, which we include in the next sub-zone, would by many be considered to belong to the zone of *Am. bisulcatus*. The arguments for and against this view are given in the discussion of the zone of *Am. semicostatus*.

A careful examination of all the large ammonites which we have met with from this zone has convinced us that *Am. bucklandi*, in its typical form, is a comparative rarity. No two specimens exactly agree either in rate of growth or in number of ribs, but the commonest form is one with numerous ribs. In consequence, it seems preferable to select a group name as index, rather than the name of a particular and rather aberrant mutation which is certainly not the commonest variation of the general form.

Am. bisulcatus, as first defined by Bruguière, covers the whole group excellently and has been used in the same extended sense by d'Orbigny in France and Brauns in Germany.

Sub-zone of Am. semicostatus.

In this division we include all the beds from the perfect shale, containing fish remains, up to the base of the thick clay which forms the top of the exposures in which these beds occur.

The semicostate (or arniocerate) ammonite group which characterizes these beds is marked out by a strong keel, flanked by furrows, and strong, simple ribs; but, above all, by having the earlier whorls conspicuously smooth.

We further subdivide this sub-zone into a lower and upper portion characterized respectively by two varieties of *Am. semicostatus*, viz., the lower by *Am. obliquecostatus* and the upper by *Am. geometricus*. As already stated, many geologists might be inclined to place the lower of these subdivisions in the *Bisulcatus* zone. The reasons for such a view are :—

1. The close lithological similarity of the hard bed in this subdivision to the hard beds of the *Bisulcatus* zone and its dissimilarity to the rubbly, discontinuous limestone bands in the beds above. The *Obliquecostatus* subdivision usually consists of a thick, perfect shale, succeeded by a hard limestone in which the index species is extremely abundant. When this thick shale thins out and the rubbly limestone bands above degenerate into mere beds

of nodules, it would seem impossible, at first sight, to draw a divisional line where we suggest.

2. *Am. obliquecostatus*, though undoubtedly at a maximum in this division, does also occur in the *Bisulcatus* beds below, and large nautili are as common here as in the beds below.

Against this view and in favour of our suggested zonal division, we may cite the following facts:—

1. We include in the same sub-zone *both* mutations of *Am. semicostatus* (whilst admitting, however, an unimportant overlap into the *Bisulcatus* zone below).

2. The lower and upper subdivisions are linked by the great abundance of *Avicula inequivalvis* and of a distinct variety of *Rh. calcicosta* which we term *Rh. calcicosta* var. *semicostati* (*Av. inequivalvis* also occurs in the *Bisulcatus* beds but very sparingly).

3. There is a very striking lithological change at the top of the *Bisulcatus* zone wherever the shale is well developed, for it is remarkably fissile, whilst all the soft beds at lower levels are more correctly described as clays.

The uppermost beds which contain abundant belemnites may be unhesitatingly included in the *Arietes* zone, rather than in the *Oxynotus* clays above, for, with the exception of a single fragment of an oxynoticerate ammonite, we have found these clays to be entirely unfossiliferous.

We have not adopted *Am. turneri* as a zonal index for two reasons: (1) It would only cover the top layers of the upper subdivision, and even there its occurrence is limited to a very small thickness of rock. (2) It is common in only one of the exposures, where only badly preserved fragments are to be found.

Am. planicosta, the earliest of the capricorn ammonites, which attain such pre-eminence in the lowest beds of the Middle Lias, is fairly common throughout the upper subdivision (whose index is *Am. geometricus*). This fossil satisfactorily links the series with the *Ziphus* zone of German authors and, should it be considered better to include the lower division (indexed by *Am. obliquecostatus*) in the *Arietes* beds, there can be no doubt that *Am. planicosta* is the best index to choose for the upper subdivision.

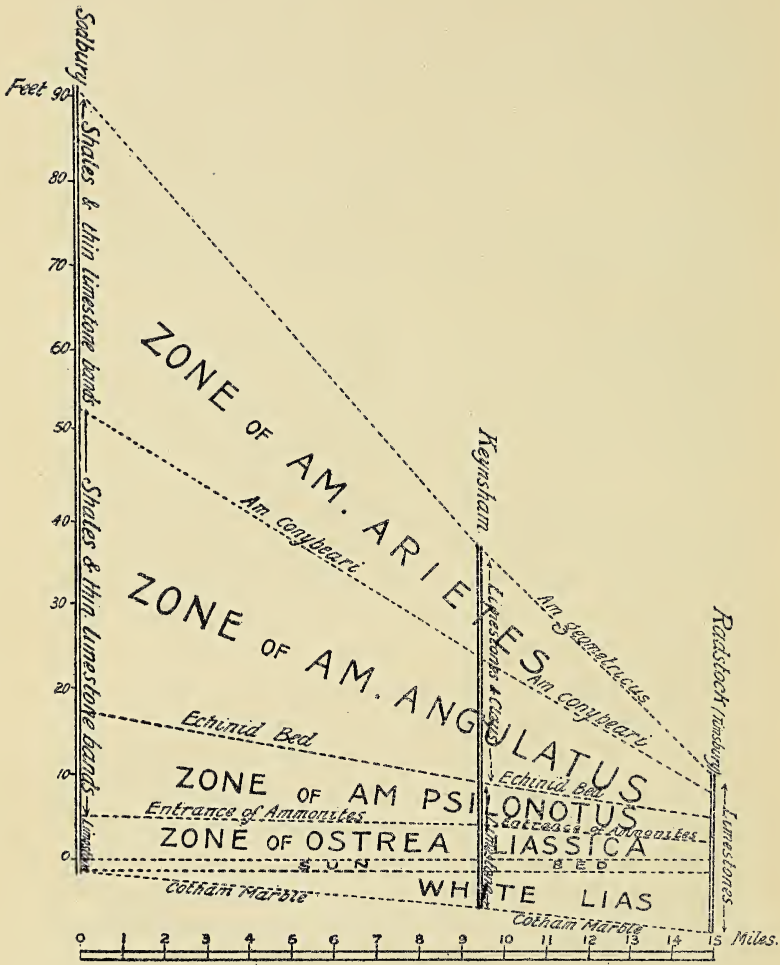
The *Semicostatus* beds of Keynsham if extended, as we suggest, so as to include a lower subdivision rich in the semicostate mutation, *Am. obliquecostatus*, form an excellent connecting link between the same beds at Radstock and Sodbury.

At Radstock this zone includes the richly fossiliferous *Spirifer* Bank (the *Spirifer* Bank of German authors occurs on a higher horizon, namely, at the base of the *Jamesoni* zone, i.e., at the bottom of the Middle Lias).

Here *Am. sauzeanus* and *Am. semicostatus* (both varieties) are the predominant forms amongst ammonites, whilst *Spiriferina walcotti*, *Rh. lineata* and a *Terebratula* identified as *Wald. indentata* are the commonest forms amongst Brachiopods. The thickness of the zone is only a few inches.

At Keynsham *Am. planicosta* takes the place of *Am. sauzeanus*, and *Am. turneri* occurs as an additional form. Amongst Brachiopods only *Rh. semicostati* is common, and this fossil is very nearly allied to the Radstock form of *Rh. lineata*. The thickness rises to nearly five feet.

At Sodbury *Am. semicostatus* and *Am. turneri* occur in vast numbers, whilst Brachiopods are excessively rare. In one point the Sodbury development is in closer relation to that of Radstock than to that of Keynsham, namely, in the fact that *Gryphea arcuata* is an associate of the semicostate ammonites, whereas, at Keynsham, this fossil is absent from this horizon. The thickness is more than twenty-five feet.



Variation of Lr. Lias from N. to S.

In all three districts a series of beds rich in semicostate ammonites, overlies beds containing large bisulcate ammonites, and is capped by strata containing abundant brevicone belemnites.

The diagram shows the change in thickness and lithological character of the zones of the Lower Lias as we proceed from Sodbury on the north, through the Keynsham district, to the Radstock area further south.

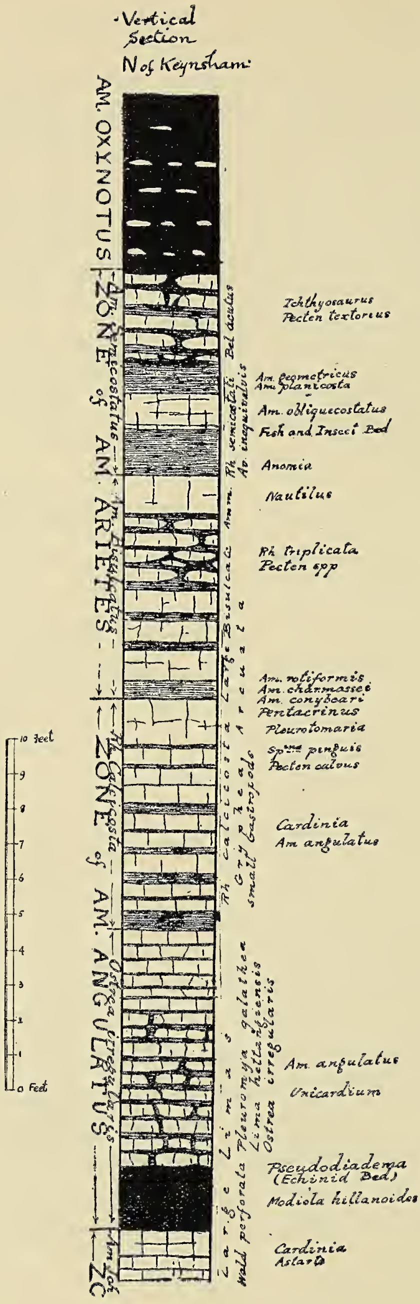
We have selected the Timsbury section as being the nearest exposure to the Keynsham area, which exhibits the characters which are peculiar to the Radstock Lias. The diagram needs no further explanation.

DETAILED ACCOUNT OF THE KEYNSHAM LIAS.

I. *The sequence North of Keynsham* (as shown in exposures 1, 2, 3, 4, 5).

At the base, hard limestone beds are succeeded by a thick clay which always forms a very marked feature wherever the quarries have been worked low enough. In these hard beds we have found no ammonites, and those fossils that do occur abundantly (*Wald. perforata*, large *Limas* and species of *Astarte* and *Cardinia*) cannot be considered to be of great value in fixing the horizon. Nevertheless, from the abundance of echinid remains in the thick clay immediately above, we are inclined to regard these hard beds as belonging to the *Johnstoni* division of the *Psilonotus* zone (compare Kelston station section and the section near Redland).

The thick clay itself forms a very characteristic palæontological horizon, but it is very difficult and, as we think, very unimportant to say whether it should be grouped with the *Angulatus* beds above or with the *Psilonotus* beds below. Only one specimen of an ammonite has been found in it, and that, a very poor cast, showed tall, curved ribs, much after the *angulatus* pattern, but more spaced than


Vertical Section N of Keynsham
AM. OXYNOTUS
ZONE of AM. ARIETES
ZONE of AM. ANGULATUS
Am. semicostatus
Am. Bisulcatus
Rh. Calcicosta
Ostrea irregularis
Bel. acutus
Rh. semicostata
Av. inaequivalvis
Large Bisulcate Amm.
Rh. Calcicosta
Gryphaea arcuata
small Gastropods
Large Limas
Pleuromya galathea
Lima hettangiensis
Ostrea irregularis
Wald. perforata
Ichthyosaurus
Pecten textorius
Am. geometricus
Am. planicosta
Am. obliquecostatus
Fish and Insect Bed
Anomia
Nautilus
Rh. triplicata
Pecten spp
Am. rotiformis
Am. charmassei
Am. conybeari
Pentacrinus
Pleurotomaria
Spiriferina pinguis
Pecten calvus
Cardinia
Am angulatus
Am. angulatus
Unicardium
Pseudodiadema
(Echinid Bed)
Modiola hillanoides
Cardinia
Astarte
10 feet
9
8
7
6
5
4
3
2
1
0 Feet

is the case in any typical specimen of that species. The most characteristic fossil is a species of *Diadema* which is fully described below.

A species of *Modiola* (identified by us as *M. hillanoides*) is abundant and characteristic, whilst small smooth *Pectens* with faint radial striæ and large *Limas* (especially *L. hermanni*) are very common.

The thick clay is followed by a series of thin, disjointed limestones with clay partings, the whole thickness amounting to about seven feet. Here ammonites are far from common, but typical fragments of *Am. angulatus* can be found *in situ*, and can be picked up in greater numbers on the spoil heaps, where they are associated with the fossils characteristic of this series of beds.

The commonest and most characteristic fossils which occur in these beds are *Pleuromya* casts, *Ostrea irregularis* and *Lima hettangiensis.*

Were we to confine our attention to the Keynsham area it is unquestionable that the most useful zonal index of these beds would be the casts of *Pleuromya* (*Gresslya*) *galathea* which is extremely common, easily recognized and, so far as we know, not found at a higher or lower horizon in the district ; but, for the purposes of comparison with neighbouring areas, we have selected the very variable *Ostrea irregularis* as the most useful index.

Large *Limas* (*L. gigantea* and *L. hermanni*) are fairly abundant in the lower part of the series, but the smaller duplicate *Lima* (*L. hettangiensis*) is more characteristic, and, consequently, of greater practical value.

The *Calcicosta* series, about six feet thick, overlies the *irregularis* beds, from which it is separated by a conspicuous band of clay.

This series forms one of the most interesting and homogeneous groups in the Lower Lias of the Keynsham district.

In general aspect the series bears a considerable resemblance to the White Lias, with its thick top block, the Sun Bed. Mainly composed of thin uniform beds of limestone, only separated by thin partings of clay, the series is immediately capped by a prominent bed which is very uniform in thickness throughout the district. This thick top block, being separated by a well-marked clay from the beds above, stands out as a prominent horizon in all the exposures in which it is seen. (How natural is the break formed by the upper surface of this block can be seen in the fact that it is used as the floor on which the quarryman works to remove the beds above, and often it forms a level top to the quarry, owing to its greater resistance to denudation.) This series is extremely rich in fossils and, where the beds have been exposed to the air for a considerable time, the joint surfaces are covered with fossils, beautifully weathered out. Small gastropods, belonging to several genera, range abundantly throughout the series, but are most prolific in the top block and in the lowest layer but one. Species of *Cardinia* and *Astarte* also abound, but the former are difficult to extract, since nearly all the specimens lie horizontally, so that the greater portion of their valves is firmly embedded in the stone.

The most prolific fossil is undoubtedly the small, sharply-ribbed *Rhynchonella*, *R. calcicosta*. The top block is, in places, completely studded with this small brachiopod, and the lowest bed of the series often contains as many. Though this species is certainly not confined to this horizon, for it ranges into the beds above and is also found much lower down (compare section near Redland), yet it is so characteristic of this series, and so abundant in it, that the designation *Calcicosta* Beds is quite justified. The fossil cannot, however, be regarded as having more than a local value as a zonal index, for it is not recorded from Radstock, and is rare at Sodbury. (In Germany the same species seems to occur at a much higher horizon, namely in the *Jamesoni* beds, though a mutation, *Rh. plicatissima*, which also occurs at Keynsham, is found as low down as the *Arietes* zone).

Large *Limas* occur sparingly at the base, but do not range to the top of the series; *O. irregularis* also becomes less common, and is replaced by *Gryphea arcuata*, which becomes more and more abundant from bed to bed, until it reaches its maximum in the top beds of this series, and in the lowest beds of the next.

As has been already noticed, the ammonite zones overlap at the top of this series, for the top block contains bisulcate ammonites in considerable number, whilst a rare specimen of *Am. angulatus* extends into the beds immediately above. Fragments of *Am. angulatus* of all ages are not uncommon throughout the lower beds of the series. *Am. charmassei* enters in the top block, but reaches its maximum in the shale immediately above, and is more characteristic of the next zone (*Arietes* zone). A very few specimens of *Bel. acutus* have been observed in the top block, but this fossil does not become abundant until the very top of the *Arietes* zone.

The *Arietes* beds, which succeed the *Calcicosta* series, reach a total thickness of twelve feet; the lower six feet is made up of massive limestones, separated by subsidiary clay bands (zone of *Am. bisulcatus*), whilst the upper six feet comprises thick shales with subsidiary limestone bands (zone of *Am. semicostatus*).

(*a*) Zone of *Am. bisulcatus*.

At the base, *Am. charmassei* and *Gryphea arcuata* each reach a maximum, *Pentacrinus* fragments are extremely common, *Rh. calcicosta* in its typical form dies out, and the most characteristic bisulcate ammonite is the *conybeari* mutation.

Throughout the main portion, mutations of bisulcate ammonites abound and include the types usually named *bucklandi*, *multicostatus* and *bisulcatus*. In our opinion these names only indicate a few links, arbitrarily chosen, in a complete chain of mutation. Besides the typical *Am. bisulcatus*, nearly allied coronicerates, typified by *Am. rotiformis*, are far from uncommon, especially towards the base (*Am. rotiformis* itself and the striking mutation which we identify with *Am. coronaries*, Quenst. are the two commoner forms). *Rhynchonella triplicata* (a member of the *Rh. variabilis* group) succeeds *Rh. calcicosta* and is quite characteristic of all the beds which contain large bisulcate ammonites.

In the top beds, though large bisulcate ammonites clearly indicate the zone to which it belongs, the occurrence of large nautili, *Avicula inequivalvis*, and the semicostate *Am. obliquecostatus* link the bed with those just above

(*b*) Zone of *Am. semicostatus.*

This is characterized throughout by the abundance of semicostate ammonites (*Arnioceras*) of this type. *Am. obliquecostatus*, which is more nearly allied to the bisulcate group, is typical of the lower beds, whilst the more characteristic mutation, *Am. geometricus*, crowds the shales or thin limestones of the upper beds.

Rhynchonella semicostati (*v.i.*), which we consider closely allied to the Radstock type of *Rh. lineata*, is extremely abundant at more than one horizon, though usually crushed.

Avicula inequivalvis and *Anomia pellucida* occur in thousands in the shales at the base, and the former is equally common in the upper portion, associated with *Am. geometricus.*

At the top of this basal shale, immediately below the massive limestone bed which contains *Am. obliquecostatus*, is a thin, but very interesting bed containing fish remains.

Am. planicosta is common in the upper beds associated with *Am. geometricus*, but all the specimens found at this horizon are crushed and poorly preserved.

The most characteristic fossil of the beds immediately above the *Geometricus* horizon is *Bel. acutus*, which here attains its maximum; satisfactory specimens can be picked out of the shales.

Oxynotus Zone.

Above the *Arietes* zone is a thick, unfossiliferous clay containing horizontal rows of large limestone nodules. These are the highest beds encountered in any of the exposures.

NOTES ON EXPOSURES 1, 2, 3, 4, 5.

The position of all the exposures is sufficiently clearly shown in the map.

Exposure 1. A quarry in work.

In the south-east corner is a fine and complete section of the *Angulatus* beds which shows this series resting upon the thick clay and capped by the thick top block of the *Calcicosta* series.

The east wall of the quarry, nearer the road, shows the *Bisulcatus* division of the *Arietes* zone very clearly, and numerous large ammonites can be seen *in situ.*

The south wall of the quarry exhibits several small flexures, of which one is a well-marked anticlinal fold in the *Angulatus* beds, and two others are monoclinic flexures or incipient faults.

Fossils can be picked up more abundantly in this quarry than in any other; they are chiefly derived from the *Angulatus* beds (*Wald. perforata*, *O. irregularis*, *Pleuromya* (casts), fragments of *Am. angulatus*, and *Lima hettangiensis* are amongst the certain finds).

Exposure 2. A disused quarry.

The only interest of this exposure is the well-marked fault.

The north wall is formed of red Keuper marls, against which the Lias beds, seen in the west wall, rest, having been thrown down to the south.

The Lias beds belong to the upper *Angulatus* and lower *Arietes* zones. Large ammonites, etc., can be obtained from the stack of stone near the entrance.

Exposure 3. A quarry in work.

A small fault, which strikes east and west across the middle of the quarry, separates *Angulatus* beds on the south from higher beds nearer the road. The downthrow is about fifteen feet to the north.

The south portion of the quarry consists of the *Angulatus* series resting on the thick clay which forms a very conspicuous band at the base of the section. In a trench, which is excavated all along at the base of the quarry wall, the hard beds beneath are well shown and large *Limas* are obtained very abundantly from these beds, as well as more sparingly from the beds just above the thick clay. *Wald. perforata* is also a very abundant fossil in these beds and occurs in the clay itself.

The thick clay dies out at the south-east corner of the quarry, where it passes laterally into limestones.

Only the lower portion of the *Calcicosta* series can be seen in this portion of the quarry.

North of the fault there is a fine section, extending from the *Calcicosta* series at the base completely through the *Arietes* zone, up into the *Oxynotus* clay at the top. The following are the most interesting points to be made out:—

The thick top block of the *Calcicosta* beds, crowded with *Rh. calcicosta*, contains numerous bisulcate ammonites and a very few specimens of *Bel. acutus*.

The *Bisulcatus* beds are extremely rich in large ammonites.

The upper *Semicostatus* beds (characterized by *Am. geometricus*) contain a band of thin, argillaceous limestones in which *Am. geometricus*, *Am. planicosta*, and *Rh. semicostati* (*v.i.*) are extremely abundant.

The shales just above this band are rich in *Bel. acutus* and its mutations.

Exposure 4. A quarry in work.

The lowest beds exposed are the thick clay and a few feet of the hard beds below. These beds are shown in a recent opening in the floor of the quarry. The upper part of the clay is crowded with the spines and fragments of the test of a small *Pseudodiadema* (*v.i.*), associated with *Modiola hillanoides* and small smooth *Pectens*. Large *Limas* are abundant below and above the clay.

The *Calcicosta* beds are extremely well shown in the face of the quarry furthest from the river, and since this face has been exposed to the action of the air for a very considerable time, the fossils in the beds are beautifully weathered out (see above).

The *Bisulcatus* beds are also shown in this face and contain abundant large ammonites and a few large nautili. The shale at the base of these beds, just above the top block of the *Calcicosta* series, is very rich in fossils and contains numerous fragments of *Pentacrinus*.

The beds in this quarry show a dip of $6\frac{1}{2}°$ to the south-east

The lower portion of our vertical section (up to the top of the *Calcicosta* series) was constructed mainly from data supplied by exposure 4.

Exposure 5. A quarry in work.

All the beds, from the base of the *Calcicosta* series up to the *Oxynotus* clay, are finely exhibited. The most interesting feature is the very perfect shale, crowded with *Avicula inequivalvis* and containing, at the top, fragments of fish. In the hard bed, above this shale, *Am. obliquecostatus* is very abundant and, in the shales above, *Am. geometricus* occurs plentifully, but always crushed.

The upper portion of our vertical section (all the beds above the top of the *Calcicosta* series) was constructed mainly from data supplied by exposure 5.

II. *The sequence immediately south of Keynsham* (as shown in exposures 6, 7, 8).

The most noteworthy feature in the development of the Lower Lias rocks immediately south of Keynsham is the local

expansion of the *Bisulcatus* beds. A consequence of this fact is that, whereas north of Keynsham the beds principally worked belong to the *Angulatus* series, south of Keynsham, nearly the whole of the stone is derived from the lower *Arietes* series. Not only is there a marked increase in the total thickness of the series, but there is, at the same time, a great diminution in the thickness of the clay partings, so that the *Bisulcatus* zone is composed of thick limestones in close superposition.

The *Calcicosta* series below and the *Semicostatus* beds above are very similar, in all their characters, to the beds on the same horizons further north.

The hard limestone band which occurs in the lower *Semicostatus* beds contains *Am. obliquecostatus* abundantly and is brought into special prominence on account of its separation, by a thick shale, from the massive limestones series below (the *Bisulcatus* beds).

Exposure 6. A quarry in work.

Above the *Calcicosta* beds come well developed *Bisulcatus* limestones, not so thick, however, as in exposures 7 and 8. The *Obliquecostatus* limestone is strongly marked and the upper *Semicostatus* beds extremely well shown. In these beds, *Am. turneri* is a common associate of *Am. geometricus.*

Exposure 7. Two small quarries close together, and a very large one, further to the south-west, in continuous work.

The two small quarries only show the massive limestones of the *Bisulcatus* zone, the top block of the *Calcicosta* beds occurring at the base. Large bisulcate ammonites are common in the top beds, *Rhynchonella triplicata* and *Pecten calvus* are common throughout and an occasional specimen of *Wald perforata* can be seen *in situ.*

The large quarry shows, at the base, a splendid mural section of the whole of the *Calcicosta* series, containing gastropods, etc., weathered out on its joint surfaces and identical, in all respects, with the same series further north.

The upper surface of these beds, which forms a platform in the quarry, is remarkable for the number of large specimens of *Am. conybeari* which lie embedded in it. The upper beds belong to the *Bisulcatus* zone and consist of a thick series of limestones with very subsidiary clay partings.

Exposure 8. A quarry.

This exposure shows the massive *Bisulcatus* limestones below, capped by a thick shale which separates them from the prominent hard band formed by the *Am. obliquecostatus* bed. This band contains abundant specimens of *Am. obliquecostatus* and also many phosphatic nodules. These nodules are of considerable interest, since they clearly mark the northern extension of the well known Phosphatic bed of the Radstock district.

The upper *Semicostatus* beds consist of shales and thin impure limestones, very similar in all respects to the beds on the same horizon shown in exposure 3 north of Keynsham.

The top of the section is formed of a thick clay, with a few beds of limestone nodules, from which a fragment of an *Oxynoticeras* was derived.

The vertical section was constructed from data supplied by this exposure.

III. *Exposures on the Keynsham, Burnet, Marksbury Road* (numbered 9, 10, 11).

Exposure 9. A low, roadside section.

At the base, the upper portion of the *O. irregularis* beds, followed by a complete *Calcicosta* series a little thinner, but otherwise very similar to the same beds further north. We may notice, however, that *Lima gigantea* and its mutation, *L. punctata*, occur here as high up as the top block of the *Calcicosta* series.

The *Bisulcatus* beds are much thinner than in the last group of exposures. They contain the usual large bisulcate ammonites as well as nautili, especially towards the top.

The highest hard bed in the section represents the lower *Semicostatus* beds and contains *Am. obliquecostatus* in profusion; good specimens showing the characteristic smooth central whorls can be seen in great numbers, but the sparry infilling of their interior renders them almost impossible to extract from the hard matrix.

Exposure 10. A disused quarry practically filled up.

The only bed still accessible is the hard *Obliquecostatus* bed, which is extremely rich in fossils. *Am. obliquecostatus* occurs in abundance in it, and *Avicula inequivalvis* and the Radstock type of *Rh. lineata* are also common in this bed. Large *Limas* extend up into the *Bisulcatus* beds and, in fact, the faunal sequence is transitional between that of the Keynsham and that of the Radstock area.

Exposure 11. A disused quarry.

The beds in this exposure are confined to the lowest zone of the Lower Lias, viz. the *Ostrea liassica* zone. Capping a few feet of thin White Lias, is a thick bed (The Sun Bed) and, above this, about 2½ feet of thin limestones and clays, belonging to the sub-ammonite section. The position of these uppermost beds is well fixed by the presence of *Lima valoniensis*. *Pinna hartmanni* and *Pholadomya glabra* are not uncommon, but all the fossils are badly preserved.

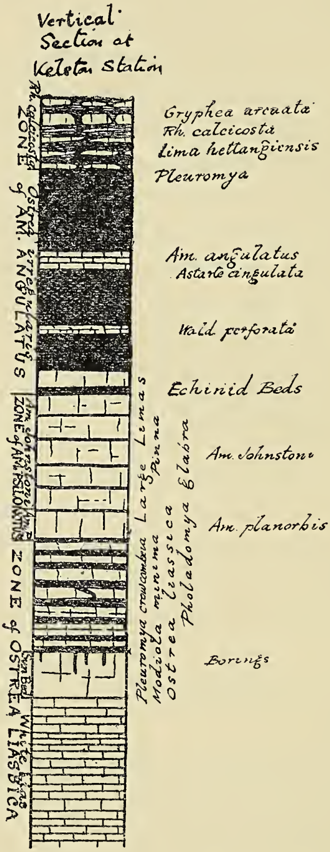
IV. *Exposure at Kelston Station* (Exposure 12).

The east face of the Midland Railway cutting, just south of Kelston station.

The Sun Bed is here seen capping a considerable thickness of typical White Lias. The base of this series is not seen but the Cotham marble is almost certainly present, since it was recorded by Sanders in the neighbouring cutting on the G.W.R. line at Saltford.[1] The upper surface of the Sun Bed shows numerous borings. (This character was stated by Moore to be a general feature of this bed in all districts, and

[1] *Loc. cit.*

it forms one of the points upon which he relied for the relegation of the White Lias to the Rhetic. As fully pointed out above, we consider the practical identity of the molluscan fauna in this bed with that in the beds above to necessitate



the return of the White Lias to the Lias.) Above the Sun Bed come the sub-ammonite *Ostrea* beds, practically identical in lithology and palæontology with the beds on the same horizon at Redland. *Ostrea liassica* and *Pleuromya crow-*

combeia are the predominant fossils. A single, thick band of compact limestone, containing *Am. planorbis*, forms the base of the *Psilonotus* zone, as it does at Redland, Radstock and Stoke Gifford. The ammonite is in places very abundant.

Immediately above the *Planorbis* bed come several thick beds of limestone, crowded with *Am. johnstoni* and large *Limas*; both *Lima gigantea* and *Lima hermanni* reach their maximum in these beds, but *L. gigantea* is by far the most abundant. *Pholadomya glabra* links the beds with the *Ostrea* beds below, whilst *O. irregularis* and smooth *Pectens* of the *calvus* type occur here, but reach their maximum in a higher zone.

Immediately on top of the *Psilonotus* limestones is a thin clay, succeeded by a limestone, both of which contain Echinid fragments in profusion, as well as abundant specimens of large *Limas*. This horizon corresponds to the Echinid Bed shown in the north Keynsham sections, which usually consists of a thick clay, but is liable to pass laterally into limestone, as we have already noted in exposure 3.

Above the Echinid Beds comes a thickness of six feet mainly composed of clay, but containing a band of thin argillaceous limestones a little above the middle of the series, as well as a thin band of rubbly limestone nearer its base.

The lower rubbly band contains few fossils (*Wald perforata* was noted), but in the middle band fossils are fairly abundant and, amongst these, *Am. angulatus* is not uncommon. From the presence of this ammonite and the absence of *Rh. calcicosta* and *Gryphea arcuata*, the whole of this series may be classified as *Ostrea irregularis* beds (lower *Angulatus* zone). Here we have another instance of the lateral passage of limestones and clays into each other, for these beds, which further west are mainly composed of limestone beds with subsidiary clays, are here represented by thick clays with a few subsidiary limestone bands.

The uppermost beds shown in the section are a thin series of limestones much broken up by the downgrowth of roots. These beds contain *Gyphea arcuata*, *Rh. calcicosta* and *Spiriferina pinguis* and can be placed, with certainty, in the *Calcicosta* series (upper *Angulatus* zone); that they belong to the lowest portion of that series is shown by the presence of *Lima hettangiensis* and *Pleuromya.*

V. *Exposure near Redland.*

This exposure does not lie within the Keynsham area and should, justly, have no place in a description of that district; it shows, however, so marked a similarity to the section at Kelston Station that its description cannot be considered entirely out of place here (compare also a detailed description of the very similar Lower Lias beds at Stoke Gifford[1]).

A general description of the Lower Lias beds in this exposure, as well as a detailed account of the Rhetic series below, has already been published by Mr. W. H. Wickes.[2] The following section and account is compiled from the results of a very exhaustive examination of the section made by one of us (A.V.).

The White Lias beds are here thin and rubbly.

The Sun Bed is very fossiliferous, though the specimens are badly preserved. As already pointed out, there is a striking resemblance between the fossils found in this bed and in the beds immediately above.

The upper *Ostrea* beds (sub-ammonite beds) are extremely fossiliferous; *Ostrea liassica*, *Pleuromya crowcombeia* and *Modiola minima* occur in profusion. *Pholadomya glabra* abounds in certain beds, and good specimens can be easily extracted. A mutation of *Cardium rheticum*, very distinct from the usual form found in the Rhetic beds below, occurs commonly, both in the Sun Bed and in the upper *Ostrea* beds.

[1] *Loc. cit.*
[2] *Bristol Nat. Soc.*, vol. ix., 1899.

Unicardium cardioides and *Pecten pollux* are also not uncommon at certain levels in the sub-ammonite beds.

The *Psilonotus* zone consists of a bottom, compact limestone containing *Am. planorbis*, succeeded by several limestone beds containing *Am. johnstoni* and *Lima gigantea* abundantly.

At the top of these beds Echinid fragments are common.

The whole series is capped by clays with a few nodular beds.

Detailed section of Lower Lias near Redland.

To top of section. Clay with nodular limestone bands.

PSILONOTUS ZONE.	13 inches; rubblylimestones.	*Pseudodiadema* (spines and test) at top. *Am. johnstoni.* *Lima gigantea*, *Lima hermanni*, *Lima hettangiensis.* *Pholadomya glabra.* *Rh. calcicosta* and *Rh.* sp.
	7 inches; red clay.	
	4 inches; compact limestone band.	*Am. planorbis*, *Lima gigantea*, *Pinna hartmanni.*

Upper OSTREA BEDS (sub-ammonite section).	4 feet 9 inches; limestones with clay partings (near the base two conspicuous double beds).	*Ostrea liassica, Pleuromya crowcombeia, Modiola minima, Avicula fallax, Pholadomya glabra, Astarte obsoleta* (?), *Cardium rheticum*, (Liassic mutation), *Unicardium cardioides, Pecten pollux, Lima valoniensis.*
(Sun Bed).	8 inches; thick, compact, cream-coloured limestone.	*Pleuromya crowcombeia, Ostrea liassica, Modiola minima, Avicula fallax, Cardium rheticum* (Liassic mutation) *? Astarte* or *Cardinia, ? Isodonta.* *Phasianella* sp.

PALÆONTOLOGICAL SUMMARY.

This portion of our work will be confined, almost entirely to notes on the Cephalopods and Brachiopods.

The Lamellibranchs will receive some little attention on account of their great stratigraphical importance; but, since we have in contemplation an exhaustive examination into the Lower Lias lamellibranchs of the whole Bristol area, no attempt will be made here to give a complete account of their mutations and relationships.

Reptilia.

Ichthyosaurus: vertebræ and teeth occur at the top of the *Semicostatus* zone.

Fish.

Fragments (chiefly scales) occur in the Fish bed, near the bottom of the *Semicostatus* zone.

Cephalopods.

Belemnites enter in the top bed of the *Calcicosta* series (*Angulatus* zone), occur sparingly throughout the *Bisulcatus* beds, but only become abundant at the top of the *Semicostatus* zone.

B. acutus, Mill. Short guard with uniformly conical point, no apical grooves.

Mutations: from a short simple cone to more elongate cylindrical forms which are slightly compressed (*B. infundibulum*, Phil. in part).

Ammonites enter at the base of the *Psilonotus* zone and become prolific in the *Arietes* zone.

Am. (*Psiloceras*) *psilonotus*, Quenst. includes both *Am. planorbis*, Sow. and *Am. johnstoni*, Sow. The two species agree in having smooth convex rims, wide umbilicus and flattened sides; but, whereas *Am. planorbis* is smooth or transversely striate, *Am. johnstoni* has tall, short, straight ribs which only occupy the central portion of the whorl sides. In the Keynsham area neither species is found associated with the other nor with any other ammonite.

Am. (*Schlotheimia*) *angulatus*, Schloth.

The young form possesses sharp, simple, similar ribs which sweep sharply forward near the edge. The ribs from opposite sides either actually meet at an acute angle on the rim, or would do so if produced. There is considerable variation as regards the spacing of the ribs.

There are two well marked mutations in the adult; one in which the whorl sides are practically smooth, and the ribs are only represented by close set crenulations on the edge, and a second, in which the edges and rim are practically smooth, but the ribs persist as strong, well-spaced, straight ridges confined to the sides. A fairly complete specimen shows that the young of the first mutation has close-set ribs, most strongly pronounced at the edges, and it may be assumed that the second form is derived from a young stage which exhibits the characters of well-spaced ribs, most strongly developed on the whorl sides and less pronounced on the edges.

Am. (*Schlotheimia*) *charmassei*, d'Orb. is recognized by the tall, close-set, erect ribs which sweep gently forward and end abruptly on each side of the rim, so as to leave a well-defined, smooth parting along the middle of the rim. The angle at which the ribs on one side would meet those on the other, if produced across the smooth parting, is always broadly obtuse and, in the adult, very nearly 180°. In the young form, the ribs are sharp and strongly developed over the whole of the whorl side, attaining their greatest height on the edge of the rim. It is a direct consequence of this fact that, when the ribs tend to disappear in old age, they are still conspicuous as strong crenulations on the edges, whilst the sides become quite smooth. This species is subject to only slight variation, which takes place chiefly in the greater or less alternation of the ribs. The broad angle between the ribs on either side completely separates this species from any mutation of *Am. angulatus*.

Ammonites of the Bisulcate group (*Coroniceras*).

This group is easily identified by the broad bisulcate and tricarinate rim, the wide umbilicus, the strong, simple ribs, running completely across the sides, and the large size to which the adult form attains. The ribs are, as a rule, simply and gently curved, and have a tendency to develop knobs near the rim edge; the ribs are never conspicuously absent from the early whorls, as in the following group:—

The suture line is essentially the same throughout all the mutations of the group and, being also usually conspicuous, it forms an important determinative character. Once carefully examined, there can be no difficulty in recognizing the peculiarity of the type, but since a minutely technical exposition of suture lines is seldom illuminating, it is sufficient to draw attention to the deep, tridigitate rim lobe, and to the broader, but shallower, tridigitate principal lobe.

The group can be readily split up into two sections, one strongly tuberculate, the other only slightly so or entirely non-tuberculate. There is little doubt that the two sections are connected by several transitional forms, but the vast majority of specimens fall readily and unquestionably into one section or the other. In each section the mutations proceed on the same lines.

A.—*The tuberculate section* (group of *Am. rotiformis*).

Of this section the two following forms are the commonest in the Keynsham area:—

Am. rotiformis, Sow. is a broad, plate-like ammonite with very numerous whorls; the ribs are close-set and nearly straight, and end in tubercles near the edge; the width of the whorl is usually greater than its thickness.

Am. coronaries, Quenst. has well-spaced, strongly-curved, coarse ribs, which develop teat-like tubercles near the edge. The whorls, which only just embrace, are strikingly narrow compared to their thickness.

B.—*The non-tuberculate section* (group of *Am. bisulcatus*).

This group includes by far the greater number of individuals.

The ribs are gently curved, and either die out gradually on approaching the rim or develop a non-prominent point, where they bend rapidly forward, at the edge.

Between any two selected individuals there is every possible mutation in regard to the rate of growth, in the number and curvature of the ribs and in the amount of involution.

Whilst recognizing to the full the complete passage of one form into another, it is nevertheless convenient to have names to indicate the most commonly occurring stages in the mutation.

The mutation does not proceed along a single line, determined by the variation of a single character, but rather the whole group must be represented by a network of lines, the angles of whose meshes are the points most deserving of special names. Three such names are in common use in the present group, viz., *Am. bucklandi*, *Am. conybeari* and *Am. bisulcatus.*

Am. conybeari, Sow. denotes plate-like forms with very numerous whorls, a slow rate of growth and little involution; very numerous short ribs, gently and simply curved, which die out quite gradually at the edge of the rim without any trace of a tubercle.

Am. bisulcatus, Brug. denotes thicker forms, with a much more rapid rate of growth and considerable involution; very numerous large ribs which form a slight knob near the edge of the rim, and then bend sharply forward.

Am. bucklandi, Sow. is an extreme form which grows rapidly in thickness, as well as in breadth, so that the section is almost square; the ribs are far apart, low and broad, they die out gradually without a trace of tubercle near the edge of the rim.

Of the three forms, *Am. bucklandi* is the most aberrant, and it seems difficult to understand how it came to be regarded by Dr. Brauns, in *Der Untere Jura* as a middle form between *Am. conybeari* and *Am. bisulcatus.* (His numerical comparisons of the several forms take note of only two variable functions, viz., the width of the whorl and the diameter of the umbilicus.)

All these three forms occur at Keynsham, but, of the three, *Am. bucklandi* is the rarest, and *Am. bisulcatus* by far the commonest.

There is at least one other form which is common in the district, and easily recognized in the young, but since we do not know the adult, it cannot yet be named. The young form has the following characters:

Diameter three inches per six whorls, only slightly embracing: whorl section rectangular, slightly taller than wide, rim square cut, strongly bisulcate and tricarinate; ribs about forty-five, close set, strong and narrow, with a distinct tendency to form points near the inner margin, as well as near the outer edge; from the outer of these points the ribs bend forward towards the rim, and from the inner they bend forward towards the innermost edge of the whorl. A characteristic feature is a shallow depression on the side of the whorl between the outer points of the ribs and the edge of the rim, in which the ribs die out.

Ammonites of the Semicostate group (*Arnioceras*). *Am. semicostatus*, Y and B.

The most important character of this group is the absence of ribs from the earlier whorls. The ribs are simple, tall and narrow, and curve or bend forward near the edge, where they attain their greatest height. The rim is bisulcate with a prominent keel. The whorls scarcely embrace (so that fragments of whorls are extremely common).

There are two well-marked varieties :

(1) *Am. obliquecostatus*, Ziet. The whorl section is as wide as tall; the ribs sweep forward near the edge with continuous curvature; they strike the inner margin somewhat obliquely. The keel is very tall, so as to be conspicuous in a side view of the test.

This form approaches to the bisulcate group, but differs radically in its semicostate character.

(2) *Am. geometricus*, Opp. Whorl section rectangular, narrower than tall; ribs run straight across the sides and reach their greatest height near the edge, where they bend abruptly forward toward the rim.

Am. turneri, Sow. is distinguished from *Am. semicostatus*, with which it occurs, by the absence of smooth inner whorls and by the broad, forward sweep of the ribs as they approach the rim.

Am. (*Microderoceras*) *planicosta*, Sow. This, the earliest of the capricorn ammonites, is characterized by simple ribs, continuous across the sides and rim; in their passage across the rim, they broaden out and become quite flat topped. (According to Dr. Brauns, this flattening is peculiar only to whorls that are covered by later ones, and is due to an absorption of the shell).

Am. (*Oxynoticeras*). A fragment, showing a partially open umbilicus, is the only evidence we have yet found of this genus.

Nautilus.—The only specimens we have found occur in the *Arietes* zone; large nautili are especially common at the top of the *Bisulcatus* Beds.

N. intermedius, Sow. Following Dr. Brauns, we have grouped the large nautili under this specific name since they exhibit the following characters:

Umbilicus partially open, siphuncle above the centre, shell marked with strong longitudinal striæ, aperture flat topped, and taller than broad. (We are inclined to think that *N. striatus* is merely the young form, in which the aperture is rounded; at least we have never seen from the Lower Lias a full-grown nautilus, which is not more or less laterally compressed and flat rimmed.)

Gastropods.

A long list of species could be compiled from the rich beds of the *Calcicosta* series, but, since the majority of the forms have already been described by Charles Moore in the paper already alluded to, we merely append the names of a few of the commonest species. (The naming is partly from the works of Terquem, Terquem and Piette, and Dumortier, but chiefly from the excellent figures in Tate and Blake's Yorkshire Lias.)

Pleurotomaria anglica, Sow. (= *Pl. similis*, Opp.)

Pl. basilica, Ch. and Dew.

Cryptœnia consobrina, Tate.
Amberleya alpina, Stol.
Eucyclus acuminatus, Ch. and Dew.
Turritella semiornata, Terq.
Phasianella (Bourgetia) morencyana, Piette.
Trochus redcarensis, Tate.

LAMELLIBRANCHS.

Ostrea:

O. liassica, Strick. Form oval, pointed at the beaks. Beaks not curled either in or out of the general surface of the valve (i.e. without either *Exogyra* or *Gryphea* affinities), large valve flattened or convex, but not geniculate, small valve flat, outer surface composed of overlapping lamellose growth margins, but marked by no radial folds. In the upper portion of its range it occurs with mutations of *O. irregularis*.

O. irregularis, Münst and Auctt.

We have tentatively grouped under this name a number of forms, usually regarded as specifically distinct, but which we regard as mutations of one elemental type. One of us has already expressed the opinion that the elemental form, from which all the mutations are derived, is a true *Gryphea*, but distinct from *G. arcuata*.[1] The unattached elemental type is very rarely found, and the mutations arise from variation in the area of attachment, combined with a more or less pronounced spiral curling of the beak to one side (after the manner of an *Exogyra*).

This conclusion is in partial agreement with the views of Dr. Brauns, who considers the majority of the forms to be attached varieties of *G. arcuata* and *G. cymbium*, but separates those which show an *Exogyra*-like character under the specific name of *O. ungula*, Münst. We cannot, however, convince ourselves that these views express the true re-

[1] *Q.J.G.S.*, vol. lviii. p. 721.

lationship of the very numerous forms which have come under our notice; the transition from a form which possesses considerable curling of the beak to one which shows none at all seems to us to be perfectly continuous. Again, though the *Exogyra* character is often strongly pronounced in the large attached valve, the upper flat valve usually exhibits no greater lateral displacement of the beak than is to be seen in *O. flabellula*, from the Eocene, and other kindred forms which are entirely removed from the true *Exogyras*. The curling of the beak in the large valve would seem to be, in part at least, directed towards securing that stability of attachment which is jeopardized by the large convex area, exposed to the action of forces of displacement.

Since variation proceeds, on the one hand, towards *Ostrea liassica*, and, on the other, towards a typical *Gryphea* whilst the maximum development of *O. irregularis*, in its most characteristic shape, takes place between the periods at which these two forms respectively flourished, it seems a natural suggestion that the present species supplies the necessary link between them.

O. anomala, Terq. and *O. marmorai*, J. Haime, seem to us to be mutations of the same general type.

The *Alectryonia* division is represented by *O. multicostata*, Terq. (non Münst) and *O. semiplicata*, Münst; the *Gryphea* division, by *G. arcuata*, Lam., with which *O. irregularis* is often associated.

Anomia:

A. pellucida, Terq. is very common at the base of the *Semicostatus* zone.

Small *Anomias* occur in the Echinid clay.

Plicatula:

P. intusstriata, Emm. is not very common. We have found specimens attached to *Lima gigantea* from the upper *Psilonotus* beds at Keynsham and Redland and others from the *Bisulcatus* zone.

Lima :

L. valoniensis, de France. (*L. punctata*, Auct) characterizes the *Ostrea liassica* beds. All the specimens we have seen are easily separated from *L. punctata*, which is a mere mutation of *L. gigantea*.

L. hermanni, Voltz. may be taken to include *L. succincta*, Schloth.

L. gigantea, Sow. may be taken to include *L. punctata*, Sow.

L. hettangiensis, Terq. is a very important stratigraphical fossil ; specimens are abundant and, when full grown, agree exactly with the figure and description given by Terquem. When the duplicate character is not developed until late, and when the interspaces are, at the same time, broader than usual, the species approaches very close to *L. pectinoides*, Sow.

This species is usually named *L. pectinoides*, and we are not yet convinced that either of the two specimens in the Sowerby collection, labelled *L. pectinoides*, is distinct from the young of *L. hettangiensis*.

L. stigma, Dum. A single specimen from the *Bisulcatus* beds is somewhat doubtfully referred to this species.

Pecten :

The group of smooth Pectens may be tentatively included in *P. calvus*, Goldf. but a more detailed study of their characters and more accurate observations on their occurrence in the rocks are needed before their mutual relationship can be considered to be definitely settled.

Smaller forms of very similar character occur in the *Psilonotus* zone, but the larger forms are most abundant in the *Angulatus* beds.

P. textorius, Schloth. occurs in its most typical form.

Avicula :

Avicula fallax, Pflücker. (*Monotis decussata*) from the zone of *Ostrea liassica.*

Avicula inequivalvis, Sow. (*Av. sinemuriensis*, Oppel) is extremely abundant at certain horizons in the upper beds and is associated with a mutational form in which the radial ribs are almost absent from the large valve.

Modiola :

M. minima, Sow.

M. hillanoides, Chap and Dew. may be considered to be intermediate between the *minima* and *scalprum* types.

Myoconcha :

M. scabra, Terq. and Piette. A single fragment from the *Semicostatus* beds.

Pinna :

P. hartmanni, Ziet.—Specimens are numerous, but can only be extracted with great difficulty ; they are all referred tentatively to this species.

Cucullea :

A few poor specimens are doubtfully referred to this genus.

Cardinia :

At certain horizons the beds are crowded with *Cardinias*, but good specimens are obtained with difficulty. If all the Lower Lias *Cardinias* are arranged under three mutational stages, as is done by Dr. Brauns, our Keynsham specimens would fall into the two groups indicated by the names *C. listeri*, Sow. and *C. crassiuscula*, Sow. Specimens of the first type are common in the upper *Psilonotus* beds and specimens of the last are abundant in the *Calcicosta* beds of the *Angulatus* zone.

Astarte:

A. cingulata, Terq. is common in the *O. irregularis* beds at Kelston.

A. obsoleta, Dunk. Concentrically marked, fair-sized *Astartes*, from the beds just below the Echinid clay, are somewhat doubtfully referred to this species.

A. limbata, Dum. Elegant little *Astartes* from the *Calcicosta* beds are considered by us to agree with Dumortier's description of this species.

Cardita:

C. heberti, Terq.—Small, finely striate, *Cardita*-shaped lamellibranchs which occur in the *Calcicosta* beds are unhesitatingly assigned to this species.

Pleuromya:

These fossils occur almost invariably as casts, and but seldom show any trace of the characteristic pallial sinus.

Pleuromya crowcombeia, Moore.—This very important fossil occurs abundantly in the *Ostrea* beds of Redland and is remarkable for the *Panopea*-like character of the adult; the small pointed beaks and the broad, concave expansion of the hind part of the valves recall the typical *Panopeas* of the Cretaceous. So far as we know, no figure has yet been given of an adult, but the young form is figured satisfactorily in Tate and Blake's Yorkshire Lias.

Pleuromya (*Gresslya*) *galathea*, Ag.—This is a very common and important fossil of the *O. irregularis* beds. It possesses the *Gresslya*-like characters of form and lunule, but the deep groove, seen in the type of the genus (*G. abducta*), is seldom, if ever, conspicuous.

Pleuromya liasina, Schübl.—To this species are referred the numerous casts which have the beaks facing each other and not placed very near to the anterior. Our specimens do not, however, in all respects, agree with the type.

Pholadomya :

P. glabra, Ag. is abundant at Redland in the *Ostrea* beds and lower *Psilonotus* zone.

Other *Pholadomyas* occur in the *Angulatus* beds, but are usually badly preserved.

Unicardium :

U. cardioides, Phil. is common in the lower beds.

BRACHIOPODS.

Spiriferina—S. pinguis, Ziet is not uncommon; no specimen of *S. walcotti* has been found by us at Keynsham.

Terebratula—T. (*Waldheimia*) *perforata*, Piette. (*T. sarthacensis*, d'Orb.) This is one of the most abundant fossils of the district; it varies slightly in shape, yielding broader and narrower forms. The figure of *T. psilonoti*, Quenst. given in *Der Jura* (t. 4, f. 21), represents exactly the commonest form found near Keynsham.

Rhynchonella :

Rh. calcicosta, Quenst.

This is by far the commonest fossil in the district and, though subject to great variation in the number of folds, is sufficiently well marked out by the following characters :—

Test small, both valves convex and usually meeting at a sharp angle, mesial sinus shallow, ribs sharp, tall and continuous to the beak, beak small and usually erect exposing the foramen. The normal mutation consists in the variation of the number of ribs; an average Keynsham specimen has four ribs on the fold and four on each flank, but these numbers can be increased to six on the fold and seven on each flank, when the form agrees with *Rh. plicatissima*, Quenst. on the other hand, a reduction to three on the fold is of very common occurrence. Occasionally the surfaces of the two valves are continuous across the junction.

A distinct mutation is produced when the ribs become coarser and more rounded and almost die out under the beak. This is the case in the shell which occurs so plentifully in the upper *Semicostatus* beds. In this *Rhynchonella*, there are four broad ribs on the mesial fold and two or three only on each flank. (In most specimens, which show the junction, this appears to be flat but, owing to the crushed state in which the shells occur, it is impossible to definitely assert that this is an original character.) This variety we have named *Rh. calcicosta*, var. *semicostati* on account of the stratigraphical position which it occupies. This form may be identical with Quenstedt's *T. belemnitica* (*Der Jura* t. 8, f. 5) which agrees in the general character of the ribbing, but differs in size and (probably) in its flatness.

It is interesting to notice that *Rh. belemnitica*, Quenst. occupies, almost exactly, the same horizon in Germany that our shell does at Keynsham, being associated with the first entrance of *Belemnites* in any abundance. In the German Lias, *Rh. plicatissima* first appears in the *Arietes* beds, whilst *Rh. calcicosta* does not occur until the *Oxynotus* zone and is not common until the *Spirifer* bank (lower *Jamesoni* beds).

Rh. triplicata, Quenst. This is a member of the *Rh. variabilis* group with deep sinus, bounded by two strong folds and an almost smooth test under the beak.

Echinids.

Pseudodiadema, n. sp. This occurs abundantly in the Echinid clay, at the top of the *Psilonotus* zone. From the very numerous fragments which we have obtained we are able to give the following detailed description of the species.

Diameter ·6 inches (to greater).

Diameter of apical disc ·15 inches.

Apical angle of interambulacral zone 55°.

Apical angle of ambulacral zone 18°.

Pores uniserial.

Interambulacral tubercles : one row of large, perforate and crenulate tubercles near the poriferous border. A second smaller row near the suture. The large tubercles surrounded by a very thin single ring of granules.

Ambulacral tubercles: two rows of alternate tubercles, small and perforate.

Anal gap incised.

Spines long and thin, finely striate and granular.

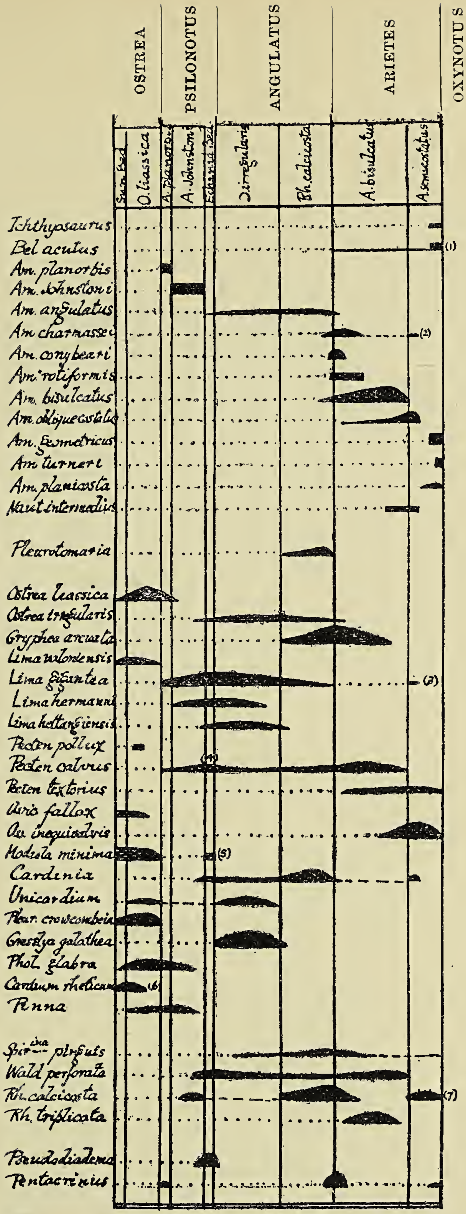
Cidaris Sp. Plates and spines of an undoubted *Cidaris* occur at the same horizon, the spines are thick and coarsely granular.

Crinoids.

Pentacrinus basaltiformis, Mill. Only fragments of the stem are found, but these are extremely common.

Corals.

Heterastrea latimeandroidea, Dunc. is the only coral we have seen. It was not found *in situ*.



Ranges and Maximum development of fossils in Keynsham district.

(1) *and Bel infundibulum.* (2) *mut. Am. lacunatus.*
(3) *mut. Lima punctata.* (4) *small forms.*
(5) *mut. between M. minima and M. scalprum named M. hillanoides.*
(6) *distinct from Rhetic type.* (7) *Rh. semicostati (r.s.)*

A Pear-tree Puzzle.

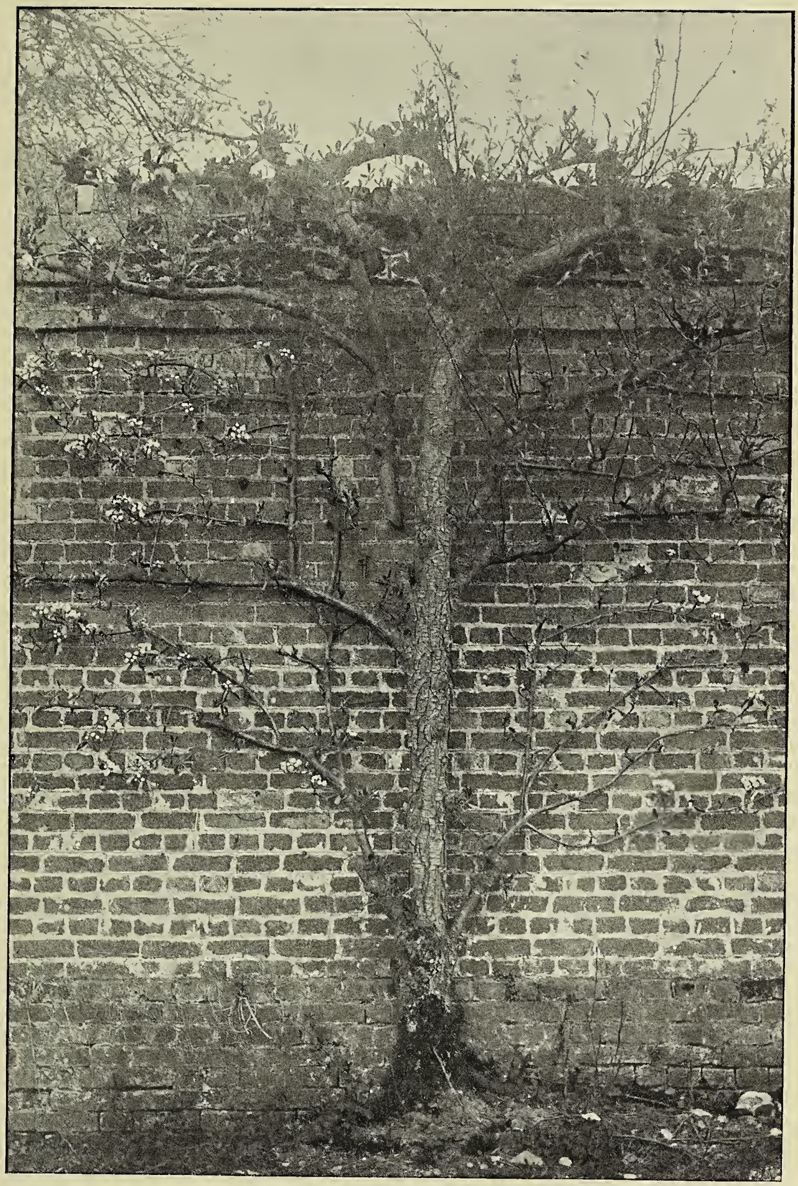
By Arthur B. Prowse, M.D. Lond., F.R.C.S., Eng.

Read November 1, 1901.

IN April, 1901, I was away from Clifton for a few days in South Buckinghamshire, at an ancient and picturesque country town, Amersham, where many years of my early life were spent. It was, by the way, one of the "pocket-boroughs," disfranchised by the first Reform Bill; for, though the population was but a few hundreds (how few the voters were I do not know) it used to return *two* Members to Parliament.

Calling one day on an old friend, who is very fond of his garden, I was shown what he rightly termed a "great curiosity"; and it is this which I have called a "puzzle," for at first sight it was impossible to detect the explanation.

Against the western side of a high brick wall is trained a pear-tree, the variety being named "Vicar of Wakefield." About half-way up on the northern side of the main stem is the lower end of a large branch severed from it, the cut surface of which is completely healed over. The stump from which it was cut is separated from it by a space of five or six inches; and its surface, too, is smoothly healed. The severed branch passes upwards somewhat obliquely, and forks into two main divisions about two feet from the top of



the wall. The more upright of the two, on reaching the top, bends over and hangs down some distance on the other side.

At the end of March, or early in April, 1889, the branch had been cut through, and the stump grafted with another variety of pear; but the grafts did not "take." The severed branch should have been removed at the time, but was forgotten and left *in situ*; and during the thirteen years which have elapsed it has been in vigorous health, blossoming freely each year, and bearing proportionately more fruit than any other part of the tree.

A year later (early in 1890), it was seen to be showing plenty of flower-buds; and then, for the first time it was examined; but no adventitious roots to the wall were found. Not until the following year was the actual cause of the continued vitality detected by the owner's personal examination of the branch where it crossed the top of the wall.

A twig about as thick as a cedar-pencil ($\frac{1}{4}$-inch) was then found coming from the top of the main stem of the tree, and this lay along the upper part of the wall, passing under the severed branch, which was about $1\frac{3}{4}$ inches in diameter. The distal portion of the twig was about the thickness of a straw, hardly half the size of the proximal part. The large branch and this twig had grown together, and the small "foster-mother" had successfully provided for all the needs of its big protegé from end to end. The union of the two must, I think, have taken place one, or possibly two, years before the grafting of the stump was attempted; and it was a very curious coincidence that the only large branch on the tree capable of surviving by reason of its vital union with another should have been left *in situ* quite unintentionally after severance from the trunk.

In 1895 the "feeder" twig was about $\frac{3}{4}$ inch thick on the near side, and $\frac{1}{4}$ inch on the far side of the large bough, which had here increased to about 2 inches in diameter.

This year the "feeder" is the same size, on the near side as the branch it nourishes, i.e., about 2½ inches thick; but its continuation beyond the point of union is not more than ¾ inch in diameter; and a few inches further on it ends in a kind of clubbed head, from which spring several smaller twigs. On the upper part of the large bough also, at the point of union, is a knobby outgrowth with a rough surface.

The accompanying print is made from a photograph which I took in April (1902). There was, unfortunately, no possibility, with the short time then at my disposal, of obtaining a nearer picture of the junction on the top of the wall.

Natural History Notes.

A Few Notes on Local Lepidoptera.

WE find but few additional local records of the capture of Lepidoptera, rare or new to the district, since the publication of Mr. George Harding's "Additions and Corrections to Mr. Hudd's Local List," which appeared in the Proceedings of the Bristol Naturalists' Society (vol. viii., part i.), bringing down our list to the end of 1895.

Amongst the Butterflies, several specimens of *Vanessa c. album* were observed by Mr. A. E. Hudd in his garden at Clifton in 1901, whilst it seems worthy of mention that *Vanessa io* has been more abundant in the neighbourhood during the present unfavourable season (1902) than in many recent years. *Lycæna argiolus* has occurred in fair numbers each year amongst holly trees in Clifton.

Sphinx convolvuli occurred in the neighbourhood of Bristol in some numbers in 1901, and a pupa of this species was found in a potato field at Kingsweston, and passed into the possession of Mr. W. N. Cooper, of Westbury-on-Trym, who, however, failed to rear the moth. The larva had no doubt fed up upon ground-convolvulus growing in the field.

Sphinx ligustri larvæ have been more than usually abundant in Clifton during 1902, though, like most other species, far behind their normal date; in 1901 a full-fed larva was found by the writer on 1st August, whilst at the present date (13th October, 1902) some larvæ have not yet pupated.

Acherontia atropos has been several times taken in the larval state, amongst other records, at Whitchurch in 1896. A fine larva, found near Clevedon in July, 1899, was brought to the writer by Prof. Lloyd Morgan, and the resulting moth emerged on 28th August of that year; in contrast to this speedy emergence, a larva, received from Bristol Museum, pupated 4th September, 1901, but did not produce a moth until August, 1902, being thus eleven months in the pupal state. The larvæ and pupæ of this interesting species were found in unusual numbers in 1901 near Westbury-on-Trym.

Drepana harpagula (*sicula*) has been recorded in the larval or imago state, but very sparingly during recent years—five larvæ were found in its sole locality, Leigh Woods, in the autumn of 1898, a single larva in each of the three following years, and there seems to be no record for the present year (1902). A specimen of the moth was bred by the writer on 16th October, 1893, but this appears to be the only record of an autumnal emergence, which probably never occurs in its British locality, though frequently on the Continent.

Notodonta chaonia was captured in Leigh Woods in 1890 by Mr. R. M. Prideaux, and a larva of *N. trepida* was found in the same locality some years since by the writer, who, however, failed to breed the moth. It may also be worthy of record that a specimen of *Acronycta leporina* was found in Leigh Woods at rest upon a larch-trunk in June, 1898, as this species appears to be very uncommon in the Bristol district.

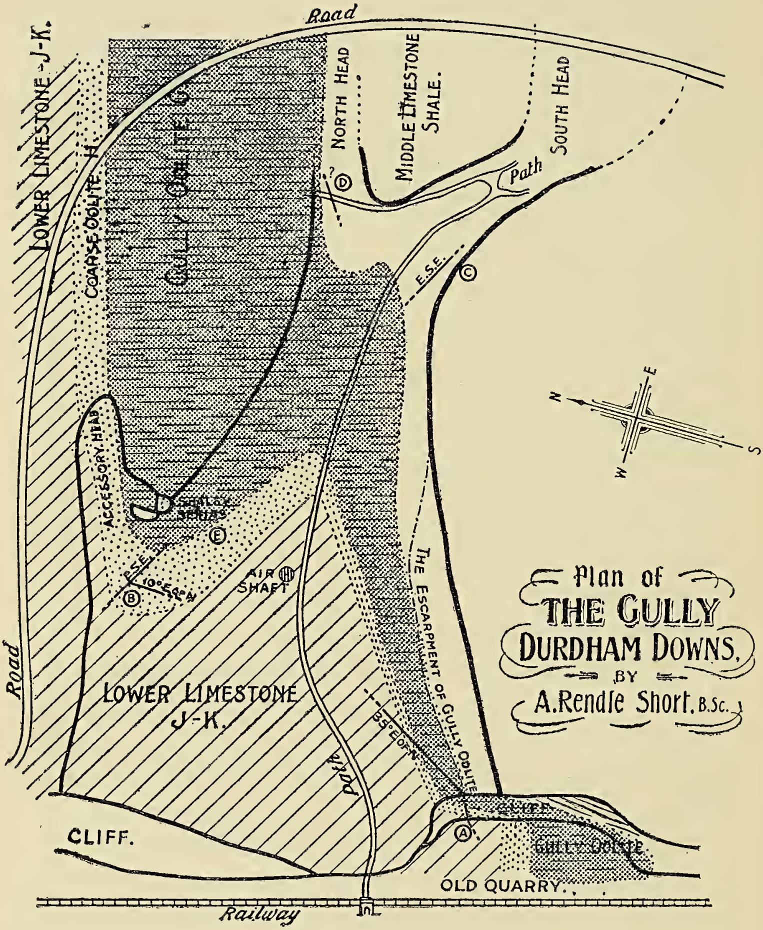
Our local *Acidalia*, *A. holosericata*, was late in emergence this season, and did not appear to be in quite its usual numbers. Only one brood of this interesting little species occurs in its British locality, Durdham Down, but Col. Partridge, who has experimented largely with the *Acidaliæ*, has succeeded in breeding a second brood of moths in August, and obtaining from them a second brood of larvæ, which went into hybernation as the natural single brood is accustomed to do. A single specimen of the second brood of this moth was also bred by the writer in August, 1902.

GEO. C. GRIFFITHS.

On a variety of the Pipistrelle.—On September 17th, 1901 a bat was noticed flying about in a lane near Winterbourne Church, which appeared to have perfectly *white* wings. It was shot a few evenings later and proved to be an adult ♀ *Vespertilio pipistrellus*, *Linn.*, measuring 8½ inches in expanse of wings; the wing membranes were quite white, like white tissue paper, the ears were also white, the arms and digits, legs and tail, pinkish, as were also the nose and chin, but the fur of the head and body was brown, and but a shade lighter than in a normal specimen.

Occurrence of Great Grey Shrike.—On November 30th, 1901, a specimen of *Lanius excubitor*, *Linn.*, was shot at Oakhill, near Bath; it was a ♀, and the stomach contained the remains of a small bird, probably robin or hedge-accentor. I have no record of its occurrence in our neighbourhood since 1888.

H. J. CHARBONNIER.


Plan of
THE GULLY
DURDHAM DOWNS,
BY
A.Rendle Short. B.Sc.
Road
LOWER LIMESTONE J-K.
COARSE OOLITE H.
NORTH HEAD
MIDDLE LIMESTONE SHALE.
SOUTH HEAD
Path
E.S.E.
ACCESSORY HEAD
AIR SHAFT
THE ESCARPMENT OF GULLY OOLITE
Road
LOWER LIMESTONE J-K.
Path
CLIFF.
CLIFF
GULLY OOLITE
OLD QUARRY.
Railway
N
E
S
W

The Structure of the Gully, Durdham Downs.

A. RENDLE SHORT, B.Sc.

THE first step in reading the history of the Gully is to determine the succession of rocks. Fortunately they differ extraordinarily in their lithological structure, and are quite easily recognizable wherever they crop out. They may best be studied in the old quarry at the bottom of the Gully, and on the railway line adjoining.

The succession is (in descending order)—

Middle Limestone Shales.

A. Near the top, a thick band of limestone very like the Gully Oolite, but with the granules less regularly packed.

B. Thick bedded and thin bedded limestones, with intervening shales. In the lower part the grain is very characteristic, the limestones being very white externally where weathered, and showing on the fresh surface a dark grey-black perfectly homogeneous structure, without granules or fossils. This band is very hard, and has a splintery racture.

C. A band about two feet thick, with a yellowish exterior, the fresh surface being dark, rough, and showing rather small plates of dark calcite. —2 feet.

D. Reddish-brown shales, weathering cream-coloured. —2 feet.

E. A rubbly limestone band, with fracture very similar to *C.* Locally, especially in its upper part, it is scarcely at all rubbly. —2 feet.

F. Brown shales and thin bedded limestone, often absent, derived chiefly from splitting of *E*, never more than a few inches thick. Variable.

Gully Oolite.

G. Gully Oolite, hard, white, and thickly set with round oolitic grains. Newly fractured surface, white and slightly rough, showing the grains; contains a few crinoid stems. —120 feet.

H. Coarse Oolite, darker, the oolitic grains much further apart, full of fragments of shells, fair specimens of spirifers crinoid stems and a few corals. Soft. —17 feet.

Lower Limestone.

J. Yellowish-white rock with a finely granular weathered surface; usually very dark on fracture.

K. White rock with a finely granular weathered surface, silver-grey or dark when broken.

The whole series dips at 26° to the S.S.E.

It is interesting to notice how the surface contour of the Gully, shown in the sketch map, reflects the characters of these beds. The Gully arises by two main heads, and a small accessory one on the north side. This last corresponds to the Coarse Soft Oolite *H.* The North Head corresponds to beds *C, D, E, F.* The South Head corresponds to the shales just above *A*, which is exposed on its northern slope.

There is a marked shelf on the southern slope at the top of the hard Gully Oolite *G.*

Behind the road, shallow depressions may be traced running to the north-east across the Downs, corresponding to each of the Heads of the Gully.

The Gully shows excellently what is elsewhere displayed in the Avon Gorge, that the lateral pressure from the south, which produced the Great Clifton Fault, also left its mark on the whole mass of Carboniferous Limestone displayed in the Gorge. As in the Great Quarry, the faults in the Gully are of a very peculiar type. They are not normal faults, neither are they in the usual sense of the word thrust-planes. What has happened is that vertical or highly inclined cracks have appeared, and one side, usually the western, has been pushed along on these almost horizontally, or with a very slight rise. They differ then from ordinary thrust-planes in that the fault-surface is nearly vertical instead of being nearly horizontal. I shall therefore refer to them as vertical thrust-planes. They were probably produced either at the time of or just before the Great Fault.

With this introduction we may proceed to examine the exposures in detail.

(*a.*) A well marked thrust-plane is twice exposed, once in the old quarry at the bottom of the Gully, and again in the Gully Oolite on the southern slope above this quarry. The thrust-surface slopes to the north-west at an angle of about 80°; the direction of the plane (and of the movement) is 35° E. of N. It is marked by slickensides rising at an angle of about 5° to the north-east. It cuts the whole face of the cliff in the quarry, maintaining precisely the same direction in the exposure on the slopes above the quarry.

It was the rocks on the western side of this vertical thrust plane that were pushed past the others, probably only a few yards.

There is some evidence of faulting in the northern corner of the quarry.

(*b*, *c*, *d*.) Vertical thrust planes of the same type, but with differing directions are exposed, as mapped, at *b* and *c*. At the latter there is also an anticline.

There is some evidence of the faulting and an anticline at *d*.

(*e*.) By far the most interesting feature in the Gully, but for which this paper would never have been written, is to be found on the southern side of the little depression that cuts off the apex of the triangular tongue of Gully Oolite. Here a series of shales is exposed, in a rough and steep path, and these are the problem for which it has been most difficult for me to find a satisfactory explanation.

Here, in a hollow in the Oolite, which dips at 26° to the S.S.E., are seen from above downwards—

(1) Horizontally bedded cream-coloured shales and fissile very thin bedded impure limestones, in appearance strikingly like the Naiadita beds of the Rhaetic at Redland and elsewhere.

(2) A nearly vertically bedded series, dipping very steeply to the north, consisting of two bands of massive limestone, together about a foot thick, and parallel with these red calcareous sandstone, very crumbly, with parallel colour-bands in it of a much darker brownish-red. The limestone is not an oolite.

(3) Dark shales and calcareous sandstones arranged as an anticline.

(4) A thick band of vertical bars of calcite crystals.

(5) A thick band of rather fine grained calcite rock.

(6) (Gully Oolite).

The shales, etc., are therefore bounded *on the left* by a prominent vertical bluff of Gully Oolite; *below* by a horizontal shelf of Gully Oolite; *on the right* by a retreating and gently sloping surface of Gully Oolite; *behind*—about two yards back at the top apparently—by the same, the contour of course not being visible; and *on top* is a grass-covered surface, which is part of the little depression previously mentioned, so that the Oolite immediately behind the shaley series is lower than that on either side of it.

The stratification of the beds in this little section is worthy of careful study.

The cream-coloured shales, (1), are *at the top* for the most part horizontal, but rise at an angle to the right, and abut against the oolite, which is here massive and unaltered. They make an angle of about 30° with the surface of oolite on which they rest, and are exactly similar close to and far from the junction, there being no conglomerate, no zone of fragments, and no crush-rock, but well-developed shale resting against well-developed limestone.

A little lower down, these same shales present a strong anticline. To the right, however, they turn up in a little syncline, and are here parallel to the oolite. Again they are unaltered at the junction.

Next comes the vertical series of thick limestones scarcely altered, and colour-banded sandstones lying parallel to the stratification of the limestones. Although these vertical beds *lie in the centre of an anticline like a door under an arched lintel*, yet there is no eroded surface, and no unconformability. The fact is, that the anticlinal banding is *superinduced* on the vertical, and blocks may readily be obtained showing cleavage and colour-banding vertically, and horizontal (or diagonal, according to position in the arch) cleavage also.

Below the vertical series is another of dark shales and sandstones arranged in an arch. But although this lies below the vertical series, it is nearer the exposed front face of the section, and has been more exposed than that series to the weather. In fact the vertical series has been the most sheltered part of all, and has only lately been displayed, partly by natural and partly by artificial (i.e. trowel and hammer) weathering.

The lower surface of the undermost calcite rock, (5), juts out about a foot beyond the Gully Oolite on which it rests, and dips *downwards* a little towards it. It is slickensided downwards and to the north-east. There is no evidence of faulting in the Gully Oolite just below this section. A big vertical crack there certainly is, but there are no slickensides, and a horizon of abundant crinoid stems passes undisturbed across the crack.

Now the question arises—how is this curious assemblage to be accounted for?

The mass of shale cannot be a Rhaetic or Trias dyke, for though the bedding above is horizontal, below it is vertical. There are no fossils, and the limestone band, which is *not* Gully Oolite, would be unaccounted for. Moreover, there are slickensides, and no pebbles.

Nor can it be due to the local alteration of the Gully Oolite by recent weathering, for the shaly series, and especially the non-oolitic limestone, would be unaccounted for.

It is therefore necessary that one should have recourse to faulting of the Middle Limestone Shales into the Gully Oolite, and the recognition of the limestone band proved this to be the true explanation.

The chief difficulty in the way is the complicated nature of the dislocation required. The first suggestion that I entertained was that it was due to two faults sloping towards one another to form a V or trough. This was negatived by the absence of faulting in the Gully Oolite below. My next idea was to invoke a curved fault, or perhaps two crossing one another at a right angle. There was no evidence to support the latter, and the angle of curve in the former would have to be extraordinarily acute. Moreover it is clear that the bottom of the series of shales rests on a more or less horizontal shelf of oolite. Indeed, judging by the lower surface of calcite rock, (5), this shelf must even *rise* to the south. The surface of the fault would have to be like that of an extremely deep spoon. Again, all the evidence in the Gully is of yielding due to pressure, not to relaxation, i.e. of a tendency to thrusting, not to normal faulting. On the whole, one is driven to the conclusion that too many improbabilities are involved in such an hypothesis.

Two facts then came to light. One was that the great thrust exposed in the old quarry at the foot of the Gully, and again on the southern hillside, described above as (a), points exactly towards the problematical series. Secondly, that the texture of the limestone in the vertical series corresponds exactly to the band in the Middle Limestone Shales described as C, or to non-rubbly parts of E.

I have no doubt that the true explanation is as follows. Horizontal compression took place after the Carboniferous Limestone had been lifted up into an anticline. Yielding, as indicated by the vertical thrust, took place in a plane passing through the locality in question; and by it a dint or notch was produced in the dipping upper surface of the Gully Oolite, into which the immediately succeeding bands of the Middle Limestone Shale were forced. Such a notch would, of course, present a lower horizontal shelf or floor, a vertical back wall, and two more or less vertical sides. Such is exactly the shape of the notch in the Gully Oolite into which the shaly series has been let. Moreover the oolite behind the notch would be much crushed, and consequently softer. The depression in it, as described in the account of the contour of the Gully, accords well with this. Again, the shales would snap at the lip of the horizontal shelf, and get driven to the back of it, so that although originally dipping at 26° they would now become vertical.

Everything I have yet discovered fits in exactly with this hypothesis. The only objection to it is that such a dislocation must be very rare. I do not recollect having read of anything similar. But the conditions were very peculiar.

Although the above may serve to explain the presence of a vertical series of Middle Limestone Shales in a notch in the Gully Oolite, we have still to account for the horizontal, and, lower, anticlinal arrangement of the superjacent cream-coloured shales.

Now the development of these is very remarkable. It will be remembered that they lie against the oolite walls of the notch sometimes nearly or quite conformably, but usually at an angle, and that there is no crushing at the junction; the shale ends abruptly against the massive rock, without slickensides.

Secondly, these horizontal and anticlinal shales have been profoundly altered, and made cream-coloured, by the action of percolating water.

Thirdly, there is no evidence either of erosion where they join the vertical beds, or of passage of the one stratification, by a complicated bend, into the other. Rather the horizontal lamination has been superinduced on the vertical, just as we may find slaty cleavage superinduced on shaly bedding.

We know that in Liassic times the top of the great Carboniferous anticline had been cut off, and the Liassic sea swept over the Downs. It so chanced that the top of the notch in the Gully Oolite was exposed to this sea, filled as it of course was with Middle Limestone Shales. Now as these shales were vertical in the notch, they were extremely permeable. But the water could far less readily soak away through the shelf of Gully Oolite below them, which is very massive. The only escape was, therefore, along the layer of shale next overlying the oolite, which had a narrow communication with the vertical series over the lip of the notch. The consequence of this arrangement must necessarily have been that in Liassic times the little group of shales in the notch must have been constantly saturated with water. Even the upper parts of the limestone band or bands would be much altered by this; and the shales would be reduced to a semi-fluid unstratified paste except in their deeper parts. Then an unknown thickness of Mesozoic deposits was laid down on top of them. The consequence was inevitable—re-stratification of the paste. Two factors combined to bring this about. Firstly, when saturated with water, mud tends to become horizontally stratified by re-arrangement of its constituent particles, and the possibility of re-stratification is alluded to by Sorby in *Q.J.G.S.*, vol. xxxvi., p. 67, when pointing out this tendency.

Secondly, the weight of the superincumbent Mesozoic rocks produced horizontal lamination by the same principle of inducing splitting at right angles to the pressure that determines slaty cleavage.

Why, then, do we find an anticline? Because it so happened, as is now shown in the exposure, that the vertical limestone band at the sides of the notch disintegrated, but in the centre remained but little altered, being probably less in the stream of percolation. It therefore formed a support to the middle of the shales above it, and they were not pressed down nearly as much in the middle as at the sides, where they had no solid support.

Probably if denudation had not removed so much, we should have been able to see the curious anomaly of Middle Limestone Shales passing conformably up into Rhaetic or Lias.

On the *Estheria*-bed in North-west Gloucestershire, and the Organic Associations of *Estheria minuta* var. *Brodieana*.

By L. RICHARDSON, F.G.S.

DURING the past ten years (1891–1901) several authors have recorded the organic associations of *Estheria minuta* var. *Brodieana*. At Pylle Hill the late Edward Wilson, F.G.S., found that Estherian in his bed "1" associated with *Naiadita* and two species of *Darwinula*; but it is in the immediate subjacent shales that the remains of the Lycopodiacean are most abundant.[1] Mr. W. H. Wickes[2] records a similar association at a section in New Clifton, but here with the addition of marine lamellibranchs. Miss I. B. J. Sollas described—on the authority of Prof. J. Phillips—the plant *Naiadita* as being in association with the same Estherian at Wainlode and Garden Cliffs. In the discussion which followed the reading of this communication, it was observed that it would be of interest to know whether this plant grew in fresh or salt water.

[1] *Quart. Journ. Geol. Soc.*, vol. xlvii. (1891), p. 548.

[2] *Proc. Bristol Nat. Soc.*, vol. ix. (1899), plate 1 facing p. 100.

The authoress had described it as being associated with *Estheria*, but according to the late Edward Wilson [1] and Mr. Wickes it occurred in the same bed with marine forms, such as *Cardium rhæticum* and *Pecten valoniensis*.[2]

The organic associations of the Estherian in North-west Gloucestershire have never been accurately determined. During the past year (1901) I have been able to bestow considerable attention upon this stratum, in the area between Bourne Bank, near Defford, and Garden Cliff at Westbury-on-Severn. For comparison with the equivalent deposit in the Bristol area, a description of the stratigraphical position and organic contents of the *Estheria*-bed in North-west Gloucestershire may be of interest.

In North-west Gloucestershire the *Estheria*-bed is remarkably persistent. Lithologically it is interesting as presenting structure analogous to the Cotham Marble of the Bristol area, but with the "marble" of the latter district as the type, the "dendritic" markings therein exhibited can only be described as simulated in the *Estheria*-bed of the district under consideration.

The cliff section at Wainlode, near Gloucester, demonstrates that four lithic varieties of the bed are present. These are: (1) A yellowish argillaceous limestone, irregularly laminated; (2) a hard bluish-black crystalline limestone with numerous shell fragments; (3) a pale greenish-grey limestone almost wholly composed of comminuted shell débris; and (4) a hard pale greenish-grey centred limestone with "dendritic" markings. These four variant phenomena occur in almost corresponding ratios. The laminated

[1] If this statement be based upon the record of Mr. Wilson's Pylle Hill section, it may be remarked that that author does not record any marine lamellibranchs from his bed "1." *Quart. Journ. Geol. Soc.*, vol. xlvii., p. 546.

[2] *Quart. Journ. Geol. Soc.*, vol. lvii. (1901), p. 312.

variety does not resist atmospheric influences to the same extent as that exhibiting "dendritic" markings, and it may be noted that the resisting capabilities of the bed are increased in proportion as the lithic structure of the bed approaches the latter variety. Since a considerable portion of this stratum is soon reducible to a calcareous clay, especially when it occurs near the surface, it follows that, that portion simulating the "dendritic" markings may be said to occur in more or less isolated masses, and the same remark may apply to the Cotham Marble bed, for as Mr. Beeby Thompson has remarked, "It may be that at some places the bed is present, but not identified because of the absence of the aborescent markings."

At Wainlode Cliff the co-existence of *Estheria* and *Naiadita* is well known, and as far as my observations extended they are confined to one stratum, clearly defined palæontologically and lithologically. At Wainlode the bed occurs 20½ feet above the Upper Keuper greenish-grey marls, but from its position in the cliff is almost inaccessible. A few blocks procured *in situ*, and from the base of the cliff, yielded *Estheria*, *Naiadita*, and fish scales; also much shell débris. Professor T. Rupert Jones noticed a "*Pteromya*," and the Rev. P. B. Brodie recorded "*Cypris liassica* (*Darwinula*), but observed that they were not abundant.

Three miles east-north-east of Wainlode the *Estheria*-bed has been exposed in a road-cutting at Coomb Hill, the association of *Estheria* being *Naiadita*. The stratum was not visible *in situ*, but detached blocks furnished the required material. The Lower Rhaetic of Edward Wilson may be examined by a little excavating, and a recent measurement placed the *Estheria*-bed at a little under 26 feet above the Upper Keuper; i.e., accepting the position of the stratum as located by H. E. Strickland, and also his record of the thickness of the immediate subjacent deposit. The portions of the bed procured were of the varieties (2) and (4).

At Bourne Bank, near Defford, a little within the boundaries of Worcestershire, the *Estheria*-bed is exposed in the wood immediately to the north of the road from Upton-on-Severn to Defford, and is here a cream-coloured argillaceous limestone replete with *Estheria* and *Naiadita lanceolata.* At no other locality in this district have I found the *Estheria* so well preserved.

Between Wainlode Cliff and the classic section at Westbury-on-Severn the same bed was seen *in situ* in a deeply-cut wheel-track about 500 yards south of the house known as "Highgrove," a little north-east of Minsterworth, near Gloucester. Here the lithic structure was of the varieties (1) and (4); and it was in the first of these, and at the base of the bed—here 6 inches thick—that the *Estheria* and *Naiadita* chiefly occurred. The same bed was again discovered in the lane-cutting which traverses the Rhaetic and Liassic outlier of Denny Hill, and contained fish scales and *Estheria.*

Garden Cliff affords the best exposure of the *Estheria*-bed.

Four main lithic varieties may be again noticed similar to those at Wainlode Cliff, and may be seen passing horizontally from one variety to another. The prevalent tint of the bed when freshly fractured is greenish-grey, but soon weathers white. From a lithological standpoint the chief interest attaches to that variety simulating the markings in the Cotham Marble. These, as exhibited in the stratum at this locality, reach the upper surface, and have caused the sediment to be so arranged as to give rise to projections on that surface. From the true Cotham Marble, the nearest approach to it in the *Estheria*-bed, may be distinguished by the more even distribution of the "dendritic" markings, by the absence of curvature in the layers of sediment in the upper portion of the stratum, and by the non-existence of any defined dark band at the base of the markings. The associations of the Estherian here, as yet recorded, are *Naiadita lanceolata*—in places abundant—fish scales, *Schizodus*, *Astarte* (?), *Pecten valoniensis*, *Darwinula* (*vide* Brodie, *Fossil Insects*, p. 79, and Professor T. Rupert Jones, *Quart. Journ. Geol. Soc.*, vol. l., 1894, p. 163) *Protocardium Rhæticum*, and *Pleurophorus*.

The fragmentary condition of the tests of the marine mollusca tend to suggest the conclusion that the habitat of the Rhaetic Estherian in this district was a low-lying swampy area subject to frequent incursions by the sea, and also that the tests of the lamellibranchs were washed into the position in which they are now found, some time subsequent to the death of the animal which inhabited them.

The *Naiadita* remains occur in conspicuous layers in a rock which is intermediate between the lithic varieties (1) and (3), but with this difference, that the bed is greenish-grey instead of yellowish. The best preserved specimens of *Estheria minuta* var. *Brodieana* that I have found at Garden Cliff occurred intermingled with the plant fragments.

In correlating the North-west Gloucestershire sections with that at Pylle Hill, the *Estheria*-bed, or the late Edward Wilson's bed "1," affords a remarkably good datum level.

At Garden Cliff it occurs about 25 feet above the Upper Keuper Marls, and is from 3 to 16 inches[1] in thickness, but at Pylle Hill the intervening deposit is only $11\frac{1}{4}$ feet.

[1] That portion exhibiting "dendritic" markings seldom exceeds 3 inches in thickness.

Reports of Meetings.

GENERAL.

DURING the year 1901, which was the thirty-eighth in the history of the society, the normal eight monthly meetings were held. At the annual meeting held on January 24, however, in accordance with a motion brought forward by Professor Lloyd Morgan, the retiring president, the society adjourned after the purely business matter had been dealt with in order to mark their sense of the nation's loss by the death of her late Majesty Queen Victoria. No exhibition meeting was held. The papers read at the general meetings were as follows:—

Feb. 7. Dr. A. C. Fryer, M.A., F.G.S., on "Prehistoric Man."

Mar. 14. Mr. L. N. Tyack, on "The Physics of Cloud Formation."

Apr. 4. Mr. G. C. Griffiths, F.Z.S., F.E.S., on "Silk and the Silk Moths."

May 2. Mr. G. Brebner, on "Plant Hairs and what they do."

Oct. 3. Mr. L. N. Tyack, on "The Makers of Modern Astronomy."

Nov. 1. Dr. F. E. Francis, on "The Atmosphere."

Dec. 5. Mr. G. Munro Smith, M.R.C.S., L.R.C.P., on "The Growth and Decay of Tissues."

The lantern was used at the February, March, May, October, and December meetings, while Dr. Francis's lecture at the November meeting was illustrated by a number of experiments.

S. H. REYNOLDS, Hon. Sec.

BOTANICAL SECTION.

PERHAPS the most interesting subject that has lately occupied the attention of the Bristol botanists is the local distribution of Bladderworts. A few years ago only one species of Utricularia (*U. vulgaris*) was known in the district, and but two in the county of Somerset. After a while some foliage specimens, obtained from ditches near Weston-in-Gordano, were thought by the Rev. E. F. Linton, who has well studied the genus, to be probably a new species or hybrid. More recently, in pits cut in the turf-moor, S.E. of Shapwick Station, *U. neglecta* has been detected, flowering freely. Again, on examining some peaty ditches in the Walton valley, there was found a quantity of fine, delicate stems with glabrous winter-buds, which it is considered can only belong to *U. minor*, the smallest species of the group. Although this had not been seen before in the area of the Bristol coal-fields, it had one other locality in Somerset on the Glastonbury moor, where flowering plants have been collected. It will be understood, therefore, that although the local flora is now believed to comprise four species or varieties of British Bladderworts, the records for two of them depend on foliage specimens merely. And it is this uncertainty in flowering which makes it so difficult to ascertain the distribution of these curious plants. One or two of the species produce flowers but rarely, while none can be said to flower regularly or freely in proportion to the number of individuals existing, except perhaps in very hot and dry summers. Propagation, however, is ensured by vegetative process through winter-buds developed at the ends of the branches. But, while flowers must always be greatly desired for determination, as it is possible to recognize the respective members of the family by foliage characters alone, peaty ditches can be raked in the autumn and specimens that seem to grovel in the mud below the water can be obtained, whose presence would otherwise remain unsuspected on account of the lack of flowers.

The bladders were formerly considered to be air receptacles and supposed to exist for the purpose of floating the plant on the surface of the water at the flowering period. Withering indeed, 120 years ago, noted that the bladders contained fluid with only a small bubble of air, and that this liquid "greatly magnified appeared to contain a quantity of minute solid particles." But it was not until 1875 that Darwin in *Insectivorous Plants* showed that the bladders were really pitchers or traps adapted for the capture of crustaceans and other minute creatures whose bodies are digested and assimilated by the plants. In this way is compensated the deficiency of nitrogenous food which results from an entire absence of roots in this genus. The bladders, in fact, carry on some of the alimentary functions that are performed by roots in other plants.

JAS. W. WHITE.

ENTOMOLOGICAL SECTION.

THREE meetings only were held during 1901, viz.:—

January. 8. Mr. H. J. Charbonnier read an interesting paper upon the flight of insects, illustrated by diagrams which showed that the motion of the wings was caused by the expansion and contraction of the thorax, thereby creating differences of inclination of the thoracic plates, to which the wings were affixed.

Mr. Charbonnier also exhibited two specimens of *Ammoptula sabulosa* from Ipswich; also on behalf of Mr. C. J. Watkins, of Painswick, photographs of the larva of *Sphinx ligustri* and a few varieties of lepidoptera.

March 12. This being the annual meeting, the financial statement for 1900 was read, and the president and secretary re-elected for the ensuing year.

November 12. Mr. G. C. Griffiths exhibited a large number of interesting specimens of lepidoptera, principally of the genera *Argynnis*, *Kallima*, *Ageronia* and *Eronia*, the latter being very well represented and showing the mimicry of certain species of *Danaidæ*.

The president and members of the Entomological Section are most anxious to obtain new members. This section is the oldest in the society, having been formed in 1864 and has been continually in existence since that time. The section has done good and useful work, including the compilation of a list of the Lepidoptera of the Bristol district, which was published in the proceedings and in book form. Meetings are held during the winter months, frequently at the members' houses, and excursions are taken in the summer. The meetings are very interesting, somewhat of a social character, and consist largely of exhibits and discussions; to any one taking even a general interest in natural history, the meetings will be found full of interest.

As there is a great danger of this section falling through for lack of interest taken in it by general members of the society, the feeling exists that it only requires the facts to be brought before the society to bring a large accession of strength and this appeal is put forth in the strong hope that such will be the case. The subscription is only 2*s.* 6*d.* and the hon. secretary (18, Henleaze Avenue) will be glad to hear from and give further particulars to any member wishing to join.

CHARLES BARTLETT, Hon. Sec.

Nov. 3, 1902.

GEOLOGICAL SECTION.

During the last year this section showed a decided advance on previous years both as regards membership and number of papers read.

At the commencement of the year there were forty-one members. Since the issue of the previous report nineteen new members have been elected, three have resigned and one has died.

Meetings were held regularly every month (excepting during the summer and at Christmas), when the following papers were read :—

January 23. "The General Principles which should guide the making of valid and useful species," by A. Vaughan, B.A., B.Sc., F.G.S.

February 6. "Sicily and Etna," by J. H. Cooke, F.G.S., F.L.S.

March 13. "The Uphill Bone Cave," by the late Edward Wilson, F.G.S., with an account of the fossils by Professor S. H. Reynolds, M.A., F.G.S.; also "Note on a specimen of Coal with fossils, from Coal Pit Heath," by H. Bolton, F.R.S.E.

April 29. "Igneous Rocks and Associated Sedimentaries of the Southern half of the Tortworth Inlier," by Professors C. Lloyd Morgan, F.R.S., F.G.S., and S. H. Reynolds, M.A., F.G.S.

May 15. "The Geology of the Torquay District," by Professor S. H. Reynolds, M.A., F.G.S.

June 12. "The Excursion to the Pelvoux district (Savoy) of the International Geological Congress of 1900," by G. W. Palmer, M.A., and Rev. H. Pentecost, M.A.

October 16. "Lantern Slides from photographs taken during the Summer Excursions of the Geological Field class of the University College," by Professor S. H. Reynolds, M.A., F.G.S.

November 20. Exhibition meeting, specimens or lantern slides were shown by the following members and friends:—Messrs. C. E. Frank, Martin Lavington, J. W. D. Marshall, Miss F. MacIver, Messrs. J. Parsons, B.Sc., F.G.S., S. H. Reynolds, M.A., F.G.S., and W. H. Wickes.

December 11. Lantern slides and photographs from the loan collection of the British Association.

The average attendance of members was between seventeen and eighteen at each meeting.

The increased attendances show a greater interest, but I think there are many interested in Geology in Bristol and the neighbourhood who might wish to join the section if members would bring the society to the notice of their friends.

B. A. BAKER, Hon. Sec.

PHYSICAL AND CHEMICAL SECTION.

The section did not meet during 1901.

L. N. TYACK, Hon. Sec.

The following Publications of the Bristol Naturalists' Society may be obtained from any Bookseller, or from

H. J. CHARBONNIER, 49, Dove Street, Kingsdown.

One Volume, bound, 5s.

FLORA OF BRISTOL.

By James Walter White, F.L.S.

The area of this flora is that included in the geological map of the Bristol coal field, by the late William Sanders, F.R.S., F.G.S.

The Fungi of the Bristol District. By Cedric Bucknall, Mus. Bac.

Part IV.	Species 690 to 836.	4 plates, 3 coloured, 1 black.		1s. 6d.
,, V.	,, 837 to 934.	2 ,, 1 ,,	. . . .	1s.
,, VI.	,, 935 to 1023.	1 plate, black	. . . . .	1s.
,, VII.	,, 1024 to 1084.	. . . .		6d.
,, VIII.	,, 1085 to 1144.	3 plates, coloured	. . . .	1s. 6d.
,, IX.	,, 1145 to 1240.	4 plates	. . . .	1s.
,, X.	,, 1241 to 1321.	4 plates	. . . .	1s.
,, XI.	,, 1322 to 1362 .	. . . .		6d.
,, XII.	,, 1363 to 1399.	2 plates	. . . .	1s.
,, XIII.	,, 1400 to 1431	}		
Index to Parts I. to XIII. and plates		}		1s.

On the Newly-Discovered Phenomenon of Apospory in Ferns. By Charles T. Druery, F.L.S. Illustrated. 1s.

Contributions to the Geology of the Avon Basin. By Prof. Lloyd Morgan, F.G.S. I. "Sub-Aerial Denudation and the Avon Gorge." Coloured Map. II. "The Millstone Grit at Long Ashton, Somerset." With Map. 1s.

III. "The Portbury and Clapton District." IV. "On the Geology of Portishead." 2 coloured maps and 2 plates. 1s. 6d.

Sleep and Dreams. By George Munro Smith, L.R.C.P. Lond., M.R.C.S. 2 plates. 1s.

The Bone-Cave or Fissure of Durdham Down. By E. Wilson, F.G.S., Curator of the Bristol Museum. 2 plates. 1s.

Notes on a Common Fin Whale, lately Stranded in the Bristol Channel. By E. Wilson, F.G.S., Curator of the Bristol Museum. Photograph. 1s.

The Severn Tunnel. By Charles Richardson, C.E., and Notes on the Geology of the Section by Prof. C. Lloyd Morgan, F.G.S., Assoc.R.S.M. With geologically coloured Section of Tunnel, map and plate. 2s.

The Arch. By Charles Richardson, C.E., with illustrations. 1s.

Portrait and Obituary Notice of the first President of the Society, William Sanders, F.R.S. 6d.

Portrait and Memoir of the second President of the Society, Henry Edward Fripp, M.D., M.R.C.P. 6d.

Portrait and Obituary Notice of the third President of the Society, George Forster Burder, M.D., F.R.C.P.

Proceedings, New Series.

Vol. I., Part 1, 1873–74.	5s.	Vol. V., Part 2, 1886–87.	5s. 6d.
,, ,, ,, 2, 1874–75.	3s.	,, ,, ,, 3, 1887–88.	5s.
,, ,, ,, 3, 1875–76.	4s. 6d.	,, VI. ,, 1, 1888–89.	4s.
,, II. ,, 1, 1876–77.	3s. 6d.	,, ,, ,, 2, 1889–90.	3s. 6d.
,, ,, ,, 2, 1877–78.	3s. 6d.	,, ,, ,, 3, 1890–91.	4s. 6d.
,, ,, ,, 3, 1878–79.	3s. 6d.	,, VII. ,, 1, 1891–92.	2s. 6d.
,, III. ,, 1, 1879–80.	3s. 6d.	,, ,, ,, 2, 1892–93.	3s. 6d.
,, ,, ,, 2, 1880–81.	3s. 6d.	,, ,, ,, 3, 1893–94.	2s. 6d.
,, ,, ,, 3, 1881–82.	3s. 6d.	,, VIII. ,, 1, 1894–95.	2s. 6d.
,, IV. ,, 1, 1882–83.	3s. 6d.	,, ,, ,, 2, 1896–97.	2s. 6d.
,, ,, ,, 2, 1883–84.	3s. 6d.	,, ,, ,, 3, 1897.	1s.
,, ,, ,, 3, 1884–85.	3s. 6d.	,, IX. ,, 1, 1898.	2s. 6d.
,, V. ,, 1, 1885–86.	4s.	,, ,, ,, 2, 1899.	2s. 6d.

Vol. IX., Part 3, 1900. 2s.

NEW SERIES, Vol. X., Part II. (issued for 1902). **Price 2s.**

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIII.

NEW SERIES, Vol. X., Part II. (issued for 1902).

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIII.

LIST OF OFFICERS

(1902)

President:

Arthur B. Prowse, M.D.

Past Presidents:

John Beddoe, M.D., F.R.S.
Prof. C. Lloyd Morgan, F.R.S., F.G.S.
Prof. W. Ramsay, F.R.S.
Prof. Sydney Young, D.Sc., F.R.S.

Vice-Presidents:

A. E. Hudd, F.S.A.
C. K. Rudge.

Members of the Council:

E. H. Cook, D.Sc.
H. B. Cornaby.
T. Fisher, M.D.
Rev. A. C. Macpherson, M.A.
A. C. Pass, J.P.
Rev. H. Pentecost, M.A.
H. C. Playne, M.A.
G. Munro Smith.
Rev. G. F. Whidborne, M.A.

Honorary Treasurer:

Harold E. Matthews, 30, The Mall, Clifton.

Honorary Secretary:

S. H. Reynolds, M.A., University College, Bristol.

Honorary Reporting Secretary:

G. Brebner, University College.

Honorary Librarian:

C. K. Rudge, Ashgrove House, 145, White Ladies' Road.

Honorary Sub-Librarian:

Henry J. Charbonnier, 49, Dove Street, Kingsdown

OFFICERS OF SECTIONS

Botanical:

President—Cedric Bucknall, Mus. Bac., 13, Whatley Road, Clifton.
Secretary—James W. White, F.L.S., Warnham, Woodland Road, Clifton.

Chemical and Physical:

President—F. W. Stoddart, F.I.C., F.C.S., Grafton Lodge, Sneyd Park.
Secretary—L. N. Tyack, University College, Bristol.

Entomological:

President—G. C. Griffiths, F.Z.S., F.E.S., 43, Caledonia Place, Clifton.
Secretary—Charles Bartlett, 18, Henleaze Avenue, Westbury-on-Trym.

Geological:

President—S. H. Reynolds, M.A., F.G.S., 9, Tottenham Place, Clifton.
Secretary—B. A. Baker, 11, Westbury Park, Durdham Down.

TABLE OF CONTENTS

NEW SERIES. VOL. X. PART II.

A Dust-fall in the South-West of England.

By ALFRED C. FRYER, Ph.D., F.I.C., F.C.S.

ON March 11, 1901, rain fell in Italy thickly charged with sand, and three days later the same dust-cloud reached parts of England and Scotland and the Danish Islands. The whole phenomenon has been carefully studied by Professors Hellmann and Meinardus in their valuable monograph entitled, *Der grosse Staubfall von 9 bis 12 März* 1901.[1]

A somewhat similar dust-fall visited the south-west of England and South Wales in January, 1902, and Dr. H. R. Mill has written an able paper upon this subject in the *Quarterly Journal of the Royal Meteorological Society.*[2] "The conclusion which seems to be inevitable," says Dr. Mill, "is that on January 22 the atmosphere over the west of Europe consisted of air which had come from the African deserts carrying with it a quantity of fine dust, which was brought down in perceptible quantities wherever rain happened to fall. The extreme sharpness of the boundary line where the dust-fall was observed seems to indicate a sharply defined dust-cloud in the air. The question whether the identity of desert air may be determined other-

1 *Abhandlungen des königlich preussischen meteorlogischen Instituts,* Bd. ii., No. 1.

2 See vol. xxviii., No. 124, p. 247.

wise than by the dust-floats it carries in its current is not without interest, and there is at least some possibility that a more delicate test may be found."[1] Dr. Mill adds: "Whatever may have been the meteorological agency by which the dust-rain of January 22, 1902, reached Northern Europe, it seems perfectly sure it was not the same as that by which the dust-cloud of March 12, 1901, pursued its roughly parallel course. There is no room in the weather-charts of January 20 to 23 for a cyclonic centre travelling directly northward across Europe; but we cannot yet tell what the distribution of pressure and wind was in the Atlantic at the time, and whether a centre of low pressure may not have turned the flank of the anti-cyclonic area and whisked the dust northward with it. I incline to think that the evidence points to transportation in the upper air, the larger amount of dust carried causing a general descent over Portugal through the opposite surface current, and a mere vestige (some 100,000 tons or so) being caught in its fall and carried on to the shores of the Channel. The farmers of the West of England have this spring ploughed many tons of the sands of the Sahara into their furrows."

From these brief notes on the dust-falls of 1901 and 1902 we must proceed to give a few details of the one recorded by many observers in February, 1903.

The May pilot chart for 1903 published by the Meteorological Office records that prior to the dust-storm reaching Europe sand-storms had interfered with the progress of the British Commission in Nigeria, south of the Sahara, and had also been experienced on the northern edge of the Sahara. Ships which were off the coast of Africa were hampered in their movements by the obscuration due to vast quantities of sand in the air from the Gulf of Guinea to 30° W. and up to the Azores. This chart shows clearly that the wind about the Canaries, becoming easterly or south-easterly in

[1] Page 248.

direction on February 19, drove the dust-cloud to W. and N.W. and near the Azores ; the wind being S.W., the cloud was quickly driven to Europe. It is deserving of notice that the R.M.S. *Briton,* keeping near the African coast, passed through huge quantities of red dust with a wind at N.E., while the s.s. *Kirkby,* running westward from Madeira, encountered the dust-fall with a S.E. wind.[1] The British and Africa Company's steamer *Bornu* fell in with the dust-storm on February 19, when she was thirty-six hours from Teneriffe, and the fall was so dense that her speed had to be reduced to dead slow, as it was impossible to see from one end of the liner to the other. On arriving at Teneriffe, the *Bornu* found that the steamer which had passed her on the previous day had gone ashore during the sand-storm.[2]

This dust-fall was noticed in many parts of the continent. In Kremsmünster, in Austria, the fall was on February 22 and 23, with the wind in the west, and a haze which was described as "smoke-like." At Loosderf, Pyhrn, Graz, and other places in Austria, it is recorded that the trees were covered with a yellow-dust on February 23.[3] In Ireland and in many localities in England the phenomenon was noticed. From a large number of actual observers of the 1902 dust-fall we will only take the experience of a few. Mr. C. Grover, of the Rousdon Observatory, Devon, says that many objects and instruments on the windward side of these buildings were "conspicuously marked with a deposit of a reddish or a rusty-coloured mud so thick as to attract attention at once."[4] The West Usk Lighthouse-keeper (Monmouthshire) reported to Trinity House that on "February 23, some time between noon and sunset, a fall of dust occurred with S.W. wind and overcast, misty

[1] *Nature,* vol. lxvii. p. 65.
[2] *The Daily Telegraph,* February 28, 1903.
[3] *Meteorlogische Zeitschrift,* Heft. II. Feb. 1903.
[4] *Nature,* vol. lxvii. (Letter from Mr. W. Marriott.)

weather. The dust was very fine, pinkish in colour, and of amount sufficient to colour the white paint." Observers in Devon describe the deposit as "a layer of cream-coloured sandy material,"[1] while in another locality the rain water as it entered the cistern was "like water with yellow clay held in solution."[2]

The recorded rainfall at Tavistock, Devon, was 0·01 inch on February 19, 0·15 inch on the 20th, 0·18 inch on the 21st, and 0·38 inch on the 22nd.[3]

At the time of the dust-fall I was staying at Tavistock, and on February 21 I observed a yellow glare in the high fog or low cloud, while on the 22nd I was successful in obtaining sufficient deposit to be able to make some examination of it. The rain contained 38·2 grains of suspended matter to the gallon, and the microscope revealed that the deposit was an amorphous clayey matter mixed with round and angular fragments resembling quartz. An analysis was made which showed that the dust was composed of a certain percentage of organic matter which was mixed with ferruginous sand, chalk, and silicates of alumina, alkalis, lime and magnesia. The figures obtained were as follows—

	Per cent.
Silica	47·62
Alumina	19·22
Iron Oxide	5·87
Lime	8·24
Magnesia	2·26
Sodium Oxide	1·28
Potassium Oxide	2·10
Carbonic Acid	6·30
Water and Organic Matter	7·11
	100·00

The figures given in the following table are obtained by calculating the organic constituents as percentages on

[1] Mr. A. G. Manley, of Torquay, Devon.

[2] An observer at Torrington, North Devon.

[3] Mr. E. E. Glyde, F. R. Met. Soc., Whitchurch, nr. Tavistock, Devon.

their sum, after deducting water and organic matter. No. 1 is an analysis made by Professor T. E. Thorpe of a sample of the recent dust-fall of February 22, 1903, taken from the roof of Bayham Abbey, Lamberhurst.[1] No. 2 is an analysis of dust from Taormina collected by Sir Arthur Rücker and now preserved at South Kensington.[2] No. 1 contained 9·08 per cent. of water and organic matter and No. 2 possessed 23·49 per cent.

	Taormina Dust. No. 1. Per cent.	*Bayham Abbey Dust.* No. 2. Per cent.
Silica	47·47	50·53
Alumina	21·37	20·18
Ferric Oxide	7·94	7·23
Cobalt Oxide	·42	—
Lime	8·16	9·50
Magnesia	2·89	2·04
Sodium Oxide	3·38	1·27
Potassium Oxide	3·56	2·53
Carbonic Acid	4·81	6·72
	100·00	100·00

It is interesting to compare the foregoing results with the following analysis made by Gibbs about half a century ago of dust which fell on a ship in the Atlantic Ocean. After deducting 18·53 per cent. of water and organic matter we have—

	Per cent.
Silica	45·58
Alumina	20·55
Ferric Oxide	9·39
Manganese Oxide	4·22
Calcium Carbonate	11·77
Magnesia	2·21
Potash	3·64
Soda	2·33
Cupric Oxide	·31
	100·00

Professor T. E. Thorpe says that in sample No. 1 the

1 *Nature*, vol. lxviii. p. 54.

2 Ibid. p. 222. The dust may be seen in the Geological department of the South Kensington Museum.

organic carbon amounted to 9·89 per cent., and the organic nitrogen to 0·16 per cent. This small proportion of nitrogen shows that the organic matter is mainly, or entirely, of vegetable origin. In sample No. 2 the organic matter contained 2·19 per cent. of carbon and 0·16 per cent. of nitrogen, the two representing probably between three and 4 per cent. of organic constituents, while most of the lime was in the form of chalk.

During the month of November, 1902, a dust-storm visited New Zealand which seemed to have its origin west of the Blue Mountains in Australia, and after travelling some 1,500 miles through the air, 1,200 of which was over the water's surface, some was collected at Invercargill in New Zealand. When the dust was examined with a $\frac{1}{8}$ inch objective it showed various vegetable cells, apparently portions of the feathery pappus of fruits of compositæ and similar light matter. Some rounded grains of inorganic matter were frequent and in some cases large enough (0·03 mm. diameter) to depolarise light. They were chiefly quartz, but some were apparently augite, and other particles of weathered minerals coloured red with iron oxides. To these last the colour of the dust in mass was due. There were also in every preparation observed several diatoms. In one preparation there was a piece of vegetable tissue composed of fine cells. In all these was much carbonised matter.[6] The chemical analysis of this dust after drying it in a water bath is thus given—

	Per cent.
SiO_2	53·68
Al_2O_3	18·44
Fe_2O_3	6·54
CaO	0·95
MgO	1·52
K_2O	2·58
Na_2O	1·67
Loss in ignition	14·60
	99·98

[6] See an interesting letter in *Nature* (vol. lxviii. p. 223), by Mr. P. Marshall.

It has been suggested by Mr. J. J. H. Teall, director of the Geological Survey, that the question of the origin of dust floats might be elucidated if the samples obtained were found to contain free aluminium hydroxide. The reason for this suggestion is that laterite, a decomposition product of the felspars, is an aluminium hydroxide, though always mixed with more or less silica. It is believed that this [7] type of decomposition occurs only in tropical regions, and consequently if uncombined alumina in the dust could be detected the evidence of a tropical origin might be established. Professor T. E. Thorpe has made some experiments in this direction on the two samples of dust he has studied, and he remarks that "the results are not conclusive, but so far as they go they point to there being no uncombined alumina in the samples." '

[7] *Nature*, vol. lxviii. p. 223.

Notes on the Corals and Brachiopods

OBTAINED FROM THE AVON SECTION AND PRESERVED IN THE STODDART COLLECTION.

By Arthur Vaughan, B.A., B.Sc., F.G.S.

CONTENTS

I. INTRODUCTION

THE collection of the late Mr. W. W. Stoddart, F.C.S., F.G.S., which, at his death, came into the possession of University College, Bristol, contains a large number of Carboniferous fossils collected from the neighbourhood of Bristol and chiefly from the Avon Gorge.

This paper deals only with the Corals and Brachiopods in this portion of the collection. The other zoological divisions are either very poorly represented throughout the Carboniferous Limestone of the Bristol area, or are only abundant at a very few particular points of the series; on the other hand, Corals and Brachiopods abound every-where, one or both of the groups being represented by vast numbers of individuals in almost every bed of the series. It is, therefore, of supreme importance to separate accurately the different forms of these two groups, and to assign to each form its proper place in the vertical and horizontal sequence.

The ultimate results of such work, when perfectly performed, will be to determine the complete relative vertical succession of life at all points; a comparison of these results at the different points will, by disclosing both resemblances and differences, enable us to select those forms which characterize particular relative levels throughout a large area, and will also throw light upon the problems of migration and evolution.

That part of the work which consists in assigning each form to its correct position, both horizontal and vertical, demands merely an exact record of the place and bed from which each fossil was obtained; for such data we have to rely upon the collections made by others, in order to supplement the necessarily limited amount of material which can be actually collected by a single individual. Also, as time goes on, certain exposures become inaccessible, whilst others, such as quarries, fall into disuse, as has been notably the case in the section on the north side of the Avon; consequently a collection such as this one, made under more favourable conditions, is of exceptional value.

Specimens when unlabelled are only of value from the standpoint of descriptive Palæontology, unless the nature of the matrix renders the source unquestionable. Even in this case, however, when the peculiarities of the matrix seem to point to one horizon and to one only, the specimens are best employed only as confirmatory of more direct evidence.

A large number of the specimens in the Stoddart collection are located with sufficient detail, but a still larger number are, unfortunately, insufficiently located or totally devoid of any location whatsoever. In the case of the great majority of located specimens I am able to confirm the locality from personal knowledge, and there are, in fact, only a very few cases where I feel doubtful whether the specimens were actually derived from local sources.

The collection has a certain value beyond that common to all collections which contain specimens correctly located. It throws a considerable light upon the actual fossils which Stoddart intended to denote, in his paper on the Avon Section,[1] in those cases in which his naming appears to be erroneous. Unfortunately, however, very many of the species mentioned by Stoddart in his paper are not represented in the collection or, at least, are not so labelled ; in other cases there are several very distinct forms classed under the same name, so that, in the absence of detailed location on the specimens themselves, it becomes impossible to assign any particular one of the forms to its correct bed in his sequence.

This brings us naturally to a consideration of the second desideratum in the labelling of specimens, namely, the necessity of appending a name which shall convey to any one who has access to Carboniferous literature a clear conception of the particular form so labelled, and of *no other*. It is just here that we are at present considerably handicapped. The species and mutations of Carboniferous forms which have as yet been figured do not cover nearly all, even of the commonest, forms.

The particular specific name under which an author places a specimen, other than the type itself, is not a matter of great consequence so long as he figures it ; his allocation of the figure to one species rather than to another is merely the expression of his personal opinion as to its closest affinities ; but whether he is right or wrong, his figure

[1] "Geology of the Bristol Coalfield," *Proc. Bristol Nat. Soc.* 1875.

becomes, in itself, a new type to which other specimens can be referred.

There is, however, a very strong objection to the registration of a long series of mutations under one and the same name. Specimens from different localities, or from the same locality but from different horizons, are found to agree with certain different figures classed together under a single specific name of great inclusion ; they are then cited in lists under this specific name, with the result that the conclusion is often drawn that the two forms are absolutely identical, though they may be, in reality, conspicuously different. Mere lists of Carboniferous Limestone fossils, including such specific names as *Productus giganteus, Spirifer trigonalis, Chonetes papilionacea, Clisiophyllum turbinatum,* etc., etc., convey far less precise information than a list of genera in Jurassic Geology. So long as we are content to consider every large, longitudinally-ribbed Productus as *Productus giganteus*, every Terebratula or Terebratuloid Athyris as *Terebratula hastata*, and every narrow Siphondendroid Lithostrotion as *Lithostrotion irregulare*, and to register them under these names without any further information, the palæontology of the Carboniferous Limestone could almost be done by occasional glances at a section from an express train.

The information thus conveyed is not only valueless in itself, but it tends to retard Carboniferous research by making it appear that, in this alone of all the systems, the same form may occur at very different horizons and yet retain identically the same characters.

I have made the above remarks as an excuse, if any such is needed, for the detailed nature of the descriptions which follow.

In the case of the Brachiopods I have in nearly- all cases, referred to the figure in Davidson's Monograph, which most nearly corresponds to the specimen I am describing, and, where no figure exactly fits the specimen, I have pointed out the most important directions of deviation; I have also made constant reference to the works of de Koninck (especially to the Carboniferous Fauna of Belgium, the Monographs on the Genera Productus and Chonetes, and to a later paper on *Spirifer Mosquensis* and its allies).

McCoy's Palæozoic Fossils has been of very great service in both the Brachiopods and the Corals.

In the examination of the Corals I have chiefly relied upon the works of Edwards and Haime (the Palæozoic Corals and the Monograph of British Fossil Corals), but I have also made considerable use of McCoy's work and of the numerous papers by James Thomson in the Proceedings of the Philosophical Society of Glasgow.

It is with great pleasure that I seize this opportunity of acknowledging my great indebtedness to Prof. S. H. Reynolds, M.A., F.G.S.; Mr. J. F. Walker, M.A., F.G.S., etc.; Dr. Wheelton Hind, M.A., F.G.S., etc.; Mr. F. W. Stoddart, F.I.C., F.C.S.; Mr. J. W. Tutcher and Mr. T. F. Sibly, B.Sc., for the great assistance they have so unselfishly and ungrudgingly given me during my work at the collection.

To Mr. J. W. Tutcher I am under a very deep obligation for the splendid photographs of which the plates are somewhat unsatisfactory reproductions.

To Mr. F. W. Stoddart I offer my sincerest thanks for the trouble he has taken in unearthing the manuscript note-books of the late Mr. W. W. Stoddart; these notes have enabled me to accurately fix the horizons of several of the forms and also to explain several apparent discrepancies between the positions in which I have found certain fossils and those to which they are referred in the collection.

II. DESCRIPTION OF THE CORALS.

Alveolites.

Alveolites septosa, Flem. (including *A. depressa*, Flem. = *A. capillaris*, Phill.).

Corallum hemispherical, cylindrospherical, etc.; diameter of corallites varying from ·35 mm. to more than ·5 mm. No sharp distinction can possibly be drawn between those forms in which the corallites are very narrow, the tabulæ very distinct, close and regularly spaced (*depressa* section), and the forms with larger corallites and with fewer and less regularly spaced tabulæ (*septosa* section). The gradation in diameter is perfectly continuous, so that specimens occur having corallites of every intermediate dimension. Again, the narrower corallites in a specimen of the typical *septosa* section are usually quite as closely and regularly tabulate as the corallites of the typical *depressa* type.

All the individuals, without regard to dimensions, usually exhibit, on their outer surface, certain scattered patches in which the tube openings are of larger size, and these patches are often a little raised above the general surface.

There are in the collection very numerous specimens, both polished and unpolished, which illustrate excellently the complete transition between the two mutations.

All the specimens have been derived from the uppermost section of the Carboniferous Limestone and from both the lower and upper divisions of that section (e.g. bottom of New Zig Zag, Boiler Bed, behind Colonnade and corresponding positions on the south side of the Avon).

Alveolites Etheridgei, Thomson.

1. This species is undoubtedly represented by a polished section which exhibits elongated, narrow spaces, bounded by thickened walls; the contiguous spaces being separated by short thickened transverse partitions. Owing to the continuity of the long walls (the elongated spaces being

arranged lineally), their irregular thickness and the short transverse partitions, the specimen bears a strong resemblance to a section of a very fine Reticulate Syringopora. In parts of the same section, however, the shape of the spaces is more obviously that of a large Alveolites.

No projections from the walls into the spaces are clearly shown, and, in the specimen we are describing, tabulæ cannot be definitely made out, but in a precisely similar specimen in the British Museum, the tabulæ are very clearly exhibited in one part of the section.

The spaces maintain an average width of ·7 mm., whilst their length may reach 4 mm.

2. A small, knob-shaped, solid specimen shows the same lineally elongated openings on its surface, but, since the natural tendency of destruction by rain is to dissolve away the cross partitions along a continuous rut, the superficial aspect may not represent the internal structure. I have, consequently, only tentatively referred this specimen to the above species.

3. A horizontal section which shows large spaces (about ·8 mm. diameter) of normal development, thick but distinct walls and no clearly defined projections from the walls is, very probably, the normal form from which the specimen described above (1) is an abnormal mutation. The removal of several adjacent walls and the deposit of carbonate of lime on those that remain would easily account for the very peculiar character exhibited by the first specimen.

None of the specimens are located.

Chœtetes.

(? *Chœtetes*) *bristoliensis*, n. sp. Pl. I, fig. 2.

Corallum broad, flattened, tall and cylindrical; the corallites of large size (·95 mm. diameter) radiating and diverging upwards and outwards and exhibiting a strong wedge-arrangement due to intermural gemmation. Externally, the weathered corallites are seen to be arranged in successive storeys of basaltiform prisms.

Tabulæ cannot be made out with certainty in all vertical sections, but occasionally very thin, regular tabulæ can be seen, and it seems probable that they are absent from most of the tubes, simply because their extreme thinness has rendered them easy of destruction.

The walls of the tubes are very thick and, in a horizontal section, numbers of small corallites can be seen starting in the thickness of the walls, especially in the corners.

Projections from the walls can apparently be occasionally made out, but are not by any means usual.

The figure represents a vertical section, natural size.

There are two fine specimens in the collection, obtained from behind the Colonnade (i.e. from almost the highest beds in the Carboniferous Limestone).

I have included this species under *Chœtetes,* rather than under *Alveolites,* on account of the gemmation being normally intermural and not fissiparous, but the occasional presence of projections inwards from the walls indicates a close relationship to *Alveolites septosa.*

Syringopora.

The specimens in the collection are not numerous and are poor in quality; they give a very imperfect idea of the great abundance of this genus almost throughout the series. Again, horizontal sections are very unsatisfactory, since they only register the diameter and infilling of the corallites and their average separation, without affording any accurate estimate of the flexion of the tubes or of the vertical spacing of their connectors, except in so far as it is possible to roughly deduce these characters from the obliquity of the sections and the number of cross sections which are in connexion.

I consequently devote less space to this genus than its prevalence seems to demand ; for I am convinced that the separation of species should be made, not from a few specimens in a collection, but from the thousands of sections and weathered specimens to be actually seen, in situ, in the field.

Syringopora ramulosa, Goldf.

Poor but indubitable specimens of this species occur in the collection which have been derived from the "Upper Limestones," Leigh Woods, and Brockley Combe.

The tubes are well separated (3·5 to 8 mm. apart), and continuously, but irregularly, fork at an angle of about 30° ; their cross sections are almost filled up and are of considerable diameter (1·5 to 2 mm.).

Syringopora distans, Fischer (*S. catenata*, de Kon.).

This I believe to be a mere mutation of *S. ramulosa*, in which the tubes are somewhat narrower and placed at less distance apart, but the complete demonstration of the transition must be worked out, in the field, from a very large series of specimens.

There are three or four specimens in the collection, derived from "Upper Shales," Clifton, "Behind Old Well House," etc.

The diameter of the tubes averages from $1\frac{1}{2}$ to 2 mm., and they are placed at a distance apart equal to 2 or 3 times their diameter ; the frequency of the connectors can only be deduced from the fact that, in the horizontal sections, a minority of cross sections are connected.

Syringopora geniculata, Phill.

There is a small, but perfectly typical, weathered specimen labelled "Clifton."

Syringopora, n.sp.

A very poor specimen from the Black Rock, Clifton, is most probably identical with a form which I have found at the same horizon in other parts of the district, and which I hope to describe later from specimens in my own collection.

Michelinia.

Michelinia tenuisepta, Phill.

A horizontal section from the Gully oolite, a vertical section from " below the oolite," and a small weathered fragment, unlocated, may all three, with great probability, be assigned to this species. The diameter of the corallites varies from 6 to 10 mm.; the vertical section and the weathered fragment clearly indicate a tall species; the horizontal section exhibits thin walls lined with a zone of small vesicular tissue; the weathered specimen has deep calices.

Michelinia megastoma, Phill.

A horizontal section which exhibits hexagonal calices, averaging 12 mm. up to 14 mm. in diagonal, bounded by thick walls (averaging 1 mm. in thickness), and in which the walls are perforated by regular channels, is probably most nearly allied to this species. (Without a knowledge of the base it is, however, impossible to assign any specimen of *Michelinia* with certainty to its correct species.) The matrix of the specimen suggests that it was derived from the Black Rock Quarry.

Cleistopora.

Cleistopora (*Michelinia*) *geometrica*, Ed. and H. Pl. I., Fig. 3.

The authors (in their *Monographie des Polypiers fossiles*) give the following definition of the species :—

"Corallum flat, free or encrusting; calices of the same mass equal and regularly hexagonal, stellar; the upper tabulæ which form the floor of the calyx are almost horizontal and strongly granulated; there are, apparently, 28 vertical striæ; the large diagonal of the calices varies from 5 to 7 mm. or even more."

Their specimens were derived from the Devonian.

In all the main characters our specimens agree, both with the above definition and with the figures given by the authors. The calices average 4 to 5 mm. in diagonal, and are usually almost perfect hexagons; the walls are thick and granular, but, when well preserved, show a thin central ridge along their middle line; there are four or five grooves running across each wall in all those specimens which have been worn down by weathering (these grooves represent tubular channels through the walls); the floor is almost horizontal and granular. (The granulation of walls and floor indicates clearly the trabecular structure of the vesicular tissue, the possession of which characterizes the genus Cleistopora). The specimens are derived only from the lowest beds (L. L. Shales).

The figure is a much weathered example, selected to show many calices, and is natural size.

This fossil has usually been named *Microcyathus cyclostoma*, to which, however, it bears practically little resemblance.

Zaphrentis (= *Cyathopsis* of McCoy = *Zaphrentis* of Ed. and H., omitting *Zaphrentis cylindrica* and its allies, which are here included in *Caninia*).

This genus, as thus restricted, is one of the most interesting and also one of the most prolific in the Carboniferous Limestone of the Bristol area, but is represented in the collection by three specimens only.

(1) *Zaphrentis sp.*, a solid, cornute specimen labelled Mendips.

All but the rim of the calyx is obscured, but this exhibits numerous septa with a second series of thinner intermediates ; there is also evidence of the fossula lying on the outer side (i.e. on the side of the broader curve of the horn).

The point being broken, the rough section shows indistinctly the usual Zaphrentis type of grouping. Until the internal structure can be more clearly made out, by means of a section, the specimen cannot be assigned to any definite species.

(2) A vertical section of a cornute form, showing a deep calyx and a fossular depression on the outer side. Diameter of calyx-rim, 18 mm. Extreme length, 42 mm. From the Black Rock. Probably *Zaphrentis* aff *Phillipsi*, Ed. and H.

(3) *Zaphrentis* aff *Phillipsi*, Ed. and H., and *Zaphrentis* aff *cornucopiœ*, Mich.

A polished section from the Black Rock Quarry, cut to exhibit a poor transverse section of a *Caninia* (v. i.) contains also two horizontal sections of small Zaphrentes.

(*a*) Probably a very young stage in the development of a member of the *Phillipsi* group, since the section (3 mm. in diameter) exhibits a relatively large fossula bisected by a long thin septum, and the arrangement of the septa shows the very marked grouping, so characteristic of this group.

(*b*) Probably a young stage in the development of a member of the *cornucopiœ* group, since the section (6 mm. in diameter) exhibits a long, narrow fossula, less obvious grouping and a dense circumferential ring, formed of the short secondaries and of the thickened ends of the primary septa.

Caninia (of McCoy) [= the group of *Zaphrentis cylindrica* of Ed. and H.].

Those Zaphrentids which have a central area crossed by broad, close tabulæ and in which each tabula has a deep depression near its circumference (the "fossula"), were separated by McCoy under the generic name *Caninia*. The convenience of this separation has been generally acknowledged, but the name *Caninia* has been discarded and replaced by the generic name *Campophyllum*.

This is, in my opinion, a mistake caused by deceptive parallel-development.

The essential characters of *Caninia*, McCoy, are the broad tabulæ and the *deep* fossula; the presence of the fossula introduces a strong bilateral symmetry which, whenever the septa extend conspicuously over the tabulæ, is rendered still more obvious by the Zaphrentis type of grouping.

Campophyllum, Ed. and H., was created to cover a group of cyathophyllids which have a broadly tabulate central area and short radial septa, not reaching the centre; the strong radial symmetry and the very inconspicuous nature of the bilateral symmetry clearly indicate the close relationship of this group to the genus *Cyathophyllum*.

Whenever, as is usually the case, the ring of short septa in a *Caninia* is not conspicuously continued over the tabulæ towards the centre, the general resemblance of the horizontal sections of *Caninia* and *Campophyllum* is remarkably striking, but in all cases the nature of the fossula forms a perfectly distinctive character for separating the two genera.

In the horizontal section of a *Caninia* the fossula is usually occupied by a short, unique septum, and is bounded by the two septa on either side, which converge round it and form an arch; usually also, one or more smaller arches lie within this main arch and indicate the intersections of the plane of section with the fossular depressions of higher tabulæ.

In the horizontal section of a *Campophyllum*, the bilateral symmetry is not conspicuous, but, as in a *Cyathophyllum*, is more or less marked out by the presence of one or more shorter septa at some point of the septal ring; the longer septa, however, on either side of the shorter ones, are straight and of normal pattern, and there is no indication of a depression in the floor of the tabula at this point.

Caninia cylindrica, var. *bristoliensis*. Pl. I., Fig. 4.

Corallum cylindrical, seldom exceeding 4 cm. in diameter.

Vertical section: central area occupied by broad, horizontal tabulæ which are well spaced vertically; an outer zone of coarse, ascending vesicles, extremely variable in width and often partially absent.

Horizontal section: Septa 50 to 54, thick (bilaminar) and lanceolate, forming a strongly marked septal ring; the septa are frequently continued across the tabulæ as thin flexuous striæ, which exhibit the Zaphrentis type of grouping.

The fossula is elongate and conspicuous and contains a unique, shorter septum enclosed in one or more arches, as explained above. Between the septa the vesicles are few and inconspicuous.

Outside the septal ring is a zone of fine vesicular tissue, very variable in width at different points; this outer vesicular ring is crossed by very thin prolongations of the septa and by a second series of equally thin intermediates. The innermost limit of this zone is formed by a strongly thickened inner wall, which runs, as a connected series of discontinuous arcs, from septum to septum, each short arc connecting the thick ends of two adjacent septa; at the fossula, the inner wall exhibits a strong outward projection.

Portions of a thin outer wall can occasionally be made out, but only in places.

As a consequence of the extreme delicacy of the outer vesicular zone, it is usually destroyed more or less completely, so that the section is bounded by the strong inner wall, festooned by the projections of the thick ends of the septa which compose the septal ring. (By this characteristic appearance polished sections of this coral from the Avon Gorge, which are common in many collections, may generally be easily recognized.) Very occasionally this inner wall is also destroyed, and nothing remains but the strong septal ring, rendered strikingly bilateral by the strongly marked fossula.

The diameter of the inner wall seldom exceeds 3 cm.

There are several characteristic specimens in the collection which have been derived from a definite horizon in the lower portion of the Great Quarry, where they are associated with *Lithostrotion Martini*. An incomplete horizontal section of a *Caninia*, derived from the Black Rock Quarry, and containing also sections of Zaphrentis (already referred to above), may belong to the mutation we are describing.

This fossil must, I think, be regarded as a local mutation of *Caninia cylindrica*, with which it agrees in all the more important structural details; the most striking points of difference in the Bristol specimens are their smaller size (and consequently fewer septa), and the frequency with which most of the outer vesicular ring has been removed.

The horizontal section figured is the most perfect section I have seen; the greater part of the outer vesicular zone is preserved, and the septa are conspicuously continued across the tabulæ, almost to the centre, and exhibit the characteristic Zaphrentis grouping.

? Caninia sp.

A horizontal section shows fifty-eight strong septa degenerating into striæ over a broad central tabulate area; the septa are prolonged outwards, still strongly marked but somewhat thinner, through a broad zone of close vesicles; no intermediate series of septa exists in the outer zone, and, owing partly to the indistinctness of the section, the bilateral symmetry is not well marked.

Diameter of the section, 25 mm.; inner diameter of the vesicular zone, 11 mm.

A vertical section shows broad tabulæ, at considerable vertical intervals, and indicates a cylindrical corallum.

The only two specimens are from the top of the Black Rock Quarry.

In the absence of further material of an intermediate nature, it is impossible to definitely assign this form to its correct position.

Amplexus.

Amplexus coralloides, Sow.

This species is represented by two poor horizontal sections; the one is almost certainly, judging by the matrix, from the top beds of the Black Rock Quarry, the other cannot be definitely located.

Lithostrotion.

Section A. *Siphonodendron*, McCoy, comprising the fasciculate forms.

Considering the enormous abundance of specimens belonging to this section throughout the whole of the upper half of the Carboniferous Limestone Series (i.e. from the Great Quarry to the end), it is astonishing how less than meagre is their representation in the collection. The paucity of material has, however, the immediate advantage of rendering any careful analysis of the weight to be attached to specific names entirely out of place in these notes; in fact, no safe conclusions can be arrived at except by the careful examination, in the field, of the thousand upon thousand specimens to be observed, sectioned and weathered out, in the rocks themselves. The results of such observations I hope to set out at no very distant date.

Lithostrotion Martini, Ed. and H. (= *L. fasciculatum*, Auct. [non Lam.]).

Here we may place a weathered specimen showing deep calices, about 8 mm. in diameter, and a polished slab which shows a large number of disconnected, but fairly adjacent, cross sections, averaging 5 mm. in diameter.

None of the specimens are located.

Lithostrotion irregulare, Phill.

A weathered specimen, composed of very many narrow, cylindrical corallites, closely packed together, parallel and flexuous, was derived from the upper beds of the section.

Numerous disconnected corallites which exhibit a characteristic forking were obtained from the very top beds of the series.

Lithostrotion junceum, Fleming.

A single typical specimen is unlocated.

Section B. *Nematophyllum*, McCoy, comprising the astræiform *Lithostrotions*.

Of this section there are a great number of specimens, the majority polished sections, which represent fully and excellently all the species belonging to this section which are found in the Carboniferous Limestone series of the Bristol area.

Lithostrotion basaltiforme, var. *bristoliense* (commonly known as *Lithostrotion aranea*, probably = *Nematophyllum arachnoideum*, McCoy).

Corallum much expanded, the calicinal surface only slightly convex.

Calices nearly equal, averaging a little over 11 mm. diagonal; walls very sharp and crenulated by the thick ends of the strongly marked septa; each calyx extremely shallow with a somewhat deeper, central, circular cup (of diameter a little over 4 mm.); from the floor of the calyx projects a prominent columella, which is compressed and somewhat fusiform in section.

In a horizontal section, the columella is non-prominent, thin, and never markedly fusiform; the inner portion is nearly free from vesicles; the outer is occupied by close, small vesicles; the boundary of the vesicles forms an inner wall whose diameter bears a variable ratio to that of the corallite (1 to $2\frac{1}{4}$ up to 1 to 3), being usually greater, the smaller the corallite.

The septa are markedly alternate, the longer reaching nearly to the columella, the shorter only extending to the inner wall and occasionally falling short of it, whilst, in some examples, they poke a little beyond; the number of the septa seldom exceeds forty, and may sink to thirty-six, whilst occasionally it rises to forty-six.

In the majority of cases the septa are more prominent than the vesicular tissue which they traverse, but examples are not uncommon in which the reverse is the case. There are also examples in which the vesicular tissue is conspicuous almost to the centre of the corallite.

In a vertical section, the central area is occupied by conical tabulæ, whose apices lie on the columella; near the inner wall each tabula usually forks; the outer area is occupied by rows of small vesicles, which ascend obliquely to the outer wall. (There are usually four vesicles in a row, but the number is variable.)

The specimens are all derived from a very limited number of beds, the Aranea beds of Stoddart, in the lower part of the Great Quarry.

This form is undoubtedly a mere local mutation of

Lithostrotion basaltiforme, Phill., from which it chiefly differs in the smaller number of its septa and in its usually more open vesicular tissue, as well as, in the majority of specimens, by the smaller extension of its shorter septa; but, as has been shown above, there is a considerable variation in all these respects amongst specimens derived from the same bed.

From *Lithostrotion aranea*, McCoy, it differs chiefly in the thinness and non-prominence of its columella; for, though the broken section of the columella, often seen in the weathered calyx, is occasionally distinctly fusiform, no such appearance is ever exhibited in a horizontal section. Since, however, the Bristol specimens are clearly intermediate between these two species, it seems possible to regard *L. aranea* as itself only an extreme mutation of *L. basaltiforme*. This species is one of the best known of all the Clifton corals.

Lithostrotion Portlocki, Bronn (= *Nematophyllum clisioides*, McCoy).

There are several specimens in the collection of the typical columnar form. The polished horizontal sections exhibit the characteristically unequal, spidery septa and very open vesicular tissue, with scarcely any well defined inner wall; diagonal of calices varying from 4 to 7 mm.

These specimens have all been derived from the very top beds, and one is even labelled, "3rd bed below Fault."

Lithostrotion, Sp.

Calices deep; columella prominently projecting and stout.

A horizontal section shows unequal calices varying from 3 mm. to 7 mm. diagonal; columella circular, often hazy, as if made up of very fine, spongy vesicular tissue; twelve or thirteen long septa reaching to the columella and an equal number of short ones just projecting beyond the inner ring. *A strongly marked inner ring bounding a large outer zone crowded with fine vesicles.* The septa are usually very inconspicuous, so that the general appearance of the section is as if it were composed of a central, circular, blurred columella lying in the middle of a small bare circle and all round a deep zone of very fine vesicles.

The specimens are not definitely located, but are, almost certainly, derived from the same horizon as those of *Lithostrotion Portlocki*.

I have not assigned a new specific name to this form, as I am not yet completely convinced of its specific separation from *Lithostrotion Portlocki*, with which it agrees in columnar habit, in general size of calices and in number of septa.

The weathered calices are remarkably similar in both, and, in fact, it is only in a horizontal section that the differences are striking. The strength of the septa and the sparseness of the vesicular tissue in *L. Portlocki* are in striking contrast to the inconspicuous septa, broad ring of fine vesicles and perfectly defined inner wall in the form under description.

Lithostrotion ensifer, Ed. and H. (? = *Nematophyllum decipiens*, McCoy).

The specimens entirely agree with the description of the calicinal surface given by Edwards and Haime, but as they make no mention of the horizontal section, a brief account of the characteristic appearance which it presents seems to be demanded. Columella in the centre of a small, almost bare circle, from the circumference of which fourteen septa project inwards like notches (and, when well preserved, are seen to extend inwards to the columella). Between two such circles there is a confused mass of very fine vesicular tissue in which septa and outer walls cannot be distinctly traced.

Distance between columellæ of adjacent corallites varying from 5 mm. to 10 mm.

One of the specimens is marked "Rownham Point," another "Leigh Woods." They are derived from the same horizon as the specimens of *Lithostrotion Portlocki.*

It is interesting to notice how similar are the horizontal sections of this species and of the one last described; the only difference consists in the well marked outer walls shown by the first described species.

Cyathophyllum.

Cyathophyllum Murchisoni, Ed. and H. (including part of *Cyathophyllum Stutchburyi*, Ed. and H. =*Strephodes multilamellatum*, McCoy).

Here I include *all* the elongate forms usually considered to be separable into two species (*C. Murchisoni* and *C. Stutchburyi*); but I exclude those short forms, previously referred to *C. Stutchburyi*, which have a broad convex rim with strongly projecting edge; these are transferred to *C. regium*. (Thus I consider Figs. 3, 3*a*, 3*b*, Pl. 33, and Figs. 2, 2*a*, Pl. 31 in the Palæontographical Monograph to belong to the same species, viz., *C. Murchisoni*, whilst Fig. 1*a*, Pl. 31 should, in my opinion, be separated and regarded as a simple form of *C. regium*.)

Some explanation is undoubtedly called for in making so radical a change, and this I give as briefly as possible. The following table gives the distinctive characters emphasized by the authors of the two species; those characters printed in italics were added subsequently to the definition of the two species, and first appeared in the Palæontographical Monograph.

	Shape.	External Rings of Growth.	Calyx.	Septa.	Tabulæ.
C. Murchisoni.	very long, slightly compressed.	mere ridges at nearly regular intervals of 5 m.m.	(not described).	nearly equal, more numerous.	very small, fairly remote.
C. Stutchburyi.	short or long.	very strong, at unequal intervals.	centre of floor frequently occupied by an elevation which has a depression at its top : rudimentary "fossula."	alternate, very straight, *stronger.*	*greatly developed.*

The calyx in *C. Murchisoni* is not described, as the figured specimen (Pl. 33, Fig. 3), which is preserved in the British Museum, had evidently been broken across whilst still in the rock, and the flat cross section, thus produced, was subsequently exposed and weathered. Exactly similar specimens (i.e. specimens exhibiting the same type of external rings and the same number and proportion of septa) with their calices well preserved are not by any means uncommon, and these show a shallow central depression surrounded by a broad flat rim ; the floor of the central depression may be almost perfectly flat, but it almost invariably exhibits a rudimentary fossula and, when the depression is considerable, a central elevation of its floor which bears a shallow depression on top is of very common occurrence. The only striking differences observable in the calyx are the presence or absence of this central elevation and the angle of slope of the rim from the outer wall to the boundary of the central depression. From an examination of hundreds of specimens, I am convinced that it is utterly impossible to separate the two species on differences in the calices, seeing that these differences vary continuously in degree, and that any particular type of calyx is found associated with every stage of difference in other respects.

Again, the external ridges vary from mere ornamental rings at fairly equal and close intervals up to a few strongly pronounced, funnel-shaped projections which clearly indicate the fact that they were the edges of earlier calices. The figure of *Strephodes multilamellatum*, given by McCoy, agrees very closely with Pl. 31, Fig. 2*a* of the Palæontographical Monograph which is specially drawn to illustrate the external form of *C. Stutchburyi*; but, seeing that McCoy's species is included by Ed. and H. under *C. Murchisoni*, it is unnecessary to dwell further upon the uselessness of the external annulation as a specific character. The slight compression noticed under *C. Murchisoni* is a common character of all elongate forms, and is not constant, even in the same individual.

The differences to be observed in the number, thickness and ratio of the septa are rather apparent than real; in *all* specimens the septa are markedly alternate, being made up of two series; all the septa forming the first series reach the centre, whilst all those of the second series stop short at approximately the same distance from the centre. (This is quite clearly shown in the figured specimen of *C. Murchisoni* and the fact is brought out in the drawing, though apparently contradicted in the text.) Again, when the septa are quite thick, their number is usually exactly the same as when thin (e.g., there are sixty-three primary septa in the type specimen, and I have counted the same number in fifteen other specimens which show every variation in thickness). The ratio of the diameter of the whole section to that of the inner area, radiated by a single-series of septa, is extremely variable and of no value whatsoever as a distinctive character.

So far I have dealt with all the characters upon which the two species were originally separated, and it seems impossible to arrive at any other conclusion than that the separation cannot be upheld. It is also to be remembered that both species were founded on the examination of specimens derived entirely from England and Ireland.

In their later work (the Monograph of British Fossil Corals, the authors introduce an important distinction founded on a supposed difference in the structure of the central area, and upon this they seem to place their chief reliance. Nothing could be more striking than the difference between the two types of structure shown in Pl. 33, Fig. 3*b* (a vertical section of *C. Murchisoni*), and in Pl. 33, Fig. 4 (a vertical section of *C. Stutchburyi*); but neither represents a normal type, common to a large number of specimens. The tabulæ are seldom so uniform as in Fig. 4, and, amongst the very great number of vertical sections which I have seen in collections or had cut from specially selected specimens, I have never seen this tabulate type continuous throughout the whole section, or, indeed, for any considerable distance. The much commoner tabulate type is that in which the tabulæ are separated by horizontal rows of broad horizontal vesicles which, as we proceed downwards, become more numerous, until the ordinary vesicular structure is reached. Again, Fig. 3*b* seems to be an extreme case of the vesicular type in which tabulæ are entirely absent (the thick double arches, shown at intervals in the figure, seem to correspond to the periodic variations in the density of the matrix which are of very common occurrence in all types); the normal type and the one which is to be seen in the great majority of specimens, at some point or other of the section, consists in broad bands of purely vesicular tissue, more or less horizontally arranged, separated at considerable intervals by one or more very short horizontal plates.

The fact that both structures occur together in the same vertical section, and that the common vesicular type is associated with every variety of external aspect and calyx, renders a specific separation based on this character utterly impossible.

The reasons for separating the short everted forms will be given under *Cyathophyllum regium* (v.i.).

The specimens in the Stoddart collection are very numerous, the greater number being polished sections, both horizontal and vertical. Amongst the uncut specimens there are examples of most of the common varieties, some of which show a flat calicinal floor, others a central elevation with a shallow depression on top and a deep fossula, whilst some show the elevation and fossula but no inner depression. The horizontal sections show every variation in the thickness of the septa and in the relative extent of the singly-septate area. The vertical sections are particularly interesting as showing the variability of the central structure and its independence of other characters. One such section, which is perfectly axial throughout its extent, is cut from a specimen exhibiting the characteristic close rings on its external surface and a calyx whose floor is perfectly flat. The central portion of this section, in its upper part for some distance below the floor of the calyx, is composed of very close tabulæ nearly 12 mm. in breadth, but this structure is succeeded lower down by the normal vesicular type in which short tabulæ, scarcely 2 mm. broad, occur at vertical intervals of about 6½ mm., and are separated by broad zones composed of row upon row of fine vesicles.

All the specimens are derived from the upper portion of the Carboniferous Limestone and chiefly from near the Point.

Cyathophyllum regium, Phill. (= *Astræa carbonaria*, McCoy).

This species has been considered by Edwards and

Haime to be a purely compound form, and this character, combined with the less numerous septa, has formed the only distinction between this and the preceding species. If, however, we examine the internal structure, we find that there is a practical absence of anything approaching a central tabulate area ; the central area is occupied by a confused mass of vesicular tissue, more or less regularly arched, the arches usually somewhat depressed at their summits.

Amongst the different forms of *C. Murchisoni* which I have had sectioned vertically were some of the short, broad, turbinate specimens, usually regarded as typical specimens of *C. Stutchburyi* ; these specimens, instead of showing a tabulate central area, exhibited a type of central area exactly similar to that shown by *C. regium.* Consequently, I am inclined to regard the broad, turbinate, simple cyathophyllums, with wide convex rims and scarcely any trace of external annulation, as the simple forms of *C. regium*, and in this opinion I am strengthened by the fact that such forms only occur at the horizon where *C. regium* is found, viz. at the very top of the series.

It is interesting to note how similar these simple forms are to the simple form of *C. helianthoides*, so common in the Devonian abroad, and as in that species, the number of septa in the simple form considerably exceeds that in the compound.

There are a few perfectly typical specimens of the compound form in the collection and one vertical section of a fine specimen of the simple form.

The specimens are undoubtedly from the uppermost beds, and, most probably, from the quarry on Rownham Hill.

Campophyllum.

As already pointed out in the discussion of the genus

Caninia, the genus *Campophyllum* embraces those simple cyathophyllids which have broad central tabulæ, in which there are no fossular depressions, whilst bilateral symmetry is only suggested by a very slight variation, in length or spacing, of the septa at one point in the septal ring.

The relationship of this genus to cyathophyllids of the type of *C. dianthoides*, McCoy, and to the genus *Diphyphyllum* is very close.

Campophyllum aff *Murchisoni*, Ed. and H. Pl. 1, Fig. 5.

Two specimens in the collection may be referred to this species, though the septa are less numerous than in the type. The one is a horizontal section, about 3 cm. in diameter, with a central tabulate area, 14 mm. broad, and a narrow outer ring, composed of coarse vesicular tissue bounded by a well marked outer wall. This outer zone maintains a constant width of about 8 mm. There are forty-four septa, short and approximately equal, which do not obviously extend across the outer vesicular zone and do not extend far, as striæ, over the central tabulate area. Bilateral symmetry is only suggested by a shorter septum at one point of the septal ring. Very short rudimentary intermediates project inwards from the inner wall.

The corallum is probably cylindrical, and its epitheca bears well-marked longitudinal striæ.

This specimen is figured, natural size ; it was probably derived from the uppermost beds.

The other specimen is a narrow cylindrical form cut in half vertically and polished at both ends, so that it exhibits both horizontal and vertical sections.

The horizontal section has a diameter of 23 mm. with a central tabulate area 10½ mm. broad. The narrow outer zone is composed of coarse vesicles and is indistinctly radiated by septal prolongations and by an intermediate septal series.

There are a little more than 40 septa.

The vertical section shows close, much broken, tabulæ in the central area which bend downward within the septal zone; the outer zone is occupied by a few (four or five) ascending rows of vesicles.

The locality is not indicated, but is probably the same as of the figured specimen.

Clisiophyllum.

This genus vies with Zaphrentis in its importance as a Carboniferous fossil group. The examples in the collection are, however, astonishingly few, when we consider how easily excellent specimens can be obtained in the Bristol district. I shall consequently defer an exhaustive examination of the group until I come to deal with a very much greater mass of material.

For the present, I include under Clisiophyllum the large number of new genera created by Thomson (partly in conjunction with Nicholson), and shall only briefly refer to such genera as sections.

Clisiophyllids allied to *Clisiophyllum urbinatum*, McCoy, Pl. 1, Fig. 6.

To this group may be referred four specimens.

The horizontal sections, not exceeding $2\frac{1}{2}$ cm. in diameter, have relatively large central areas (from $\frac{1}{3}$ to $\frac{1}{2}$ the total diameter). The central area is bisected by a strong meisal plate which extends almost completely across it; on either side of this plate there are a small number (usually six or seven, but often more) of short, prominent, radiating lamellæ, which traverse close, concentric rows of narrow vesicles.

Primary septa short, a little more than forty in number, with an inconspicuous secondary series which are very short and often rudimentary ; the outer vesicular zone is very narrow.

Two distinct mutations may be included here :—

(1) Short turbinate specimens with broad, everted rims, and (2) elongated, narrow, conical forms. In both forms the cup is deep and its floor is occupied by a large, rounded oval eminence with a prominent crest extending almost across it, whilst sharp ridges ascend the sides of the eminence towards the crest.

This assemblage of characters corresponds, in all essential points, with the definition given by McCoy of *C. turbinatum*, but the specimens he had under observation had a wider conical angle, and consequently exhibited a greater number of septa. On the other hand, it is evident that Edwards and Haime were only acquainted with the two forms I have alluded to above.

[The *rounded* central boss, the *extended* mesial crest and the more or less obvious concavity of the rows of vesicles, seen in the central area of a vertical section, mark out this group as members of the section *Dibunophyllum* (Nich. and Thom.)]

A small turbinate example is labelled "Upr. L. Shales, Ashton."

The figure represents, natural size, the horizontal section of one of the more elongate forms.

A Clisiophyllid perhaps belonging to the *Acrophyllum* section.

This is a horizontal section, with a narrow central area (about $\frac{1}{5}$ the total diameter) ; a strong mesial plate bisects the central area, and on either side of this plate are indistinct, spiral, concentric intersections.

The inner septal area is narrow and practically non-vesicular ; there are thirty-six strong septa.

The outer septal area is very broad and crowded with fine vesicles, whilst, between the primary septa, are a conspicuous series of secondaries which extend almost to the inner boundary of the broad vesicular area.

The specimen may be doubtfully referred to the section *Acrophyllum* (Thomson), but it is possible that the central area originally exhibited lamellæ which have been subsequently removed by solution. (In this case the specimen would belong to the section *Dibunophyllum.*)

Clisiophyllum, sp., or *Cyathophyllum*, sp.

There is, in the collection, a short, cylindrical specimen, cut across and polished, which cannot be definitely assigned to its correct genus until more material is at hand.

The total diameter is about 38 m.m., with a central tabulate area of 14 mm., which is surrounded by a prominent septal ring, a little over 4 mm. wide. The outer area (nearly 8 m.m. wide) is occupied by close vesicular tissue, crossed by delicate prolongations of the primary septa, as well as by an equally thin series of secondary septa.

There are sixty-four septa, which exhibit an almost perfect radial symmetry, bilateral symmetry being only suggested by the occurrence of two septa placed close together at one point. The vesicles are small and very regularly arranged, in radial rows, between the septa.

The nature of the central area is not very distinctly shown, but appears to be purely tabular. The outer vesicular area strongly suggests some member of the Clisiophyllid group, and it is possible that the specimen may be some member of the *Koninckophyllum* section (cf. Pl. 1, Fig. 3, vol. x., *Proc. Phil. Soc., Glasgow*), in which the central structure is almost purely tabular.

The specimen also bears close resemblance to *Cyathophylla* of the *dianthoides* section (cf. Pl. 3c., Fig. 7*a*, McCoy, Palæozoic Fossils), and is less clearly allied to the genus

Campophyllum. More material is required to definitely settle the relationship.

The specimen is from the uppermost beds ("marly bed behind the Colonnade").

Lonsdaleia.

Lonsdaleia floriformis, Fleming.

Several typical specimens, cut and uncut, are in the collection, derived from the uppermost beds.

The horizontal sections illustrate that form in which the central area shows a characteristic spongy structure, which is probably a subsequent result of solution and deposition upon the typical cobweb arrangement of radials and concentrics.

Lonsdaleia aff *rugosa*, McCoy.

A few poor specimens in which the corallites tend to separate and are cylindrical, with strong external swellings, may belong to this species, but, until they are sectioned, they cannot be definitely named.

MONTICULIPOROID.

Fistulipora.

Fistulipora aff *incrustans*, Phill. Pl. I. Fig. 1.

The only specimen in the collection is a polished slab, labelled Ashton, which exhibits both horizontal and vertical sections.

Horizontal section :—

Autopores almost or quite circular, with their walls of nearly uniform thickness and without any obvious septal projections.

The autopores are separated by one, two, or more rows of much narrower, polygonal mesopores which fit closely together.

The centres of the autopores are rather less than ·5 mm. apart, and the interspaces between them usually vary from half a diameter up to one diameter. There are however a few, much broader areas entirely composed of mesopores ("maculæ.")

Vertical section :—

The autopores are cylindrical and somewhat distantly tabulate ; the mesopores are very closely tabulate and usually separated by well defined walls, but, in many places, there are no definite separating walls between the mesopores, and consequently the autopores lie embedded, at such points, in a mere mass of vesicular tissue.

The corallum apparently formed thin, spreading, attached masses.

[In the absence of a marked trifoliate section to the autopores, as well as in the fact that no portion of their walls is very strongly thickened, the specimen deviates from the most typical members of the *Fistulipora* group and approaches near to *Heliolites* ; but the absence of regular septa and the frequent suppression of the walls between the mesopores renders it most probable that its place is with the Monticuliporoids rather than with the Corals. I have consequently referred the specimen to that species of *Fistulipora* in which the characters of the genus are least exaggerated.]

The figure shows the horizontal section magnified three times lineally.

III. DESCRIPTION OF THE BRACHIOPODS.

TERETRATULIDS.

Dielasma.

Dielasma hastata, Sow.

There is one specimen, labelled "Clifton," which has the typical form of Pl. 1, Fig. 3, Dav.[1] I feel rather doubtful whether this is really a local specimen.

ATHYRIDS.

Seminula.

Seminula ficoidea, n. sp., Pl. II., Figs. 1, 1*a*, 1*b*.

Valves convex, oval, smooth, often exhibiting strong concentric growth interruptions. Dorsal valve most convex under the beak; beak angle usually nearly a right angle, the valve margins being nearly straight on either side of the beak; usually a more or less prominent, broad, axial swelling which is, however, never distinctly marked off from the flanks; frontal margin usually continuously convex, but occasionally truncated. Margins of valves almost uniplanar. Ventral valve uniformly convex, with usually a shallow, ill-defined, axial groove, which is only conspicuous near the frontal margin. Beak prominent with a large foramen; the lower lip of the foramen is recurved (spout-like) over the umbo of the dorsal valve. Spiral arms conspicuously and characteristically shown in weathered specimens and in sections. Shell structure apparently purely fibrous, but occasionally punctations are suggested.

Affinities.—So close are some of the commonest forms found in the Bristol area to *S. ficus*, McCoy, and to *S. virgoides*, McCoy (see Pl. 3D, Figs. 22 and 23, Palæozoic Fossils), that it would be unnecessary to create a new species, were it not that the shell of our species seems to differ essentially in structure from that shown in McCoy's figures (22*a* and 23*d*, *loc. cit.*). (I am, however, far from convinced that some of our specimens do not exhibit the punctated type of structure, and, furthermore, the preservation of the shell usually leaves much to be desired.)

[1] Dav. is used throughout as an abbreviation for *Davidson's Monograph of the Brachiopoda, Carboniferous Section*, Pal. Soc.

The presence of spiral arms is clearly illustrated by two polished sections in the collection, and is exhibited by hundreds of chance sections and by weathered specimens in the rocks themselves, throughout the Bristol area. It seems indeed most probable, judging by the great similarity of form to our specimens, that both McCoy's species are true athyrids (i.e. really possessed spiral arms), notwithstanding the fact that both he and Davidson fix upon *D. hastata* as their closest relative. However this may be, there is no doubt that the myriads of individuals which teem in the middle beds of the Carboniferous Limestone series, throughout the Bristol area, are true athyrids, whilst possessing the form shown in Figs. 12, 13, 14, 15, Pl. 1., Dav.

Probably the commonest form is one like Pl. 1., Fig. 14, Dav., but less elongate ; there is, however, every possible gradation of shape within the general limits laid down in the definition.

Some mutations closely resemble the figures of *Seminula subtilita*, Hall, but, in our species, there is seldom any marked deflection of the frontal margin, whilst the foramen is usually larger.

Another common mutation, in which the athyrid characters are more prominent and the relationship to *S. ambigua*, Sow, somewhat strongly suggested, is represented in our figures.

The figured specimen is labelled "Middle Limestones."

Nearly all the examples in the collection are from the Great Quarry ("Middle Limestones"), and include very characteristic slabs of shale, from the lower beds of the quarry, crowded with crushed specimens. Two polished slabs of limestone, labelled "Terebratula Bed, 2nd Tunnel," exhibit good sections of the spiral arms.

There are several small specimens from Weston-super-Mare, some of which are apparently the very young stage of this species ; others are more transverse, with a more distinctly bounded mesial fold, and indicate a further transition towards the *ambigua* type.

Cleiothyris.

Cleiothyris Royssii, L'Eveillé.

There are a large number of good specimens in the collection, derived from the well-known horizon ("40 ft. below the Palate Bed"). They exhibit the characteristic fringes and agree well with Pl. 18, Fig. 8, Dav.

A *mutation*, Pl. 2, Fig. 2.

Specimens derived from somewhat higher beds closely resemble Pl. 18, Fig. 3, Dav.; they have always lost their fringes, but usually exhibit close concentrics, more or less crossed by faint longitudinal striæ. The beak is usually broader and the perforation larger than in the forms found lower down. In the absence of the characteristic ornament, such specimens can only be distinguished from *Athyris planosulcata*, Phill., by the larger beak, less sloping shoulders, and by the presence of a mesial fold.

The figured specimen from the "Lower Limestone Shales" shows strong, concentric interruptions of growth and traces of faint longitudinal striæ on one side. The usual concentric ornament is inconspicuous.

There are, besides this specimen, three or four others (poor specimens) which are derived from the "Lower Limestone Shales" or from the "Black Rock."

SPIRIFERIDS.

Spirifer (Sensu stricto).

Group of *Spirifer bisulcatus*, Sow.

This large group may be considered to include all spirifers which exhibit the following characters:—

In the dorsal valve, a prominent, rounded mesial fold, separated from the flanks by more or less pronounced grooves; the ribs on the fold divided into two or three groups by strongly marked grooves ; the ribs on the flanks normally simple throughout their course (i.e. no doubling of ribs, either by splitting or by intercallation), with the exception of the two ribs on either side of the fold in which splitting is the normal rule ; margin of fold truncated.

In the ventral valve, the sinus is, at first, usually composed of a single, buried rib with a strongly projecting rib on either side ; the number of ribs in the sinus gradually increases, with age, by the repeated splitting of these side ribs, whilst, at the same time, the boundaries of the sinus become less and less distinct. The ribs on the flanks are simple and continuous, as in the dorsal valve, but occasional splitting is less infrequent than is the case in that valve. The hinge line is, as a rule, at least as long as the greatest width of the shell.

By this definition we connote a group rather than define a species, for, by variations in the convexity and dimensional ratio of the valves, as well as by alterations in the nature and spacing of the ribs, we can produce an almost endless series of distinct forms. Two such mutations occur, in enormous abundance, in the lower part of the Carboniferous Limestone series of the Bristol area, both of which are characterized by fine ribbing. These I shall denote simply by the letters B^1 and B^2.

Mutation B^1 (=*Spirifer* aff *clathratus*, McCoy). Pl. 2, Fig. 3.

Ventral valve very convex ; ribs somewhat close together and a little flattened ; there is usually (especially in middle age) a short wing on either side of the hinge line, but the general contour of the valve is, in middle age, nearly semicircular, becoming still less transverse when full grown.

When full grown, this mutation bears a strong general resemblance to *Spirifer cinctus*, A de Keyserling[1] but the

[1] De Kon, *Bull. musée Royal Belg.*, 1883, Pl. 15, Fig. 4.

fact that, in this species, the hinge line is normally less than the width of the shell makes it easy to distinguish from our form by a comparison of the growth lines, whilst there is no trace in the mutation B^1 of the fine longitudinal striation on the ribs which characterizes the foreign species.[1]

The smaller specimens closely resemble *S. clathratus*, McCoy, with which they agree exactly in shape, convexity and fineness of ribbing as well as in the narrowness and depth of the sinus and in the small number of ribs on the fold. [That McCoy's species belongs rather to the group of *S. bisulcatus* than to that of *S. striatus* has been pointed out by Mr. J. Wright (Dav., p. 221)]. Our mutation seems to differ, however, in the infrequency of split ribs on the flanks ; but though McCoy cites this as a character of his species, his figure does not appear to bear him out, as not more than two of the flank ribs show any tendency to splitting. The fact that the fine reticulate striation of the ribs is not noticeable on our specimens may easily be due to their poor state of preservation.

McCoy states that his species grows to the size of *Spirifer giganteus*, a remark which applies equally well to our mutation.

The figured specimen is the ventral valve of a full-grown specimen from the Black Rock Quarry ; it shows a trace of the side wings which characterized its middle age ; the number of split flank ribs is greater than usual. The figure also illustrates how shallow and indistinctly bounded the sinus becomes in old age.

There is one other specimen in the collection.

Mutation B^2 [= part of *Spirifer attenuatus*, McCoy (non Sow),] Pl. 2, Figs. 3, 3*a*, 3*b*.

This mutation is well characterized by its usually trans-

[1] The relationship of this mutation to *Spirifer tornocensis*, de Kon, is, for the present, deferred.

verse and attenuate form, the lateral valve-margins being almost straight, so that there are no side wings. The mesial fold and sinus are of the typical Bisulcate type, and are always strongly defined ; the ribs are always sharp and very distinct. McCoy clearly included in his definition both this form and the true *Spirifer attenuatus*, Sow. The latter is easily separated from our mutation by its large number of ribs on the mesial fold and by the similarity of their nature and grouping to those on the flanks (cf. Fig. 12, Pl. 2, Dav., and Fig. 12, Pl. 14, de Kon, *loc. cit.*).

Pl. 6, Fig. 18, Dav. apparently represents a form which somewhat closely resembles that under description.

When quite young, this mutation is remarkably transverse, but, with age, the growth axially outstrips the growth transversely, so that we often meet with examples in which the axial exceeds the transverse dimension ; such examples are often labelled *S. mosquensis*, Fisch, though agreeing in no other character whatsoever, except the dimensional ratio (e.g. *S. mosquensis* has a very finely ribbed mesial fold, whilst our form has a typically bisulcate fold, etc., etc.)

Fig. 3*a* is a solid specimen showing three groups on the mesial fold, each group splitting into two.

Fig. 3*b* illustrates the type in which there are two groups only, and the splitting takes place rather late. Both figures show excellently the splitting of the two ribs on either side of the fold.

Fig. 3*c* shows a characteristic ventral valve. This specimen has already been figured by Stoddart in a serial work, the Palæontologia Bristoliensis (a work of which only two numbers were ever published) ; he refers it to *Spirifer striatus* var *attenuatus*, Sow., and gives an unsatisfactory description of extremely wide application.

There are a large number of specimens in the collection, illustrating both mutations ; they are derived from the "Lower Limestone Shales" and the Black Rock Quarry.

Spirifer bisulcatus, Sow.

A single specimen illustrates the normal type with coarse ribbing (cf. Pl. 6, Fig. 15, Dav.). It is labelled "Lower Limestone."

Spirifer crassus (?), de Kon.

A large specimen, with a short hinge line, and ribbing somewhat of the type of Fig. 20,Pl. 6, Dav.,but with a more produced fold, may perhaps belong here, though it differs very considerably from the figure and description given by De Koninck (Pl. 15 bis. Fig. 5, Carb. Foss. of Belgium).

Spirifer pinguis, Sow., is represented by a single small specimen from Clifton.

Spirifer ovalis (?), Phill., is doubtfully represented by a partially exposed ventral valve which shows broad, indistinct, rounded ribs. The only interest of this specimen is that it is derived from the uppermost beds ("N. end of Colonnade, Hotwells").

Syringothyris:

Syringothyris cuspidata, Martin.

Large typical specimens from the Black Rock Quarry, cf. Pl. 8, figs. 21 and 24, Dav., are represented in the collection. One specimen, in which the shell is partially removed from the mesial fold, exhibits characteristic deep grooves, corresponding to internal septa.

Martinia:

Martinia glabra, Martin.

A specimen from the "Lower Carboniferous, Clifton," agrees with Pl. 11, fig. 3 Dav., whilst suggesting the type of ribbing shown in Pl. 12, fig. 3, Dav.

Reticularia:

Reticularia lineata, Martin.

A broad, flattened, reticulated specimen, labelled *Athyris* *expansa*, probably belongs here, as it shows a weak area and a broad shallow fold. Cf. Pl. 13, fig. 4, Dav.

A second decorticated specimen, in a poor state of preservation, is most probably also an example of this species.

RHYNCHONELLIDS.

Rhynchonella (sensu stricto):

Rhynchonella pleurodon, var *Davreuxiana*, de Kon.

Small Rhynchonellas, with sharp continuous folds, a deep sinus containing two buried ribs and a strongly projecting mesial fold, composed of three sharp angular ribs, agree fairly well with Pl. 23, fig. 19, Dav., but are usually considerably more elongate.

A more exhaustive discussion of the forms must be based on better and more numerous examples than are to be found in the collection. This form is extremely abundant in the lowest beds of the " Lower Limestone Shales " ; the specimens in the collection are all only partially exposed on the surface of slabs, derived from " Lower Limestone Shales, Leigh Woods," and from the well-known "*Buchiana* Bed."

Pugnax:

Pugnax accuminata, Martin.

A single specimen from " Lower Carboniferous, Clifton " agrees with Pl. 21, figs. 4 to 13, Dav. It has three angular folds on the mesial fold.

Pugnax reniformis, Sow., agrees Pl. 19, fig. 3, Dav.

Pugnax pugnus, Martin, agrees Pl. 22, fig. 2, Dav.

STROPHOMENIDS.

Leptena:

Leptena analoga, Phill.

Two poor, but unmistakable specimens occur in the collection, one being from the horizon of the "*Bryozoa* Beds."

Orthotetes (*Streptorhynchus* of Davidson's Monograph)

Orthotetes crenistria, Phill.

Considering the enormous abundance of this form and its mutations in the Carboniferous Limestone series of the Bristol area, the number and variety of the specimens in the collection are extremely disappointing; furthermore, the few specimens which are preserved in it are all from approximately the same horizon, namely, from the "Lower Limestone Shales." No purpose would be served by a detailed description, the only satisfactory specimens being examples of those with a strongly convex small valve and a markedly resupinate beak-value.

ORTHIDS.

Schizophoria:

Schizophoria resupinata, Martin.

A single, small but perfect, specimen is in so complete a state of preservation as to render the locality "Clifton" a little doubtful (all the specimens I have seen from the district, where they often occur in thousands, are impossible of complete extraction).

Rhipidomella:

Rhipidomella Michelini, L'Eveillé.

A single valve, and a partially buried example from "Lower Limestone Shales, Cook's Folly," are the only specimens in the collection.

PRODUCTIDS.

Productus:

Productus sp.

This small species has affinities both to *Productus acu-*

leatus, Martin, and to *Productus muricatus*, Phill., but is quite distinct from either ; since, however, its characters cannot be completely defined entirely from the specimens in the collection, I defer a detailed description to a more fitting place, where I can include the large number of specimens I have myself collected, with the express purpose of completely defining this very interesting form.

The few specimens in the collection are derived from the "Lower Limestone Shales."

Productus martini, Sow.

A single specimen containing a group of examples (cf. Pl. 43, fig. 7. Dav.) represents this very characteristic form in the collection.

Productus elegans, McCoy, is represented by a single specimen.

Productus semi-reticulatus, Martin, is represented by a very few indifferent examples.

Productus (*Marginifera*) *longispinus* (?), Sow.

This species, which has given its name to a particular horizon in the lower part of the Great Quarry, is only represented in the collection by a small piece of shale which exhibits a few long spines scattered over its surface. I consequently defer for the present the inquiry as to the relationship which the form found at Bristol bears to the more normal type found elsewhere.

Productus aff. *Cora*, d'Orb. Pl. II. fig. 4.

I here figure a specimen of the form usually accepted as representing *Productus Cora*, in order to illustrate the nature of the ribbing and the type of cross wrinkling. The specimen agrees very well with specimens in the Davidson collection which are included under this species.

The most noticeable features are the two distinct zones at which intermediate ribs start and the rapidity with which these intermediate ribs acquire the size of the primary series. I defer the necessary discussion of the relationship of these forms to wrinkled examples of *Productus hemisphericus*, Sow, with which they are very usually confused.

Producti of the *giganteus* group.

The specimens in the collection being very few and very poor, there is no need, in this place, to enter upon the most difficult of all the questions which cry for solution, viz. the relationship of the various mutations, at present included under the loose specific name *giganteus*, to each other and to nearly related forms.

Productus scabriculus, Martin.

Fragmentary specimens, probably belonging to this species, from beds usually classed as Millstone Grit, are represented in this collection. They have been derived from grit beds " Behind the General Draper," i.e. above the top of the recognized Carboniferous Limestone series.

Chonetes:

Chonetes Buchiana, de Kon.

There are numerous specimens, crowding slabs from the well-known horizon in the " Lower Limestone Shales." These have already been figured by Davidson (Pl. 55, fig. 12).

Chonetes Hardrensis, Phill.

Slabs covered with a mutation of this species (near *Chonetes polita*, McCoy) have been derived from the " Lower Limestone Shales " and from the Black Rock Quarry.

Chonetes aff. *comoides*, Sow., and aff. *papilionacea*, Phill.

The vast abundance of this form in the rocks themselves, and its representation in the collections by a single specimen are sufficient excuse for deferring any discussion of its relationship in this place.

INARTICULATE BRACHIPODS :—

Discina :

Discina nitida, Phill, is represented by several specimens from the " Palate Bed " of quite typical form (cf. *Discina bulla*, McCoy).

Lingula :

Lingula mytiloides, Sow., is represented by several poor specimens of the mutation *Lingula parallela*, Phill. from the " Palate Bed."

Lingula Scotica. To this species I refer a partially buried specimen from just above the " Palate Bed."

IV. SUMMARY.

The most interesting results arrived at in this paper are as follows—

A. THE CORALS.

(1) The description of a new species of *Chætetes*.

(2) The identification of a species, common in the lower beds, with *Cleistopora geometrica*, Ed. and H.

(3) The re-introduction of the genus *Caninia* to cover the group typified by *Caninia* (*Zaphrentis*) *cylindrica*, Scouler, and a description of the well-known Bristol mutation.

(4) The reasons for regarding the well-known Bristol form as a mutation of *Lithostrotion basaltiforme*, Phill.

(5) The inclusion of the elongate forms of *Cyathophyllum Stutchburyi*, Ed. and H. with *Cyathophyllum Murchisoni*, Ed. and H., and the separation of the short,

turbinate, everted forms which are here regarded as the simple form of *Cyathophyllum regium*, Phill.

(6) The detailed examination of the group typified by *Clisiophyllum turbinatum*, McCoy, and a description of the common Bristol forms.

(7) A description of a very interesting new form either of *Cyathophyllum* or *Clisiophyllum.*

B. The Brachiopods.

(1) The separation of Athyrids closely resembling, in external form, *Seminula ficus*, McCoy (*Terebratula hastata* var. *ficus* of Davidson), under a new specific name *Seminula ficoidea.*

(2) A detailed description of the Bisulcate Spirifers common in the Bristol area, and a discussion of their relationship to allied forms.

(3) The commencement of a more detailed examination of the great group of longitudinally-ribbed Producti.

PLATE 1.

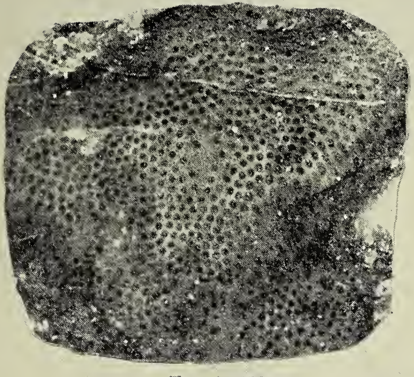


FIG. 1. X°3.

FIG. 5.

FIG. 6.

FIG. 3

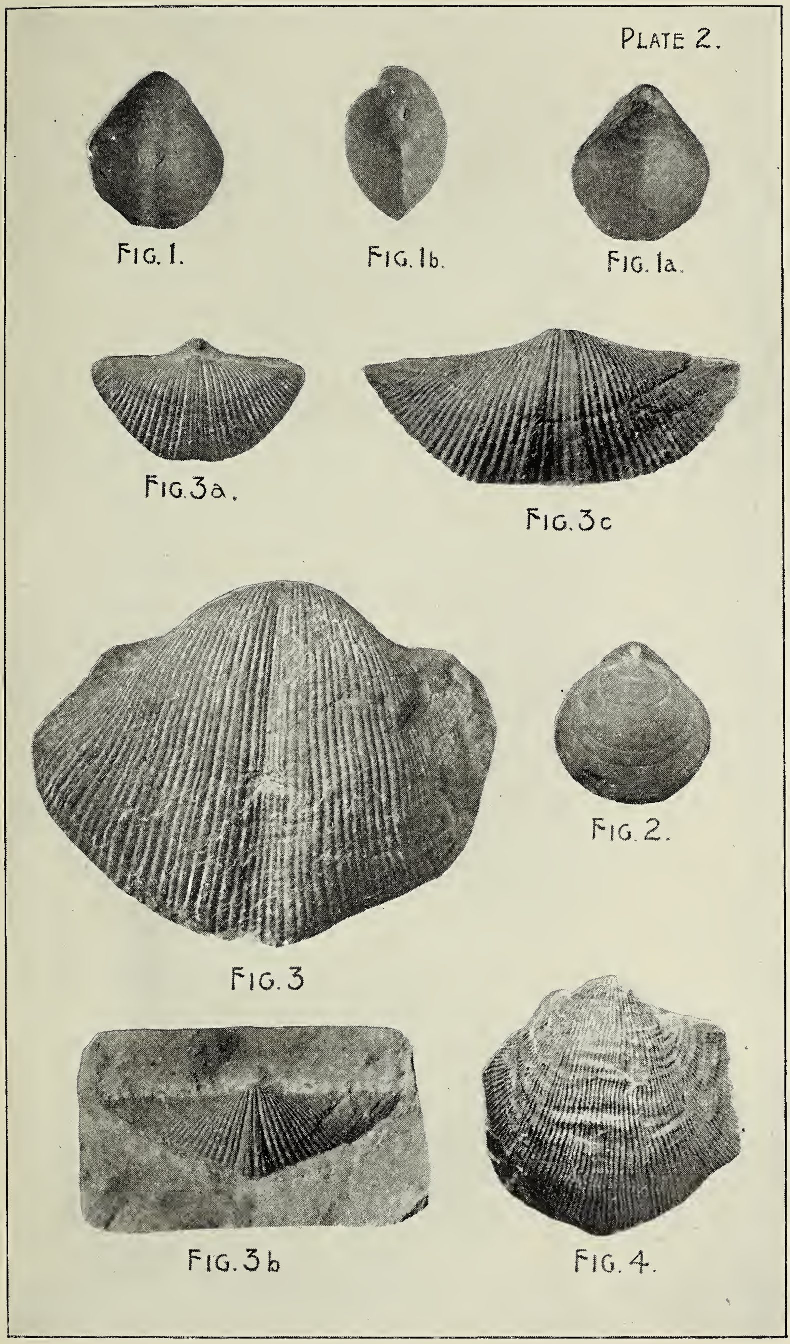
FIG. 2

FIG. 4.

CARBONIFEROUS CORALS.

1. *Fistulipora* aff. *incrustans*, N. & F.
2. *Chætetes bristoliensis*, n. sp.
3. *Cleistopora geometrica*, Ed. & H.
4. *Caninia cylindrica* var. *bristoliensis*.
5. *Campophyllum* aff. *Murchisoni*, Ed. & H.
6. *Clisiophyllum turbinatum*, McCoy.

To face p. 134.



CARBONIFEROUS BRACHIOPODS.

1. 1a, 1b. *Seminula ficoidea*, n. sp.
2. *Cleiothyris Royssii, L'Eveillé* (a mutation).
3. *Spirifer* aff. *clathratus*. McCoy. 3a, 3b, 3c. *Spirifer bisulcatus*, Sow. (a mutation).
4. *Productus* aff. *Cora*, d'Orb.

To face p. 134.

On the Cotham Marble.[1]

By A. RENDLE SHORT, B.Sc.

Bibliography

I "Observations on the Earths, Rocks, Stones and Minerals for some miles about Bristol." Owen, 1754.

II "Geology of East Somerset" (*Geol. Surv. Mem.*). H. B. Woodward.

III *Geological Magazine*, 1892, p. 110. H. B. Woodward.

IV *Jurassic Rocks of Britain*, vol. v. p. 230. H. B. Woodward.

V *Geological Magazine*, 1899, p. 77. H. B. Woodward.

VI *Q. J. G. S.*, 1894, p. 393, Beeby Thompson.

CONTENTS

A. General Description.

THIS rock occurs in irregular lenticular patches varying from one to twelve or more inches in thickness, from Bristol to Uplyme, in Devon, reaching the coast between Axmouth and Lyme Regis. The patches are usually only a few feet in length, but stone of similar texture, without the characteristic arborescent

[1] This communication is a short abstract of a rather lengthy essay, and the condensation that is necessary must be my apology for its baldness.

markings, may form very continuous bands; and at Redland and Stoke Gifford, patches of perfectly typical Landscape Marble, respectively 20 yards and 100 yards in length, have been exposed.

Its geological horizon is at the top of the Rhaetic series just below the White Lias, and separated by clays and limestones from the Black Shales. It is at the horizon of special abundance of *Monotis decussata*, which fossil abounds in the less pure shelly forms of the marble. *Modiola minima* is usually more abundant. The other fossils are *Chemnitzia nitida* (Moore) *Rhynchonella calcicosta*, *Axinus* sp., and among fish *Pholidophorus nitidus*, *P. Higginsi* (Strickland), and *Legnonotus Cothamensis* (Egerton), the above being represented by complete specimens, while *Sphaerodus minimus* and *Saurichthys apicalis* are represented only by teeth. The elytra of beetles and insect wings are also found.

A general description of the stone itself is scarcely necessary after Thompson's excellent account (VI). A few points may however be mentioned.

In Vertical Section.

The stone consists of :—

(a) *Basement beds*, of very variable thickness. The thicker bands are usually paler. Bands often die out in a way that recalls current-bedding.

(*b*) *The "Hedge"*—a row of dark close-set projections from ¼ to ½ an inch high. Each of these projections is *concentrically ringed.*

(*c*) *The "Atmosphere" and "Trees."* The "trees" are usually freely branched above, and always rise from the bottom to the top, as may easily be verified by dissection, though this is often concealed by their obliquity, some *appearing* to have no stem, and others no top, if they are examined only in one plane. The "trees" and "branches" are concentrically ringed. They are harder and darker than the atmosphere, and stand out in weathered specimens. The " atmosphere " is light coloured and usually of coarser texture ; it is horizontally banded, the bands usually rising to the " trees " at their tops, a point on which Thompson lays great stress. But at the bottoms of the trees they do *not* so rise, and occasionally even slope down a little.

(*d*) " *Islands*." In the upper part of the " atmosphere," dark circles, $\frac{1}{4}$ inch across, are often found which are *not attached to any* " *tree*," but are completely isolated from every other dark band. This can be proved by dissecting them out, and examining the cube so extracted on each of its six sides and observing no dark bands in it at all. The importance of these will appear later.

(*e*) *The* " *Canopy*." This presents a hummocky upper surface, the arrangement being not so much in round bosses as in interlacing ridges. The layers composing it resemble the basement beds. The lowest ones are thick between the trees, and thin over them. Unless the canopy is fractured, the trees rise *under* the hummocks, not between them.

The Horizontal Section (fig 1) Shows the surprising fact that the " trees " are not cylindrical columns, but the expression, in section, of vertical walls arranged polygonally. I have examined hundreds of specimens for this point, and find it quite constant. Indeed, many of my specimens show it better than the one figured.

Texture.—The most characteristic feature of the Cotham Marble is its peculiar texture. The colour, almost conchoidal fracture, hardness, and very fine grain and high polish are unmistakable. It is an important point that the " atmosphere " always shows these features least perfectly, and often not at all, being sometimes an ordinary shelly limestone.

Thompson says the " trees " are usually aragonite, coloured by carbon. Teall describes the rock as composed of " extremely finely granular calcite with a few very small grains of quartz. In the landscape there are patches of clear and coarsely crystalline calcite" (veins). With two of Thompson's observations I cannot concur. He says we cannot have " trees " without hummocks, but that we can have hummocks without " trees." Examples of the first are however common, but in a somewhat extended experience I have never seen the second.

Special Varieties of Cotham Marble.

I. *True or typical forms of Cotham Marble.*

(*a*) *Double Cotham Marble,* and

(*b*) *Triple Cotham Marble* are fairly common. The intermediate canopies are usually flat.

(*c*) " *End Cothams.*" By this I mean the terminal piece of one of the lenticular masses. The " trees " are usually not deflected in. The " canopy " creeps half way down the landscape, and the space between it and the basement is filled with a mass of " branches." The landscape is very coarse and shelly. The whole slopes off at an angle of about 45°.

II. *Atypical Forms of Cotham Marble.*—These are, I believe, essential for a true understanding of the method of formation of all varieties.

(*a*) *False Cotham Marble* (Fig. 2). This occurs at Aust, Redland and elsewhere, and passes laterally into the true Cotham, or Landscape Marble. It is never found on any other horizon. It consists of a confused mass of slabs having the characteristic Cotham texture, with parallel banding and occasionally a tiny " hedge, "embedded in a shelly limestone. In the most elementary forms of False Cotham Marble these slabs take the form of horizontal bands separated by layers of shelly limestone. The confusion is rarely so extreme as in the specimen figured. The slabs are usually straight, but in specimens from one locality at Redland they are often curved somewhat. Sometimes spherical concretions, of the typical texture, are found embedded in these masses of False Cotham Marble. The matrix *between large slabs* and *inside shells* is often less shelly and even approximates to the true Cotham texture.

Many bars of the False Cotham Marble bear a " hedge " ensheathing their upturned ends. They never bear " trees."

(*b*) *Mixed Forms* (Fig. 3), combining the features of the Landscape and False Marbles also occur. In these the " trees " are always thick and straight, and the " atmosphere " coarse and shelly. The bars of False Cotham Marble are often " hedged " at their upturned ends.

(*c*) *Spherical Concretions* (Fig. 4).—These are not very common, but show the typical texture, and usually " hedging." They are beautifully concentrically banded.

(*d*) *Simple Horizontally-banded Beds* of the typical texture, about 2 inches thick, present the simplest form of all.

I propose to include all the above under the name of " Cotham Marble," reserving the designation " Landscape Stone " for the form showing " trees."

Similar Structures from other Horizons.—H. B. Woodward has collected several, e.g. from the Purbeck, Inferior Oolite, and even Carboniferous Limestone. These show banding, and a " hedge," and an upper surface rather like the Landscape Stone. They appear to be concretionary in origin (see figures in Woodward's papers).

B. Previous Theories as to Mode of Origin.

i. *Owen's Theory*—that the markings were due to bubbling of entangled gases from the darker lower layers. This has been revived by Thompson, and is criticized later.

(Thompson seems to think Owen's theory was not the same as his own, and that the dark layer referred to was the Black Shales. This scarcely appears to be Owen's meaning).

ii. *The Mineral Infiltration Theory*—but the dark matter is carbonaceous, not metallic.

iii. *Rev. Osmund Fisher's Theory*, that "thicker layers of rotten plants gave way under the superincumbent tufa, which broke down, and the carbonaceous mud was forced up." This fails to account for the concentrically banded branches, hummocky surface, and many other details.

iv. *Mr. H. B. Woodward's Theory.* "The arborescent markings were produced during the consolidation of the stone, and more particularly by the shrinking of its upper portions. In this way, and while the mud was still in a more or less pasty condition, one or more of the dark films in the banded mass were disarranged and dispersed in an arborescent form in the slowly setting rock." This took place in an ooze, "occasionally exposed to the sun's rays." He admits that he may have "appealed too strongly to mechanical causes as apart from the obscure processes of segregation or even of concretionary action."

There are many inadequacies in this theory. Why should the upper layer be dry whilst the lower was fluid? Why was the fluid forced only *up*, not *down* as well? How could this produce the concentrically banded "hedge"? Why are the "branches" rounded and concentrically ringed, instead of tailing out into finer and finer arborizations, as they would if filling cracks? The theory also fails to account for "islands," gives no explanation of the extraordinary hummocky surface, and is totally at a loss to explain the False Cotham Marble.

I have performed one or two experiments with wet powdered chalk resting on a mixture of oil, soot and chalk; the whole carefully dried under a weight of 3 lbs. and then cut into and examined. This presents a drying layer on a fluid one, but the black fluid does not rise into the cracks of the chalk cake at all; i.e. there were neither "hedge" nor "trees."

v. *Mr. Thompson's Theory.*—That the "trees," "hedges" and "hummocky" surface were due to bubbling off of gases from the dark band in which the "hedge" arises, carrying up the dark stuff.

Objections are the *concentrically ringed* "branches," often directed horizontally, or even downwards from the "trees"; the presence of "islands"; and especially the fact that in horizontal section the "trees" are seen to be not cylindrical columns but polygonal walls. Moreover, his chief argument rests on a fallacy, for he lays great stress on the fact that the "atmosphere" rises to the "trees." So it does at their tops, but not near their bases, where it is usually horizontal, and occasionally even falls a little.

He advanced some experimental evidence, under somewhat abnormal conditions, in support of his theory. I have modified these as follows:—take equal parts of oxalic acid in powder, soot, and sodium bicarbonate, mix, lay at the bottom of a basin, and smooth. Cover with a layer ½–1 inch thick of precipitated chalk, and smooth. Pour on water (over a filter paper, so as not to disturb). These conditions are I submit much more natural. Ebullition takes place, and columns of black stuff are carried up and spread out on the top. Dry gently, when sections can be cut. These show no resemblance to the Cotham Marble. The only hummocks formed are the outpoured soot. There is nothing like either "hedge," "branches," or polygonal walls. Thompson suggested that the hummocky surface was supported by air-bubbles, quoting the analogy of a copper-zinc couple under water, but surely no bubble could support such thick masses, often an inch high, and as soon as it burst the hummock would collapse.

C. A New Theory of the Cotham Marble.

I. I believe the Cotham Marble to have had a *Chemical Origin*, for the following reasons.

i. *The texture and composition of the stone.* From these, Thompson also deduces a chemical origin. The purity, the freedom from mud, and the uniformly grained very finely crystalline structure all suggest this. Other chemically formed bodies, e.g. urinary calculi, present just the same microscopical appearance.

ii. *The nature of the slabs, of the typical texture, in False Cotham Marble.* These were obviously once horizontal, in the midst of a calcareous ooze, and yet were so dry and brittle that when disturbed they broke up rather than bend. Only in one locality is there even slight bending. Now it is well known that a crystalline or chemical deposit hardens rapidly ; not so a product of drying. Moreover, in the wet ooze *dried* layers would soften ; only chemically formed ones could remain brittle.

iii. *The presence of spherical concentrically banded concretions* of typical texture in the same horizon, often showing "hedge-structure" and even found embedded in the False Cotham Marble. It is well recognized that spherical concretions *must* be chemical. The imitations of Cotham Marble from the Purbeck and Oolite also seem to be concretionary. Every writer on the subject has acknowledged how like the "canopy" is to a concretion.

Sometimes these concretions enclose pale bluish-white baryto-celestine in large crystals, which has evidently crystallized out subsequently *in situ*.

iv. *The Analogy of Urinary Calculi*, especially those formed of calcium oxalate (Fig. 5). These present :—

(*a*) The exact texture, polish, hardness and grain that characterize the Marble.

(*b*) The uniformly finely crystalline structure.

(*c*) The delicate banding.

(*d*) The darkness of the thin bands, and paleness of the thicker ones, as a general rule. This is due in each case to the inclusion of a *constant* amount of pigment in a *variable* amount of precipitate. Abundant precipitation involves a thick, pale band, and vice versa.

(*e*) But *especially*, the presence of typical "hedge-structure." (See fig. 5.) So marked is this that these stones are called "Mulberry Calculi." The "hedge" in both is dark coloured and concentrically ringed. The importance of this analogy is that we *know* that calculi are chemically formed.

"Hedge-structure" is not peculiar to the Landscape Stone and calculi. It also occurs in "fortification-agate, malachite, and stalactites. It is the hall-mark of a chemical origin.

v. *Modern Analogies*. At the mouth of the Rhone, a crystalline calcareous deposit is found, due to evaporation of the lighter river water spread out on the surface. (See Geikie, *Textbook of Geology*, p. 453.) Carbonate of lime is only precipitated when $\frac{17}{18}$ of salt water have been evaporated (Bischof, *Chemical Geology*, I. p. 178). Near Nice, a hard varnish-like crust of carbonate of lime is deposited over rocks within reach of the sea, due to rapid evaporation.

I have noticed on our own coasts, e.g. at Tintagel (in the Devonian slates), that in shallow rock pools a layer of hard white calcareous deposit up to $\frac{1}{4}$-inch in thickness forms *all over* that area which is covered by water when the pool is nearly or quite full. The lustre, grain, and appearance strongly suggest Cotham Marble. It appears to be due to loss of carbon dioxide, owing to the heat of the sun, combined with a little evaporation, precipitating the carbonate held in solution by that gas. It is not due to evaporation alone beyond the $\frac{17}{18}$, because it nearly completely lines the pool.

Experiment with a solution of carbonate of lime held by carbon dioxide, and warmed to 35° for an hour, shows how a little carbonate can thus be precipitated, especially if evaporation is allowed.

Now the Cotham Marble may have been deposited (1) in an estuary, as in the Rhone deposit, or (2) in an evaporating Dead Sea, or (3) in a very shallow lagoon by a process like that at Nice and Tintagel. I incline to the last hypothesis. A study of the other members of the Rhaetic series has convinced me that they are not estuarine, and the abundant life, and rarity of gypsum and salt, preclude a Dead Sea. This subject will be returned to later.

II. *Explanation of the "Hedge-Structure."*—This is formed as follows (referring, for simplicity's sake, to the calculus). After a period of free deposition, the calculus is smooth, hard and spherical. Then comes a period of scanty deposition. The bands laid down are therefore darker (see above). These thin impure bands, when first laid down, are not hard and solid like the foundation they rest on, but have to contract to attain their final condition of firmness. But as the calculus will not yield, they have to crack into squares. When the next coat is laid down, it has to follow the surface it finds, and rounds off the angles and exaggerates the hummocks. Every fresh layer follows suit, provided it is very thin.

It may be objected that the individual "hummocks" are too far apart for such an origin in the case of Cotham Marble. But they are sometimes even farther apart in calculi. We have no data to show us how far away from one another the hummocks *would* contract in setting. Probably, too, some of them are dissolved off entirely in the intervals between deposition. Branching of the "hedge" is similarly produced.

III. *Detailed Account of the Origin of Cotham Marble.*

During hot, calm summer weather, the waters of a very shallow but extensive lagoon, only a few inches deep in places, were so heated that by loss of carbon dioxide, and evaporation, carbonate of lime was precipitated, and shortly set into a firm layer at the bottom. Band after band followed, and thus the whole of the basement beds were laid down. In some places, spherical concretions were laid down instead, owing probably to the existence of some calcite nucleus of detrital origin.

Then came autumn and winter, and with them—(*a*) less sun heat, (*b*) more rain, i.e., less deposition of the calcite, and (*c*) more silt.

[I use the names of the seasons for simplicity's sake. "Summer" means a period, of uncertain length, of dry years; "winter" a corresponding period of wet years.]

As a consequence precipitation stopped, and a somewhat impure calcareous silt, with occasionally a few shells, was washed over the basement beds to a depth of several inches. In the deeper parts, in which alone the Landscape Marble was deposited, there were no detrital shells, the water being too still to move them.

When "spring" returned, chemical precipitation was gradually re-established. At first the supply was only sufficient to furnish a "hedge." Just at this time, *the silt was nearly or quite exposed to the air for a short time*, and therefore developed *a tendency to crack into squares and polygons.* That actually visible cracks appeared was only occasionally the case. And as the upper layers of the silt dried most, they tended to crack most.

Now as precipitation recommenced, it not only deposited a "hedge" on the basement beds, but *it also formed vertical walls in the silt enclosing polygons along these* *lines of least resistance.* Thus began the " trees." On the " trees " the " branches " were laid down by a process analogous to " hedge-structure." The " branches " differ in no respect from the " hedge." Owing to the greater tendency to contraction above, the " trees " spread out at the top.

Wherever in the silt there was a nodule of chemically-formed calcite, the precipitate, seeking it out, formed a tiny concretion round it, leading to the production of " islands."

There is no difficulty in understanding the precipitation of the carbonate at the bottom of the silt if we remember that that was probably semi-fluid. Similarly oxalate will deposit on calculi through a layer of mucus.

When " summer " returned, it found a set of hard polygonal walls, arranged like a honeycomb, with soft silt between, resting on the basement beds below. Now as the silt in the Landscape Stone was very calcareous, very fine, surrounded by calcite crystals, and moist, it was inevitable that it should more or less recrystallize. In doing so it must contract. The polygonal walls kept it from contracting laterally, so it had to contract chiefly downwards, rising however to the " trees " or walls at their tops. This formed the " atmosphere," and explains why the rising to the " trees " is chiefly at the tops, and also why the " atmosphere" is always the least typical in texture of the constituents of the Landscape Stone.

When, therefore, chemical precipitation took place in the new " summer," it found a surface like the top of a honeycomb, the septa being very concave. To this the now abundant precipitate had to fit itself. It did so, in parallel layers, and could only partially obliterate it. *Therefore it presented the characteristic hummocky upper surface of the Landscape Marble.* It will be remembered that we pointed out that these hummocks were not rounded bosses, but elongated and interlacing ridges, and that the " trees " rose *into*, not between them.

Doubtless some recrystallization of the silt into " atmosphere " went on long afterwards, and both exaggerated the hummocky surface and occasionally fractured the "canopy," which is not uncommon.

A few objections may here be noticed.

(i) Why when the precipitate was scanty did it soak to the bottom of the silt, but when abundant deposit on the top ? Firstly, because in the " summer " the silt was much firmer. Secondly, because it is well known to chemists that rapid crystallization from solution leads to many small crystals, but if slow, like seeks like, and all is deposited on one or two large crystals. When the precipitate is abundant it will set anywhere ; when scanty, it seeks its like.

(ii) Why do all the " trees " reach the bottom ? Because, even if all the cracks did not, a line of percolation once taken up would be permanent.

(iii) Do all the " trees " rise to the top ? Yes, if dissected back. High " hedges " and " branches " do not.

IV. *Detailed Account of the Origin of Peculiar Forms of Cotham Marble.*

(i) *End-Cothams.* These *exist*, or in other words the Landscape Marble is patchy in distribution, because in all but the stillest water the precipitate was washed away. They are always coarse and shelly because they were laid down in slightly rougher water than the more central parts. They contain slabs of False Cotham Marble, because that is a rougher water deposit. They slope off at an angle because the uppers contracted in taking their final form, whilst the basement beds were already set.

(ii) *The Simple Horizontally Banded Form* probably represents basement or top beds, the other members having been washed away.

(iii) *Double Cotham Marble* is formed by a repetition of the processes laying down the Landscape Stone, and is of local distribution.

(iv) *False Cotham Marble.* This was laid down under exactly the same conditions as the Landscape Stone, between which and itself every gradation may be found, except that it was formed in the slightly shallower, and therefore slightly rougher waters. After the basement beds, or part of them, had been laid down, a little movement swept a shelly ooze over the surface. Then another chemically formed layer followed, to be in its turn covered by the pasty calcareous mud. So alternate layers of semi-liquid ooze and of brittle solid were formed. Then, in the " autumnal " or " winter " storms, considerable disturbance of the water took place, and the still plastic mud yielded to the strain, shifted about, and snapped and upheaved the precipitate beds. I have specimens showing the lower beds undisturbed, and the upper ones bent up just in this way.

After this disruption came " spring," the " hedge " period, and a " hedge " was often deposited on the tops of the upturned edges (*vide* fig. 3). Also, a certain amount of recrystallization of the shelly ooze took place inside shells and in other sheltered places.

In the *Mixed Forms*, linking the True and False Marbles, the " atmosphere " or matrix, is coarse and shelly ; and the " trees " have thick straight trunks, because here actual cracks would be more likely to form, owing partly to the shallowness, and partly to the coarser nature of the silt.

Conclusion.

The chief objection to the above theory, I take it, will be the peculiar combination of circumstances which I have

FIG 1. FIG 2. FIG 3. FIG 4. FIG 5.

1. Horizontal section of Landscape Marble (Redland). 2. False Cotham Marble (Aust).
3. Mixed Cotham Marble (Redland). 4. Spherical Concretion of Cotham Marble (Redland).
5. Oxalate Calculus (Museum of Bristol Royal Infirmary).

To face p. 149.

adduced. This is in reality an advantage. In spite of the imitations collected by Woodward of arborescent structure, there is nothing to parallel the true Landscape, with its combination of "hedge," "trees," "branches," and hummocky canopy. It stands alone in the records of Nature, whether ancient or modern. Therefore any explanation that is commonplace is seriously discounted, and only in some fortuitous chain of circumstances must the true reading of the riddle be found. The shallow lagoon, the chemical precipitation, the embryonic sun-cracking, the first scanty and then abundant repetition of the precipitation—these constitute a record not likely to be repeated. From the extravagance of my postulates I argue for their truth.

The "hedge-structure," however, need not be, and is not, uncommon.

Another question arises—is there independent evidence that the Rhætics were laid down in a very shallow but extensive lagoon? I believe there is. The Keuper lake had evaporated nearly to dryness, and left an immense nearly flat plain. The bone-bed is a shallow-water formation. Ripple-marks and sun-cracks abound in the Rhætics And the Cotham Marble itself contains evidence of hot sun, and still shallow water, in the numerous insect wings it contains. It will be noticed that all theories of the Cotham Marble involve shallow water.

I am deeply indebted in the preparation of this essay to my friend James Parsons, Esq., B.Sc., F.G.S., for his able criticisms and advice, and for some of my specimens. I have also heartily to thank Mr. J. Case for the photography, and Dr. T. Fisher for permission to photograph calculi from the museum of the Royal Infirmary.

The Lower Oolites near Bristol

By J. W. TUTCHER.

CONTENTS

I. INTRODUCTION.

THE object of this paper is to indicate the localities nearest Bristol where the Inferior Oolite and Great Oolite series may be observed in fairly complete sequence, and also to enumerate the principal faunal contents of each bed of the series at these localities. The palæontological record has, however, no pretension to completeness, only those species being mentioned which have come under my own observation.

In addition to the usual zonal arrangement, that portion of Mr. S. S. Buckman's palæontological time table which is applicable to the deposits under review is introduced. It will serve as a standard, by reference to which the completeness or otherwise of the sections to be described may be tested. The use of this table will also help to render familiar the method of detailed palæontological subdivision, on the lines of which much recent work has been done.[1]

Mr. Buckman divides the period during which the beds from the Midford Sands to the Cornbrash were formed into twenty-five parts or "hemeræ," indexed chiefly by Ammonites. In introducing the term "hemera" he says: [2] "The geological unit for the correlation of strata has hitherto been the 'zone.' Gradually, however, it has been felt that either the zones must be increased in number, or some modification adopted, if the true faunal sequence is to be expressed with that accuracy which is now necessary. It is for a palæontological purpose that I propose the term 'hemera.' Its meaning is 'day' or 'time'; and I wish

[1] I desire to acknowledge my indebtedness to Mr. S. S. Buckman, Mr. J. W. D. Marshall, and Mr. A. Vaughan, for help rendered in the identification of specimens.

[2] "The Bajocian of the Sherborne District," *Q.J.G.S.*, vol. xlix.

Table of Stratigraphical, Zonal, and Chronological Terms.

Stage	Stratigraphical Terms as used by certain Authors.		Approximate Zonal Terms used by Dr. Wright.	Chronological Terms. Proposed Hemeral Names.	Full Title of Distinctive Fossil.
				Hemera	
Bathonien	Great Oolite Series	Cornbrash Forest Marble Bradford Clay Great Oolite Stonesfield Slate Fullers' Earth		*disci*	*Oppelia* (?) *discus*
				(*coarctatæ*)	*Dictyothyris coarctata*
				(*maxillatæ*)	*Terebratula maxillata*
				subcontracti	*Macrocephalites subcontractus*
Bajocien	Inferior Oolite Series	Inferior Oolite Upper Division	Parkinsoni	*fuscæ*	*Oppelia fusca*
				zigzag	"*Stepheoceras*" *zigzag*
				Truelli	*Sirigoceras Trueltii*
				Garantianæ	*Parkinsonia Garantiana*
		Inferior Oolite Lower Division	Humphriesianum	*nortensis*	,, *niortensis*
				Blagdeni	*Cœloceras Blagdeni*
				Sauzei	"*Sphæroceras*" *Sauzei*
				Witchelliæ sp.	*Witchellia* sp.
				Sonniniæ sp.	*Sonninia* sp.
				discitæ	*Hyperlioceras discites*
				concavi	"*Lioceras*" *concavum*
Aalenien			Murchisonae	*bradfordensis*	*Brasilia bradfordensis*
				Murchisonæ	*Ludwigia Murchisonæ*
		Northampton Sands		*scissi*	*Tmetoceras scissum*
		Yeovil Sands	Opalinum	*opaliniformis*	"*Lioceras*" *opaliniforme*, sp. nov.
				aalensis	*Grammoceras aalense*
				Moorei	*Dumortieria Moorei*
		Midford Sands	Jurensis	*Dumortieriæ* sp.	,, sp.
				dispansi	*Grammoceras dispansum*
		Striatulus Shales (Yorkshire)		*Struckmanni*	,, *Struckmanni*
	Upper Lias	Cotteswold Sands		*striatuli*	,, *striatulum*

Extracted from a paper "On the grouping of some divisions of so-called 'Jurassic' time." By S. S. Buckman, Esq., F.G.S. [*Quarterly Journal of the Geological Society* for August, 1898, vol. liv.].

In a note to the table Mr. Buckman says, "I take no responsibility for the stratigraphical terms. They are only placed here to give a rough guidance; and, with the exception of the Sands which are placed according to faunal contents, they are interpreted from the very different views which authorities have as to their use."

to use it as the chronological indicator of the faunal sequence. Successive 'hemeræ' should mark the smallest consecutive divisions which the sequence of different species enables us to separate in the maximum developments of strata. . . . The term 'hemera' is intended to mark the acme of development of one or more species. It is designed as a chronological division, and will not therefore replace the term 'zone' or be a subdivision of it, for that term is strictly a stratigraphical one."

II. DESCRIPTION OF EXPOSURES.

Midford Sands.

The lowest beds within the purview of this paper are termed Midford Sands; or, Midford, Cotteswold, or Yeovil Sands, according to the locality in which they are found.

In Gloucestershire these sands are usually capped by a marly, ironshot limestone of variable thickness, crowded with Ammonites, and termed by Dr. Wright the "Cephalopoda Bed."

The sands, with their Cephalopoda bed, have been placed alternately in the Lias and in the Inferior Oolite, and subsequently divided between them, being regarded by the Survey as Passage beds.

Mr. Buckman objects to this view, because, as is undoubtedly the case, the sands in the three localities named are on different palæontological horizons, occupying higher positions in the South than in the North. In the Cotteswolds the sands were deposited earlier than the beds of the Striatuli hemera; at Midford and at Yeovil they are of later date, ranging, in point of time, from the Striatuli hemera to the Dumortieriæ hemera at the former place, and from the Dispansi hemera to the Opaliniformis hemera[1] at the latter place.

Jay Hill, near Bitton.

A section in the Midford sands can be seen at Jay Hill east of Bitton Station. Some hard beds at the base contain badly preserved Ammonites of Upper Lias (sic) character and a number of small undetermined Brachiopods; the softer beds appear to be unfossiliferous, as is usual.

Upton Cheney and North Stoke.

A little further east, at Upton Cheney and at North Stoke, a Cephalopoda bed can be traced in the road cuttings, and from it many Ammonites have been obtained, including *Grammoceras dispansum* and *Dumortieria Moorei*; the distinctive Brachiopod *Rhynchonella cynocephala* is also common.

Directly above the Cephalopoda bed at these localities there are a few feet of Inferior Oolite limestones containing fossils characteristic of the Parkinsoni zone, thus indicating a break in the deposits from, at least, Opaliniformis to Garantianæ time. A similar non-sequence is very general in this district, excepting at Dundry, where some of the missing beds are represented.

Dundry Hill.[2]

(1) *Beds below the Inferior Oolite at Dundry.*

At the base of the Inferior Oolite limestone series at Dundry there is a series of clays and sandstones—the

[1] Vide Table of Terms, p. 152.

[2] For the information regarding Dundry Hill, including details of the sections, I am greatly indebted to the important paper entitled "Dundry Hill, its Upper Portion, etc.," by S. S. Buckman, Esq., F.G.S., and E. Wilson, Esq., F.G.S., *Q J.G.S.*, vol. lii.

Dumortieriæ Beds, which maintain a fairly uniform thickness of about 50 ft. throughout the hill.

Judging by the palæontological evidence, these beds are contemporaneous with the upper portion of the Midford Sands, and they forcibly illustrate the possible variability of lithological characters even in areas not very remote from each other.

The Dumortieriæ Beds can best be seen at the east or Maes Knoll end of Dundry Hill; but, since there are no sections, and one has to depend on the weathered slopes for exposures, the collection of fossils at this horizon is a tedious and disappointing process.

The following species may, however, be obtained :—

Dumortieria Striatulo-costata.
,, aff. *prisca.*
,, aff. *radians.*
Rhynchonella Moorei.
Pecten inutilis.

(2) *The Inferior Oolite at Dundry.*

In order to examine the Inferior Oolite Limestone series of deposits at Dundry it will be best, first, to visit a small quarry at the extreme western end of the hill, on a road leading up to Castle Farm.

The sequence at this section is as follows :—

SECTION AT THE WESTERN END OF DUNDRY, NEAR CASTLE FARM.

	ft.	in.
Thin bedded, grey, unfossiliferous limestones, extending upwards		
GARANTIANÆ.		
Soft, brown, ironshot limestone, with derived nodular lumps of a dense limestone . . .	0	5
Acanthothyris spinosa.		
Pleurotomaria palæmon.		

	ft.	in.
Pseudomelania aff. *coarctata.*		
Natica bajocensis.		
Trochus dimidiatus.		
Amberleya aff. *ornata.*		
Lima semicircularis.		
Astarte Manseli.		
Limatula gibbosa.		
Gouldia ovalis.		
Trigonia aff. *costata.*		
Clypeus trigen.		
Montlivaltia Delabechii.		
SONNINIÆ.		
Whitish ironshot limestone, with planed-off top and thin sandy parting at base	1	7
Sphæroceras Brocchii.		
Sonninia Browni.		
,, *fissilobata.*		
,, *Zurcheri.*		
,, *ovalis.*		
Strigoceras compressum.		
Lima Etheridgei.		
,, *pectiniformis.*		
Trigonia striata.		
Gresslya abducta.		
Pholadomya Murchisoni.		
Pecten barbatus.		
DISCITÆ.		
Grey, crystalline limestones with yellow marl partings	1	4
Hyperlioceras aff. *discites.*		
,, aff. *Walkeri.*		
Lioceras intermedium.		
Belemnites Blainvillei.		

ft. in.

Terebratula cortonensis.
,, *Eudesiana.*
Rhynchonella Forbesi.
Astarte elegans.
,, *excavata.*
Lima Etheridgei.
Myaconcha crassa.

CONCAVI.

Grey, earthy and sandy limestones with marly partings 3 6
Lioceras concavum.
Terebratula Eudesi.
,, *perovalis.*
,, *cortonensis.*
Modiola Sowerbyana.
Ceromya bajociana.

BRADFORDENSIS AND MURCHISONÆ.

Light grey limestones of varied texture with an ironshot bed at the base 6 4
Lioceras cf. *Bradfordense.*
Terebratula shirbuirniensis.
,, *Etheridgei.*
Zeilleria anglica.
Rhynchonella aff. *Stephensi.*
Trigonia striata.
Myacites aff. *jurassi.*
Opis trigonalis.
Cypricardia cordiiformis.

OPALINIFORMIS.

Grey, earthy limestone, coarsely iron-shot . . 1 6
Lioceras partitum.
Lima Etheridgei.

	ft.	in.
Aalensis.		
Blue, compact, argillaceous limestone . .	0	3
Dumortieriæ.		
Greenish-blue clay	50	0

The lowest beds exposed at this section in ordinary quarrying operations are the deposits of Bradfordensis and Murchisonæ hemeræ. The earlier deposits were proved by excavations undertaken by Messrs. Buckman and Wilson. The Sonniniæ beds exhibit a planed-off top with Lithodomus borings, and beds of the Lower Parkinsoni zone ("Garantianæ hemera") rest non-sequentially on them. The gap is partly filled by some strata met with in a section to be described presently.

The next section is taken from the large quarry near the church (the Building Stone Quarry).

	ft.	in.
Zigzag ? (Coralline Beds).		
1. White crystalline limestone in one thick bed .	1	6
2. Thin-bedded whitish ragstones . . .	6	0
Truelli ? (Freestone Beds).		
3. Pale-grey, white or yellow limestone passing downwards into compact yellow ragstone .	5	9
4. Compact freestone somewhat variable in thickness, about	12	0

From the Coralline Beds, here and at the section to be described next, the following fossils have been collected—

Zeilleria Waltoni.
Acanthothyris panacanthina.
Terebratula globata.
,, *sphæroidalis.*
Rhynchonella subtetrahedra.
,, *plicatella.*
,, aff. *parvula.*

Acanthothyris spinosa.
Aulacothyris carinata.
Pleurotomaria Palæmon.
Trigonia costata.
Ostrea gregaria.
Pecten spinicostatus.
Magnotia Forbesi.
Hemicidaris granulosa.
,, *pustulosa.*
Cidaris Fowleri.
,, *Bouchardi.*
Holectypus hemisphericus.
Stomechinus bigranularis.
Isastræa explanata.
Thamnastræa Defranciana.
,, *Terquemi.*
Montlivaltia lens.

These are the highest beds at Dundry, their date is somewhat uncertain, but there is some evidence that they were deposited during the hemeræ indicated.

Again travelling east, until we strike the main road which crosses the hill from Bishopsworth to Chewstoke, we have a choice of two quarries: one on the north or Bristol side of the ridge, and the other on the south or Chewstoke side. The former is the classical section from which so many beautiful fossils have been obtained, but it has not been worked for some years. We therefore choose the one on the south of the ridge which exhibits similar beds and is still occasionally used.

THE SOUTHERN MAIN ROAD QUARRY.

	ft.	in.
Coralline limestone, containing a similar suite of fossils to those in the top beds in our last section .	5	0
Equivalent of Freestone	3	4

	ft.	in.
GARANTIANÆ.		
Grey, crystalline, somewhat ironshot "ragstone"	0	10
SAUZEI.		
Hard ironshot limestone with planed-off top (the Fossil bed)	1	0

Stephanoceras Sauzei.
,, *Braikenridgii.*
,, *Bayleanum.*
Sonninia Sowerbyi.
,, *corrugata.*
Oppelia præradiata.
Belemnites, sp.
Nautilus ornatus.
Acanthothyris paucispina.
Pleurotomaria elongata.
,, *phyrospira.*
,, *armata.*
,, *granulata.*
,, *distinguenda.*
,, *fasciata.*
,, *sulcata.*
Trochus Zetes.
Pseudomelania lineata.
Spinigera trinitatis.
Goniomya angulifera.
Astarte multicostata.
Myacites jurassi.
Pholadomya decemcostata
Opis lunulatus.
Cucullaea oblonga.
,, *elongata.*
Ostrea explanata.
Lima alticosta.
Hinnites abjectus.

Lima pectiniformis.
Isocardia gibbosa.

Witchelliæ	ft.	in.
Whitish, ironshot limestone	0	8

Witchellia læviuscula.
W. aff. *Sutneri.*
Sphæroceras Brocchi, Sow.
Pleurotomaria actinomphala.
Amberleya ornata.
Alaria dundriensis.
Natica dundriensis.
Opis similis.
Myaconcha crassa.
Cypricardia bathonica.
Pecten barbatus.
Unicardium gibbosum.

It should be noted that the deposits of Sanzei and Witchelliæ hemeræ here represented are missing both on the eastern and western portions of the hill, The exact geographical limits of these deposits have not been determined, but at Maes Knoll strata of Garantianæ hemera rest unconformably on those of Dumortieriæ hemera, while west of the church, strata of Garantianæ time are lying on beds of the Sonniniæ hemera. Messrs. Buckman and Wilson attribute this arrangement to denudation which set in towards the end of Bajocian time. This denudation, they believe, removed all the strata then deposited down to that of the Sonniniæ hemera, excepting at the middle of the hill, where beds of Witchelliæ and Sauzei age were preserved. It then ceased at the central and western parts of the hill, but continued into, or was renewed, in Bathonian time at the eastern end until all the deposits down to those of the Dumortieriæ hemera had disappeared. They find evidence of this denudation, in the planed-off top of the Sauzei strata in the middle, in the Sonniniæ beds at the west of the hill, and in the presence of a conglomeratic bed of Garantianæ hemera, containing fossils of Dumortieriæ age, at the eastern end of the hill.

Stantonbury Hill

Four miles east of Dundry, at Stantonbury Hill, the sands (and here they are true sands as at Midford) are capped by about 7 to 8 feet of Oolitic limestone of the Parkinsoni zone. These beds are very fossiliferous, but, as there is no section, we have to depend for specimens on the weathered escarpment and the runnels formed by innumerable rabbits which burrow in the sands beneath. Notwithstanding this difficulty, on a recent occasion the following fossils were collected in about half an hour.

Ammonite of the *Garantianus* group.
Rhynchonella spinosa.
,, *hamponensis.*
Terebratula sphæroidalis.
Aulacothyris carinata.
Lima pectiniformis.
Pecten, sp.
Avicula costata.
Isastræa limitata.
Montlivaltia, abundant in a bed considerably bored by *Lithodomi.*
Holectypus hemisphericus.
Pentacrinus Milleri.
Serpula socialis.
Cylindrites, sp.

I have also obtained from these beds *Lissoceras psilodiscum.* In reference to this Ammonite Mr. Buckman remarks, " It has not been previously recorded north of the

Mendips, and being one of the Truellii hemera, indicates an horizon higher than Garantianæ hemera." The Gasteropod, *Cylindrites*, is also a Bathonian type of fossil.

Fullers' Earth.

Still going east, at Midford, three miles south of Bath, in the first railway cutting south of the station, the junction of the Fullers' Earth and the Inferior Oolite is well shown. As at North Stoke and at Stantonbury only the Parkinsoni zone of the Inferior Oolite is represented, these beds resting directly on the sands. From the Fullers' Earth, which consists of Lower Fullers' Earth Clays, a rich series of fossils may be obtained. The following species are common.

Railway Cutting, Midford.

Rhynchonella varians.
,, *powerstockensis.*
Ornithella ornithocephala.
Terebratula globata.
Ostrea acuminata.
Plicatula, sp.
Modiola gibbosa.
Goniomya literata.
Pholadomya Heraulti.
Cypricardia rostrata.
Isocardia, sp.
Collyrites ringens.
,, *ovalis.*

The Fullers' Earth Rock (Sub-contracti hemera) is not shown in this section, and it nowhere makes a conspicuous feature in the neighbourhood, but *Macrocephalites subcontractus* has been found near Bath.

Great Oolite.

The Great Oolite, a deposit of the Maxillatæ hemera, has been, in years gone by, extensively quarried between Bath and Bradford-on-Avon.

Avoncliffe, on the left bank of the Avon, near Westwood, is noted for the large number of specimens of a lilliputian fauna which one of its beds has yielded; many of the species collected by Lonsdale and named by Sowerby are probably, however, immature specimens. The same fossil bed has been identified by Mr. W. H. Wickes at Murhill, near Winsley, on the opposite side of the river. This quarry, like the first named, has not been worked for some years, but fossils can still be obtained from the weathered surfaces of the fallen blocks. The following section is given in the "Survey Memoirs" on the authority of Lonsdale for the lower portion, and of Mr. W. H. Wickes for the upper portion.

(1) Murhill Quarry.

	ft.	in.
Upper Division—		
Coral band. *Calamophyllia radiata*, *Isastræa*, etc.	6	0
Clay parting	0	4
"Fossil Bed." Polyzoa, *Entalophora straminea*; Echinoderms, *Acrosalenia*; numerous small Gastropods, etc.	16	0
Clay with sponges, crustaceans, small ostreæ, etc.	1	6
Rag	7	0
Lower Division.		
Freestone	10	0
Ragbeds with layers of Freestone and occasional partings of clay	43	0

(2) KINGSDOWN.

Four miles north of Winsley, at Kingsdown above Bathford, higher beds of the Great Oolite are quarried and yield an interesting fauna including the following species—

Disculina hemispherica.
Terebratula maxillata.
Ornithella digona.
Rhynchonella obsoleta.
,, aff. *concinna.*
Dictyothyris coarctata.
Eudesia cardium.
Terebratella Buckmani.
Pecten hemicostatus.
Perna rugosa.
Lima cardiiformis.
Lithodomus inclusus.
Isastræa limitata.
,, sp.
Stylina solida.
Montlivaltia Smithii.
Hemicidaris minor.

BRADFORD CLAY AND FOREST MARBLE.

At Bradford-on-Avon, in a well-known quarry on the canal bank, south of the town, the Great Oolite is still extracted from underground workings and fossils from it can often be obtained from the quarrymen, but the interest in this quarry, and in the one on the opposite bank of the canal, centres in the overlying Bradford clay. The clay is about 10 feet thick, and very fossiliferous, especially at the base; capping the clay there are a few feet of characteristic Forest Marble. The sequence is as follows—

QUARRY, SOUTH OF BRADFORD.

	ft.	in.
FOREST MARBLE—		
1. Clay and thin stone		
2. False bedded oolitic limestone . . .	6	0
BRADFORD CLAY—		
3. Grey marly clay, few if any fossils . .	8	0
4. Fossil bed. Marly clay here and there cemented into a tolerably hard bed by calcareous matter, and with an impersistent layer of shelly limestone (6–8 in.) at the base . .	2	0
GREAT OOLITE.		
5. Shelly oolite and hard brown marly oolitic limestone	to base	

The fossils of the Bradford clay include the following species—

Strophodus magnus.
Ornithella digona.
Terebratula maxillata.
Rhynchonella obsoleta.
,, *varians.*
Eudesia cardium.
Dictyothyris coarctata.
Flabellothyris flabellum.
Pleurotomaria Thiarella.
Avicula costata.
Lima duplicata.
Mytilus furcatus.
Ostrea gregaria.
,, *Sowerbyi.*
Pecten vagans.
Trigonia pullus.
Apiocrinus Parkinsoni.
Acrosalenia spinosa.

Cidaris bradfordensis.
Serpula grandis.
Terebellaria ramosissima.
Diastopora foliacea.
Berenicea diluviana.
,, *archiaci.*
,, *scobinula.*
Stomatopora dichotoma.
Theonoa distorta.

The fossils of the Forest Marble are, as usual, very much crushed and difficult of extraction; *Ostrea Sowerbyi*, *Pecten vagans*, and *Trigonia detrita* can, however, be obtained in good condition.

Although there is evidence that the Bradford clay extends from Cirencester in the north to the Dorsetshire coast in the south, as a formation it is local and insignificant. Messrs. Reynolds and Vaughan were unable to separate a Bradford clay horizon at the eastern end of the Sodbury Tunnel, where the Great Oolite and Forest Marble series are well developed. No specimens of Dictyothyris coarctata nor of Apiocrinus were found, but with these exceptions, they say:[1] "It would be utterly impossible to separate the top beds of the Upper Great Oolite from the Bradford clay, on palæontological grounds."

It is evident that, locally, there was some pause in deposition between the Great Oolite and Bradford clay, and where this occurred the Crinoids flourished on the floor of the Great Oolite, becoming encrusted, as we find them to be, with Serpulæ and Polyzoa before the muddy sediments of the Bradford clay were laid down. In other localities, where there is no distinctive evidence of Bradford clay, there was probably no pause in deposition, no growth of crinoids, and no accumulation of organic remains to form a fossil bed.

[1] *Q.J.G.S.*, vol. lvii. p. 746.

Cornbrash.

The highest member of the Great Oolite series, the "Cornbrash" (Disci,hemera), can be seen in some ploughed fields between Bradford-on-Avon and Farleigh Castle to the south, and also in the banks of the stream near the Castle. *Terebratula intermedia*, and *Goniomya literata*, are the only fossils I am able to record from these small exposures.

III. ADDNEDUM.

I have not included in this sketch any detailed account of the Cotteswold area where the Inferior Oolite is so highly developed. The series of beds, which at Leckhampton attain a thickness of 250 feet as against about 50 feet at Dundry, is of such a different character, at all events as regards the beds below the Parkinsoni zone, from those in the district chosen, that their correlation could not, in my opinion, be clearly exhibited within the limits of this brief review. Not only do the beds exhibit marked lithological differences, but the faunal differences are also very obvious. In Mr. Buckman's view these are sufficiently great to require the supposition of a barrier cutting off the Cotteswolds from the Dundry and Dorset areas during the whole of Bajocian time. This view was expressed, and reasons for it given, in a paper contributed to the "Cotteswold Field Club" in 1889, and in response to a recent inquiry, Mr. Buckman informs me that all recent work has confirmed him in the opinion that Dundry was cut off from the Cotteswolds but in connexion with the Paris basin from, perhaps, Liassic times until the close of the deposits of the Humphriesianum zone when a subsidence of the barrier, as well as of the whole district, united the two areas and the Parkinsoni zone, common to all, was deposited. Dundry Hill is, in this view, more correctly described as the northernmost outlier of the Paris basin than as an outlier of the Cotteswolds.

Reports of Meetings.

GENERAL

THE usual eight monthly meetings were held during the year 1902, at which the following papers were read.

Jan. 23 (Annual Meeting).—Dr. A. B. Prowse on "Some Botanical Photomicrographs."

Feb. 26.—Professor S. H. Reynolds on "Volcanoes."

March 6.—Dr. W. B. Gubbin on "Extinct forms of animal life."

April 3.—Dr. T. Fisher on "A visit to the Mountains of Algeria."

May 1.—Major H. H. Austin, D.S.O., on "A journey from Omdurman to Mombassa viâ Lake Rudolf."

Oct. 2.—Mr. G. Brebner on "The Plant as a living thing."

Nov. 3.—Dr. F. E. Francis on "Liquid Air."

Dec. 4.—Professor S. H. Reynolds on "Geology and Scenery."

The lantern was used at all the meetings except that of November; Dr. Francis' lecture was, however, fully illustrated by a remarkable series of experiments. The Hannah More Hall was taken for Major Austin's lecture.

S. H. REYNOLDS,

Hon. Secretary.

REPORT OF THE BOTANICAL SECTION

AMONG the plants that grow in the neighbourhood of Bristol are a large number of aliens or "introduced species." The latter term, as opposed to natives, indicates plants which owe their presence to man's doings as distinct from other more natural agencies. The distinction can often be made without difficulty, and in the case of Bristol aliens the great majority are obviously casuals, dropped from foreign forage or derived from imported barley now much used in malting, the siftings from which are scattered far and wide in feeding poultry. Station-yards, sidings where trucks are swept free from rubbish, and tips of town refuse produce many of these plants. St. Philip's Marsh, now unhappily almost entirely enclosed and utilized (the circumstance that suggested the writing of this note), has for many years shown an interesting vegetation to those who cared to brave the vile odours that environ it. Here was one of the earliest British stations for the Hoary Cress (*Lepidium Draba*), which during the last half-century has greatly spread throughout the country until one begins to fear that in time it may become as great a pest to our agriculturists as it is now in Southern Europe. Here also in former days I gathered many specimens of the rare and beautiful grass *Polypogon litoralis*. This grew upon the original alluvium twenty feet or so below the surface of the made ground one sees to-day ; and I could never feel quite sure that it was not native in the locality. The natural orders Cruciferæ and Leguminosæ have always been well represented at St. Philip's : the former by *Sisymbrium pannonicum*, *Erysimum repandum*, *Lepidium Draba*, *L. latifolium*, *L. perfoliatum*, *Alyssum campestre*, *A. dasycarpum*, *Rapistrum perenne*, *etc.* ; and the latter order by *Trigonella cœrulea*, *Melilotus arvensis*, *M. indica*, *Vicia hybrida*, *V. hyrcanica*, *V. lutea*, *V. varia*, *V. villosa*, *Lathyrus annuus* and *L. Cicera*. Another interesting plant which has crossed the Atlantic and seems likely to stay is the American ragweed (*Ambrosia artemisiæfolia*). I have seen it at Portishead, and on the light railway near Blagdon; and it is similarly met with in the North of England, and in several continental countries where its mode of growth from slender underground stolons enables it to persist, even if fruit be not ripened.

In some other parts of the Bristol district plants occur whose introduction is not so easily accounted for:—for example, the Limestone Polypody that has made a home in Saltford railway cutting; and *Leycesteria formosa* in Shute Shelve Wood.

However, many of these aliens endure but for a season. If annuals they may not ripen seed; if perennials they may not survive the winter cold; or should they do so they are sooner or later crowded out from the soil by stronger native species—the grasses, docks and thistles of our waste lands.

JAMES W. WHITE.

ENTOMOLOGICAL SECTION

DURING the year 1902 only two meetings were held by this section.

March 12 (Annual Meeting).—After the usual business Mr. Charbonnier exhibited a parasitic dipteron *Rhogas circumscriptus*, one of the *Braconidæ*, parasitic on the larvæ of a *Noctuid* moth; an ichneumon of the genus *Colpomeria* bred from *Sesia tipuliformis*; also a rare bug, *Ledra aurita*, taken in Leigh Woods.

Mr. Griffiths exhibited interesting specimens of Lepidoptera, including many species of the genera *Pericopis*, *Composia* and *Bizone*; also a specimen of *Epicopeia philenora* from Sikkim, a moth which mimics one of the *Papilio* butterflies.

The Hon. Secretary exhibited some varieties of *Boarmia repandata* including slate coloured, banded and black specimens; types of *Tabanus bovinus*, *T. autumnalis*, *Atylotus fulvus* and *Echinomyia ferox* from Saundersfoot; a very dark melanic form of *Sirex gigas* taken in Rupert Street, Bristol; and a specimen of *Strangalia aurulenta*, Lynton.

November 21.—Mr. Griffiths exhibited a fine and representative series of *Colias*, including the following rare and local species :—

Colias	*wiskotti*,	Amoor.	
,,	,,	var. *separata*, Turkestan.	
,,	,,	*Chrysoptera*, Amoor.	
,,	*aurorina*	Mountains of Armenia.	
,,	,,	var. *libanotica*, Lebanon.	
,,	*regia*		Turkestan.
,,	*Christophi*		Samarkand.
,,	*superbus*		
,,	*eogene*		Turkestan.
,,	*sierversi*		Amoor.
,,	*alpherakii*		Pamir.
,,	*cocandica*		Khokand.

The Hon. Secretary exhibited a specimen of *Chrysophanus phlœas* var. *suffusa* taken at Woolacombe in 1900.

CHARLES BARTLETT,
Hon. Secretary.

GEOLOGICAL SECTION

DURING the year 1902 this section continued to advance in membership, for while at the commencement of the year there were forty-one members, the membership at the end of the year had risen to forty-eight.

The following papers were read at nine meetings—

Jan. 29.—The Clogher Head Inlier (County Kerry) by Prof. S. H. Reynolds, M.A., F.G.S., illustrated by lantern slides.

Feb. 26.—Notes on the Geology of the Puy-de-Dome district (Auvergne) by Miss F. MacIver. Illustrated by lantern slides.

March 20.—Ammonites and their allies by A. Vaughan, Esq., B.A., B.Sc., F.G.S. Illustrated by photographs and specimens.

April 24.—Geological notes on a trip to Iceland by Prof. C. Lloyd Morgan, F.R.S., F.G.S. Illustrated by lantern slides.

May 15.—Notes on the Geology of Swanage. By Prof. S. H. Reynolds, M.A., F.G.S. Illustrated by maps and lantern slides.

June 12.—The Lower Lias of Keynsham and the fossils found there, by Messrs. A. Vaughan, B.A., B.Sc., F.G.S., and J. W. Tutcher. Illustrated by lantern slides, photographs and fossils.

Oct. 15.—Lantern slides (and a short description of each) of photographs taken during the summer excursions of the University College Geological Field Class, by Prof. S. H. Reynolds, M.A., F.G.S.

Nov. 12.—A new theory of the Cotham Marble. By A. Rendle Short, Esq., B.Sc.

Dec. 17.—The Jurassic rocks of the South Wales direct Railway line (Patchway to Wootton Bassett). By Prof.

H. Reynolds, M.A., and A. Vaughan, Esq., B.Sc. Illustrated by lantern slides and fossils.

The average attendance at the meeting was seventeen, which is about the same as last year.

The financial report showed a satisfactory state of affairs, the total receipts including a balance of £2 3*s*. 3*d*. from the previous year, amounting to £7 8*s*. 3*d*. The expenditure for the year amounted to £4 4*s*. 7*d*., leaving a balance of £3 3*s*. 8*d*.

The following Publications of the Bristol Naturalists' Society may be obtained from any Bookseller, or from

H. J. CHARBONNIER, 49, DOVE STREET, KINGSDOWN.

One Volume, bound, 5s.

FLORA OF BRISTOL.

By JAMES WALTER WHITE, F.L.S.

The area of this flora is that included in the geological map of the Bristol coal field, by the late William Sanders, F.R.S., F.G.S.

The Fungi of the Bristol District. By CEDRIC BUCKNALL, Mus. Bac.

Part IV.	Species	690 to 836.	4 plates, 3 coloured, 1 black.	1*s*. 6*d*.
,, V.	,,	837 to 934.	2 ,, 1 ,,	1*s*.
,, VI.	,,	935 to 1023.	1 plate, black	1*s*.
,, VII.	,,	1024 to 1084.		6*d*.
,, VIII.	,,	1085 to 1144.	3 plates, coloured	1*s*. 6*d*.
,, IX.	,,	1145 to 1240.	4 plates	1*s*.
,, X.	,,	1241 to 1321.	4 plates	1*s*.
,, XI.	,,	1322 to 1362.		6*d*.
,, XII.	,,	1363 to 1399.	2 plates	1*s*.
,, XIII.	,,	1400 to 1431 } Index to Parts I. to XIII. and plates		1*s*.

On the Newly-Discovered Phenomenon of Apospory in Ferns. By CHARLES T. DRUERY, F.L.S. Illustrated. 1*s*.

Contributions to the Geology of the Avon Basin. By Prof. LLOYD MORGAN, F.G.S. I. "Sub-Aerial Denudation and the Avon Gorge." Coloured Map. II. "The Millstone Grit at Long Ashton, Somerset." With Map. 1*s*.

III. "The Portbury and Clapton District." IV. "On the Geology of Portishead." 2 coloured maps and 2 plates. 1*s*. 6*d*.

Sleep and Dreams. By GEORGE MUNRO SMITH, L.R.C.P. Lond., M.R.C.S. 2 plates. 1*s*.

The Bone-Cave or Fissure of Durdham Down. By E. WILSON, F.G.S., Curator of the Bristol Museum. 2 plates. 1*s*.

Notes on a Common Fin Whale, lately Stranded in the Bristol Channel. By E. WILSON, F.G.S., Curator of the Bristol Museum. Photograph. 1*s*.

The Severn Tunnel. By CHARLES RICHARDSON, C.E., and Notes on the Geology of the Section by Prof. C. LLOYD MORGAN, F.G.S., Assoc.R.S.M. With geologically coloured Section of Tunnel, map and plate. 2*s*.

The Arch. By CHARLES RICHARDSON, C.E., with illustrations. 1*s*.

Portrait and Obituary Notice of the first President of the Society, WILLIAM SANDERS, F.R.S. 6*d*.

Portrait and Memoir of the second President of the Society, HENRY EDWARD FRIPP, M.D., M.R.C.P. 6*d*.

Portrait and Obituary Notice of the third President of the Society, GEORGE FORSTER BURDER, M.D., F.R.C.P.

Proceedings, NEW SERIES.

Vol. I., Part	1, 1873–74.	5*s*.	Vol. V. Part	3, 1887–88.	5*s*.
,, ,, ,,	2, 1874–75.	3*s*.	,, VI. ,,	1, 1888–89.	4*s*.
,, ,, ,,	3, 1875–76.	4*s* 6*d*.	,, ,, ,,	2, 1889–90.	3*s*. 6*d*.
,, II. ,,	1, 1876–77.	3*s*. 6*d*.	,, ,, ,,	3, 1890–91.	4*s*. 6*d*.
,, ,, ,,	2, 1877–78.	3*s*. 6*d*.	,, VII. ,,	1, 1891–92.	2*s*. 6*d*.
,, ,, ,,	3, 1878–79.	3*s*. 6*d*.	,, ,, ,,	2, 1892–93.	3*s*. 6*d*.
,, III. ,,	1, 1879–80.	3*s*. 6*d*.	,, ,, ,,	3, 1893–94.	2*s*. 6*d*.
,, ,, ,,	2, 1880–81.	3*s*. 6*d*.	,, VIII. ,,	1, 1894–95.	2*s*. 6*d*.
,, ,, ,,	3, 1881–82.	3*s*. 6*d*.	,, ,, ,,	2, 1896–97.	2*s*. 6*d*.
,, IV. ,,	1, 1882–83.	3*s*. 6*d*.	,, ,, ,,	3, 1897.	1*s*.
,, ,, ,,	2, 1883–84.	3*s*. 6*d*.	,, IX. ,,	1, 1898.	2*s*. 6*d*.
,, ,, ,,	3, 1884–85.	3*s*. 6*d*.	,, ,, ,,	2, 1899.	2*s*. 6*d*.
,, V. ,,	1, 1885–86.	4*s*.	,, ,, ,,	3, 1900.	2*s*.
,, ,, ,,	2, 1886–87.	5*s*. 6*d*.	,, X. ,,	1, 1901.	2*s*.

NEW SERIES, Vol. X., Part III. (issued for 1903). Price 2s.

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIV.

NEW SERIES, Vol. X., Part III. (issued for 1903).

PROCEEDINGS

OF THE

BRISTOL NATURALISTS' SOCIETY.

EDITED BY THE HONORARY SECRETARY.

"*Rerum cognoscere causas.*"—VIRGIL.

BRISTOL.

PRINTED FOR THE SOCIETY.

MCMIV.

LIST OF OFFICERS

(1903)

President:

Arthur B. Prowse, M.D.

Past Presidents:

John Beddoe, M.D., F.R.S.
Prof. C. Lloyd Morgan, LL.D., F.R.S., F.G.S.
Prof. W. Ramsay, F.R.S.
Prof. Sydney Young, D.Sc., F.R.S.

Vice-Presidents:

A. E. Hudd, F.S.A.
C. K. Rudge.

Members of the Council:

E. H. Cook, D.Sc.
H. B. Cornaby.
T. Fisher, M.D.
S. J. Hayman.
Rev. A. C. Macpherson, M.A.
H. C. Playne, M.A.
J. Rafter.
G. Munro Smith.
Rev. G. F. Whiddborne, M.A.

Honorary Treasurer:

Harold E. Matthews, 30, The Mall, Clifton.

Honorary Secretary:

S. H. Reynolds, M.A., University College, Bristol.

Honorary Reporting Secretary:

G. Brebner, University College, Bristol.

Honorary Librarian:

C. K. Rudge, Ashgrove House, 145, White Ladies' Road.

Honorary Sub-Librarian:

Henry J. Charbonnier, 43, Dove Street, Kingsdown.

OFFICERS OF SECTIONS

Botanical:

President—Cedric Bucknall, Mus. Bac., 13, Whatley Road, Clifton.
Secretary—James W. White, F.L.S., Warnham, Woodland Road, Clifton.

Entomological:

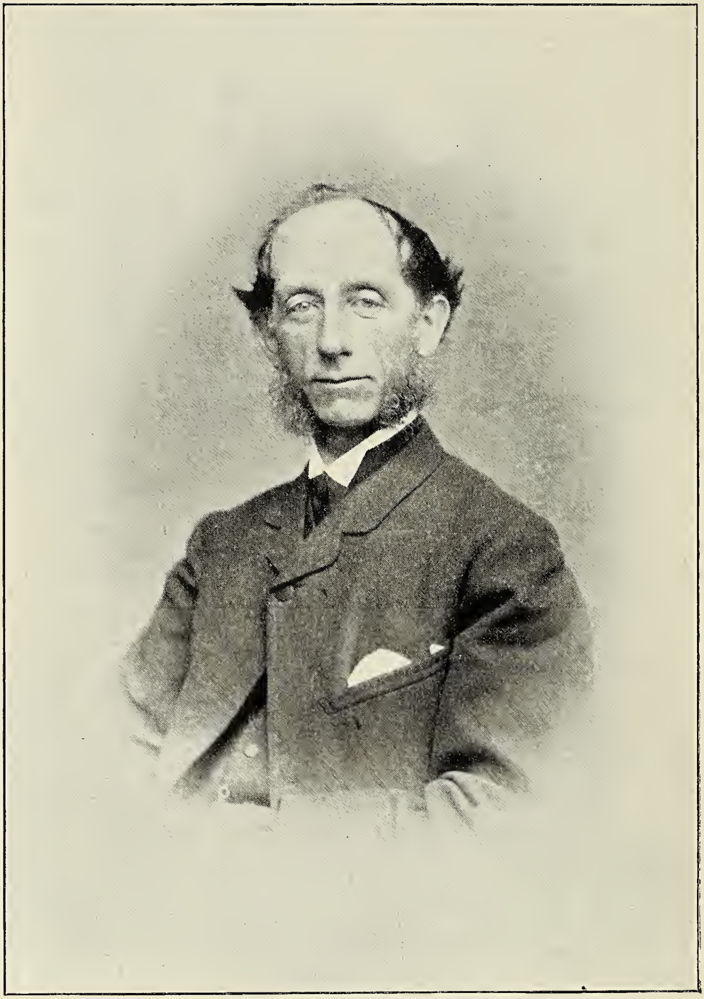
President—G. C. Griffiths, F.Z.S., F.E.S., 43, Caledonia Place, Clifton.
Secretary—Charles Bartlett, 18, Henleaze Avenue, Westbury-on-Trym.

Geological:

President—S. H. Reynolds, M.A., F.G.S., 9, Tottenham Place, Clifton.
Secretary—B. A. Baker, 11, Westbury Park, Durdham Down.

TABLE OF CONTENTS

NEW SERIES. VOL. X. PART III.



ROBERT ETHERIDGE, F.R.S., ETC.

(Reproduced by the kind permission of William Blackwood and Sons)

A Memoir of Robert Etheridge, F.R.S., etc.

By HORACE B. WOODWARD, F.R.S.

ALTHOUGH not a native of Bristol, nor one who achieved distinction in the city, yet Robert Etheridge may be appropriately enrolled among the worthies who have emanated from this ancient seaport. Born at Ross, in Herefordshire, on December 3, 1819, he received an ordinary school education in that town, and proceeded as a youth to seek occupation at Bristol. His grandfather, on the paternal side, was then Harbour Master, and through his influence Robert Etheridge gained employment at first as an usher in a school, and afterwards as assistant in a commercial establishment. There are few records of his life at this period, but his interest in natural science had been aroused by specimens given to him by his grandfather, who during frequent voyages abroad had collected many natural curiosities. Thus, while still a youth, he commenced to form a collection, using his mother's linen press for a cabinet. He then made a beautiful collection of mosses and other dried plants, and to these he added minerals and sundry geological specimens, so that by the time he was twenty-one years of age he had a carefully arranged museum of his own.

During these early years he attended lectures at the

Bristol Institution, thereby coming into contact with men of culture, learned in several branches of physical and natural science, who helped him in various ways ; and it is evident that he was imbued with a strong desire to exchange the monotony of business life for the more interesting career of a naturalist. Apart from this guidance and encouragement in his youthful days, Etheridge was for the most part self-educated, so far as his scientific knowledge was concerned.[1]

Bristol at this date (about 1840 to 1850) had become a centre of scientific activity. In 1835 there was founded *The West of England Journal of Science and Literature*, and although in the course of two years only five numbers of the journal were published, the Editor in his address to his readers, stated that "during the last few years the tastes and pursuits of a large section of the inhabitants have been undergoing a gradual but important change. Science and Literature have become more popular, the tone of general conversation has improved, and the demand for instructive and profitable books has proportionately increased." The Reading Room of the Bristol Philosophical Institution[2] was much frequented, while the Museum became too small for the specimens that were contributed. The collection had been gathered together largely by the instrumentality of J. S. Miller, author of *A Natural History of the Crinoidea, or Lily-shaped Animals* (4to, Bristol, 1821). Miller (originally Müller)

[1] For some of the particulars here given I am indebted to Mrs. Etheridge, and also to Dr. John Beddoe, F.R.S., with whom Etheridge was connected on his mother's side, through the Pardoes, an old Worcestershire family.

[2] This Institution in Park Street was opened in 1823, but not completed until 1825. The new Bristol Museum and Library in Queen's Road, which was completed in 1871, was formed by an amalgamation of the old Institution with the Bristol Library Society, founded in 1772. See *Guide to the Bristol Museum*, by the late E. B. Tawney, edited by James Dallas. 1883.

was, as he tells in the preface to his book, "a native of the once free Hanseatic town of Dantzig," and he appears to have been the first curator. He was succeeded in 1831 by Samuel Stutchbury, F.G.S., a naturalist of wide knowledge, remembered more particularly for his description, in conjunction with Dr. H. Riley, of bones and teeth of the Saurians, *Thecodontosaurus* and *Palæosaurus*, which were discovered in the Dolomitic Conglomerate in the quarry east of Durdham Down, near Bristol. He also named and described *Plesiosaurus megacephalus* from the Lower Lias, as well as some fossil mollusca. It is interesting to note that many years afterwards (1870) Etheridge read before the Geological Society of London a paper on the Dolomitic Conglomerate of the Bristol area, in which he gave a sketch made by Stutchbury to show the position in which the reptilian remains were found.

The collection of the Bristol Institution in 1835 included Ethnological and Antiquarian objects, as well as Zoological, Mineralogical, and Geological specimens. Notable among the geological treasures was the fine collection of Crinoidea formed by Miller, an excellent series of fossils from the Lias and Oolites, especially from the Inferior Oolite of Dundry, and others from the Greensand of Blackdown and Warminster.[1]

Stutchbury retired from the Curatorship of this Museum of Natural History in 1850, passing a portion of the later years of his life in Australia[2]; and Robert Etheridge was appointed to succeed him. From this it may be inferred that he owed much to Stutchbury in the way of preparation and recommendation for this responsible position. That Etheridge was well qualified for the work he now took in hand may be judged from the fact that during his holding

[1] See *West of England Journal*, 1835, pp. 19, 20; and article by W. D. Conybeare, p. 98, etc.

[2] He died on February 12, 1859, aged 61. See brief obituary in *Quart. Journ. Geol. Soc.*, vol. xvi. p. xxix.

of the office he was for five years lecturer on Vegetable Physiology and Botany in the Bristol Medical School. As Curator his ability and strenuous industry attracted the attention of those under whom he served, notably of John Scandrett Harford, of Blaize Castle, and William Sanders, F.R.S. Sanders was then Honorary Secretary of the Bristol Institution, and a geologist of great local knowledge.

Bristol is happily situated in a region famed for the variety of the geological formations that can be studied within easy distance. It is rich also in associations with the geologists of the early part of the last century—Buckland, W. D. Conybeare, Thomas Weaver, De la Beche, William Lonsdale, and others. It is interesting, therefore, to read in the list of subscribers to Miller's *Crinoidea* that in 1821 De la Beche resided at Clifton, J. J. Conybeare at Batheaston, W. D. Conybeare at Brislington, C. G. B. Daubeny at Bristol, and Thomas Weaver at Tortworth.

William Sanders, who was born in 1799, had commenced about the year 1835 to make a geological map of the neighbourhood of Bristol, on a scale of four inches to a mile. This great task was published in 1862, but long prior to its completion, the results of his work in the country extending from Bristol northwards to Berkeley, were given to his friend De la Beche and incorporated on Sheet 35 of the one-inch Geological Survey map issued in 1845. With this painstaking geologist Etheridge worked a good deal, and learned some of his earliest lessons in field-geology.

He was introduced to the Cotteswold Naturalists' Field Club soon after its formation in 1846; as we read that in 1848 "the club met at Gloucester, at nine o'clock, having Mr. Etheridge as a visitor."[1] At this date the active

[1] See W. C. Lucy, "The Origin of the Cotteswold Club," *Proc. Cotteswold Club*, vol. ix., 1888.

geological members included H. E. Strickland, Dr. T. Wright, S. P. Woodward, John Jones (of Gloucester), J. Lycett, Dr. C. G. B. Daubeny, and James Buckman. A few years later (January 10, 1852) the club met for the first time at Bristol, when they visited the Museum under the guidance of William Sanders and H. E. Strickland, and subsequently examined the gorge of the Avon. In the same year the Earl of Ducie (then Lord Moreton) was elected a member. Thenceforth the club occasionally met for breakfast at Tortworth Court, and after taking to the field, returned to that hospitable mansion for dinner. It was on one of these occasions that Mr. Etheridge was introduced to Sir Roderick Murchison, who in 1855 had succeeded De la Beche as Director-General of the Geological Survey. The event was a memorable one.

Murchison was evidently impressed with the knowledge and energy manifested by Etheridge, and took steps to obtain for him a post in the Government service. In consequence, he was appointed Assistant Naturalist to the Geological Survey on July 1, 1857, working at first under the directions of the naturalist, Prof. T. H. Huxley. At that time J. W. Salter, a man eminent for his knowledge of Palæozoic invertebrata, was Palæontologist. Etheridge came to the Museum at Jermyn Street with a special knowledge of Jurassic fossils, and he was called upon to identify and catalogue the fossils of the Mesozoic and Cainozoic formations. In the course of the next few years he contributed lists of fossils to the *Memoirs on the Geology of Parts of Wiltshire and Gloucestershire* (1858), *Geology of Woodstock* (1859), *Geology of Parts of Northampton and Warwick* (1860), *Geology of Parts of Oxfordshire and Berkshire* (1861), *Geology of Parts of Berkshire and Hampshire* (1862), and *Geology of the Isle of Wight* (1862).

In 1863, on the retirement of Salter, he was appointed Palæontologist, and henceforth, until he himself resigned in 1881, he was responsible for preparing or supervising all the lists of fossils published in the *Survey Memoirs*.

In addition to these labours he aided Huxley, who was Professor of Natural History at the Royal School of Mines, by giving annually for fifteen years demonstrations in palæontology to the students. Together in 1865 they issued a catalogue of the Collection of Fossils in the Museum of Practical Geology, the catalogue being the work of Etheridge, and the explanatory preface being written by Huxley. At this time the fossil vertebrata and the arrangement of all the fossils in the Museum were under the charge of Prof. Huxley, aided after 1866 by Mr. E. T. Newton, while the naming and listing of the invertebrata were under the charge of Mr. Etheridge, aided by the talented and painstaking assistant palæontologist, Mr. George Sharman.

The need of full lists of the known species of fossils, with references to figures and geological horizons, led Etheridge in 1865 to commence his great work on the *Fossils of the British Islands, Stratigraphically and Zoologically Arranged.*

The excellent *Catalogue of British Fossils,* by John Morris, of which a second edition was published in 1854, did not give the stratigraphical information that it was increasingly necessary to record. Hence the importance of this new undertaking. The difficulties that arose were in connection with the printing, as no publisher from a business point of view could well incur the responsibility.

To aid and encourage Etheridge in his task, the Wollaston Donation Fund in 1871 and the Murchison Medal in 1880 were awarded to him by the Geological Society. It was not, however, until 1888 that the first volume of the work was printed and issued by the Delegates of the Oxford University Press. This comprised the Palæozoic species, the information being brought up to 1886. The succeeding portions of the work have unfortunately remained in manuscript, and it is needless to say that every year increases the difficulty of keeping pace with the additions and with the manifold and perplexing changes in nomenclature of the species.

Etheridge, who was elected President of the Geological Society in 1881 and 1882, availed himself of the materials he had so industriously gathered together to give in his two addresses an Analysis and Distribution of the British Palæozoic and Jurassic Fossils. Later on, in 1885, he prepared an elaborate volume on *Stratigraphical Geology and Palæontology*, which was published as Part II. of a second edition of Phillips' *Manual of Geology*. This was practically a new work, and it consisted of rather full particulars of the British strata and their fossils, with ample references. Of his other works a list has been already published.[1]

Considering his extensive knowledge and experience as a palæontologist, Etheridge described comparatively few new species, but these include various forms of invertebrata and some plants, from all quarters of the globe. Attention may, however, be called to the work which has more local bearings.

That Etheridge had acquired an intimate knowledge of the geology of the Bristol district is apparent from the three lectures he gave to the Bristol Mining School[2] in 1857 on "Geology: its Relation and Bearing upon Mining," printed, with other lectures, in a little volume entitled *Lectures Delivered at the Bristol Mining School*, 1857 (8vo, Bristol, 1859).

[1] See obituary, by Dr. Henry Woodward, *Geol. Mag.*, Dec. V., vol. i., 1904, pp. 46–48.

[2] The Bristol Mining School was established in 1856, and "was designed to enable those who wish to fill situations of trust in connection with mining to obtain a good, cheap, and practical education."

Later on he read before the Cotteswold Naturalists' Club an interesting paper " On the Physical Structure of the Northern Part of the Bristol Coal Basin, chiefly having Reference to the Iron Ores of the Tortworth Area." Dealing historically with the subject, he pointed out that the " process of smelting was carried on prior to the use of coal, and that wood was used as fuel for the reduction or conversion of the raw ore to the metallic state "—perhaps from the time of the Roman occupation until nearly the middle of the eighteenth century.

After the researches of Dr. Wright and of Charles Moore on the Rhætic Beds (zone of *Avicula contorta*) in this country, it was thought desirable by the Director-General of the Geological Survey to ascertain how far the strata could be represented on the Geological Survey maps. H. W. Bristow and R. Etheridge were accordingly instructed to investigate the matter, and they examined and measured the sections at Saltford, Uphill, Aust, Garden Cliff, Watchet, Penarth, and other places.[1] The lower portion of the Rhætic formation was then taken to consist " of alternations of hard and soft marls, passing gradually into the red and green marls of the Keuper formation " ; the central portion included the Aust Bone-bed and the black shales with *Avicula contorta* ; while the upper portion comprised the Cotham marble or Landscape stone and various white limestones and marls, in mass grouped as the White Lias. Etheridge thus became keenly interested in the Rhætic formation, and described in detail the beds at Garden Cliff near Westbury-on-Severn, at Aust Cliff, Penarth and Lavernock, and also those at Watchet. Interest in these strata, which connect the New Red Sandstone series with the Jurassic system, has been generally maintained, and especially in the country around Bristol, where the strata have been so well exposed in many

[1] See *Geol. Mag.*, vol. i. 1864, p. 236.

a cliff and railway-cutting, where the "Bristol Bone-bed" has yielded so many fine vertebrate remains, and where the Landscape Marble of Cotham is locally so well developed. The grouping of the Grey marls that occur below the Black shales, with the Rhætic rather than with the Keuper formation, has led to frequent criticism, and it will not be out of place, therefore, to refer more particularly to Etheridge's views on this subject. In his paper on the Rhætic Beds at Garden Cliff, Westbury-on-Severn, he included with the Red (Keuper) Marls sixteen feet of "alternating bands of grey and red fissile and conchoidal Marls (No. 1 in section), apparently here containing no fossils." He added that these Marls "correspond in position and age to the same (but lithologically rather different) beds at Watchett, Penarth, and Puriton, at which places I have termed them 'Tea-green Marls,' from the peculiar hue of the freshly-fractured shales when exposed, and the constancy of their conditions." [1]

Above these "Tea-green" Keuper Marls there is a series of Grey Marls (17 ft. 3 in. thick), which he linked with the Rhætic Beds, on the ground of "Collateral evidence, and equivalent beds, as determined through correlation with other sections, with the occurrence of fish and other remains in these pale grey Marls." He regarded them as "the equivalents of the Tübingen sandstones and marls of Quenstedt."

A good deal of discussion has taken place with reference to the so-called "Tea-green Marls," and it has not been recognized that Etheridge originally placed them in the Keuper, and distinguished them from the Grey Marls which frequently form the base of the Rhætic. This is not to be wondered at when we find that the descriptions in his text do not tally with his diagrams. Thus, the brackets in his Penarth section show the Tea-green Marls as extending

[1] *Proc. Cotteswold Club*, vol. iii. pp. 220, 221.

from the base of the Black Shales well into the Red Keuper Marls ![1] It seems hopeless now to attempt to disentangle the meaning of these "Tea-green Marls"; they can only be regarded as a local phase of the passage-beds that occur between the main mass of red and variegated Keuper Marls and the Rhætic Beds. As remarked by the present writer, "In some localities the more marked boundary would be taken at the base of the Black Shales, as the Grey Marls appear more closely linked with the Red Marls; but in other localities the Grey Marls present features markedly different from the Keuper Marls, and appear more closely connected with the Black Shales and White Lias."[2] Much may be said locally in favour of either view; thus, Edward Wilson strongly supported the view that the Grey Marls should be classed as Keuper, while the results of the latest observations in South Wales show the intimate local connection between the Keuper Marls and Rhætic Beds.

Etheridge's most important paper was that "On the Physical Structure of North Devon, and on the Palæontological Value of the Devonian Fossils." It was prepared by request of Murchison as an answer to the heterodox views expressed by J. Beete Jukes, then Director of the Irish branch of the Geological Survey. On and off since 1852[3] Jukes had experienced doubts with regard to the Devonian as a separate system, believing that the slates were in the main Lower Carboniferous and the sandstones Old Red Sandstone. Matters were brought to a climax when his paper "On the Carboniferous Slate (or Devonian Rocks) and the Old Red Sandstone of South Ireland and North Devon," was read before the Geological Society

[1] See paper "On the Rhætic Beds of Penarth and Lavernock," *Trans. Cardiff Nat. Soc.*, vol. iii. p. 39. See also Etheridge's *Stratigraphical Geology*, p. 342.

[2] *Geology of England and Wales*, ed. 2, 1887, p. 245.

[3] *Letters*, etc. of J. B. Jukes, 1871, p. 561.

in 1866. Jukes, while then admitting that there appeared to be a regular ascending succession of rock-groups from Lynton to Barnstaple, felt compelled to dispute the reality of this order, and to maintain that there was either a concealed anticline with an inversion to the north, or that the strata were repeated by an extensive fault with a downthrow to the north. To combat these views was the task set to Robert Etheridge in the autumn of the same year, and in March of the following year (1867) he had prepared the defence. At the outset he felt the work before him to be almost overwhelming; but he was a man of indomitable energy and great activity. In the end he mapped out the main divisions of the rocks; he gathered all the help he could from the long-continued researches of local observers; he listed and tabulated all the known fossils, giving their range in time and distribution in this country and on the continent; and finally he maintained that the Devonian system, as a whole, was chronologically the same as the Old Red Sandstone.

Although the main contention of Etheridge has been generally accepted, there is yet a great deal to be done in reference to the classification of the rocks in Devonshire. As remarked by Sir A. Geikie, "Jukes did a great service by boldly attacking it and bringing to bear upon it all his long experience in the south of Ireland, which gave him an advantage possessed at the time by hardly any one else." [1]

During subsequent researches, Dr. Henry Hicks found fossils in the Morte Slates which had previously been thought to be unfossiliferous, and these he regarded as Upper Silurian and Lower Devonian. This discovery renewed the controversy on the succession of the strata, and although Etheridge disputed the identification of the fossils, yet other authorities were of opinion that the fauna was of Lower Devonian if not of Silurian age, and

[1] *Life of Sir Roderick I. Murchison*, vol. ii. 1875, p. 328.

that Dr. Hicks had established his contention that the apparent succession in North Devon was not the true one.[1]

In 1882 Etheridge contributed *Notes on some Fossils from the Red Beds of the Lower Devonian, Torquay, South Devon*, in which he described some species collected by the late A. Champernowne ;[2] but, except in discussion at the Geological Society's meetings, and in his manual of *Stratigraphical Geology*, he did not enter further into the Devonian question.

For his researches especially on Devonian Geology he was awarded the Bolitho Medal by the Royal Geological Society of Cornwall in 1896.

In 1881 Etheridge resigned his position on the Geological Survey, on being transferred to the post of Assistant Keeper in the Geological Department of the British Museum (Natural History) at South Kensington. There he laboured for ten years, with much advantage to that Institution, retiring from the public service at the end of 1891, when he was seventy-two years of age. While, however, he had retired from official work, he never ceased to labour in the pursuit of science.

Throughout his scientific career he had given much attention to questions of economic importance, and had frequently been consulted by engineers in reference to water supply, coal, and other matters. The deep borings in the London area had naturally interested him, and he contributed an essay on "The Position of the Silurian, Devonian, and Carboniferous Rocks of the London Area."[3] He then remarked: "The fact that the Upper Devonian rocks were under the heart of London, and the Silurian some miles north of that, induces us to believe that we must look to the south of London, as pointed out by Mr.

[1] *Quart. Journ. Geol. Soc.*, vol. liii., 1897, p. 458, etc.
[2] *Geol. Mag.*, Dec. II., vol. ix., p. 154.
[3] *Popular Science Review*, N.S., vol. iii., July, 1879, p. 279.

Godwin-Austen, as the area where we should expect to find the Coal Measures, ranging probably under or north of the North Downs." These suggestions received confirmation from the subsequent discovery of coal in the deep boring at Dover; and Etheridge was afterwards appointed consulting geologist to the promoters of the Dover Coal Exploration. Thus for a number of years he had the congenial task of noting the strata and recording the fossils that were obtained at Dover and at other localities in the south-east of England where trial borings were made. He laboured at this work until within a short time of his decease.

It should be mentioned that in 1893 he contributed to the *Proceedings of the Cotteswold Club* an elaborate essay "On the Rivers of the Cotteswold Hills within the Watershed of the Thames, and their Importance as Supply to the Main River and the Metropolis."[1] This was an amplification of the evidence given by him before the Royal Commission on Metropolitan Water Supply.

One of his latest tasks in connection with this subject was to advise the late Thomas Hawksley, M.Inst.C.E., with regard to the water supply for Bristol.

Personally, Robert Etheridge was beloved by all who knew him. He was ever ready, publicly and privately, to give assistance and information to those who sought it. In disposition he was cheery and good-humoured, active and alert on all occasions, and he maintained a youthful energy until almost the close of his life in his 85th year.

He was three times married, and leaves (by his first wife) one son, Robert Etheridge, who is distinguished as a palæontologist, and is now Curator of the Australian Museum at Sydney, New South Wales.

[1] Vol. xi. pp. 49–101.

The Field Relations of the Carboniferous Volcanic Rocks of Somerset.

BY C. LLOYD MORGAN, LL.D., F.R.S., F.G.S., AND S. H. REYNOLDS, M.A., F.G.S., WITH EXTRACTS FROM PAPERS BY SIR ARCHIBALD GEIKIE, D.C.L., LL.D., F.R.S., ETC., AND MESSRS. A. STRAHAN, M.A., F.R.S., AND W. S. BOULTON, F.G.S.

CONTENTS.

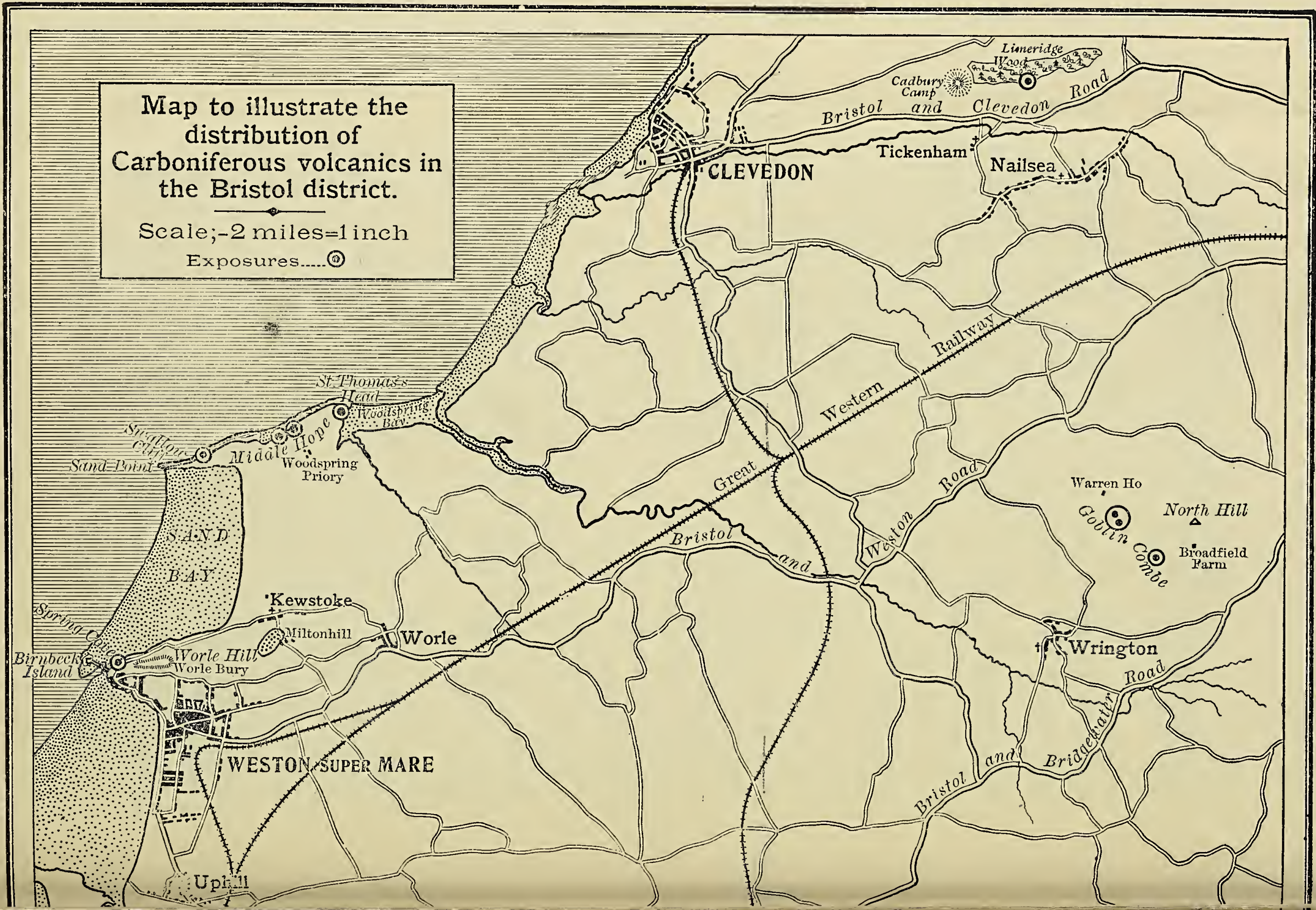
I. *INTRODUCTION.*

DURING the past few years the igneous rocks associated with the Carboniferous Limestone series of the Bristol district have attracted a good deal of attention, and three accounts of them have been published :—

1. In the *Summary of Progress of the Geological Survey for* 1898 [1] Sir Archibald Geikie and Mr. A. Strahan give a detailed account of the majority of the exposures, and clearly establish the contemporaneous character of the rocks.

2. In the *Quarterly Journal of the Geological Society* for 1904 [2] the authors of the present paper summarize in the introduction the literature of the subject, deal with the evidence for the contemporaneous origin of the igneous

[1] P. 104–111.
[2] Vol. lx. p. 137–157.



Map to illustrate the distribution of Carboniferous volcanics in the Bristol district.
Scale;-2 miles=1 inch
Exposures.....
CLEVEDON
Tickenham
Nailsea
Cadbury Camp
Lineridge Wood
Bristol and Clevedon Road
Great Western Railway
St Thomas's Head
Woodspring Bay
Middle Hope
Woodspring Priory
Sand Point
SAND BAY
Kewstoke
Miltonhill
Worle
Worle Hill
Worle Bury
Birnbeck Island
WESTON SUPER MARE
Uphill
Bristol and Weston Road
Bristol and Bridgewater Road
Wrington
Warren Ho
North Hill
Goblin Combe
Broadfield Farm

rocks, and with their approximate horizon, concluding with an account of their petrology.

3. In the same part of the *Quarterly Journal*[1] Mr. Boulton records a number of fresh observations on the Spring Cove section.

The two latter papers have added to some extent to the field observations recorded in the *Summary of Progress*, and it has occurred to us that it would be useful to have the principal facts recorded in these various papers brought together in a convenient form, and especially that the details of the various sections should be presented in such a way as to afford to local geologists a convenient basis for field observation. This we are enabled to do through the kind permission of the Controller of His Majesty's Stationery Office, of the Council of the Geological Society, of Sir Archibald Geikie, and of Messrs. A. Strahan and W. S. Boulton, to all of whom our best thanks are tendered.

The Carboniferous volcanic rocks of the Bristol district occur (see map, p. 189) at the following localities—(1) Woodspring (Middle Hope); (2) Spring Cove, Weston-super-Mare; (3) above ~~Trent~~ Stoke, Milton Hill; (4) ~~Golden~~ Combe; (5) Uphill; (6) near Cadbury Camp. At all the above localities, with the exception of Uphill and near Cadbury Camp, there is evidence of the occurrence of both lavas and tuffs. There is nothing to show whether the igneous rocks of Uphill and near Cadbury Camp are contemporaneous or not, but with these exceptions and the possible further exception of Milton Hill, the igneous rocks are undoubtedly contemporaneous.

By the help of Dr. Arthur Vaughan, who most kindly determined the fossils collected from the limestone associated with the volcanic series at each locality, we were

[1] Vol. lx. p. 158–169.

NOTE.—The maps accompanying this paper, on pages 189 and 197, are reproduced by the kind permission of the Council of the Geological Society from the *Quarterly Journal.*

enabled to show that it was extremely probable that (1) the igneous rocks in the various localities occurred on one horizon and marked one episode; (2) that this occurred at a period marked by the marine fauna of group B in the following table supplied by Dr. Vaughan:—

	Position of Beds referred to the section N. of Avon at Bristol.	Sequence	Palæontological characteristics.
	Lower part of Great Quarry and underlying Dolomitic Beds.	Higher Beds.	Marked by the entrance of *Lithostrotion*, *Producti* belonging to the *giganteus* group, and *Athyrids* of the *ambigua* group (*Seminula*).
About 135 feet	Oolitic beds in the Quarry at foot of Gully. / Beds between Gully and Black-Rock Quarry.	Group C.	Marked by the great abundance of *Orthotetes* (*Streptorhynchus*) *crenistria* and *Chonetes papilionacea* and aff. *comoides*. In these beds *Spirifer* aff. *laminosus* reaches its maximum.
About 100 feet.	Upper Third of Black-Rock	Group B. resting immediately upon	Marked by the abundance of a *Zaphrentid* of the *cylindrica* type (*Campophyllum*=*Zaphrentis cylindrica* of Edw. & Haime).
	Quarry.	Group A.	Containing cornute *Zaphrentids* in great abundance.
	Lower and Middle Thirds of Black Rock Quarry.	Lower Beds.	Marked by the rarity of *Zaphrentids* and by the gradual increase downwards of *Spirifers* of the *bisulcatus* group; and of the *glaber* type (*Martinia*); *Athyrids* of the *Royssii* type (*Cleiothyris*); *Orthids* of the *Michelini* and *resupinata* types, *Leptena analoga*, and *Producti* of the *punctatus* and *Martini* types.

As regards the petrology of the igneous rocks, they may in brief be said to be all basaltic in character. The lavas are basalts or dolerites, some with, some without olivine; in one case (Spring Cove) much of the basalt is variolitic. The tuffs are also entirely basaltic in character, and are frequently highly calcareous. They often contain oolitic grains. The igneous rocks are described in some detail, and illustrated by means of a plate in the *Quart. Journ. of the Geol. Soc.*, vol. lx. p. 151–155, Plate XVII.

II. *DESCRIPTION OF THE EXPOSURES.*

(1) *Middle Hope* (*Woodspring*).

The most complete and interesting of these sections are those of Middle Hope or Woodspring. The pedestrian coming from Weston-super-Mare will reach them most conveniently by following the road round by the old pier to the northern slope of Worle Hill, and then striking along the shore of Sand Bay to the targets at its northern end. By crossing the hill and bearing to the left the westerly exposure is reached. If it be desired to cycle or drive, the road through the village of Worle, skirting the eastern end of Worle Hill to Woodspring Priory, is the most convenient.

First Exposure.—The principal and most westerly section is described by Sir A. Geikie and Mr. Strahan as follows:—

"Two miles to the north of Weston another parallel ridge of limestone, known as the Middle Hope, runs out into the Bristol Channel and displays along its northern coast-line a still more interesting intercalation of contemporaneous volcanic material. Three separate sections have been laid open by the sea within the space of a mile. The most westerly of these is illustrated in the accompanying figure, which represents the whole volcanic group, about 100 feet thick, intercalated between the ordinary crinoidal limestones (1 and 14). At the base from low-water up the beach, between 30 and 40 feet of highly fossiliferous crinoidal limestone (1) appear from under the sea in successive beds, which towards the top pass into a reddish banded limestone with thin partings of red clay. The argillaceous material probably results from decayed volcanic

Section of Volcanic Rocks in Carboniferous Limestone.
Middle Hope, Mouth of Severn, Somerset.
(By Sir A. Geikie, LL.D., F.R.S., and Mr. A. Strahan, F.R.S.).

dust, and marks the beginning of the eruptions from the vent in this neighbourhood, for above the reddish limestone lies a greenish tuff (2) with calcareous bands. Much of this band is concealed under the detritus of the beach, but it may be more than 12 feet thick. It is followed by a thin-bedded limestone (3) crowded with *Productus* and other fossils, about 3 feet thick, but swelling out to a much greater bulk further east. Next comes a group of green and red tuffs (4) with lenticular bands of limestone. Some of the tuffs are marked by bunches of coral in the position of growth. At the top of these tuffs a band of red ferruginous limestone (5) appears; it is thin-bedded, lenticular, and about 5 feet thick. It passes upward into about 15 feet of highly fossiliferous limestone (6). The quiet interval marked by the intercalation of this crowded mass of organic remains was brought to an end by a much more vigorous display of volcanic energy. The explosions began with the discharge of ashes, which in the section are now represented by from 12 to 14 feet of green tuff (7). The lapilli varied continually in size so that the tuff is made up of lenticular layers of fine and coarser material. The band, moreover, is much veined with calcite, no doubt derived from the solution of calcareous organisms either in the surrounding limestones or in the tuff itself. The top of this accumulation of pyroclastic material is marked by a thin red cherty layer (8), immediately above which lies the chief member of the volcanic group—a dull green amygdaloid of the usual basic character (9). This bed, perhaps 12 to 14 feet in thickness, has been a thoroughly vesicular scoriaceous basalt. It shows the 'pillow' structure already referred to, some of the 'pillows' being a yard or more in diameter. The vesicles, sometimes 4 inches long, have been filled with calcite. The upper surface of the sheet is rugged and scoriform, and the overlying sediments have filled up its hollows.

"The outflow of this lava was followed by a much quieter phase of volcanic activity, when only occasional showers of dust were discharged over the floor of the sea on which the calcareous organisms had again spread. This portion of the record is contained in a band, about 9 feet thick, of lenticular seams of blue limestone (10), full of fossils, and divided by partings of fine tuff. A more prolonged and vigorous discharge of ashes is indicated by a band of green tuffs about 9 feet thick (11). The base of this band passes down into the ashy limestone group (10) below, so that there was obviously no interruption in the continuity of the volcanic phenomena. But the discharge of the ashes must have been sufficiently gentle or intermittent to allow of the continued presence of living organisms even on the bottom over which the volcanic detritus was accumulating, for the tuff contains lenticular seams and nodules of crinoidal limestone. In this band one of the characteristic features of Carboniferous tuffs already referred to is well displayed—the presence of abundant lapilli of a minutely vesicular basic pumice. A thin slice prepared from one of the calcareous bands was found under the microscope to be full of these lapilli and of various organisms, among which Mr. Newton detected foraminifera (*Endothyra ?*), and probably also echinoderms, corals, and entomostraca.

"The gradual cessation of volcanic activity was marked by a return of the phase of sedimentation that had preceded the last more violent outbreak. The tuff-band just described passes upward into a red limestone (12) about three feet thick, banded with lenticular seams of green tuff like that underneath. Then comes a reddish nodular limestone (13), about three feet thick, with irregular partings of a ferruginous argillaceous material which may be highly decomposed volcanic detritus of the finest kind, marking some of the last efforts of the expiring volcano. Immediately above lies the ordinary well-bedded coarsely-crinoidal limestone of the district. Its lower seams include little blotches which may possibly also be decayed ashy material. But above this part of the section all trace of volcanic activity disappears, and the normal limestone, made up entirely of organic remains, resumes its place."

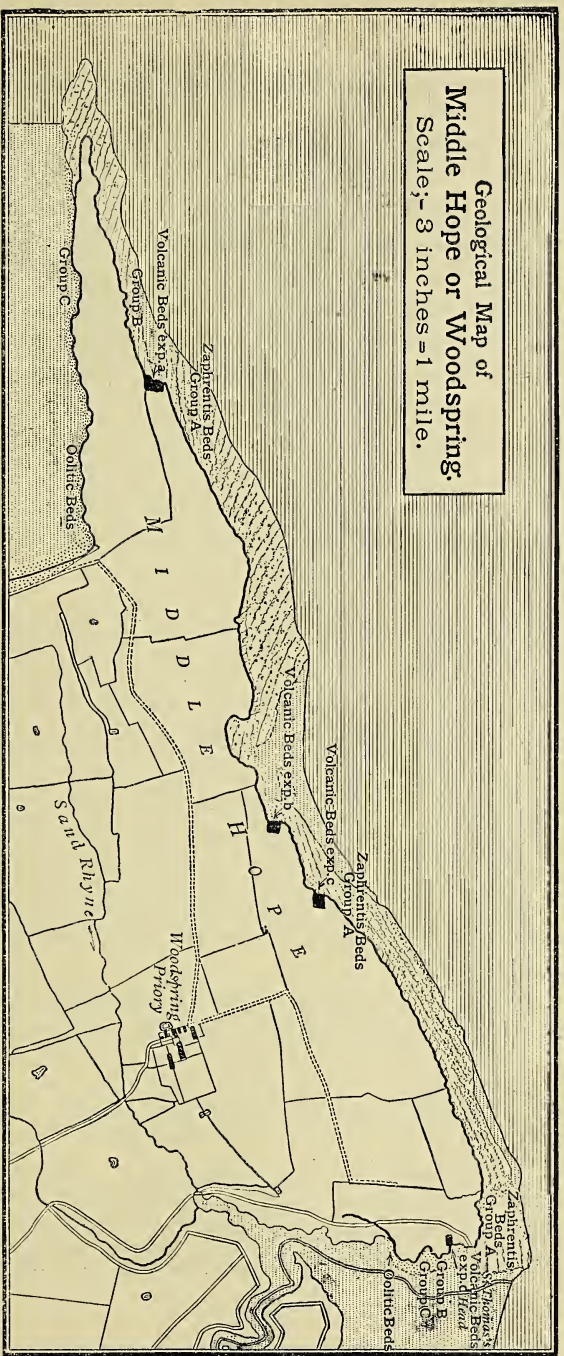
We have very little to add to the above description.

The limestone at the base (No. 1 in the above section) contains abundant chert. The basalt (No. 9) is always in a very much weathered state, and is sometimes converted into a brown, sandy-looking material in which little can be made out except the amygdules. The highest bed (No. 14) contains larger lapilli than any of the others, as they reach a length of 2 inches. They are fairly plentiful up to a height of at least 7 feet from the base.

Second Exposure.—Sir A. Geikie's and Mr. Strahan's description of this is as follows :—

" The next section of the volcanic group has been laid bare in a small bay three-quarters of a mile further to the east. Here again the rocks have been thrown into a highly inclined position, so that a considerable thickness of strata has been packed into a narrow strip of the beach. Short as is the interval between this outcrop and that just described, the succession of strata between the two places has entirely changed. The sheet of lava has disappeared, and a number of the tuffs which towards the west are separated by layers of limestone here form more continuous deposits. But the whole volcanic group is thinner.

" At the base of the section the thick crinoidal limestone, with bunches of coral in the position of growth, passes upwards as before into reddish banded limestone with red clay partings, which no doubt represent much-decayed fine volcanic dust, for immediately above comes a deposit about 50 feet thick of green finely-bedded tuff. This band repeats the characters above described. It includes in its upper part a coarser layer, which encloses pieces of limestone, chert, and basalt, sometimes six inches long. It is marked also by the same evidence of contemporary organic growth and deposit, for at different platforms throughout its mass occur thin layers of ashy limestone and dark chert, while some of the finer portions of the tuff are nearly as fossiliferous as the ordinary limestone, being



Geological Map of
Middle Hope or Woodspring.
Scale;- 3 inches =1 mile.
Group C
Oolitic Beds
Group B
Volcanic Beds exp.a
Zaphrentis Beds
Group A
M I D D L E H O P E
Volcanic Beds exp.b
Volcanic Beds exp.c
Zaphrentis Beds
Group A
Sand Rhyne
Woodspring
Priory
Zaphrentis Beds
Group A
Volcanic Beds
exp.d
St. Thomas's
Head
Group B
Group C
Oolitic Beds

crowded with crinoidal joints, corals, bryozoa, brachiopods, etc.

"Above this tuff lies a bed of hard, fine-grained, finely-laminated purple and grey sandstone, about 2½ feet in thickness, the most marked feature in which is the presence of numerous small cylindrical pencil-like bodies which descend from the upper surface of the band vertically across the lamination of the sediment. This may be worm-burrows. This arenaceous band seems to mark a pause of some duration during which volcanic activity was quiescent, and the calcareous organisms had not yet recovered their former place over this part of the sea-floor. Possibly this band may be paralleled with the lenticular limestones (No. 10) in the previous section.

"Eruptions were renewed for the last time, when a quantity of ashes was discharged, now represented by a band of green and red tuffs from 5 to 7 feet thick. These materials may be continuous with the band No. 11 further west, like which their layers of coarser and finer material are mingled with much calcareous material. They are well banded, and in their upper part enclose rows of blocks of finely slaggy amygdaloid. Immediately above them comes a limestone 12 feet thick, which passes upward into some red, impure, decaying and probably ashy limestone, and this is followed by the great overlying mass of crinoidal limestone."

We have little or nothing to add to the above general account, but our reading of the section is as follows :—

	ft.	in.
20. Thick crinoidal limestone to top of cliff . . .		
19. Weathered gap with red shale visible at eastern corner	10	0
18. Limestone	12	0
17. Green and red ash. . . . . . . 5 to	7	0
16. Sandstone with vertical cylindrical bodies . .	2	6
15. Fine ash	2	0
14. Lenticular limestone band	3 to 6	
13. Fairly coarse ash with several highly calcareous bands		

		ft.	in.
	in the lower part, numerous large fragments of limestone and some of grit in the upper part . . .	11	6
12.	Coarse ash	3	6
11.	Brown ash very much decomposed and veined with calcite	1	2
10.	Limestone	0	4
9.	Ash as above (No. 11), upper part with many fossils especially *Edmondia*	22	0
8.	Reddish crinoidal limestone	1	0
7.	Ash as above	2	0
6.	Argillaceous limestone	0	3
5.	Ash as above	3	6
4.	Compact somewhat argillaceous limestone . .	0	6
3.	Ash as above	11	0
2.	Limestone in bands from 3 in. to 6 in. thick, with partings of red shale, and at about a foot from the top one of green ashy material, top band of limestone very argillaceous	7	0
1.	Massive limestone, with much chert to base of section .		
		95	6

Third Exposure.—This lies some 200 yards further east. It is briefly described by Sir A. Geikie and Mr. Strahan, who refer to it as the most easterly of the coast stations. Their account is as follows :—

"The most easterly of the three coast-sections lies 600 feet further along the shore. The upper part of the volcanic series is there cut out by a fault, which brings the tuff against the limestone. The calcareous bands in the tuff are here much thicker and more numerous than they are further west, and continue to be crowded with organic remains. The volcanic material appears to be dying out in an easterly direction. Taking the whole evidence of this series of sections, we may reasonably conclude that in this instance also the eruptive vent lay somewhere to the west or north-west of the present shore-line."

The following is our reading of the section :—

		ft.	in.
11.	Sandstone with vertical cylindrical bodies to top of section	1	6 seen
10.	Brown ash much disturbed and calcite-veined about	17	0
9.	Somewhat nodular limestone	2	4
8.	Argillaceous limestone	8	0

	ft.	in.
7. Somewhat nodular limestone	2	6
6. Fine brown ash often calcareous, with occasional fragments of limestone and chert	27	0
5. Reddish impure limestone	4	6
4. Brown decomposed ash with nodular calcareous bands	4	6
3. Argillaceous limestone	0	5
2. Brown decomposed ash with nodular calcareous bands	13	0
1. Limestone with chert and corals to base of section		
	80	9

Fourth Exposure.—Still further to the east, in a little cove just south of the point where the coast line bends due south, is a small and much attenuated representation of the volcanic series. This is not described by Sir A. Geikie and Mr. Strahan. The section is as follows :—

	ft.	in.
5. Thin bedded limestone dipping at 40°S, 10 E. to top of section		
4. Shaly beds	2	6
3. Fine red ashy limestone	2	0
2. Fairly coarse ash	2	0
(gap, no exposures.)		
1. Reddish limestone to base of section		

The most interesting points about these sections are (1) that the lava is only met with in the most westerly exposure, and (2) that the whole series becomes progressively thinner when followed to the east, showing that the centre of volcanic activity probably lay further to the west.

(2) *Spring or Birnbeck Cove, Weston-super-Mare.*

Sir A. Geikie and Mr. Strahan give a full description of this section in the *Summary of Progress.* Their account is as follows :—

" At Spring Cove, immediately to the west of the town of Weston, a cliff between the high road and the sea exposes the succession of rocks given in the subjoined table in descending order :—

Massive limestone full of fossils. The lowest three feet of the rock are crowded with fine volcanic dust, which under the microscope is seen to consist of fine vesicular lapilli.

Highly amygdaloidal altered basalt, having a 'pillow'-structure and with abundant calcareous and hæmatitic veins, and threads of carbonate of copper; about 35 or 40 feet.

Red limestone, full of fine volcanic dust, and passing down into the ordinary grey fossiliferous limestone.

"This section places clearly before the mind the succession of volcanic events of which it retains the record. From some vent in the neighbourhood fine dust continued to be ejected during a considerable interval, for the limestone, through some 30 or 40 feet of its mass below the basalt, is full of disseminated volcanic particles. The lapilli abound in vesicular basic pumice, and show the prevalent dull-green palagonitic modification of what was no doubt originally a basic glass.

"At last a stream of lava flowed over this part of the sea bottom. It rested immediately on the calcareous sediment to which it is now firmly bound, and which is highly crystalline; but there is no conclusive evidence that this crystalline structure has been due to the heat of the overlying lava. This lava is now much oxidised and decayed, strongly amygdaloidal, and presenting the characteristic 'pillow' or sack-like structure that has been so frequently observed among the submarine volcanic eruptions of former geological periods. The interstices between the large irregularly shaped pillow-like masses of the sheet have been filled up with calcareous material, which, in the form of a network of limestone ribs with veinings of hæmatite, traverses the rock. The basalt contains also lumps of limestone, while some of its more solid parts have been broken up and have been involved in portions possessing a much more slaggy structure. The bottom of the sheet is much brecciated, the fragments being finely vesicular.

"On the rugged upper surface of this basalt the limestones have been laid down in the same way as underneath. The volcanic episode, although it locally interrupted the continuity of the accumulation of organic detritus on the sea bottom, seems to have effected no change in the general conditions of sedimentation. Fine volcanic dust appears in the overlying limestone for about three feet above the surface of the lava, and thereafter the calcareous rock assumes its usual highly fossiliferous character.

"That the little vent from which the discharges took place lay to the westward, under what is now the Bristol Channel, may be inferred from the disappearance of the volcanic zone as the ground is traversed in the opposite direction."

Our reading of the section is as follows, at the top :—

	ft.
6. Limestone often ironstained, with many small ashy fragments in the lower four feet	40 seen
5. Amygdaloidal and variolitic basalt . . .	35–40
4. Compact grey or reddish limestone with cherty patches	9
3. Ironstained limestone	18
2. Compact ironstained limestone with many Zaphrentid corals	6
1. Argillaceous limestone	

Beds (1) and (2) are seen in the path leading down to Spring Cove, and the dip here is 38° S. A dip of 25° S. 10° W. was obtained from the beds above the basalt. Sir A. Geikie and Mr. Strahan say that the limestone, through some 30 or 40 feet of its mass below the basalt, is full of disseminated volcanic particles. Though we have sliced specimens, three of them taken respectively from levels of 12, 17, and 27 feet below the basalt, we have obtaned no clear evidence of the presence of ashy fragments in the limestone below the basalt, but ashy particles are plentiful above it to a height of at least 8 feet.

Mr. W. S. Boulton's paper, the greater part of which we are enabled, through his kindness and that of the Council of the Geological Society, to reprint, contains a far fuller account of the lava than has hitherto been published, and presents many new observations. He begins with a general description of the rocks :[1]—

"The basalt at Spring Cove, immediately north of Weston Pier, runs obliquely to the high road, and is exposed from low-water mark along the foreshore into the face of the cliff, the exposed length being about 150 yards. The massive beds of Carboniferous Limestone, between which the basalt is intercalated, strike north-eastward, and dip south-eastward (towards Weston) at about 40°. The basalt sheet is parallel to the bedding of the limestone, and has a thickness of about 45 feet.

"A traverse from end to end of the exposure shows clearly that the rock varies considerably in structure and appearance, and that it is by no means a simple basalt-lava flow. Starting from low-water mark, the rock is a hard, compact, red, slightly amygdaloidal olivine-basalt, containing very occasional lumps of limestone, from a few inches to a foot or more across. For the first hundred yards its upper junction with the limestone cannot be seen, because of the accumulated boulders at the foot of the cliff, while the lower junction is covered with water, even at lowest spring-tide. Then, a little more than half-way from the low-water end, and along to the cliff, the basalt changes in character somewhat suddenly. It now contains big lumps of burnt limestone, and the whole mass becomes broken up into a very coarse tuff or agglomerate, containing great lenticular masses of highly slaggy basalt, 5 to 6 feet long, together with lumps and bands of lime-stone, often considerably fractured, and up to 10 or 12 feet in length. About 20 or 30 yards further on, and as far as the end of the exposure in the cliff, the rock is more uniform in character, being a 'pillowy' basalt, though considerably

[1] *Quart. Journ. Geol. Soc.* vol. lx. p. 158.

brecciated and very amygdaloidal, with comparatively little tuff. But it still contains masses of limestone, even larger than those in the middle of the exposure. The whole mass appears to consist of great lenticles of basalt, or tuff, or both confusedly mixed, together with the included limestone. The median planes of these lenticles run obliquely to the limestone beds above and below, so that the lenticles dip at a steeper angle than the sheet as a whole. It would thus appear that the mass is capable of being roughly divided into three portions. Commencing at the cliff-end to the north (in which direction the vent was probably situated), the rock for the first 30 yards is a 'pillowy' basalt, with tuff and limestone often occupying irregular spaces between the spheroids of amygdaloidal basalt; then, for about 20 yards, the rock is mainly a coarse agglomerate, with lapilli and bombs of basalt and lumps of limestone; while for the remaining 100 yards or so it is an ordinary basalt coulée, with very few, and always small, lumps of burnt limestone."

Then follows a section devoted to some special characters of the basalt-sheet:—

"The characters of this igneous flow which are of especial interest are (*a*) the 'pillowy' structure, together with the tuffy or agglomeratic structure; and (*b*) the included lumps and masses of limestone. The pillowy, oval or spheroidal masses of basalt, 2 to 8 feet across, usually very amygdaloidal, especially round their periphery, and sometimes containing small oval or angular cores of a slightly different and earlier lava, are usually embedded in a tuff made up of lapilli up to 2 or 3 inches across. Near the middle of the sheet, covered and underlain by massive lava, is a mass 5 to 6 feet wide, with a dip roughly parallel to the other lenticular masses, consisting of a confused mass of coarse tuffy material, made up of angular fragments of lava 1 to 2 inches across, imbedded in a fine red and green matrix, and containing lenticular ashes of vesicular lava, phacoids (often broken and torn) of limestone, and higher up the cliff larger spheroidal lumps of lava. The whole band suggests forcibly the augen-structure characteristic of gneisses. It probably represents, however, a torrent of agglomeratic material that flowed down a slope on the surface of an already-extruded bed of lava, carrying in among the finer lapilli larger, irregular, and plastic masses of scoriaceous basalt-lava of the nature of bombs, together with lumps and fragments of limestone, which from their form and broken character suggest that they were ejected from the vent with the basaltic material. In all cases where the phacoidal or lenticular structure is seen, whether on a large or on a small scale, the material forming the ground-mass is fragmental and tuff-like, while the included phacoidal masses consists of vesicular lava or limestone, or very occasionally masses of coarse tuff. A thin slice of the typical tuffy matrix shows small sub-angular or rounded, closely-fitting, equal-sized lapilli, about an eighth of an inch across, with little or no interstitial matter, except secondary calcite and iron-oxide. The lapilli consists of basalt-glass crowded with felspar microlites, and in all general characters suggest strongly an analogy with the 'volcanic sand' of the recent West Indian eruptions, as graphically described by Dr. T. Anderson and Dr. J. S. Flett.[1]

"It is highly probable that this basaltic mass, like other pillowy lavas containing portions of sedimentary materials, was ejected under water; and it is certain, I think, that the tuff or agglomerate was not in the main forced into the air by an eruption and deposited in the sea-water. There is no evidence of sedimentation or the quiet accumulation of dust and lapilli; all the appearances point to flow. It might be termed a fluxion-tuff or agglomerate.

[1] *Phil. Trans. Roy. Soc.*, ser. A., vol. cc. (1903), pp. 448–49.

" Possibly if the vent had been situated in very shallow water, or on the land, much of this fragmental material would have been blown into the air, fallen in the water, and settled down quietly on the sea-floor, as, indeed, appears to have been the case with much of the tuff at Middle Hope, two miles to the north. At Weston, however, the greater weight of water above may have prevented this, and compelled the fragmental material to flow as lava. Or, again, as in the West Indian examples already cited, the expansive force of the imprisoned vapours may have been sufficient to break up the lava within the vent, but insufficient to do more than just force the tuff over the lip of the vent, whence it flowed along the sea-floor in obedience to gravity, and impelled forward, in part, by the expanding gases.

" One of the most remarkable features of the sheet is the abundance of lumps and irregular masses of limestone, enclosed in the amygdaloidal and 'pillowy' basalt, or occurring as phacoids and lumps in the tuffy material." . . . " Characteristic features are the concave surfaces of the limestone, often due to the fact that the latter occupies an irregular space between a number of spheroids or 'pillows' of the basalt, looking as if either the limestone had been absorbed by the hot lava, or, more probably, squeezed into its present shape by the distending and moving spheroidal masses.

" There can be no doubt that this limestone is not secondary, due to the deposition of calcareous material from aqueous solution subsequent to the outflow and consolidation of the lava; nor has it been deposited as sediment in irregular spaces between the spheroids after the cooling of the basalt; but it is unquestionably part of the calcareous floor upon which the basalt-flow rests. Many of these included masses are oolitic, the structure being visible sometimes to the naked eye, while a microscopic examination shows the oolitic grains distinctly, together with the remains of encrinites, etc., and the basalt has penetrated, fused, and absorbed the limestone along its borders. . . .

"In some instances the limestone, more especially that occurring as irregular lumps in the tuff, is so cracked and broken, evidently during the movement of the flow, as to suggest that it must have been hard and consolidated before the extrusion of the lava, and was probably torn from the vent and ejected with the igneous matter. Small oval bodies generally a few inches long occur in the basalt; these, when broken, show a yellow or red shell of carbonate of lime, the rest being filled with pure white, secondary calcite, and in some cases quartz; indeed, in a few instances rounded or oval bodies up to a foot in length consist entirely of silica. These may be lumps of limestone, burnt and hardened on the outside by the hot lava, their centres being subsequently removed in solution, the hollows thus formed serving as receptacles for secondary calcite or quartz; while in a few cases the whole lump of limestone has been replaced by silica. It is possible, however, that some of them may be large vesicles filled with secondary minerals.

"But in most cases the general behaviour and shape of the limestone-masses, particularly between the spheroids of basalt, seem rather to suggest that the calcareous material must have been only in part consolidated, so that it behaved as a pulverulent or more or less plastic substance, and got rolled in and picked up by the lava, and was able to fit itself in between the moving and distending spheroidal masses.

"In the account of these Weston rocks by the officers of the Geological Survey, it is suggested that the vent from which the rocks of Spring Cove were derived lay somewhere to the west, where now the Bristol Channel lies;

but from the fact that the included masses of limestone dwindle rapidly in size and number from north to south, and that the lenticular sheets of lava and tuff representing individual minor flows also slope from north to south, it would seem that the vent lay somewhere to the north of this Spring Cove exposure.

" Except for the presence of lapilli of basalt in the base of the limestone resting at once on the basalt, it might be difficult to show that the whole is not an intrusive sheet. The conditions in these submarine flows appear to be very like those in a sill or intrusive sheet, where, as Prof. Lapworth has suggested, we may get tuffs and included masses of sedimentary material confusedly mixed, and drawn out into lenticles as here described."

(3) *Above Kewstoke, Milton Hill.*

In the *Summary of Progress* it is stated that " fragments of the amygdaloid were found by Mr. Spencer Perceval at the Tollgate, which shows that this rock extends inland for a mile and a half. But immediately to the east over the bare limestone surface above Kewstoke or Milton Hill and the ground towards Worle Mr. Strahan could find no trace of it." Mr. Spencer George Perceval writes to one of us : " What Tollgate is meant I do not know. In the fields immediately outside the wood on Worle Hill at the east end, north of the Lodge, I found in 1890 that an overflow of trap occurred not visible on the surface, but at a slight depth underneath. I got specimens with the limestone and trap in contact. I certainly should not term the trap an amygdaloid." In a further communication Mr. Perceval has courteously supplied extracts from his notes made at the time. It is quite clear from these notes that he then discovered an extensive run of the " trap " on Milton Hill, In gardens west of the road running from Milton to Kewstoke he instituted a series of diggings which showed that the " trap bed " was there *in situ*. It was also found by digging in the garden of the lodge just outside the wood on the western end of Worle Hill. " Trap " was also found in places within the wood on the same strike. These observations leave no doubt of the extension of the lava in this direction. One of us became acquainted (without any knowledge of Mr. Spencer George Perceval's previous discovery) with the " trap " fragments, some of them very vesicular, which are scattered over the gardens in the north-west angle of the cross-tracks, one leading along the crest of the hill, the other crossing from Milton to Kewstoke. A cottager, who was digging in the garden, pointed out a strip running across the field where, he said, all the stones turned up in digging were of this kind. Another man in 1902 made a similar statement. From this field we have ourselves collected many fragments of lava and a few of a brecciated rock. Moreover, in 1894, at a spot 150 yards down the track leading to Kewstoke, one of us observed a small excavation in which unmistakable volcanic ash was seen *in situ*. This exposure was shown at the time to Mr. A. C. Pass, then Secretary of the Geological Section of the Bristol Naturalists' Society, who was satisfied as to the nature of the rock. Unfortunately, when we visited the spot in 1902, we found that the excavation had been walled in, stone-lined, and converted into a small pond. A note made in 1894 is here transcribed :—

" Volcanic ash in field [near track] leading down to Kewstoke Steps. Soft friable reddish beds, seemingly greener when not exposed (i.e. when dug into with hammer). Numerous vesicular lapilli up to $\frac{1}{2}$ inch in diameter."

In 1903, round a small pond just above the upper extremity of Kewstoke Steps, we found abundant fragments of lava (? lapilli) in a red earthy surface material. Further eastwards we have found no trace of lavas or ashes.

(4) *Goblin Combe.*

The volcanic rocks of Goblin Combe occur in two isolated patches, the more westerly about one-third of a mile to the south of Warren House, the other about half a mile south-east of the house.

They may be approached (1) from the main road from Bristol to Bridgewater. Turn to the right along the lane about midway between the seventh and eighth milestones. The track leads past some new cottages (on the right), it enters the Combe, and about half a mile down forks; the left hand path ascends the hill, the right hand path passes through a gate. About a hundred yards further on is another gate entering a field; the easterly exposure of the volcanic beds is in a very small quarry to the right, under a hanging wood. From this a road running near an orchard on the left may be reached by a gate in the lower hedge of the field. The Combe should then be followed down for half a mile, when a path is reached running up to the right to Warren House. The westerly exposure lies on either side of this path, about 40 or 50 feet up the slope. (2) From the village of Cleeve, which is reached from Yatton station. The path up the Combe should be followed to the point where the path leads off to Warren House. (3) From Nailsea via Brockley Combe. Turn off to the right through a gate just where the road emerges from the wood, and follow the path across the Warren, descending and bearing to the right.

Lava as well as ash is met with at both these exposures: in each case the lava probably underlies the ash. The westerly patch includes two small exposures, the first of which occurs on the fork of the two paths S.S.E. of Warren

House. Lava only is met with here, the rock being a much weathered and highly amygdaloidal olivine basalt.

A few yards further north, beyond the north-easterly trending branch of the path, is a more continuous section of the volcanic series. The section is as follows :—

	feet.
3. Pale yellow marl to top of section.	
2. Reddish ashy limestone, thickness doubtful, perhaps .	4–6
Gap, no exposures	3–4
1. Thin bedded, greenish, ashy and gritty oolitic limestone, coarser below finer above	6

These beds dip west at 18°, and probably overlie the basalt just described. The volcanic series ought to crop out on the slopes to the west and south-west of this exposure, and we did find one minute exposure of ash a few yards to the south-west, but on the other side of the ravine no trace could be found of the volcanic series.

The more easterly of the Goblin Combe exposures is a much better one than the more westerly. The section is as follows :—

	ft.	in.
3. Limestone and calcareous ash seen in the southern part of the exposure	7	0
2. Lenticular mass of coarse greenish ash with thin impersistent bands of hard limestone. These beds are seen in the middle part of the exposure, and in part replace and in part overlie band 1	1	6
1. Red ash, with coarser, finer, and more calcareous bands .	5	0
	13	6

The red calcareous ash (No. 1) is by far the most conspicuous rock ; it varies much in coarseness. A remarkably fresh olivine dolerite occurs not *in situ* but as blocks scattered over the surface of the field to the west of the above exposure.

Sir A. Geikie and Mr. Strahan give a somewhat brief description of these beds, mentioning that the country had not yet been mapped in detail. They suggest that the two outcrops may be really parts of the same band. They found the lava, though not *in situ*, at the western exposure, but apparently did not meet with it at the eastern exposure. The tuffs are described by them as "consisting of alternations of finer and coarser green and red volcanic dust and lapilli, with partings of limestone. They abound in the usual highly vesicular basic pumice. They are generally calcareous, and pass laterally and vertically into ashy limestone. The limestone bands in both are full of volcanic sediment, especially of lapilli of the green pumice. Some of these are partially oolitic, the oolitic grains being scattered through the ashy material."

(5) *Uphill.*

The Uphill exposure is reached by following the road from Uphill village to Bleadon and Uphill station. There is a toll gate visible when the station is in view. The igneous rock occurs in an old quarry in the railway cutting, and may be approached by climbing down into the cutting about 50 yards before reaching the toll gate.

The relations of the amygdaloidal basalt or dolerite to the limestone are not well seen, and the ground is much faulted. There is, in our opinion, nothing to enable us to decide whether we have here a sill or a contemporaneous lava-flow, and we have not been able to find in the limestones, either above or below, any traces of ash or lapilli. The igneous rock occupies just the same position in the stratigraphical series that the volcanic rocks occupy in other localities.

(6) *Near Cadbury Camp.*

Beyond the occurrence of fragments of "trap" thrown out from rabbit-burrows in Wood Lane, at the angle between Round Wood and St. John's Wood, we have found no indication of the exposures marked in Sanders's map. There is nothing to show whether or not the trap is contemporaneous.

The Rhaetic Bone Beds.

By W. H. WICKES.

Introduction.

PERHAPS the most interesting bed of its size, in the West of England, is that known as the "Bone Bed." Alike for the richness of the fossil remains and other special features, it has attracted the attention of all observers for a long period; but while many geologists have frequently mentioned it in various papers, and lists of the fossils, more or less reliable, have been given, it is doubtful if it has received the full attention it deserves. Few of the writers venture to give any opinion as to its origin, and as those who do usually omit to produce any evidence in support of their theories, the solution of the matter is not much facilitated thereby.

Many of the ideas current have been handed down from one generation to another, with apparently very little investigation as to their soundness, and are based on views dating from fifty to sixty years ago, at which period the Rhætic formation was very imperfectly understood. (It is not thoroughly understood now, but considerable advance has been made of recent years.)

The various theories brought forward were so contradictory and generally unsatisfactory, being mainly based on premature conclusions from local generalizations, that it was resolved to try the experiment of a fresh start by discarding them all, making a "clean slate," and going to the rocks themselves, carefully noting every fact which could be found therein, and then seeing in what direction the evidence pointed.

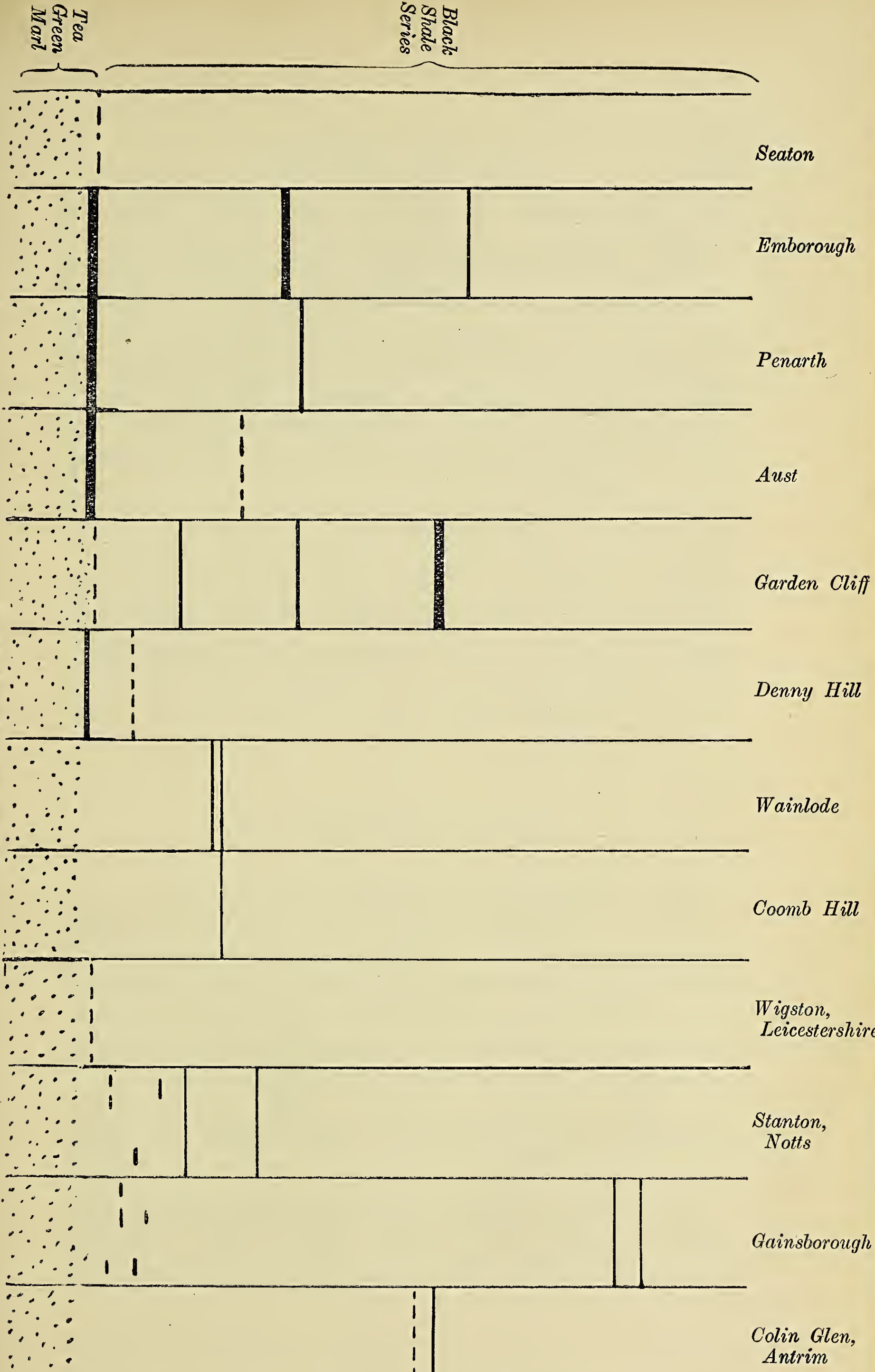
This examination has been greatly facilitated by the opening up lately of several fine new sections, such as Emborrow, Redland, and the Lilliput and other cuttings on the new Great Western Railway from Patchway to Wootton Basset.

It has been carried on for several years, during which some hundreds of specimens have been carefully examined, and many sections visited and revisited. In some cases where sections were inaccessible, or grown or built over, use has been made of the details noted by the observers who originally surveyed them.

Position of the Bone Beds.

The first result of a comparison of various sections was seemingly to increase the difficulty. The Bone Bed not only declined to fit in with preconceived ideas, but also obstinately refused to fit in with itself! It exhibited so many discrepancies in position that it was considered advisable to go over a lot of the work again, to see if any errors had been made. But although a few slight corrections were noted, the main results were not only unaltered, but strengthened by the revision.

The final result showed that the old idea of the Bone Bed being a definite bed, occupying a definite position, is untenable, being quite at variance with the actual facts, While some sections have a bed which would fit in with this old idea, others vary in a remarkable way, some having no Bone Bed at all, others only small patches or pockets, while several have two or even three well defined Bone Beds, with varying thicknesses of stratified deposits between them. The height of these beds from the base



Vertical scale, 1 *in.* = $3\frac{1}{2}$ *ft.*

Diagram showing the position of the Bone Beds in the various sections (the broken lines indicate patchy beds).

line shows equally remarkable variations (see diagram p. 215.)

After a careful consideration of these different (and differing) sections, the only solution apparent is that the Bone Bed is not a regular or persistent bed, but consists of a number or series of thin sheets (or lenticules) of greater or less extent, coming in at various levels in the Lower Rhætics, and having no connexion with each other, no instance having been noted of a lower bed joining a higher one, or *vice versa*.

A further feature to be noticed is the remarkable similarity of their fossil contents. No matter where situated, whether a basal bed, or several feet above the base, the main group of fossils is identical, and this without the slightest reference to the character of the neighbouring beds, whether fossiliferous or not, thereby showing that all these Bone Beds, though separate from each other, have a common origin.

Composition of the Bone Beds.

We now pass to the composition of these beds.

The true Bone Bed is always a hard rock ; that is, harder than the clays, sands, or loose marls in which it occurs, so that on exposure it tends to weather out. It is more or less crystalline, the usual crystals being calcite, selenite, and iron pyrites. The only exception to the crystalline character is when it occurs in a sandy bed, for then it is usually an indurated sandstone. (This statement applies to fresh sections, as exposed or weathered beds frequently break up.)

It is mainly composed of organic remains of Fishes, etc., and it frequently (in the basal beds) contains fragments of the underlying rocks. The matrix is mainly calcareous or pyritic, except when it occurs in or upon a sandy bed, when it is of the nature of a sandstone. A good example of this is seen at Lilliput—where it rests on Carboniferous limestone it is calcareous, but when on the Old Red, it is almost a sandstone.

The animal remains are individual and separate, the occurrence of two or more bones, teeth, or scales joined together being extremely rare. Further, the bones are almost invariably broken or comminuted, a perfect bone (especially of the larger sizes) being seldom found.

The usual idea that the bones are "rolled" is not borne out by close examination, especially of fresh or unweathered pieces. It appears to be founded on weathered specimens, or those which falling out of the cliff have been recently rolled about on the beach. This is the case at those three classic sections at Aust, Penarth, and Garden Cliff, where a considerable amount of weathering and water rolling has taken place. Another reason for the damaged appearance of the larger bones would be found in the vitriolic action of the iron pyrites, to which the larger bones, from their greater porosity, would be more vulnerable, many of them being quite rotten from this cause. Experience shows that the bigger the bone, the less chance there is of securing it in a decent condition.

The teeth and scales, however, are mostly in a splendid state of preservation, all the delicate little points and markings being sharp and well defined, and exhibiting no trace of the wear and tear that "drifted" or "rolled" fossils ought to show.

Further, the position these fossils occupy in the rock deserves attention. In a fairly tranquil or ordinary sediment the fossils usually lie on their flat sides, or on their longest axes, and are but rarely found at an angle or upright. But in a drift or storm deposit, on the contrary, the fossils are heaped up at all angles, and may frequently be noticed erect, or even reversed. Now, the great majority of the fossils in these Bone Beds conform to the first rule of tranquil deposition, and not to the second or "drift" rule. A very small proportion are in any way heaped up, and these few instances can be easily accounted for by local disturbances or irregularities in the underlying beds.

A further interesting feature is the comparative absence of molluscan remains in the Bone Beds, so few being found that they might almost be said to be non-existent. This is a curious fact, and indicates that we have to deal with deposits different from the stratified beds in which they occur, as in many instances the latter are crowded with shelly remains. Another point is, that while the adjacent beds usually show well marked lines of stratification, in the Bone Beds they are frequently obscure or altogether absent. (This statement does not apply to the thin sandy beds, which generally have the lines.)

"*False*" *or Atypical Bone Beds.*

It will be noticed that the term "True Bone Bed" is used, suggestive of other or "False" Beds. It may be as well to briefly indicate what these are, and in what points they differ.

(1) *Drift Beds.* The first is a "Drift Bed," which is sometimes erroneously classed as a "Bone Bed." It is a soft bed, usually black clay or marl, and is the result of current or wave action cutting into the Bone Bed before consolidation, and drifting off a portion of its contents for deposition elsewhere. It may be known by its soft nature, by having but few fossils, and those of the lighter and smaller sorts

(scales and teeth), such as would drift easily, and the comparative absence of the larger and heavier fossils; also, it has well marked lines of stratification.

(2) *Beach Beds.* The second is a "Beach Bed." The Rhætic sea, like other seas, had beach deposits, of which we find examples, notably at Redland. This bed comes pretty close to the "Bone Bed" in character, being frequently hard and crystalline, but it agrees with the "Drift Bed" in the poverty of its fossils, both in number and size, and also in the well marked stratification, but the principal difference is that it is largely composed of broken shells, which are wanting in the "True Bone Bed."

As these two beds are often mistaken for the Bone Bed, it is advisable to point out in what respects they differ, and then proceed with our subject.

Contents of the Bone Bed.

A "True Bone Bed" will be found to contain five principal constituents: (1) Bones; (2) Teeth; (3) Scales; (4) Coprolites; (5) Quartz pebbles. Any bed containing less than four of these, or only a small amount of them, should be carefully examined, as it may be only a "Beach" or "Drift Bed."

It may seem odd to say that a Bone Bed should contain bones, but it has more than once happened that a bed with only a few teeth and scales, and no bones, has been termed the Bone Bed. This is incorrect, as otherwise the whole range of Upper and Lower Rhætics would have to be classed as "Bone Beds," not a single bed being quite free from teeth and scales! The "True Bone Beds" always have a fair proportion of bones, more or less broken.

The first four constituents (bones, teeth, scales, and coprolites) can be grouped together, and attributed to three classes of animals :

(1) Saurians, of which *Plesiosaurus* is decidedly the most plentiful, with *Ichthyosaurus* in much smaller numbers. (There are other and rarer kinds, but as this paper is not intended to be a list of fossils, only the more prominent will be noticed.)

(2) Fishes, of which the most plentiful are *Hybodus*, *Nemacanthus*, *Saurichthys*, *Gyrolepis*, *Sargodon*, *Acrodus*, and last, but not least, the great mud-fish *Ceratodus*. If the size of the teeth of the latter is any criterion, this must have been some 15 or 20 feet long. This fish has been erroneously termed a vegetarian, the fact being it will eat anything, especially dead fish.

(3) Amphibians. The representative of this class include only one animal, known as "*Metoposaurus*" or "*Metopias*," a curious complex beast, "half toad and half alligator," belonging to the Labyrinthodonts.

Now we come to the fifth constituent, Quartz pebbles, the occurrence of which opens up a most interesting question. The fact is, that wherever we get these animal remains we also find the pebbles intermixed with them, and this quite independently of the adjacent rock, whether limestone, sandstone, clay, or marl. Where the Bone Bed is, there also are these pebbles!

It has been suggested that these pebbles were drifted or water borne to the localities where we now find them, but a careful examination of the facts soon disposes of the drift theory; the absence of any traces of erosion, the position of the fossils, and their extraordinary freedom from scratches and abrasions, all militate against this notion, which is simply an evasion of the difficulty, and raises other questions, such as—(1) Where did this deposit drift from ? and (2) How did the bed from which this imaginary drift took place originate ? It does not take long to see that this theory explains nothing, and is only an easy way of shelving the question.

Now, it does not seem to have occurred to the advocates of the drift theory that there might be another and much simpler way of accounting for these pebbles, and yet such a process can be shown to be in operation at the present time. It is a fact, well known to all who have to deal with marine fishes, that their stomachs frequently contain an appreciable quantity of foreign material, in which pebbles figure largely. Whether these pebbles are swallowed accidentally or intentionally is debatable, but there is no doubt as to their presence, testimony being forthcoming from fishermen, yachtsmen, naturalists, and scientists on this point. In addition, we have evidence of the formation now proceeding of a fossiliferous deposit in the Torres Straits, in which pebbles derived from fish form a perceptible feature. It is further stated that reptiles (crocodiles, etc.) are also addicted to this habit, several notes to that effect appearing in various papers, both English and foreign. (See notes at end.)

Need we go further for the explanation of the presence of these pebbles ? Here is a simple and natural solution, which has the additional advantage of fitting in with two otherwise awkward facts—(1) that these pebbles are always found in the Bone Beds ; and (2) that the most delicate and fragile fossils are uninjured by them, although found in actual contact !

As regard the number of these pebbles, it must be noted that quartz, being comparatively imperishable, would remain after a large amount of the animal debris had been removed or broken up by decomposition and other causes ;

as a result, the pebbles would be in larger proportion than they were originally.

Respecting the Coprolites little need be added, except to note that their enormous quantity, position, and generally uninjured condition provide additional proof that the animals lived on the spot, and also furnish another "nail in the coffin" for the drift theory.

Origin of the Bone Beds.

The way is now clear for considering the origin of the Bone Beds.

In the last days of the Triassic Marls we have the spectacle of a worn-out dying formation, slowly sinking into its grave—a desert land, almost totally destitute of life in any shape.

But from the east, or south-east, a remarkable change of scene was approaching. Following on the slowly sinking land, the waters of the great Rhætic Sea (which at that time probably covered a large proportion of what is now Europe) were advancing, not rushing in as a tempestuous flood, but slowly and surely encroaching, corresponding with the gradual depression of the land; evidence of this is found in the small amount of erosion of the underlying rocks, and the absence of large or numerous fragments torn off in its progress, the pieces included in the basement beds being comparatively small, and not occurring in any great quantity.

In the wake of this Rhætic Sea came immense shoals of fish, mostly of a carnivorous character, and these were followed up by numbers of the fierce and voracious "Sea Dragons," known as Saurians. The struggle for life in this multitude would be tremendous, and probably many thousands were killed and eaten daily. A fish would be caught by a *Plesiosaurus*, crushed to pieces in his powerful jaws, the softer parts swallowed, and the indigestible portions, such as scales, teeth, and broken bones, would be rejected and sink to the bottom. (The peculiar build of this Saurian, and the almost complete absence of such fragments in the coprolites, warrants the supposition that they were not swallowed.) On their way through the water these fragments were exposed to further attacks from the fishes, while any larger pieces which reached the lower depths were gone over by the big scavenger, *Ceratodus*, and still further broken up. The scene might be occasionally varied by a Saurian becoming a victim, and being served in a similar manner. The result would be a continual shower of these animal fragments to the sea bottom, and these, combined with coprolites, would form a deposit, the extent and thickness of which would be determined by two factors—(1) the size of the shoal; (2) the time it remained at that station.

After a time the shoal would shift to another locality, followed by the Saurians, and the same process would be repeated. But while the first Bone Bed was forming a considerable deposit of mud would settle elsewhere, and therefore the animal refuse at the second station would be deposited at a higher horizon than that of the first bed. Further shiftings of the shoal would occur at intervals, followed by deposits of "Bone Beds," each with an increased thickness of sediment beneath; while the return of a shoal (or visit of another shoal) to a station previously occupied would account for the phenomenon of two or more Bone Beds in the same section.

The patches or pockets occasionally met with might occur in two ways—(1) a comparative scarcity of the animals producing the deposit; or (2) by their occurring while the shoal was moving from one station to another, when the resulting deposit would be both scanty and erratic in character.

It is evident that the late Edward Wilson had this theory in his mind when he wrote in his paper on the "Rhætics at Stanton, Notts,"[1] these significant words : "Since these beds were, in all probability, the resulting deposits of migratory shoals, and not of a universal swarm of fishes, a certain amount of time must be allowed for their transit from one place to another."

In effect, these deposits may be termed "Submarine Guano Beds," though as regards their bulk they are but trifling when compared with modern instances of a like character ; for instance, the guano beds of the Chincha Islands and other places in South America have shown thicknesses of 50, 60 and even 100 feet. This is more striking when we remember that these enormous masses were deposited by birds within a period geologically recent.

Summary.

These are the plain facts as observed in the Bone Beds, and the conclusions which they indicate. In order to make the principal points clearer, the following abstract or summary may be useful :—

1. The "Bone Bed" is not a regular or persistent bed, but a series of thin sheets (or lenticules) of varying extent, coming in at various horizons and deposited at various times.

2. These sheets are separate and have no connexion with each other, except that they are of common origin, the general structure and fossils being identical.

3. They are chiefly caused by the Saurians and carnivorous fishes, being the remains of their victims, with the addition of coprolites, etc.

4. The extent of each sheet was determined by the size

[1] *Quart. Journ. Geol. Soc.*, xxxviii. p. 455.

of the shoal, and the thickness by the time it remained at that station.

5. At intervals the shoal shifted to another station, where the process was repeated, and another Bone Bed formed.

6. Owing to deposition of sediment, each successive bed was on a higher horizon than its predecessors.

7. These bone sheets are original deposits *in situ*, and not drifted material.

8. They may be summed up as submarine guano beds laid down by the floating population of the period.

In conclusion, while not being so sanguine as to expect that these views will find immediate acceptance (as old ideas are hard to eradicate), the writer firmly believes that any geologist who will clear his mind of antiquated traditions and preconceived notions, who will refer to the Bone Beds themselves, and carefully and fairly read the evidence contained therein, will not be able to avoid coming to conclusions similar to those brought forward in this paper.

The author tenders his thanks to the writers of the appended letters, and also to the following for information and assistance in various matters: Drs. A. Smith Woodward, C. W. Andrews, and A. Vaughan, Professors C. Lloyd Morgan and S. H. Reynolds, Messrs. H. B. Woodward, C. D. Sherborn, L. Richardson, F. M. Burton, W. Jerome Harrison, and W. S. Moxley).

APPENDIX.

The following are extracts from letters received by the author with regard to the occurrence of pebbles in fish's stomachs :—

Mr. F. G. Aflalo, F.Z.S., etc. (the well known writer on Sea Fish), writes : " Yes ; large sea fish often have masses of stones, gravel, cultch, etc., in their stomach. Whether this is taken purposely, as birds swallow grit, to aid in digesting hard food, or whether it is merely swallowed incidentally for the sake of anemones, herring spawn, etc., adhering to it, is guess work. How can we tell, after all ? "

In a further note he writes : " I think that fishes furnish us with a very simple explanation, for their stomachs often contain stones. These may have been swallowed in one or two ways. Either the fish took them down voluntarily, as we know many birds do, to act as millstones and grind indigestible food, or else the stones were swallowed along with the herring spawn, anemones, or other adhesive delicacy that covered them. Either explanation is sufficiently probable to command support, and the chief thing is that these stones do undoubtedly occur in the inside of living fishes, so that there is no difficulty in accounting for their presence in the fossil deposits."

The Director of the Marine Biological Station, Millport, N.B. (Mr. Alexander Gray), writes : " I think you are right in your surmises regarding the association of pebbles and fish remains in the Rhætic Beds, as I know it is a matter of common knowledge among fishermen that such are often found in cod, saithe, etc."

The Director of the Marine Biological Station at Plymouth (Dr. E. J. Allen), writes : " The enclosed note from Mr. S. Pace, one of our naturalists, may be useful to you, as it records his own personal observation :—

'. . . with regard to the occurrence of apparently undrifted pebbles in the Rhætic Bone Bed, I have no doubt in my own mind that the suggestion of Mr. Wickes affords the true explanation. Although I have not noted the presence of stones within the stomach in any Gadoid fish, yet they are by no means uncommonly met with in those of other forms. For instance, in the case of the "Stingaree" (or Sting Ray) of tropical Queensland, the stomach frequently contains a fair accummulation of small stones, which probably function in much the same way as do those contained in a fowl's gizzard. These pebbles often show indications of having remained in the stomach for a lengthy period; and in some places in Torres Straits, where the Stingaree is abundant, they form part of a fossiliferous rock which is now in course of very rapid formation.

"'S. PACE.'"

For further notes on this subject see (1) *Quart. Journ. Geol. Soc.*, vol. xiv., p. 258 (Godwin-Austin, Bowerbank, Deslongchamps). (2) *Ibid.*, vol. xxiii., p. 318 (F. M. Burton on "Rhætics near Gainsborough"). (3) *Bulletin Soc. Geol. France* (3), xx., 1892, p. 111 (Vaillant, "Sur . . . galets . . . dans l'appareil digestif des Poissons"). (4) *Ibid.* (3) xix., 1891, p. 903 (C. Janet).

The Avon and its Gravels.

By the Rev. B. ORIEL, B.A., B.Sc., F.G.S.

THE Avon is now for the greater part of its course a sluggish river winding through some of the most beautiful scenery in the south-west of England. It was not always so. At the close of the Tertiary period a great and uninterrupted plain stretched across from the Dundry Downs to the Durdham Downs and eastward to the hills which surround Bath. The districts indicated are outliers only—remnants of that vast plain which have withstood the denuding effects of both water and the atmosphere. In thinking of the times when the Avon began to flow we must imagine this plain emerging after its long submergence with slight irregularities only, and with very little on its surface to indicate the future course of the river. Escarpments, valleys, gorges as yet were not. But when once the course of a river has been determined, there are few more persistent objects in nature. The hardest bands of rock may oppose, but these will be worn down rather than the river be deflected from its course. Of this our Avon gorge is an admirable example.

The Avon is usualyl regarded as rising in the north-west of Wiltshire near Marshfield, which is about fourteen miles in a direct line from Avonmouth; its course is over seventy miles long. There is, however, the usual local rivalry as to the real source of the Avon; the inhabitants of Didmarton also making out a good case.

The two results which accompany the action of water-denudation and deposition are as usual abundantly evident. By denudation the broad and rich valleys have been hollowed out, while many accumulations of sand and gravel remains as footprints to mark the river's former course.

The Gravels found in association with the Avon are of two kinds:—

I. An old assemblage of pebbles composed chiefly of flint and quartz, found in one spot only, and of doubtful origin. These we may call *The High Level Gravels.*

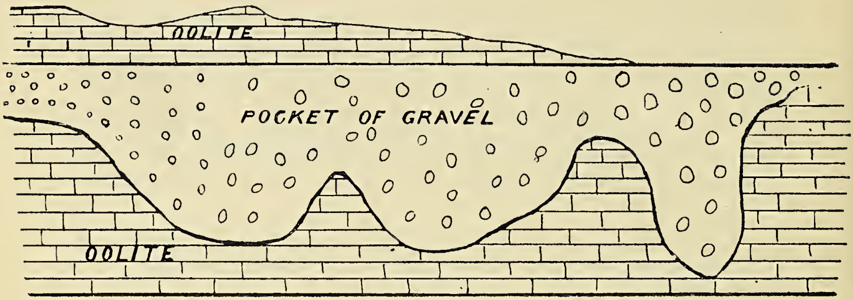
II. The more recent deposits found at various heights and in different localities along the course of the Avon, and obviously due to the action of the present river. These may be termed *The Low Level Gravels.*

I. The High Level Gravels.

1. These older gravels occur in a large pocket of the Oolites on the escarpment at Kingsdown. In certain conditions of the working of the little quarry these pebbles seem to be interstratified among the oolitic formation (see fig.). At other times the connection with the surface is evident. These pebbles were carried into this great cavity and at last filled it up. The workings are about 20 feet long, and the thickness of the accumulations varies from 5 to 8 feet. Professor Prestwich thus described the formation in 1890,[1] "... there is at one spot, Kingsdown, near Bathford, about 550 feet high and five miles from Bath, a drift of the Westleton character. It forms only a small patch on the otherwise bare surface of the Oolites, and consists

[1] *Quart. Journ. Geol. Soc.*, xlvi., p. 143 (1890).

of a light brown sandy loam, with slightly subangular flints, some flint pebbles, many white quartz-pebbles, and



an occasional pebble of sandstone and of a greenish quartz. It is covered by a brown earth with local Oolite débris. The whole is only a few (5–8) feet thick, and is preserved in a trough or hollow in the Oolite." (A note indicates that the Rev. H. H. Winwood had also found a subangular fragment of Sansen stone and a pebble of black chert or hornstone.)

There is obvious difficulty in correlating isolated patches at considerable distances, but Professor Prestwich's contention is that the distinctive features of the accumulation which he calls the "Westleton Shingle" are of so marked a character and so different from those of the overlying glacial series where both occur together, that their origin must be different. He contended that the flint-pebbles of the Westleton Drift were derived from the shingle beds of Diestian (Bagshot and Lower Tertiary age), but whether from those in Belgium, the North of France, or Kent it is difficult to determine.

2. The pebbles of white and rose-coloured quartz come apparently from the older rocks of the Ardennes, or in-

directly from some of the Bolderberg or Diestian beds of Belgium.

3. The subangular fragments of flint—some retaining their natural colours and others more worn and stained brown—are derived, the former directly from the Chalk, the latter from an older drift, possibly of the Pliocene age.

The suggestion of Professor Prestwich that the Kingsdown gravel may be part of the Westleton Shingle implies :—

(*a*) That this region was submerged until the period immediately preceding the glacial epoch ;

(*b*) That the enormous amount of denudation which has taken place in our district is of glacial and post-glacial age ;

(*c*) That of the deposits which must have been formed during the submergence all have been removed, leaving barely a trace of their existence.

These conclusions had of course been considered by Professor Prestwich ; yet on the evidence only of the similarity of the deposit to the Westleton Shingle, he is reluctant to exclude this western district from the submerged area. He writes,[1] " Of the escarpment of the Oolites one can speak with less certainty, though if we admit the Kingsdown drift to be of the Westleton age, it favours the conclusion that the escarpment of the Oolites dates no further back than the commencement of the Quarternary or Pleistocene period. The fact likewise that the two escarpments (i.e. *of the Avon oolites and of the Chalk*) run in parallel lines seems to be in favour of a common denuding cause in the same direction. The time, geologically measured, is, however, so limited and the extent of the denudation so vast, that it is not easy to realize that these limits can suffice. Nevertheless, I do not see how the conclusions we have arrived at on this subject can well be avoided."

[1] *Quart. Journ. Geol. Soc.*, xlvi., p. 151 (1890).

The present writer does not agree with the foregoing conclusions, and for the following reasons :—

1. *The Avon valleys are deep and wide, and bear all the marks of geological antiquity.* The contrast between the banks of the Avon and those of a river which does undoubtedly flow through recent formations is very striking. The banks of the Avon are undulating and weathered; the materials composing the sides have long since found their angle of repose, and are covered by luxuriant vegetation; the scars are concealed. On the other hand, a river like the St. Lawrence flows through territory where the marks of weathering are quite fresh. The scars are not covered. The grooves caused by the passage of ice, the striated boulders, even the till and boulder clay can be seen easily by the passenger on the steamer's deck as he descends the river from Toronto to Montreal.

2. *There is an entire absence of the material which would have been deposited had this region been submerged.* It is almost inconceivable that such an enormous tract of country should have been denuded without some trace being left of the old deposit. For example, in the Bristol district the Triassic formations have been almost entirely removed from such areas as the Durdham Downs; still fragments do persist—e.g., small isolated patches are found resting on the Carboniferous Limestone, and great pebbles fill the cavities of the limestone. In the same way, seeing that the theory of Professor Prestwich demands the submergence of the whole western area, one would expect to find traces of the deposits of the period. Such traces are, as I think, entirely wanting.

3. *Palæontological evidence.* No organic remains have been found in these High level gravels, but the remains which characterize the Low level gravels (to be described later) are so characteristic of the glacial and post-glacial periods that there seems to be abundant evidence for

regarding them and not the high level gravels as being immediately post-glacial.

If this conclusion is maintained, then it follows that the West of England was a land surface and subject to subaerial denudation, while the south-eastern portion of England was submerged. It follows, too, that the Avon during Pleistocene times was slowly cutting down its bed, and by the time the glacial epoch had arrived its waters were within one hundred feet or so of their present level.

With regard to the material of which these high level gravels are composed, at least 80 per cent. of the pebbles are of flint which would be derived from the Chalk of the neighbouring downs. The accumulation of flints after the weathering out of the Chalk is very common, and would account for the greater part of this material. It is very difficult to locate the source of the quartz-pebbles after so much denudation has taken place. They are evidently a secondary accumulation bearing marks of redistribution.

The entire deposit bears marks of the sifting process which the action of water always effects. In the further reaches of the trough or pocket referred to, the fragments are comminuted. I regard the high level gravels as a record of the work done by the Avon in its early days.

II. The Low Level Gravels.—These gravels are exceedingly common on the hillsides near Bath. The deposits vary in size from small patches of a few square yards to masses which extend across the hillside for half a mile or more. They occur at varying heights, but the range is fixed by a maximum of one hundred feet or so above the present bed of the river. Gravel is largely used for paths and public walks locally, and is therefore extracted from open pits. I have watched carefully excavations which have taken place at three gravel pits in Twerton. They are :—

1. Claude Avenue Pit,	103 ft.	above river	and	152	above	sea	level.
2. Victoria Gravel ,,	100	,,	,,	,,	149	,,	,,	,,
3. Bellot's Road ,,	39	,,	,,	,,	88	,,	,,	,,

The gravel is largely composed of oolitic fragments from the neighbouring hills. These fragments are little worn, and characteristic fossils from the hard band capping the hills to the east of Bath are abundant. Next in importance as a contributor to this accumulation is the Chalk formation. Rounded fragments of flint abound. These are, generally speaking, much more worn than the oolitic fragments. Other pebbles which I have collected are composed of Millstone Grit, Mountain Limestone, and Old Red Sandstone. These have come down from the Mendips by the Frome tributary, which joins the Avon near Freshford. Many of these are much worn, but some of considerable size are subangular only. One is surprised that, having come so far, they bear such slight traces of their journey. In addition to these pebbles which make up the gravels proper, there often occur at the base of the gravels, and resting on the old land surface, large boulders weighing from three to five cwt. each. (The workmen estimate them as weighing half a ton.) The presence of these large blocks has been noticed and discussed by other writers on the gravels, and various theories advanced to account for their position. Thus, the Rev. H. H. Winwood, who for many years has watched these excavations and collected assiduously, writes in the *Proceedings of the Bath Field Club* (vol. vi., pp. 327–8), "I would venture to suggest that these blocks may have been rafted down from their sites by ice-floes, which, as they gradually melted, dropped their burden on the floor on which they grounded." I think Mr. Winwood must have felt that he was calling in the aid of an agent for which no direct evidence could be found, for he adds, "The rocks around us are too soft to preserve any traces of a glacial period, yet we may infer that there was a time when our local hills and valleys were coated in an ice sheet, as were, we know, those of the North and Midland counties. Indeed, Charles Moore always held this opinion from other indications which he had observed." The "other indications" seem to refer to the fact that the soft Liassic clay is furrowed where it is overlain by the gravels.

It is never wise to postulate an agency which usually does its work on a vast scale and leaves its evidence written large, to account for small and local phenomena when evidence on a large scale is wanting. The large blocks are, I think, evidence of the great volume of water which flowed in the channel in those times. The work of the Avon as an excavator is now almost done; but when it flowed one hundred feet above the present bed and was in flood, the amount of descent, together with the great mass of water which rushed along, would probably be sufficient to account for the presence of these blocks in its bed.

In these low level gravels mammalian remains are abundant. They include teeth and bones of many Quaternary forms. In the two highest gravel pits mentioned teeth and bones are generally found resting on the Liassic clay. In some cases one half of the fossil retains the bluish tint of the material on which it rests, while the other side takes on the yellowish tint of the gravels. In the lowest gravels the fossils are generally found mixed up with the pebbles.

The palæontology of the Avon gravels should, I think, form the subject of a separate paper, but as the evidence the fossils yield as to the age of the Avon is important, it is briefly mentioned here. The following are the principal fossils found :—

1. The Mammoth (*Elephas primigenius*). The remains of this species of elephant are fairly abundant, and include molar and incisor teeth (tusks), and bones.

Of *Elephas primigenius* I have found in our gravels the following remains :—

(*a*) Over twenty true molars, some of which were in a good state of preservation.
(*b*) Portions of incisors. The tusks were of enormous size and only slightly curved. They are badly preserved.
(*c*) The proximal end of a tibia.
(*d*) The calcaneum. (N.B.—The sides are unequally compressed, which is characteristic of this bone as compared with that of *Elephas antiquus*.)

Range in time. In an important paper by Professor Boyd Dawkins on the "Range of the Mammoth,"[1] he argues that the mammoth was pre-glacial, inter-glacial, and post-glacial, but it is still doubtful whether the presence of this form in pre-glacial times is proven. Evidence more or less convincing, derived from the South of England, from Scotland, Cheshire, and the Forest bed of Norfolk and Suffolk, points to the probability of its being pre-glacial ; but in the first-mentioned cases there is difficulty in determining whether the material in which the remains were imbedded was as a matter of fact pre-glacial, and in the case of the finds from the Forest bed the teeth and bones are not found *in situ*, but are either washed ashore or brought up in the dredge.

Range in space. Remains are abundant in the Midlands and on the east coast, less abundant in Ireland and Scotland. They have been found in considerable numbers in the river deposits of France, and rarely in those of Spain. The mammoth inhabited the district on which Rome now stands. It ranged through Germany, but has not been found in Scandinavia or Finland ; it was abundant in the Urals and Siberia, also in Russian Asia. The remains of *E. armeniacus* link the mammoth with the elephant of India, which it very closely resembles in all essential points.

[1] *Quart. Journ. Geol. Soc.*, vol. xxv., p. 138 (1879).

2. *Elephas antiquus.* The presence of *Elephas antiquus* amongst the fauna of the low level gravels is in many respects interesting. I believe the specimen in my possession to be the only good one found as yet in the alluvial deposits locally. A small fragment, considered by Professor Boyd Dawkins to be a part of a molar of *Elephas antiquus*, was found in the Victoria gravels some years ago by the Rev. H. H. Winwood, but as the height of the tooth and width of the crown are such important factors in determining the species, the fact that the fragment consisted of a small portion of the crown surface only, made it difficult of identification. This fragment is in the Bath Museum and has not been described.

Leith-Adams[1] records three localities only in the south-west of England where the remains of *E. antiquus* had been found, viz., Durdham Downs, the Mendip Hills, and Bleadon Hill. In each case the find was made in a cavern.

Up to the year 1844 all remains of elephants found in Britain were regarded as those of *Elephas primigenius*. In that year Falconer was impressed by the similarity of the teeth from the older formations (i.e. the Norwich Crag) to those of the Indian elephant. To this old form he gave the name of *Elephas antiquus*, the molars of which more closely resemble those of *E. meridionalis* than those of *E. primigenius*.

There are three types of molars referred to *E. antiquus*. My example is of the "narrow crown" variety. Leith-Adams thus describes this class of molars:—

"The crown is narrow in comparison with the length and height. This is apparent in the 'broad' and 'thick-plated' crowns, and is pronounced in the more common British specimens, or, in other words, what is named the

[1] British Fossil Elephants Palæont. Soc. pp. 6, 7. See also his map showing distribution.

'narrow crown' variety. The enamel of the plate is very much crimped." This crimping is very characteristic, for, although it is to be seen in all forms in some degree, in *E. antiquus*, it amounts to a festooning of the entire enamel. Of course, the older and more worn the plate the more pronounced is the crimping, as the specimen in the author's possession well shows. Moreover, the plates are much thicker than are those of *E. primigenius*, for whereas in six inches of tooth an average of twelve plates occur in *E. primigenius*, in *E. antiquus* eight plates only would be found in a similar length.

The range of *E. antiquus* was much more restricted than that of its successor, *E. primigenius*. It has not been found in Scotland nor Ireland. Yorkshire marks the northern limit and Wales the western. In the southern and south-eastern counties of England it becomes more abundant. The headquarters of this form was the south of Europe. *E. antiquus* and *E. meridionalis* were pre-glacial and contemporary, and both seem to have been supplanted by *E. primigenius*. It would seem as though *E. antiquus* was driven south before the advancing cold, and a few stragglers only came back north again as the ice cap retreated. It soon afterwards became extinct.

3. *Rhinoceros tichorhinus* (or *R. antiquitatis* of Blumenbach). Teeth of *R. tichorhinus* are frequently found in the gravels. I have six—five of which are from the lower and one from the upper jaw. The upper tooth had only just pierced the gums, as is evident by the fact that the enamel is only worn slightly in one spot. These teeth wear flat horizontally, and are more easily described when the crown is worn. The three great sinuses are evident—anterior, posterior, and median, together with the "combing plates" on either side of the valley. So too are the strong bounding "columns" on either side of the sinuses. The nearest living species to *R. tichorhinus* is the African species *R.*

bicornis. They have the following points in common :

1. They have two fronto-nasal bones.
2. They have no functional incisors when adult.
3. A buttress common on the molars of other forms is absent from these.
4. There are three digits on the manus.
5. They are highly specialized.

The present distribution of the genus *Rhinoceros* is interesting. To-day it is confined to the warmer parts of Asia and Africa. The genus includes five well-marked species, one of which (*R. simus*), the large flat-nosed African form, is now probably extinct. The other African form is *R. bicornis*. The three Asiatic forms are *R. unicornis* and *R. sondaicus*, both of which are one-horned, and *R. sumatrensis*, which is two-horned and the smallest of the group.

In Miocene times the *Rhinocerotidæ* were well represented in both old and new worlds, though in America they became extinct before the end of the Pliocene. Judging from the abundance of their remains and from the unspecialized forms found in the Eocene of the Rocky Mountains, it has been inferred that they originated in this region. Three species are believed to have inhabited the British Isles, of which *R. tichorinus* is the most familiar.

Other finds include a horncore of *Bison priscus*, with its characteristic longitudinal furrowing, and teeth and other parts of *Equus*. The palæontology, however, of the gravel is so rich and interesting that it deserves a separate paper, and has only been introduced here as an aid in determining the age of the Avon.

In conclusion, the main points of interest may be summarized as follows :—

1. The western part of England was elevated before the eastern ; the Avon has therefore been longer at work than the Thames throughout its entire course.

2. The denudation of these valleys was far advanced in glacial times.

3. The large subangular pebbles of Millstone Grit and Mountain Limestone, which have travelled long distances and are only little worn, are evidence of their having been transported rapidly from their old home to their present position by a large volume of water.

4. The fauna of the alluvial deposits of the highest of the Low Level gravels is that which may be regarded as typical of the period which immediately followed the glacial epoch. It may therefore be assumed that the bed of the river at the close of the glacial epoch was about 100 feet higher than it is at present.

On the Occurrence of a Shell-bearing Gravel at Dumball Island.

BY HERBERT BOLTON, F.R.S.E., CURATOR OF THE BRISTOL MUSEUM.

IN March of the present year I was informed by Mr. Pearce, Resident Engineer upon the Avonmouth Dock Works, that at a considerable depth in the excavations at the south-east corner of Dumball Island, a shell-bearing layer had been met with which might prove of interest. On March 28 I visited the dock works, and was shown over the ground by Mr. Pearce. The latter gentleman directed my attention to the excavations which were proceeding for the wall of the inner gates of the lock which runs along the south-eastern side of the old Dumball Island. At a depth of about 24 feet from Ordnance Datum, or 44 feet from the surface, a layer of sand, mud, and fine gravel had been met with having an average thickness of five and a half feet. The whole surface of this layer could be seen dotted over with the separated valves of *Tellina balthica.* An examination of the material showed that the shells were distributed throughout the mass, and were not confined to the surface layers only.

A vertical section of the deposits at this part of the Dumball Island has been kindly furnished to me by Mr. Pearce. It is as follows :—

	ft.	in.
Mud	33	0
Mud and loam	11	6
Sand, mud, and fine gravel, with shells . .	5	6
Stiff clay	6	0
Ballast (Gravel)	10	0
	66	0

The surface of the island at this point is about 21 feet above Ordnance Datum, the section therefore passing down to 45 feet below Ordnance Datum. Below this depth the Marl is reached, beyond which the excavations are not carried.

In order to determine what shells were present in the deposit, a small boxful of the material was obtained, and carefully washed and sifted. An examination of the washed material resulted in the discovery of no less than twenty-four species of mollusca, *Tellina balthica* predominating.

The identification of the collection proved extremely interesting, as it showed the deposit contained a commingling of land, freshwater, and marine forms, together with a portion of a claw of a crab.

The following is a list of the shells obtained :—

Land and Freshwater—

Vitrea (Polita) cellaria.
Hygromia (Fruticicola) hispida.
Pyramidula (Gonyodiscus) rotundata.
Helix hortensis.
Cochlicopa lubrica.
Succinea putris.
Planorbis albus.
,, glaber (parvus).
,, complanatus (umbilicatus).
Limnea peregra.
Ancylus fluviatilis.
Cyclostoma elegans.
Bithynia tentaculata.
,, leachii.
Valvata piscinalis.
Pisidium pusillum.
Paludestrina stagnalis.

Marine—

Littorina obtusata.
,, rudis
Neritina fluviatilis.
Leuconia bidentata.
Vallonia pulchella.
Scrobicularia piperata.
Tellina, balthica.

All the land and freshwater species in this list are found in the North Somerset vice-county as defined by the Conchological Society of Great Britain and Ireland, and all, with the exception of *Planorbis glaber* (*parvus*) and *Pisidium pusillum*, in the West Gloucestershire vice-county.

A little consideration will show that this association of mollusca is of considerable interest from a geological no less than a zoological point of view. Of the molluscan fauna of the land in past geological time we know very little. Extensive deposits formed upon the land can hardly be looked for; marine and estuarine deposits are common enough, yet in this case we have an estuarine deposit containing a large majority of land molluscan forms.

The manner in which these members of the land molluscan fauna have been brought to their present position is easily understood. It will have been noticed that eleven species, or twelve, if we add *Paludestrina stagnalis*, are freshwater forms, inhabiting ponds, ditches, and streams. During freshets and floods, and probably also during the ordinary course of drainage, the empty shells of these forms would easily be swept into the Avon, and carried onwards until the current received a check, when the Avon reached the Channel. The empty shells of the land species would not be so easily swept into ditches or streams to be carried onwards, hence their rarity and the absence of many of the commoner species of *Helix*, etc. The depth of the deposit indicates that it must have been formed at a time when the North Channel was not only navigable but deep, and probably serving as the main outlet of the river.

The presence of the marine species can be accounted for by the vast volume of sea water, and the consequently strong current which set up the river on a rising tide, although such forms as *Tellina balthica* might perhaps have been able to live where they are now found.

This latter view I should not care to emphasize were it not for the great number of specimens found throughout the shell-bearing deposit. Against this view it must be borne in mind that the large flat valves of *Tellina* are so admirably fitted for easy removal by moving water that they might well be carried to the spot where they are now found from deeper water outside.

Reasoning from analogy, it is possible that older deposits of mud and fine gravel might yield similar land and fresh-water forms. Such species may even be known to us, but regarded as marine or brackish-water forms. At any rate, at Dumball Island we have evidence of the formation of an estuarine deposit, in which the majority of forms have been water-borne from land and freshwater areas.

The deposits at Dumball Island have an interest of their own apart from the shell-bearing gravel. By reference to the section, it will be noted that the lowest bed of all is a bed of "ballast" ten feet thick. This "ballast" bed is really a bed of clean, large, well-rolled pebbles mixed with sand. It has all the characters of a pebble beach. Its presence at this depth and in this situation would seem to indicate either that the flow of the river Avon was so great at one period that pebbles could be carried or rolled as far down as Dumball, or else that the river bed was shallow, and its course farther out into the channel, so that all the mud carried in suspension was deposited outside the area in which the "ballast" occurs.

On an Interesting Habitat for "Diplotaxis Tenuifolia," the Narrow-leaved Wall Mustard.

By ALFRED C. FRYER, Ph.D., F.C.S.

FOR many years no blade of grass or humble weed would grow upon the unsightly waste heaps belonging to the United Alkali Company at their Netham Chemical Works, Bristol. However, a little plant known as the *Diplotaxis tenuifolia*, commonly called the Narrow-leaved wall mustard, is fast spreading over these and other heaps of chemical refuse. This plant is rare in some counties, but it flourishes in many localities in the south, south-west, and east of England. It grows in about a third of the 112 counties and vice-counties into which Britain has been divided for botanical purposes. Mr. H. C. Watson regarded it as not indigenous to this country, but what he termed "a denizen"; however, for many years past it has been growing like a native plant in many parts. Sir William Hooker and Dr. Arnott mention St. David's, Fifeshire, as a Scottish habitat for it, but add that it was introduced there among ballast. Miss Anne Pratt says that "it is often found in England, near houses, and on dry banks or old walls and heaps of rubbish about towns, and is very plentiful in the suburbs of London."[1] Mr. F. H. Davey, who is at present engaged on the flora

[1] See *Flowering Plants and Ferns of Great Britain*, by Anne Pratt, vol. i. p. 153.

of Cornwall, writes to me: "It is most interesting to find the *Diplotaxis tenuifolia* springing up in such quantities on waste heaps such as you describe. In Cornwall I have found it at Fowey, Par, Pentewan, Penpoll, and Devoran, and Penpoll is the only place where it occurs on cinder heaps. There it grows luxuriantly on the refuse from the smelting works." Mr. Davey adds that, "taking Britain as a whole, it is rather a rare plant."

In the *Flora of Plymouth* it is described as "very rare," but "plentiful in the Cattedown quarries."[1] In the *Flora of the English Lake District* it is mentioned as being found on the walls of Carlisle and Penrith Castle.[2] The author of the *Flora of West Yorkshire* speaks of it being found at Pontefract, but considers the plant very rare.[3] It has been found at Ludlow,[4] in Shropshire. In Guernsey it is said to be "local, but abundant where it occurs," while in the Island of Alderney it is so abundant that it is described as a "troublesome weed."[5] In the *Flora Bristoliensis* it is called *The Wall Rocket*, and is stated to have been found in 1854 on St. Philip's Marsh, on a wall at White Ladies, and at Horfield by Mr. T. B. Flower, and Miss M. Atwood discovered it on the edge of the quarry near the Suspension Bridge, on the Somersetshire side of the Avon.[5] In the valuable compilation of the *Flora of the Bristol Coal Field*,[5] it is stated to have been found in 1881 on old walls and buildings in Bristol and the vicinity, but it is considered rare. Mr. W. B. Waterfall informs me that he first gathered it on some old walls near the works of the Avon Manure Company, on St. Philip's

[1] See Brigg's *The Flora of Plymouth* (1880).
[2] See Baker's *Flora of the English Lake District* (1885).
[3] See Lee's *Flora of West Yorkshire* (1887).
[4] See Ley's *Flora of Herefordshire* (1889). It is not found in Herefordshire, but at Ludlow, in Shropshire.
[5] See *Flora of the Bristol Coal Field* (Bristol Naturalists' Society), 1881.

Marsh, Bristol, in the year 1878, and since then it has greatly increased, and covers all the waste ground.

The stem of *Diplotaxis tenuifolia* is about a foot to a foot and a half in height, and its narrow, acute, pinnatifid, or twice-pinnatifid, smooth leaves emit a nauseous scent when crushed ; but from June to September it bears pale yellow flowers possessing a sweet almond-like fragrance, It would be interesting to know if this little plant is beautifying other unsightly refuse heaps in other parts of the country besides those we have in the city of Bristol.

On Abnormally Marked Lion Cubs.

By HERBERT BOLTON, F.R.S.E., CURATOR OF THE BRISTOL MUSEUM.

DURING the early part of the year the museum received two lion cubs from the Clifton Zoological Gardens, both of which present marked details of coloration of a somewhat unusual type. The smaller of the two cubs was born dead, and shows a degree of coloration much in advance of the second, which latter lived for a short time.

The fur of the stillborn cub is marked out, especially along the dorsal line of the back, into a series of polygonal areas of a blackish to fawn colour, separated by narrow rims of lighter fawn-coloured hair. On the flanks and the limbs the spotted appearance is also well developed, but the enclosed areas are lighter in colour than those on the back, and stand out less prominently from the fawn rims, which are likewise paler in colour than on the back.

From the nape of the neck on to the crown of the head are a few patches of fur darker than all the rest, and showing a tendency towards the formation of stripes, which radiate out on to the head between the ears, and come together in the nape of the neck. When viewed from above, the light fawn borders of the dark areas seem to run down the sides of the body as somewhat irregular stripes.

The second and older cub, which lived a short while, displays the same spotted character of the fur, but it is much less defined, whilst the lateral stripes are more prominent, and of a whitish-fawn colour.

In both cases the spots are continued on the tail and the legs. The outer surface of the ear in both is clothed with a close fur of black hair. A slight tendency to fawn stripes on a dark ground is seen on the face of the stillborn cub.

The interest and value of these cubs lies in the fact that they show very clearly that the lion, although sand-coloured when adult, has nevertheless been derived from spotted ancestors. The presence of faint stripes upon the fur of young lion cubs is, I believe, fairly general, and the spotted condition is not rare, but scarcely so well marked usually as in the case of the stillborn cub.

Mr. F. E. Beddard, in discussing the question of coloration of the Felidæ, draws attention to other sand-coloured species besides the lion, as, for example, the puma, the cubs of which are markedly spotted.

In the two cubs now under consideration, it is evident that the formation of light-coloured stripes is a subsequent effect to the formation of spots.

In the tiger it has been noticed that some of the dark stripes so characteristic of the animal are like spots drawn out, and if such has been the case—that is, if the spotted areas have passed into stripes by the development of the colour areas in two opposite directions—then the intervening spaces would be the equivalents of the faintly indicated fawn stripes on the bodies of these two cubs.

Various theories and conjectures have been put forward from time to time respecting the coloration of the Felidæ, and upon certain points there is a fair amount of agreement, viz., that the spotted coloration which is most marked in cats leading an arboreal existence is a necessity of such a habit, and a most effective protection, simulating as it does the flecks of sunlight broken up by passing through foliage.

The stripes of the tiger are held similarly to cause the body to resemble clumps of bamboos, and of the grasses in which they lurk, and the sand-coloured fur of the adult lion matches perfectly with the arid country in which it mainly finds a home.

Eimer has concluded that the primitive colour condition was one of longitudinal stripes, that this by the breaking up of the stripes resolved itself into a spotted one, and that the spots afterwards re-arranged themselves into transverse stripes, the sand-coloured lion and puma being the final stage in this colour evolution.

If his conclusions be correct, we may look upon the longitudinal stripes upon the head and neck of the still-born cub as the primitive condition, and the spots and stripes as later developments, although it must be borne in mind that the light-coloured stripes are not the homologues of the dark stripes of the tiger, but of the interspaces between them.

If the spotted character is the primitive coloration, and also indicative of an arboreal habit, then we must assume that the lion was formerly arboreal, and its preference for open country and scrub a later acquired habit.

Reports of the Meetings.

GENERAL.

THE subjects brought before the Society at the General Meetings have been as follows :—

Feb. 5.—Mr. G. Munro Smith, M.R.C.S., L.R.C.P., on "The Structure of Organs."

Mar. 5.—Mr. Herbert Bolton, F.R.S.E., on "The Treasures of the Bristol Museum."

April 2.—Dr. Theodore Fisher, on "Some Autumn Holidays with the Birds."

May 7.—Rev. F. Howlett, M.A., F.R.A.S., on "Solar Spots."

Oct. 1.—Mr. G. Brebner, on "The Dispersal of Seeds."

Nov. 5.—Mr. O. C. M. Davis, B.Sc., on "Foods, Natural and Artificial."

Dec. 3.—Dr. F. E. Francis, on "Water."

At the March meeting a paper by Dr. A. C. Fryer, on "A Dust Fall in the South-West of England," was also read. This paper is published in the Proceedings of the Society.

The subject dealt with by the President, Dr. A. B. Prowse, at the Annual Meeting, was "The Wansdyke in the Neighbourhood of Bristol."

The papers by Dr. Francis and Mr. Davis were illustrated by many experiments ; at all the others the lantern was used.

S. H. REYNOLDS,

Hon. Secretary.

BOTANICAL SECTION,

REPORT FOR 1903.

A FEW facts of interest to local botanists have been lately made known to members of the Section. *Barbarea intermedia*, a rare species, although probably not native, was gathered on waste ground near Portishead; and the Fritillary (plants with white and coloured flowers) is recorded from a private policy near Frenchay, and from a meadow at Barrow Gourney, where it was pointed out by children of the village.

JAS. W. WHITE, F.L.S.

GEOLOGICAL SECTION.

REPORT FOR 1903.

THIS Section commenced the year with fifty members, and during the twelve months three resigned and three new members joined the Section.

Prof. S. H. Reynolds, M.A., F.G.S., was re-elected President, and Mr. B. A. Baker Hon. Sec.

The following subjects were brought before the Section on the nine occasions on which it met :—

Jan. 28.—" Some notes on the Jurassic Brachiopoda of Dundry Hill," by J. W. D. Marshall.

Feb. 17.—" The Volcanic Rocks Associated with the Carboniferous Beds of the Bristol District," by Professors C. Lloyd Morgan, F.R.S., F.G.S., and S. H. Reynolds, M.A., F.G.S.

March 19.—" The Story of a Pacific Island," by Dr. H. B. Guppy.

April 30.—" Notes on the Inferior Oolite of the District," by J. W. Tutcher.

May 21.—"Notes on the Geology of Ilfracombe," by Prof. S. H. Reynolds, M.A., F.G.S.

June 18.—"Notes on the Carboniferous Corals and Brachiopods in the Stoddart Collection," by A. Vaughan, B.A., B.Sc., F.G.S.

Oct. 22.—"Notes on the Geology of the Belfast District," by Prof. S. H. Reynolds, M.A., F.G.S.

Nov. 19.—Exhibition Meeting, when the following were exhibited :—

(1) (*a*) Lantern slides illustrating the Geology of Ilfracombe ; (*b*) second series of the British Association geological photographs ; (*c*) Geological map of Japan ; (*d*) Two plaster casts of Pterodactyles from the Munich Museum ; (*e*) Rocks and minerals from the Tyrol, by Prof. S. H. Reynolds, M.A., F.G.S.

(2) Lava specimens from Mount Vesuvius ; (*b*) First series of the British Association geological photographs, by Miss F. MacIver.

(3) Neolithic remains from Ballintoy ; (*b*) Palæolithic chert implements from Broom Pit, Axminster ; (*c*) Eolithic flints, Salisbury, etc. ; (*d*) Distorted or "crazy" Cotham marble, by W. H. Wickes.

(4) Collection of fossils from the Bognor Rock, by J. T. Kemp, M.A.

(5) Specimens from the Travertin Leaf Beds of Italy ; (*b*) Examples of Palæozoic Trilobites, etc., from Bohemia, by Dr. W. B. Gubbin.

(6) Sharks' teeth and other fossils from the Barton Beds, Hampshire ; sharks' teeth from Phosphate Beds, Florida. Photograph and lantern slide of Ichthyosaurus from Stockton, near Rugby. Lantern slide of chalk quarry, showing pipes of Plateau gravel, Salisbury. Lantern slide of Basalt quarry, Rhine. Specimens of Strontia deposited with other minerals, by B. A. Baker.

(7) Specimens from Bryozoa beds, especially those col-

lected by Mr. W. H. Wickes from Portishead. Felspars, by A. Vaughan, B.A., B.Sc.

(8) Specimen of a large fish from London Clay of Sheppy, by J. Underhill.

(9) Photographs of Fossils, by J. W. Tutcher,

(10) Microscopic section of coal plants, by G. Brebner.

Dec. 17.—"The Avon and its Gravels," by Rev. B. Oriel, B.A., B.Sc., F.G.S.

The average attendance was twenty at each meeting.

The financial report shows a total receipt of £7 11*s*. 2*d*., with eighteen members still to pay their subscription, making a total of £9 16*s*. 2*d*. on the year, and an expenditure of £4 17*s*. 4*d*., showing the Section having a credit balance of £4 18*s*. 10*d*., against £3 3*s*. 8*d*. last year, or a gain of £1 15*s*. 2*d*.

ENTOMOLOGICAL SECTION.

DURING the year 1903 this Section met on three occasions.

January 9.—Annual Meeting. The officers were re-elected for the ensuing year.

Mr. Charbonnier exhibited a live example of the bug *Ploiaria culiciformis*, and remarked upon its habits.

February 20.—Mr. Griffiths exhibited a large number of Lepidoptera genera *Pierella* and *Antirrhœa* of the fam. *Satyrinæ*. The Secretary exhibited a series of the most recently discovered British butterfly, *Hesperia lineola*, from Essex, with a series of *H. Linea* from Dorset for comparison; a supposed variety of *Psilura monacha*, New Forest; a pair of *Nonagria sparganii*, Kent, and a pair of *N. albipuncta*, from Dartmouth.

March 17.—Mr. Charbonnier exhibited a specimen of the Bee Louse, *Braula coeca*, and described its life history ; also specimens of *Ornithomyia avicularia* and *Hippobosca equina*. Mr. Griffiths exhibited the following varieties and aberrations : *Argynnis paphia*, with white spots, and another with dark rays ; *Vanessa io*, with spots on forewing green in place of the usual blue ; *Satyrus janira*, with cream-coloured spots on wings ; *Psilura monacha*, a black ♂ and a banded ♀ ; *Euchelia jacobeæ*, straw-coloured aberration with faint red markings, and another drab variety.

Dr. Rudge exhibited a fine example of the Lantern Fly, *Fulgora laternaria* from British Guiana, and a specimen of the large water bug, *Belostoma grandis*.

November 14.—Mr. Watkins communicated the capture by Mr. W. B. Davis, at Stroud, of a ♀ specimen of *Æschna grandis* on August 11, 1903.

Mr. Griffiths exhibited a number of species of *Lemoniidæ*, a group of Lepidoptera of very varied character inhabiting tropical South America.

CHARLES BARTLETT,
Hon. Secretary.

JUNE 3, 1904.