14. *The* Paradoxidian Fauna *of a* Part *of the* Stockingford Shales.

By Vincent Charles Illing, B.A., F.G.S.

(Read June 24th, 1914.)

[Plates XXVIII–XXXVIII.]

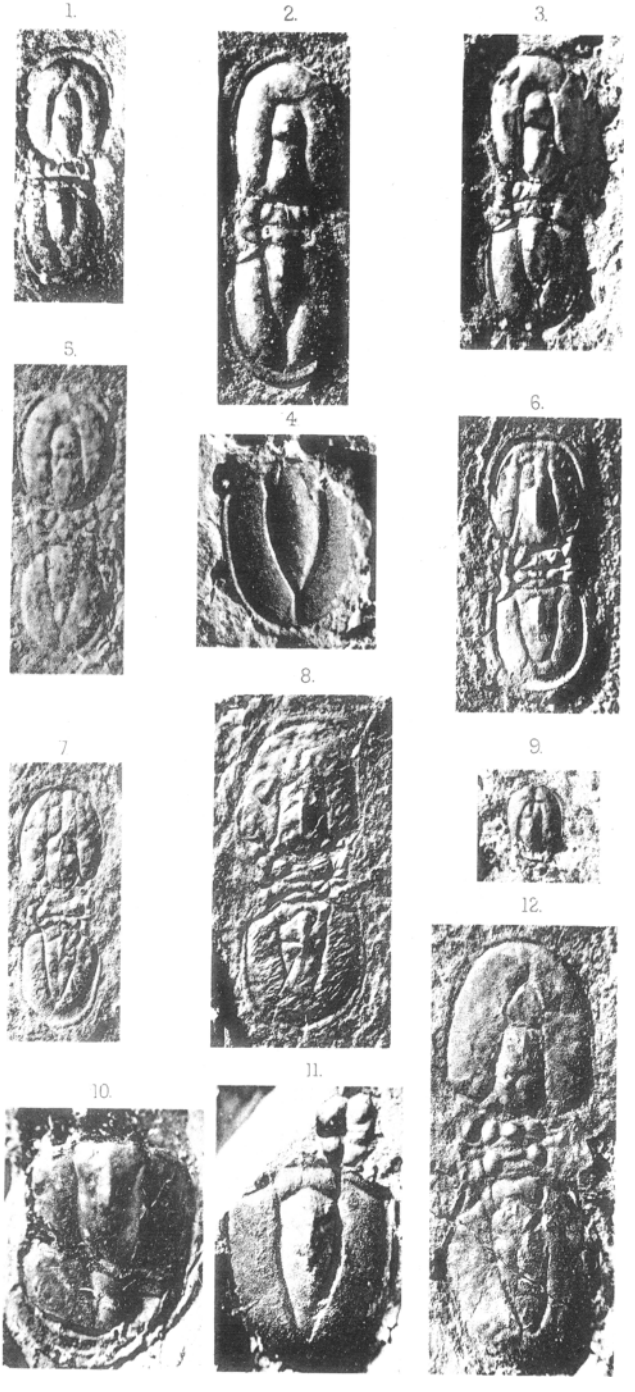
Contents.

I. Introduction and Previous Literature.

The strata which form the subject of this paper make up a small part of the Cambrian succession cropping out near Nuneaton, in the very heart of the Midlands. Here, an inlier of Cambrian age forms a narrow belt of country about 9 miles long, running in a general north-westerly and south-easterly direction, between the towns of Atherstone and Bedworth. On the north-eastern side lies the rolling plain of down-thrown Trias, while on the opposite, or south-western side, the highly-dipping Cambrian shales are unconformably overlain by the Coal Measures.

In the early Geological Survey publication of 1859, by H. H. Howell, these lower strata were not differentiated from the overlying Carboniferous System. The Lower Cambrian Quartzites were correlated with the Millstone Grit Series, while the immediately overlying shales were included in the Coal-Measure Shales proper. The next noteworthy contribution was the brilliant work of Samuel Allport in 1879, on the intrusive igneous rocks. To these he applied the term 'diorites,' distinguishing them from the doleritic type that usually occurs in the Carboniferous of the Midlands.

However, it was not until 1882 that Prof. Charles Lapworth and W. J. Harrison, noting the similarity of the quartzites of Lickey and Hartshill, investigated the area, and proved the bedded nature of the Lower Caldecote igneous rocks. Finally, by the discovery of Cambrian *Lingulæ* in the overlying shales at Stockingford Cutting, Prof. Lapworth was able to establish the true age of these beds. The same author divided the succession nto a lower Hartshill Quartzite and an upper series of the tockingford Shales, in which typical Upper Cambrian trilobites



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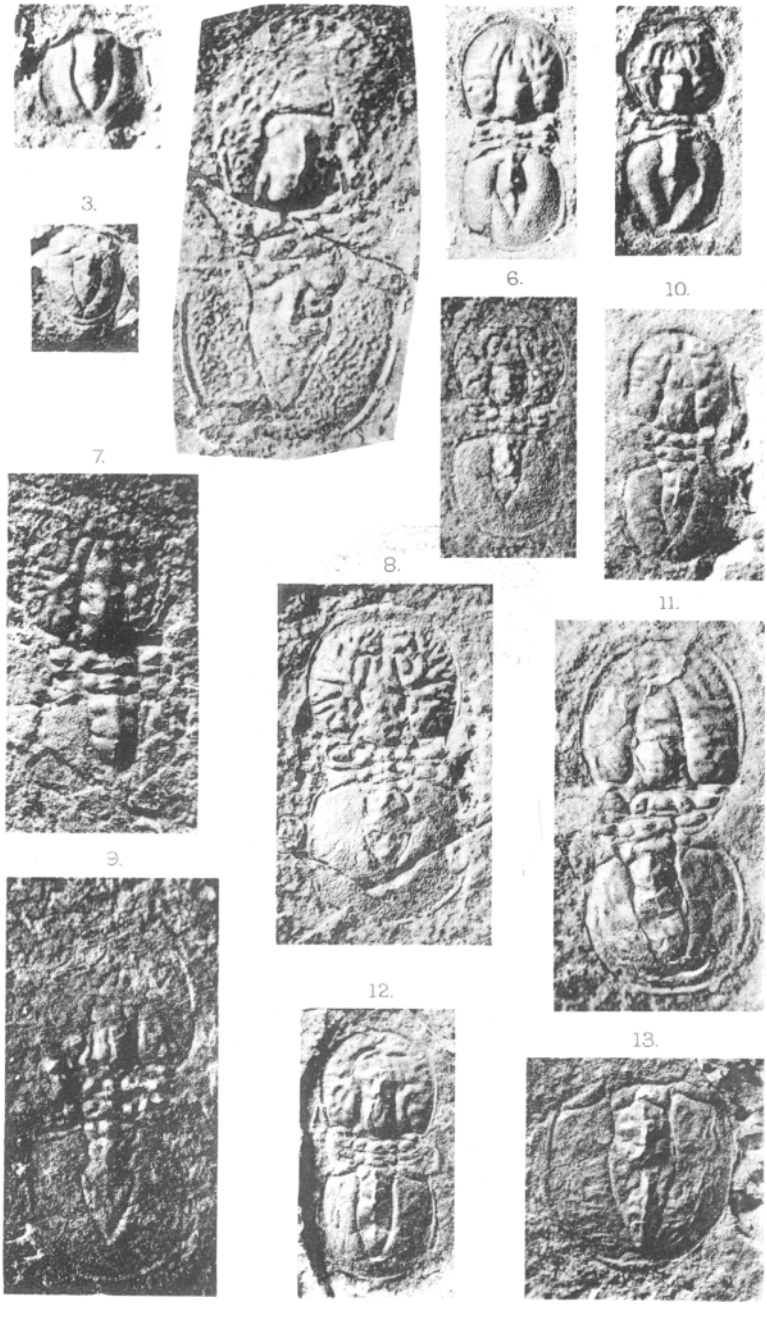

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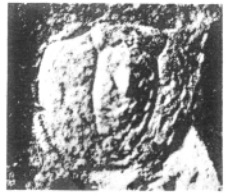

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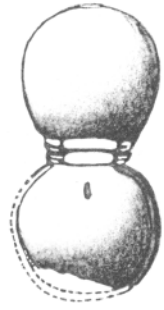

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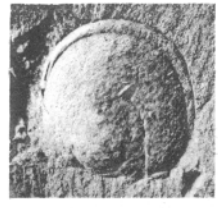

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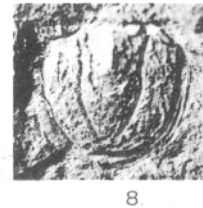

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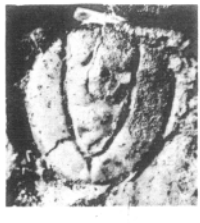

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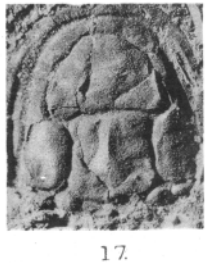

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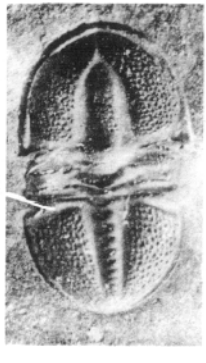

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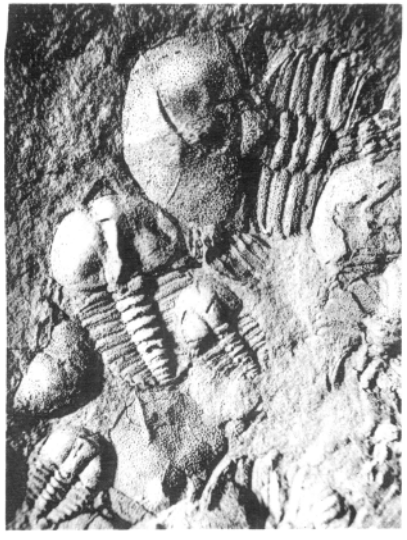

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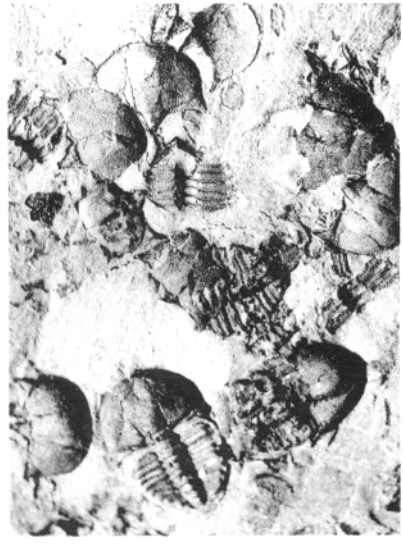

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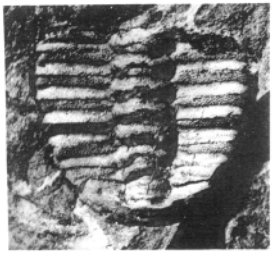

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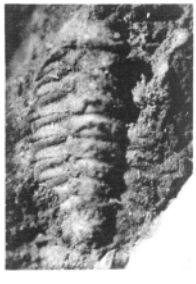

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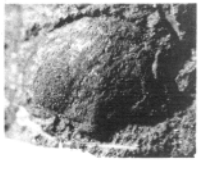

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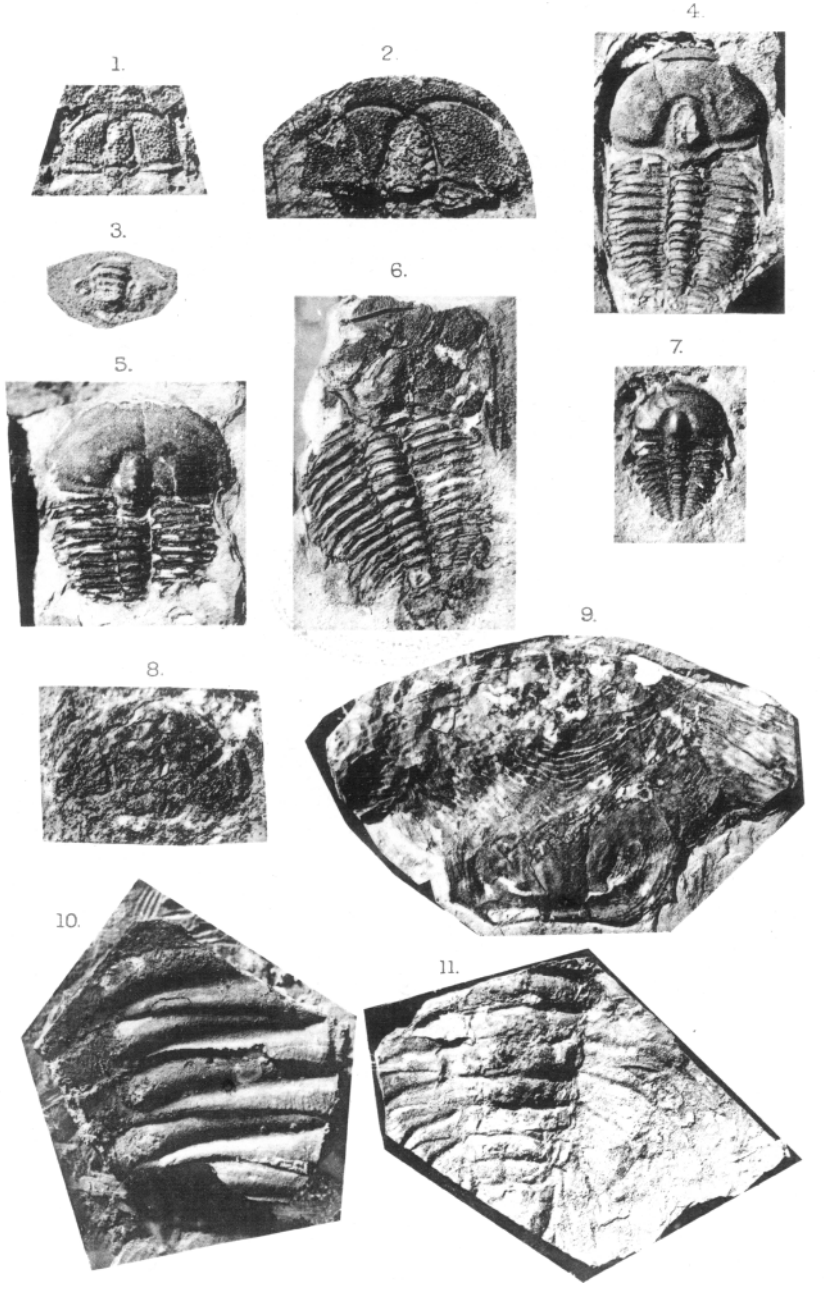
HARTSHILLIA AND HOLOCEPHALINA.



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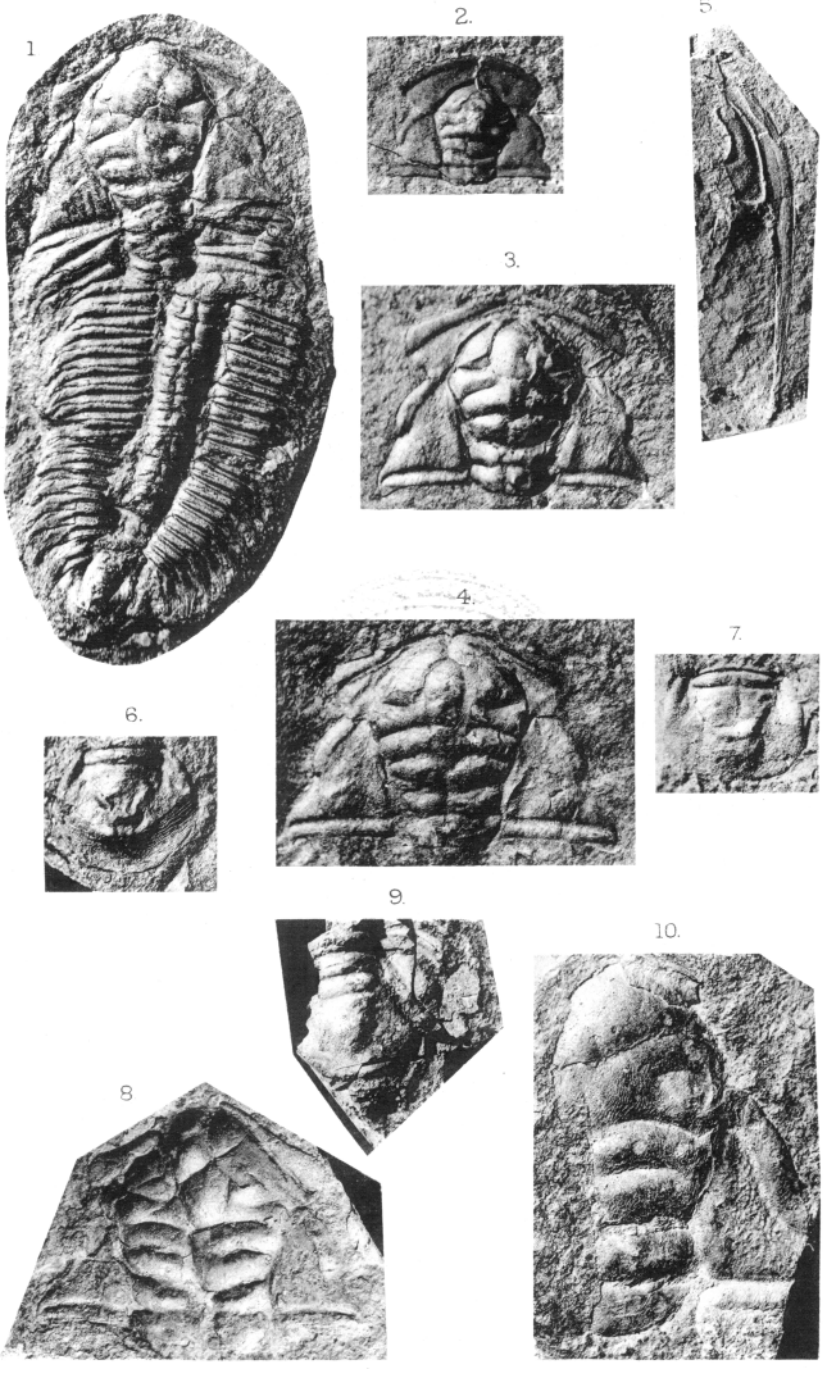
CONOCORYPHE, HOLOCEPHALINA, AND PARADOXIDES.



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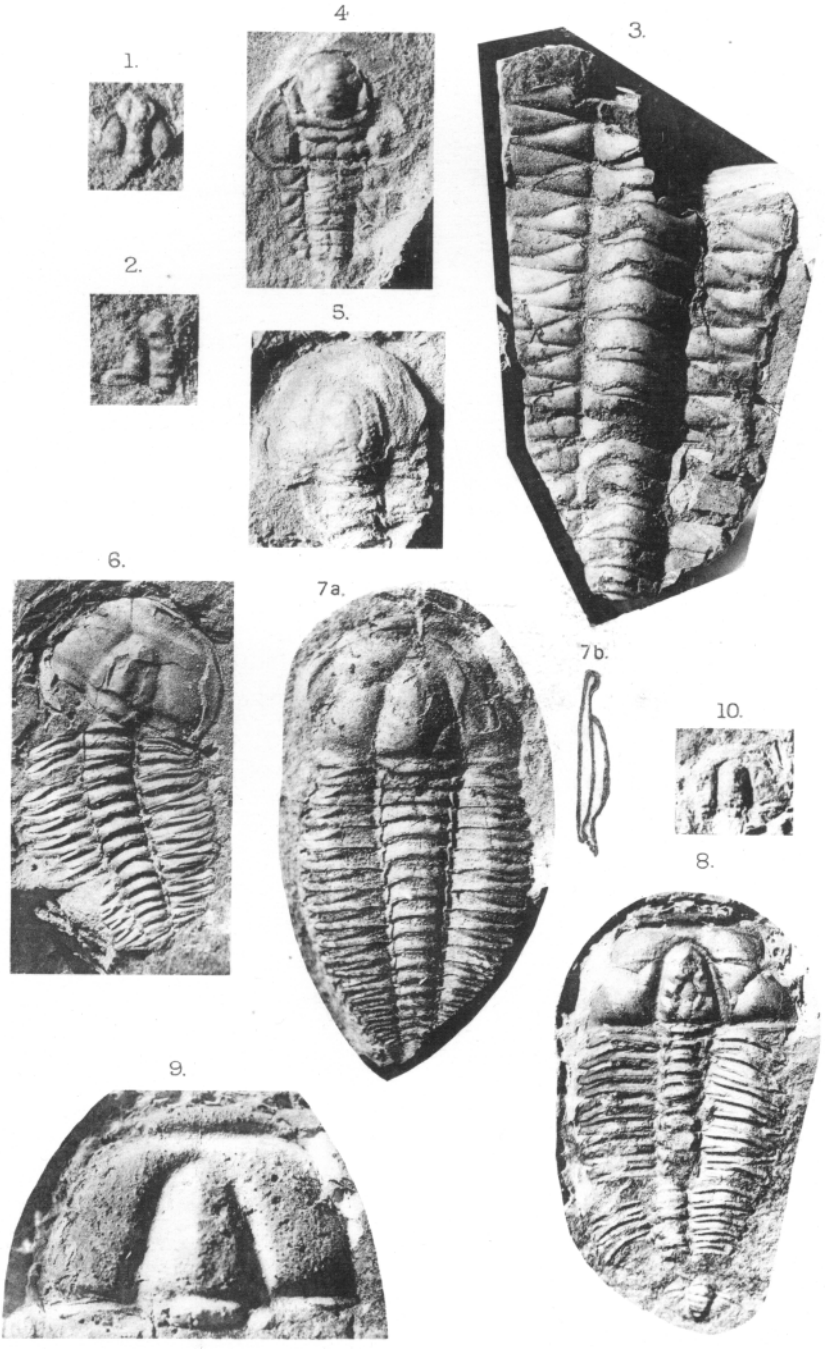
PARADOXIDES.



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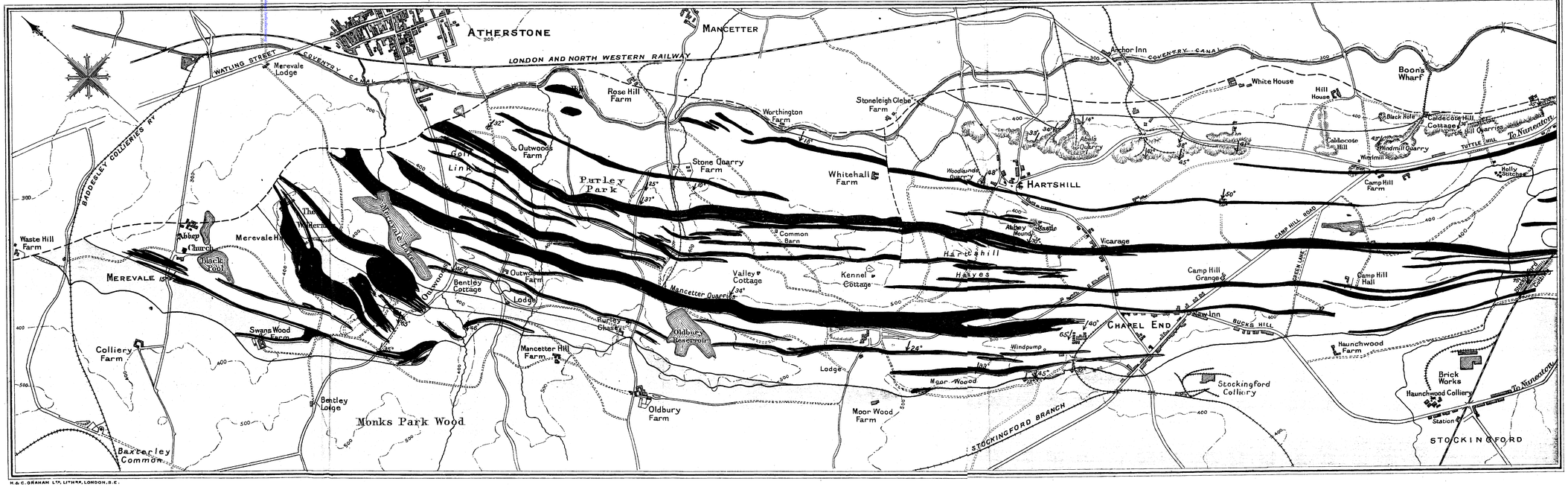
CORYNEXOCHUS, CENTROPLEURA, AGRAULOS, LIOSTRACUS, AND SOLENOPLEURA.

Geological Map of the District between Nuneaton & Atherstone (North-East Warwickshire)

By Vincent Charles Illing, B.A., F.G.S.

Quart. Journ. Geol. Soc. Vol. LXXI Pl. XXXVIII.



INDEX OF COLOURS.

- Trias
- Carboniferous
- Intrusive Diorites and Camptonites
- Stockingford Shales
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  - Monks Park Shales
  - Moor Wood Flags and Shales — Lingula Flags
  - Outwoods Shales
  - Abbey Shales — Middle Cambrian
  - Purley Shales
  - Hartshill Quartzite — Lower Cambrian
- Caldecote Rocks. — Pre-Cambrian

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were noted. About four years later, the succession was amplified by a subdivision of the Stockingford Shales into

Upper, or Merevale Shales.
Middle, or Oldbury Shales.
Lower, or Purley Shales.

In the same year the rocks were re-surveyed by the officers of H.M. Geological Survey, and Dr. A. Strahan proved that the line of junction between the Carboniferous and the Cambrian, which had previously been regarded as a fault, was in reality an unconformity. In Prof. Lapworth's classic paper on 'The Geology of the Birmingham District' Proc. Geol. Assoc. vol. xv (1898–99) p. 313, we have a masterly description of the whole succession, with a full list of the fauna, and a correlation, so far as was then possible, of the various members of the group:—

Merevale Shales	= *Dictyonema* Band of North Wales.
Oldbury Shales	= Dolgelly Beds of North Wales.
Purley Shales	= Paradoxidian Division.
Hartshill Quartzite	= Olenellidian Division.

He then continues,

'there is as yet no direct evidence forthcoming of the presence of the Lower *Lingula* Flags (Maentwrog and Ffestiniog Beds) in the Nuneaton area; but, as the Nuneaton sequence appears to be continuous from base to summit, it is just possible that they are represented by the upper bands of the Purley Shales, and the lowest zones of the Oldbury Series.'

This assumption of a complete succession has been justified by later work, although the faunas occur at a somewhat higher horizon than was expected. Thus, Mr. John Pringle, of H.M. Geological Survey, discovered *Callavia* at the base of the Purley Shales, while a rich Paradoxidian fauna occurs in the Lower Oldbury Shales. In a short paper of mine in 1913,[1] a further subdivision of the Oldbury Shales was suggested, and the classification and correlation of the Cambrian drawn up as follows:—

Merevale Shales		= Lower Tremadoc.
Oldbury Shales	Monks-Park Shales	= Dolgelly.
	Moor-Wood Flags and Shales	= Ffestiniog (?).
	Outwoods Shales	= Maentwrog.
	Abbey Shales	= Menevian.
Purley Shales	Upper	= Menevian (?).
	Middle	= Menevian (?).
	Lower	= Taconian.
Hartshill Quartzite	Camp-Hill Grit	= Taconian.
	Tuttle-Hill Quartzite	= Taconian.
	Park-Hill Quartzite	= Taconian.

In this correlation the term 'Taconian' may be replaced with advantage by 'Lower Cambrian,' while 'Menevian' was used in an extended sense, as advocated by Linnarsson,[2] to include the

[1] Geol. Mag. dec. 5, vol. x (1913) p. 452.
[2] 'Oldest Fossiliferous Rocks of Northern Europe' Geol. Mag. dec. 2, vol. iii (1876) p. 288.

whole of the Paradoxidian. The age of the Moor-Wood Flags and Shales was postulated, on the evidence of their position and lithology.

The various subdivisions have been mapped over the northern half of the outcrop, and will form the subject of a future communication. For the present, attention is confined to the Abbey Shales, a small subdivision at the base of the Oldbury Shales barely 90 feet thick, but containing a rich fauna of Paradoxidian age, showing a definite sequence of types and indicating a time-range extending over a large portion of the Middle Cambrian.

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II. General Outcrop.

The best exposure of the Abbey Shales is in Purley Lane, near Purley Park. Here, towards the top of the cutting, the red Purley Shales pass up into a series of blue and grey siliceous shales with well-marked jointing, followed by soft, laminated, blue shale. Higher up, a series of camptonite-sills intervene, and the upper shales are unexposed.

The line of junction between the Purley and the Abbey Shales has been mapped from Stockingford Cutting, about 60 yards east

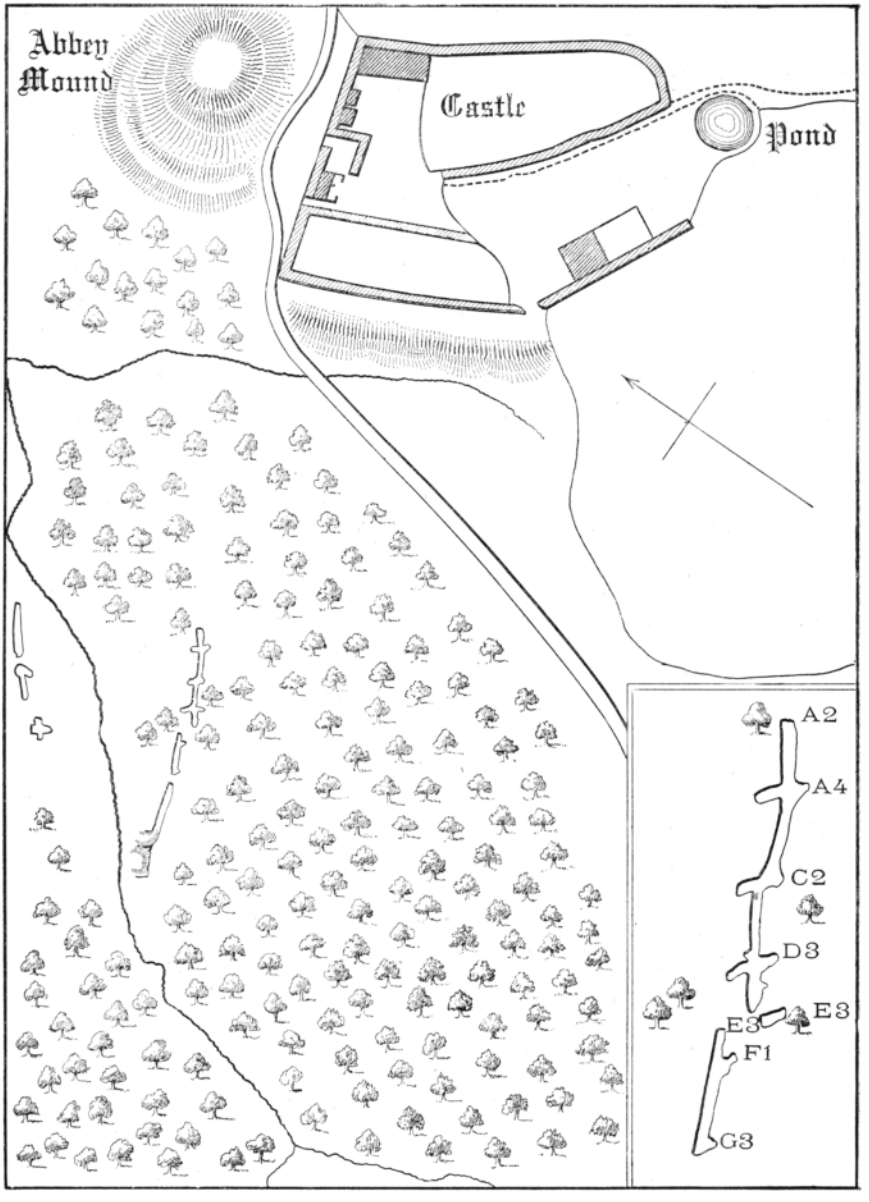
of the bridge over the railway, to the golf-links near Atherstone. It proceeds under the cottage 200 yards east of Camp-Hill Hall to Hartshill Church, and then through the northern end of the cemetery and Hartshill Hayes, to Purley Cutting. Thence, through Purley Park, it runs 50 yards west of Outwoods Farm towards the Pound at Atherstone, but is faulted down below the surface, near the edge of the Outwoods.

The 100 feet or so of Abbey Shales above this junction form a narrow band about 40 yards wide, but broadening towards the north with the decreasing dip. It has a general north-west to south-east trend; but, while in the latter direction it becomes more easterly, in the former it curves slightly towards the north. Thus it crops out as a slightly-curved band, which indicates that the beds have a broad anticlinal structure.

Exposures along the outcrop are extremely rare. In the Midland Railway cutting at Stockingford most of the surface is overgrown; but, in a recently-cleared ditch on the south side of the line, the Upper Purley and Lower Abbey Shales can be seen. Between the cutting and Hartshill Hayes, exposures are confined to a few poor surface-outcrops; but in the Hayes itself, old trenches, dug in search of road-metal, yielded the first traces of trilobites. Shale-fragments obtained from an excavated pond near the Common Barn, between Oldbury Hall and Mancetter, contained numerous brachiopods of the lower siliceous shales. The Purley-Lane Cutting has already been mentioned; in Purley Park the road has been excavated into the side of the hill, and although much of the surface is overgrown, a considerable portion of the Abbey Shales is seen, together with part of the Purley Shales below, and the Lower Outwoods Shales above. In the spinney near Outwoods Farm, a trial-hole for diorite has yielded shale-fragments containing *Paradoxides hicksii* and *Agnostus fissus* with numerous brachiopods, while a poor exposure occurs in a ditch at the northern end of the golf-links.

Owing to the absence of a good section, either natural or artificial, trenches were dug across the outcrop in Hartshill Hayes, the situation chosen being along the sides of a dip-valley. At first, a long narrow cutting was made, and the position of the fossiliferous horizons noted. The soil on the higher side of the trench was then removed for a width of about a foot and a half, and the shales below were examined carefully bit by bit. Thus, the danger of missing a fossil-band was minimized. The strata, in which trilobites abound, were worked in cross-cuttings made in the direction of the strike. The accompanying map (p. 390) shows the exact position of the trenches; while the inset on a larger scale indicates the relative positions of the fossiliferous beds, the lettering corresponding to the most important horizons from which fossils have been obtained.

Sketch-map of a portion of Hartshill Hayes, on the scale of 50 yards to the inch, indicating the position of the trenches.



[The inset represents the main trench on the approximate scale of 16½ yards to the inch.]

III. Detailed Succession.

The following is a detailed account, in descending order, of the section from the top of the Abbey Shales to the passage-beds at the base, as measured in the main trench :—

Horizon.	*Lithology.*	*Thickness in feet*	*inches.*
G 3.	Calcareous glauconitic conglomerate	0	3
	(Eroded surface.)		
	Hard, blue, siliceous shale, well jointed, with inclusions of iron-oxide in the upper layers	1	0
	Soft, grey, laminated shale	0	3
	Hard blue and grey shale, with calcareous concretions. (Fossils common.)	0	11
	Soft blue and grey shale	0	6
G 2.	Hard grey shale, with calcareous bands and inclusions	1	3
	Dark glauconitic sandstone, with phosphates	0	1
	Black weathered limestone, with phosphates	0	1
G 1.	Alternating bands of hard grey shales and soft blue shales	2	1
	Soft green shale, with glauconite grains	0	2
F 3.	Soft grey shales with red partings. (Fossils.)	0	4
	Alternating hard grey and green shales, and soft, blue, laminated shales	5	6
	Soft blue shale weathered to clay	0	2
F 2.	Dark-blue shales, softer in the upper part	1	6
	Hard blue, grey, and green shales, with iron-stained bedding-planes	1	2
	Thin, black, weathered limestone, with brown calcareous shale below	0	1
	Hard grey shale, with bright slickensided surfaces near the top	0	9
F 1.	Extremely brittle blue-grey shales, with iron-stained surfaces. (Fossil band 1 foot 8 inches from the top.)	5	4
	Hard grey shale	0	6
	Brittle blue shale, with a few compact layers	2	6
E 3.	Hard blue and grey laminated shales, with brachiopods and sponge-spicules	1	0
	Blue and grey shales with brown partings, and a 2-inch brown calcareous bed with fossils	0	6
	Camptonite-sill	2	9
E 2.	Hard grey shale with softer, blue, laminated shales	3	0
	Well-jointed grey shale with coarser brown bands, with fossils	0	4
	Blue laminated shale	0	8
	Brown well-jointed shale, as above	0	4
E 1.	Hard and soft, blue, laminated shales with yellow partings	2	0
	Hard greyish-green shale with slickensided surfaces. (Fossils abundant.)	0	4
	Blue laminated shale with tough non-laminated shale about the middle, and a thin, micaceous, sandy horizon near the base	5	6
D 3.	Blue laminated shale. (*Paradoxides hicksii* abundant.)	1	2
	Blue shale with red, yellow, and brown coarser partings, containing abundant *Agnosti*, etc.	0	3

Horizon.	*Lithology.*	*Thickness in feet*	*inches.*
D 2.	**Hard blue shale, with fossils near the top**	2	3
	Soft, blue, laminated shale with large chocolate-brown calcareous nodules, up to 18 inches in length	0	6
D 1.	**Hard bluish-grey shale and soft, blue, laminated shale, containing black inclusions with hæmatite prisms**	6	8
C 3.	**Hard, well-jointed, brown and blue shale with brown inclusions, and a band of tough calcareous shale. (Fossils.)**	0	5
	Soft, blue, laminated shales	1	0
	Hard blue shales with micaceous laminæ. (Fossils.)	1	0
C 2.	Soft blue shales	0	10
	Grey shale, with brown coarser layers containing glauconite. (Fossils abundant.)	0	1
C 1.	Blue-grey shale with bright slickensided surfaces	0	1
	Soft blue shale, with brown bands near the top, and fossils near the base	1	0
B 3.	Hard, bluish-grey, unlaminated shale	2	0
	Brown calcareous shale, well jointed. (Fossils.)	3	0
B 2.	Soft blue shale, with black inclusions containing hæmatite, and a few calcareous bands near the top	3	3
	Brittle bluish-grey and green shales, weathered yellow and green	1	6
	Hard blue shale with brown band	0	2
	Brittle shales as above	0	7
	Hard blue shale with brown partings, fossiliferous	0	3
B 1.	Brittle blue and green shales	4	6
	Compact, blue, laminated shales	2	8
A 4.	Blue shale with brown inclusions; abundant brachiopods and trilobite fragments	0	2
	Tough, laminated, blue shales, with a few green bands	5	0
A 3.	Hard, bluish-grey, well-jointed, siliceous shales	0	9
	Black, porous, weathered limestone	0	2
	Well-jointed, grey, siliceous shale, with a few brachiopods.	1	0
	Soft blue shale	0	3
	Hard, grey, well-jointed, siliceous shale, with brick-red laminæ and inclusions	2	4
	Grey limestone weathered chocolate-brown and black	0	1
	Micaceous brown shale, with glauconite and abundant fragments of brachiopods, etc.	0	3
A 2.	Hard bluish-grey shale with brick-red inclusions near the summit; lower down red laminæ appear, and alternate with the grey. The red layers become finer, and resemble the Purley Shales below. Base not exposed	6	0
	Total	90	0

Purley-Lane Cutting.

In the following section of the Lower Abbey Shales, in Purley Lane, the lettering of the horizons corresponds approximately with that applied to the preceding section. It will be noticed that the aggregate thicknesses of the corresponding beds are almost equal in both localities:—

Horizon.	Lithology.	Thickness in feet	Thickness inches.
C 3.	Well-jointed grey shale with brown inclusions	0	2
	Blue laminated shale	1	10
C 2.	Greenish-brown calcareous band	0	1
	Soft blue and grey shales, badly exposed	9	0
C 1–B 2.	Brown calcareous shale	0	1
	Soft blue shale	5	0
	Sandstone, with abundant fragments of trilobites and brachiopods; contains glauconite	0	2
B 1.	Green and grey shales, weathered yellow	4	0
A 4.	Soft blue and pale-green shales, with abundant fossils near the top	5	0
A 3.	Bluish-grey, well-jointed, siliceous shale	1	0
	Chocolate-brown to black weathered limestone, of variable thickness	0	2
	(Probable eroded surface.)		
	Grey, well-jointed, siliceous shale. The thickness differs on each side of the cutting, being 6 feet 9 inches and 3 feet 6 inches	3	6
	Black, weathered, porous limestone. The thickness differs on each side of the cutting, being 1 inch and 5 inches.	0	5
	Brown shale, with fragments of brachiopods, etc.	0	3
A 2.	Compact, well-jointed, siliceous shale. Greenish grey near the top, with pink coloration along the joints. Lower down, the latter colour spreads to form pink laminæ, and coarser brick-red layers and inclusions appear. Manganese occurs, especially near the middle.	9	0
A 1.	Pale-greenish shale, with yellow patches and manganese films. The shales contain large patches up to 2 feet 6 inches long, having the usual red colour of the Purley Shales. These beds pass down into the latter.	7	0
	Total	46	8

IV. General Description of the Sediments.

The bulk of the beds which form the Abbey Shales consist of soft but tough shales, laminated in light- and dark-blue colours, and breaking with a rough conchoidal fracture. In the fine material which forms the shale, minute bright specks of mica are often abundantly distributed.

Variations in Hardness and Colour.

Sometimes the blue shale is replaced by a grey variety showing a greenish tinge. This change in colour is generally accompanied by an increase in hardness, while the lamination disappears and the shale breaks more irregularly. In other cases the shale becomes extremely brittle, and splits along numerous bedding-planes which are often covered with a hard, brown, shining film of iron-oxide. This brittle shale weathers to brown, green, and yellow tints; inclusions are not common, but a few radiating bunches of gypsum-crystals occur. It is interesting to notice the great similarity between these brittle shales and hand-specimens of the homotaxial Lower Alum Shales of Sweden.

At some horizons the colour of the shale darkens to a deep blue or almost black. This change is accompanied by the disappearance of lamination—the beds being extremely tough, and the conchoidal fracture well marked.

A further modification is an unlaminated, hard, siliceous shale, which might almost be termed a 'fine flagstone.' This is characterized by well-developed jointing, the rock breaking up into regular rhombs and prisms. The colour is generally either blue or grey, and in the former variety bright-red hemispherical or irregularly-shaped inclusions are sometimes abundant.

Intercalated among the softer blue shales are thin yellow or bright-red laminæ; while micaceous layers occur more rarely, and are generally associated with a coarsening of the material. The harder shales often contain laminæ identical in colour with the Purley Shales below.

Inclusions.

The inclusions, which occur abundantly at certain levels, are of two main types: namely, a pyritous type weathering to iron-oxide, and a calcareous type containing phosphates. In the case of the former, the pyrite generally occurs as bunches of cuboidal crystals filling up irregularly-shaped hollows in the shale. In similar cavities is found a dark-brown or black material containing flat prisms of hæmatite in place of pyrite from which probably the iron-oxide has been derived. In the hard siliceous shales of Horizon G 3 some of the upper layers are crowded with bright-red pisolitic vesicles of limonite, which are sometimes completely filled with a core of the same material.

The calcareous inclusions vary in size and shape, from chocolate-brown or black nodules about the size of a small marble to masses $1\frac{1}{2}$ feet long, 6 inches thick, and at least 8 inches broad. These inclusions generally consist of a dark-brown or black porous substance with rectangular jointing. The porous nature of the material is probably due to the leaching-out of the calcium carbonate during weathering; for, at Horizon A, many of the brown nodules obtained in the base of the trench were found to have a core of pink calcite passing gradually outwards to the weathered residue. The proportion of phosphates, estimated as the pentoxide, is about 1 per cent., this substance being formed from the tests of trilobites; and in a few cases these have been found embedded in the matrix. Iron also is an important constituent of the nodules, and manganese is present in appreciable quantities.

Sandstones.

At frequent intervals in the succession—notably in C 2, E 1, G 2—thin beds of fine sandy material occur; and sometimes, as in E 1, the sand-grains exceed 0·5 mm. in diameter, and are accompanied by flakes of mica. At other horizons the beds

are less coarse, slightly calcareous, and coloured brown; while a third type is a brownish-green or black phosphatic rock containing glauconite with fragments of trilobites and brachiopods. Glauconite and phosphatic material are generally found together, though this rule is subject to one important exception in the case of phosphatic nodules. One of the most important characteristics of these sandstones is their rapid variation when followed in the direction of the strike. Thus at Horizon B 2 in the main trench, among the brittle shales, two bands of coarse brown calcareous shale occur. In a trial-hole on the same horizon only 5 feet away, these coarse shale-bands are replaced by two glauconitic sandstones with fragmentary fossils. In the trench on the other side of the stream these sandstones have disappeared; while at the same horizon in Purley Lane there is found an exactly similar sandstone 3 inches thick, with the same fossils.

This lateral variation of the coarser beds has been proved again and again when the fossiliferous horizons have been followed up. The blue shale contains brown and brownish-green coarse layers, which, when followed laterally, are found to split up into thinner bands, and disappear, or (on the other hand) to unite into thicker beds.

Conglomerate.

The upper limit of the Abbey Shales is marked by a coarse calcareous conglomerate, varying in thickness from 1 to 3 inches. It rests upon an eroded surface of the underlying blue shales, though the extent of the erosion cannot well be judged, owing to the proximity of the two trenches. In a single trench the bed is found to migrate over horizons varying in vertical position by 2 inches, while between two trenches about 70 feet apart the migration is at least 6 inches. The conglomerate contains large flat and rounded pebbles of the underlying shales, abundant irregular quartz-grains showing strain-shadows, a few felspars, large zircons, and numerous pebbles of fine-grained igneous material which appears to be a partly-devitrified pitchstone. Glauconite and calcite are both abundant, and many of the pebbles and crystals have an iron-stained border.

There is no known horizon, either in the underlying Abbey Shales or in the Purley Shales, from which this igneous material could have been derived, and the facts seem to require the postulation of extensive erosion in the neighbourhood, with perhaps the exposure to denudation of the pre-Cambrian igneous suite. The large pebbles in the bed, the rapid variation in thickness, and the abundant glauconite and quartz-grains all point to the conclusion that it was deposited under shallow-water conditions. Further, this conglomerate is followed by a type of lithology quite different from that of the beds below, consisting of a greenish-grey micaceous shale which, at a higher horizon, alternates with abundant beds of flagstone.

Eroded Surfaces.

In addition to the surface of erosion which has just been discussed, a further example occurs near the base of the series at Horizon A 3 in Purley-Park Lane, although in this case no conglomerate appears. Two calcareous bands are found in the shaly series. The upper one is chocolate-brown to black, with yellow discoloration at the base and red at the top. Its thickness varies, and (where well exposed) the lower surface is obviously irregular. The lower calcareous bed occurs on both sides of the lane, in each case overlying a peculiar brown shale full of fossil fragments. Between the two calcareous beds are fine siliceous shales; but, whereas on one side of the cutting the thickness of these shales is only 3 feet, on the other side and within a distance of 5 yards the shales have thickened to 6 feet. This cannot be due to variation in the thickness of the individual beds of shale, for the latter are constant wherever exposed. When viewed in conjunction with the irregular base of the overlying calcareous bed, it appears that this is another case of discontinuity of sedimentation. This probably is merely an instance of contemporaneous erosion of slight extent, due to shallowing of the water; for, in Hartshill Hayes, the two calcareous beds occur with the same intermediate grey shales, attaining here a thickness of 3 feet.

Calcareous Beds.

In addition to the calcareous conglomerate which has already been noted, some of the beds of shales contain carbonates, and become extremely tough. In Horizons A and G chocolate-brown and black porous beds occur, similar lithologically to the calcareous phosphatic nodules, but forming continuous strata which vary in thickness along the strike. The phosphatic material was probably obtained from the tests of trilobites; fossils are, however, conspicuous for their rarity in these beds.

Slickensided Surfaces.

These occur in some of the hard grey shales. In every case the slickensided surfaces are confined to thin bands of shales seldom more than 2 inches thick; and it is noteworthy that in every instance the bands are accompanied by rich fossiliferous horizons, which occur in most cases immediately above. The striæ of the shining slickensided surfaces run more or less in the direction of the dip, and the surfaces are not flat, but form a network of curved planes which break up the hard shale into phacoids.

V. Occurrence and Distribution of the Fauna.

Probably the most interesting feature of the Abbey Shales is the richness of the trilobite fauna, which distinguishes them so sharply from the relatively-unfossiliferous beds both above and below. The suite of types rivals in abundance the rich homotaxial

faunas of Scandinavia; while the mode of their preservation in the uncleaved shales leaves little to be desired. The number of distinct forms of trilobites exceeds fifty, and with these is associated a rich fauna of brachiopods, Hyolithidæ, etc.

The fossils generally occur as casts and moulds in the shale, but in some cases the test is preserved. In the case of the fossil-bands which occur in the tough coarse shales, it is often found that even the richest horizons are quite unfossiliferous in some portions of their outcrop.

Among the genera of trilobites which constitute the fauna, the Agnostidæ are by far the most abundant. Over thirty different types of this family have been found, and the fact that in many cases these have been preserved whole has materially aided the work of identification of the fossils. In addition to the Agnostidæ, *Paradoxides* is represented by five species, while other genera represented include *Centropleura*, *Holocephalina*, *Conocoryphe*, *Erinnys*, *Solenopleura*, *Liostracus*, *Agraulos*, *Corynexochus*, *Microdiscus*, and *Hartshillia*.

Another important feature is the abundance of young forms at certain horizons; and it has been found possible to construct ontogenetic series of such forms as *Paradoxides hicksii*, *Liostracus elegans*, *Hartshillia inflata*, and several of the Agnostidæ.

At first sight, it would appear remarkable that this abundant fauna had hitherto completely escaped detection. But, when it is considered that the fossil-bands are extremely thin, are separated by thick series of barren blue shales, and last, but by no means least, that the exposures of the beds are extremely poor, this is by no means surprising.

The following is an account of each of the fossiliferous horizons, in ascending order:—

Horizons A 1, A 2, A 3. In these lower beds fossils are confined mainly to brachiopods and sponge-spicules; a few fragments of trilobites occur, but are insufficient for identification.

Horizon A 4. The fauna includes the following forms:—

Paradoxides hicksii (rare).
Paradoxides aurora.
Paradoxides sp. nov.
Agnostus granulatus.
Agnostus exaratus, var. *tenuis*.
Agnostus barrandei?
Agnostus rex.
Agnostus cf. *intermedius*.
Agnostus sulcatus?
Agnostus lobatus.
Conocoryphe bufo.

Horizon B 1. These beds contain the following forms:—

Paradoxides hicksii.
Hartshillia inflata.
Agnostus rex.
Agnostus lobatus.
Agnostus exaratus, var. *tenuis*.
Agnostus cf. *intermedius*.
Liostracus elegans.

Horizon B 2. The fauna of this horizon is as follows:—

Agnostus fissus.
Agnostus exaratus, var. *tenuis*.
Liostracus elegans.
Hartshillia inflata (rare).

Horizon B 3. Here the forms are somewhat more abundant, and include

Paradoxides hicksii (rare).
Microdiscus punctatus, var. *scanicus*.
Corynexochus pusillus.
Agnostus exaratus, var. *tenuis*.
Agnostus lobatus.
Agnostus rex.
Agnostus fissus.
Agnostus corrugatus.
Agnostus barrandei?
Liostracus elegans.
Hartshillia inflata (rare).

The specimens found in these beds contain abundant young forms, from the protaspid stage upwards; indeed, almost all the specimens are youthful, mature specimens being extremely rare.

Horizon C 1. This horizon contains the following:—

Conocoryphe sp.
Microdiscus punctatus, var. *scanicus*.
Hartshillia inflata (rare).
Agnostus barlowi, var. *spinatus*.
Agnostus cf. *intermedius*.
Agnostus sulcatus.
Agnostus exaratus, var. *tenuis*.
Liostracus elegans.

The most interesting feature of this fauna is the predominance of *Agnostus* cf. *intermedius* and the disappearance of *A. rex*. The latter form occurs in the calcareous beds both above and below, where *A.* cf. *intermedius* is extremely rare; however, in the blue shales of Horizon D 2 the last-named form again becomes common. It appears probable that the cause of this alternation of species is a question of habitat—*A. rex* occurring in the coarser brown beds, while *A.* cf. *intermedius* seems to have preferred slightly-deeper water, where the blue shale was deposited.

Horizon C 2. This is one of the most prolific horizons in the whole sequence, and the following forms have been noted:—

Paradoxides hicksii.
Holocephalina incerta.
Hartshillia inflata (rare).
Agnostus barlowi, var. *spinatus*.
Agnostus nudus.
Agnostus sulcatus.
Agnostus regius, var. *globosus*.
Agnostus rex.
Agnostus cf. *intermedius* (only one specimen).
Agnostus fissus.
Agnostus granulatus.
Agnostus integer.
Agnostus lobatus.
Liostracus elegans.
Microdiscus punctatus, var. *scanicus*.

This fauna is characterized by the abundance of *Agnostus rex*, specimens of which make up more than half the forms found. *Liostracus elegans* is also common, and here reaches its maximum development.

Horizon C 3. These beds have yielded the following types:—

Liostracus elegans.
Agnostus fissus.
Agnostus parvifrons.
Agnostus exaratus.
Holocephalina incerta.

The occurrence of *Agnostus parvifrons* is the main feature of interest, this horizon being the lowest in which that form has been noted.

Horizon D 1. Specimens are scarce in these beds, but the following have been found:—

Paradoxides hicksii.
Agnostus fissus.
Agnostus exaratus, var. *tenuis*.
Agnostus rex.
Holocephalina incerta.
Liostracus elegans.

Horizon D 2. This contains the following:—

Paradoxides hicksii.
Agnostus cf. *intermedius.*
Agnostus parvifrons.
Agnostus fallax.
Agnostus gracilis.
Agnostus rex (rare).
Agnostus fissus.
Agnostus granulatus.
Agnostus exaratus, var. *tenuis.*
Solenopleura applanata.

In this horizon it is noticeable that both *Agnostus rex* and *A.* cf. *intermedius* occur. The beds consist of blue shale with thin bands of coarser brown material, and it is in the latter only that *A. rex* has been noted while every specimen of *A.* cf. *intermedius* comes from the blue shale.

Horizon D 3. This is one of the principal horizons in the succession, the forms occurring in two well-marked beds.

The upper bed contains numerous specimens of *Paradoxides hicksii*, while other types are relatively scarce. The lower portion is extremely rich in *Agnosti.*

Paradoxides hicksii.
Solenopleura applanata.
Microdiscus punctatus, var. *scanicus.*
Agnostus fissus.
Agnostus sulcatus.
Agnostus gracilis.
Agnostus fallax.
Agnostus barrandei.
Agnostus rex (rare).
Agnostus corrugatus.
Agnostus tuberculatus.
Agnostus cf. *intermedius.*
Agnostus exaratus, var. *tenuis.*
Agnostus integer.
Agnostus parvifrons.
Agnostus triangulatus.
Hartshillia inflata.
Centropleura pugnax.

Among the Agnostidæ *A. fissus* predominates, forming half the number of specimens. Other common forms are *A. gracilis*, *A. corrugatus*, and to a less extent *A. exaratus*, var. *tenuis*, *A. tuberculatus*, and *A. barrandei.*

Horizon E 1. The fauna of this horizon is somewhat similar to the preceding, but relatively poorer, including

Hartshillia inflata.
Holocephalina incerta.
Paradoxides sp. indet.
Agnostus tuberculatus.
Agnostus barrandei.
Agnostus sulcatus.
Agnostus integer.
Centropleura pugnax.
Microdiscus punctatus, var. *scanicus* (rare).

All the Agnostidæ are confined to the lower part of this horizon; at the very summit occurs a band extremely rich in *Holocephalina incerta* and *Hartshillia inflata*, but not a single specimen of *Agnostus* has been noted.

Horizon E 2. This fauna agrees with that of the immediately-underlying beds in the extreme paucity of Agnostidæ; and, although fossils are abundant, they are almost wholly confined to the single type, *Hartshillia inflata.*

Hartshillia inflata.
Microdiscus punctatus, var. *scanicus.*
Holocephalina incerta.
Agnostus barrandei.

Horizon E 3. The following species have been noted:—

Paradoxides rugulosus.
Microdiscus punctatus.
Microdiscus punctatus, var. *scanicus.*
Agnostus exaratus, var. *tenuis.*
Agnostus gracilis?
Agnostus lens (rare).
Hartshillia inflata.
Holocephalina incerta (rare).

Although this horizon contains a number of types, the sole really common form is *Hartshillia inflata*. *Microdiscus punctatus*, var. *scanicus* occurs to a less extent, while all the other forms are rare. It is interesting at this point to notice the change in the fauna between Horizons D 3 and F 1. In the lower part of E 1 occur the remnants of the underlying fauna; these disappear, and for some distance Agnostidæ do not occur. When in Horizon E 3 they reappear, the old species have been replaced by forms characteristic of the overlying beds.

Horizon F 1. This band has yielded abundant specimens, although the preservation is often spoilt by overcrowding. The following forms have been identified:—

Paradoxides rugulosus.
Hartshillia inflata (rare).
Agnostus punctuosus.
Agnostus parvifrons.
Agnostus fallax.
Agnostus pulchellus.
Agnostus lens.
Agnostus granulatus.
Agnostus exaratus.
Agnostus exaratus, var. *tenuis?*
Agnostus bibullatus.
Solenopleura cf. *applanata.*

Agnostus punctuosus and *A. lens* form quite 90 per cent. of the entire fauna, while of the remaining forms *A. granulatus* is the commonest. Heads of *Paradoxides* are by no means rare, though these are nearly always in a youthful stage of development.

Horizon F 2. This fauna is very similar to that of the underlying beds, and includes the following:—

Paradoxides rugulosus.
Microdiscus punctatus.
Agraulos sp.
Agnostus punctuosus.
Agnostus lens.
Agnostus bibullatus.
Agnostus granulatus.
Agnostus altus.
Agnostus fallax.
Agnostus exaratus, var. *tenuis.*
Agnostus tuberculatus (rare).
Agnostus cf. *incertus.*
Agnostus barrandei.
Erinnys venulosa.
Hartshillia spinata.

Of these, the commonest forms are *Agnostus punctuosus*, *A. lens*, and *A. granulatus*.

Horizon F 3. These beds have yielded the following forms:—

Microdiscus punctatus.
Agnostus exaratus?
Agnostus exaratus, var. *tenuis* (rare).
Agnostus fissus, var. *perrugatus.*
Agnostus nudus, var. *ovalis.*
Agnostus altus.
Agnostus granulatus.
Agnostus fallax.
Agnostus punctuosus.
Solenopleura variolaris?

Microdiscus punctatus, with its long nuchal spines, is one of the most abundant forms present. *Agnostus granulatus* appears here for the last time, and is replaced in the overlying beds by the closely-allied form *A. bifurcatus*.

Horizon G 1. This fauna is relatively poor, and includes the following:—

Microdiscus punctatus.
Agnostus punctuosus.
Agnostus altus.
Agnostus fallax?

Horizon G 2. In these beds the fauna is somewhat different:—

Microdiscus punctatus.
Agnostus altus.
Agnostus kjerulfi.
Agnostus punctuosus.
Agnostus bifurcatus.
Paradoxides davidis (rare).

Agnostus punctuosus is perhaps the most abundant form, but the most interesting species are *Paradoxides davidis*, *Agnostus kjerulfi*, and *A. bifurcatus*, which appear here as comparatively rare forms.

Horizon G 3. The following fossils have been identified :—

Paradoxides davidis.
Paradoxides rugulosus (rare).
Centropleura henrici.
Agnostus punctuosus.
Agnostus rotundus.
Agnostus bifurcatus.
Agnostus nathorsti.
Agnostus exaratus.
Agnostus exaratus, var. *tenuis* (rare).
Agnostus altus.
Agnostus glandiformis.
Holocephalina primordialis.

Fragments of *Paradoxides* and *Centropleura* are common; while among the Agnostidæ, *Agnostus punctuosus* and *A. bifurcatus* are the most abundant.

If we review the fauna from a more general standpoint, the most important feature appears to be the division into a main upper fauna (Horizons F 1 to G 3) and a lower fauna (Horizons A 1 to D 3), each of which contains an abundant and characteristic suite of species of *Agnostus*. Between these two faunas—that is, in Horizons E 1 (top) to E 3—the form *Hartshillia inflata* occurs in great abundance, while *Agnosti* are almost non-existent. The upper fauna may be conveniently divided into two portions, the lower of which contains *Paradoxides rugulosus* with *Agnostus punctuosus*, *A. lens*, and *A. granulatus* (Horizons F 1 to F 3). In the upper subdivision *Paradoxides davidis* is abundant, and is accompanied by such forms as *Agnostus punctuosus*, *A. rotundus*, *A. bifurcatus*, *A. nathorsti*, and *A. kjerulfi*. The lower fauna may be divided into three subdivisions :—

(*a*) Horizons D 1–D 3. *Paradoxides hicksii* abundant, with *Agnostus fissus* (common), *A. tuberculatus*.

(*b*) Horizons B 1–C 3. *Paradoxides* (rare), *Agnostus rex* (common), *A. granulatus*.

(*c*) Horizons A 1–A 4. *Paradoxides aurora*, *Conocoryphe bufo*; while *P. hicksii* occurs rarely in the upper beds.

The danger of introducing as zones, faunal changes which have their origin in local variations of the physical conditions of sedimentation, must be carefully avoided. That these are by no means a negligible factor in faunal distribution, may be easily indicated by the following example :—

At Horizon C 1 a fauna occurs in the blue shale, characterized by the predominance of *Agnostus* cf. *intermedius*. Only 1 foot above, in the coarse glauconitic band of Horizon C 2, *A.* cf. *intermedius* occurs but rarely, while *A. rex* constitutes more than half the rich fauna. This would appear, at first sight, to be a good example of two definite time-zones; but in the brown coarser beds below C 1 *A. rex* again predominates, while in the blue shale of Horizon D 2 *A.* cf. *intermedius* is quite a common form. Thus we note the following alternations :—

Horizons.		
B 3	Brown coarse beds.	*Agnostus rex* predominates.
C 1	Blue shale.	*Agnostus* cf. *intermedius*.
C 2	Glauconitic bed.	*Agnostus rex* predominates.
D 2	Blue shale.	*Agnostus* cf. *intermedius*.
	Brown coarser beds.	*Agnostus rex*.

TABLE I.—LIST OF FOSSILS FOUND AT HARTSHILL HAYES, INDICATING THEIR VERTICAL DISTRIBUTION.

[a = abundant; r = rare; and p = predominant.] Name.	*P. aurora* Zone.	*Paradoxides-hicksii* Zone.									*Hartshillia* Zone.			*Paradoxides-davidis* Zone.						Also found in	
		Lower.						Upper.						Lower.			Upper.				
	A 4.	B 1.	B 2.	B 3.	C 1.	C 2.	C 3.	D 1.	D 2.	D 3.	E 1.	E 2.	E 3.	F 1.	F 2.	F 3.	G 1.	G 2.	G 3.	South Wales.	Scandinavia.
Agnostus rex Barrande	*r	*r	?	*	...	*p	...	*	*	*r	...	...	...	...	...	...	...	...	...	...	*
A. exaratus Grönwall	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	?	...	...	*	*	*
A. exaratus, var. *tenuis* nov.	*	*	?	*	*	...	*	*	*	*a	*	...	*r	?	*	*r	...	...	*r	*	
A. granulatus Barrande	*r	...	...	...	...	*	...	..	*	...	...	...	...	*a	*	*					
A. lobatus, sp. nov.	*r	*r	...	*	...	*															
A. cf. *intermedius* Tullberg	*r	*r	...	...	*	*r	...	...	*	*r	...	...	...	...	...	...	...	...	...	...	*
A. fallax Linnarsson	...	...	...	...	...	...	...	...	*	*	...	...	..	*	*	*	?	...	...	*	*
A. fissus Linnarsson	...	...	*	*	...	*	*	*	*	*p	...	...	...	...	...	...	...	...	...	*	*
A. fissus, var. *perrugatus* Grönwall	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	*
A. barrandei Salter	?	...	...	?	...	...	...	...	...	*	*r	*r	...	...	*r	...	...	...	...	*	
A. corrugatus, sp. nov.	...	...	...	*	...	...	...	...	...	*a											
A. sulcatus, sp. nov.	*	...	...	...	*	*	...	...	...	*	*r										
A. barlowi Belt, var. *spinatus* nov.	...	...	...	...	*	*															
A. integer Beyrich	...	...	...	...	...	*	...	...	...	*	*r	...	...	...	...	...	...	...	...	*	
A. regius Sjögren, var. *globosus* nov.	...	...	...	...	...	*															
A. nudus Beyrich	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*
A. parvifrons Linnarsson	...	...	...	...	...	...	*	...	*	*	...	...	...	*	...	...	...	...	...	...	*
A. gracilis, sp. nov.	...	...	...	...	...	...	...	...	*	*a											
A. triangulatus, sp. nov.	...	...	...	...	...	...	...	...	...	*											
A. tuberculatus, sp. nov.	...	...	...	...	...	...	...	...	...	*	*r	...	...	...	*r						
A. lens Grönwall	...	...	...	...	...	...	...	...	...	...	...	...	*r	*a	*	...	...	...	...	...	*
A. punctuosus Angelin	...	...	...	...	...	...	...	..	...	...	...	...	...	*a	*	*	*	*	*	*	*
A. bibullatus Barrande	...	...	...	...	...	...	...	..	...	...	...	...	...	*	*						
A. pulchellus, sp. nov.	...	...	...	...	...	...	...	...	..	...	...	...	...	*							

A. altus Grönwall	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*	*	*	*	*	*
A. nudus, var. *ovalis* nov.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
A. cf. *incertus* Brögger	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	*
A. kjerulfi Brögger	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	*	*
A. bifurcatus, sp. nov.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*		
A. rotundus Grönwall	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*	*
A. glandiformis Angelin	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	*
A. cf. *nathorsti* Brögger	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	*
Microdiscus punctatus Salter	...	...	...	...	...	...	...	...	...	...	*r	...	*	?	*	*	*	*	...	*	*
M. punctatus, var. *scanicus* Lnnrs.	...	...	...	*	*	*	...	...	...	*a	*	*	*	...	...	...	...	...	...	*	*
Hartshillia inflata, gen. nov.; sp. Hicks	...	*r	*r	*r	*r	*r	...	...	...	*r	*a	*p	*p	*r	...	...	...	...	...	*	
H. spinata, sp. nov.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*						
Conocoryphe bufo Hicks	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	
Erinnys venulosa Salter	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	*	*
Holocephalina primordialis Salter	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*	*
H. incerta, sp. nov.	...	...	...	...	...	*	*	*	...	...	*a	*	*r								
Paradoxides aurora Salter	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	
P. sp. nov.	*																				
P. hicksii Salter	*r	*r	...	*r	*r	*r	...	*	*	*p	...	...	...	...	...	...	...	...	...	*	*
P. rugulosus Corda	...	...	...	...	...	...	...	...	...	...	...	...	*r	*	*r	...	...	...	*r	...	*
P. davidis Salter	...	...	...	...	...	...	...	...		...	...	...	...	...	...	...	...	*r	*	*	*
Centropleura pugnax, sp. nov.	...	...	...	...	...	...	...	...	...	*	*										
C. henrici Salter	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	*	
Corynexochus pusillus, sp. nov.	...	...	...	*																	
Liostracus elegans, sp. nov.	...	*	*	*	*	*a	*	*													
Solenopleura applanata Salter	...	...	...	...	...	...	...	...	*	*	...	...	...	...	...	...	...	...	...	*	
S. cf. *applanata* Salter	...	...	...	...	...	...	...	...	...	.	...	...	...	*							
S. variolaris (?) Salter	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*	
Agraulos sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*						

Another interesting case, which may be due to the same cause, is the recurrence of *Agnostus granulatus*. It is found mainly at Horizons C 2 and F 1–F 2, but in the intermediate beds of Horizon D 3 is replaced by the allied form *A. tuberculatus*. In this case, however, the sediments do not show any well-marked variation which would account for this anomaly, as in the previous example. Another possible explanation is that the upper forms of *A. granulatus* are homœomorphs of the lower; and, indeed, there are certain minor characters in which they appear to differ from the corresponding forms below. Further evidence is needed on this point, although it is hoped that ontogenetic considerations may throw some light on the question.

If the whole fauna be taken into consideration, rather than certain isolated species, changes due to varying physical conditions of deposition are minimized. The following classification into six subdivisions appears to accord well with the evidence. In the case of each division attention is drawn to three or more of the most important types, which may be considered as nuclei for the associated species.

Horizon.	Zone.	Characteristic Forms.
G 1–G 3	Upper *Paradoxides davidis.*	*Paradoxides davidis*, *Agnostus punctuosus*, *A. kjerulfi*, *A. bifurcatus*, *A. rotundus.*
F 1–F 3	Lower *Paradoxides davidis.*	*Paradoxides rugulosus*, *Agnostus punctuosus*, *A. lens*, *A. granulatus.*
E 1 (pars)–E 3.	*Hartshillia inflata.*	*Hartshillia inflata* (abundant), *Agnosti* (rare).
E 1 (pars)–D 3.	Upper *Paradoxides hicksii.*	*P. hicksii* (abundant), *Agnostus fissus* (common), *A. tuberculatus*, *A. gracilis.*
B 2–D 3	Lower *Paradoxides hicksii.*	*P. hicksii* (rare), *Agnostus rex* (abundant), *A.* aff. *intermedius.*
A 1–B 1	*Paradoxides aurora.*	*P. aurora*, *P. hicksii* (rare), *Conocoryphe bufo.*

VI. Detailed description of the Fauna.[1]

Agnostus Brongniart.

The extremely-divergent forms which have been grouped together under the genus *Agnostus*, have been subdivided by Tullberg into the following groups:—

(1) Longifrontes.
(2) Lævigati.
(3) Limbati.
  (*a*) Fallaces.
  (*b*) Regii.
(4) Parvifrontes.

More recently O. Jækel[2] and P. E. Raymond[3] have introduced

[1] In the detailed description of the fossils I have omitted comparison with American types.

[2] 'Ueber die Agnostiden' Zeitschr. Deutsch. Geol. Gesellsch. vol. lxi (1909) p. 380.

[3] Zittel's 'Text-book of Palæontology' (Eastman's Transl.) 2nd ed. vol. i, p. 710.

independently more detailed subdivisions. None of these classifications appear wholly satisfactory, when viewed in the light of the development of certain forms of the genus. For the present, I have adopted the older classification into sub-groups, pending the results of further research.

(1) Longifrontes.

Agnostus exaratus Grönwall. (Pl. XXVIII, fig. 1.)

1866. *Agnostus scutalis* Salter (pars), Rep. Brit. Assoc. for 1865, p. 285.
1872. *Agnostus scutalis* Hicks, Q. J. G. S. vol. xxviii, p. 175 & pl. v, figs. 12–13.
1902. *Agnostus exaratus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 77 & pl. i, fig. 17.
1906. *Agnostus exaratus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 6 & pl. i, figs. 8–10.

In the original description of this species by Grönwall, only the tail was described. The type is characterized by its rather small size and wide axis, the latter being broad, unsegmented, and tapering rapidly behind. The lateral lobes are considerably narrower than the axis, and slightly expand posteriorly, where they are separated by a deep furrow.

The specimens referred by Mr. Lake to this species are much larger than Grönwall's type, while the axis is more slender and tapering. They agree more closely with the variety of this form, *tenuis*, to be described below.

Among the *Agnosti* found at Horizon G 3, occurs one whole form, together with several isolated heads and tails, referable to this species. Among a large series of specimens collected by Mr. J. Pringle from the *Paradoxides-davidis* horizon at Porth-y-Rhaw, St. David's, and kindly lent to me for examination by H.M. Geological Survey, a large number of small tails occur agreeing with Grönwall's figure and description. With these are associated numerous heads, which are similar to those found at Horizon G 3, and show that they differ in certain respects from the heads of the forms referred by Mr. Lake to *Agnostus exaratus*.

Head.—Small, rounded, moderately convex. Glabella short, less than two-thirds of the length of the head, broad, convex. Anterior lobe almost semicircular, length generally about two-thirds of the breadth. Posterior lobe of equal width to anterior lobe, short, almost parallel-sided, rounded posteriorly, with small sub-triangular basal lobes. Cheeks moderately convex, equal in width to the glabella, of approximately equal width throughout, confluent in front of the glabella, from which they are separated by deep dorsal furrows. Margin moderate.

Thorax.—Axis has two lateral bosses and a wide central raised portion.

Tail.—Tail rounded, moderately convex, widest posteriorly with deep axial furrows. Axis broad, convex, unsegmented; tapering rather rapidly behind, with a well-marked medial tubercle at the anterior third. Lateral lobes narrower than the axis, widening posteriorly, and separated by a deep furrow. Margin narrow anteriorly, widening behind.

Size.—Length of the head- and tail-shields = 1·9 mm.; breadth of the same = 2 mm.

Horizons.—G 3 and F 1.

AGNOSTUS EXARATUS Grönwall, var. TENUIS nov. (Pl. XXVIII, figs. 2–4.)

1906. *Agnostus exaratus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 6 & pl. i, figs. 8–10.

Head.—Rounded, with deep axial and marginal furrows. Glabella very convex: moderate in size, approximately equal in width throughout; anterior lobe subquadrate. Posterior lobe equal in width to anterior, almost parallel-sided, but sometimes slightly wider posteriorly where it is bluntly rounded. The small medial tubercle which occurs on the posterior lobe is sometimes obliterated. Basal lobes small. Cheeks convex, width approximately equal to the glabella and uniform throughout, confluent in front of the glabella (Mr. Lake notes a deep furrow in front of the latter: none of the Hartshill specimens show this groove, nor does it appear on the Welsh specimens examined by me). Margin well defined. Surface smooth.

Thorax.—Axis has small but prominent lateral bosses, and a wide medial subtriangular raised portion.

Tail.—Slightly elongate, rounded, with deep axial and marginal furrows. Axis very convex, with no segmentation, tapering to an acute point; a well-marked medial tubercle at the anterior third. Lateral lobes about equal in width to the glabella anteriorly, widening posteriorly, especially in the younger forms, and separated behind by a deep furrow. Margin slightly widened posteriorly. Surface smooth.

Size.—Head- and tail-shields = 4 to 5 mm. in length in mature specimens.

Horizons.—A 4–G 3.

The tails of this form vary, both according to their age and to their position in the sequence. In the young forms the axis is short, narrow, and more tapering, with wide lateral lobes; while in the older stages the axis becomes longer and wider, with a corresponding decrease in the width of the lateral lobes.

This form is generally much larger than *A. exaratus*, from which it differs also in the subquadrate shape of the anterior glabellar lobe, and in the narrower and more tapering tail-axis.

In the *Paradoxides-davidis* Zone the specimens of this variety differ slightly from those at a lower horizon in the shape of the tail-axis: this is slightly longer, and the posterior portion is more depressed. Its shape approximates rather to the posterior portion of the tail-axis of *A. incertus*. (See Pl. XXVIII, fig. 10, also P. Lake, *op. supra cit.* pt. i, pl. i, fig. 8.)

AGNOSTUS FISSUS Lundgren MS. (Pl. XXVIII, figs. 6–8.)

1879. *Agnostus fissus* Linnarsson, 'Om Faunan i Kalken med *Conocoryphe exsulans*' Sver. Geol. Undersökn. ser. C, no. 35, p. 23 & pl. ii, fig. 34.
1880. *Agnostus fissus* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 16 & pl. i, figs. 3 *a*–3 *d*.
1896. *Agnostus fissus* Matthew, Trans. N.Y. Acad. Sci. vol. xv, p. 230.
1906. *Agnostus fissus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 3 & pl. i, figs. 1–3.

Specimens of this form occur in great profusion, especially at Horizon D 3. These agree in general characters with the figures and descriptions, but the relative proportions of the glabellar lobes differ slightly from some of the figured specimens. When the forms found at low and high horizons are compared, there appear

to be mutational variations of the species, corresponding to different positions in the sequence. Thus, at Horizon C 2, the anterior lobe of the glabella is more elongate than in the forms contained in the higher beds of D 3. Further work on the species is necessary before a more definite statement can be made; such mutational forms may, however, be of great use in the work of correlation.

Horizons.—B 2–D 3.

AGNOSTUS FISSUS, var. PERRUGATUS Grönwall. (Pl. XXVIII, fig. 9.)

1902. *Agnostus fissus*, var. *perrugatus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 50 & pl. i, fig. 1.

A single head has been found agreeing with Grönwall's type.

Head.—Rounded, convex, with narrow margin. Glabella two-thirds of the length of the head, slightly broadening posteriorly, convex. Anterior lobe truncate, conical, broader than long, with medial fissure. Posterior lobe widened very slightly behind, constricted at the anterior third, rounded posteriorly. Cheeks nearly equal in width to the glabella, narrower in front, with a shallow groove. Surface ornamented with irregular radial furrows, especially near the margin. Two furrows occur near to, and parallel with, the sides of the anterior lobe of the glabella.

Size.—Length of head = 1·9 mm.; breadth of the same = 2 mm.

Horizon.—F 3.

This form agrees in many of its characters with *A. corrugatus*, but the latter is much larger, less convex, and the glabella more tapering; also, the anterior lobe of the glabella is longer, its fissure is deeper and occurs only in the anterior portion of the lobe, and the cheeks are wider.

A. fissus, var. *perrugatus* agrees closely with *A. fissus*, especially in the shape of the anterior lobe of the glabella; on the other hand, in some of its characters it closely resembles *A. corrugatus*. Until, however, the tails corresponding to this form are found, it is difficult to estimate the true affinities of this variety.

AGNOSTUS cf. INCERTUS Brögger. (Pl. XXVIII, fig. 10.)

1879. *Agnostus incertus* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 70 & pl. vi, figs. 4 *a*–4 *b*.

1880. *Agnostus incertus* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 19 & pl. i, figs. 6 *a*–6 *b*.

1907. *Agnostus incertus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. ii, p. 29 & pl. iii, figs. 1–3.

A single tail agrees very closely with the Scandinavian forms, the well-marked constriction at the posterior end of the axis being strongly developed. The specimen, however, does not possess the short spines characteristic of this species, although this may be due to imperfect preservation, the fossil being slightly crushed.

Size.—Length = 5·6 mm.; breadth = 5·9 mm.

Horizon.—F 2.

AGNOSTUS cf. INTERMEDIUS Tullberg. (Pl. XXVIII, figs. 11 & 12.)

1880. *Agnostus intermedius* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 17 & pl. i, fig. 4.

Head.—Semi-elliptical, slightly convex. Glabella large, three-fourths of the entire length, convex, conical. Anterior lobe sub-equilateral, with slightly-rounded sides. Posterior lobe widened backwards, constricted at the anterior third, rounded posteriorly. Basal lobes moderate in size, triangular. Cheeks slightly convex, subequal in width to the glabella posteriorly; slightly constricted in front, and separated by a shallow groove. Margin narrow. Surface smooth, or faintly furrowed.

Thorax.—Axis moderate, with large lateral bosses. Central portion in anterior segment with subtriangular boss. Posterior segment bearing an impressed medial longitudinal furrow.

Tail.—Semi-elliptical, gently convex, with large axis. The latter elongate, nearly five-sixths of the entire length of the tail, tri-segmented; slightly constricted at the anterior fourth, posterior portion gradually constricted to an acute point. Anterior segment slightly shorter medially; second segment hexagonal; posterior segment greater than half the entire length of the axis, less convex posteriorly. Lateral lobes convex, slightly narrower than the axis; confluent behind, though slightly constricted. Margin narrow. Surface smooth.

Size.—In full-grown specimens the head- and tail-shields are 5 mm. in length and breadth.

Horizons.—C 1–D 3; rare in A 4 and B 1.

This form is closely allied to Tullberg's type, but differs from the latter in the shorter basal lobes of the glabella; while the second groove on the axis is not bent back medially in Tullberg's figure.

AGNOSTUS cf. NATHORSTI Brögger. (Pl. XXIX, fig. 1.)

1879. *Agnostus nathorsti* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 68 & pl. v, fig. 1.

1880. *Agnostus nathorsti* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 21 & pl. i, fig. 9.

Only two tails referable to this species have been found.

Tail.—Rounded, convex, with a well-defined axis and a narrow margin. Axis long, constricted at the anterior third, tapering to an acute point. Two sets of faint furrows divide the axis into three segments. The first is very short, two faint grooves dividing it into two lateral lobes and a much smaller medial lobe. Second segment narrow, but longer than the first, with medial tubercle abruptly ended posteriorly. Posterior segment occupying more than half the length of the axis and sloping down rather suddenly from the second segment, so that the posterior portion is much less convex. Lateral lobes slightly convex: anteriorly they are slightly narrower than the axis, but become suddenly constricted behind, and are separated by a short shallow groove. Margin narrow, with two short spines. Surface smooth.

Size.—Length of tail = 2·9 mm.; width of tail = 2·9 mm.

Horizon.—G 3.

The tails of this form are somewhat similar to those of *A. punctuosus*, but they differ in the faintness of the axial furrows, the trilobation of the anterior axial segment, the presence of posterior lateral spines, and the smoothness of the surface.

AGNOSTUS PUNCTUOSUS Angelin. (Pl. XXIX, figs. 2 & 3.)

1852. *Agnostus punctuosus* Angelin, 'Palæontologia Scandinavica' p. 8 & pl. vi, fig. 11.
1875. *Agnostus punctuosus* Brögger, Geol. För. Stockh. Förhandl. vol. ii, p. 576 & pl. xxv, fig. 2.
1879. *Agnostus punctuosus* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 67 & pl. vi, figs. 12 *a*–12 *b*.
1879. *Agnostus punctuosus* (var. *affinis*) Brögger, *ibid.* p. 68 & pl. v, figs. 2 *a*–2 *b*.
1879. *Agnostus punctuosus* (var. *bipunctatus*) Brögger, *ibid.* p. 68 & pl. v, fig. 2 *c*.
1872. *Agnostus scutalis* Salter (pars), Hicks, Q. J. G. S. vol. xxviii, p. 175 & pl. v, fig. 9, also perhaps fig. 10.
1872. *Agnostus scarabæoides* Salter, Hicks, *ibid.* p. 175 & pl. v, fig. 8.
1880. *Agnostus punctuosus* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn, ser. C, no. 42, p. 17 & pl. i, figs. 5 *a*–5 *d*.
1896. *Agnostus punctuosus* Matthew, Trans. N.Y. Acad. Sci. vol. xv, p. 232 & pl. xvi, figs. 11 *a*–11 *b*.
1906. *Agnostus punctuosus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 4 & pl. i, figs. 4–6.

A large number of specimens belonging to this species have been found. These include many young forms, in which the tail-axis is shortened and the lateral lobes are separated posteriorly by a well-marked groove (compare the tail of *A. punctuosus*, var. *affinis* Brögger), a feature which has already been noticed and figured by Mr. Lake (*op. supra cit.* p. 5). Most of the specimens show a well-marked granulated surface on the tail, whereas the cheeks of the heads are ornamented with numerous irregular radiating grooves, while the granular markings tend to disappear.

Horizons.—F 1–G 3.

AGNOSTUS CORRUGATUS, sp. nov. (Pl. XXIX, figs. 4–9.)

Head.—Rounded, almost circular in young forms, slightly convex, with a narrow margin. Glabella generally prominent, but in the largest specimens almost obliterated, widening regularly backwards. About two-thirds of the length of head. Anterior lobe truncato-conical, length equal to, sometimes greater than, the maximum breadth; with a deep medial fissure in the anterior half, more convex posteriorly. Posterior lobe wider and more convex than the anterior, gradually broadening posteriorly; constricted laterally at the anterior third and two-thirds by deep impressions; rounded posteriorly, and ornamented with a small central tubercle. Basal lobes small, triangular; often difficult to differentiate from the posterior lobe of the glabella. Cheeks slightly narrower than the glabella behind, but widening forwards; and in front of the glabella is a wide shallow groove. Cheeks slightly convex, radially furrowed, with two lobes lapping around the anterior lobe of the glabella. Near the anterior margin the surface is depressed and finely granular. Margin narrow.

Thorax.—Axis narrow, with relatively large lateral bosses, and a smaller subtriangular, raised, central portion showing longitudinal shallow grooves.

Tail.—More quadrate than the head, moderately convex, with a narrow margin. Axis small, convex, trisegmented, deeply constricted at the anterior third; posterior portion narrowing to an acute point. Anterior segment short, with two grooves dividing off two lateral lobes and a more convex central portion. Second segment narrow, with a medial keel projecting slightly backwards over the posterior segment. The latter is long, being more than half the length of the axis, sloping down

suddenly from the second segment, so that the posterior segment is much less convex. Lateral lobes slightly convex, broader than the axis, confluent behind, except in young forms. Surface granular. Margin narrow.

Size.—Most of the head- and tail-shields are from 3 to 4·5 mm. long. Larger specimens occur, up to 6 mm. in diameter; these are always flattened, and the segmentation of the head and tail is partly obliterated.

Horizons.—B 3 and D 3.

The head of this form is somewhat similar to that of *Agnostus fissus*, var. *perrugatus* Grönwall; the features by which it is distinguished from the latter are dealt with under that heading.

AGNOSTUS GRACILIS, sp. nov. (Pl. XXIX, figs. 10–13.)

Head.—Rounded, maximum width at the anterior half, slightly convex, with a narrow margin. Glabella only slightly more convex than the cheeks; in the younger forms (heads up to 3 mm. in length) the anterior lobe is well defined, elongate, narrower forwards, and has an anterior medial fissure. This lobe, however, becomes obscure in the larger specimens, and ultimately disappears. Posterior lobe more convex, slightly widened posteriorly, where it is rounded off. Basal lobes rather large, triangular, almost confluent behind the glabella. Dorsal furrows faint, more deeply impressed behind. Cheeks equal in width to the glabella, confluent in front, ornamented with numerous radiating furrows. On some specimens two faint furrows occur near the anterior segment, forming two lobes which lap round the sides of the latter. Margin narrow.

Thorax.—Axis rather narrow, with small lateral bosses, and a central raised portion bearing impressed longitudinal grooves.

Tail.—Rounded posteriorly, maximum width at the anterior half. Axis elongate, narrow, convex; constricted at the anterior fourth, widening to the anterior three-fifths, tapering posteriorly, trisegmented by two well-defined furrows. Anterior segment short, slightly constricted medially. The second segment narrower but longer than the anterior, hexagonal. Posterior segment occupying three-fifths of the length of the axis. Lateral lobes gently convex, wider than the axis, suddenly constricted behind, especially in old forms, but confluent. Margin narrow, but well defined. Surface smooth, though in old specimens it tends to become wrinkled.

Size.—Most of the specimens of the head- and tail-shields are from 3 to 5 mm. long and broad, but specimens occur having a length of 6·5 mm.

Horizons.—D 2–D 3.

The tail of this species is somewhat similar to that of *A.* cf. *intermedius* found in the beds below, but the outline and segmentation of the axis is different, the posterior segment being relatively longer. The head of this species is easily distinguished from that of *A.* cf. *intermedius* by the fissure in the anterior segment of the glabella. In the latter feature this form resembles *A. corrugatus*, but the furrows are much less pronounced. The tails of these two species are quite unlike each other.

AGNOSTUS PULCHELLUS, sp. nov. (Pl. XXX, figs. 1 & 2.)

Head.—Semi-elliptical, slightly convex. Glabella moderate, about three-fourths of the length of the head, tapering gradually forwards, moderately convex. Anterior lobe subtriangular, but with the sides slightly

rounded. Posterior lobe widened moderately to the anterior half, obtusely rounded behind, with faint constrictions at the anterior third. Basal lobes small, triangular. Cheeks subequal in width to the glabella, separated in front by a well-marked groove. Margin narrow. Surface smooth or wrinkled.

Thorax.—Unknown.

Tail.—Semi-elliptical, slightly convex. Axis large, more than five-sixths of the length of the tail, tapering rapidly to the anterior fifth, parallel-sided or slightly expanding to the anterior half, and tapering gradually behind. Two well-marked transverse grooves: the first arched slightly forwards, and the second bent back suddenly about half-way across. First segment forming the widest portion of the axis; second segment produced medially backwards to an elongate tubercle or keel. Posterior segment occupying approximately half the length of the axis. Lateral lobes slightly narrower than the axis, constricted suddenly behind, but confluent. Margin narrow. Surface smooth or wrinkled.

Size.—Length and breadth of largest head = 2·1 mm.; length and breadth of largest tail = 2·5 mm.

Horizon.—F 1.

The specimens on which this species is based are fragmentary. These include numerous separate heads and tails; but, as a whole specimen has not been found, it is uncertain whether they belong to the same species. However, their occurrence in association makes this probable. The most important feature of the species is the long backward extension of the medial portion of the second axial segment, a character which this form has in common with *Agnostus stenorrhachis* Grönwall; but it differs from the latter in the absence of grooves on the anterior segment of the tail-axis.

AGNOSTUS SULCATUS, sp. nov. (Pl. XXX, figs. 3–6.)

Head.—Rounded, convex, with a narrow margin. Glabella prominent, very convex, three-fourths of the length of the head, narrowing very slightly in front. Anterior lobe subglobose behind, with a short anterior groove or fissure. Posterior lobe widening slightly behind, with a slight constriction at the anterior third; rounded posteriorly, moderate basal lobes often confluent behind the glabella. Cheeks equal to the glabella in width, confluent in front, surface ornamented with well-marked radial furrows, and with two auxiliary lobes lapping round the anterior portion of the glabella. Margin narrow.

Thorax.—Axis broad, with large lateral bosses; central portion slightly convex, with longitudinal furrows situated posteriorly in the anterior segment, and midway in the posterior segment.

Tail.—Subquadrate, rounded posteriorly, with a well-defined margin. Axis large, constricted at the anterior third, trisegmented. Anterior segment extremely short medially, with two shallow grooves dividing off two lateral convex lobes and a smaller medial portion. Second segment narrower, but longer, with a medial tubercle behind. Posterior segment large, less convex behind. Lateral lobes of width subequal to the axis, but narrower in the larger specimens, constricted but confluent posteriorly. Surface granular. Margin slightly wider than that of the head, with two short spines.

Size.—Most of the head- and tail-shields are from 3 to 5 mm. in length and breadth.

Horizons.—A 4–E 1.

This form is in general appearance similar to *A. corrugatus*, but differs therefrom in the following particulars:—

In the head, the glabella is slightly more elongate and less tapering; the anterior lobe is more globular and the medial fissure shorter; the posterior lobe is less constricted at the anterior third, and slightly more rounded behind.

The chief distinguishing feature, however, is the axis of the tail. This is much broader and longer, and differs also in its general shape. The lateral lobes are narrower, and the margin is characterized by the presence of two short spines.

AGNOSTUS TRIANGULATUS, sp. nov. (Pl. XXX, figs. 7 & 8.)

Head.—Semi-elliptical, convex, with a narrow margin. Glabella elongate, four-fifths of the length of the head, conical. Anterior lobe large, equilaterally triangular; posterior lobe widening gradually behind, where it is well rounded; basal lobes small, triangular, indistinct. Cheeks equal in width to the glabella, separated in front by an ill-defined groove. Margin narrow. Surface smooth.

Thorax.—Axis with small lateral bosses, and a wider medial raised portion.

Tail.—Semi-elliptical, convex, with a narrow margin. Axis prominent, more than four-fifths of the length of the tail, constricted at the anterior fourth, expanding to the anterior half, and then tapering gradually to an acute point. Trisegmented: anterior segment divided into two separate lateral portions, owing to the fact that the first axial groove extends obliquely forward, and cuts the anterior margin near the medial line. Second segment subhexagonal, more convex than the rest of the axis, extending well back in the medial plane. Third segment greater than half of the length of the axis, depressed, acutely pointed behind. Lateral lobes convex, approximately equal in width to the axis, slightly constricted behind, but confluent. Margin narrow, widening posteriorly. Surface smooth.

Size.—Length and breadth of head and tail = 2 mm.

Horizon.—D 3.

This form is allied to *A.* cf. *intermedius*, from which it is distinguished by its anterior glabellar lobe being more triangular and acutely pointed in front, while the anterior segment of the tail-axis is much shorter and separated into two portions, whereas in *A.* cf. *intermedius* this segment is equal in length throughout.

(2) Lævigati.

AGNOSTUS ALTUS Grönwall. (Pl. XXX, figs. 9 & 10.)

1902. *Agnostus altus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 58 & pl. i, figs. 3–4.

1906. *Agnostus altus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 12 & pl. ii, fig. 1.

A whole specimen and several heads and tails belong to this species. They are rather large, the length and breadth of the head- and tail-shields being about 6 mm.

Mr. Lake enumerates the chief features which distinguish this form from *A. barrandei*. In addition, it is noticeable that the axis of *A. altus* is broader than that of *A. barrandei*, and is not constricted to so great an extent at the anterior third.

Horizons.—F 2–G 3.

AGNOSTUS BARLOWI Belt, var. SPINATUS nov. (Pl. XXX, figs. 11 & 12.)

1868. *Agnostus barlowi* Belt, Geol. Mag. vol. v, p. 11 & pl. ii, figs. 17–18.
1880. *Agnostus cicer* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 26 & pl. ii, figs. 16 *a*–16 *b*.
1906. *Agnostus barlowi* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 16 & pl. ii, fig. 7.

Two well-preserved tails of this form occur.

Tail.—Semi-elliptical, convex, with a well-defined margin. The presence of an axis is suggested by two sharply-defined grooves situated about half the width of the tail apart. Grooves short, only a third of the length of the tail; a prominent medial tubercle occurs near the anterior margin. Margin well developed, expanding posteriorly, slightly upturned, with two short posterior spines. Surface smooth.
Size.—Length of larger specimen =5·2 mm.; breadth of same =5·1 mm.
Horizons.—C 1 and C 2.

This form differs from Belt's type in its greater size, in its posteriorly widening border, and in the short posterior spines. It may also be noted that *A. cicer* (*A. barlowi*) occurs in Sweden at a much higher horizon, as, for example, in the *Paradoxides-davidis* and *Conocoryphe-æqualis* Zones.

AGNOSTUS BARRANDEI Salter. (Pl. XXX, figs. 13 & 14.)

1872. *Agnostus barrandei* Salter, Hicks, Q. J. G. S. vol. xxviii, p. 176 & pl. v, figs. 5–6.
1906. *Agnostus barrandei* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 13 & pl. ii, fig. 2.

This species is represented by about a dozen whole specimens, together with isolated heads and tails.

The surface of the tests is smooth, and no case occurs of a minutely-tuberculated form, such as that figured by Mr. Lake. A medial tubercle occurs on the head at about the anterior three-fifths. This has not been previously noticed, although it appears to occur on some of the figured specimens. The forms are generally large, the head and tail-shields in one specimen being each 8·5 mm. in length and breadth.

Horizons.—D 3–E 2, F 2 (?).

A single specimen referable to this type occurs at Horizon F 2, but most of the forms have been obtained at Horizon D 3.

AGNOSTUS BIBULLATUS Barrande. (Pl. XXXI, fig. 1.)

1852. *Agnostus bibullatus* Barrande, 'Système Silurien de la Bohême' vol. i, p. 906 & pl. xlix, figs. 1–7.

Two whole specimens agree in all particulars with Barrande's type.

Head.—Slightly elongate, greatest breadth at the anterior half, rounded in front, convex. Glabella almost obliterated, indicated by two short curved grooves about half the width of the head apart. Margin extremely narrow. Surface smooth.

Thorax.—Axis wide, plain, with two faint transverse grooves on the anterior segment which divide off two small lateral portions.

Tail.—In shape similar to the head, slightly convex. Axis represented by two widely-separated grooves, two-thirds of the breadth of the tail apart. These extend posteriorly almost to the margin. An elongated medial tubercle occurs anteriorly. Margin narrow. Surface smooth.

Size.—Length of head = 3·2 mm.; breadth of head = 3 mm. The dimensions of the tail are similar.

Horizons.—F 1 and F 2.

AGNOSTUS GLANDIFORMIS Angelin. (Pl. XXXI, fig. 2.)

1852. *Agnostus glandiformis* Angelin, 'Palæontologia Scandinavica' p. 5 & pl. vi, fig. 1.
1879. *Agnostus glandiformis* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 58 & pl. vi, fig. 7.
1880. *Agnostus glandiformis* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 29 & pl. ii, fig. 20.
1902. *Agnostus glandiformis* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 63 & pl. i, fig. 6.

Only one whole specimen of this species occurs, and unfortunately the tail, which was preserved in soft brown material, was somewhat broken during development. Associated with this form were several smooth head- and tail-shields, some of which are referable to *A. altus*, but others appear to belong to this type.

Head.—Rounded, convex, surface plain with no traces of glabellar furrows. No margin.

Thorax.—Axial segments apparently quite plain.

Tail.—Rounded, convex. Margin well defined where seen, but almost wholly broken away. Surface smooth; but a small medial tubercle occurs well forward towards the anterior margin.

Size.—Length and breadth of head-shield = 5 mm. Tail broken.

Horizon.—G 3.

AGNOSTUS LENS Grönwall. (Pl. XXXI, figs. 4–7.)

1902. *Agnostus lens* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 65 & pl. i, figs. 8–9.

Numerous specimens referable to this species have been found at two horizons in the sequence.

Head.—Rounded, slightly convex, margin narrow posteriorly, but widening forward. Glabella limited laterally by two short dorsal furrows slightly greater than a third of the width of the head apart, widest near the middle of the furrows. Length of the latter variable, according to the size of the specimens. In the smaller types with heads less than 3 mm. in diameter, the furrows are generally a third to two-fifths of the length of the head; in larger specimens they become shorter, and in a few cases disappear altogether. Basal lobes oval, placed transversely. The smaller specimens have a small medial tubercle opposite the anterior ends of the grooves, similar to Grönwall's types, but this is lost in the larger specimens. Surface smooth or slightly wrinkled in the older forms.

Thorax.—Axis wide, with lateral bosses and a central raised portion but slightly impressed, so that in many specimens the axis appears plain.

Tail.—Rounded, slightly convex, with a moderate margin. Axis about three-fourths of the length of the tail, but longer in large specimens. Only slightly more convex than the lateral lobes. Axis tapering, more

rapidly at first, then becoming almost parallel-sided, while towards the posterior extremity it tapers to a blunt point. In the best-preserved forms are traces of two pairs of short axial grooves. Axis ornamented with a medial elongate tubercle at the anterior third. Lateral lobes narrower than the axis, tapering posteriorly, especially in older forms; confluent behind. Surface smooth or slightly wrinkled.

Size.—In moderate specimens the length and breadth of the head- and tail-shields = 3·5 to 4 mm. The largest specimens found measure approximately 5 mm. in diameter.

Horizons.—F 1 and F 2. One specimen from E 3.

This species has been referred by Mr. Lake to *Agnostus barrandei*, but differs from that form in certain well-defined characters.

The glabellar lobes are oval, not triangular, the grooves on the head are shorter; the axis of the tail is not constricted at the anterior third to such an extent as in *A. barrandei*, and the well-defined transverse furrows of the latter are absent in this type. Also, specimens of *A. lens* are much smaller than the usual forms of *A. barrandei*.

AGNOSTUS NUDUS (Beyrich). (Pl. XXXI, fig. 8.)

1845. *Battus nudus* Beyrich, 'Ueber einige Böhmische Trilobiten' p. 46, fig. 20.
1846. *Battus nudus* Barrande, 'Notice préliminaire sur le Système Silurien & les Trilobites de Bohême' p. 15.
1847. *Phalacroma nudum, Ph. emarginatum, Ph. carinatum, Ph. scutiforme, Ph. gibbosum*, Hawle & Corda, 'Prodrom einer Monographie der Böhmischen Trilobiten' pp. 43–45 & pl. iii, fig. 20.
1852. *Agnostus nudus* Barrande, 'Système Silurien de la Bohême' vol. i, p. 903 & pl. xlix.
1880. *Agnostus nudus*, var. *scanicus*, Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 29 & pl. ii, figs. 18 *a*–18 *b*.
1895. *Agnostus nudus* Pompeckj, Jahrb. k.-k. Geol. Reichsanst. vol. xlv, p. 518 & pl. xvi, figs. 7 *a*–7 *c*, 8 *a*–8 *b*.

A single whole specimen, and several heads and tails agree closely with Beyrich's form. The head is plain, and no margin is apparent, while the border of the tail is but slightly wider than that of the type-specimen.

Horizon.—C 2.

AGNOSTUS NUDUS (Beyrich), var. OVALIS nov. (Pl. XXXI, figs. 9 & 10.)

Head.—Oval, rather convex, no margin apparent, although this may have been broken off owing to imperfect preservation. Surface smooth.

Tail.—Shape similar to that of the head, with a circular medial convex portion in the anterior two-thirds, having a medial tubercle near its anterior end. The rest of the tail is flat, and widens posteriorly.

Size.—Length of head and tail = 4 mm.; breadth of head and tail = 3·6 mm.

Horizon.—F 3.

This variety is most closely allied to *A. nudus*, var. *marginatus* Brögger, but differs in its general shape, and in the extreme width of the flat posterior portion of the tail. In the last character it agrees somewhat with the specimen of *A. nudus* figured by Mr. Lake in 'British Cambrian Trilobites' pl. ii, fig. 5.

AGNOSTUS ROTUNDUS Grönwall. (Pl. XXXI, fig. 11.)

1902. *Agnostus rotundus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii. p. 78 & pl. i, fig. 19.
1906. *Agnostus rotundus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 14 & pl. ii, figs. 3–4.

Three tails found in the *Paradoxides-davidis* Zone agree with Grönwall's figure and description of this species.

Good specimens of the head of this type have not been noted. From rather obscure specimens, Mr. Lake has suggested that the head is slightly convex, with basal lobes marking the only trace of a glabella. A rather broken head is attached to one of the tails found at Horizon G 3. This appears to agree with Mr. Lake's description; the basal lobes are faintly marked, while there may be two short grooves running forward from them, such as occur in *A. barrandei*.

Size.—Length of tail = 4·5 mm.; breadth of tail = 4 mm.
Horizon.—G 3.

(3) Limbati.

(3 *a*) Fallaces.

AGNOSTUS FALLAX Linnarsson. (Pl. XXXI, figs. 12–15.)

1869. *Agnostus fallax* Linnarsson, 'Om Vestergötlands Cambriska & Siluriska Aflagringar' Kongl. Svensk. Vet.-Akad. Handl. n. s. vol. viii, no. 2, p. 81 & pl. ii, figs. 54–55.
1877. *Agnostus fallax* Linnarsson, Geol. För. Stockh. Förhandl. vol. iii, p. 371 & pl. xv, fig. 7.
1879. *Agnostus fallax* Brögger, Nyt Mag. for Naturv. vol. xxiv, p. 64 & pl. vi, fig. 1.
1879. *Agnostus fallax* Linnarsson, 'Om Faunan i Kalken med *Conocoryphe exsulans*' Sver. Geol. Undersökn. ser. C, no. 35, p. 22 & pl. ii, fig. 33.
1880. *Agnostus fallax* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 31 & pl. ii, fig. 22 (forma typica).
1896. *Agnostus fallax* G. F. Matthew, Trans. N.Y. Acad. Sci. vol. xv, p. 214 & pl. xv, fig. 8.
1902. *Agnostus fallax* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 68.
1906. *Agnostus fallax* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 20 & pl. ii, fig. 12.

Several whole specimens, together with heads and tails, occur in the upper half of the succession. The large basal lobes of the glabella, faint segmentation of the axis, and the short posterior spines which characterize this form are well developed.

Horizons.—D 2–F 3.

AGNOSTUS INTEGER (Beyrich). (Pl. XXXII, figs. 1–4.)

1845. *Battus integer* Beyrich, 'Ueber einige Böhmische Trilobiten' p. 44, fig. 19.
1846. *Battus integer*, *B. orion*, *B. affinis*, *B. cuneifer* (pars), Barrande, 'Notice préliminaire sur le Système Silurien & les Trilobites de la Bohême' pp. 14–18.
1847. *Mesospheniscus cuneifer*, *Diplorrhina rotundata*, *D. triplicata*, *D. orion*, *D. umbonata*, *D. sirius*, *D. elliptica*, *D. asperula*, *D. selenophora*, *D. monas*, *D. affinis*, *D. cristata*, *Peronopsis integra*, Hawle & Corda, 'Prodrom einer Monographie der Böhmischen Trilobiten' pp. 46–50, 115, pl. iii, figs. 22–23, & pl. vi, fig. 62.

1852. *Agnostus integer* Barrande, 'Système Silurien de la Bohême' vol. i, p. 900 & pl. xlix.
1872. *Agnostus cambrensis* Hicks, Q. J. G. S. vol. xxviii, pl. v, fig. 1.
1895. *Agnostus integer* Pompeckj, Jahrb. k.-k. Geol. Reichsanst. vol. xlv, p. 521.
1906. *Agnostus integer* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. i, p. 18 & pl. ii, fig. 10.

Specimens of this type include several whole forms and isolated head- and tail-shields.

Head.—Subquadrate, rounded anteriorly, convex, with a narrow margin. Glabella about three-fifths of the length of the head, broad, almost equal in width throughout in some specimens, convex. Anterior lobe transverse, rounded in front. Posterior lobe of equal or slightly greater width; subparallel-sided, or slightly widening posteriorly; well rounded behind, with central tubercle. Basal lobes small, triangular. Cheeks convex, a little narrower than the glabella, of subequal width throughout. Margin narrow, convex. Surface smooth.

Thorax.—Axis wide, with well-developed lateral bosses. Central portion wider, convex, on the anterior segment subtriangular, on the posterior segment subrectangular, with a longitudinal medial groove.

Tail.—Subquadrate, rounded posteriorly, convex, with a well-defined margin. Axis long, three-fourths of the length of the head, almost reaching the margin, wide, convex. Axis very slightly constricted at the anterior third. Widening to the anterior two-fifths, quickly tapering posteriorly to a blunt point. Two pairs of short faint furrows at the anterior fifth and anterior two-fifths. Prominent medial tubercle at the anterior third. Lateral lobes extremely narrow, about half the width of the axis, tapering to a point behind, and separated by a short groove. Margin well defined, convex, widening posteriorly. Surface smooth.

Size.—Length of head- and tail-shields = 3·5 mm.; breadth of the same = 3·5 mm.

Horizons.—C 2 and D 3.

This form is most closely allied to *A. fallax*. It is distinguished from the latter by its wider glabella, smaller basal lobes, wider axis of the tail, and the posteriorly widening margin. Another distinguishing feature seems to be the absence of spines: Corda and Beyrich note the presence of short spines on the tail; but Barrande denies this, and is supported by Pompeckj. The figures in Barrande's 'Système Silurien' agree with the forms found in the Abbey Shales, the only point of difference being the slightly-shorter glabella in the Hartshill specimens.

At the lower Horizon C 2 occur two heads agreeing with those found at D 3 in all particulars except the anterior lobe, which is smaller and narrower than the posterior. This latter feature is stated by Mr. Lake to be characteristic of the species, but appears in this case to be merely a variation of the type, and is not seen in the figures supplied by Barrande.

Agnostus kjerulfi Brögger. (Pl. XXXII, fig. 6.)

1879. *Agnostus kjerulfi* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 65 & pl. v, fig. 7.
1880. *Agnostus kjerulfi* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 32.
1902. *Agnostus kjerulfi* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 69 & pl. i, fig. 11.

Only a single tail with the attached pleuræ has been found.

Thorax.—Axis wide, with large lateral bosses and a smaller central raised portion. The anterior segment is wider than the posterior one.

Tail.—Subquadrate, slightly broader than long. Abruptly rounded posteriorly, with short marginal spines. Axis large, almost parallel-sided, abruptly constricted behind, trisegmented. Two anterior segments short; posterior segment long; an elongated ridge or tubercle occurs on the middle segment, and overlaps slightly on to both the anterior and the posterior segments. Lateral lobes only half the width of the axis, convex near the latter, concave near the margin, so that the cheeks slope down abruptly midway between the axis and the border, especially posteriorly. Margin narrow, with short spines.

Size.—Length of tail = 4 mm.; breadth of tail = 4·1 mm.

Horizon.—G 2.

AGNOSTUS LOBATUS, sp. nov. (Pl. XXXII, figs. 7 & 8.)

The specimens upon which this description is based include six whole tails, found at four different horizons in the succession.

Tail.—Subquadrate, rounded posteriorly, slightly convex, with a well-defined margin, especially in the young stages. Axis extremely large, convex, extending behind almost to the margin, and occupying half the breadth of the tail. Axis constricted at the anterior third, slightly widening posteriorly, and rounded off behind to a blunt point. Trisegmented, furrows well defined, extending the whole way across the axis; anterior furrows slightly bent forward, posterior furrow transverse, but medially bent back by the keel. Anterior segment short, with a medial keel or tubercle; second segment slightly longer, medial keel well developed; posterior segment occupying more than half the length of the axis. Lateral lobes narrow, gradually constricted behind to a point, and separated by a short groove. Margin widening posteriorly, with two short spines.

Size.—Length and breadth of largest specimen = 3·2 mm.

Horizons.—A 4–C 2.

This form is unlike the tail of any species with which I am acquainted. The nearest allied type appears to be *A. fallax*; but the axis is much wider, the segmentation more distinct, and the form is characterized by the well-defined medial keel.

AGNOSTUS sp. (Pl. XXXII, fig. 9.)

Associated with the tails of *Agnostus lobatus*, five specimens of detached heads occur. These may belong to *A. lobatus*, but the dorsal furrows are so deep that it appears improbable that the two forms belong to the same type. It seems preferable to separate these heads, without distinguishing them by a new name, and await further evidence on the subject of their affinities.

Head.—Subquadrate, rounded anteriorly, very convex, with deep dorsal furrows. Glabella strongly defined, convex; between three-fifths and three-fourths of the length of the head, bilobed. Anterior lobe slightly transverse, rounded in front. Posterior lobe deeply constricted at the anterior third and widening to the posterior two-thirds, where it is suddenly constricted, and then rounded off gradually; more convex than the anterior lobe, with a medial and posterior tubercle. Basal lobes strongly defined, globular, moderate in size. Cheeks convex, though slightly less so than the glabella, subequal in width to the latter,

confluent in front. Margin narrow, not well preserved. Surface smooth.

Size.—Length and breadth of head = 2·9 mm.

Horizon.—C 2.

This form has features in common with both *A. exaratus* var. *tenuis* and *A. fallax*. With the former it agrees in the strongly-marked dorsal furrows, though differing in the shape of the glabellar lobes; while it resembles *A. fallax* in the shape of the glabella (although the basal lobes are smaller), but the dorsal furrows are much deeper.

(3 *b*) Regii.

AGNOSTUS GRANULATUS Barrande. (Pl. XXXII, figs. 11–13.)

1852. *Agnostus granulatus* Barrande, 'Système Silurien de la Bohême' vol. i, p. 911 & pl. xlix.

This Bohemian species is abundantly represented at three positions in the sequence, Horizons C 2, F 1, and F 2, while it occurs more rarely in the intervening beds. The specimens agree with Barrande's figures and descriptions, including both the transverse and the more elongate forms, and in the better-preserved specimens the finely-granulate surface is well shown.

Head.—Generally subquadrate, slightly rounded in front, convex, with a moderate margin. Glabella large, bilobed. Anterior lobe broad, curved backwards laterally, breadth three-fifths of that of the head, anterior margin slightly indented medially. Posterior lobe narrower, with a medial spine placed somewhat posteriorly, and a small tubercle at the posterior margin immediately behind the spine. Cheeks narrow, confluent in front. Margin moderate, with two posterior spines, often not preserved. Surface finely granular.

Thorax.—Axis with lateral rounded bosses and a slightly-larger raised central portion.

Tail.—Rounded posteriorly; slightly convex, with a large convex axis. The latter is long, narrows at the anterior third, expands to a maximum at the anterior three-fourths, rounded posteriorly. Three sets of short furrows occur; anterior pair directed inwards and slightly forwards, second pair transverse, third pair obscure, directed obliquely backwards. A well-developed medial spine occurs at the posterior end of each of the first three segments. Posterior segment large. Lateral lobes narrow, confluent behind. Margin moderate, with two long posteriorly-directed spines, often not preserved.

Size.—Head and tail-shields of mature specimens = 4 to 5 mm. in length and breadth.

Horizons.—C 2–F 3. One specimen in A 4.

This species has been found recently by Mr. T. C. Nicholas in the Menevian of St. Tudwal's Peninsula (North Wales).[1]

AGNOSTUS REGIUS Sjögren, var. GLOBOSUS nov. (Pl. XXXII, fig. 14.)

1872. *Agnostus regius* Sjögren, Geol. För. Stockh. Förhandl. vol. i, p. 76 & pl. v, fig. 6.

1877. *Agnostus regius* Linnarsson, 'Om Faunan i Lagren med *Paradoxides ölandicus*' *ibid.* vol. iii, p. 372 & pl. xv, figs. 9–10.

[1] Q. J. G. S. vol. lxxi, pt. 1 (1915) p. 101.

Three specimens of the tail of this form have been found, all occurring in association at one horizon.

Tail.—Semi-elliptical, flattened, with a very prominent axis. The latter extremely convex, broad, slightly more than three-fourths of the length of the tail; constricted at the anterior fourth, then almost parallel-sided, bluntly rounded posteriorly. Axis having a well-marked anterior furrow directed transversely, and slightly forward; the second set of furrows are short and obscure. The anterior segment has two faint furrows, which divide it into two large lateral portions and a raised central portion. Medial portion of axis very convex, with a slight keel and central elongate tubercle, which marks the position of maximum convexity of the axis. Lateral lobes less than half the width of the axis, very slightly convex, of equal width throughout, separated behind by a shallow furrow. Margin moderate. Surface smooth.

Size.—Length and breadth = 3 mm.

Horizon.—C 2.

In the shape of its axis this form corresponds most closely to the Regii group of Agnostidæ, and agrees in most of its characters with *A. regius* Sjögren. The only differences are the absence of the raised triangular portions in the anterior half of the lateral lobes, their flatter appearance, and the presence of a shallow groove behind the axis.

AGNOSTUS REX Barrande. (Pl. XXXII, figs. 15–17, & Pl. XXXIII, fig. 1.)

1846. *Battus rex* Barrande, 'Notice préliminaire sur le Système Silurien & les Trilobites de la Bohême' p. 17.

1847. *Condylopyge rex* Corda, 'Prodrom einer Monographie der Böhmischen Trilobiten' p. 50 & pl. iii, fig. 24.

1852. *Agnostus rex* Barrande, 'Système Silurien de la Bohême' vol. i, p. 908 & pl. xlix.

1880. *Agnostus rex* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 30 & pl. ii, fig. 21.

This species is extremely abundant at Horizon C 2; the specimens include several whole forms, as also numerous separate head- and tail-shields.

Head.—Rounded anteriorly, convex, with an upturned margin. Glabella large, bilobed. Anterior lobe large, half the width of the head, subtriangular, with rounded sides. Posterior lobe narrower, about two-fifths of the length of the head, parallel-sided, with two faint lateral furrows at the anterior third and two-thirds; faint elongate medial tubercle at the anterior two-fifths, and small posterior tubercle. Basal lobes extremely short, narrowing inwards. Cheeks narrow, convex, confluent in front as a thin strip. Surface smooth. Margin prominent, upturned.

Thorax.—Axis broad, with large lateral bosses and small subtriangular raised portions in the centre.

Tail.—Rounded posteriorly, with a large convex axis. Cheeks but slightly convex. Axis contracting to the anterior half, then expanding more rapidly, rounded posteriorly. Three pairs of short furrows cut off three short segments, and a large posterior segment. Prominent medial keel on the three anterior segments; fourth segment occupying slightly less than half the length of the axis. Lateral lobes narrow, confluent behind as a thin strip; slightly convex. Surface smooth; margin upturned, widening backwards.

Size.—Length of head and tail in the larger specimens = 6 mm.; width of the same = 5·8 mm.

Horizons.—B 3–D 3. Rare in A 4 and B 1.

A number of medium-sized specimens of the tail of this species do not possess the usual terminal expansion of the tail-axis—in this character agreeing with the form *Agnostus cambrensis* Hicks, which appears to be merely a variation of *A. rex*.

AGNOSTUS BIFURCATUS, sp. nov. (Pl. XXXIII, figs. 2 *a*–3 *b*.)

Head.—Subquadrate, rounded in front, with two posterior marginal spines, convex. Glabella large, three-fourths of the length of the head. Anterior lobe large, convex, crescent-shaped, lapping round the sides of the anterior portion of the posterior lobe; maximum width, about three-fifths that of the head. Posterior lobe less than half the length of the head, about a quarter of the width of the head, anterior border rounded. Posterior lobe more convex than the anterior lobe, with a large medial spine; at the posterior margin it bears another short spine directed upwards. Cheeks slightly convex, narrow but confluent in front of the glabella, wider posteriorly. Margin well developed and convex; posterior margin produced into long slender spines directed backwards and slightly outwards. Surface strongly granulate.

Thorax.—Axis wide, with lateral globose bosses and a larger medial raised portion.

Tail.—Slightly expanding posteriorly, where it is abruptly rounded. Axis long, very convex, without segmentation (faint traces of two sets of anteriorly-directed furrows occur on one specimen). Constricted to the anterior third; then expanding to its maximum width at the anterior three-fourths; bluntly rounded posteriorly. At the anterior end the axis has two tubercles. On the anterior half of the axis is a row of three short medial spines; on the posterior half these are replaced by two parallel rows, each consisting of three smaller spines. The lateral lobes are but slightly convex; they are narrower than the axis anteriorly, and constricted behind, but confluent. The margin is well developed, convex, with two long posteriorly-directed spines. Surface strongly granulate.

Size.—Length of head and tail = 3 mm.; breadth of the same = 2·9 mm.

Horizons.—G 2 and G 3.

The nearest allied form is *A. granulatus* Barrande; but in that form the glabella is relatively smaller, and the surface is not so coarsely granulate. The two posterior rows of spines on the axis distinguish *A. bifurcatus* from all other known species.

AGNOSTUS TUBERCULATUS, sp. nov. (Pl. XXXIII, figs. 4–8.)

Head.—Transverse, widening anteriorly, rounded in front, rather depressed, with an extremely-convex glabella. The latter bilobed. Anterior lobe crescent-shaped, about a third of the width of the head, convex. Posterior lobe narrower, elongate, extremely convex, bulging up from the anterior lobe and sinking rapidly behind, with a small central tubercle, and a short spine at the posterior extremity. Basal lobes apparently represented by two small bosses at the base of the glabella. Cheeks approximately equal in width to the glabella, confluent anteriorly; surface flat, but bulging up near the posterior portion of the glabella. Margin convex, well defined, with two posteriorly-directed marginal spines. Surface very faintly granular.

Thorax.—Axis rather narrow, with small but well-developed lateral bosses. Central portion relatively wide.

Tail.—Transverse, expanding to the anterior two-thirds, abruptly rounded behind. Axis very convex, about two-thirds of the length of the tail; narrowing slightly to the anterior half, then expanding, and abruptly terminated posteriorly. Axis with three pairs of faint furrows. Anterior pair short, transverse; second pair directed slightly backwards; third pair bent very obliquely backwards. The first and second segments of large and well-preserved specimens show well-defined lateral tubercles between the deep furrows which correspond to the first two sets of axial grooves. Three large medial spines or tubercles; the first small, and situated between the first lateral tubercles; the second larger, and slightly posterior to the second pair of tubercles. The third and largest tubercle is situated near the posterior portion of the axis overhanging the last segment. Posterior segment short, very convex. Lateral lobes almost flat. Surface finely granular. Margin convex, moderately wide, with long spines directed posteriorly and slightly outwards.

Size.—Length of head- and tail-shields of large specimen = 3·8 mm.; breadth of the same = 4 mm.

Horizon.—D 3. Rare in E 1 and F 2.

Agnostus tuberculatus is distinguished from *A. granulatus* by the following characters:—

In the head the glabella is much smaller; the anterior margin of the front lobe is wholly convex, and does not possess the slight medial concavity; the posterior lobe is longer, much more convex, and with a different arrangement of spines.

In the tail the axis is much shorter and more abruptly terminated, the spines are large, more tubercular, and the posterior spine occurs farther back on the axis; also the lateral lobes are wider. In addition, the general shape of the heads (expanding forwards) and that of the tails (expanding backwards) are useful characters in distinguishing the specimens of this form from those of *A. granulatus*.

(4) Parvifrontes.

AGNOSTUS PARVIFRONS Linnarsson. (Pl. XXXII, fig. 10.)

1869. *Agnostus parvifrons* Linnarsson, 'Om Vestergötlands Cambriska & Siluriska Aflagringar' K. Svensk. Vet.-Akad. Handl. n. s. vol. viii, no. 2, p. 82 & pl. ii, figs. 56–57.

1879. *Agnostus parvifrons*, var. *mamillata* and var. *nepos* Brögger, '*Paradoxides*-skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 72, pl. v, fig. 3, & pl. vi, fig. 2.

1880. *Agnostus parvifrons* Tullberg, 'Om *Agnostus* Arterna' Sver. Geol. Undersökn. ser. C, no. 42, p. 34 & pl. ii, figs. 26–28.

Isolated heads occur at four horizons in the sequence. Associated with these are tails which may belong to the same species; but, owing to their diminutive size, their identification is difficult.

Head.—Rounded, very convex, but often flattened during preservation. Glabella represented by a single elliptical lobe, very convex, sharply marked off from the cheeks. Length, from a third to two-fifths of the head. Ornamented with a slight medial tubercle placed somewhat anteriorly. Basal lobes small. Cheeks less convex than the axis, wide, confluent in front. Surface smooth. Margin narrow, but well defined.

Size.—Length of largest head = 2·2 mm.; breadth of largest head = 2 mm.

Horizons.—C 3, D 2, D 3, F 1.

Microdiscus Emmons.

Microdiscus punctatus Salter. (Pl. XXXIII, figs. 9 & 10.)

1864. *Microdiscus punctatus* Salter, Q. J. G. S. vol. xx, p. 237 & pl. xiii, figs. 11 *a*–11 *c*.
1882. *Microdiscus eucentrus* Linnarsson, 'De Undre *Paradoxides*lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, no. 54, p. 30 & pl. iv, figs. 19–20.
1884. *Microdiscus punctatus* Walcott, Bull. U.S. Geol. Surv. no. 10, p. 24 & pl. ii, figs. 1, 1 *a*–1 *c*.
1886. *Microdiscus punctatus*, var. *pulchellus* Matthew, Proc. & Trans. Roy. Soc. Can. vol. iii, sect. 4, p. 74 & pl. vii, figs. 12 *a*–12 *c*.
1896. *Microdiscus pulchellus* Matthew, Trans. N.Y. Acad. Sci. vol. xv, p. 242 & pl. xvii, figs. 8 *a*–8 *f*.
1896. *Microdiscus punctatus* Matthew, *ibid.* p. 244.
1902. *Microdiscus scanicus* var. *eucentrus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 79 & pl. i, fig. 20.
1907. *Microdiscus punctatus* Lake, 'British Cambrian Trilobites' Monogr. Pal. Soc. pt. ii, p. 36 & pl. iii, figs. 11–17.

This species has recently been exhaustively described by Mr. Lake. In many cases the specimens are so preserved as to show the cast of the internal surface and the mould of the corresponding external surface.

Horizons.—E 1–G 2.

Microdiscus punctatus, var. scanicus Linnarsson. (Pl. XXXIII, figs. 11 *a*–12.)

1882. *Microdiscus scanicus* Linnarsson, 'De Undre *Paradoxides*lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, no. 54, p. 29 & pl. iv, figs. 17–18.
1902. *Microdiscus scanicus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 79.

Among the Microdiscidæ found in the Abbey Shales, it is noticeable that, whereas between Horizons E 3 and G 2 all the specimens have long nuchal spines directed backwards, those found below Horizon E 1 are distinguished by the absence of the latter, being replaced by almost vertical spines, generally broken away in the specimens. Between Horizons E 1 and E 3, we find an intermixture of these two types. This distribution of forms is similar to that of *Microdiscus scanicus* and *M. eucentrus* in Sweden, where the high zonal form appears identical with *M. punctatus*, while the chief distinguishing feature of the lower form is the absence of a posteriorly-directed nuchal spine.

As shown recently by Mr. Lake, some of the features on which Linnarsson relied for differentiating his two forms are merely differences between the internal and the external markings of the test; but, even when these characters are taken into account, well-marked differences appear which warrant the separation of the lower form from *Microdiscus punctatus* Salter, as a variety apparently identical with Linnarsson's type *M. scanicus*.

If we compare this form with *M. punctatus* sensu stricto, the most important differences appear to be the following:—

In the internal cast of the head, the nuchal spine is directed upwards at an angle greater than 60°, and is generally broken off short; the groove in front of the glabella is narrower and steeper-sided, while the cheeks are narrower anteriorly. The external

surface is strongly punctate as in Salter's type, but the cheeks more raised, especially forward.

The internal casts of these forms agree perfectly with Linnarsson's figure, for the head is smooth, and the margin so narrow that it is often difficult, except in the largest specimens, to make out the transverse ridges on the latter. Also, it has been noted by Grönwall that some specimens of the Scandinavian form have a crenulate margin.

Horizons.—B 3–E 3.

Hartshillia, gen. nov.

Hartshillia inflata (Hicks). (Pl. XXXIV, figs. 1 *a*–5.)

1872. *Holocephalina inflata* Hicks, Q. J. G. S. vol. xxviii, p. 178 & pl. vi, figs. 8–10.

Head.—Almost semicircular, very convex, with large posterior spines. Glabella almost obliterated in mature forms, defined laterally by two short grooves less than a third of the length of the head, and placed about a fifth the width of the head apart; slightly constricted near the anterior end; a well-defined transverse neck-furrow. Neck-ring wider than the rest of the glabella, produced posteriorly into a strong backward-directed spine. [In young specimens the glabella is very convex and well defined; almost the whole length of the head.] Fixed cheeks large, convex, with strongly-developed posterior lateral spines, separated from the rest of the cheek by a well-defined groove, which is produced inwards to the neck-ring. Most of the specimens have no free cheeks, but some forms show a narrow border broken away from the head which appears to correspond to the free cheek, and it would appear probable that the facial suture was almost marginal and continuous in front. Surface covered with fine granules or raised dots.

Thorax.—The axis appears to have consisted of ten segments in the largest specimens, but in the smaller and better-preserved forms, only nine occur. The first six axial segments are subequal in length, while the last four shorten considerably. Pleuræ straight, slightly longer than the axial segments in large specimens, more so in the smaller forms, with a broad medial groove bent back near the extremity where the pleuræ end in a short blunt spine.

Tail.—Subtriangular, transverse, with a well-developed axis, having three segments, the posterior one being ill-defined. Lateral lobes small, triangular; in the best-preserved specimens it is apparent that the lobes have been formed by the fusion of two pairs of pleuræ, and the longitudinal grooves of the latter are still preserved. Margin wide, sloping steeply; where it meets the lateral lobes there are on each side two elongate ridges which are almost spined.

The surface of the whole test is granulate.

Size.—Length of specimens = 1·2 cms.

Horizons.—Rare from Horizons B 1–D 3, and also in Horizon F 2. Abundant in Horizons E 1, E 2, E 3.

This form is identical with *Holocephalina inflata* of Hicks, who referred the species to the same genus as Salter's type *H. primordialis*. The abundant material found at Hartshill includes a number of beautifully-preserved young forms, which show that, even in medium-sized specimens of *Hartshillia inflata*, there is a large convex glabella widening forwards. In this latter character, there is an important difference between *Hartshillia* and *Holocephalina*. In the older specimens the ill-defined glabella is quite

different from the conical glabella common to *Holocephalina* and other Conocoryphidæ. Another important difference, which may or may not be of generic value, is the presence of a large nuchal spine and the posterior lateral spines on the fixed cheek; whereas, in *Holocephalina*, the nuchal ring has a small tubercle, and the lateral spines are placed on the free cheek.

HARTSHILLIA SPINATA, sp. nov. (Pl. XXXIV, figs. 6 & 7.)

This species is based on four heads, a whole thorax, with numerous detached pleuræ, and two tails.

Head.—Semi-elliptical, very convex. Glabella almost obliterated in the adult stage, being defined laterally by two short furrows about a quarter of the length of the head, and set about a third of the width of the head apart. In more youthful stages there is a large glabella equal to the length of the head, attaining its maximum width near the anterior end, tapering to the anterior three-fourths and then expanding slightly behind, with no furrows, but a short nuchal spine. Fixed cheeks large in adult forms, convex; posterior lateral margins rounded, with no indications of spines. One specimen appears to have a detached lateral portion corresponding to a free cheek, such as is found in *Hartshillia inflata*.

Thorax.—The thorax of the best-preserved specimen contains eight segments, and this appears to be the complete number. Axis wide, but narrowing in the last four segments, each ring having a large medial spine often broken away. Pleuræ short, slightly more than half the width of the axis, with deep longitudinal grooves; anterior pleuræ tapering gradually, posterior pleuræ abruptly terminated.

Tail.—Shows a prominent convex axis divided into three well-defined segments; lateral lobes small, joined behind the axis by a narrow strip, depressed.

Size.—Length of specimen = 1·3 cms.

Horizon.—F 2.

This species resembles *Hartshillia inflata* in the remarkable development of the glabella, and for this reason it has been included in the same genus. It differs, however, in the absence of spines on the head, the presence of medial spines on the axial rings, the tapering anterior pleuræ, and the convexity of the tail-axis.

CONOCORYPHE Corda.

CONOCORYPHE BUFO Salter. (Pl. XXXV, figs. 1–3.)

1866. *Conocoryphe bufo* Salter, Rep. Brit. Assoc. for 1865, p. 285.
1868. *Conocoryphe bufo* Hicks & Salter, Q. J. G. S. vol. xxv, 1869, p. 52 & pl. ii, fig. 8.
1913. *Conocoryphe bufo* Cobbold, *ibid.* vol. lxix, p. 32 & pl. iii, figs. 17 *a*–17 *c*.

Four heads, several portions of the thorax, and a single tail belonging to this species have been found in the lower beds. The heads agree closely with Hicks's form. They differ from his description in the more elongate character of the glabella, and in the anterior merging of the dorsal and marginal furrows, though in both these characters they appear to agree with his figure.

The tail of the species has not been previously noted, and therefore a short description is appended.

Tail.—Rather small, with a relatively-large and very convex axis. The latter tapers behind, and is abruptly terminated; it has three well-marked transverse grooves which divide it into three narrow axial segments with strong tubercles, and a longer posterior segment with a faint trace of a fourth transverse groove. Lateral lobes small, rather depressed, subtriangular, with transverse grooves corresponding to three or more fused pleuræ.

Horizon.—A 4.

One of the heads corresponds to a slightly-earlier stage of development, in which the tumid marginal boss in front of the glabella is much less pronounced and the dorsal and marginal furrows do not merge one into the other. In both these characters this specimen approximates more closely to *Conocoryphe dalmani* Angelin, which appears to be the Swedish equivalent of *C. bufo*—both forms occurring at similar horizons in the Paradoxidian sequence.

Erinnys Salter.

Erinnys venulosa Salter.

1866. ***Erinnys venulosa*** Salter, Rep. Brit. Assoc. for 1865, p. 285.
1872. ***Erinnys venulosa*** Hicks, 'On some Undescribed Fossils from the Menevian Group' Q. J. G. S. vol. xxviii, p. 177 & pl. vi, figs. 1–6.
1902. ***Erinnys venulosa*** Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 94 & pl. i, fig. 23.

A single specimen of a head belonging to this type has been found. It agrees in all particulars with Hicks's description and figures, showing the depressed furrowed glabella, wide fixed cheeks with the characteristic venulose markings, and wide margin.

Size.—Length of head = 9 mm.; breadth of head = 17 mm.
Horizon.—F 2.

Holocephalina Salter.

Holocephalina primordialis Salter. (Pl. XXXIV, figs. 8 & 9.)

1864. ***Holocephalina primordialis*** Salter, Q. J. G. S. vol. xx, p. 237 & pl. xiii, fig. 9.
1902. ***Liocephalus teres*** Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 103 & pl. ii, fig. 2.

Numerous specimens of this form have been found in the uppermost beds. They are identical with Salter's type and with other specimens corresponding to the same form found at Porth-y-rhaw. The species appears to be the same as Grönwall's form *Liocephalus teres*, the only difference being the absence of the small tubercle and vascular impressions. The fact that this genus corresponds to Grönwall's genus *Liocephalus* was suggested by the latter (*op. supra cit.* p. 87).

Head.—Semicircular, moderately convex, with an obscure glabella and wide margin. Glabella small, very low, conical, rounded anteriorly, slightly longer than broad; showing faint traces of three sets of glabellar furrows, of which only the first can be made out with certainty. Neck-furrow shallow, transverse laterally, but slightly convex forward near the medial plane. Neck-ring showing a small medial tubercle. Fixed cheeks broad, moderately convex, with a shallow furrow separating off a marginal portion widening anteriorly to the medial plane. Free cheek narrow, with a short posterior spine. Surface very finely granular.

Thorax.—The axis contains at least eleven, and perhaps as many as fourteen, segments. The pleuræ are slightly longer, and bent over suddenly at three-fifths of their length, with wide longitudinal grooves; extremities rather obliterated in the specimens, but apparently rounded.

Horizon.—G 3.

HOLOCEPHALINA INCERTA, sp. nov. (Pl. XXXV, figs. 4–7.)

This species is based on numerous specimens, some of which are almost complete, occurring most abundantly in association with *Hartshillia inflata*.

Head.—Transverse, semi-elliptical, very convex, with deep dorsal furrows. Glabella small, extremely convex, about half the length of the head; conical, breadth subequal to length. Neck-furrow broad, well defined; no traces of glabellar furrows, except faint impressions of a pair of lateral furrows on some specimens. Neck-ring produced backwards as a strong thick spine. Fixed cheeks wide, convex, wider than the glabella, outer margin steeply inclined. No well-defined anterior border, but the posterior margin is separated from the cheeks by a deep groove. Surface ornamented with numerous punctæ which tend to have a radial arrangement; on some specimens there is also a subradial series of faint venulose markings, best developed near the front of the glabella. Free cheeks extremely narrow, with a strong posteriorly-directed spine reaching the level of the fourth pleuræ. Facial suture almost marginal, arching inwards both anteriorly and posteriorly.

Thorax.—Apparently consisting of sixteen or seventeen segments in the largest specimens. Axis narrow, gradually tapering behind. Pleuræ about 1½ times the length of the axial rings, with deep longitudinal furrows running from the inner anterior margin to the outer posterior margin; the pleuræ are bent over at about two-thirds of their length, the extremities acutely rounded.

Tail.—Small, triangular, slightly convex. Axis indistinctly developed, with one transverse furrow. Lateral lobes small, flat, with a pair of transverse grooves.

The surface of the fixed cheeks, thorax, and tail is covered with microscopic granules instead of the larger punctæ which are found on the fixed cheeks.

Size.—Length of the largest specimen = 1·7 cms.

Horizons.—C 2–E 3; abundant at E 1.

This form is referred to the genus *Holocephalina*, on account of its small glabella and the size and shape of the free cheeks. It differs from other species of this genus, however, in the presence of deep dorsal furrows and the strong nuchal spine.

PARADOXIDES Brongniart.

PARADOXIDES AURORA Salter. (Pl. XXXV, fig. 8.)

1866. *Paradoxides aurora* Salter, Rep. Brit. Assoc. for 1865, p. 285.
1869. *Paradoxides aurora* Salter, Q. J. G. S. vol. xxv, p. 54 & pl. ii, figs. 9–12.

This species is found only at one horizon, A 4. One specimen shows the whole of the glabella with fixed cheeks, eyes, and a portion of the anterior margin. Other fragmentary heads occur, while some of the pleuræ and tails found in association probably belong to this type.

The specimens agree with Salter's description, except for the fact that the second pair of glabellar furrows do not seem to be continuous across the axial line.

Paradoxides aurora appears to be most closely allied to *P. hicksii*, var. *palpebrosus* Linnarsson, from which it differs in the greater width of its glabella and in the shape of the anterior portion of the latter, while the eyes are not quite so long. It is interesting that these two forms, each differing from *P. hicksii* mainly in the possession of a longer eye-lobe, occur at a similar horizon respectively in Great Britain and Scandinavia.

PARADOXIDES DAVIDIS Salter. (Pl. XXXV, figs. 9–11.)

1863. *Paradoxides davidis* Salter, Q. J. G. S. vol. xix, pp. 275–276.
1864. *Paradoxides davidis* Salter, *ibid.* vol. xx, p. 234 & pl. xiii, figs. 1–3.
1864. *Paradoxides davidis* Salter, Mem. Geol. Surv. dec. xi, pl. x, figs. 1–8.
1882. *Paradoxides davidis* Linnarsson, 'De Undre *Paradoxides*lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, no. 54, p. 11 & pl. i, figs. 14–15; pl. ii.
1902. *Paradoxides davidis* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 106 & pl. ii, figs. 3–7.

Fragments of this form are numerous in the upper beds, and consist mainly of thoracic segments. Portions of the glabella show the two transverse furrows, while several specimens of the thick spine of the free cheek occur. Other fragments include the long spinous pleuræ near the tail, a portion of the tail itself with the associated pleuræ, and several good specimens of the hypostome.

Horizons.—G 2 and G 3.

PARADOXIDES HICKSII Salter. (Pl. XXXVI, figs. 1–7.)

1866. *Paradoxides hicksii* Salter, Rep. Brit. Assoc. for 1865, p. 285.
1869. *Paradoxides hicksii* Salter & Hicks, Q. J. G. S. vol. xxv, p. 55 & pl. iii, figs. 1–10.
1882. *Paradoxides hicksii* Linnarsson, Sver. Geol. Undersökn. ser. C, no. 54, p. 14 & pl. iii, figs. 1–5.
1913. *Paradoxides hicksii* Cobbold, Q. J. G. S. vol. lxix, p. 47 & pl. iv, figs. 1–5.

This species is abundantly represented in the beds of Horizon D, and occurs less frequently in the lower portion of the succession. The forms agree with Salter's description and figure, and need but a short notice here, as it is hoped that the ontogeny of the species will be dealt with in a future communication. In the smaller specimens (with heads of a maximum length of 5 mm.) there is a well-defined medial ridge running from the front of the glabella to the anterior margin. Another point of interest is the presence of a medial tubercle on the neck-ring. Salter refers doubtfully to the last two pleuræ as forming a portion of the tail. None of the isolated tails among the Hartshill specimens have these attached pleuræ, and it appears more probable that they belong to the thorax. On the surface of the free cheeks a number of raised lines run outwards and slightly backwards from the eye with a subradial orientation.

The tails of the species found in the beds of Horizon D agree with those of Salter's figures, the length of the tail being equal to, or only slightly less than, its breadth; but those which occur in association with heads of *P. hicksii* at Horizon A 4 are much more transverse, and agree in this respect with Linnarsson's

figures. In the transverse shape of the tails of these lower forms there is close agreement with the tails of *P. hicksii*, var. *palpebrosus* from the sub-zone of *Ct. exsulans*, although the length of the tail-axis appears to be shorter than in the latter.

Horizons.—D 3 (abundant); also A 4–D 2.

PARADOXIDES sp. nov. (Pl. XXXVI, fig. 8.)

Among the fossil fragments of Horizon A 4 occur several fragmentary heads of a form of *Paradoxides* which does not appear to correspond with any known species. Associated with these are numerous pleuræ and several free cheeks; but it is difficult to determine whether these belong to this type, or to the other forms of *Paradoxides* that occur in the same beds.

Head.—Subtriangular, depressed, with the anterior margin produced forward and rounded medially. Glabella large, almost equal to the length of the head, flat; acutely rounded anteriorly, attaining its maximum width at the anterior third, where it is four-fifths of the length, tapers gradually and but slightly to the posterior margin. Four sets of furrows. Neck-furrow transverse, well developed; first pair of furrows directed slightly backwards, extending across a third of the width of the glabella. Second and third pairs slightly longer than the first, transverse, arched slightly forwards. Fourth pair of furrows occurring at the position of the glabella's maximum width, directed obliquely backwards. Neck-ring wide, with no trace of a tubercle. Fixed cheeks small, depressed, subtriangular, about two-thirds of the width of the glabella posteriorly. Anterior border of the head in contact with the glabella throughout almost its entire length; extremely narrow medially, widening laterally. Eyes large, slightly curved, extending obliquely backwards from the glabella at its maximum width almost to the level of the first glabellar furrows. Anterior branch of the facial suture directed obliquely forwards at an angle of about 40° to the axial line; posterior branch slightly shorter than the eye, directed obliquely backwards with a slight curvature.

Size.—Length of largest head = 3·3 mm.; breadth of the same, without free cheeks = 4·3 mm.

Horizons.—A 4 and D 3 (?).

This form is most closely allied to *P. hicksii*, from which it differs in the shape of the glabella, its extreme width posteriorly, the narrow fixed cheeks, and the slightly longer eyes.

PARADOXIDES RUGULOSUS Corda. (Pl. XXXVI, figs. 9 & 10.)

1847. *Paradoxides rugulosus* Hawle & Corda, 'Prodrom einer Monographie der Böhmischen Trilobiten' p. 32.
1852. *Paradoxides rugulosus* Barrande, 'Système Silurien' vol. i, p. 374 & pl. ix, fig. 31, pl. xiii, figs. 3–9, and Supplement, 1872, p. 11 & pl. iii, fig. 36.
1879. *Paradoxides rugulosus* Brögger, '*Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv, p. 39 & pl. ii, figs. 1–3.
1882. *Paradoxides brachyrrhachis* Linnarsson, 'De Undre *Paradoxides*lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, no. 54, p. 16 & pl. iii, figs. 6–10.
1902. *Paradoxides rugulosus* Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii, p. 113 & pl. iii, figs. 1–4.
1911. *Paradoxides rugulosus* Cobbold, Q. J. G. S. vol. lxvii, p. 286 & pl. xxiv, figs. 14–16 *c*.

Fragmentary specimens referable to this species occur in Horizons E 3, F 1, F 2, and G 3.

Portions of the head show the glabella with two short anterior sets of furrows, the next set being almost or quite continuous across, and the posterior furrow well defined. The long eye is also well shown, but in the largest specimens its posterior portion is curved slightly outwards, and not upwards as is the case in most forms of *P. rugulosus*; the smaller heads, however, show the usual large curved eye. A single tail found in the beds of Horizon G 3 agrees with those figured by Grönwall, but, unfortunately, the posterior portion is not preserved.

Horizons.—E 3–G 3.

Centropleura Angelin.

A discussion of the genus will be found in Grönwall's treatise on 'Bornholms *Paradoxides*lag' pp. 122, 123, where it is pointed out that the genus is identical with Salter's *Anopolenus*.

Centropleura henrici (Salter). (Pl. XXXVII, fig. 3.)

1864. ***Anopolenus henrici*** Salter, Q. J. G. S. vol. xx, p. 236 & pl. xiii, figs. 4–5.
1865. ***Anopolenus henrici*** Hicks, *ibid.* vol. xxi, pp. 478–82, figs. 2 & 3.

The specimens include several fragments of the head, two free cheeks with long spines, a large portion of the thorax, and numerous isolated pleuræ. They show the wide glabella and axis of the thorax, which distinguish this form from *Centropleura salteri* and *C. impar*.

Horizons.—G 3 (abundant). F 2 (?) (one thoracic segment).

Centropleura pugnax, sp. nov. (Pl. XXXVII, fig. 4.)

This species is based on three specimens of the head without free cheeks, and five pleuræ attached to one of the heads.

Head.—Probably semicircular, but the free cheeks have not been found. Glabella large, convex, not quite reaching the anterior margin, rounded in front, broadest at the anterior third, posteriorly about four-fifths of the maximum width. First set of furrows short, discontinuous across; second and third pair of furrows laterally well developed, discontinuous across the axial line, or connected by a shallow groove; neck-furrow well developed. Anterior lobe of glabella large, occupying about half the length of the head. Fixed cheeks small, depressed, from half to two-thirds of the width of the glabella. Anterior margin of head equal in width throughout, separated from the glabella medially by a narrow strip which widens laterally. Eyes large, curved, extending from the glabella at its maximum width to about the level of the first glabellar furrows, but not reaching the posterior margin. Facial suture extending outwards and only slightly forward from the eye to the anterior margin.

Thorax.—Only six segments have been preserved. Axis rather narrow, decreasing regularly in width backwards; axial rings with longitudinal grooves placed somewhat posteriorly. Pleuræ extremely short, only half the width of the axis; they decrease rapidly in size posteriorly, with a deep groove running from the inner anterior extremity to the posterior lateral margin; ends of pleuræ abruptly terminated.

Size.—Length of head = 9 mm.
Horizons.—D 3 and E 1.

This form is allied to *Centropleura impar* Hicks, from which species it is distinguished by the greater length of the glabella, and the shorter eyes which do not reach the posterior margin.

Corynexochus Angelin.

Corynexochus pusillus, sp. nov. (Pl. XXXVII, figs. 1 & 2.)

The species is based upon five heads found at Horizon B 3.

Head.—Slightly convex, with a large glabella. The latter is convex, elongate, obtusely rounded in front, reaching its maximum width near the anterior margin; tapering rapidly backwards to the anterior third, the posterior portion being subequal in width throughout. Neck-furrow deeply impressed; there are three pairs of well-developed but short lateral furrows, and faint traces of a fourth pair behind the position of maximum width. Neck-ring convex, with a central tubercle. Fixed cheeks small, slightly convex, expanding in width rapidly near the posterior margin. Eyes long, curved, directed obliquely backwards from the glabella at its greatest width to the level of the posterior pair of glabellar furrows. Behind the eye, the facial suture turns abruptly outwards, and is then rounded off to the posterior margin.
Size.—Length of head = 2 mm.
Horizon.—B 3.

This species is distinguished from the nearest allied form, *C. bornholmiensis*,[1] by the shape of the glabella, the longer eyes, and the direction of the facial suture immediately behind the eyes.

Agraulos Corda.

Agraulos sp. indet. (Pl. XXXVII, fig. 5.)

Two heads and attached pleuræ occur at Horizon F 2, and appear to correspond to the genus *Agraulos*.

Head.—Semicircular, slightly convex; glabella large, depressed, parabolic, abruptly terminated in front, about three-fifths of the length of the head. Neck-furrow well defined, slightly convex forwards, no traces of glabellar furrows visible; neck-ring well defined, but broken behind in the specimens. Cheeks about two-thirds of the width of the glabella, approximately equal in width throughout, sloping gently down from the glabella, and bent up slightly near the anterior marginal fold. Eyes rather large, about a third of the length of the head; facial suture proceeding forward and slightly inwards from the eye, while posteriorly it is short and directed backwards. Free cheeks narrow, rounded at the posterior lateral margin.
Thorax.—Only six segments have been preserved in conjunction. The axis is rather wide, axial rings showing a longitudinal groove. Pleuræ equal in length to the axial rings, with deep longitudinal grooves and rounded extremities.
Size.—Length of head = 5 mm.
Horizon.—F 2.

[1] *Corynexochus bornholmiensis*, Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii (1902) p. 137 & pl. iv, figs. 1–2.

Liostracus Angelin.

Liostracus elegans, sp. nov. (Pl. XXXVII, figs. 6–7 *b*.)

This form is by far the most abundant of the Ptychoparidæ found in the Abbey Shales, the specimens representing all stages of development.

Head.—Almost semicircular, gently convex. Glabella moderate, conical, about two-thirds of the length of the head, slightly longer than broad, more convex than the rest of the head. Neck-ring well defined, produced backwards to a blunt spine, which is often not preserved in the specimens. Traces of glabellar furrows occur in some specimens, forming three sets of faint lateral furrows, but in most forms the glabella is smooth. Fixed cheeks wide, slightly convex, concave and constricted in front of the glabella, where they are turned upwards to the anterior marginal fold. Eyes small, situated remote from the glabella at a distance greater than its width, and connected to the latter by a faint eye-line. Facial suture directed forward from the eye, and then obliquely inwards to the anterior margin; behind the eye it is long and curved obliquely outwards, then bent back in a graceful curve and rounded off at the posterior margin. Free cheeks moderate in size, posterior lateral margin rounded.

Thorax.—Consists of seventeen segments. Axis broad anteriorly, narrowing regularly behind, axial rings with a broad longitudinal groove. Pleuræ shorter than the width of the axis anteriorly, lengthen to the sixth pleuræ where they are slightly longer than the corresponding axial rings, and shorten regularly behind. Pleuræ showing deep longitudinal grooves, extremities rounded in the anterior segments, but posteriorly the latter terminate in abrupt short spines.

Tail.—Small, with short but extremely-convex axis, divided into three lobes by two obscure furrows, lateral lobes small, depressed, connected behind by a narrow strip.

Surface of test ornamented with fine, almost microscopic granules.

Size.—Length of largest specimen = 2·5 cms.

Horizons.—B 1–D 1; most abundant at B 3 and C 2.

The most closely-allied form to this species appears to be *L. aculeatus* Angelin, from which it is distinguished by less convexity and by the direction of the facial suture, while the anterior margin of the head is less strongly upturned.

Solenopleura Angelin.

Solenopleura applanata (Salter). (Pl. XXXVII, figs. 8 & 9.)

1866. *Conocoryphe applanata* Salter, Rep. Brit. Assoc. for 1865, p. 285.
1869. *Conocoryphe applanata* Salter, Q. J. G. S. vol. xxv, p. 53 & pl. ii, figs. 1, 2, 4, 5.
1900. *Solenopleura applanata* Reed, Geol. Mag. dec. 4, vol. vii, p. 252.

Two whole specimens and a detached head correspond to this species, the best-preserved form having the ocular ridge well developed. As pointed out recently by Dr. F. R. C. Reed, this species belongs to the genus *Solenopleura*.

Size.—Length of largest specimen = 2·9 mm.

Horizons.—D 2 and D 3.

SOLENOPLEURA cf. APPLANATA Salter. (Pl. XXXVII, fig. 10.)

At Horizon F 1 occur isolated heads and tails which resemble *Solenopleura applanata* in most of their characters. Unfortunately, the forms are young, while the largest head is poorly preserved. The glabella tapers less anteriorly than in Salter's form, and the eyes are placed nearer the glabella, while the neck-ring has a well-marked tubercle. The specimens appear to correspond in many of their characters with Grönwall's form *S. brachymetopa* Angelin, var. *nuntia*, with which they may be identical, but the material is insufficient to establish this fact.

SOLENOPLEURA VARIOLARIS Salter.

1864. *Conocoryphe (?) variolaris* Salter, Q. J. G. S. vol. xx, p. 236 & pl. xiii, figs. 6–7.

A single specimen of the head of a *Solenopleura* has been found, showing the strong tuberculation which is characteristic of this species.

Horizon.—F 3.

VII. AFFINITIES OF THE FAUNA.

Just as Hartshill lies geographically between Wales and Scandinavia, so the fauna of the Abbey Shales has striking affinities with the corresponding faunas of each of these two areas.

Comparing it in the first place with the Middle Cambrian faunas of Scandinavia, there are at least twenty-one species common to both areas, while of these forms, eight have been noted nowhere else in Great Britain. This may be due, in some cases, to the difficulty of collection and identification in the cleaved rocks of Wales, but it is curious that such forms as *Agnostus rex* and *A.* cf. *intermedius*, so abundant at Hartshill, have not been noted elsewhere in Great Britain.

On the other hand, there are many features which unite the Hartshill fauna more strongly with that of Wales. Thus, *Hartshillia inflata*, *Agnostus exaratus*, var. *tenuis*, and *A. barrandei* are found commonly in British areas, while in Scandinavia these forms have not been noted. In any case, however, it must be admitted that the resemblances between the faunas of all three areas are much stronger than their divergences, and a detailed comparison leads to the following general conclusions :—

(*a*) There appears to be a general fauna of species common to all three areas.

(*b*) Some of the species are relatively more abundant in different areas and extend over a longer period of time: for instance, *A. fissus* is more abundant, and has a longer time-range, in Great Britain than in Sweden.

(*c*) Certain forms in one region are represented in the others, at a corresponding horizon, by closely-allied, but not identical, species:

for instance, *Conocoryphe dalmani* of Sweden is represented by *C. bufo* of Great Britain.

(*d*) Other forms occur abundantly in, and are restricted to, one or two of the areas, as, for example :—

Agnostus exaratus, var. *tenuis* is restricted to Hartshill and Wales.

Agnostus rex is restricted to Hartshill and Scandinavia.

Paradoxides tessini occurs in Sweden, but has not been noted in Great Britain.

Thus it appears that the fauna is composed of cosmopolitan and local types, and in the case of the former there seems to be distinct evidence of the processes of migration, with or without a slight variation in the type.

Another region, the fauna of which shows close affinities with that of Hartshill, is Bohemia. This is particularly so in the case of the Agnostidæ, for each of the five species noted by Barrande from the Middle Cambrian of that region has been found in the Abbey Shales. In the following list of fossils, identical or similar species occurring in both areas are noted :—

Hartshill.	Bohemia.
Agnostus integer.	*Agnostus integer.*
Agnostus bibullatus.	*Agnostus bibullatus.*
Agnostus fallax.	*Agnostus integer*, var. *spinosus.*
Agnostus nudus.	*Agnostus nudus.*
Agnostus rex.	*Agnostus rex.*
Agnostus granulatus.	*Agnostus granulatus.*
Paradoxides davidis.	*Paradoxides bohemicus.*
Paradoxides hicksii.	*Paradoxides rotundatus.*
Paradoxides rugulosus.	*Paradoxides rugulosus.*

VIII. Correlation.

In dealing with the zonal classification of the Abbey Shales, with a view to their comparison with the Middle Cambrian succession of other regions, it will be sufficient to confine attention mainly to the two historic areas, Scandinavia and South Wales, where zonal subdivision of the Paradoxidian faunas was first carried out. In Scandinavia, the invaluable work of Linnarsson,[1] Tullberg,[2] Brögger,[3] and others has produced the following subdivision of the faunas :—

5. Zone with *Agnostus lævigatus.*
4. Zone with *Paradoxides forchhammeri.*
3. Zone with *Paradoxides davidis.*
2. Zone with *Paradoxides tessini.*
1. Zone with *Paradoxides ölandicus.*

[1] G. Linnarsson, 'Vester Götlands Cambriska & Siluriska Aflagringar' K. Svenska Vet.-Ak. Handl. vol. viii, no. 2 (1869) ; also 'De Undre *Paradoxides*-lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, no. 54 (1882).

[2] S. A. Tullberg, 'Om *Agnostus* Arterna i de Kambriska Aflagringarne vid Andrarum' *ibid.* no. 42 (1880).

[3] W. C. Brögger, 'Om *Paradoxides*skifrene ved Krekling' Nyt Mag. for Naturv. vol. xxiv (1879) p. 18.

At Andrarum itself a more detailed subdivision has been attempted [1]:—

10. Zone of *Agnostus lævigatus.*
9. Zone of *Paradoxides forchhammeri.*
8. Zone of *Agnostus lundgreni.*
7. Zone of *Paradoxides davidis.*
6. Zone of *Conocoryphe æqualis.*
5. Zone of *Agnostus rex.*
4. Zone of *Agnostus intermedius.*
3. Zone of *Microdiscus scanicus.*
2. Zone of *Ctenocephalus exsulans.*
1. Zone of *Agnostus atavus.*

Prof. Grönwall, in his classic work on the Paradoxidian Beds of Bornholm, suggests that the latter classification is somewhat too detailed for extensive correlation, and, among other modifications, adopts a tripartite subdivision of the *Paradoxides-tessini* Zone, the Subzones of *Agnostus rex*, *A. intermedius*, and *Microdiscus scanicus* being included in the Zone of *A. parvifrons.* Thus, the final classification of the Paradoxidian Beds of Scandinavia would read as follows:—

(5) Zone of *Agnostus lævigatus.*
(4) Zone of *Paradoxides forchhammeri.*
(3) Zone of *Paradoxides davidis.*
(2) Zone of *Paradoxides tessini.* { Subzone of *Conocoryphe æqualis.* / Subzone of *Agnostus parvifrons.* / Subzone of *Ctenocephalus exsulans.*
(1) Zone of *Paradoxides ölandicus.*

From the accompanying diagram (Table II, facing p. 436) of the life-ranges of the most important species common to both Scandinavia [2] and Hartshill the following correlation may be drawn up:—

(*a*) Hor. F. & G. = *Paradoxides-davidis* Zone of Scandinavia.
(*b*) Hor. E 3–E 1 (pars) = *Conocoryphe-æqualis* Zone of Scandinavia.
(*c*) Hor. E 1 (pars)–B 1 = *Agnostus-parvifrons* Zone of Scandinavia.
(*d*) Hor. A = part of *Ctenocephalus-exsulans* Zone of Scandinavia.

Age of the Lowest Beds. (Horizon A.)

With regard to the age of the lowest horizon, I stated in 1913 that these beds contained *Agnostus atavus.* The specimens were fragmental, containing only the axis of the tail in good preservation; further material shows that the form is really a new species, similar to *A. atavus* in the axis of the tail, but differing

[1] (See Tullberg & Linnarsson above.) C. Lapworth, 'On the Correlation of the Lower Palæozoic Rocks of Britain & Scandinavia' Geol. Mag. dec. 2, vol. viii (1881) p. 260; J. C. Moberg, 'Geological Guide to Andrarum' Sver. Geol. Undersökn. ser. C, no. 229 (1910).

[2] The diagram for the Scandinavian fauna is based on those of Brögger (1879: 'Om *Paradoxides*skifrene ved Krekling') and Tullberg (1880: 'Om *Agnostus* Arterna vid Andrarum'), with modifications to include the work of Linnarsson (1882: 'De Undre *Paradoxides*lagren vid Andrarum') and Grönwall (1902: 'Bornholms *Paradoxides*lag').

widely in other characters. However, that these beds correspond to a portion of the *Ctenocephalus-exsulans* Subzone of Scandinavia seems probable from the following considerations:—

(*a*) *Conocoryphe bufo* appears to be the equivalent in Great Britain of the Swedish form *C. dalmani*. The latter occurs as a typical form of the *Ct.-exsulans* Subzone, although, it is true, Linnarsson has noted its occurrence in the succeeding beds containing *Microdiscus scanicus*.

(*b*) *Microdiscus punctatus*, var. *scanicus* is not found in these beds, its lowest occurrence being in Horizon B 3. This form is abundant in the beds immediately overlying the *Ctenocephalus-exsulans* Subzone of Andrarum, and, indeed, has given its name to the beds in which it is found.

(*c*) Among the *Paradoxides* fragments from the top of Horizon A 4, a few heads of *P. hicksii* occur. With these are four tails, none of which corresponds to the tails of the typical form from the upper horizons, but are much broader, and approach those of the form *P. hicksii*, var. *palpebrosus*, one of the typical species of the Lower *Paradoxides-tessini* Zone of Sweden.

(*d*) Although seven species of *Agnostus* have been found, they are extremely rare, forming collectively much less than 1 per cent. of the total number of specimens. They occur in the uppermost bed, and appear to be the first arrivals of the oncoming *A.-parvifrons* fauna.

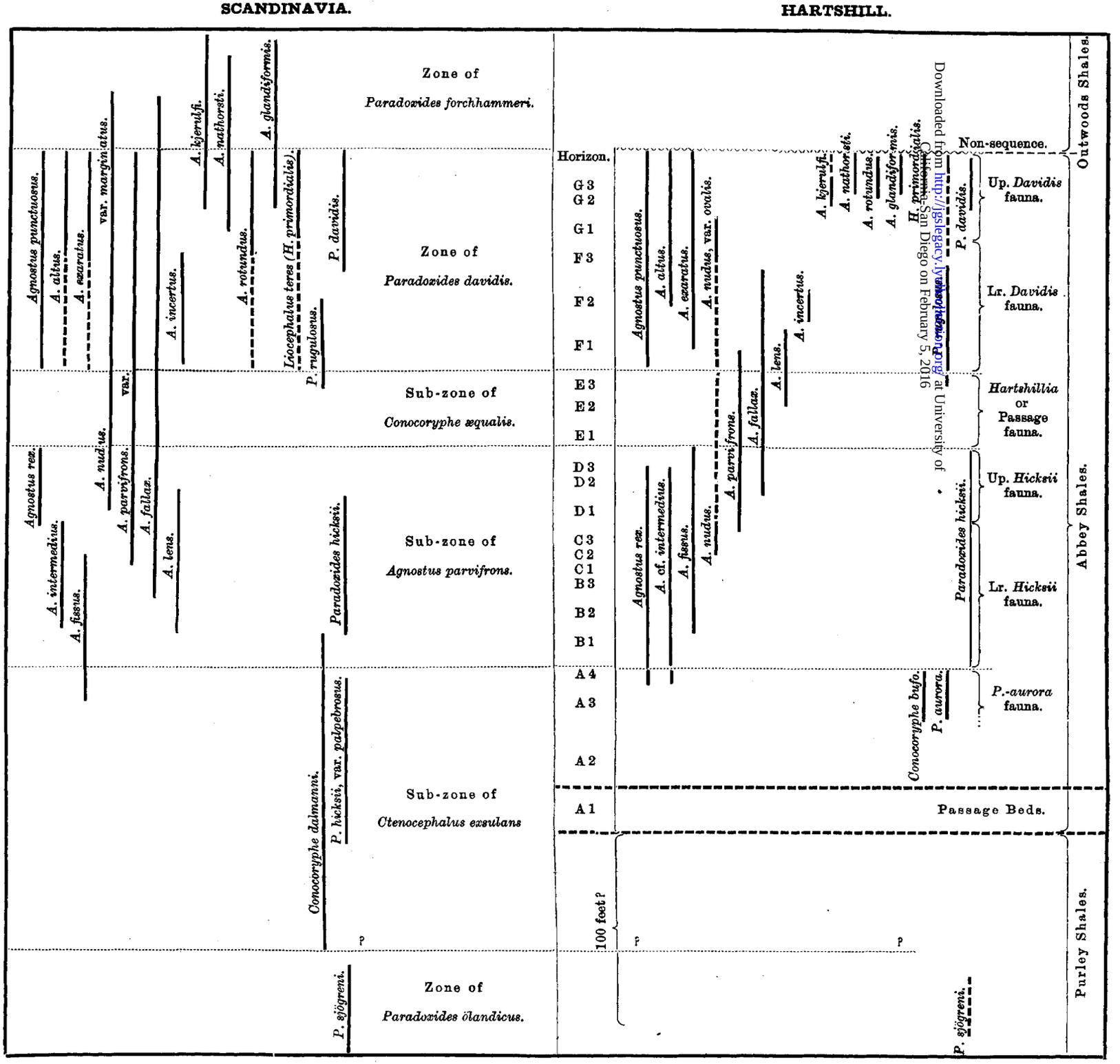
Quite recently, important evidence on the age of the basal Abbey Shales and underlying Purley Shales has been forthcoming. Among the fossils in the collection at Birmingham University are two specimens obtained from Purley-Park Lane. One of these contains the tail and a portion of the thorax belonging to one of the Conocoryphidæ, and forms the basis of the name *Conocoryphe coronata*, which is affixed. The other specimen is a head of *Paradoxides*, a very convex type with well-developed though rather small eyes, and faint glabellar furrows corresponding to *P. sjögreni*, which is found in the *Paradoxides-ölandicus* Zone of Sweden.

The horizon at which these two forms occur is of some importance. They were found in a heap of shales by the road-side in Purley-Park Road, where the hill-slope has been excavated in the formation of the latter. This excavation is only in the uppermost 150 feet of the Purley Shales; therefore the fossils must occur within these limits. The specimens are preserved in rather tough shales, one red, while the other is green. Hard green bands occur in Purley-Lane Cutting close by, about 100 feet from the top of the Purley Shales. Hence it would appear that, at about 100 feet from the base of the Abbey Shales, trilobites exist indicating a horizon probably equivalent to the *P.-ölandicus* Zone of Scandinavia: that is, the lowest Paradoxidian Zone of that country. This conclusion is admittedly based on a single species; but *P. sjögreni* has never been found above the *P.-ölandicus* horizon, and the conclusion fits in with the fact that the lower Purley Shales contain *Callavia*, which is characteristic of only the middle zone of the Lower Cambrian.

It would appear probable that the uppermost Purley Shales may be included with the basal Abbey Shales as corresponding to the *Ctenocephalus-exsulans* Subzone, for it may be noted that

TABLE II.—DIAGRAMMATIC REPRESENTATION OF THE LIFE-RANGE OF SPECIES COMMON TO SCANDINAVIA AND TO HARTSHILL.

[The spacing of the horizons in the Abbey Shales corresponds to their relative thicknesses.]



Ct. exsulans itself has not been found at Horizon A, and the forms which occur in the latter have, in some respects, the character of a passage-fauna between the Lower and the Middle *Paradoxides-tessini* Zones.

Age of Horizons B 1–E 1 (*pars*).

There can be very little doubt that these beds correspond to the Middle *P.-tessini* Subzone of Sweden. They contain all the characteristic forms of the *Microdiscus-scanicus, Agnostus-intermedius*, and *A.-rex* Beds of Andrarum, *A. intermedius* being represented by *A.* cf. *intermedius*, which differs from the sole published figure of the type in a few small details. On the other hand, it is found impossible to divide the faunas at Hartshill into these three subzones, for there are several alternations of *A.* cf. *intermedius* and *A. rex*, which appear to depend on changes in the conditions of deposition.

Age of Horizons E 1 (*pars*)–E 3.

These are referred doubtfully to the *Conocoryphe-æqualis* Subzone, on account of their intermediate position between the two rich faunas of *Paradoxides davidis* and *P. hicksii* (Middle *tessini* Zone). The zone-fossil does not occur; indeed, *C. æqualis* has only been noted from one locality in Great Britain.[1] It is of interest, however, to note that these horizons resemble the subzone of *Conocoryphe æqualis* in the paucity of the Agnostid fauna, the sole really abundant fossil being *Hartshillia inflata*.

Age of the Upper Beds. (Horizons F 1–G 3.)

These beds correspond in age to the *Paradoxides-davidis* Zone of Sweden, and it is a fact worth noting that *P. davidis* itself only occurs in the upper portions of the zone at both Andrarum and Hartshill. At the summit of the series a break occurs in the succession, and it is probable that a portion of the *P.-davidis* Zone has been eroded. However, the occurrence of *Agnostus kjerulfi* and *A.* cf. *nathorsti* in the uppermost beds indicates that these correspond to a high position in the *P.-davidis* Zone.

South Wales.

With regard to the succession in South Wales, the subdivision of these beds is mainly the result of Hicks's investigations.[2] To the upper half of the Middle Cambrian he applied the term

[1] E. S. Cobbold, 'On the Trilobite Fauna of the Comley Breccia-Bed' Q. J. G. S. vol. lxix (1913) p. 32 & pl. iii, figs. 18 *a*–18 *c*.

[2] J. W. Salter, Q. J. G. S. vol. xix (1863) pp. 274–77; *ibid.* vol. xx (1864) pp. 233–41 & pl. xiii; H. Hicks & J. W. Salter, *ibid.* vol. xxi (1865) pp. 476–82, and vol. xxv (1869) pp. 51–57 & pls. ii–iii; H. Hicks, *ibid.* vol. xxviii (1872) pp. 173–85 & pls. v–vii; H. Hicks & R. Harkness, *ibid.* vol. xxvii (1871) pp. 384–404 & pls. xv–xvi.

'Menevian'—a convenient name, which has, unfortunately, come to bear quite different meanings when used by various writers. As originally defined, the term included not only the blue and grey shales containing *P. davidis* and *P. hicksii*, but also the underlying grey flags with the allied form *P. aurora*.[1] Later, these lower beds were removed from the Menevian group and placed in the underlying Solva Beds, although the author of the term still loosely joined them to the Menevian in some of his writings.[2]

Thus the term Menevian is used at present with three different meanings:—

(*a*) As originally defined, including the zones of *Paradoxides davidis*, *P. hicksii*, and *P. aurora*.[3]
(*b*) In Hicks's later restricted sense, containing the zones of *Orthis hicksii*, *P. davidis*, and *P. hicksii*.
(*c*) With a more extended meaning, so as to include the whole of the Paradoxidian Beds, as suggested by Linnarsson.[4]

The Abbey Shales correspond closely with the original limits of the Menevian. I had the pleasure of hammering over the typical section at Porth-y-rhaw recently, in the company of Mr. J. Pringle, and was impressed by the similarity between the faunal sequences of the Abbey Shales and the 'Menevian' of South Wales; while the total thickness of the latter beds, though much greater than that of the Abbey Shales, appears to be somewhat less than that stated in published accounts.

Correlation.

South Wales.	Horizon.	Hartshill.
Upper Menevian—*Orthis hicksii*.		
		Non-sequence.
Middle Menevian—*P. davidis*.		G.—Upper *davidis* fauna.
		F.—Lower *davidis* fauna.
		E.—*Hartshillia-inflata* (passage) fauna.
Lower Menevian—*P. hicksii*.		D.—Upper *hicksii* fauna.
		C.—Lower *hicksii* fauna.
		B.—Lower *hicksii* fauna.
Upper Solva—*P. aurora*.		A.—*Paradoxides-aurora* fauna.

In this comparison, the correlation of Horizon E with the lower portion of the *Paradoxides-davidis* Beds of Wales is doubtful. Hicks does not expressly state in which zone his specimens of *Hartshillia inflata* occur, although the comparison given above appears probable from consideration of his statement as to the thickness of the two zones.

A closer correspondence can be made in the case of two horizons at Porth-y-rhaw:—

[1] H. Hicks & J. W. Salter, Q. J. G. S. vol. xxv (1869) pp. 51–57 & pls. ii–iii.
[2] H. Hicks, *ibid.* vol. xxviii (1872) pp. 182–83.
[3] E. S. Cobbold, 'On the Trilobite Fauna of the Comley Breccia-Bed' *ibid.* vol. lxix (1913) p. 39.
[4] G. Linnarsson, 'The Oldest Fossiliferous Rocks of Northern Europe' Geol. Mag. dec. 2, vol. iii (1876) p. 287.

(*a*) The first is the type-locality for *Paradoxides davidis*, and occurs 46 feet below the dolerite sill. The bed is 3 feet thick, and the fauna corresponds closely with that of Horizons G 2–G 3 in the Abbey Shales, the following forms being common to both :—

Paradoxides davidis.	*Agnostus punctuosus.*
Holocephalina primordialis.	*Agnostus exaratus*, var. *tenuis* (rare).
Agnostus exaratus.[1]	*Agnostus kjerulfi.*[1]
Agnostus altus.	*Centropleura henrici.*

(*b*) The other horizon occurs about 120 feet below the previous bed, and yields the following fossils in common with Horizon C 3 :—

Paradoxides hicksii (abundant).	*Agnostus sulcatus.*[1]
Agnostus fissus (abundant).	*Microdiscus punctatus*, var. *scanicus.*
Agnostus exaratus, var. *tenuis.*	

In North Wales the Paradoxidian fauna has been noted at Cwm Prysor, Afon Mawddach, and recently in the St. Tudwal's Peninsula. In the last-named area Mr. T. C. Nicholas has found Middle Cambrian trilobites in the Nant-pig Mudstones, and in the upper portion of the underlying Caered Flags and Mudstones. At the time of writing, his paper had not been printed *in extenso*; but I was taken over the area by Mr. Nicholas, who most kindly prepared a list of fossils for comparison. From the recent publication of his results in this Journal (vol. lxxi, pt. 1, p. 83), it would appear that

(*a*) The fauna of the upper portion of the Nant-pig Mudstones is equivalent to the Lower *davidis* fauna of Horizon E. Mr. Nicholas has called his upper fauna a 'passage-fauna,' noting the absence of *P. davidis*, and is in agreement with me on the subject of its correlation. The Upper *davidis* fauna, characterized by the presence of *P. davidis*, appears to have been cut out by the unconformably-overlying Maentwrog Series, although the presence of *Agnostus kjerulfi* in the calcareous grit between the two shaly series suggests that this bed may belong to the lower portion of the Upper *davidis* Zone.

(*b*) The main portion of the Nant-pig Mudstones corresponds to the Upper *hicksii* fauna of Horizon D.

(*c*) The Upper Caered Flags and Mudstones are probably equivalent to the Lower *hicksii* fauna, such forms as *Agnostus* cf. *gibbus* indicating their ancient origin.

In the other two localities of North Wales the Upper *davidis* fauna is known to be present, together with the underlying *Paradoxides-hicksii* Zone; but no detailed account of these sections has been published.

Shropshire.

Mr. E. S. Cobbold's research at Comley has proved the existence of two Paradoxidian faunas :—

(*a*) A lower *Paradoxides-groomi* fauna from the Quarry-Ridge Grits.[2]

(*b*) A later fauna found in a breccia-bed.[3]

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[1] These forms are new to the area, and have been found in material kindly submitted for examination by H.M. Geological Survey and collected by Mr. John Pringle; *Agnostus sulcatus* was found by Mr. Pringle and myself during a recent visit.

[2] Q. J. G. S. vol. lxvii (1911) p. 297.

[3] *Ibid.* vol. lxix (1913) pp. 27–42.

The latter he correlates with the *P.-tessini* Zone, stating that it represents a part, if not the whole, of that zone. The only fossils which it contains in common with the Abbey Shales are *Microdiscus punctatus* and *Conocoryphe bufo (?)*, and it is remarkable that the faunas of these two localities have so little in common.

A fauna of the *Paradoxides-davidis* Zone occurs in the Shoot-Rough Road Beds.[1]

The *Paradoxides-hicksii* Zone has been noted at Neve's Castle, near the Wrekin.[2]

Other Areas.

A short comparison between the Scandinavian deposits of Middle Cambrian age and the corresponding horizons in Europe and America is found in the works of Frech[3] and Grönwall.[4] The only region requiring further consideration is Bohemia. The faunas of the Abbey Shales and Bohemia have been compared in § VII of this paper (p. 434): it appears evident that the beds in the latter country range over a period equivalent to that of the Abbey Shales, and probably include in their lower portion horizons corresponding to the underlying Upper Purley Shales.

IX. Conditions of Deposition.

The fact that the Abbey Shales are less than a quarter of the thickness of the homotaxial beds of South Wales would seem to imply, at first sight, that they were deposited under deeper-water conditions. A definite opinion on this point can hardly be reached until a more detailed account of the Menevian sediments in Wales is forthcoming. However, in the case of the Abbey Shales themselves, all the evidence points to the fact that the conditions under which they were deposited were rather those of shallow open water than deep sea.

The facts on which this opinion is based have been included in the general description of sediments, and need only a brief recapitulation here. In the first place, the shales which form most of the succession are by no means uniform, but vary rapidly in vertical succession, becoming in some cases fine flagstones. At intervals, thin glauconitic sandstones appear, and many of the coarser fossiliferous beds are impersistent. At Horizon B 2 is a case where two hard shale-bands, when traced along the strike, change within the distance of 5 feet into glauconitic sandstones with abundant fragments of trilobites and brachiopods. Again, the thin limestones, although fairly persistent, change rapidly in thickness along the strike. A good example occurs in Purley-Lane Cutting, at Horizon A 3, where one of these beds changes

[1] Q. J. G. S. vol. lxvii (1911) p. 283. [2] *Ibid.* vol. lxix (1913) p. 45.

[3] F. Frech, 'Lethæa Geognostica: Pt. I—Lethæa Palæozoica' vol. ii, pt. 1 (1897).

[4] K. A. Grönwall, 'Bornholms *Paradoxides*lag' Danmarks Geol. Undersög. ser. 2, no. xiii (1902).

from 1 to 5 inches in thickness within the distance of 15 feet. Further, two surfaces of erosion have been noted, one of which lies within the limits of the shaly series. Whether the Lingulidæ and associated *Acrotreta*, which swarm at certain horizons in the shales, are positive evidence for shallow-water conditions so far back as the Cambrian Period may perhaps be doubted; but the rich trilobite faunas would probably flourish in the waters of a shallow sea where food was abundant.

The conclusion that this area was occupied by shallow water at that period agrees with the results obtained by Mr. E. S. Cobbold in Shropshire,[1] where the Middle Cambrian sediments include calcareous breccias with abundant evidence of contemporaneous erosion.

The more or less continuous deposition came to an end in Upper Paradoxidian times, and was succeeded by a period of erosion, during which the old sea-floor was probably scoured by wave- and current-action or may even have undergone subaërial erosion.

A break in the succession at approximately this horizon seems to have occurred all over England and Wales; for it is a remarkable and suggestive fact that the rich fauna of the *Paradoxides-forchhammeri* Zone of Sweden has never been discovered in this country. In the St. Tudwal's Peninsula in North Wales, Mr. T. C. Nicholas has recently shown that the Maentwrog Beds rest unconformably on the underlying Paradoxidian. As stated elsewhere in this paper (see § VIII, p. 439), the uppermost Nant-pig Mudstones appear to belong to the Lower *davidis* Zone, so that the break in the succession is slightly earlier than at Hartshill. In South Wales, between the *Paradoxides-davidis* Beds and the coarse sandstones of the Lower *Lingula* Flags, occurs a thin series of shales and sandstones containing *Orthis hicksii* and estimated as 100 feet thick.[2] This series has been correlated with the *P.-forchhammeri* Zone of Sweden,[3] but no trilobites belonging to this fauna have been found up to the present. A break has been postulated already in the middle of the Menevian of St. David's by Mr. J. F. N. Green,[4] and it would appear probable that another may be looked for with some confidence between the bands containing *Paradoxides davidis* and the Lower *Lingula* Flags. As has been suggested recently by Mr. G. W. Lamplugh,[5] marine sedimentation is often a discontinuous process; many breaks in the succession are extremely

[1] 'On the Trilobite Fauna of the Comley Breccia-Bed' Q. J. G. S. vol. lxix (1913) p. 41.

[2] R. Harkness & H. Hicks, 'On the Ancient Rocks of the St. David's Promontory, South Wales, & their Fossil Contents' Q. J. G. S. vol. xxvii (1871) p. 384.

[3] C. Lapworth, 'Materials for the Correlation of the Lower Palæozoic Rocks of Britain & Scandinavia' Geol. Mag. dec. 2, vol. viii (1881) p. 321.

[4] 'The Geology of the District around St. David's' Proc. Geol. Assoc. vol. xxii (1911) pp. 125 & 135; J. F. N Green & O. T. Jones, 'Excursion to the St. David's District, South Wales' *ibid.* p. 219.

[5] Discussion on E. S. Cobbold's 'Trilobite Fauna of the Comley Breccia-Bed' Q. J. G. S. vol. lxix (1913) p. 49.

difficult to detect, although it is probable that careful collecting in the best-exposed sections of the Middle Cambrian of North and South Wales will throw much light on the alternation of conditions which prevailed over England and Wales at this period.

X. Conclusions.

1. The Abbey Shales form a thin series, about 90 feet thick, overlying the Purley Shales and constituting the basal beds of the Oldbury Shales.

2. Their importance lies in the fact that they contain a hitherto unsuspected fauna of Paradoxidian age.

3. This fauna contains over fifty different species of trilobites, many of them beautifully preserved, and it has strong affinities with the homotaxial faunas of Sweden and Wales. It is also closely allied with the corresponding fauna of Bohemia.

4. The fauna has been classified as follows:—

Horizon.	Non-sequence.
G 3–G 1.	Upper *Paradoxides-davidis* fauna.
F 3–F 1.	Lower *Paradoxides-davidis* fauna.
E 3–E 1 (pars).	*Hartshillia-inflata* (passage) fauna.
E 1 (pars)–D 1.	Upper *Paradoxides-hicksii* fauna.
C 3–B 1.	Lower *Paradoxides-hicksii* fauna.
A 4–A 1.	*Paradoxides-aurora* fauna.

5. The succession is similar to the Menevian and Upper Solva Beds of South Wales. The Abbey Shales are also equivalent to the *Paradoxides-davidis* and the Upper, Middle, and part of the Lower *P.-tessini* Subzones of Sweden; while the upper beds of the underlying Purley Shales appear to correspond to the rest of the *P.-tessini* and the *P.-ölandicus* Zones.

6. The main mass of the beds consists of shales, but thin sandstones and limestones containing glauconite and phosphates occur frequently, and the deposits seem to have been formed in the waters of a shallow open sea.

7. The Lower *Lingula* Flags appear to be separated from the *Paradoxides-davidis* Beds by a break in the sequence. No equivalent of the *P.-forchhammeri* Zone has been found, and a widespread break in the succession over a large part, if not all, of Great Britain appears probable at about this horizon.

In my work on this area, extending over a period of three years, I have been constantly helped by the enthusiastic collecting of my father, Mr. T. Illing, to whose untiring search much of the best material is due. The cost of excavation has been defrayed by grants from the Excavation Committee of the British Association.

Finally, it is a very pleasant duty to acknowledge my indebtedness to the host of friends who have helped me with heir interest, criticism, and advice. To Prof. W. W. Watts my hanks are due for helpful suggestions in the preparation of the

paper; and to Prof. W. G. Fearnsides I owe my first training in geological investigation. Prof. W. S. Boulton kindly lent me the two specimens from Birmingham University; while to Mr. T. C. Nicholas and to Mr. J. Pringle I am indebted, among other matters, for guiding me over the St. Tudwal's Peninsula and Porth-y-rhaw, respectively. In addition, I have been greatly helped by Dr. A. M. Davies, Mr. H. H. Read, Dr. P. G. H. Boswell, and others, at the Royal School of Mines; I desire also to render my thanks to Mr. G. S. Sweeting for aid in the preparation of the manuscript.

EXPLANATION OF PLATES XXVIII–XXXVIII.

PLATE XXVIII.

Fig. 1. *Agnostus exaratus* Grönwall. × 8. Horizon G 3. (See p. 405.)
2. Do. do. , var. *tenuis* nov. A rather young specimen, showing the short axis and expanding lateral lobes. × 8. Horizon D 3. (See p. 406.)
3. Do. do. do. The specimen shows clearly the parallel-sided glabella. × 8. Horizon D 3.
4. Do. do. do. A tail of a large specimen, differing from the usual type in the shape of the lateral lobes. × 5. Horizon D 3.
5. Do. do. do. A mutational form from the upper beds, showing the constriction near the posterior portion of the tail-axis. × 5. Horizon F 3.
6. *Agnostus fissus* Lundgren. × 5. Horizon D 3. (See p. 406.)
7. Do. do. A specimen from the lower beds, showing the subquadrate anterior glabellar lobe. × 5. Horizon D 2.
8. Do. do. A large specimen with furrowed surface, showing the large anterior glabellar lobe of low-zone forms. × 5. Horizon D 3.
9. Do. do. , var. *perrugatus* Grönwall. Head. × 5. Horizon F 3. (See p. 407.)
10. *Agnostus* cf. *incertus* Brögger. A broken specimen of the tail without spines. × 4. Horizon F 2. (See p. 407.)
11. *Agnostus* cf. *intermedius* Tullberg. A rather convex tail. × 5. Horizon C 2. (See p. 408.)
12. Do. do. A somewhat flattened specimen. × 5. Horizon C 1.

PLATE XXIX.

Fig. 1. *Agnostus* cf. *nathorsti* Brögger. A small tail; the spines are not well shown in the figure. × 5. Horizon G 3. (See p. 408.)
2. *Agnostus punctuosus* Angelin. × 5. Horizon G 3. (See p. 409.)
3. Do. do. The tail of a young form. × 5. Horizon F 2.
4. *Agnostus corrugatus*, sp. nov. Showing the furrowed head and granulate tail. × 5. Horizon D 3. (See p. 409.)

Fig. 5. *Agnostus corrugatus*, sp. nov. The surface of the tail is almost smooth. × 5. Horizon B 3. (See p. 409.)
6. Do. do. A flattened specimen. × 5. Horizon D 3.
7. Do. do. A specimen showing clearly the segmentation of the glabella and tail-axis. × 5. Horizon D 3.
8. Do. do. A flattened form with strong surface-markings. × 5. Horizon D 3.
9. Do. do. Specimen showing the obliteration of the markings on the head characteristic of larger forms. × 5. Horizon D 3.
10. *Agnostus gracilis*, sp. nov. × 5. Horizon D 3. (See p. 410.)
11. Do. do. The anterior lobe of the glabella is partly obliterated. × 5. Horizon D 3.
12. Do. do. The anterior lobe of the glabella is almost wholly obliterated. × 5. Horizon D 3.
13. Do. do. A large tail showing the increased length of the axis. × 5. Horizon D 3.

Plate XXX.

Fig. 1. *Agnostus pulchellus*, sp. nov. Head. × 5. Horizon F 1. (See p. 410.)
2. Do. do. Tail. × 5. Horizon F 1.
3. *Agnostus sulcatus*, sp. nov. Showing the tail-spines. × 5. Horizon D 3. (See p. 411.)
4. Do. do. The subglobose shape of the anterior glabellar lobe is well shown. × 5. Horizon C 1.
5. Do. do. A large specimen showing the broad tail-axis. × 5. Horizon D 3.
6. Do. do. Shows the segmentation of the tail-axis, and granulate surface. × 5. Horizon D 3.
7. *Agnostus triangulatus*, sp. nov. A small specimen. × 5. Horizon D 3. (See p. 412.)
8. Do. do. Another specimen. × 5. Horizon D 3.
9. *Agnostus altus* Grönwall. A well-preserved tail, rather convex. × 5. Horizon F 2. (See p. 412.)
10. Do. do. A flattened specimen, with the axis almost obliterated. × 5. Horizon F 3.
11. *Agnostus barlowi* Belt, var. *spinatus* nov. Tail with well-preserved spines. × 5. Horizon C 2. (See p. 413.)
12. Do. do. do. Tail, showing the prominent elongate medial tubercle. × 5. Horizon C 1.
13. *Agnostus barrandei* Salter. × 5. Horizon D 3. (See p. 413.)
14. Do. do. A very convex form. × 5. Horizon D 3.

Plate XXXI.

Fig. 1. *Agnostus bibullatus* Barrande. Head and tail separated, showing the medial tubercle on the latter. × 5. Horizon F 2. (See p. 413.)
2. *Agnostus glandiformis* Angelin. × 5. Horizon G 3. (See p. 414.)
3. *Agnostus lens* Grönwall. Whole specimen. × 5. Horizon F 2. (See p. 414.)
4. Do. do. Showing the glabellar furrows and small tubercles. × 5. Horizon F 1.
5. Do. do. Head with well-marked basal lobes. Furrows almost obliterated. × 5. Horizon F 2.

Fig. 6. *Agnostus lens* Grönwall. Tail, showing the usual shape of the axis. × 5. Horizon F 1. (See p. 414.)
7. Do. do. Tail, more constricted at the anterior third than the usual type. × 5. Horizon F 1.
8. *Agnostus nudus* (Beyrich). × 5. Horizon C 2. (See p. 415.)
9. Do. do. , var. *ovalis* nov. Head. × 5. Horizon F 3. (See p. 415.)
10. Do. do. do. Tail. × 5. Horizon F 3.
11. *Agnostus rotundus* Grönwall. Tail. × 5. Horizon G 3. (See p. 416.)
12. *Agnostus fallax* Linnarsson. Head. × 5. Horizon F 2. (See p. 416.)
13. Do. do. Tail with well-developed spines. × 5. Horizon D 3.
14. Do. do. Tail flattened, with axis more tapering than the usual type. × 5. Horizon D 2.
15. Do. do. A flattened form, with less tapering axis than the preceding. × 5. Horizon F 2.

Plate XXXII.

Fig. 1. *Agnostus integer* (Beyrich). × 5. Horizon D 3. (See p. 416.)
2. Do. do. A more convex specimen, with very globose posterior glabellar lobe. × 5. Horizon D 3.
3. Do. do. A young specimen, showing a smaller tail-axis. × 10. Horizon D 3.
4. Do. do. Tail of large specimen. × 5. Horizon D 3.
5. Do. do. A head from a lower horizon, with a small anterior glabellar lobe. × 5. Horizon C 2.
6. *Agnostus kjerulfi* Brögger. Tail and thorax. × 5. Horizon G 2. (See p. 417.)
7. *Agnostus lobatus*, sp. nov. Tail with one of the spines faintly indicated. × 5. Horizon C 2. (See p. 418.)
8. Do. do. A larger tail, showing the segmentation of the axis. × 5. Horizon B 3.
9. *Agnostus* sp. Head, showing the deep dorsal furrows and subglobose basal lobes. × 5. Horizon C 2. (See p. 418.)
10. *Agnostus parvifrons* Linnarsson. Head. × 5. Horizon D 2. (See p. 422.)
11. *Agnostus granulatus* Barrande. Tail, with spines partly broken off. × 5. Horizon F 2. (See p. 419.)
12. Do. do. Complete specimen. × 5. Horizon F 1.
13. Do. do. Flattened head. × 5. Horizon F 2.
14. *Agnostus regius* Sjögren, var. *globosus* nov. Tail, showing the convex axis. × 5. Horizon C 2. (See p. 419.)
15. *Agnostus rex* Barrande. Head. × 5. Horizon C 2. (See p. 420.)
16. Do. do. Tail. × 5. Horizon C 2.
17. Do. do. Smaller tail, showing the absence of expansion at the posterior end of the axis. × 5. Horizon B 3.

Plate XXXIII.

Fig. 1. *Agnostus rex* Barrande. Complete specimen. × 5. Horizon C 2.
2 *a*. *Agnostus bifurcatus*, sp. nov. Complete specimen, showing the long tail-spines; the glabella not well preserved. × 5. Horizon G 3. (See p. 421.)
2 *b*. Do. do. Profile of the tail of the same.
Figs. 3 *a* & 3 *b*. Do. do. Smaller form, with well-marked glabella. × 5. Horizon G 3.—Fig. 3 *b*. Profile.

Fig. 4. *Agnostus tuberculatus*, sp. nov. Head. × 5. Horizon D 3. (See p. 421.)

5. Do. do. Tail, with spines well preserved. × 5. Horizon D 3.

6. Do. do. A somewhat flattened tail, showing the granulate surface. × 5. Horizon D 3.

7 *a*. Do. do. Complete specimen. × 5. Horizon D 3.

7 *b*. Do. do. Lateral view of the same.

8. Do. do. Head, showing posterior lateral spines. × 5. Horizon D 3.

9. *Microdiscus punctatus* Salter. Internal cast of head; the nuchal spine partly broken away. × 5. Horizon E 3. (See p. 423.)

10. Do. do. Cast of external punctate surface, with long posterior spines. × 5. Horizon F 3.

11 *a*. *Microdiscus punctatus*, var. *scanicus* Linnarsson. Mould of external punctate surface. × 8. Horizon E 3. (See p. 423.)

11 *b*. Do. do. do. Cast of internal surface of the same specimen. × 8.

11 *c*. Do. do. do. Side view of the same.

12. Do. do. do. Cast of internal surface, showing the crenulate margin of the head. × 5. Horizon D 3.

PLATE XXXIV.

Figs. 1 *a* & 1 *b*. *Hartshillia inflata* (Hicks), gen. nov. Groups of specimens, showing the method of preservation.—Fig. 1 *a*. × 4. Horizon E 3.—Fig. 1 *b*. × 3. Horizon E 1. (See p. 424.)

Fig. 2. Do. do. Head, showing an extremely-strong nuchal spine. From lower beds. × 3. Horizon C 2.

3. Do. do. Head, with a more slender nuchal spine, characteristic of Horizon E. × 3. Horizon E 3.

4. Do. do. Thorax and tail. × 3. Horizon D 3.

5. Do. do. Tail. × 4. Horizon E 2.

6. *Hartshillia spinata*, sp. nov. Thorax and tail. × 3. Horizon F 2. (See p. 425.)

7. Do. do. Showing the head with one short glabellar furrow, a portion of the thorax, and the tail. × 3. Horizon F 2.

8. *Holocephalina primordialis* Salter. Small head, showing the border and faint glabellar furrows. × 4. Horizon G 3. (See p. 426.)

9. Do. do. Head of a larger specimen, showing the granulate surface, and the tubercle on the neck-ring. × 4. Horizon G 3.

PLATE XXXV.

Fig. 1. *Conocoryphe bufo* Salter. Head of a young specimen. × 4. Horizon A 4. (See p. 425.)
2. Do. do. Head of a mature form. × 3. Horizon A 4.
3. Do. do. Tail. × 4. Horizon A 4.
4. *Holocephalina incerta*, sp. nov. × 3. Horizon E 1. (See p. 427.)
5. Do. do. Specimen showing an extremely-small glabella, and punctate fixed cheeks. × 3. Horizon E 1.
6. Do. do. Almost complete specimen; the fixed cheeks show the venulose markings; one fixed cheek also is present. × 3. Horizon E 1.
7. Do. do. Small, almost complete specimen. × 3. Horizon E 1.
8. *Paradoxides aurora* Salter. Head. × 3. Horizon A 4. (See p. 427.)
9. *Paradoxides davidis* Salter. Hypostome, showing the characteristic surface-markings. Natural size. Horizon G 3. (See p. 428.)
10. Do. do. Pleuræ. × 1½. Horizon G 3.
11. Do. do. Portion of the tail and posterior pleuræ. Natural size. Horizon G 3.

PLATE XXXVI.

Fig. 1. *Paradoxides hicksii* Salter. × 2. Horizon D 3. (See p. 428.)
2. Do. do. Head of young form, showing the ridge between the glabella and the anterior margin. × 5. Horizon D 3.
3. Do. do. Head of a medium-sized specimen. × 3. Horizon D 3.
4. Do. do. Head of a larger individual. × 2. Horizon D 3.
5. Do. do. Free cheek. × 3. Horizon D 3.
6. Do. do. Tail. × 3. Horizon D 3.
7. Do. do. (?) Tail; broader than the usual type. × 4. Horizon A 4.
8. *Paradoxides* sp. nov. Head, without free cheeks. Natural size. Horizon A 4. (See p. 429.)
9. *Paradoxides rugulosus* Corda. Portion of tail and posterior pleuræ. Natural size. Horizon G 3. (See p. 429.)
10. Do. do. Portion of head, showing the elongate eye. × 2. Horizon F 1.

PLATE XXXVII.

Fig. 1. *Corynexochus pusillus*, sp. nov. Head. × 8. Horizon B 3. (See p. 431.)
2. Do. do. Portion of the head, showing glabellar furrows. × 8. Horizon B 3.
3. *Centropleura henrici* (Salter). Portion of thorax. Natural size. Horizon G 3. (See p. 430.)
4. *Centropleura pugnax*, sp. nov. × 4. Horizon D 3. (See p. 430.)
5. *Agraulos* sp. × 4. Horizon F 2. (See p. 431.)
6. *Liostracus elegans*, sp. nov. Almost complete specimen. Nuchal spine broken. × 3. Horizon D 1. (See p. 432.)
7 *a*. Do. do. Nuchal spine, broken, from the head. × 3. Horizon C 2.
7 *b*. Do. do. Side view of head of the same.

Fig. 8. *Solenopleura applanata* Salter. Specimen almost complete, showing the well-marked eye-lines. × 3. Horizon D 3. (See p. 432.)
9. Do. do. Head. × 2. Horizon D 3.
10. *Solenopleura* cf. *applanata* Salter. Head. × 4. Horizon F 1. (See p. 433.)

PLATE XXXVIII.

Geological map of the Atherstone & Nuneaton District, on the scale of $3\frac{1}{16}$ inches to the mile, or 1 : 16091.

DISCUSSION.

Prof. C. LAPWORTH commented on the extreme geological interest of the palæontological work accomplished by the Author, and the clear, modest, and convincing way in which he had presented and illustrated his discoveries and correlations to the meeting. The Birmingham geologists, who originally demonstrated the Cambrian age of the Nuneaton rocks, and worked out and named (1881–1898) their major divisions since generally accepted, discovered but few fossils in these rocks; and the correlation (1898) of the lowest formation, the Hartshill Quartzite, etc., with the *Olenellus* Zone or Lower Cambrian, of the Purley Shales with the Paradoxidian or Middle Cambrian, and of the Oldbury Shales with the *Lingula* Flags, was, and remained for some years, general inference drawn from the fossils then already obtained, and those by no means the most characteristic genera. The highest formation, the Merevale Shales, it is true, had its horizon definitely fixed by the detection within it of *Dictyonema* during Dr. Strahan's remapping of the area for H.M. Geological Survey.

It was a striking example of the reliability of even inconspicuous and little-known forms, as indices of geological age, that within the last few years the characteristic genus *Callavia* had been discovered by Mr. Pringle and the Author in the formation inferred to be the *Olenellus* Zone or Lower Cambrian; and forms of *Paradoxides* had been found by the Author in the beds inferentially set down as Paradoxidian or Middle Cambrian. But it was still more welcome, and indeed almost startling, to learn of the existence in the apparently-unpromising Nuneaton deposits of so rich and varied a fauna as that described by the Author from these Abbey Shales, to which now for the first time, on the evidence of their fauna, had been assigned their true importance and their proper place as a member of the local Middle Cambrian. The Author's discoveries went far in the direction of indicating that the day is not far distant when the Midland Nuneaton area, so simple and definite in its lithology and its stratigraphy, may perhaps become a British standard; and that species and varieties of trilobites may eventually serve as the means of correlating the many widely-scattered Cambrian deposits which occur in what, for the sake of distinction, may be called the Atlantic Province (including the Baltic region, Central Europe, and

Britain, Newfoundland, Nova Scotia, and the eastern parts of the United States), in contrast with the Pacific Province of the Rocky Mountains, Siberia, China, Indo-China, and Western Australia, so conspicuous in recent palæontological literature.

The name Paradoxidian (Middle Cambrian) was originally proposed (1880) to include Hicks's Menevian and Solva groups and their equivalents; and of late years proofs had been accumulating that this grouping was the most natural one, and that the Menevian and the Solvian must be distinguished in our maps and fossil collections. The non-conformity recognized by the Author at the base of the Abbey Shales proper marked possibly the local boundary between the two, and corresponding phenomena and the faunal distinction were known elsewhere.

Aside from its geological importance, it was most pleasant to welcome the results of detailed work so enthusiastically and fully carried out as that of the Author, and to learn that he had been greatly aided in that work by a grant from the Excavation Committee of the British Association.

Prof. W. G. Fearnsides also wished to congratulate the Author on his completion of this important first instalment of the results which he had obtained at Hartshill. As a member of the same Cambridge College, he was proud to be able to claim the Author as his pupil.

Prof. Lapworth had testified to the worth of the detailed palæontological and stratigraphical researches which are represented by the paper; and the speaker, while agreeing with all that had been said on that subject, wished also to emphasize the importance of the field-work involved. Field-work had come before, and had made practicable, the proving by actual excavation of the detailed palæontological succession which is described in the paper; and, to the speaker, the large-scale map exhibited was as much an integral and necessary portion of the paper as were the illustrations of the fossils themselves.

Respecting the breaks in the continuity of the deposition, he was glad that the Author had accepted the non-committal term 'non-sequence.' The phenomena observed at these surfaces of discontinuity seem to the speaker quite analogous with the 'Korrosionsgruppar' described by Dr. Gunnar Andersson and others as characteristic of many non-sequential planes among the Cambrian and Lower Ordovician rocks of Scandinavia. Having these in mind, the speaker enquired—what precisely did the Author mean when he spoke of these Paradoxidian beds as of shallow-water origin? If by 'shallow' the Author meant to indicate deposition upon a continental shelf, just within the range of tidal scour and drag, then the speaker would agree with him. If, on the other hand, the term 'shallow water' was meant further to imply that the deposit was laid down close to the shore and under littoral conditions, then, in the opinion of the speaker, the weight of evidence—petrographical, palæontological, and stratigraphical—lay all on the other side.

The PRESIDENT (Dr. A. SMITH WOODWARD) congratulated the Author on his first contribution to the Society, and expressed special interest in his account of the reappearance of some species with the repetition of certain types of rock.

The AUTHOR, in reply, stated that he had given the example of *Agnostus rex* and *A.* cf. *intermedius* alternating with the changing physical conditions as a typical instance, though it was by no means the only case that occurred in the succession. He was in agreement with Prof. Fearnsides in laying stress on the fact that the conditions of deposition were those of open water, with oceanic currents supplying adequate food to the teeming marine population; although it did not appear to him that the depth was very great. In conclusion, he wished to thank the Fellows present for their kind reception of his paper.