17. *The* Olenellus Zone *in the* North-west Highlands of Scotland.

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[Communicated by permission of the Director-General of the Geological Survey.]

[Plate V.]

Contents.

While tracing the various subdivisions of the Durness Series of quartzites and limestones from Sutherland southwards into Ross-shire, careful attention has been paid to any indications of fossiliferous zones which might throw additional light on the age of the strata. During last season's campaign, certain sections in the Dundonnell Forest happily furnished the evidence which has been eagerly sought after.

§ 1. Physical Features of the Dundonnell Forest.

Between Little Loch Broom and Loch Maree the members of this series traverse one of the wildest tracts in the west of Ross-shire. The Dundonnell Forest lies mainly to the south of the head of Little Loch Broom, stretching southwards by An Teallach (3483 ft.) to Loch an Nid and Creag Rainich (2646 ft.). The southern portion of the Forest is drained by the Loch an Nid river, which, finding its source in the loch of that name, flows northwards for about three miles towards the shooting-lodge of Achneigie. The river is bounded on the east for part of this distance by a precipitous crag (1000 ft. high), and on the west by the long dip-slopes of quartzite and Torridon Sandstone of Sgurr Ban (3194 ft.) and Ben a Chlaidheimh. Near Achneigie the river bends towards the north-west, soon pouring its waters into Loch na Sheallag. From this loch issues the Gruinard river, discharging into Gruinard Bay.

The sections from which the fragments of *Olenellus* were obtained occur along the eastern slope of the valley drained by the Loch an Nid river, between Loch an Nid and Achneigie. Though there is here conclusive evidence of the continuation of those terrestrial displacements described in a former communication to this Society,[1] the area is comparatively free from those extreme complications

[1] 'Report on the Recent Work of the Geological Survey,' &c., Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 378.

so characteristic of the region between Assynt and Loch Eriboll. Owing to the admirable exposures on the mountain-slopes and to the well-nigh continuous sections in some of the streams the relations of the strata are clearly displayed.

§ 2. General Geological Features.

In this portion of the Dundonnell Forest the basal quartzites rest with a marked unconformability on the Torridon Sandstone, which is admirably defined on the dip-slopes of Sgurr Ban and Ben a Chlaidheimh. Bed after bed of the underlying Torridon Sandstone is transgressed by the pebbly grit at the base of the quartzites. Here, as elsewhere, the evidence plainly demonstrates that, prior to the deposition of the quartzites, the older rocks were elevated, gently inclined, and subsequently worn down to a great plane of marine denudation (see fig. 2, p. 233).

From the base of the quartzites there is an unbroken sequence, in certain sections, either to the 'Serpulite Grit' or to the basal bands of the Durness Limestone. At these horizons the fossiliferous strata are truncated by a powerful thrust, which, at Loch an Nid, brings forward a slice of Archæan rocks with the Torridon Sandstone and basal quartzites, forming one of the striking geological features of the district. The fragments of *Olenellus* were discovered in the undisturbed area to the west of this important structural line.

§ 3. Allt Righ Ian Section.

The locality where the fossiliferous dark blue shales in the 'Fucoid Beds' were first observed while mapping this part of the Forest, and where portions of *Olenellus* were first found by Mr. Macconochie, occurs in a small stream on the eastern side of the valley, joining the Loch an Nid river about half a mile to the east of Achneigie. Rising in the drift-clad plateau formed by the eastern schists, the Allt Righ Ian furnishes, in the lower part of its course, a continuous section of certain members of the Durness Series. From the materials brought down during heavy floods a great cone has been formed at the mouth of this burn on the right bank of the river.

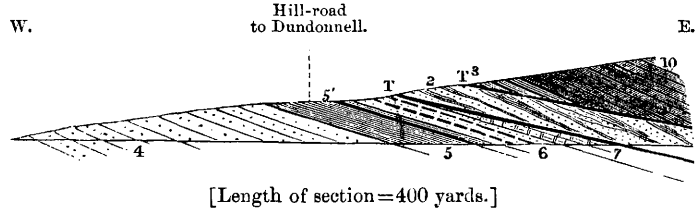
Joining the burn at the head of this cone, the passage-beds between the basal quartzites and the overlying 'Pipe-Rock' are exposed. Ascending the section, all the various sub-zones of the 'Pipe-Rock'[1] are met with, followed in regular order by the 'Fucoid Beds.' Here the burn has cut a small gorge in the brown dolomitic shales and bands of rusty dolomite forming the lower part of this zone. Just above the point where the burn is crossed by the hill-road between Dundonnell and Achneigie, the upper portion of the 'Fucoid Beds' is seen. Owing to a slight fall in the slope of the ground, the stream has carved for a short distance above the

[1] See Vertical Section II. of Durness Series, Quart. Journ. Geol. Soc. vol. xliv. (1888) p. 406.

mountain-path a broader channel, which is partly filled with gravel, particularly after a heavy rainfall. For this reason the higher members of the zone are not so well exposed.

At this part of the section the attention of the observer is at once arrested by two prominent bands of dark blue shale, intercalated in the normal dolomitic beds of the zone. The upper band is about 3 feet and the lower one about 9 feet from the top of the 'Fucoid Beds.' Some of these dark blue shales are slightly calcareous and are traversed by small worm-casts. The fragments of *Olenellus* were found in the lower band, the best specimens being confined to a seam less than an inch thick.

Fig. 1.—*Section in Allt Righ Ian, from the base of the 'Pipe-Rock' to the Moine thrust-plane.*



[Length of section = 400 yards.]

2. Thrust Torridon Sandstone.
4. 'Pipe-Rock.'
5. 'Fucoid Beds.'
5'. *Olenellus* Zone in 'Fucoid Beds.'
6. 'Serpulite Grit.'
7. Basal Bands of Durness Limestone.
10. Eastern schists.

T. Glen Logan Thrust.
T^3. Moine Thrust.

The upper limit of the 'Fucoid Beds' is well defined, the base of the 'Serpulite Grit' forming a small cascade over which the stream leaps on to the softer beds below. Along certain lines, the higher zone, which here consists of a massive grit, is crowded with *Serpulites Maccullochii* (*Salterella*) in splendid preservation.

From the base of the 'Pipe-Rock' to the highest visible portion of the 'Serpulite Grit,' the strata have a persistent dip to the south of east at an average angle of 16°; the total thickness of beds amounting to 400 feet.

The normal sequence of the Durness Series is here interrupted by a powerful thrust, already referred to as one of the striking geological features of the district, which brings forward a thin wedge of Torridon Sandstone, through which the stream has cut a small gorge. Though changed in tint and considerably crushed, this mass can be readily identified after a careful study of the geological structure of the region. When traced southwards in the direction of Loch an Nid, this slice of Torridon Sandstone increases in thickness and is seen to rest unconformably on undoubted Archæan rocks. Within a short distance to the east, in Allt Righ Ian, the crushed Torridon

Sandstone is truncated by the Moine Thrust which ushers in the Eastern Schists.

§ 4. Sections north of Allt Righ Ian.

Immediately to the north of Allt Righ Ian the strata between the higher zones of the 'Pipe-Rock' and the basal bands of the Durness Limestone are admirably displayed in several important stream-sections. They are of special interest from the excellent exposures of the *Olenellus* shales and from the organisms found in the dolomitic bands associated with the dark blue shales. No fragments of trilobites have as yet been found in these sections, partly owing to the difficulty of following the fossiliferous layer along the line of outcrop.

One of these streams (unnamed on the six-inch map) rises on the moory watershed between Allt Coire Chaorachain (draining into Strath Beg) and Strath na Sheallag. About a mile to the north of Allt Righ Ian it is crossed by the hill-road leading to Dundonnell, whence it flows southwards for $\frac{2}{3}$ mile, where it is joined by a small tributary (Allt a Chip). Here the main stream is deflected to the south-west, joining the Loch an Nid river near the mouth of Allt Righ Ian.

Ascending Allt a Chip from the point of junction with the main stream, where the lowest sub-zone of the 'Pipe-Rock' is seen resting on the basal quartzites, an excellent section is exposed in the sides of a small gorge. The various sub-zones of the 'Pipe-Rock' are overlain by the 'Fucoid Beds,' the two bands of dark blue shale occupying their respective horizons near the top of the zone and separated by the normal dolomitic beds. Here their thickness can be accurately measured on the sides of the chasm; that of the upper being 3 feet and the lower 19 inches. A layer of rusty dolomite about a foot thick, overlying the lower band of dark blue shale, was found to be crowded with excellent specimens of *Hyolithes*, sp.

Returning to the main stream of which Allt a Chip is an affluent, the observer crosses a similar succession of strata as he follows the section towards the watershed. Here again both layers of dark blue shales are visible near the top of the 'Fucoid Beds,' the upper one cropping out at the base of a small waterfall formed by the overlying 'Serpulite Grit.' A few yards below this latter locality numerous serpulites (*Salterella*) were observed in a brown dolomitic band associated with the *Olenellus* shales. Crossing the 'Serpulite Grit' there is an excellent exposure of the basal bands of the overlying Durness Limestone, forming a prominent cliff on the east bank of the stream about 300 yards to the south of the point where it is traversed by the hill-road leading to Dundonnell. Here the top of the 'Serpulite Grit' passes below black shaly limestone, 4 feet in thickness, succeeded by 15 feet of dark mottled limestone. The black limestone-shales, weathering with a brown tint, are slightly cleaved, but they are crowded with splendidly-preserved specimens

of *Serpulites Maccullochii* (*Salterella*) which are readily seen on the weathered surfaces. These beds forming the base of Group I. of the Durness Limestone Series[1] are truncated by the thrust traversing Allt Righ Ian, bringing forward a wedge of Torridon Sandstone which is here only 15 feet thick.

§ 5. Sections near Loch an Nid.

The locality where the trilobites were found in the zone of the 'Serpulite Grit' is near Loch an Nid, about eight miles to the N.N.E. of Loch Maree.

For nearly two miles to the north of Loch an Nid, the quartzites form prominent escarpments on the eastern side of the valley and rise to a height of several hundred feet above the level of the stream. Ascending the rocky slope to the horizon of the highest zones of the 'Pipe-Rock' the observer finds a narrow belt of bright-green grassy ground, formed by the surface-soil of the decomposing 'Fucoid Beds' and partly covered with morainic matter. The overlying 'Serpulite Grit' gives rise to a more or less continuous escarpment, disappearing at intervals underneath a thin coating of drift or surface-soil. At this level the attention is at once arrested by a conspicuous geological feature, forming one of the great structural lines on the eastern side of the valley. By means of a powerful thrust a slice of Archæan rocks, covered unconformably by the Torridon Sandstone and basal quartzites, is made to overlie the members of the Durness Series. This line of disruption, which is the northern continuation of the well-known thrust-plane in Glen Logan near Kinlochewe, can be traced with remarkable precision along the mountain-slope east of the Loch an Nid river. The materials immediately overlying the thrust-plane form a prominent cliff, over which, after a heavy rainfall, numerous rivulets leap on to the members of the Durness Series. Many of these streamlets are not indicated on the six-inch Ordnance map, but they are of especial importance, on account of the excellent sections of the strata close to the line of displacement.

Immediately to the north of Loch an Nid there are three small streams traversing this escarpment of disrupted gneiss. The first of these is about 250 yards distant from the northern shore of Loch an Nid; after crossing the Glen Logan thrust-plane it descends a grassy slope to the underlying quartzites, joining the river below a fine waterfall near the mouth of the loch. As this stream is indicated on the six-inch Ordnance map, it forms a base-line for measuring the distance to the section which now falls to be described.

About 200 yards north of the above-mentioned rivulet there is a small section of especial interest at the base of the escarpment of displaced Archæan gneiss. It traverses the 'Serpulite Grit' and the top of the 'Fucoid Beds,' the underlying strata being concealed

[1] See our Report on the Geology of the North-west of Sutherland, 'Nature,' vol. xxxi. p. 31.

by materials carried down during heavy floods and by morainic matter. The following vertical section, measured with an Abney level, is exposed in the small escarpment cut by this streamlet.

		feet.	inches.
Zone of 'Serpulite Grit.'	Grey quartzose grit	18	—
	Flaggy grits, with intercalated shales	7	—
	Grey shales	1	—
	Dark blue shales containing *Olenellus*	0	8
	Grey grit	2	—
	Dark grey shales	1	6
	Grey quartzite	7	3
Top of 'Fucoid Beds.'	Brown dolomitic shales, with bands of dark shales	5	3

In the dark-blue fossiliferous shales we obtained a head-shield and other fragments of *Olenellus* in fine preservation. These shales are underlain by grey grits and quartzites forming the lower portion of the escarpment of the 'Serpulite Grit.' When traced southwards along the hill-slope, the upper and lower ledges of quartzose grit coalesce and form a prominent escarpment overlying the 'Fucoid Beds.'

About 100 yards to the south of the foregoing section, a fragment of *Olenellus* was found by Mr. Macconochie in a dark shale in the 'Fucoid Beds,' exposed in a streamlet not far below the cliff of disrupted gneiss.

For nearly ½ mile to the north of Loch an Nid, the 'Serpulite Grit' is overlain by a few feet of the basal bands of the Durness Limestone, forming the lower plane or 'sole' of the Glen Logan thrust. The limestone is not visible in all the streamlets within the foregoing limits, but where it is exposed and not much altered by the displacement of the overlying materials, serpulites (*Salterella*) occur in fine preservation.

The geological structure of the disrupted masses overlying the Glen Logan thrust-plane along this portion of the Loch an Nid Craig is of absorbing interest. But the description of these complications is foreign to the main object of this paper. It is sufficient for our present purpose to state that these displaced masses are abruptly truncated at a higher level by the Moine thrust, which forms the second great structural feature of this magnificent crag.

§ 6. Comparison of the Zones of the Durness Series, exposed in the Dundonnell Forest, with their Prolongations to the north and south of that region.

The discovery of *Olenellus* in the 'Fucoid Beds' and 'Serpulite Grit' suggests certain interesting questions regarding the probable variation of the subdivisions of the Durness Series along the belt between Loch Eriboll and Strome Ferry. One striking result of the tracing of the various zones from Sutherland southwards into Ross-shire is the remarkable persistence of the sub-zones identified in Assynt and at Loch Eriboll.

Beginning with the basal quartzites (from 200 to 300 feet in thickness) they preserve the same character along the whole line. They consist of flaggy false-bedded grits and quartzites, with occasional

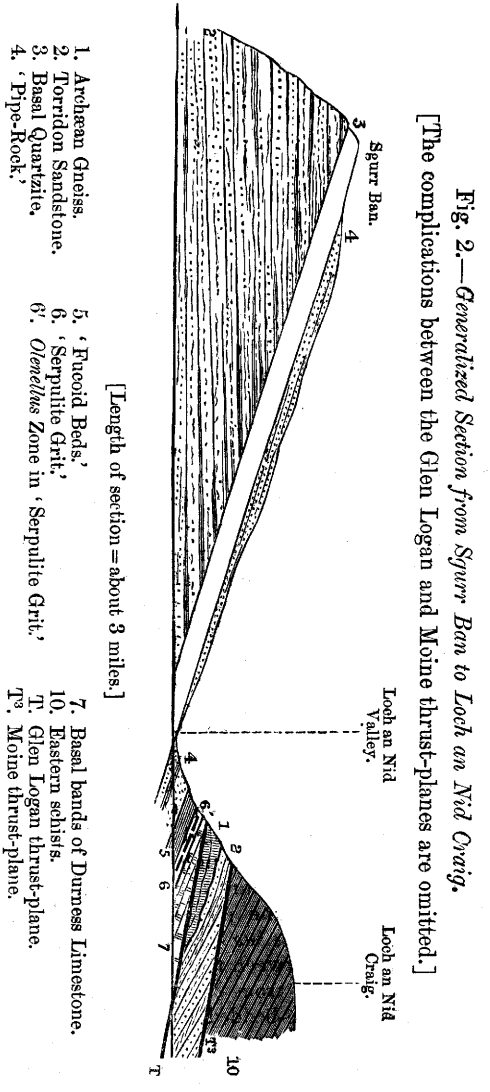


Fig. 2.—*Generalized Section from Sgurr Ban to Loch an Nid Craig.*

[The complications between the Glen Logan and Moine thrust-planes are omitted.]

1. Archæan Gneiss.
2. Torridon Sandstone.
3. Basal Quartzite.
4. 'Pipe-Rock.'
5. 'Fucoid Beds.'
6. 'Serpulite Grit.'
6'. *Olenellus* Zone in 'Serpulite Grit.'
7. Basal bands of Durness Limestone.
10. Eastern schists.
T. Glen Logan thrust-plane.
T3. Moine thrust-plane.

[Length of section = about 3 miles.]

partings of shale, which are destitute of those worm-casts so characteristic of the overlying zone. One exception seems to have been found to this apparent absence of organic life. In the course of last season

one of us observed along the crest of the ridge between Sgurr Ban and Ben a Chlaidheimh, on the west side of the Loch an Nid valley, vertical worm-casts in a band of quartzite belonging to this zone. In the Ben Eay Forest, south of Loch Maree, certain dark grey shales, which may probably yield organic remains at some future time, occur near the base of the series.

The overlying zone of 'Pipe-Rock,' from 250 to 300 feet thick, displays in the Dundonnell Forest the five sub-zones so typical of this subdivision in Assynt and the regions northwards to Loch Eriboll.[1] They have been traced southwards through the mountainous region south of Loch Maree towards Loch Kishorn. The sub-zones are based on the peculiar features of the vertical burrows in the quartzite, which are probably due to different species of errant annelids.

At the top of the third sub-zone on Ben Arkle, Sutherlandshire, numerous examples of *Serpulites Maccullochii* (*Salterella*) were observed in massive quartzite free from the vertical worm-burrows. A band possessing the same lithological characters, and occupying the same relative position, has been noted in certain sections in Assynt and to the south of Loch Maree, but hitherto it has yielded no serpulites.

The 'Fucoid Beds,' varying from 50 to 80 feet in thickness, are remarkably uniform in character when traced along the belt southwards from Loch Eriboll. Consisting mainly of brown dolomitic shales with bands of rusty dolomite, they are traversed by numerous worm-casts, usually flattened and resembling fucoidal impressions, a resemblance which misled the older observers. But between Little Loch Broom and Loch Kishorn dark blue shales near the top of the zone have been observed at various localities evidently occupying the same horizon as the *Olenellus* Shales in the Dundonnell Forest. Our colleague, Mr. Gunn, has traced these dark blue shales across the *col* from Strath na Sheallag into Allt Gleann Chaorachain, towards Strath Beg. They have been observed in Glen Logan, near Kinlochewe, and on Meall Giubhais to the south of Loch Maree. Another officer of the Geological Survey, Mr. Lionel Hinxman, has also detected them at the top of the 'Fucoid Beds,' in the thrust-area that occupies the pass between Glen Kishorn and Tulloch in Strath Carron. It is not improbable that the *Olenellus* Shales may yet be traced continuously through a great part of Ross-shire.

Of special interest is the occurrence of *Serpulites Maccullochii* (*Salterella*) and *Hyolithes*, in fine preservation, in brown dolomitic bands associated with the *Olenellus* Shales near the top of this zone.

Along the boundary-line between the 'Fucoid Beds' and the overlying zone of 'Serpulite Grit,' from 25 to 40 feet thick, there is frequently an alternation of false-bedded grits and shales, evidently the passage-beds from the one horizon to the other. This intermediate series is conspicuously developed in the Loch Eriboll region, and it has been observed to a more limited extent in Ross-shire. Near the crest of the zone the quartzites merge into carious dolomitic grit

[1] See Quart. Journ. Geol. Soc. vol. xliv. (1888), p. 406.

crowded with *Serpulites Maccullochii* (*Salterella*) and traversed by vertical worm-burrows, projecting as long pipes, several inches in length, on weathered surfaces.

The small development of the Durness Limestone represented in the Dundonnell Forest belongs to the base of the Ghrudaidh Group. The bands immediately overlying the 'Serpulite Grit,' are richly charged with serpulites like the corresponding beds in the Eriboll sections, a sub-zone which has been recognized along the whole line from Eriboll to Loch Kishorn.

The appearance of serpulites (*Salterella*) on these various horizons ranging from the 'Pipe-Rock' to the basal limestone, and their association with *Olenellus* in the 'Fucoid Beds' and 'Serpulite Grit' lead us to cherish the hope that portions of *Olenellus* may yet be found in certain shales in the quartzites and probably in the lowest group of limestone.

§ 7. Conclusions drawn from the Discovery of *Olenellus*.

The evidence now adduced proves (1) that the 'Fucoid Beds' and 'Serpulite Grit' are of Lower Cambrian age, the quartzites forming the sandy base of the system; (2) that the Torridon Sandstone, which is everywhere separated from the overlying quartzites by a marked unconformability, is pre-Cambrian.

§ 8. Description of Fossil Remains.

Of the organic remains obtained from the dark shale-bands mentioned in the former part of this paper, fragments of trilobites are the most abundant, and the portions most commonly met with are their carapaces.[1]

From a collection of over fifty specimens there are only three that show any other recognizable part of the animal. One is a body-segment, either the first or second; another, from its greatly developed recurved pleural spine, may be referred to the third segment; while the remaining one appears to be a portion of a styliform telson.

The form of the carapaces, the arrangement of the glabella, the palpebral lobes and eye-slits, the cheek-spines, and the absence of any true facial suture, indicate that these remains are referable to the genus *Olenellus* and to that section of it characterized by *O. Thompsoni* of Hall.

With the exception of a few portions of a large species too fragmentary for description all the remains may be ranked under one species, which however shows a considerable range of individual variation.

The fragments of body-rings and telson above alluded to appear to belong to different individuals and cannot be referred to any one

[1] [In the present paper I use the term 'carapace' for that portion of the test of the trilobite which is homologous with the shield bearing the eyes and covering the six pairs of limbs in *Limulus*, *Scorpio*, *Slimonia*, *Eurypterus*, and *Pterygotus*.—B. N. P., Feb. 26th, 1892.]

of the numerous carapaces found, yet all the fragments are marked with a similar surface-ornamentation. This consists of a network of finely-raised lines enclosing polygonal flat-bottomed depressions. Further, the collection affords carapaces of the dominant species of the proper size to fit these other fragments. The presumption therefore is in favour of the opinion that all these remains belong to members of one species. It is to be hoped that a further search will yield us sufficient material to clear up this point and will also afford us the means of describing the larger species, the remains of which at present in our possession seem to indicate that its carapace sometimes attained a breadth of six inches. The thanks of the Authors are due to Mr. Charles D. Walcott, Prof. Brögger, and Prof. Lapworth for valuable assistance in directing them to the literature bearing upon the subject of *Olenellus*.

Genus Olenellus, Hall, 1862.

Before entering on the detailed description of the fossils, it may be fitting to state the view as to the subdivision of the genus adopted in this paper; it is practically identical with that of Walcott as given in his 'Fauna of the Lower Cambrian or *Olenellus* Zone,'[1] which is as follows:

I. *Olenellus* to be restricted to such forms as have the characteristic Olenellid carapace and styliform telson, the type of which is *O. Thompsoni*, Hall, and including the species *O. Gilberti*, Meek, *O. Iddingsi*, Walcott, and *O. Walcotti*, Schaler and Foerste.

II. *Mesonacis*.[2] To include those forms with Olenellid carapace, Paradoxidean pygidium, and with greatly produced spines upon the central lobes of one or more of the body- or abdominal segments. Type:—*Mesonacis vermontana*, Hall, including *M. asaphoides*, Emmons, and *M. Mickwitzi*, Schmidt.

III. *Holmia*.[3] To include those forms that have the Olenellid carapace with Paradoxidean pygidium, and a row of spines down the centre of the axis of the body-rings and the occiput, the occipital spine being often greatly elongated. Type:—*Holmia Kjerulfi*, Holm, including *H. Bröggeri*, Walcott, and *H. Callavei*, Lapworth.

It is in this restricted sense that the generic term *Olenellus* is here used.

Olenellus Lapworthi, nov. spec. Pl. V. figs. 1–11.

Carapace in a general way semicircular, but varying in different individuals, from the length being sometimes more and sometimes less than half the breadth. On the dorsal aspect it is

[1] Tenth Annual Report U.S. Geol. Survey, 1888–1889, pp. 633–635.
[2] Walcott, Am. Journ. Sci. vol. xxix. (1885) p. 328, figs. 1 & 2.
[3] Matthew, Trans. Roy. Soc. Canada, vol. vii. sec. 4 (1889), pp. 135–162.

margined on the front and sides by a raised border, rounded off outside and separated from the cheeks and frontal area by a depression. This border is narrow, but varies in breadth in different individuals, being nearly twice as wide in some as it is in others. In all it is widest nearest the postero-lateral angles and gradually diminishes in front towards the middle line, being about one third narrower in front than behind. At each of the postero-lateral angles the carapace is continued into a long strong spine, directed backwards and slightly outwards. The spine also varies in different individuals, being longest and strongest in the most elongated forms. On an average the spine measures about two thirds of the length of the carapace.

The posterior margin is concave and divided into three areas, viz. a central one coinciding with the boundary of the occiput, and two side wings. Each of these latter has a thickened border, which begins narrow at the edge of the occipital ring, widens out gradually for $\frac{3}{4}$ of its extent, and then suddenly tapers off just before reaching the cheek-spine, from which it is cut off by a wide and shallow notch. No tubercle or rudiment of a spine is observable at the angle where the band bends into the notch.

The cheeks and the frontal area are continuous, rising gently and evenly from the depression bordering the marginal fold; but since the fossils are preserved in shale and are in consequence somewhat compressed, there is no means of finding out from them the amount of original convexity. The glabella and eye-lobes rise steeply out of the combined genal and frontal area, the external or visual wall of the eye-lobes being almost vertical.

The glabella is club-shaped, rounded in front, and widest where the eye-lobes merge into it just in front of the foremost furrow. From this point it tapers very gradually backwards; it is crossed by three furrows, each of which begins at the outer margins, passes forward, and suddenly bending round upon itself, passes inwards and backwards to meet its other half in the middle line. Each furrow is deepest at the two angles and shallowest at the middle line. A fourth, the occipital furrow, crosses from side to side with a straighter course than the others, though it is still bent backwards a little in the middle line. As a consequence of this arrangement of furrows the anterior portion of the carapace is cordate; the three succeeding lobes are M-shaped, and the occipital ring, which is large, is deeper at the sides than in the middle line. The occipital ring bears a short rudimentary spine or tubercle in the middle line, near its posterior margin.

The eye-lobes are crescent-shaped and are more than $\frac{1}{3}$ the length of the carapace. Anteriorly they merge with the glabella just in front of its first furrow. Thence they extend backwards and slightly outwards, and end at a point a little behind the occipital furrow and a considerable distance from the edges of the occipital ring.

The exterior margin of the orbit is steep, and from its crest the test sinks more gently inwards to the general level of the head.

The visual portion of the eye occupies the greater part of the steep outer edge of the crescent, and though no actual remnant of the visual membrane has been preserved, the place it once occupied is represented by a narrow crescent-shaped slit with rounded extremities, which describes a curve of about one third of a circle. This is margined by a thickened ridge or pseudo-palpebra. The inner or anterior canthus of the eye is a little wider and more rounded than the outer or posterior. The eye-lobe and the edge of the glabella almost enclose a portion of the test which stands up in the form of a gently-swelling elongated boss. No trace of a facial suture is observable on the dorsal aspect of any carapace that we have studied.

On the underside of some specimens the *doublure* is shown and is always a little wider than the dorsal marginal ridge. The suture along the external edge of the *doublure* has not been observed, but this may be because the specimens are not sufficiently well preserved to show it. No trace of the facial suture has been found where it cuts the posterior margin in *Paradoxides*, though the specimens were favourable for its observation. The hypostome has not been observed.

A table of measurements of several carapaces of O. Lapworthi *is here given to show the amount of variation in form*:—

	M 2473d, fig. 1.	M 2468d, fig. 2.	Sg. 1. fig. 3.	M 2472d, fig. 4.	M 2476d, fig. 7.	M 2502d.
	mm.	mm.	mm.	mm.	mm.	mm.
Length along middle line .	16	16·5	18	15	9	8
Breadth just in front of genal spines	28	35	40	25	18	14
Distance between inner canthus of eyes.....	8	10	11	5		
Distance between outer canthus of eyes.....	11	14	12	8		
Length of genal spine	...	10	...	8		
Breadth of margin in front of genal spine	1·25	1·5	3	2		
Breadth of margin near middle line	·45	1	1	1·5		

The figures at the top of the columns in the above table apply to the numbers of the specimens in the books of the Geological Survey of Scotland.

Though no body-segment has been found attached to any one of the numerous carapaces, yet the presumption is in favour of the opinion that the remains of segments and the telson already mentioned belong to this species.

The first or second body-segment (Pl. V. fig. 9) consists of a central lobe 7 mm. wide by 1·5 mm. deep. The left pleuron is best preserved, and is 8 mm. by 1·5 mm. deep. It is continued in the same straight line as the axis of the central lobe, and is strengthened on

both margins by a thickening, the anterior one being the stronger; it ends in a short pleural spine bent backwards at nearly a right angle to the pleuron. A groove passes obliquely from the angle made by the anterior margin with the edge of the middle lobe to the postero-lateral angle. No tubercle is seen on the middle lobe.

A body-segment with central lobe, 7 mm. long by 3 mm. deep, with left pleuron attached 7 mm. long (Pl. V. fig. 10), curves off into a greatly elongated pleural spine 15 mm. in length. A similar groove to that already described crosses the pleuron obliquely and is continued into the spine. From the great length of the spine it is probable that this is part of the third body-segment. No other segment has been observed.

Telson.—A portion of a styliform telson 12 mm. long, with an articular surface 5 mm. wide at the anterior end and 4 mm. wide at the broken extremity, is preserved as an isolated fragment on a slab with the remains of this species (Pl. V. figs. 11 & 11 *a*).

On every portion of the upper surface the test is ornamented by a network of raised lines which enclose polygonal spaces (Pl. V. fig. 2 *b*). The nature of this ornament is the same throughout, but the pattern is varied according to position—the spaces becoming more elongated towards the lateral margins. In the present species it is most pronounced upon the medial lobes of the glabella, where it can be seen by the use of a strong lens. On an average three of these spaces measure about one millimetre.[1]

The above description shows that the present species is very near to *Olenellus Thompsoni* of Hall. It differs from that species in being smaller, in the glabellar furrows crossing the glabella, in their general arrangement, and in the presence of a rudimentary mesial spine on the occipital ring.

From *O. Gilberti* it differs in the posterior angle of the palpebral lobes being removed from the edge of the glabella, and from *O. Iddingsi* and *O. Walcotti* in the form of the carapace.

It is named after Prof. Chas. Lapworth, F.R.S., who has done so much towards the elucidation of our older Palæozoic rocks and who was the first to prove the existence of *Olenellus* in our own country.

Among the *disjecta membra* of Olenellid trilobites from the dark shales above described are certain portions of the carapaces of a much larger species than that described. Two of these fragments allow of the part of the animal to which they belong being made out. The first, represented in Pl. V. fig. 12, natural size, is part of the left angle of a carapace with the genal spine. It bears a broad marginal band, and the genal spine is short and broad. The width of *doublure* is also indicated by the bulge its inner margin causes by being com-

[1] An ornamentation similar to this has been described by Walcott as occurring in *O.* (*Mesonacis*) *asaphoides*, Emmons, and also in *O.* (*Holmia*) *Bröggeri*, and by Schmidt in *O.* (*Mesonacis*) *Mickwitzi*.—Dr. Hicks, in his article on 'The Fauna of the *Olenellus* Zone in Wales' in Geol. Mag. for 1892, p. 21, mentions the occurrence in the St. David's rocks of fragments of a trilobite which 'show a reticulated ornamentation.' These fragments he ascribes to *Olenellus*.

pressed against the carapace, and shows that it is wider than the dorsal marginal band. No trace of an 'interocular' spine of Foord is seen on the posterior margin. The chief value of this fragment is to show that the characteristic ornamentation is on so large a scale as to be apparent to the naked eye. The elongation of the pattern on the marginal rim is also very distinctly shown (Pl. V. fig. 12 *b*), and reminds one very much of the characteristic markings of the *Asaphidæ*.

Portions of test with this characteristic ornamentation, which must have belonged to even larger individuals, occur in the collection; but they are too fragmentary to allow of their being located with accuracy.

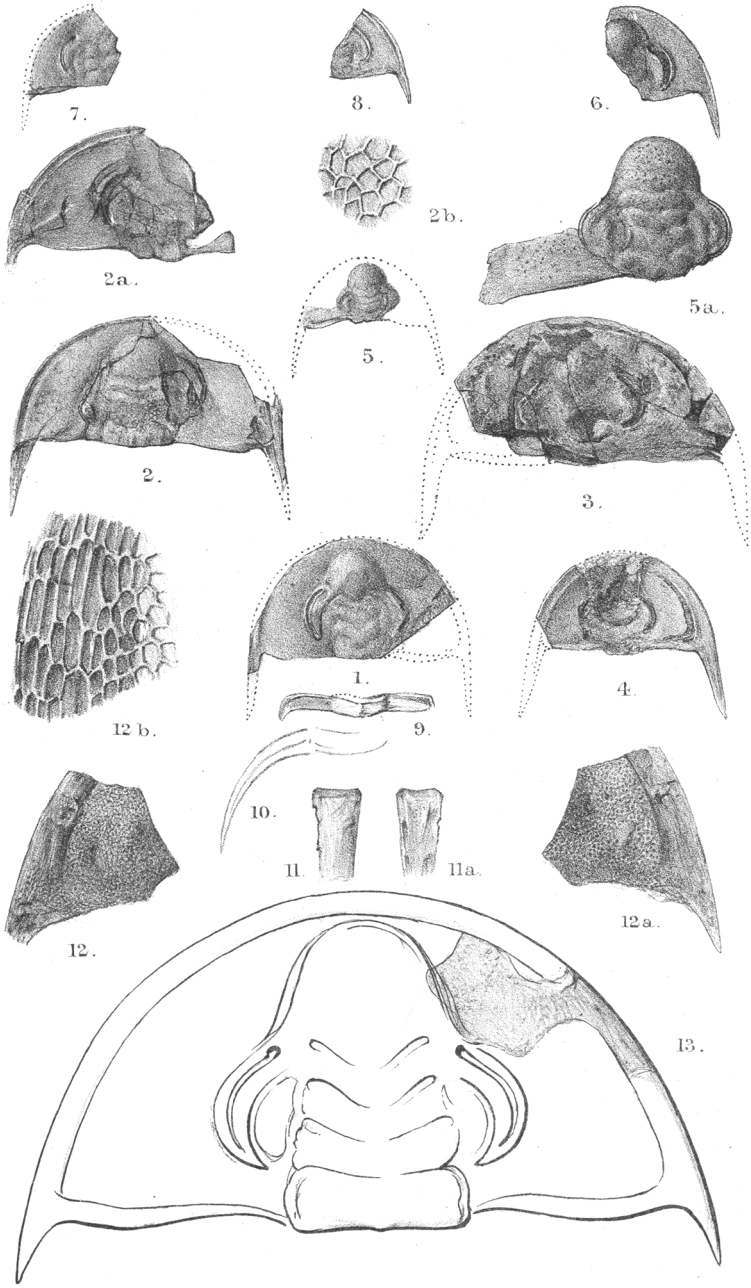
The fossils, other than trilobites, that have as yet been obtained from these dark shales are chiefly remains of pteropods, among which a *Salterella* like *S. pulchella* occurs. Several species of *Hyolithes* also occur, together with a flattened curved tube resembling the *Helenia bella* described by Walcott. One specimen of a large Entomostracan, near to *Aristozoe rotundata*, is also found in the collection.

We may be allowed to suggest that the elongated pleural spines, together with the enlarged third segment so pronounced in some species of *Olenellus* and *Paradoxides*, are in some way connected with the genital apparatus, and they may be sexual. This may account for their being sometimes present and sometimes absent in the same species.

One word of speculation as to the systematic position of the Olenellids may be admissible here. The absence of facial sutures suggests that it is from this group that the Limuloids branch off. The ornamentation, the styliform telson, and the small number of body-segments in *Olenellus* proper appear to indicate a close relationship to the Merostomata through such forms as *Stylonurus* and *Eurypterus*. *Olenellus* therefore seems to form a central point upon which the more modern trilobites, the Limuloids, and the Merostomata converge.

EXPLANATION OF PLATE V.

Fig. 1. *Olenellus Lapworthi*.—Carapace, nat. size. From 'Fucoid Beds,' Allt Righ Ian, Dundonnell, Ross-shire. M 2473[d].
Fig. 2. *O. Lapworthi*.—Carapace, nat. size. M 2468[d].
Fig. 2 *a*. *O. Lapworthi*.—Counterpart, nat. size, of fig. 2. Allt Righ Ian.
Fig. 2 *b*. *O. Lapworthi*.—Ornamentation of surface of carapace, enlarged.
Fig. 3. *O. Lapworthi*, nat. size, from 'Serpulite Grit' near Loch an Nid, Ross-shire.
Fig. 4. *O. Lapworthi*.—Carapace showing underside, nat. size. 'Fucoid Beds,' Allt Righ Ian. M 2472[d].
Fig. 5. *O. Lapworthi*.—Carapace, nat. size. M 2482[d].
Fig. 5 *a*. *O. Lapworthi*.—Carapace enlarged, shows glabellar furrows and surface ornamentation. 'Fucoid Beds,' Allt Righ Ian.
Fig. 6. *O. Lapworthi*.—Portion of carapace, nat. size. 'Fucoid Beds,' Allt Righ Ian. M 2479[d].
Fig. 7. *O. Lapworthi*.—Portion of carapace, nat. size. 'Fucoid Beds,' Allt Righ Ian. M 2476[d].
Fig. 8. *O. Lapworthi*.—Portion of carapace, nat. size. 'Fucoid Beds,' near Loch an Nid. M 2517[d].



B. N. Peach del.
F. H. Michael lith.

Mintern Bros. imp.

OLENELLUS

Fig. 9. *O. Lapworthi.*—? First or second body-segment, nat. size. 'Fucoid Beds,' Allt Righ Ian.
Fig. 10. *O. Lapworthi.*—? Third body-segment, nat. size. 'Serpulite Grit,' near Loch an Nid.
Fig. 11. *O. Lapworthi.*—Fragment of telson, nat. size. 'Fucoid Beds,' Allt Righ Ian. M 2479^{d}.
Fig. 11 *a*. Counterpart of fig. 11.
Fig. 12. *Olenellus*, sp.—Fragment of carapace, nat. size. 'Fucoid Beds,' Allt Righ Ian.
Fig. 12 *a*. Counterpart of fig. 12.
Fig. 12 *b*. Ornamentation from margin of fig. 12, magnified.
Fig. 13. *Olenellus*, sp.—Fragment of carapace, nat. size. Conjectural restored outline to show probable position of part preserved. 'Fucoid Beds,' Allt Righ Ian.

The numbers M 2473^{d}, etc., refer to the List-books of the Geological Survey of Scotland.

Discussion.

Dr. Hicks was much pleased to find that the interpretation of the succession in the older rocks of Scotland now given by the Authors agreed entirely with the views which he had advocated for so many years, not only as applicable to Wales, but generally to the British Isles, and to most of the continent of Europe. In a map of Europe published in the Quart. Journ. Geol. Soc. in 1875, he indicated by sections the varying thicknesses of the deposits in the different countries, and the order of the succession of the faunas, and he pointed out that wherever the base-line of the Cambrian rocks was seen, it was found to rest unconformably on pre-Cambrian rocks. He had found fragments of *Olenellus* at St. David's in the year 1868, but had only recently recognized that they were portions of the carapace of that genus. Along with the *Olenellus* at St. David's there appears to be a species of *Conocoryphe*. The latter genus as now defined has, like *Olenellus*, no true facial sutures, but it ranges also into the Middle Cambrian, and is there associated with the genus *Paradoxides*. Now that the Torridon Sandstone is recognized to be of pre-Cambrian age, it is a matter of much importance to find out the nature of the fragments contained in it, as by that means it may be possible to arrive at some idea as to the composition of the still earlier pre-Cambrian formations. He had already tabulated a considerable number; but doubtless there were many others which he had not met with. He congratulated the Authors and the officers of the Survey associated with them on the important results of their labours, and he hoped they would soon be able to add to their discoveries by finding other faunas.

Dr. Woodward congratulated the Authors on their admirable paper. The discovery of *Olenellus* in Scotland fixed with certainty the Lower Cambrian age of the 'Serpulite Grits' and 'Fucoid Beds.' He pointed out that Mr. Walcott denies the presence of *Olenellus* in Australia, but in 1886 Mr. Hardman had sent home the head and spine of a trilobite, and numerous pteropods, from Kimberley, Western Australia; these had been identified by Messrs. R. Etheridge, Jr., A. H. Foord, and Dr. Woodward as *Olenellus* (?)

and *Salterella*, and their associated occurrence seemed to prove most conclusively the Lower Cambrian age of these rocks. Great stress had been laid by Mr. Peach on the non-detection of the facial suture in *Olenellus*, as proving that the *Olenelli* had *no free-cheeks*, and should therefore be separated from the Trilobita. But in *Conocoryphe* and many other trilobites the facial suture was often obscure, nevertheless he saw no reason to doubt its existence in all the group—only in some trilobites it was more visible than in others; nor did he see any grounds whatever for separating the *Olenelli* from the Trilobita, as ancestral forms of *Limuli*, more than any other members of the order, with which they certainly agreed in all their general characters.

The PRESIDENT spoke of the detailed and accurate field-work on which the paper was based. There could now no longer be any question as to the pre-Cambrian age of the Torridon Sandstone, which might for the sake of brevity be termed Torridonian, until its true place in the geological record was fixed. He objected to the Torridon Sandstone being classed as Archæan, and remarked that already the officers of the Geological Survey had detected traces of organic remains in it, and by further investigation other and better-preserved forms might be obtained. With regard to the discovery of the *Olenellus*-zone, he believed that we were only at the threshold of what was yet to be found. It was intended to prosecute a vigorous search along the outcrops of the strata this summer, and he hoped that before long they would have further results to communicate to the Society regarding these early portions of the Palæozoic rocks.

Prof. LAPWORTH also spoke.

Mr. PEACH replied to the remarks made by previous speakers.