

NOTES ON THE SILURIAN ROCKS OF ARISAIG,
NOVA SCOTIA.

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After the meeting of the British Association for the Advancement of Science at Toronto in August, 1924, I visited the well-known section of Silurian rocks near Arisaig on the northwest coast of Nova Scotia, in order more particularly to examine the lowest beds of the system. These have been correlated, directly or indirectly, with the Llandovery rocks of Britain. Dawson appears to have regarded them as the equivalents of the Clinton which was deemed to be Upper Llandovery. Fletcher supposed them to be the representatives of the Medina and Lower and Upper Clinton, while Schuchert and Twenhofel, though correlating them with the Clinton, regarded the latter as Lower Llandovery.¹ In a recent article I gave reasons for correlating both Lower and Upper Clinton with the Upper Llandovery of Britain,² and stated that the Lower Llandovery was very imperfectly represented in North America, if indeed it was represented at all in most sections. A short time before my visit an important memoir by Dr. F. H. McLearn³ had been published in which the lowest fossiliferous strata (Beechhill formation) that could be assigned with certainty to the Silurian were correlated tentatively with the Mulloch Hill group which lies at the base of the Lower Llandovery in the Girvan district of Ayrshire (Southwest Scotland), and with the Lower Llandovery of Llandovery and Haverfordwest. The correlation was based on the occurrence at Arisaig of *Schizophorella arisaigensis* (allied to *S. mullochensis*), *Whitfieldella* ? *crassa* var. *beecehillensis*, *W.* ? *angustifrons*, which are represented in Britain by identical or closely allied forms. During my visit to the Victoria Memorial Museum at Ottawa, Dr. McLearn kindly showed me specimens of these forms, and although the evidence was somewhat scanty, I was on the whole inclined to agree with that correlation, especially as *Whitfieldella* ? *crassa*, which ranges (in Britain) from the upper beds of the Bala throughout the Lower Llandovery, never seems to ascend into higher strata.

¹ For a Bibliography of the authors who have written on the section see F. H. McLearn (below).

² O. T. Jones, The Ordovician-Silurian Boundary in Britain and North America, Journ. Geol. 33, pp. 371-388.

³ Palaeontology of the Silurian Rocks of Arisaig, Can. Geol. Surv. Memr., 137, 1924.

The Beechhill formation is overlain by the Ross Brook formation at the base of which a group of black shales has been noted by W. H. Twenhofel,⁴ M. Y. Williams⁵ and F. H. McLearn.⁶ My first objective was the examination of these shales in the hope that they might yield graptolites—organisms which have been found to be of the greatest service in the correlation of the British Ordovician and Silurian rocks. My first contact with the section was near Angus McDonald's fishing-stage at the south end of Beechhill Bay, and on this and other occasions I was accompanied by Father D. Rankin of Arisaig, to whom I am indebted for much kindness and hospitality during my visit. Near the fishing-stage the Beechhill sandstones pass up by a conformable but rapid lithological transition into smooth fine black shales which were exposed at the time of our visit close to the upper edge of the foreshore, a few yards north of the track leading to the shore. Their appearance agreed closely with the graptoliferous beds of Britain and the first attack on them revealed *Climacograptus scalaris* in abundance. Father Rankin, who was working a few yards away, almost simultaneously turned out some shales which were covered with species of *Monograptus*. This exposure is, in fact, extraordinarily prolific in graptolite individuals, although the number of species is restricted. The strata are in a vertical attitude and their outcrop is slightly disturbed by a strike-fault which produces a repetition of a few feet of the shales; the total thickness exposed is probably not more than 15 feet. On making enquiries from Mr. Angus McDonald I learnt that the part of the foreshore where the graptoliferous beds were exposed, had been laid bare some months previously as the result of heavy seas. This accounts for their not having been observed by previous investigators. Farther north in Beechhill Bay this band of shales was not exposed; such rocks as were visible above the Beechhill sandstones were rubbly, dark-grey, slightly iron-stained, cleaved and broken shales in which I found only a single specimen of *Monograptus jaculum*.

This particular horizon is not exposed in any other part of the coast section, but on Doctor's Brook a few feet of dark, iron-stained shales were visible in a narrow cleft descending the right hand bank a few yards above the Arisaig road-bridge. The exposure was of limited extent, and there was evidence of some shearing in the shales. There was

⁴ The Silurian Section at Arisaig, this Jour., 28, pp. 143-164, 1909.

⁵ Arisaig-Antigonish District, Can. Geol. Surv. Memoir 60, 1914.

⁶ Op. cit. sup.

plenty of material available for collecting, but graptolites were scarce and although the same species occurred as on the shore, their proportional abundance was different. These shales are probably not on exactly the same horizon as those which yielded graptolites on the foreshore.

The following species were collected:—*Monograptus tenuis* (vc), *M. lobiferus* (r), *M. nudus* and var., *M. jaculum* (c), *Climacograptus scalaris* (vc), cf. *Cl. hughesi*, *Glyptograptus serratus*. So far as I can discover this fauna has not been recorded hitherto from the American continent, and as it enables a very precise correlation of these strata to be made with a certain horizon in the Valentian (or Llandovery) rocks of Britain, it may be of interest to indicate the bearing of this discovery upon the age and correlation of the Arisaig rocks.

In Britain the Valentian rocks are developed in two distinct facies, namely, a graptolitic and a shelly facies. On the basis of the graptolite fauna the Valentian Series has been subdivided as follows:⁷

Gala stage	Upper Gala	Zone of <i>Monograptus crenulatus</i> Zone of <i>Monograptus gricstonensis</i>
	Lower Gala	Zone of <i>Monograptus crispus</i> Zone of <i>Monograptus turriculatus</i> Zone of <i>Rastrites maximus</i>
Birkhill stage	Upper Birkhill	Zone of <i>Monograptus halli</i> Zone of <i>Monograptus sedgwicki</i> Zone of <i>Monograptus convolutus</i> (with sub-zone of <i>Cephalograptus cometa</i> near the top)
	Middle Birkhill	Zone of <i>Monograptus leptotheca</i> Zone of <i>Mesograptus magnus</i> Zone of <i>Monograptus triangulatus</i>
	Lower Birkhill	Zone of <i>Monograptus cyphus</i> Zone of <i>Monograptus acinaces</i> Zone of <i>Monograptus atavus</i> Zone of <i>Mesograptus modestus</i> Zone of <i>Cephalograptus ? acuminatus</i> Zone of <i>Glyptograptus persculptus</i>

In the paper from which this table is taken (p. 153) the correlation is made of the subdivisions of the shelly facies with the above. Subsequent work on the Valentian rocks of the Llandovery area (after which the Llandovery formation was

⁷ O. T. Jones, The Valentian Series, Quart. Journ. Geol. Soc., 77, pp. 144-174, 1921.

named by Murchison) has thrown further light on this correlation. In that district the rocks belong to the shelly facies but at certain horizons graptolites have been found interbedded with shelly strata, or in association with brachiopods and trilobites. The succession is described in a forthcoming paper by the Author in the Quarterly Journal of the Geological Society of London; a brief *résumé* is all that is necessary for the present purpose.

The Valentian Series at Llandovery is divisible into three major stages, termed Lower, Middle and Upper Llandovery, which are separated one from the other by well-marked unconformities. The uppermost part of the Lower Llandovery has yielded graptolites indicating a level in, or about the base of, the zone of *Monograptus cyphus*, and as the stage appears to be conformable with the underlying Bala the lower parts of it are probably equivalent to the underlying zones of the Lower Birkhill. It was shown some years ago⁸ that the base of the Lower Llandovery at Haverfordwest, which is closely comparable with that of Llandovery, is at approximately the same horizon as the base of the Lower Birkhill.

The Middle Llandovery stage contains near the top certain graptolites indicative of the upper part of the zone of *Monograptus convolutus* (sub-zone of *Cephalograptus cometa*). The stage rests with marked unconformity upon the Lower Llandovery, but in the absence of graptolites at lower levels, the horizon of the earliest beds of the stage cannot be determined directly by reference to the graptolitic scale. In view, however, of the unconformity and other evidence in the area of physical changes between the Lower and Middle Llandovery, it is probable that a remarkable change in lithology which takes place in the graptolitic rocks of Britain should also be attributed to those conditions. The Lower Birkhill consists in the main of dark-blue, pyritiferous shales, while the Middle Birkhill consists in part of dark shales and in part of massive, greenish-blue mudstones, within which are intercalated a few dark shale bands, and peculiar green beds varying from a fraction of an inch to several inches in thickness. The change in lithology takes place in a conformable sequence and the earliest indication of it is found in the zone of *Mesograptus magnus*, which consists of a dark shale band below containing the zonal graptolite and others, and massive greenish-blue mudstones above, with a characteristic irregular,

⁸ The Geology of the South Wales Coalfield, pl. xi, Haverfordwest 1914, p. 80, Mem. Geol. Survey; and Valentian Series (op. cit.) p. 158.

dark mottling. I have elsewhere⁹ given reasons for associating such mottled beds with physical breaks in the succession, and in view of the more recent discovery of an important break at a level well below the zone of *Monograptus convolutus* it is not unlikely that the horizon of the break descends as low as the zone of *Mesograptus magnus*. It follows that on physical grounds the base of the Middle Birkhill should be drawn above and not below the zone of *Monograptus triangulatus*, which would then fall within the Lower Birkhill.

The Upper Llandovery stage also rests with marked unconformity upon the Lower or Middle Llandovery and, in an adjoining area, upon low Ordovician beds. The basal group consists of about 150 feet of shelly sandstones, which are followed by a thin band containing *Monograptus sedgwicki*, *M. tenuis* and *M. jaculum* indicative of the zone of *M. sedgwicki*. Since the upper part of the Middle Llandovery is equivalent to the upper part of the *M. convolutus* zone, the unconformity lies between the *M. convolutus* and the *M. sedgwicki* zones, i.e. between the Middle and the Upper Birkhill. This break is well marked towards the margin of the area where the graptolitic facies is developed as at Rhavader.¹⁰ Elsewhere the break cannot be detected in the graptolitic succession, but Prof. J. E. Marr¹¹ has recently shown that another marked change in the character of the Valentian sediments takes place at about that level. The succession above this break up to the base of the Wenlock appears to be continuous.

Among the graptolites collected from the black shales at the base of the Ross Brook formation of Arisaig, *Monograptus nudus*, *M. jaculum* and *Glyptograptus serratus* make their first appearance in Britain in the zone of *Monograptus sedgwicki*; *Climacograptus scalaris* occurs throughout the Middle and Upper Birkhill and ranges into the Gala. *Monograptus tenuis* is specially characteristic of the *M. sedgwicki* zone where it occurs in swarms, but it has been recorded with doubt from the *M. convolutus* zone. In the South of Scotland,¹² the Lake District¹³ and in Central Wales¹⁴ the shales assigned to the *M. sedgwicki* zone, which vary in different places from 3½ feet to 20 or more feet, are divisible into two distinct horizons, an upper containing abundance of *Monograptus*

⁹ Valentian Series (cit. sup.) p. 174.

¹⁰ H. Lanworth, Quart. Journ. Geol. Soc., 56, pp. 67-137, 1900.

¹¹ Ibid., 81, pp. 118, 119, 1925.

¹² C. Lanworth, Quart. Journ. Geol. Soc., 34, pp. 240-346, 1878.

¹³ I. E. Marr and H. A. Nicholson. Ibid., 44, p. 673, 1888.

¹⁴ O. T. Jones and W. J. Pugh. Ibid., 71, pp. 358, 380, 1915.

sedgwicki with occasional *M. tenuis* and a lower crowded with *Monograptus tenuis* and few, if any, examples of *M. sedgwicki*. The Arisaig band can be correlated with the lower horizon of the *M. sedgwicki* zone; the latter fossil might be expected to occur at Arisaig if a few feet more of the shales were exposed. The graptoliferous band at Arisaig is thus probably *slightly lower* than the band with *M. sedgwicki* in the Upper Llandovery of Llandovery. In the latter district about 150 feet of shelly sandstones intervene between it and the base of the Upper Llandovery; at Arisaig the Beechhill formation consists of 160 to 200 feet of rather similar sandstones. It appears, therefore, that as nearly as possible the base of the Silurian at Arisaig is at the same level as the base of the Upper Llandovery of Llandovery. The Lower and Middle Llandovery of the latter area which have a combined thickness of over 3,000 feet are absent at Arisaig unless they are represented in part by the volcanic rocks which underlie the Beechhill formation.

Higher part of the Valentian Series. The coast section which begins some 200-300 yards southwest of the lobster-factory at Arisaig, shows in its lithological succession a considerable analogy with that of the Upper Valentian rocks in the Tarannon district in Central Wales as described by Dame Ethel Shakespear.¹⁵ The lower beds in both sections are shales and are succeeded by shales with numerous alternations of thin arenaceous beds. The upper beds in turn consist of pale green mudstones, but at Tarannon these include some bands of purple or red mudstones, which do not appear to occur at Arisaig.

The Arisaig rocks contain, however, a fairly prolific shelly fauna while graptolites appear to be scarce or are confined to certain thin bands, whereas at Tarannon graptolites were the only fossils found. The commonest graptolite at Arisaig is *Monograptus clintonensis* which has not been recorded from Britain. The specimens so labelled in various American collections include in my opinion more than one form, and the species calls for careful re-examination. The form that occurs abundantly near the middle of the Valentian succession at Arisaig (zone 8, Twenhofel) in association with *Retiolites geinitzianus* var. *venosus*, and abundance of Eurypterid fragments, is clearly allied to the European *Monograptus marri* Perner, which is a characteristic species of the British Lower Gala. Towards the top of the Lower Gala there are intermediate forms which connect that graptolite with *Monograptus priodon*, so that within a certain thickness of strata there are

¹⁵ Quart. Journ. Geol. Soc., 62, pp. 644-701, 1906.

forms which may be regarded as advanced types of *M. marri* or early types of *M. priodon*. It was such a form that was described by Perner as *M. holmi*, and as that author pointed out it is distinguished from *M. marri* by somewhat longer thecae, a smaller inclination of the thecae to the polypary and by somewhat greater overlap. In *M. priodon* these characteristics are still more marked. I have elsewhere¹⁶ (p. 518) recorded such forms as occurring very abundantly in the upper part of the zone of *Monograptus turriculatus*, and they probably extend into the zone of *M. crispus*. The above horizon at Arisaig probably lies, therefore, near the junction of these two zones.

In conclusion it may be stated definitely that comparison with the British succession shows that the Beechhill and Ross Brook formations are, in general, equivalent to the Upper Llandovery shelly facies, or to the combined Upper Birkhill and Gala rocks of the graptolitic facies. It is possible, however, that, as Twenhofel and Schuchert have suggested, some part of the McAdam formation is also of Upper Llandovery age. There is little doubt that if the graptolites which occur at various levels in the Arisaig rocks were carefully compared with European specimens a closer correlation could be made than is possible at present.

The Base of the Valentian. The Beechhill formation rests in Doctor's Brook on rhyolitic rocks with a conglomerate about 1 foot thick at the base. The contact between the conglomerate and the volcanic rock is quite sharp and may indicate a minor break or a great unconformity. The relative strike of the Beechhill beds and the underlying volcanic rocks give no evidence of an unconformity. Rather the parallelism that may be observed between the boundaries of the various divisions of the volcanic series as they are traced along the foreshore and the strike of the basal Silurian rocks suggests the possibility that the two series of rocks may be conformable. Volcanic rocks occur at the base, or in the lower part, of the Upper Llandovery in the Mendip Hills and Tortworth (near Bristol), Marloes Bay (in the extreme southwest of Wales), and in the Dingle peninsula (southwest Ireland), the relations in each case proving that they are an integral part of the Silurian succession. The relations of the volcanic rocks of Arisaig to other formations in the district, especially to the Malignant Cove conglomerates, require further study.

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¹⁶ O. T. Jones, *The Hartfell-Valentian Succession in the District around Plynlimon and Pont Erwyd (North Cardiganshire)*, *Quart. Jour. Geol. Soc.* 65, pp. 463-537, 1909.