THE ORDOVICIAN AND SILURIAN GRAPTOLITE ZONES IN BRITAIN

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ABSTRACT

The graptolite zones used in Britain are basically those formulated by Lapworth in 1873–1880, modified and added to by later workers, especially Elles and Wood. The sequence is compiled from Welsh, English and Scottish localities but recent work shows that these are sometimes in different faunal provinces. Thus the assemblages supposedly characteristic of the zones can vary and there is some confusion and overlap in the zonal scheme. The British succession has been widely used as a reference scale for correlation in Europe, N. America and Australia but modern workers are finding it more and more difficult to apply the zones strictly. Many of the difficulties can be resolved by a re-examination of the British zones and the recognition that faunal provinces occur even with graptolites. The Scottish Middle and Upper Ordovician shows considerable differences from the Anglo-Welsh development and similar differences occur in parts of the Silurian. The zonal ranges of individual species are often compounded from widely separated localities which cannot now be closely correlated in Britain and such ranges must be used with great caution in correlations elsewhere.

"THESE subdivisions or Graptolite horizons answer roughly to the Ammonite zones of the Jurassic rocks of Europe, and will, in all probability, prove of equal value in the correlation of widely separated deposits." (Lapworth, 1879—80, p. 101).

Between 1870 and 1880 Lapworth studied the graptolites of the South of Scotland in detail and showed that a sequence of zones could be made out which matched similar successions elsewhere in Britain, Scandinavia and even N. America. His pioneer work was amplified by G. L. Elles and E. M. R. Wood in their various studies of the Ordovician and Silurian at the beginning of this century and the table of zonal ranges at the end of their joint monograph on British Graptolites shows the result of the thirty years work following Lapworth's similar table of 1880. The number of zones recognised was increased from 20 to 36, mainly in the Middle and Upper Silurian, and it is this zonal scheme, and those ranges, which have been used in British, and to a large extent world-wide, correlations. In order to stress the importance of *assemblages* rather than zonal index fossils, Miss Elles prepared lists of the characteristic assemblages of the various zones with comments on some of the zones (Elles 1925). Since then very little work on British graptolite zones has been published until recently but workers in Bohemia and Scandinavia, applying more precise standards of specific characters than were current 50 years ago, have found the British zones inadequate in some cases.

Re-examination of British material and further collecting have shown the writer that many more species can be recognised in Britain than appear in the Monograph. Other workers, notably A. K. Davies (1929) and Bulman (various papers) have also found previously unrecorded or new species and the recent paper by Sudbury (1958) shows how extensive collecting from even a restricted horizon can reveal

a greater variety of forms than was known before. It should be remembered, however, that apart from the studies of the Welsh Tarannon, Wenlock and Ludlow graptolite successions and some smaller Ordovician collections made by Elles and Wood, the Monograph was based on Lapworth's own collection and those of the principal museums in the country. As a result some forms could be easily overlooked and the zonal ranges were generally derived at second-hand and were better related to Lapworth's zonal scheme than to that finally published at the end of the Monograph. These ranges were compiled from different localities in Wales, the Lake District and the south of Scotland. Work on the shelly faunas from these areas has shown that at various times throughout the Lower Palaeozoic, there were distinct faunal provinces in these areas and the graptolites show some similar differences. For example, the zone of *Monograptus griestoniensis* was erected by Wood (1906) for beds in N. Wales. The slender vomerinids from there are, however, distinct from those from Nicol's type locality at Grieston Quarry in Scotland (as was recognised by Elles and Wood) and although the zone of *griestoniensis* is apparently widely found in Europe, the assemblage from the type locality of the index species has never been fully described and has several common elements in it which are missing from the published assemblages correlated with this zone. As the stratigraphical relationships of Nicol's original locality are at present unknown—it is surrounded by highly folded, unfossiliferous greywackes—this is a particularly unhappy choice of index fossil.

Bulman has recently (1958) given an account of the sequence of graptolite faunas in Britain and this seems an opportune time to provide graptolithologists with some comments on the detailed zonal scheme which has been in use for over forty years. Ireland has been excluded since the succession in Northern Ireland almost exactly parallels that in South Scotland (Swanston and Lapworth, 1877) and the other areas in Ireland have all been described on the basis of the British zonal scheme.

The Tremadocian has been usually put in the Cambrian by British workers and as Stubblefield has already discussed it recently (1956), it need not be treated here.

The succeeding Arenigian is probably incomplete in Wales and the succession of zones described by Elles in the Lake District has been disputed by other workers in the area. The lowest generally recognised zone is that of *Didymograptus extensus* above which, in various places, there is a good sequence up to the zone of *Didymograptus murchisoni* in the Llandeilian. The succession of narrow stiped then broad stiped didymograptids of horizontal and then pendent habit appears to be a satisfactory zonal scheme as the accompanying forms generally seem to have relatively long ranges or to be very local in their occurrence. The combination of the zones of *D. bifidus* and *D. murchisoni* as a separate stage, the Llanvirnian, is not now generally advocated. The Shelve area shows a complete sequence from the Arenigian to the Caradocian and through the kindness of Professor Whittard of Bristol the writer has had the opportunity of examining his extensive collection of graptolites from these beds. It was hoped that some sort of succession comparable to that described by Ekström (1937) for the Upper Didymograptus Shale of Scania would be found but the graptolites have proved to be generally quite different in their relative abundances. For example, while a zone of *Glossograptus hincksii* has been long recognised in Sweden, the Shelve beds yielded only one specimen of *Glossograptus* although the genus is common in South Scotland. It was found difficult to

separate the zones of *D. bifidus* and *D. murchisoni* as there seemed to be many transient forms between the two index fossils although the extreme forms are of course easily separable. There was an abundance of *D. geminus,* corresponding with the Scanian beds, but an almost complete absence of the other common Swedish forms. The pendent didymograptids disappear abruptly when the succession is traced upwards but the assemblage of the *Glyptograptus teretiusculus* zone could not be satisfactorily identified. *Diplograptus foliaceus,* which Elles (1925) gives as practically confined to this zone, ranges into beds above the zone of *Nemagraptus gracilis* and so do the other diplograptids such as *Climacograptus antiquus*. This horizon in the Shelve area however includes the Meadowtown Limestone so probably the conditions of deposition were not favourable for a varied graptolite fauna. Further south at Builth, there is a better representation of the *teretiusculus* zone but unfortunately the succession does not go above *gracilis* zone there and the persistence of the earlier diplograptids cannot be determined.

The zone of *Nemagraptus gracilis* is recognised throughout the world and forms the base-line from which much of the correlation of the Middle and Upper Ordovician is made. The zone fossil is easily recognisable but other nemagrapti range, in Scotland at any rate, into the *peltifer* beds above so that recognition of the genus alone does not give the zonal horizon. The Shelve succession at this level consists of the Rorrington Flags, dark micaceous shales yielding abundant *N. gracilis* at some levels and large numbers of diplograptids at others, making it difficult to decide on the assemblage for the zone as a whole.

The zonal sequence to this level has mainly concerned Wales as the Lake District successions are poor and there is an apparent absence of graptolites in Scotland from the Arenigian (at Girvan) to the Glenkiln Shales (*gracilis* zone) which are widespread throughout the Southern Uplands. The recent discovery of Arenigian and Llandeilian conodonts in the cherts below the Glenkiln Shales (Lamont and Lindström, 1957) should stimulate further search for the characteristic graptolites of the earlier zones. The sequence of zones from *N. gracilis* to *Monograptus sedgwicki* is based on Lapworth's description of the Moffat sections and has required little modification since 1878 although many new species have been found since then. Sections of graptolitic beds in other parts of Britain are generally incomplete for this part of the geological column and thus the Moffat Series provides a standard succession for correlations.

The faunas immediately above the *N. gracilis* zone have given some trouble since Lapworth took as his next zone the beds with *Climacograptus wilsoni* which at Moffat have a characteristic lithology—soft black mudstones with the graptolites in full relief—which contrasts with the cherty shales below and the thin-bedded shales above with *Dicranograptus clingani* and abundant orthograptids. It is now recognised that the beds between *gracilis* and *clingani* zones generally have a "passage fauna" and the two zones of *Climacograptus peltifer* and *Cl. wilsoni* can not be distinguished outside the Moffat belt of deposition. In Wales and the Welsh Borders Miss Elles introduced the zone of *"Mesograptus" multidens* as an equivalent of *peltifer* which was not known to occur there. This was an unfortunate choice since *Diplograptus multidens,* in its typical form reaching 4 mm. in breadth, has only been described from a small area in Shropshire (at Pontesford) and does not appear at all in the main Shelve area a few miles to the south-west, where, however, a

specimen of *C. peltifer* has been found near the top of the Ordovician succession of that area. The recognition in South Wales of three "zones" between *gracilis* and *clingani* would appear to be another subdivision of only local value. A similar series of "zones", with different index fossils, could be claimed in the Shelve area for a series of beds above the *gracilis* zone, corresponding to successive local dominance of particular graptolites apparently sometimes related to particular lithologies such as ash beds. These would have no value in general correlation and hence should not be introduced into the present scheme.

The abundance of orthograptids of the *"truncatus"* group (*Rectograptus*) appears to mark the zone of *D. clingani* which has been almost as widely recognised as that of *N. gracilis*. Unfortunately the upper limit of the zone cannot be easily defined since shelly faunas occur in Wales and the Lake District above this horizon. The index fossil *Pleurograptus linearis* is not uncommon in the Moffat area above the *clingani* beds and it is usually accompanied by other leptograptids which make the zone easy to recognise in the black shale facies. Correlations with the occasional graptolitic bands in the shelly facies require further investigation since they more nearly resemble the Swedish sequence which has been recently re-examined.

Miss Elles has already discussed the status of the zone of *Dicellograptus complanatus* (Elles 1925) and no further studies are available. The zone of *Dicellograptus anceps* at the top of the Ordovician is easily recognisable lithologically in the Moffat area but correlations with other areas are very difficult since, apart from the index fossil, the fauna consists of the longer ranging forms which can be followed into the lower Silurian zones above. Davies (1929) has described the succession between the zones of *P. linearis* and *O. vesiculosus* and shown that several lines of evolution can be traced which could help to define the various zones and sub-zones.

The first monograptids appear in the *O. vesiculosus* zone although the base of the Silurian is generally put lower down. This and the succeeding zones of the Birkhill Shales and their equivalents (up to *Rastrites maximus* zone) remain much as defined originally by Lapworth (1878) although the zone of *M. gregarius* has been sub-divided. M. Sudbury (1958) has recently shown that the sub-zonal index fossils do not always occur in the order which has been generally claimed. She has also shown that there is a much greater variety of species from this level than had been recognised and that short evolutionary series may give a better zonal classification than poorly identified assemblages.

The zone of *R. maximus* (put as part of the *M. turriculatus* zone by Elles and Wood) appears to coincide in Scotland and North England with the change from uniform dark graptolitic shales below to alternations of greywackes or light coloured shales with dark graptolitic bands. The index fossil is common in various places in South Scotland and the Lake District but appears to be rare in Wales where the similar form *R. linnaei* occurs. The succeeding zones of the Upper Valentian require considerable further investigation. E. M. R. Wood's description of the Tarannon area provides a basis for this since the Scottish succession is complicated by much folding and by great thicknesses of unfossiliferous beds so that the stratigraphic relationships of the fossil localities is poorly known. The problem of the *M. griestoniensis zone* has already been mentioned. In the Lake District neither *griestoniensis* nor *crenulatus* zones appear to be present. The record of *crenulatus* zone from the Crossfell Inlier (Shotton, 1935) is in doubt since fragments of a cyrtograptid have

since been obtained from his locality and the vomerinids, although relatively narrow, do not seem to have the long sicula characteristic of *M. crenulatus*.

The basal Wenlock zone has been taken as that of *Cyrtograptus murchisoni*. Investigations into the British cyrtograptids show that *C. murchisoni*, with curved primary and secondary branches, is apparently unknown outside the type locality. Wood (1906) mentions that only fragments of cyrtograptids were available in the Tarannon area and examination by the writer of material from the Lake District and South Scotland has shown that the common form in the basal Wenlock (Brathay Flags and Riccarton Beds respectively) is *Cyrtograptus centrifugus* Bouček (which has 4 stiff primary branches only) although *C. insectus* Bouček (with a few well-spaced branches) also occurs. These two species have been found together and it is clear that the basal Wenlockian can be recognised by the occurrence of stout cyrtograptids with a proximal spiral of more than 360° even though the number of branches may be small or large. The remaining Wenlock and Ludlow graptolite zones in Britain are based on the Welsh Border successions worked out sixty years ago by Elles and Wood. It is probable that many of the species described since then from Central Europe will also be found in Britain if they are looked for. Whether the detailed zonal subdivision will also be found remains for future work to prove.

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