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THE SEQUENCE OF GRAPTOLITE FAUNAS IN THE ORDOVICIAN OF THE SHELVE INLIER, WELSH BORDERLAND

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The Shelve Inlier exposes a sequence of beds from Arenig to Caradoc with a mixed fauna of brachiopods, trilobites and graptolites. This allows correlation between the zonal schemes set up for the purely graptolitic facies and the brachiopod-trilobite faunas. There are about 70 species of graptoloids present and, at one horizon, numerous dendroids which still await critical examination. Some of the faunas show restriction to particular lithologies and the reason for this is discussed. Correlation with other areas of graptolitic development in Britain and elsewhere is attempted.

Key words: Graptolites, Ordovician, Great Britain, correlation, graptolite and shelly faunas.

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INTRODUCTION

The Shelve area of Ordovician rocks lies on the eastern edge of the Welsh Lower Palaeozoic basin and provides a succession from Arenig to Caradoc in rocks which are comparatively undeformed. The beds strike roughly north-south and occupy an area about 10 km from E to W and a similar distance N-S). To the north, west and south, the Ordovician is unconformably covered by Silurian (Upper Llandovery) sandstones and shales, while on the east the Arenig sandstones rest unconformably on Tremadoc shales and flags. Further east there is an area of Precambrian sediments and in the Caradoc type area about 15 km east of Shelve, Caradocian sediments rest directly on Tremadoc or older rocks and the greater part of the Ordovician succession is missing. The Shelve rocks also contain a mixed fauna of graptolites, brachiopods and trilobites throughout the succession and so provide the opportunity for correlating biostratigraphical zonations based on the different fossil groups. Unfortunately

the shelly fossils show considerable provinciality and the graptolite faunas are poor in variety compared with those described from Scandinavia or North America. Both these factors make correlations with other areas less than satisfactory and further work is required.

Early work on the area by Lapworth between 1880 and 1915 was never fully published and the collections only partly studied. Later, W. F. Whittard took up research in the area and in the 1950's extensive collections were made until his death. He published a monograph (1957—1967) on the trilobites and during that time I identified the graptolites which were found and provided some evidence for the zoning of the beds in the standard zonal sequence. More recently Williams (1974) has provided a report on the brachiopods from the same collection but the graptolites remain unmonographed as yet. However, some preliminary account seems to be required since the Shelve area is now assuming greater importance in the study of the Ordovician because of the completeness of the succession. (Since this paper was prepared, Dean has provided a compilation of Whittard's stratigraphical notes, Whittard 1979).

My identifications remain on the whole preliminary and it is probable that many of the new species described in the last ten years will be recognised when the graptolites are monographed. Others may go into synonymies when the range of variation of species is better known.

STRATIGRAPHICAL SUCCESSION

The stratigraphical succession has long been subdivided on a local basis into a series of lithological units and the comparative simplicity of the structure allows fairly easy local correlation of outcrops. The nomenclature established by Lapworth has been only slightly modified by later work and it was on the basis of these units that I identified the specimens for Whittard. The succession is as follows, starting from the basal beds:

Arenig

a) Stiperstones Quartizite: coarse white sandstone, resting unconformably on Tremadocian; very rare trilobites (*Neseuretus grandior* Whittard); 120 m.

b) Mytton Flags (including the Shelve Church Beds): quartzitic siltstones and shales with highly fossiliferous layers; 850 m; fauna of brachiopods, trilobites and graptolites, including didymograptids (*Corymbograptus deflexus* (Elles et Wood-, *Expansograptus extensus* (Hall), *C. nitidus* (Hall), etc., very rare *Tetragraptus* and some specimen of *Isograptus* sp.) *Glyptograptus shelvensis* and *G. austrodentatus anglicus* have been discus-

sed by Bulman (1963) from the Shelve Church Beds which also include abundant dendroids belonging to *Dictyonema, Aspidograptus, Callograptus, Desmograptus* and *Ptilograptus*. The association of species indicates the *extensus* Zone but until the detailed relationships of the localities can be worked out, it is not possible to say how much of the zone is present.
c) Tankerville Flags: 30 m. These are lithologically similar to the underlying Mytton Flags but have a distinct trilobite fauna as well as some different graptolites including *Expansograptus hirundo* (Salter) indicating the *hirundo* Zone of the Upper Arenig.

Llanvirn

a) Hope Shales, Stapeley Volcanic group, Stapeley Shales: 1,200 m; soft, dark gray micaceous shales with interbedded water-deposited andesitic tuffs. The shales yield comparatively few brachiopods, mostly inarticulates, but fairly rich trilobite assemblages. The graptolites are mostly pendent didymograptids (*D. artus* Elles et Wood, *D. bifidus* (Hall), *D. stabilis* Elles et Wood) but rare *Phyllograptus angustifolius* Hall and *P. glossograptoides* Ekström occur in the Hope Shales, while *Glossograptus acanthus* Elles et Wood and *G. fimbriatus* (Hopkinson) are found in the Stapeley Shales. The intervening volcanic sequence has yielded *D. artus* and *Glyptograptus* sp. All three units are assigned to the *bifidus* Zone.
b) Weston Beds: 300 m; transitional from the Stapeley Shales but containing more arenaceous material. The trilobite fauna changes abruptly but the graptolite fauna is poor although it includes *Didymograptus pandus* Bulman and *D. speciosus* Ekström both suggesting the *murchisoni* Zone. The brachiopod fauna is again very poor except for the occurrence of *Tissintia prototypa* (Williams) which was first described from the Llanvirn rocks of the Llandeilo district.
c) Betton Beds: 180 m; dark micaceous shales with *D. murchisoni* (Beck), *D. geminus* (Hisinger), *D. acutus* Ekström and *Lasiograptus retusus* (Lapworth). These are also assigned to the *murchisoni* Zone.

Llandeilo

a) Meadowtown Beds: calcareous siltstones or fine-grained sandstones; 390 m; characterised by the trilobites *Lloydolithus lloydi* (Murchison) and *Ogygiocarella debuchii* (Brongniart). Some of the beds are impure limestones and would not be expected to yield graptolites. However rare *Dicellograptus divaricatus* (Hall), *D. vagus* Hadding, *Dicranograptus brevicaulis* Elles et Wood and *D. irregularis* Hadding occur in addition to much commoner diplograptids and clearly indicate a different zone from that of the beds below. Most of these species also are found in the succeeding beds.

b) Rorrington Beds: mainly dark graptolitic shales but with trilobites and brachiopods throughout; 300 m. The graptolite fauna includes most of the species from the Meadowtown Beds but with *Nemagraptus* spp. and *Leptograptus* spp. in addition. The horizon is clearly that of the *N. gracilis* Zone and therefore the Meadowtown Beds below are assigned to the *G. teretiusculus* Zone as being post-*murchisoni* and pre-*gracilis*. In modern correlation, both Meadowtown and Rorrington Beds are to be correlated with the Llandeilo of the type area on shelly and graptolitic faunal associations, and the base of the Caradoc is taken in the Shelve area at the Spy Wood Grit which succeeds the Rorrington Beds.

Caradoc

a) Spy Wood Grit: calcareous sandstones, somewhat similar to the Meadowtown Beds; 90 m. The graptolite fauna consists largely of diplograptids (including *Orthograptus uplandicus* (Wiman) with rare dicellograptids and dicranograptids continuing from the Rorrington Beds below. It is difficult to place it in the zonal scheme but it is probably about the junction of the *gracilis* and *multidens* Zones. The occurrence of *O. uplandicus* matches that recorded by Männil from the uppermost Kukruse of the East Baltic area, suggesting *gracilis* Zone. The trilobites include *Costonia ultima* (Bancroft) which provides correlation with the Costonian (basal Caradoc) of the type area.
b) Aldress Shales: dark micaceous shales; 300 m. The abundant graptolitic fauna is similar to that of the Rorrington Shales but without nemagraptids or leptograptids. *Dictyonema fluitans* Bulman occurs at a well-marked horizon, and the beds belong to the *multidens* Zone.
c) Hagley Volcanic Group (100 m), Hagley Shales (45 m), Whittery Volcanic Group (90 m) and Whittery Shales (300+ m): alternations of water-laid tuffs and dark shales. Diplograptids occur throughout but only a few different forms and nothing distinctive of any higher zones. It is doubtful if the zone of *Dicranograptus clingani* is reached since *D. multidens* occurs in the Whittery Shales but the faunas are not sufficiently diagnostic for a decision to be made.

CORRELATION

The general correlation of the Shelve succession with a standard set of graptolite zones does not present many problems which are not already inherent in the zonal scheme. The Arenig faunas are clearly marked off from the Llanvirn by the incoming of pendent didymograptids in the

Hope Shales. Much of the Arenig (the Mytton Flags) is assigned to the *extensus* Zone on the lack of broad dichograptid stipes which appear in the Tankerville Flags and correspond to *E. hirundo*. Distinction between the zones is hampered by the lack of large well-localised collections.

The Llanvirn certainly includes the beds from the Hope Shales up to the Betton Beds which are all characterised by abundant pendent didymograptids. Division into *bifidus* and *murchisoni* zones is tied up with the taxonomy of the whole group and the allowable range of variation within species. The Shelve collections have not yet been adequately analysed from this point of view but the attribution of the Weston Beds to the *murchisoni* Zone appears to fit the trilobite associations. The upper limit of the Llanvirn is slightly debatable since there is a change of lithology to the Meadowtown Beds which have a very limited graptolite fauna. The extinction of pendent didymograptids makes a convenient local upper boundary but there is little positive evidence in the Lower Meadowtown Beds for the recognition of the succeeding zonal assemblage.

On brachiopod and trilobite associations, correlation of the Meadowtown Beds and the succeeding Rorrington Beds with the Llandeilo of the type area seems now to be established. This means that on the graptolitic scale the Llandeilo is no longer just the *G. teretiusculus* Zone but includes most, if not all, of the *N. gracilis* Zone. Skevington has suggested that the *teretiusculus* Zone should be abandoned as its definition is difficult but there does appear to be a sequence of graptolite beds lying between the typical *murchisoni* fauna with pendent didymograptids and the full development of the *gracilis* fauna with the name fossil and abundant associated dicellograptids and leptograptids. The lithology of the Meadowtown Beds does not help in resolving the problem since the graptolite fauna here may well be limited by other factors, so the *teretiusculus* Zone is retained at present. Taking the base of the *gracilis* Zone where *N. gracilis* makes its first appearance has its own problems on a world-wide scale since it is clear from published figures of the species that several different forms could be present and they need not be contemporaneous.

The upper limit of the *gracilis* Zone also provides problems which have been discussed before. The Aldress Shales have an almost exclusively diplograptid fauna so far as graptolites are concerned and this includes rare *Diplograptus multidens*. This is rather surprising since the type area for this species is near the north-east corner of the Shelve area but separated from it by a major structural line. One specimen of *Climacograptus peltifer* is known from the Hagley Volcanic Group above the Aldress Shales. A critical study of the various diplograptids is essential before any subdivision of the fauna between the *gracilis* and *clingani* zones is attempted. Meanwhile, recognition internationally of a "*multi-*

dens Zone" is no better than that of the *teretiusculus* Zone. In the Shelve area there is little evidence of the *clingani* Zone as recognized in Scotland and this is supported by the trilobite—brachiopod evidence that the highest beds in Shelve are Lower Soudleyan in age.

Correlation with Balto-Scandia is limited by the different faunas present in the two areas. It was hoped that the Shelve area would provide faunas to match those described by Ekström from Scania and later by Berry from Oslo but they have not proved so rich in variety. The broad correlations are not changed significantly by the present information but when the faunas are fully described, following publication of the stratigraphic detail, it may be possible to recognise more of the recently described species from other parts of the world. Correlations with USSR sections in Kazakhstan and elsewhere also remain at the general level while comparison with much of the USA is difficult through the provincial differences.

LITHOLOGICAL CONTROL OF FAUNAS

A point of considerable interest is the occurrence of species in particular lithologies and their absence from intervening beds. Three of the pendent didymograptids occur in the Hope Shales and the Weston Beds but not in the Stapeley Volcanics or Shales and similarly *Diplograptus leptotheca* Bulman occurs in the Rorrington and Aldress Shales but not in the Spy Wood Grit. These restrictions are what one would expect since in general coarse lithologies have poor graptolite faunas compared with finer grained deposits. This has usually been attributed to destruction of the skeletons in a high-energy oxygen-rich environment. A more difficult problem is the occurrence of *Diplograptus foliaceus* (Murchison) in the sandy Meadowtown Beds but not in the overlying Rorrington Shales although it reappears higher in the succession in both shales and tuffs. *Amplexograptus perexcavatus* (Lapworth) has a similar distribution.

There has been some discussion in recent years on a possible depth zonation of graptolites so that shallow-water forms could occur by themselves in shallow-water deposits while deeper living forms would only occur in deep-water deposits although they could then be associated with the shallow-living forms from the overlying water mass. A noteworthy feature of many North American graptolites from limestones is that the occurrences are almost monospecific, if not entirely so, such as *Climacograptus typicalis* Hall from Ohio. Baltic limestone graptolite faunas however appear to be more varied and the Scottish occurrences at Girvan yield a dozen or more species. Assuming that graptolites were planktonic or nektonic, swarms of one species seem to have occurred regularly and

in fact such swarms are found in typical graptolite shales as well as in limestones. Given comparatively rapid sedimentation, it would be quite possible for such swarms to occur at successive horizons which then merely reflect the changing water masses above the area of deposition and not necessarily a temporal sequence of more than local occurrence. The changing patterns of sedimentation marked by different lithologies would then provide sharp faunal changes since presumably current directions must have changed within the sedimentary basin. The Shelve area with its abundant branchiopod and trilobite faunas must have been one of shallow shelf deposition throughout the Ordovician and so the graptolite faunas, limited though they are, must also have inhabited comparatively shallow waters compared with those which have usually been suggested for graptolitic deposits, in particular with those proposed by Erdtmann (1976) as characteristic of the "Atlantic" faunas. Skevington has noted that in the Llanvirn of Britain, diplograptids are more abundant in the north of England than in South Wales and he suggested that the pendent didymograptids characterised cooler water than the diplograptids. The incoming of diplograptids in the Meadowtown Beds could then represent an influx of warmer water from the Ordovician tropical area while the return to shales in the Rorrington Beds, this time with nemagraptids and leptograptids, could represent cooler water again. Ecological control of the faunas like this would make zonal stratigraphy on a fine scale very difficult and fortunately the trilobite and brachiopod sequences show no changes to support such ecological speculations. The problem of lithological association with particular graptolite faunas needs much further investigation since it may provide some constraints on the discussion of the mode of life of graptolites.

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SEKWENCJA ORDOWICKICH FAUN GRAPTOLITOWYCH W OBRĘBIE SHELVE (WELSH BORDERLAND)

Streszczenie

Odsłonięcia ordowickie na obszarze Shelve ukazują sekwencję warstw od arenigu do karadoku, z mieszaną fauną ramienionogów, trylobitów i graptolitów. Pozwala to na korelację podziału stratygraficznego ustalonego dla typowej facji graptolitowej, z podziałami opartymi na faunie brachiopodowo-trylobitowej. W profilu występuje około 70 gatunków graptoloidów, a w jednym z poziomów także liczne dendroidy, które wymagają bliższego zbadania. Niektóre zespoły faunistyczne ograniczone są do osadów o określonych cechach litologicznych i w pracy dyskutuje się przyczyny tego zjawiska. Podano też próbę korelacji z innymi obszarami rozwiniętymi w facji graptolitowej, zarówno na Wyspach Brytyjskich jak i w innych krajach.