THE LOWER BOUNDARY OF THE ORDOVICIAN SYSTEM

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Abstract. The position of the lower boundary of the Ordovician System has long been in dispute. Interest in this question has been revived following a recent article by Whittington and Williams (1964), who, for historical reasons, site the boundary at the base of the Arenig Series. An attempt is made to justify placing the boundary at the base of the *Dictyonema flabelliforme* sensu lato Zone of the Tremadoc Series, in the belief that on this occasion there are grounds for allowing ease of application to overrule priority.

At the present time, opinion is divided on the question of the stratigraphical position of the lower boundary of the Ordovician System: on the one hand, this boundary is drawn coincident with the base of the Tremadoc Series and, on the other, with the base of the Arenig Series. Whittard (1960) has most recently argued the case of the former school on the grounds of the Ordovician aspect of the Tremadoc fauna and on structural evidence, while Whittington and Williams (1964), in what is essentially a reply to Whittard, contend that the Tremadoc fauna has equally strong links with the Cambrian, that the structural evidence is inconclusive, and that, by reason of historical priority, the systemic boundary must lie at the base of the Arenig Series.

If, indeed, faunal affinities and structural considerations are inconclusive, recourse to the Law of Priority would seem to settle the matter firmly in favour of Whittington and Williams. However, it is suggested that, in attempting to fix this boundary, as with any other, due regard be given to a fourth factor: Ease of Application. This approach to the question at issue is elaborated below, and it is claimed to be a valid approach, for if, in the last resort, all stratigraphical boundaries are arbitrary, it would seem natural to select that boundary

which it is most easy to define and to trace. In the belief, then, that ease of application is a measure of the value of a stratigraphic boundary, it is recommended:

1) that the lower boundary of the Ordovician System is taken at the base of the *Dictyonema flabelliforme* sensu lato Zone of the Tremadoc Series, and

2) that the base of the Tremadoc Series is stabilized to accord with this same horizon, which is also the base of the *Ceratopyge* Series in Scandinavia.

The remainder of this article is intended as an elaboration and a justification of these views.

The Ordovician System in the type area of North Wales was defined by LAPWORTH (1879, p. 14) to include all rocks below the base of the Llandovery Series and above the base of the Arenig Series. In the Arenig district itself, FEARNSIDES (1905) has detected, though not without difficulty, a sub-Arenig unconformity above which a Basal (or Basement) Grit may be developed, but where absent the Llyfnant Flags form the lowest division of the Arenig Series. These flags have yielded a graptolite fauna which FEARNSIDES (1905, p. 619) has interpreted to be indicative of the *Didymograptus extensus* Zone, though without reference to any particular subzone. However, a consideration of Fearnsides' faunal list and of material in this writer's collection shows that it is the *Didymograptus deflexus* Zone (the subzones of the *D. extensus* Zone are now usually accorded full zonal status) which is represented in the Llyfnant Flags. Beneath the unconformity, the youngest beds of the Tremadoc Series which are preserved in the area —the Amnodd or *Shumardia* Shales—probably correlate with the Penmorfa Beds of Ynyscynhaiarn, the type area of the Tremadoc Series some fifteen or sixteen miles to the west. The highest division of the Tremadoc Series in Ynyscynhaiarn, the Garth Hill Beds, which succeed the Penmorfa Beds, is cut out by the sub-Arenig unconformity in the Arenig district, and the time gap represented by this break is there correspondingly greater. It is this unconformity which Lapworth took as the base of his Ordovician System and which Sedgwick (in SALTER 1873) had earlier taken as the base of his Arenig Group.

Now that the facts relating to the lower boundary of the Ordovician System in its classical conception have been briefly stated, it would seem appropriate to follow with a review of the situation in Scandinavia,

for it is the sequences exposed there, or rather the interpretations placed upon those sequences, which have been largely responsible for the present dichotomy of opinion. The relevant portion of the succession in Sweden has recently been reviewed in a series of papers by TJERNVIK (1956, 1958, 1960). As a framework for his stratigraphical synthesis, Tjernvik favoured a dual zonal scheme based on graptolites and trilobites and applicable, respectively, to graptolitic and shelly facies developments; futhermore, he proposed two chronostratigraphic units of substage category. These aspects of his work are presented in Table 1.

Substage	Trilobite Zones	Graptolite Zones
Billingen	Megistaspis estonica	Phyllograptus a. elongatus
	Megalaspides dalecarlicus	Phyllograptus densus
Hunneberg	Megistaspis planilimbata	Didymograptus balticus Tetragraptus phyllograptoides
	Megistaspis armata	graptolites undescribed

Table 1. *Classification of part of the early Ordovician of Sweden, with a correlation of shelly and graptolitic sequences. Based on Tjernvik (1956, Correlation Table, p. 185) with modifications after Jaanusson (1960a, Table 9, p. 346)*

Of particular relevance to the present discussion are the several well-documented successions in the province of Västergötland (see TJERNVIK 1956, pp. 114–40). There, Tjernvik has demonstrated the equivalence of the upper part of the *M. planilimbata* Zone with the

Zone of *D. balticus* and, following ELLES (1933), MONSEN (1937), and others, has correlated the latter with the British *D. deflexus* Zone. Support for this correlation, though admittedly tenuous, is found in the association of *Didymograptus* cf. *D. balticus vincinatus* MONSEN with a *D. deflexus* Zone fauna in Canada (JACKSON 1964); stronger evidence is to hand, however, and is provided by the ubiquitous and distinctive *Tetragraptus approximatus*. The value of this species in correlation has been noted elsewhere (SKEVINGTON 1963). In its somewhat restricted stratigraphical range, this species has as associates multiramous anisograptids, other species of *Tetragraptus*, and, though probably only in the later part of its range, the first extensiform species of *Didymograptus*; this fauna has been recognized in Newfoundland (KINDLE and WHITTINGTON 1958), Texas (BERRY 1960), Australia (HARRIS and THOMAS 1938, THOMAS 1960), the Yukon (JACKSON and LENZ 1962), and elsewhere. In Scandinavia, at Mossebo in Västergötland, *T. approximatus* is found with *Didymograptus geometricus* in beds attributed by TJERNVIK (1956) to the *D. balticus* Zone, and at Töyen, in the City of Oslo, a newly described section (ERDTMANN 1965) has provided *T. approximatus* in association with *T. phyllograptoides* subsp. nov., *Didymograptus* aff. *D. geometricus*, *D. protobalticus*, and *D. balticus*. Finally, JACKSON (1964, p. 530) has reported an occurrence of *T. approximatus* in the Skiddaw Group of North-West England immediately beneath beds yielding a *D. deflexus* Zone fauna. It is apparent, therefore, that *T. approximatus* is everywhere an associate, in time at least, of the first significant appearance of species of (extensiform) *Didymograptus*, but disappears quickly after this event, and a consideration of its occurrence in Scandinavia and in Britain leads to the conclusion that the *D. balticus* Zone can be equated with the *D. deflexus* Zone, in part at least if not in whole.

In Västergötland, as elsewhere in Scandinavia, the *Ceratopyge* Series is represented by the *Dictyonema* Shales below and the *Ceratopyge* Beds above, with the highest levels yielding the trilobite fauna of the *Apatokephalus serratus* Zone. The Garth Hill Beds of Ynyscynhaiarn possibly belong in the lower part of this zone, but the upper part is unrepresented in Britain, where any beds which may have been deposited above the Garth Hill Beds have been cut out by the sub-Arenig unconformity which, in its least expression, separates the Garth Hill Beds from beds with a *D. deflexus* Zone fauna. In Väster-

götland, however, this interval is occupied by the lower part of the Hunneberg Substage, that is by beds referable to the lower part of the *M. planilimbata* Zone and the *M. armata* Zone. Similarly at Töyen, Oslo, in the section described by ERDTMANN (1965), the upper part of the *Ceratopyge* Limestone (*A. serratus* Zone) and those horizons in the Lower *Didymograptus* Shale attributable to the *D. balticus* Zone are separated by an essentially shale sequence yielding the *T. phyllograptoides* Zone fauna above and Tjernvik's dichograptid fauna below.

Clearly, the bases of the Hunneberg Substage and of the Arenig Series are not coeval (cf. TJERNVIK 1956, p. 178). If the Law of Priority is rigidly enforced, the base of the Ordovician System in Scandinavia must lie within the Hunneberg Substage and, more precisely, within the *M. planilimbata* Zone of the trilobite zonal scheme and at, or in the vicinity of, the base of the *D. balticus* Zone in the graptolitic developments. Thereby, the essentially Ordovician graptolite and trilobite faunas of the lower part of the Hunneberg Substage must be relegated to the Cambrian (see TJERNVIK 1956, p. 179, WHITTINGTON and WILLIAMS 1964, p. 246). Moreover, this lower part of the Hunneberg Substage can be assigned neither to the Tremadoc Series nor to the Arenig Series of the British succession, because in the type area of North Wales corresponding beds are missing, and there would seem to be ample support for a specifically Balto-Scandian chronostratigraphic scheme, as proposed and detailed by JAANUSSON (1960 a, b), quite separate from that in use in Britain.

While it is justifiable to erect series and chronostratigraphic categories of lower rank to satisfy regional needs, it is generally conceded that a system should be capable of universal interpretation. If the limits of a system as at present defined create a situation such as that outlined above, surely there are grounds for reconsidering those limits to facilitate universal recognition, whatever the priorities involved. The base of the *Dictyonema flabelliforme* sensu lato Zone seems to satisfactorily fulfil most of the requirements of a good systemic boundary, and it is recommended that, henceforth, this level be taken as the lower limit of the Ordovician System. If this course is adopted, beds which were deposited in Scandinavia and elsewhere during the time interval represented by the sub-Arenig unconformity belong in the Ordovician System, and at the sub-systemic levels they must be catered for by chronostratigraphic schemes of regional extent.

It is unfortunate that the base of the Tremadoc Series has never been rigidly defined in the type area of the series. In his description of the Tremadoc Series of Ynyscynhaiarn, FEARNSIDES (1910) referred the two hundred feet of Tynllan or *Niobe* Beds, which there underlie the *Dictyonema*-bearing beds (the so-called *Dictyonema* Band), to the base of the series, though in the Arenig district he had earlier selected the *Dictyonema* Band as the lowest division of the Tremadoc and had attributed the *Niobe* Beds to the top of the Dolgelly Stage of the *Lingula* Flags (FEARNSIDES 1905, pp. 612, 614–5). Fearnsides has been equally indecisive in positioning the lower boundary of the Ordovician System in the Welsh succession. In 1905, he referred the Tremadoc Series in its entirety to the Cambrian (1905, p. 612), but in 1907 he was disposed 'to separate the Cambrian and Ordovician systems in such a way that the *Dictyonema*-bearing beds may be included ... within the latter' (1907, p. 304), and in 1910 he could not bring himself to place the series in either system. The confusion arising from the variable position of the base of the Tremadoc Series and the consequent disparity, on occasions, between this level and the base of the *Dictyonema* Band has been alleviated somewhat by a recent description of a section at Ogof-ddû, near Criccieth, in Ynyscynhaiarn (STUBBLEFIELD 1956). There, '... the basal Tremadoc is marked by a phosphate nodule bed overlying Dolgelly Beds; above the phosphate nodule bed are 20 ft of striped mudstones with occasional sandy beds and lines of phosphatic nodules until *Dictyonema* occurs in force' (p. 37).

In Scandinavia, the base of the *Ceratopyge* Series is typified by the entrance of *Dictyonema flabelliforme* sensu lato and the essentially dendrograptid fauna of the lowest part of the series is accommodated in the *D. flabelliforme* sensu lato Zone. In the well-documented sequences of Norway (BULMAN 1954) and Sweden (TJERNVIK 1958), a zonal scheme has been effected on the basis of the several described subspecies of *D. flabelliforme*. Each such zone is essentially an epibole (acme-zone, peak-zone) according to the Copenhagen principles governing stratigraphic terminology (1960) and is determined by the dominance, rather than by the total range (range-zone), or by the associates (assemblage-zone), of a particular subspecies. Elsewhere, however, this part of the succession is insufficiently well known for such a detailed zonal scheme to be applied, but for the purpose of establishing a base

for the Ordovician System it is enough to demonstrate the reality of a more broadly conceived *D. flabelliforme* sensu lato Zone.

The particular subspecies of *D. flabelliforme* occurring so abundantly in the *Dictyonema* Band at Ogof-ddû is *D. f. sociale*, which in Scandinavia achieves its acme in the second zone from the base of the *Dictyonema* Shales (TJERNVIK 1958). Thus, it may be that the first twenty feet above the nodule bed in the section briefly described by STUBBLEFIELD (1956, p. 37) is referable to the lowest, or *D. f. desmograptoides*, zone. Alternatively, beds belonging in the lowest zone may not be present in Ynyscynhaiarn, and this would not be surprising in view of the absence of correlatives of the highest part of the Scandinavian Olenid Series below the phosphate nodule bed (STUBBLEFIELD 1956, p. 38). Whatever the interpretation placed upon this lowest part of the Tremadoc Series at Ogof-ddû, the presence and ready recognition of a *D. flabelliforme* sensu lato fauna are beyond dispute and permit an undoubted correlation with the basal beds of the *Dictyonema* Shales of Scandinavia.

In another context, HOLLAND (1965, p. 213) has observed that type areas for the boundaries between systems, as distinct from the systems themselves, have seldom been established and certainly this is true in the case of the lower boundary of the Ordovician System. If at any time it should be decided to formally define such a line, it would seem wise to be guided by the dictum of WILSON (1954), who has suggested that '. . . systemic boundaries should be established by adopting preponderant local usage or by international agreement at or near the type areas by naming a definite stratigraphical boundary at a definite geographical site' (p. 1605). Clearly, from what has been stated above, there is no preponderant local usage, in which case the section briefly referred to by STUBBLEFIELD (1956, p. 37), suitably investigated and described, could be nominated as the type, though it would not serve ideally as a standard section because of an evident break in sedimentation between the phosphate nodule bed and the top of the Dolgelly Beds. For reference purposes, it would be advisable to select, for example, the section at Nærsnes described by HENNINGSMOEN (1956, pp. 52–3), which has the merit of having belonged in the same (Acado-Baltic) marine faunal province as North Wales in late Cambrian – early Tremadocian times. At Nærsnes, a continuous sequence from the Olenid Shales of the Upper Cambrian into the *Dictyonema* Shales of the

Ceratopyge Series is known; lithologically, there is no evidence of a break in the section and palaeontologically it is essentially the entrance of *Dictyonema flabelliforme parabola* which defines the base of the *Dictyonema* Shale and hence of the *Ceratopyge* Series and of the Ordovician System.

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