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### **3. Biostratigraphical divisions**

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Since the 19<sup>th</sup> century geologists working on Cambrian rocks world-wide have relied largely on trilobites as biostratigraphical guides, and these remain important, especially in Series 3 and the Furongian Series, where they enable refined correlations. In Series 2, especially in its lower part where trilobite biostratigraphy becomes increasingly difficult, other criteria are employed, for example the distribution of small shelly fossils, bradoriid arthropods and, where available, archaeocyaths. In Avalonia there are no archaeocyaths, but the bradoriids have been revised and exploited stratigraphically (Siveter & Williams 1997, Williams & Siveter 1998). The recent development of acritarch biostratigraphy, which has made a vital contribution, is discussed below. Towards the base of the Cambrian, body fossils may be very scarce and trace fossils have been used biostratigraphically (Narbonne & Myrow 1988; Bland & Goldring 1995; McIlroy & Horák 2006), though they may be difficult to work with. All the zones referred to are biozones (Rawson *et al.* 2002), most of those in the Terreneuvian and Series 2 and 3 being assemblage zones, whilst those in the Furongian are local range-zones of selected species.

#### **Shelly fossil and trace fossil zones**

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##### *Terreneuvian*

The subdivisions of the earlier parts of the standard used here are composite and are based on those of the Burin and St Mary's successions in the Avalon Peninsula of south-eastern Newfoundland (Bengtson & Fletcher 1983; Landing 1992, 1996; Fletcher 2006). The lower two zonal divisions of the Terreneuvian used here are based on the first appearances of characteristic trace fossils. The lower zone, the *Trichophycus pedum* Ichnozone, has been identified in some of the oldest Cambrian recognized in England & Wales (McIlroy & Horák 2006), and the presence of the overlying *Rusophycus avalonensis* Ichnozone in south-west Wales was inferred by Loughlin & Hillier (2010). The upper two zones are named after small shelly fossils

(SSFs), many of which are sclerites of debated classification. A large number of SSF taxa are described and their stratigraphical ranges documented (Brasier 1984, 1986; Landing *et al.* 1989; Khomentovsky & Karlova 1993), and although some forms have a wide geographical distribution, their detailed biostratigraphical use is dependent on resolving problems with their taxonomy (Bengtson & Conway Morris 1992), morphological variation (e.g. Conway Morris & Chen Menge 1991), and palaeoecology (e.g. Landing 1992), as well as elucidating their stratigraphical ranges. The zonal division on the correlation charts labelled *Sunnaginia* refers to the *Sunnaginia imbricata* Biozone recognized in Newfoundland (Landing *et al.* 1989; Fletcher 2006), and the overlying division labelled *Camanella* refers likewise to the *Camanella baltica* Biozone. These are essentially assemblage zones.

### *Series 2*

The zonal divisions in Series 2 employ the trilobite zones recognized in the Avalon Peninsula, as described by Fletcher (2006): the Avalon standard is considered appropriate because England, Wales and south-eastern Ireland share in the geological history of the Avalonian terrane (Landing 1996), and at these levels the successions in SE Newfoundland are better known and more complete than those of the British Isles. Even so, a hiatus is reported in Newfoundland in the sequence between the Fosters Point and Broad Cove members of the Smith Point Formation (Fletcher 2006, p. 45), at the base of Landing's 4<sup>th</sup> depositional sequence (Landing 1996, figs 2, 5). In our zonal standard we place the trilobite zones of *Eofallotaspis* and *Fallotaspis* at this level, though no trilobites definitive of these zones are reliably known from British rocks. It is recognized that there may be an overlap between the SSF zone of *Camenella baltica* and the lowest trilobite fragments known in Britain, as discussed by Harvey *et al.* (2011). This is only one of the uncertainties in the correlation of the earlier Cambrian in Britain; no more than a general correlation is locally possible at the level of the Terreneuvian to Series 2 boundary interval. The overlying zone is the *Callavia* Trilobite Zone, characterized by the appearance of *Callavia* with the eodiscoid *Dipharus attleborensis* [formerly *Hebediscus attleborensis*]; this marks the upper part of the *Callavia* Biozone in Newfoundland (Fletcher 2006) though Fletcher's lower subdivision of the *Callavia* Biozone is not yet recognized in British sections. In Stage 4, equivalents of Fletcher's (2006) zones of *Strenuella sabulosa*, *Orodes* and *Cephalopyge* can be recognized locally (Fig. 12).

### *Series 3*

The biostratigraphic schemes in Series 3 and the Furongian used here largely follow those used by Cowie *et al.* (1972) for their St David's and Merioneth series. The lowest zone of Stage 5 of Series 3 combines the *Kiskinella* Zone and the overlying *harlani* Zone, as developed in the lower 73 metres of the Chamberlain's Brook Formation in the St Mary's succession of Avalon, Newfoundland (Fletcher 2006). British sections commonly have a hiatus at about this level, and where strata are present, they have not revealed enough evidence to enable us to recognize those two zones individually. Fletcher (2006, p. 65) has tentatively suggested that the large but very fragmentary species *Paradoxides groomi* from Comley, Shropshire, might be a synonym of *Eoparadoxides harlani* from North America, though he was cautious about their stratigraphical correlation.

Apart from this composite basal division, the zones of Series 3 are based on agnostoid and paradoxidid trilobite zones that were originally developed largely through work on the Middle Cambrian Alum Shale Formation of the Baltic area, as summarized by Westergård (1946, 1953). The lowest of these, the *Baltoparadoxides oelandicus* Zone (or Superzone), is divided into two zones in Sweden, but only the upper of these divisions, the *pinus* Biozone, has been recognized in Britain. The overlying agnostoid zones of the *Paradoxides paradoxissimus* and *P. forchhammeri* superzones share several species with the Scandinavian successions and they have proved effective for correlation in England and Wales through the Drumian Stage to the top of the Guzhangian. They allow more detailed correlation than the paradoxidid divisions at present recognized at the same levels in Newfoundland (Hutchinson 1962).

### *Furongian*

In the Furongian it has been possible to use many of the 30 olenid subzones developed in Scandinavia by Westergård (1944, 1947) and Henningsmoen (1957), although there are local modifications to the *Olenus* Biozone, and the four Scandinavian subzones of the *Acerocare* Biozone have not been separately recognized in Wales (Rushton 1982). These subzonal divisions, which are based mainly on the local ranges of olenid trilobites, are too numerous to show on the main charts. They commonly represent thin stratal divisions: in North Wales some 20 of these subzones

occupy 40 m of strata and in the Nuneaton district 15 subzones are on average each about 1.5 m in thickness. Their presence in the various districts in which they have been recognized is recorded in Figure 2. Terfelt *et al.* (2008) reviewed the Scandinavian subdivisions and accepted almost all of Westergård's (1944) and Henningsmoen's (1957) subzonal units, raising them to zonal status. Terfelt *et al.* (2008) grouped the olenid zones into four larger agnostoid-based divisions, named after *Glyptagnostus reticulatus*, *Pseudagnostus cyclopyge*, *Lotagnostus americanus* and *Trilobagnostus holmi* (Fig. 2). The new agnostoid divisions, though coarser than the olenid zones, allow a readier correlation with successions outside the realm of the olenid biofacies.

### **Cambrian acritarch zones**

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The Cambrian acritarch zones in Figures 3 and 4 are based on zonation schemes developed on the East European Platform (for the Terreneuvian Series and Series 2) and in eastern Newfoundland (for Series 3 and the Furongian Series). Both sets of zonal schemes are applicable to British and Irish successions.

#### *Terreneuvian and Series 2*

Moczyłowska (1991) defined four lower Cambrian acritarch assemblage biozones based on assemblages from boreholes on the Lublin Slope of Poland. In upward succession, these are the *Asteridium tornatum–Comasphaeridium velvetum* Biozone, the *Skiagia ornata–Fimbriaglomerella membranacea* Biozone, the *Heliosphaeridium dissimulare–Skiagia ciliosa* Biozone and the *Volkovia dentifera–Liepaina plana* Biozone. The biozones have been recorded from other localities in the Baltic/East European Platform and further afield.

The *Asteridium tornatum–Comasphaeridium velvetum* Biozone on the Lublin Slope is correlated with the *Platysolenites antiquissimus* Biozone (Moczyłowska 1991). Based on acritarchs, Volkova *et al.* (1979, 1983) correlated the *Platysolenites* Biozone of eastern Poland with the Lontova Stage of the wider East European Platform (Fig. 3). The *Platysolenites antiquissimus* Biozone is in part equivalent to the *Trichophycus pedum* Ichnozone and includes *T. pedum* at the base (Moczyłowska & Zang 2006). Furthermore, the Lontova Stage was correlated with the Tommotian Stage by Mens *et al.* (1990). Hence, the *tornatum–velvetum* Biozone

is shown in Figure 3 as extending through the Terreneuvian Series. Correlation of the base of the zone remains uncertain. Moczyłowska (1991, p. 27) extended the *Asteridium tornatum*–*Comasphaeridium velvetum* Biozone down into the uppermost part of the Rovno Stage, which underlies the Lontova Stage, because of the occurrence of *Asteridium tornatum* in the latter. This suggests that the base of the zone lies close to the base of the Cambrian.

The first appearance datum of *Skiagia ornata* is reported to be close to but preceding the diversification of trilobites (e.g. Moczyłowska & Zang 2006). Hence, the base of the *Skiagia ornata*–*Fimbriaglomerella membranacea* Biozone is placed at about the base of Series 2, Stage 3 (Fig. 3). The *ornata*–*membranacea* Biozone is correlated with the Dominopol’ Stage of the East European Platform (Nielsen & Schovsbo 2006, fig. 2), the *Schmidtiellus mickwitzi* Trilobite Zone of Baltica (Moczyłowska 1991; only the lower part of the zone according to Nielsen & Schovsbo 2006, fig. 2) and the *Abadiella huoi* Trilobite Zone of Australia (Moczyłowska & Zang 2006).

The base of the *Heliosphaeridium dissimulare*–*Skiagia ciliosa* Biozone is placed within Stage 3, with the first appearance datum of *S. ciliosa* reported to precede that of the trilobite *Olenellus* (Moczyłowska & Zang 2006). In Baltica, the *dissimulare-ciliosa* Acritarch Zone has been correlated with the *Holmia kjerulfi* Assemblage Zone (Moczyłowska 1991), which Geyer (2005) correlated, at least in part, with the *Callavia* Trilobite Zone (Fig. 3). Nielsen & Schovsbo (2006, fig. 2), however, show the lower part of the *dissimulare-ciliosa* Acritarch Zone to correlate with the upper part of the *Schmidtiellus mickwitzi* Trilobite Zone. In Australia, the *dissimulare-ciliosa* Acritarch Zone has been correlated with the upper part of the *Abadiella huoi* Trilobite Zones, the *Pararaia tatei* and *P. bunyeroensis* trilobite zones, and the lower part of the *P. janeae* Trilobite Zone (Moczyłowska & Zang 2006). This interval embraces the *Callavia* and *H. kjerulfi* trilobite zones, but Geyer’s (2005) correlation of the *P. bunyeroensis* and lower *P. janeae* zones with the lower part of the *Ornamentaspis? linnarssoni*/*Protolenus* interval also implies that the *dissimulare-ciliosa* Acritarch Zone extends above the *Callavia* and *Holmia kjerulfi* biozones (Fig. 3). Similarly, Nielsen & Schovsbo (2006, fig. 2) show the upper part of the *dissimulare-ciliosa* Acritarch Zone to correlate with the lower part of the *Ornamentaspis? linnarssoni* Trilobite Zone in Baltica. Hence, the *dissimulare-ciliosa* Acritarch Zone is shown in Figure 3 as extending from a level in Stage 3 below the

top of the *Schmidtiellus* Trilobite Zone, through the *Holmia* Trilobite Zone and into the lower parts of Stage 4 and the “*Protolenus*” interval. Acritarch assemblages from the Vergale Stage of the East European Platform are similar in composition to those of the *Heliosphaeridium dissimilare*–*Skiagia ciliosa* Biozone of the Lublin Slope (Volkova *et al.* 1979, 1983), and Nielsen & Schovsbo (2006, fig. 2) correlate the *dissimilare-ciliosa* Biozone with the Vergale Stage (*Holmia kjerulfi* and lower *Ornamentaspis? linnarssoni* trilobite zones) and the underlying Ljuboml’ Stage (upper *Schmidtiellus mickwitzi* Biozone).

The upper part of the Bastion Formation and the overlying Ella Island Formation of east Greenland (Vidal 1979; Downie 1982) have yielded acritarchs of the *dissimilare-ciliosa* assemblage (Moczydłowska & Zang 2006) and trilobites of the *Bonnia*–*Olenellus* Biozone (Stouge *et al.* 2001; Skovsted 2006). Acritarchs of the *dissimilare-ciliosa* assemblage also occur in the Buen Formation of north Greenland (Vidal & Peel 1993). Well-preserved olenellid trilobites were reported from the Buen Formation by Palmer & Peel (1979), but those authors commented that none of the faunas from that formation could be unequivocally assigned to the *Bonnia*–*Olenellus* Trilobite Zone. They suggested that the Buen Formation trilobites might indicate the older *Nevadella* Trilobite Zone, which correlates with the *Callavia* Trilobite Zone (Hollingsworth 2005). These occurrences of the *dissimilare-ciliosa* assemblage further support the conclusion that the *dissimilare-ciliosa* Acritarch Zone spans the Stage 3-Stage 4 boundary (Fig. 3).

Moczydłowska (1991) considered the *Volkovia dentifera*–*Liepaina plana* Biozone, the highest of her early Cambrian acritarch assemblage zones on the Lublin Slope, to correspond to the “*Protolenus* interval” of traditional usage and the Rausve Stage of the East European Platform. Moczydłowska & Zang (2006), however, placed the base of the *dentifera-plana* Acritarch Zone within the *Pararaia janeae* Trilobite Zone of Australia, and Geyer (2005) placed the base of the *P. janeae* Zone within the *O.? linnarssoni* / “*Protolenus*” interval. Hence, the base of the *dentifera-plana* Acritarch Zone is placed above the base of the “*Protolenus*” interval in Figure 3. The top of the *dentifera-plana* Biozone is generally equated with the top of the *Ornamentaspis? linnarssoni* / “*Protolenus*” interval, but Axheimer *et al.* (2007, fig. 3) depicted correlation of the latter to be either diachronous or uncertain, rising from the base of the *Cephalopyge notabilis* Trilobite Zone to the base of the *Eoparadoxides harlani* Trilobite Zone (Fig. 3).

### *Series 3 and Furongian*

The acritarch zonation for the upper two series of the Cambrian is based on the succession of acritarch microfloras in the Cambrian succession of the Avalon Peninsula, eastern Newfoundland. The zonation for Series 3 and the Paibian Stage of the Furongian was elucidated by Martin & Dean (1981, 1984, 1988). The zonation for stages 9 and 10 of the Furongian is also based on the work of Martin & Dean (1981, 1988), supplemented by the more recent and detailed work of Parsons & Anderson (2000). See Figure 4.

The lowest zone, **A0-1**, was based originally on samples from the upper part of the Chamberlains Brook Formation on Random Island, eastern Newfoundland (Martin & Dean 1984). There was no macrofossil evidence of age, but the whole of the Chamberlains Brook Formation was correlated by both Howell (1925) and Hutchinson (1962) with the '*Paradoxides bennettii* [trilobite] Zone', as then used [the '*bennettii* Zone' has since been revised and restricted by Fletcher (2006, p. 72)]. Hence, Zone A0-1 was tentatively assigned to the '*P. bennettii* Zone' by Martin & Dean (1984), which they correlated with the upper part of the *Baltoparadoxides oelandicus* Trilobite Zone and the lower part of the *Ptychagnostus gibbus* Trilobite Zone (Martin & Dean 1984, fig. 57.3). Martin & Dean (1988) subsequently moved the top of the '*P. bennettii* Zone' to a level equivalent to the top of the *P. gibbus* Zone and modified the correlation so that Zone A0-1 is correlated in its entirety with the *P. gibbus* Zone (Fig. 4).

Acritarch **Zone A0**, otherwise referred to as the ***Rugosphaera terranovana* Zone**, occurs in the lower part of the Manuels River Formation of eastern Newfoundland, and is correlated on the basis of associated trilobites with the '*Paradoxides hicksii* Zone', equivalent to the *Tomagnostus fissus*–*Ptychagnostus atavus* Trilobite Zone (Martin & Dean 1984, 1988). The overlying **Zone A1**, the ***Adara alea* Zone**, also occurs in the Manuels River Formation and was correlated by Martin & Dean (1981, 1984, 1988) with the upper part of the *Tomagnostus fissus*–*Ptychagnostus atavus* Zone (upper '*Paradoxides hicksii* Zone') and the lower part of the undifferentiated *Hypagnostus parvifrons* and *Ptychagnostus punctuosus* trilobite zones ('*Paradoxides davidis* Zone').

**Zone A2** of Martin & Dean (1981) was divided (Martin & Dean 1988) into a **lower A2 Zone**, with *Timofeevia phosphoritica* but without *Vulcanisphaera turbata*,

and an **upper A2 Zone**, the *Timofeevia phosphoritica*–*Vulcanisphaera turbata* **Zone**. Microfloras indicative of the lower A2 Zone occur in the upper part of the Manuels River Formation and in the base of the overlying Elliott Cove Formation. Following Martin & Dean (1988, fig. 9), the base of the lower A2 Zone is correlated with a level in the upper part of the *Ptychagnostus punctuosus* Trilobite Zone, and the top of the lower A2 Zone probably correlates with a level in the *Lejopyge laevigata* Trilobite Zone (Fig. 4). The lowest occurrences of the upper A2 assemblage are a little above the base of the Elliott Cove Formation, possibly in the upper part of the *L. laevigata* Biozone and certainly below the first appearance of *Agnostus pisiformis*. On the evidence of associated macrofaunas, higher occurrences of upper A2 microfloras are from the *A. pisiformis* and *Olenus* trilobite zones. The highest occurrence of the A2 microflora in eastern Newfoundland is above the highest fauna of the *Olenus* Biozone, but below faunas indicative of the *Parabolina spinulosa* Biozone. The base of the upper A2 Zone is therefore placed at a level in the *Lejopyge laevigata* Biozone, and its top at a level approximately equivalent to the top of the *Olenus* Biozone.

Two parallel acritarch zonations exist for Cambrian stages 9 and 10, based on the same eastern Newfoundland sections: the earlier zonation scheme of Martin & Dean (1981, 1988) and the more recent scheme of Parsons & Anderson (2000). **Zone A3** of Martin & Dean (1981), divided into A3a (below) and A3b (above) by Martin & Dean (1988), occurs in the middle of the Elliott Cove Formation. Microfloras indicative of both A3a and A3b are associated with the brachiopod *Orusia lenticularis* and are therefore correlated with the *Parabolina spinulosa* Trilobite Zone. The lowest occurrences of A3a microfloras on Random Island, eastern Newfoundland, are from strata that lack macrofossils but are above the highest beds from which *Olenus* was collected, so the possibility that the base of A3a is in the top of the *Olenus* Trilobite Zone cannot be discounted. **Zone RA3** of Parsons & Anderson (2000) was not discussed by those authors but they describe it (p. 9) as being ‘virtually equivalent’ to microflora A3.

**Zone A4** of Martin & Dean (1981, 1988), also in the Elliott Cove Formation, was initially correlated with the upper part of the *Parabolina spinulosa* Trilobite Zone and the *Leptoplastus* Trilobite Zone. *Parabolina spinulosa* is associated with A4 microfloras at several localities, and in some cases they are abundant and well preserved. Parsons & Anderson (2000, text-figure 2), however, showed the

*Leptoplastus* Biozone to be missing on Random Island, and the stratigraphically higher localities of Martin & Dean's (1981, 1988) A4 Zone to occur in the base of the *Protopeltura praecursor* Trilobite Zone (GSC localities 87789, C-98021-22). As defined by Martin & Dean (1981, 1988), but taking Parsons & Anderson's (2000) revised correlation into account, Zone A4 therefore spans the interval from the upper *P. spinulosa* Biozone into the base of the *P. praecursor* Biozone. **Zone RA4** of Parsons & Anderson (2000) in contrast is restricted to the upper *P. spinulosa* Biozone (Fig. 4). The base of A4 either coincides with or is slightly below that of RA4, depending on whether the microflora from GSC locality 87789 is included in A4 or not. Martin & Dean (1981) only tentatively assigned the microflora from that locality to A4, and Parsons & Anderson (2000, text-fig. 2) placed it in the upper part of A3b at a level below the base of their RA4 Zone, making the bases of A4 and RA4 coincident. The microflora from 87789, however, includes *Dasydiacrodium caudatum* and the first appearance of this species was one of the criteria used by Martin & Dean (1981) to distinguish A4 from A3b. Based on this and the position of the locality shown in Parsons & Anderson's (2000) text-figure 2, the base of A4 is placed below that of RA4 in Figure 4.

**Zone A5** of Martin & Dean (1981, 1988) occurs in the upper part of the Elliott Cove Formation. It was divided into A5a and A5b by Martin & Dean (1981), but the stratigraphical relationships and order of superposition, with A5a below A5b, were inferred from the palynological data. Subsequently, Parsons & Anderson (2000) revised the stratigraphical relationships of the localities that Martin & Dean used to define A5 and its correlation with macrofaunal zones. Based on the revised stratigraphical positions, the lowest microflora in A5 is from GSC locality C-98023 (Martin & Dean 1988) and is from the same locality as fragments of the trilobite *Ctenopyge (Eoctenopyge) flagellifera* (Angelin 1854), a species confined to the top subzone of the *Protopeltura praecursor* Trilobite Zone. This is the only microflora retained in A5a. Two microfloras, from GSC localities 92998 and 94432, were placed in A5b by Martin & Dean (1981) and correlated with an undifferentiated *Peltura* Biozone, although Martin & Dean (1988) reassigned locality 94432 to the *Acerocare* Trilobite Zone. Parsons & Anderson (2000) placed both localities in the *Ctenopyge tumida* Subzone in the upper half of the *Peltura minor* Trilobite Zone. A microflora from a fourth GSC locality, 94435, was used originally to define A5a by Martin & Dean (1981) and was from strata reported to yield *Peltura scarabaeoides*. Parsons &

Anderson's (2000) placed locality 94435 in the *Ctenopyge linnarssoni* Subzone of the *Peltura scarabaeoides* Biozone, and therefore above the A5b microfloras.

Parsons & Anderson (2000, text-fig. 2) correlated the base of A5a with the base of their RA5 Zone and the base of the *Protopeltura praecursor* Trilobite Zone. The base of A5a, however, is defined by the first appearance of *Ladogella rommelaerei*, and the lowest occurrence of that acritarch species in eastern Newfoundland is in the upper part of the *praecursor* Biozone (GSC locality C-98023, *flagellifera* Subzone). Consequently, A5a can only be correlated with the *flagellifera* Subzone, and A5b with the *tumida* Subzone of the *Peltura minor* Biozone, possibly, if the microflora from GSC locality 94435 is included, extending upwards to the *linnarssoni* Subzone of the *Peltura scarabaeoides* Biozone.

Parsons & Anderson (2000) based their **RA5 Zone** on samples from five sections, two of which are correlated with the *Protopeltura praecursor* Trilobite Zone and the other three with the *Peltura minor* Trilobite Zone. The lowest part of RA5 correlates with the upper part of Martin & Dean's (1981, 1988) A4 Zone, in the lower part of the *P. praecursor* Biozone (Fig. 4).

Parsons & Anderson (2000) defined a succession of acritarch zones in the *Peltura scarabaeoides* and lower *Acerocare* trilobite zones of the Elliott Cove Formation, **RA6**, **RA7**, **RA8** and subdivisions, that have no equivalents in Martin & Dean's scheme. Zone RA6 is divided into RA6a (lower) and RA6b (upper). Based on associated trilobites, **RA6a** is correlated with the *Ctenopyge bisulcata* Subzone of the *Peltura scarabaeoides* Biozone, and **RA6b** with the *Ctenopyge linnarssoni* Subzone of the same zone. RA6b is thus equivalent to the highest part of Martin & Dean's (1981) A5b Zone, based on correlation of the microflora from locality 94435. Zone RA7 (*Ladogella rotundiformis*–*Poikilofusa squama*) is also divided into RA7a (lower) and RA7b (upper). Trilobites indicate correlation of RA7a with the uppermost *Ctenopyge linnarssoni* Subzone and possibly the *Parabolina lobata* Subzone of the *Peltura scarabaeoides* Biozone, and correlation of RA7b with the *Acerocare* Trilobite Zone, inferred to be the lower part of that zone. Zones **RA8** (*Ooidium? clavigerum*–*Striatotheca? randomensis*), **RA9** (*Ooidium rossicum*–*Nellia acifera*) and **RA10a**, the lower part of the **RA10** (*Nellia? longispinata*–*Nellia sukatschevii*) Acritarch Zone of Parsons & Anderson (2000), are also correlated with the *Acerocare* Biozone on the basis of associated trilobites. The upper part of Zone RA10, **RA10b**, is correlated with the Early Ordovician (Tremadocian).

The highest of Martin & Dean's (1981) acritarch zones from the Cambrian of eastern Newfoundland, **A6** (*Arbusculidium destombesii*–*Vulcanisphaera capillata*), is from the Clarendville Formation. Martin & Dean (1981) noted that macrofaunal evidence was generally indicative of the lower Tremadocian, although recognizing, in one instance, that the trilobites *Araiopleura beothuk* and *Conophrys* sp. might indicate the *Acerocare* Biozone. Parsons & Anderson (2000), however, equated A6 with their RA9, RA10a and RA10b zones, based on their assessment of the stratigraphical position of Martin & Dean's (1981) localities, and thus extended it through the middle and upper parts of the *Acerocare* Biozone into the Tremadocian.

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Cambrian Correlation Report – Figures

Series	agnostid zones	olenid zones	olenid subzones	North Wales			South Wales	Shropshire			Malvern	Warwickshire			
				N	E	S		Lilleshall	Wrekin	Bentleyford		Dosthill	Nuneaton	Midlands BHs	
Furongian	Trilobagnostus holmi	<i>Acerocare</i> (undivided in Britain)		?	+										
		<i>Peltura scarabaeoides</i>	<i>Peltura paradoxa</i>												
			<i>Parabolina lobata</i>	+	+						?		?	?	
			<i>Ct. linnarssoni</i>	+	?	?	+				+		+	+	
	<i>Ct. bisulcata</i>		?	+	+					+	+	+	+		
	Lotagnostus americanus	<i>Peltura minor</i>	<i>Ct. affinis</i>				?								?
			<i>Ct. tumida</i>				+							+	
			<i>Ct. spectabilis</i>	?				↑						+	
			<i>Ct. similis</i>					↓		+				+	
	Pseudagnostus cyclopyge	<i>Protopeltura praecursor</i>	<i>Ct. flagellifera</i>	+			+		+		?		+		
			<i>Ct. postcurrens</i>						+				+		
			<i>Ct. neglectus</i>	+					+						
		<i>Leptoplastus</i>	<i>L. stenotus</i>												
			<i>L. angustatus</i>	↑						+					+
			<i>L. ovatus</i>	↓		?				+					+
	<i>L. crassicomis</i>								+					+	
	<i>Parabolina spinulosa</i>	<i>L. raphidophorus</i>								+				?	
		<i>L. paucisegmentatus</i>							+					+	
		<i>P. spinulosa</i>	+	+	+				+		↑	↑		+	
	Glyptagnostus reticulatus	<i>Olenus</i>	<i>P. brevispina</i>								↓	↓		+	
<i>O. cataractes</i>			+	+		+							+		
<i>O. wahlenbergi</i>													+		
<i>O. truncatus</i>				+									+		
<i>O. gibbosus</i>				+									+		
		<i>Agnostus pisiformis</i>				+						+	?		

**Fig. 2.** Trilobite zones and subzones in the Furongian and their distribution in England and Wales by region. In the subzones column, *Ct.* stands for *Ctenopyge*, *L.* for *Leptoplastus*, *O.* for *Olenus* and *P.* for *Parabolina*. In the North Wales column, N = north, chiefly Ogof Ddû, E = eastern edge of the Harlech Dome, including Bryn-llin-fawr, S = southern edge. In the column for South Wales, the records of the *Agnostus pisiformis* Biozone and *O. cataractes* Subzone are from the St David's area; all the higher records, in the *Peltura* zones, are from Llangynog. In the Shropshire column, Lilleshall = Lilleshall Borehole, Wrekin = Dryton Brook, Bentleyford = Bentleyford Brook. In the Warwickshire column Nuneaton includes the Merevale boreholes, and Midlands BHs are other boreholes in the regions of Birmingham, Coventry and Warwick.

System/Series		International stages	British regional series	Biostratigraphical zones and subzones used here	Acritarch zones	Baltic zones	East European Platform stages	Siberian stages	Australian zones	North American (Laurentian) zones, stages and series			
Cambrian (lower)	Series 3 (part)	Stage 5 (part)	St David's (part)	<i>Baltoparadoxides oelandicus</i> Superzone		<i>Eccaparadoxides insularis</i>	Kibartai	Amgan	<i>Pentagnostus anabarensis</i>	<i>Peronopsis bonnerensis</i>	Delamaran	Lincolnian	
				<i>Eoperadoxides harlani</i>						<i>Albertella</i>			<i>Foliella denticulata/</i> <i>Cryptocephalus indicus</i>
				<i>Kiskinella</i>						<i>Amecephalus arrosensis</i>			<i>Eokochaspis nodosa</i>
	Series 2	Stage 4	Comley	<i>Cephalopyge</i>		'Protolenus' interval	Rausve	Toyonian	<i>Xystridura/</i> <i>Redlichia</i>	<i>Pararaia janeae</i>	Dyeran	Waucoban	
				<i>Orodes</i>						<i>V. dentifera -</i> <i>L. plana</i> - ?			<i>Bonnia-Olenellus</i>
				<i>Strenuella sabulosa</i>						<i>H. dissimilare -</i> <i>S. ciliosa</i>			<i>Pararaia bunyeroensis</i>
				<i>Callavia</i>						<i>Holmia</i>			<i>Pararaia tatei</i>
	Terreneuvian	Stage 3	Comley	<i>Fallotaspis</i>		<i>S. ornata -</i> <i>F. membranacea</i>	Vergale	Botomian	<i>Abadiella huoi</i>	<i>Nevadella</i>	Montezuman	Waucoban	
				<i>Eofallotaspis</i>						<i>Schmidtellus</i>			<i>Fallotaspis</i>
				<i>Camarella baltica</i>						<i>A. tornatum -</i> <i>C. velvetum</i>			<i>Fritzaspis</i>
Fortunian	Stage 2	Comley	<i>Sunnaginia imbricata</i>		<i>Platysolenites antiquissimus</i>	Lontova	Tommotian			(un-named)	Begadecan		
			<i>Rusophycus avalonensis</i>									<i>A. tornatum -</i> <i>C. velvetum</i>	
Precambrian (Ediacaran)				<i>Trichophycus pedum</i>			Rovno	Nemakit-Daldynian					

**Fig. 3.** Suggested correlation of acritarch assemblage zones to selected international stages and zones from the base of the Cambrian to Series 3. Correlations shown are based on the following sources, with modifications in some instances. 1. Baltic zones: Geyer (2005), Moczyłowska & Zang (2006), Nielsen & Schovsbo (2006), Shergold & Geyer (2003). 2. East European Platform stages: Nielsen & Schovsbo (2006). 3. Siberian stages: Babcock & Peng (2007), Geyer (2005), Mens et al. (1990), Shergold & Geyer (2003). 4. Australian zones: Babcock & Peng (2007), Geyer (2005), Jago et al. (2006), Laurie (2006), Moczyłowska & Zang (2006), Shergold & Geyer (2003). 5. North America (Laurentia): Babcock & Peng (2007), Geyer (2005), Hollingsworth (2005), Shergold & Geyer (2003).

		Macrofossil zones		Olenid subzones (Furongian)	Acritarch zones			
CAMBRIAN	Ordovician	Tremadocian	<i>Rhabdinopora praeparabola</i>			A6	RA10b	
							RA10a	
	Furongian	Stage 10	<i>Acerocare</i>					RA9
			<i>Peltura scarabaeoides</i>		<i>P. paradoxa</i>	not sampled		RA8
					<i>P. lobata</i>			RA7b
					<i>Ct. linnarssoni</i>			missing
					<i>Ct. bisulcata</i>			?
				<i>Ct. affinis</i>		RA7a		
				<i>Ct. tumida</i>	A5b?	RA6b		
				<i>Ct. spectabilis</i>	not sampled	RA6a		
				<i>Ct. similis</i>		RA5		
				<i>Ct. flagellifera</i>	A5a			
			<i>Ct. postcurrens</i>	not sampled				
			<i>Protopeltura praecursor</i>	<i>Ct. neglectus</i>				
		Stage 9	<i>Leptoplastus</i>	6 subzones	A4	missing		
			<i>Parabolina spinulosa</i>	<i>P. spinulosa</i>		RA4		
				<i>P. brevispina</i>	A3b	RA3		
					A3a			
		Paibian	Olenus Zone		<i>O. cataractes</i>	Tp-Vt Zone (= upper A2)		
					<i>O. wahlenbergi</i>			
				<i>O. truncatus</i>				
				<i>O. gibbosus</i>				
	Series 3	Guzhangian	<i>Agnostus pisiformis</i>	See Fig. 2 for genera				
			<i>Paradoxides forchhammeri</i> Superzone	<i>Lejopyge laevigata</i>		lower A2		
				<i>'Solenopleura' brachymetopa</i>				
				<i>Goniagnostus nathorsti</i>				
		Drumian	<i>Paradoxides paradoxissimus</i> Superzone	<i>Ptychagnostus punctuosus</i>				
				<i>Hypagnostus parvifrons</i>				
<i>Tomagnostus fissus</i>								
Stage 5		<i>Baltoparadoxides oelandicus</i> Superzone	<i>Ptychagnostus gibbus</i>					
			<i>Kiskinella &amp; Eoparadoxides harlani</i>					
Series 2		Stage 4	<i>Cephalopyge</i>		dentifera-plana ?			
	<i>Orodes</i>							
	<i>Strenuella sabulosa</i>							
	Stage 3	<i>Callavia</i>						
		<i>Fallotaspis</i>						
		<i>Eofallotaspis</i>						
Terreneuvian	Stage 2	<i>Camenella baltica</i>		ornata-membranacea				
		<i>Sunnaginia imbricata</i>						
	Fortunian	<i>Rusophycus avalonensis</i>						
		<i>Trichophycus pedum</i>		tornatum-velvetum				

**Fig. 4.** Correlation of Cambrian acritarch biozones to the macrofossil zones used here. Acritarch zones in the Terreneuvian Series and Series 2 are based on based on assemblages from the East European Platform, but have wider distributions; see text and Fig. 3. Acritarch zones from Stage 5 upwards (i.e from Zone A0-1) are based on eastern Newfoundland (Avalonian) assemblages. Two parallel sets of zones have been developed for stages 9 and 10 based on the same succession in eastern Newfoundland: A3a-A6 and RA3-RA10b. See text for discussion.