# Some aspects of late Cambrian and early Ordovician acritarchs

*by* F. MARTIN

ABSTRACT. Late Cambrian and early Ordovician acritarch assemblages dated by means of trilobites and graptolites have been little studied; their stratigraphic usefulness for establishing detailed interregional correlations is consequently limited. Acritarchs from the Upper Cambrian, Tremadoc Series, and Arenig Series of eastern Newfoundland are reviewed in relation to those of the Mediterranean region, western Europe, and North Africa, to which they bear a marked resemblance.

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ACRITARCHS occur frequently in marine sediments of the Upper Cambrian (Merioneth Series), Tremadoc Series, and Arenig Series. The importance of their diversity and abundance was indicated by Downie (1973, fig. 1), while Cramer and Diez (1979) noted the publications devoted to their study; the latter are few for the late Cambrian but numerous for the early Ordovician. In general the lack of published monographs dealing with the palynology of type sections and/or sediments dated with reference to the established trilobite and graptolite zones has so far limited the detailed stratigraphic usefulness of the group over a wide geographical area. This paper reviews acritarch microfloras of late Cambrian, Tremadoc, and Arenig ages obtained by the author from the Avalon Platform, eastern Newfoundland (Martin *in* Dean and Martin 1978, *in* Martin and Dean 1981) and compares them with data as compiled in summer 1980 from many sources (text-fig. 1). Thirty-eight taxa from the Avalon Platform (text-


TEXT-FIG. 1. Generalized map of localities from which late Cambrian, Tremadoc, and Arenig acritarchs listed in text-figs. 2 and 3 are recorded. Numbers are those printed in bold type on the right-hand side of text-fig. 3.

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fig. 2) are selected here to illustrate the evolutionary succession of microfloras, but none of the steps in this succession are designated as a formal biostratigraphic unit because of the lack of sufficient comparative data. With the exception of *Marrocanium simplex* Cramer, Kanes *et al.*, 1974 and *Tetraniveum arenigum* (Vavrdová) Vavrdová, 1976, both of which are figured here (Pl. 1), all the taxa have been discussed or figured by Martin (*in* Dean and Martin 1978, *in* Martin and Dean 1981).

As the above data are the only ones at present available for the late Cambrian and early Ordovician of eastern North America, the degree of reliability of the age assignments for the relevant strata at Random Island and Bell Island is reviewed here. At Random Island, situated in Trinity Bay, the Elliott Cove Formation contains, according to Dean (*in* Martin and Dean 1981), five of the six trilobite zones recognized in Scandinavia and the Anglo-Welsh area; in ascending order these are the *Agnostus pisiformis* Zone, *Olenus* Zone, *Parabolina spinulosa* Zone, *Leptoplastus* Zone, and *Peltura* Zone. The presence of the *Acerocare* Zone, the youngest zone of the Upper Cambrian, has not been proved and it may be that part of the overlying Clarenville Formation, containing *Araiopleura beothuk* Dean, 1970 and *Conophrys* sp., belongs to this level by analogy with corresponding strata in North Wales (A. W. A.

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EXPLANATION OF PLATE 1

Locality numbers with prefix GSC refer to the locality index of the Geological Survey of Canada, Ottawa, where specimens with numbers prefixed GSC are also housed. Specimen numbers with prefix IRScNB are in the Institut Royal des Sciences Naturelles de Belgique, Brussels. Details of certain localities are noted in the section on New Locality Data; others are listed in Martin and Dean (1981).

Fig. 1. *Tetraniveum arenigum* (Vavrdová) Vavrdová, 1976. Lower Arenig, GSC loc. 94424, Bell Island, eastern Newfoundland. GSC 65675, × 700.

Fig. 2. *Marrocanium simplex* Cramer, Kanes *et al.*, 1974. Lower Arenig, GSC loc. 94424, Bell Island, eastern Newfoundland. GSC 65676, × 1000.

Fig. 3. *Vogtlandia flosmaris* (Deunff) Martin, 1978. Lower Arenig, LDR-15, Montagne Noire, Hérault, France. IRScNB b1302, × 1000.

Fig. 4. *Dicrodiacrodium normale* Burmann, 1968. Upper Arenig, FM-75-1c, Massif of Dave, Belgium. IRScNB b1303, × 960.

Fig. 5. *Aureotesta clathrata* Vavrdová, 1972. Lower Arenig, LDR-17, Montagne Noire, Hérault, France. IRScNB b1304, × 1000.

Fig. 6. *Striatotheca principalis* Burmann, 1970. Lower Arenig, LDR-17, Montagne Noire, Hérault, France. IRScNB b1305, × 700.

Fig. 7. *Saharidia fragile* (Downie) Combaz, 1967. Lower Tremadoc, GSC loc. 92999, Random Island, eastern Newfoundland. GSC 65677, × 500.

Fig. 8. *Baltisphaeridium crinitum* Martin, 1978. Probably lower Arenig, GSC loc. 94419, Bell Island, eastern Newfoundland. GSC 65678, × 1000.

Fig. 9. *Pirea* sp. Upper Arenig, FM-75-1c, Massif of Dave, Belgium. IRScNB b1306, × 700.

Fig. 10. *Vulcanisphaera africana* Deunff, 1961. Probably Lower Arenig, GSC loc. 94419, Bell Island, eastern Newfoundland. GSC 65679, × 1000.

Fig. 11. *Acanthodiacrodium* sp. Probably Lower Arenig, GSC loc. 94419, Bell Island, eastern Newfoundland. GSC 65680, × 700.

Fig. 12. *Cymatiogalea cuvillieri* (Deunff) Deunff *et al.*, 1974. Lower Tremadoc, ARG-6, Salta Province, Argentina. IRScNB b1307, × 1000.

Fig. 13. *Acanthodiacrodium angustum* (Downie) Combaz, 1967. ARG-6, Salta Province, Argentina. IRScNB b1308, × 1000.

Fig. 14. *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976. Upper Cambrian, GSC loc. 92997, Random Island, eastern Newfoundland. GSC 65681, × 1000.

Fig. 15. *Timofeevia microretis* Martin *in* Martin and Dean, 1981. Upper Cambrian, GSC loc. 92990, Random Island, eastern Newfoundland. GSC 57794, × 700.

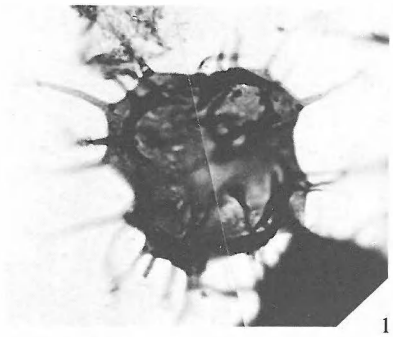
Fig. 16. *Arbusculidium rommelaerei* Martin *in* Martin and Dean, 1981. Upper Cambrian, GSC loc. 94435, Random Island, eastern Newfoundland. GSC 57819, × 1000.

Fig. 17. *Veryhachium dumontii* Vanguestaine, 1973. Upper Cambrian, GSC loc. 92997, Random Island, eastern Newfoundland. GSC 65682, × 1000.

Fig. 18. *Cristallinium randomense* Martin *in* Martin and Dean, 1981. Upper Cambrian, GSC loc. 92998, Random Island, eastern Newfoundland. GSC 57806, × 1000.

Fig. 19. *Vulcanisphaera turbata* Martin *in* Martin and Dean, 1981. Upper Cambrian, GSC loc. 92989, Random Island, eastern Newfoundland. GSC 57764, × 1000.

Fig. 20. *Timofeevia lancarae* (Cramer and Diez) Vanguestaine, 1978. Upper Cambrian, GSC loc. 92993, Random Island, eastern Newfoundland. GSC 57789, × 1000.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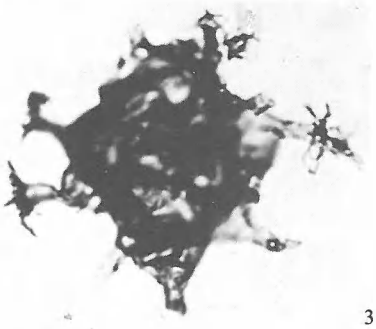
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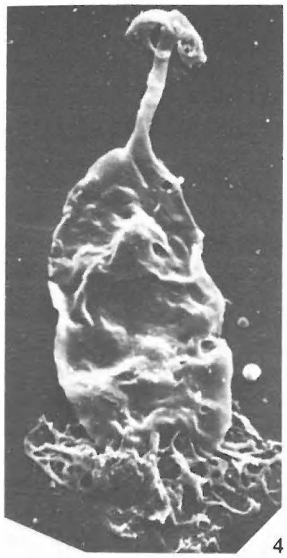
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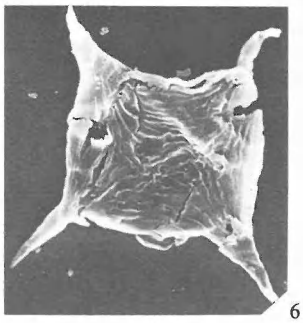
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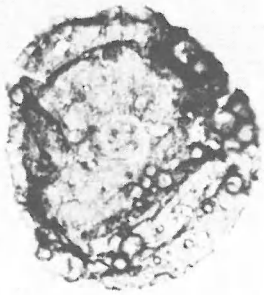
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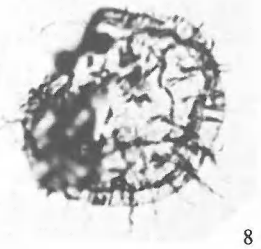
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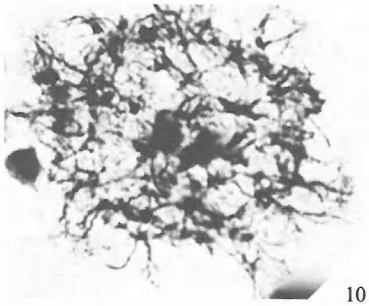
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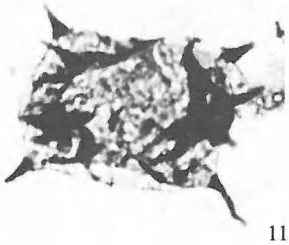
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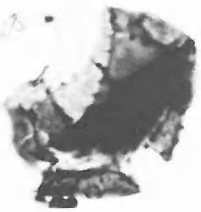
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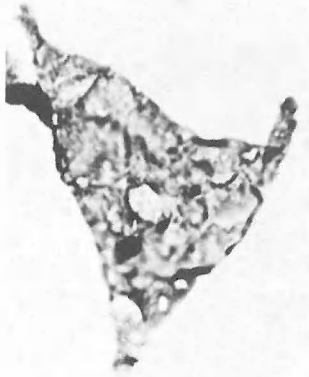

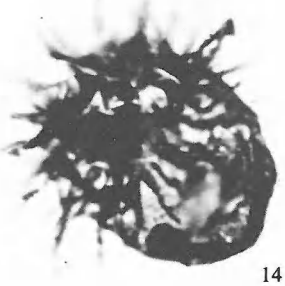
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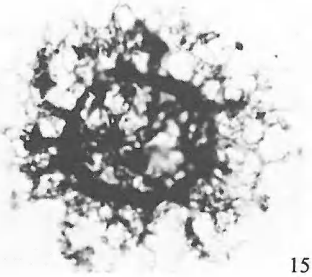
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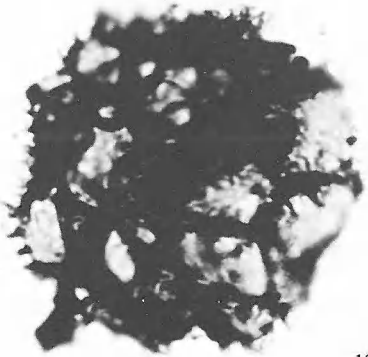
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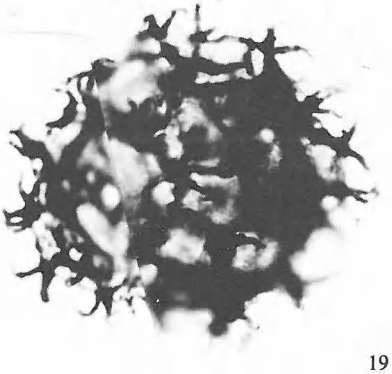
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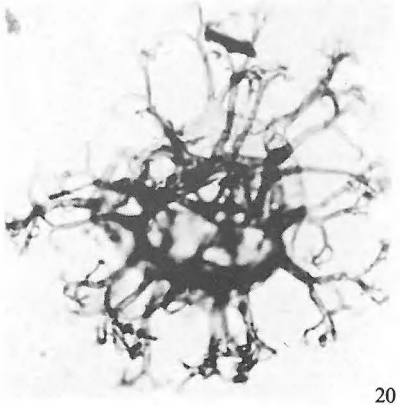
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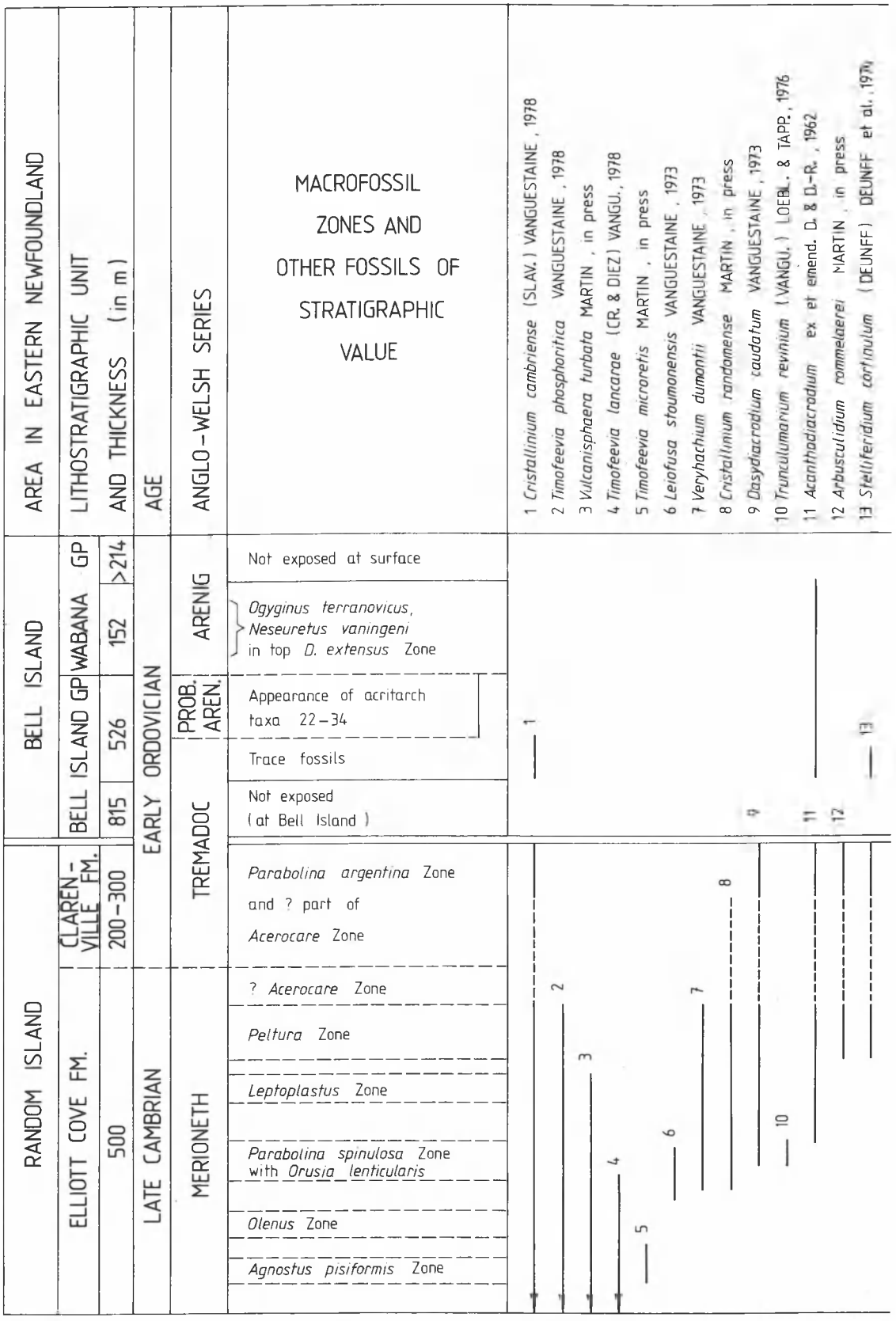
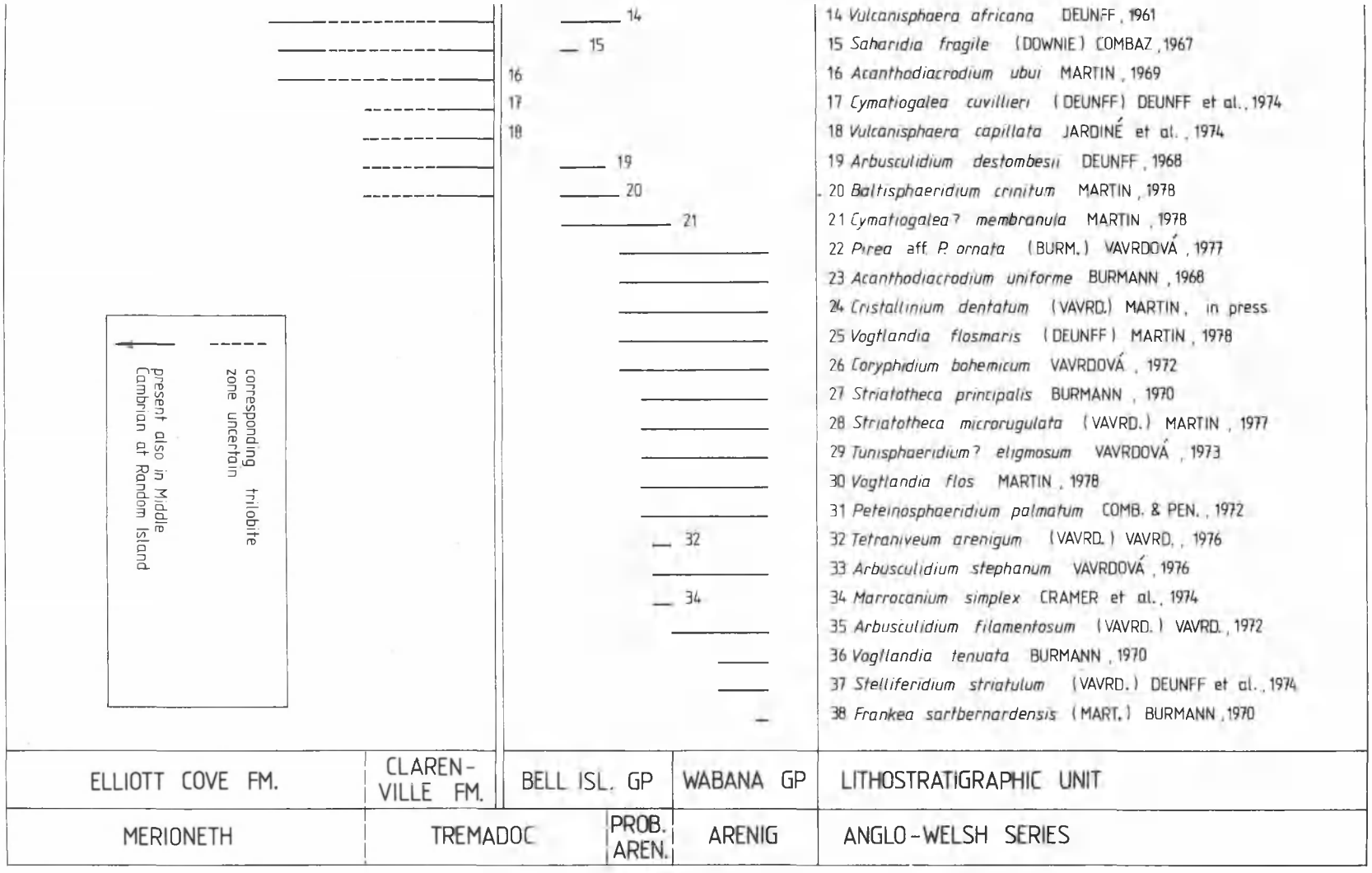
MARTIN, Cambrian–Ordovician acritarchs




TEXT-FIG. 2. Vertical distribution of selected late Cambrian and early Ordovician acritarchs in eastern Newfoundland (not to scale). Taxa listed as Martin, in press are now published by Martin *in* Martin and Dean (1981).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34
corresponding trilobite zone uncertain
present also in Middle Cambrian at Random Island
14 Vulcanisphaera africana DEUNFF, 1961
15 Saharidia fragile (DOWNIE) COMBAZ, 1967
16 Acanthodiacrodium ubui MARTIN, 1969
17 Cymatiogalea cuvillieri (DEUNFF) DEUNFF et al., 1974
18 Vulcanisphaera capillata JARDINÉ et al., 1974
19 Arbusculidium destombesii DEUNFF, 1968
20 Baltisphaeridium crinitum MARTIN, 1978
21 Cymatiogalea? membranula MARTIN, 1978
22 Pirea aff. P. ornata (BURM.) VAVRDOVÁ, 1977
23 Acanthodiacrodium uniforme BURMANN, 1968
24 Cristallinium dentatum (VAVRD.) MARTIN, in press
25 Vogtlandia flosmaris (DEUNFF) MARTIN, 1978
26 Coryphidium bohemicum VAVRDOVÁ, 1972
27 Striatotheca principalis BURMANN, 1970
28 Striatotheca microrugulata (VAVRD.) MARTIN, 1977
29 Tunisphaeridium? eligmosum VAVRDOVÁ, 1973
30 Vogtlandia flos MARTIN, 1978
31 Peteinosphaeridium palmatum COMB. & PEN., 1972
32 Tetraniveum arenigum (VAVRD.) VAVRD., 1976
33 Arbusculidium stephanum VAVRDOVÁ, 1976
34 Marrocanium simplex CRAMER et al., 1974
35 Arbusculidium filamentosum (VAVRD.) VAVRD., 1972
36 Vogtlandia tenuata BURMANN, 1970
37 Stelliferidium striatulum (VAVRD.) DEUNFF et al., 1974
38 Frankea sartbernardensis (MART.) BURMANN, 1970
ELLIOTT COVE FM.
CLAREN-VILLE FM.
BELL ISL. GP
WABANA GP
LITHOSTRATIGRAPHIC UNIT
MERIONETH
TREMADOC
PROB. AREN.
ARENIG
ANGLO-WELSH SERIES

Rushton 1979, and pers. comm. to W. T. Dean 1980). The greater part of the Clarenville Formation, containing the *Parabolina argentina* Zone as identified by Dean (1976, p. 243, *in* Martin and Dean 1981), is considered to belong to the Lower Tremadoc by comparison with the succession established in Argentina by Harrington and Leanza (1957), though it is possible that trilobites closely resembling, or conspecific with, *P. argentina* (Kayser, 1876) occur also in the highest Upper Cambrian (W. T. Dean pers. comm. 1980). Because of folding and faulting of the relevant strata, it has not yet proved possible to establish precisely the position of the Cambrian–Ordovician boundary on Random Island. In Conception Bay the works of Van Ingen (1914), Howell (1926), and Rose (1952) indicate that the Bell Island Group cropping out on Kellys Island, Little Bell Island, and Bell Island is younger than the Clarenville Formation of Trinity Bay. The youngest accessible surface outcrops of the Bell Island Group occur on the north-west coast of Bell Island and were described first by Hayes (1915); the succession is relatively continuous and contains rare inarticulate brachiopods and trace fossils. Study of the latter, including particularly *Cruziana*, led Bergström (1976) to draw the Tremadoc–Arenig Series boundary approximately 137 m above the base of the Bell Island Group as exposed on Bell Island, where the lowest 815 m are not seen. The acritarch evidence (text-fig. 2, taxa 22–34) indicates an approximate boundary between 130 m and 330 m above the same reference level. Assuming that Iron Ore Zone 1 of Hayes (1915) does not coincide with a break in sedimentation, this estimate would imply that *Vulcanisphaera africana* Deunff, 1961 and *Baltisphaeridium crinitum* Martin, 1978 may still be present at the base of the Arenig. It may be noted that the genus *Vulcanisphaera* Deunff, 1961 emend., Rasul, 1976 has been reported by Downie *et al.* (1979) from the Arenig in the Pennant Slates of Wales. The lower part of the Wabana Group, which overlies the Bell Island Group at Bell Island, represents the uppermost part of the *Didymograptus extensus* Zone (Rickards *in* Dean and Martin 1978), and associated deposits also contain the trilobites *Ogyginus terranovicus* Dean, 1978 and *Neseuretus vaningeni* Dean, 1978.

The thirty-two selected taxa which form the basis of the generalized succession of microfloras now proposed (text-fig. 3) after integrating all available data from eastern Newfoundland, possess morphographic characters sufficiently distinct to permit unambiguous determinations; each taxon is known from at least two, and generally at least four, different regions. Numerals in bold type in the right-hand column indicate references which are not necessarily either the original ones or the most complete; they correspond in general to the most recent papers listing primary sources. The absence of an asterisk (*) indicates that the taxon is figured for the region concerned but without necessarily being illustrated in the work quoted here. In order to avoid confusion with possibly reworked material, the references cited do not refer to deposits younger than the Arenig Series; consequently, taxa such as *Frankea sartbernardensis*, *Dicrodiacrodium normale*, *Striatotheca quieta* (as '*S. acutiuscula*'), and the genus *Pirea*, described as '*Deunffia*' from the Llanvirn Series of East Germany by Burmann (1970), are not included here. Relatively uncertain data indicated as 'Upper Arenig–Lower Llanvirn' (e.g. see Cramer, Allam *et al.* 1974 for Morocco), are incorporated.

The range tables for the selected acritarchs (text-figs. 2, 3) are considered to be sufficiently explicit to require little comment other than concerning the first appearance of acritarch taxa dated with reference to macrofossil zones. *Vulcanisphaera* and *Saharidia* Combaz, 1967, which are often considered indicative of the Tremadoc Series in Europe and North Africa (see Cramer and Diez 1979, p. 123), appear respectively in the Middle Cambrian (*Paradoxides davidis* Zone) and the Upper Cambrian (*Peltura* Zone) of eastern Newfoundland. The successive appearances of *Leiofusa stoumonensis* Vanguestaine, 1973, *Verychachium dumontii* Vanguestaine, 1973, *Cristallinium randomense* Martin *in* Martin and Dean, 1981, *Dasydiacrodium caudatum* Vanguestaine, 1973, *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976, and *Acanthodiacrodium* sp. are 'stepped' between levels slightly below and at the summit of the *Parabolina spinulosa* Zone. Of these species, *T. revinium* has the most restricted vertical distribution, its range corresponding to the upper part of the *P. spinulosa* Zone. The stratigraphic value of *L. stoumonensis*, *V. dumontii*, *D. caudatum*, and *T. revinium* was emphasized by Vanguestaine (1974, 1978) for Revinian deposits devoid of macrofossils in the Belgian and French Ardennes and, in the case of the three last-named taxa, for the Orusia Shales, Upper Cambrian, of the Anglo-Welsh area.

In the Upper Cambrian and Lower Tremadoc at Random Island the most apparent palynological change occurs within the *Peltura* Zone; it is characterized mainly by the successive appearance of *Arbusculidium rommelaerei* Martin *in* Martin and Dean, 1981, *Stelliferidium cortinulum* (Deunff) Deunff *et al.*, 1974, *Vulcanisphaera africana* Deunff, 1961, *Saharidia* fragile (Downie) Combaz, 1967, and *Acanthodiacrodium ubui* Martin, 1969. Although these four taxa are very widespread geographically in the Tremadoc Series of the Northern Hemisphere (see Martin *in* Martin and Dean 1981 for references), the succession demonstrated at Random Island has not yet been reported elsewhere. In Spain (Cramer and Diez 1972; Fombella 1977, 1978, 1979) and Algeria (Baudelot and Gery 1979), for example, assignment of strata to the Upper Cambrian was proposed on the basis of acritarchs and without reference to the established macrofossil zones.

Downie *et al.* (1979) and Booth *et al.* (1980) have indicated that the microfloras of the Merioneth Series in the Anglo-Welsh area show the progressive appearance of taxa previously known especially from the Tremadoc Series.

In view of the present uncertainty as to the presence of the *Acerocare* Zone at Random Island and the absence of both trilobites and graptolites from the lower part of the succession exposed at Bell Island, the acritarch assemblages of eastern Newfoundland are considered as a whole. By comparison with the Upper Cambrian, *Peltura* Zone, *Cymatiogalea cuvillieri* (Deunff) Deunff *et al.*, 1974, *Vulcanisphaera capillata* Jardiné *et al.*, 1974, *Arbusculidium destombesii* Deunff, 1968 and *Baltisphaeridium crinitum* Martin *in* Dean and Martin, 1978 appear in the *Parabolina argentina* Zone of the Lower Tremadoc. *C. cuvillieri* has a long range in the Shineton Shales of the Wrekin district, Shropshire and is very widespread in the Tremadoc of Europe and North Africa (see Cramer and Diez 1980 for references); it has also been recognized in the Tremadoc of north-west Argentina (author's notes; see below, New Locality Data, locality ARG-6). *A. destombesii* is found in the *Dictyonema*-bearing beds of the Shineton Shales (Rasul and Downie 1974), in the Moroccan Anti-Atlas (Deunff 1968; J. Destombes pers. comm. 1979) and in Belgium (Martin 1977); an unillustrated record of the species from the Arenig of Bohemia (Vavrdová, 1979) is considered with reserve. *V. capillata* is one of the elements of Zone BO of Jardiné *et al.* (1974) in the Algerian Sahara, the age of which was regarded by Combaz (1967) as being similar to that of the Obolus Beds (early Tremadoc). In eastern Newfoundland *Poikilofusa squama* (Deunff) Martin, 1973 is present in the Tremadoc strata of the Bell Island Group but not in those of the Clarenville Formation. The species extends throughout the Shineton Shales of Shropshire (Rasul and Downie 1974); it is found in the Algerian Sahara (Jardiné *et al.* 1974) and in Belgium (Martin 1977) in beds containing *Dictyonema*.

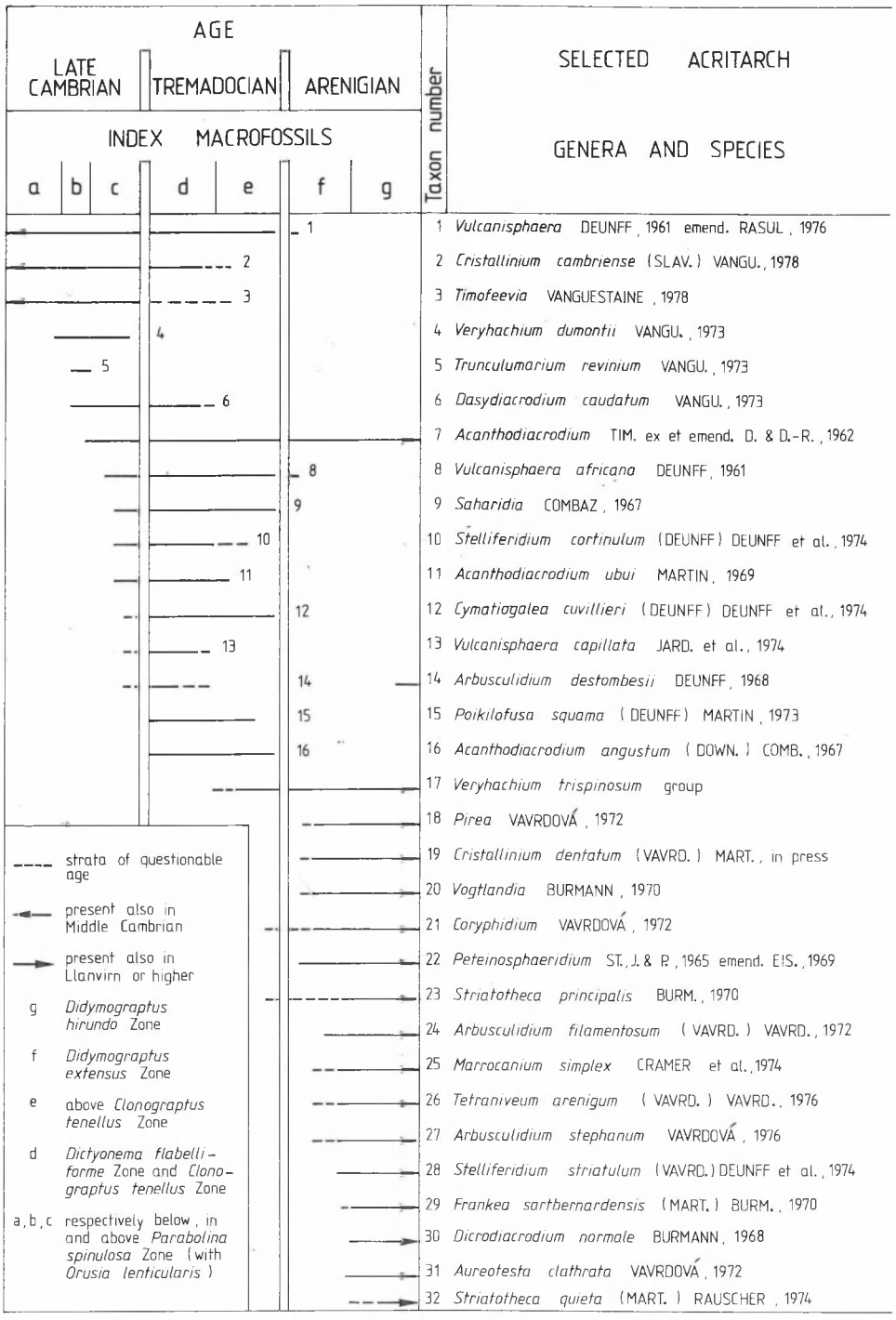
In the Tremadoc as represented by the Shineton Shales, Rasul (1979) recognized eight acritarch zones (1–8). The majority of the taxa forming the basis of these zones were new and Rasul did not establish any comparison with the four zones (BO, B1, B2, and C1) proposed by Jardiné *et al.* (1974) for the Tremadoc of the Algerian Sahara. Judging from these two publications it seems that the *Veryhachium trispinosum* group (represented by '*V. antiquum* sp. nov.' *in* Rasul 1979) appears in the upper part of the Tremadoc Series, i.e. above the *Clonograptus tenellus* Zone. It should be noted that *Ooidium* Timofeev, 1957 *ex* Norris and Sarjeant, 1965, which according to Timofeev (1959), Jankauskas (1976*a*) and Loeblich (1970) is characteristic of the lowest Tremadoc (Obolus Beds) in the western USSR, is not included here in text-fig. 3 because its presence in the Tremadoc of other regions has not been proved satisfactorily. However, Davies and Downie (1964) recorded the genus from the Newgale Beds, Middle Cambrian, of South Wales.

At Bell Island, the successive appearance of taxa 22–34 (text-fig. 2) indicates, with reservations, an Arenig age, all the genera and the majority of the species being known from the Arenig Series of Czechoslovakia. Overlying deposits at Bell Island which contain *Arbusculidium filamentosum* (Vavrdová) Vavrdová, 1972, *Vogtlandia tenuata* Burmann, 1970, and *Stelliferidium striatulum* (Vavrdová) Deunff *et al.*, 1974 belong to the highest part of the *Didymograptus extensus* Zone; finally, and above the last-named horizon, appears *Frankea sartbernardensis*.

In my opinion, the abrupt palynological change between the Tremadoc and Arenig Series shown in text-fig. 3 is apparent rather than real and results from insufficient palynological information from strata, dated by means of graptolites, of the *Tetragraptus approximatus* Subzone and the *Didymograptus deflexus* Subzone, successively the lowest subdivisions of the *D. extensus* Zone. However, Downie *et al.* (1979) consider that in the Anglo-Welsh area a relatively small gap in sampling at the Tremadoc–Arenig boundary coincides with a considerable change in acritarch assemblages.

In Bohemia, all the acritarchs recorded by Vavrdová (1965, 1966, 1972, 1973, 1976) from 'Ustarého hradu, SE of Klabava, near Rokycany' come from the *Tetragraptus* cf. *pseudobigsbyi* Zone of Kraft (1977) (M. Vavrdová pers. comm. 1980), a subdivision which replaced the *Tetragraptus reclinatus abbreviatus* Zone used by Bouček (1973). The assemblage from 'Krušná Hora, near Beroun, Gabriela Mine' described by Vavrdová (1979) was said to come from the *Schizograptus tardibrachiatus* Zone of Bouček (1973). According to Bouček (1973, table II) the *T. reclinatus abbreviatus* Zone corresponds to the combined *Isograptus gibberulus* Zone and *Didymograptus hirundo* Zone in the British Isles, while the *S. tardibrachiatus* Zone corresponds to the *Didymograptus nitidus* Zone. Following the subdivision of the Arenig Series into 'lower' and 'upper', as used by Williams *et al.* (1972) and adopted here, part of the material described by Vavrdová (1979) is therefore from strata below the upper Arenig. In the Landeyran Valley, Montagne Noire, Hérault, southern France, the acritarchs determined by Rauscher (1974) and by me (see below, New Locality Data, localities LDR-15, LDR-17, LDR-106) come from strata of the *D. extensus* Zone (undivided) according to Strachan (*in* Dean 1966).

It is possible, though not yet proved, that some taxa generally stated to come from the 'Arenig–Llanvirn' appeared at the top of the Tremadoc. Thus, for example, the general composition of the microfloras of the Glen Dhoo Flags and the Logan Flags




TEXT-FIG. 3. Schematic stratigraphic ranges and geographical distribution of selected late Cambrian and early Ordovician acritarchs. The numbers in bold type refer to the following publications and should not be confused with the taxon numbers on the left side. 1, Rasul 1976. 2, Potter 1974. 3, T. L. Potter unpublished Ph.D. thesis 1974; information given by Downie *in* Vanguestaine 1974. 4, Rasul and Downie 1974. 5, Rasul 1974. 6, Rasul 1979; taxon 17 as '*Veryhachium antiquum*'. 7, Molyneux 1979; taxon 20 as '*Multiplicisphaeridium* cf. *maroquense*'. 8, Turner and Wadge 1979; taxon 23 as '*Striatotheca principalis parva*', taxon 25? as 'cf. *Maroccanium simplex*'. 9, Lister *et al.* 1969. 10, Gardiner and Vanguestaine 1971. 11, Colthurst and Smith 1977; taxon 2 as '*Archaeohystrichosphaeridium*', taxon 5? as '*Ooidium* cf. *revinium*', taxon 28? as '*Priscogalea* cf. *striatula*'. 12, Rauscher 1974. 13, Martin 1973. 14, author's unpublished data from the Landeyran Valley, Montagne Noire, Hérault, France (see New Locality Data). 15, Fournier-Vinas 1978. 16, 17, Fombella 1978, 1979; taxon 2 as '*Cristallinium ovillense*'. 18, Wolf 1980. 19, 20, Martin 1969, 1977. 21, author's unpublished data from Sart-Bernard, Massif of Dave, Belgium (see New Locality Data). 22, Martin and Rickards 1979. 23, 24, Vanguestaine 1974, 1978. 25, Vavrdová 1976; taxon 3 as '*Multiplicisphaeridium lancarae*'. 26, Vavrdová 1977; taxon 17 as '*Veryhachium aquila*'. 27, Vavrdová 1979; taxon 14? is usually recorded from strata older than the Arenig

| Taxon number | ANGLO-WELSH AREA | S. IRELAND | FRANCE | SPAIN | BELGIUM | CZECHOSLOVAKIA | D.D.R. | S. SWEDEN | POLAND | W. U.S.S.R. | S. CANADIAN ROCKIES | E. NEWFOUNDLAND | N.W. ARGENTINA | N. AFRICA | N.W. AUSTRALIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 10* | 12 | 16 | 20 | | 29* | | 31 | 32 | | 39 | 40* | 43 | |
| 2 | 2* | 10 | 13 | 16 | 24 | 25• | | | | 33•• | | 38 | | | |
| 3 | 7 | 11 | | 17 | 24 | 25• | | | | 33•• | | 38 | | 42 | |
| 4 | 3* | | | | 23 | | | | | | | 38 | | ?42* | |
| 5 | 3* | ?11 | | | 23 | | | | | | | 38 | | ?42* | |
| 6 | 3* | | | | 23 | | | | | | | 38 | | | |
| 7 | 4 | 11 | 12 | 18* | 19 | 26 | 29 | | 31 | 32 | | 38 | | 43 | |
| 8 | 1 | | 12 | 18* | 20 | | | | | ?32 | | 39 | | 41 | |
| 9 | 4 | | 13 | | | | | | | | | 38 | 40* | 43 | 48* |
| 10 | 5 | | 13 | 18* | 20 | | | | | ?32 | | 38 | | 41 | |
| 11 | 6 | | | 18* | 20 | | | | | | | 38 | | | |
| 12 | 5 | | 12 | 18* | 20 | | | | | | | 38* | 40 | 41 | |
| 13 | | | | | | | | | | | | 38 | | 43 | |
| 14 | 4* | | 15* | | 20 | ?27* | | | | | | 38 | | 41 | |
| 15 | 4* | | 12 | 18* | 20 | | | | | | | 38 | | 41 | |
| 16 | 4 | | 12 | 18* | 20 | | | | | ?34 | | 38* | 40 | 43 | |
| 17 | 6 | 11 | 12 | | 19 | 26 | | | | 32 | | 37* | | 43 | |
| 18 | | | | | 21 | 26 | | | | 49 | | 37 | | 45 | |
| 19 | | | | | | 25 | | | | | | 37 | | | |
| 20 | 7* | | 14 | | 22* | 27 | 29 | | | | | 37 | | 46 | |
| 21 | 8 | 11 | 12 | | 22 | 25 | | | | | | 37 | | 44 | |
| 22 | 7 | | 12 | | 20 | 25 | | 30 | 31 | 35 | 36 | 37 | | 43 | 48 |
| 23 | 8 | | 12 | | 20 | 27 | 29 | | | | | 37 | | 47 | |
| 24 | 7 | | 12 | | 20 | 25 | 28 | | | | | 37 | | 45 | |
| 25 | ?8 | | | | 22 | 27* | | | | | | 39 | | 47 | |
| 26 | | | | | | 27 | | | | | | 39 | | | |
| 27 | 7* | | | | | 25 | | | | | | 37 | | ?45 | |
| 28 | 9* | ?11 | 12 | 18* | 19 | 25 | | | | | | 37 | | 43 | |
| 29 | 8 | | 12 | | 22 | 27 | | | | | | 37* | | 45 | |
| 30 | | | 12 | | 21 | 25 | | | | | | | | 47 | |
| 31 | | | 14 | | | 26 | | | | | | | | 45 | |
| 32 | | | | | 21 | 26* | | | | | | | | 47 | |

* not yet illustrated from relevant area

• Middle Cambrian (*Eccaparadoxides pusillus* Zone to *Hydrocephalus lyelli* Zone inclusive)

•• questionably of Lower Cambrian age on basis of acritarchs

Series and its record in the upper part of the Klabava Formation may be a dubious identification; taxon 23 as '*Striatotheca principalis parva*'. 28, 29, Burmann 1968, 1970. 30, Kjellström 1971. 31, Górka 1969. 32, Jankauskas 1976*a*; taxa 8 and 10 were not adequately illustrated and must be considered questionable. 33, Jankauskas 1976*b*; taxon 2 as '*Cymatiosphaera favosa*' and '*Cymatiosphaera lazdynica*', taxon 3 as '*Baltisphaeridium vilnense*'; these specific determinations by Jankauskas, though maintained by Volkova *et al.* (1979), are not accepted here; taxon 3 has been illustrated as '*Multiplicisphaeridium lancarae*' by Jankauskas (1980) and Volkova (1980). 34, Umnova and Vanderflit 1971; taxon 16? listed as '*Lophodiacrodium gracile*'. 35, Eisenack 1969. 36, 37, 38, Martin *in* Dean and Martin 1982, *in* Dean and Martin 1978, *in* Martin and Dean 1981. 39, 40, author's unpublished data from, respectively, Bell Island, eastern Newfoundland and Salta Province, Argentina (see New Locality Data). 41, Deunff and Massa 1975. 42, Baudelot and Gery 1979; taxon 4? as '*Veryhachium* cf. *dumontii*', taxon 5? as '*Ooidium* aff. *revinium*'. 43, Jardiné *et al.* 1974. 44, Cramer and Diez 1976. 45, Cramer and Diez 1977; taxon 27? as '*Barakella felix*'. 46, Cramer, Allam *et al.* 1974; taxon 20 as '*Multiplicisphaeridium maroquense*'. 47, Cramer, Kanes *et al.* 1974; taxon 23 as '*Rugulidium rugulatum*', taxon 30 as '*Dicrodiacrodium ancoriforme*'. 48, Combaz and Peniguel 1972. 49, Volkova 1980.

on the Isle of Man clearly indicate a Tremadoc age according to Molyneux (1979). However, they contain also *Striatotheca* Burmann, 1970 and *Coryphidium* Vavrdová, 1972, genera which, in the Klabava Formation of Bohemia (Vavrdová 1979), are known from the *S. tardibrachiatus* Zone upwards, the determination of the latter being considered probable, though not yet confirmed (M. Vavrdová pers. comm. 1980). Other taxa among those considered here (text-figs. 2, 3) which occur in the Klabava Formation are *Tetraniveum arenigum* (Vavrdová) Vavrdová, 1976, *Pirea* Vavrdová, 1972, *Stelliferidium striatulum* (Vavrdová) Deunff *et al.*, 1974, *Tunisphaeridium*? *eligmosum* Vavrdová, 1973, *Arbusculidium stephanum* Vavrdová, 1976, *Peteinosphaeridium* Staplin *et al.*, 1965 emend. Eisenack, 1969, and *Marrocanium simplex* Cramer *et al.*, 1974.

Of the thirty-two taxa selected here (text-fig. 3), all except three (taxa 30–32, *Dicrodiacrodium normale* Burmann, 1968, *Aureotesta clathrata* Vavrdová, 1972, and *Striatotheca quieta* (Martin) Rauscher, 1974, which are not found in the lower Arenig) are present on either Random Island or Bell Island. Their lateral distribution in the Upper Cambrian, Tremadoc, and Arenig provides evidence for the resemblance between the microfloras of eastern Newfoundland and the Mediterranean region, located along the periphery of Gondwanaland as shown by Dean (1976, text-fig. 5, pp. 241–3) for macrofaunas at the beginning of the Ordovician, using the reconstruction by Bullard *et al.* (1965). The present observations conform with and complete those of Vavrdová (1974), who showed that in Europe the acritarch assemblages from the Tremadoc to Llanvirn Series are divisible into a Baltic Province and a Mediterranean Province. On the basis of dispersed but positive palynological comparisons for the Tremadoc and/or Arenig Series, the latter province includes, *inter al.*, eastern Newfoundland, the Anglo-Welsh area, Spain, France, Belgium, Czechoslovakia, North Africa, and north-west Argentina. Late Cambrian acritarchs from Random Island exhibit affinities with those of the Franco-Belgian Ardennes, the Anglo-Welsh area, and northern Spain. For the time being this comparison involves individual taxa rather than assemblages.

### New locality data

Data given below are included in text-figs. 1 to 3 and are based on material collected by the author, except for samples from Argentina, which were obtained by P. Bultynck, Institut Royal des Sciences Naturelles de Belgique, Brussels.

**14.** Landeyran Valley, Montagne Noire, Hérault, France. Couches du Landeyran supérieures, lower Arenig, *Didymograptus extensus* Zone. Localities LDR-15 and LDR-17, corresponding respectively to λ16 and λ17 of Dean (1966, p. 256, fig. 3) and situated by the east side of the St. Nazaire road section, about 440 m north of Pont des Quatre Chemins. Locality LDR-106, Couches du Foulon, lower Arenig, Ruisseau de Landeyran section, 110 m north of λ6 of Dean (1966, p. 256, fig. 3).

**21.** Massif of Dave, Belgium. 'Assise de Huy', unnamed formation, upper Arenig, top of *Didymograptus hirundo* Zone according to Bulman (1950). Locality FM-75-1c, Km 22.244, north side of railway cutting north-west of Sart-Bernard railway station, 8 km south-east of Namur.

**39.** Bell Island, eastern Newfoundland, Canada. GSC locality 94419, Bell Island Group, probably lower Arenig, 53 m below Iron Ore Zone 1 of Hayes 1915 (see Dean and Martin 1978, p. 5, fig. 3) and 1 m below top of cliff, east side of tip of Polls Head. GSC locality 94429, top of Bell Island Group, lower Arenig, below top of *Didymograptus extensus* Zone, just below Iron Ore Zone 2 of Hayes 1915 (see Dean and Martin 1978, p. 5, fig. 3) and 4 m below top of cliff in gully immediately south-east of ruined building at Gull Island, South Head.

**40.** Salta Province, Caldera Department, Argentina. Locality ARG-3, 'San José shales', Tremadoc Series, about 70 m above base of section at west end of Rio approximately 1500 m west of Yacones, between localities S. Cal-7, point M4 (Tremadoc) and S.Cal.1, point 1 (Arenig) of Harrington and Leanza (1957, p. 236, fig. 133). Locality ARG-6, shale intercalated in the Caldera Sandstones, upper part of the Lower Tremadoc, locality S.Cal.2, point 2 of Harrington and Leanza (1957, p. 236, fig. 133), immediately north of Alto de la Sierra, road No. 9 between Salta and Jujuy.

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