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-
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, Leptoplatus 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.}

**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. *Voglantia flaminars* (Deunff) Martin, 1978. Lower Arenig, LDR-15, Montagne Noire, Hérault, France. IRScNB b1302, ×1000.

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

Fig. 5. *Asseotea 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 cavillierii* (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. 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 dumontii* 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. 92899, 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.
<table>
<thead>
<tr>
<th>RANDOM ISLAND</th>
<th>BELL ISLAND</th>
<th>AREA IN EASTERN NEWFOUNDLAND</th>
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<td>CLARENVILLE FM.</td>
<td>BELL ISLAND GP</td>
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**LATE CAMBRIAN**

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<th>TREMADOC</th>
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<tr>
<td>Aquata Zone</td>
<td>Acritarch Zone</td>
<td>? Acritarch Zone</td>
<td>? Acritarch Zone</td>
<td>Not exposed at Bell Island</td>
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<tr>
<td>Argentina Zone</td>
<td>Parabolina Zone</td>
<td>Parabolina Zone</td>
<td>Parabolina Zone</td>
<td>Not exposed at surface</td>
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**OTHER FOSSILS OF STRATIGRAPHIC VALUE**

1. Cristallinium cambriense (SLAN.) VANGUESTAIN, 1978
2. Timofeevia phosphorifica VANGUESTAIN, 1978
3. Volcanisphaera turbata MARTIN, in press
4. Timofeevia lancata (CR. & DIEZ) VANGU, 1978
5. Timofeevia micrutelis MARTIN, in press
6. Leptopus stauromenes VANGUESTAIN, 1973
7. Vexiphosphus dumeri VANGUESTAIN, 1973
8. Cristallinium randamense MARTIN, in press
9. Lascoptracadium caudatum VANGUESTAIN, 1973
10. Trunculium retinum (VANGU, LOEBL. & TAPP, 1976
12. Arbusculidium rommelaei MARTIN, in press
13. Stilloferidium cornutum (DEUNFF). DEUNFF et al., 1974

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).
<table>
<thead>
<tr>
<th>ELLIOTT COVE FM.</th>
<th>CLARENVILLE FM.</th>
<th>BELL ISL. GP</th>
<th>WABANA GP</th>
<th>LITHOSTRATIGRAPHIC UNIT</th>
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<td>MERIONETH</td>
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<td>PROB. AREN.</td>
<td>ARENIG</td>
<td>ANGLO-WELSH SERIES</td>
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**Corresponding trilobite zone uncertain**: present only in Middle Cambrian at Random Island.
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 Ogygimus 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, Dicroidiacoellidium normale, Striatotheca quetia (as 'S. acutisculpta'), 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 davidi Zone) and the Upper Cambrian (Peltura Zone) of eastern Newfoundland. The successive appearances of Leiofusa stoumonensis Vanguestaine, 1973, Veryhachium dumontii Vanguestaine, 1973, Cristallinium randomense Martin in Martin and Dean, 1981, Dasydiacrodium caudatum Vanguestaine, 1973, Trunculamarinium 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 ronnmaarei Martin in Martin and Dean, 1981, Stelliferidium curvatum (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 MICRORYTHRAS OF THE MERRION 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 GRAPTOPLATES
FROM THE LOWER PART OF THE SUCCESSION EXPOSED AT BELL
ISLAND, THE ACIRYTHRAS ASSEMBLAGES OF EASTERN
NEWFOUNDLAND ARE CONSIDERED AS A WHOLE. BY COMPARISON
WITH THE UPPER TREMADOC, PELTURA ZONE, CYMATHIO-
GALEA CUVILLIERI (DEUNFF) DEUNFF ET AL., 1974, VULCAN-
ISPHAERA CAPILLATA JARDINE ET AL., 1974, ARBUSCULIDIUM
DESTOMBESII DEUNFF, 1966 AND BALITISPHAERIDUM CRINIT-
TUM MARTIN IN DEAN AND MARTIN, 1979 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 WIDE-
SPREAD IN THE TREMADOC OF EUROPE AND NORTH AFRICA
SEE CRAMER AND DICE 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. DESTOMBS PERS. COMM. 1979)
AND IN BELGIUM (MARTIN 1977); AN UNIILLSTRATED
RECORD OF THE SPECIES FROM THE ARENGI OF BOHEMIA
(M. VAVRDÒVÁ, 1979) IS CONSIDERED WITH RESERVE.
V. CAPILLATA IS ONE OF THE ELEMENTS OF THE ZONE BO OF JARDINE
WAS REGARDED BY COMBZ (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 ACROSS THE SHINETON SHALES OF SHROPSHIRE (RASUL AND DOWNIE 1974); IT IS FOUND IN THE ALGERIAN SAHARA (JARDINE ET AL. 1974) AND IN BELGIUM (MARTIN 1977) IN BEDS CONTAINING DICTYONEMATA.

FEV (1959), JANNAUSKAS (1976a) AND LOEBLICH (1970) IS CHARACTERISTIC OF THE LOWEST TREMADOC (OBOLUS BEDS) IN THE WESTERN USSR, IT IS NOT INCLUDED HERE IN TEXT-FIG. 3 BECAUSE ITS PRESENCE IN THE TREMADOC OF
OTHER REGIONS HAS NOT BEEN PROVED SATISFACTORY.
HOWEVER, DAVIES AND DOWNIE (1964) RECORDED THE GENUS FROM THE NEWGALE BEDS, MIDDLE TREMADOC, OF SOUTH WALES.

AT BELL ISLAND, THE SUCCESSIVE APPEARANCE OF TAXA
22-34 (TEXT-FIG. 2) INDICATES, WITH RESERVATIONS, AN ARENGI AGE, ALL THE GENERA AND THE MAJORITY OF THE SPECIES BEING KNOWN FROM THE ARENGI SERIES OF CZECHOSLOVAKIA. OVERLAPPING DEPOSITS AT BELL ISLAND WHICH CONTAIN ARBUSCULIDIUM FILAMENTOSUM (VAVRDÒVÁ) VAVRDÒVÁ, 1972, VOGELANDIA TENUATA BURMANN, 1970, AND STELLIFERIDUM SRIATATUM
(VAVRDÒVÁ) DEUNFF ET AL., 1974 BELONG TO THE HIGHEST
PART OF THE DIDYMOGRAPTIUS EXTENSUS-ZONE; FINALLY, AND
ABOVE THE LAST-NAMED HORIZON, APPEARS FRANKIA SARBERNARDENSIS.

IN MY OPINION, THE ABRUPT PALYNOLOGICAL CHANGE BETWEEN THE TREMADOC AND ARENGI SERIES SHOWN IN TEXT-FIG. 3 IS APPARENT RATHER THAN REAL AND RESULTS FROM INSUFFICIENT PALYNOLOGICAL INFORMATION FROM STRATA, DATED BY MEANS OF GRAPTOPLATES, OF THE TETRA-
GRAPTIUS APPROXIMATUS SUB-ZONE AND THE DIDYM-
GRAPTIUS DEFLEXUS SUB-ZONE, 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-ARENGI BOUNDARY COINCIDES WITH A CONSIDERABLE CHANGE IN ACIRYTHRAS ASSEMBLAGES.

IN BOHEMIA, ALL THE ACIRYTHRAS RECORDED BY VAVR-
DIVISION WHICH REPLACED THE TETRAGRAPTIUS RECLINATUS
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 'ARENGI-
LANVIRN' APPEARED AT THE TOP OF THE TREMADOC. Thus,
FOR EXAMPLE, THE GENERAL COMPOSITION OF THE MICRO-
FLORAS OF THE GLEN DHOO FLAGS AND THE LOGAN FLAGS...
### LATE CAMBRIAN INDEX MACROFOSSILS

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<th>d</th>
<th>e</th>
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- Index: a, b, c, d, e, f, g
- Macrofossils: present in Lower Cambrian
- Taxon numbers refer to the following publications:
  - Rasul 1976
  - Potter 1974
  - Vanguestaine 1974
  - Rasul and Downie 1974
  - Rasul 1979
  - Molyneux 1979
  - Turner and Wadge 1979
  - Lister et al. 1969
  - Gardiner and Vanguestaine 1971
  - Colthurst and Smith 1977
  - Fombella 1978, 1979
  - Wolf 1980
  - Martin 1969, 1977
  - Fournier-Vinas 1978, 1979
  - Vavrdová 1976
  - Vavrdová 1977
  - Vavrdová 1979

### SELECTED ACRITARCH GENERA AND SPECIES

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<td><em>Saharidia</em> <strong>COMBAZ, 1967</strong></td>
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<td><em>Stelliferidium</em> <strong>corvus</strong> <em>DEUNFF et al., 1974</em>*</td>
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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 1976a; taxon 8 and 10 were not adequately illustrated and must be considered questionable. 33, Jankauskas 1976b; taxon 2 as 'Cymatiosphaera favosa' and 'Cymatiopsphaera 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, Unnova and Vanderflit 1971; taxon 16 listed as 'Lophodiacoacidum 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 47 as 'Veryhachium cf. dumontii', taxon 9 as 'Ooidium aff. revinium'. 43, Jardiné et al. 1974. 44, Cramer and Allam 1974; taxon 20 as 'Multiplicisphaeridium maroquense'. 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.

Of the thirty-two taxa selected here (text-fig. 3), all except three (taxa 30–32, *Dicrodacrum normale* Burmann, 1968, *Aureotesta clathrata* Vavrdová, 1972, and *Striatatheca quiesa* (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 Gulf Island, South Head.

40. Salta Province, Calchaqui 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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