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LATE DEVONIAN AND CARBONIFEROUS ACRITARCH STRATIGRAPHY AND PALEOGEOGRAPHY

by

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(6 figures)

ABSTRACT. - Detailed analysis of literature on late Devonian and Carboniferous acritarchs learns that, up to now, late Devonian acritarch zonation has been proposed only for Algeria, U.S.A. and Belgium. These zonations comprise only part of the Upper Devonian sequence in U.S.A. and Belgium, whereas the complete Upper Devonian acritarch zonation for Algeria is not matched by a detailed chronostratigraphic subdivision for that last area. Upper Devonian and Carboniferous acritarchs have also been described from many other areas in North and South America, Africa, Europe, Asia and Australia, but the data are mainly based on spot sampling or these are restricted to rather reduced intervals.

Comparison between the abundance of acritarchs in late Devonian sequences of Ohio and Belgium reveals consistent patterns of successive maxima and minima. They may reflect global changes in the environment and be related to worldwide events. Remarkable is the extremely low number of acritarchs throughout the Carboniferous succession. This forms a clear contrast with the relative abundance of acritarchs in marine Devonian sediments.

RESUME. - Un examen attentif des publications concernées par les acritarches du Dévonien Supérieur et du Carbonifère indique qu'une zonation d'acritarches n'a été proposée, jusqu'à présent, que pour le Dévonien Supérieur d'Algérie, des Etats-Unis et de Belgique. Aux Etats-Unis et en Belgique, la zonation porte sur une partie seulement du Dévonien Supérieur. En Algérie, elle concerne l'ensemble de cette série qui y souffre toutefois d'un manque de détails chronostratigraphiques. Des acritarches ont aussi été décrits dans de nombreuses autres régions d'Amérique du Nord et du Sud, d'Afrique, d'Europe, d'Asie et d'Australie, mais les observations y reposent sur des échantillons isolés ou n'ont trait qu'à des intervalles stratigraphiques réduits.

La comparaison de l'abondance des acritarches du Dévonien Supérieur en Ohio et en Belgique révèle une évolution semblable de leur teneur. Cette similitude pourrait être l'expression de modifications planétaires de l'environnement, c'est-à-dire être en relation avec des événements mondiaux. L'extrême pauvreté en acritarches du Carbonifère est caractéristique et contraste avec leur abondance dans les dépôts marins du Dévonien.

This synthesis is based on over 80 publications on Upper Devonian and Carboniferous acritarchs. Only a few papers dealing with acritarchs from North and South America have not been taken into consideration, since these essentially focus on systematics rather than on stratigraphy.

Brief comments are made on the state of art of acritarch zonations in Gondwana (chapter 1) and Euramerica (chapter 2) along with a review of the paleogeographic distribution of some genera.

Apparent anomalies in the stratigraphic distribution may be explained as possible reworking from older strata (chapter 3). And eventually, remarkable similarities in the acritarch abundance profiles for late Devonian successions in Ohio and Belgium may indicate supraregional influences controlling these phenomena (chapter 4).

1. - GONDWANA

Jardiné *et al.*, (1974) distinguished four acritarch zones (L4 to L7) between a " Frasnian-Famennian " and a " Famennian-Strunian " of the Illizi-Tinrhert Basin, Algeria (figs. 1 and 2). They also used data published

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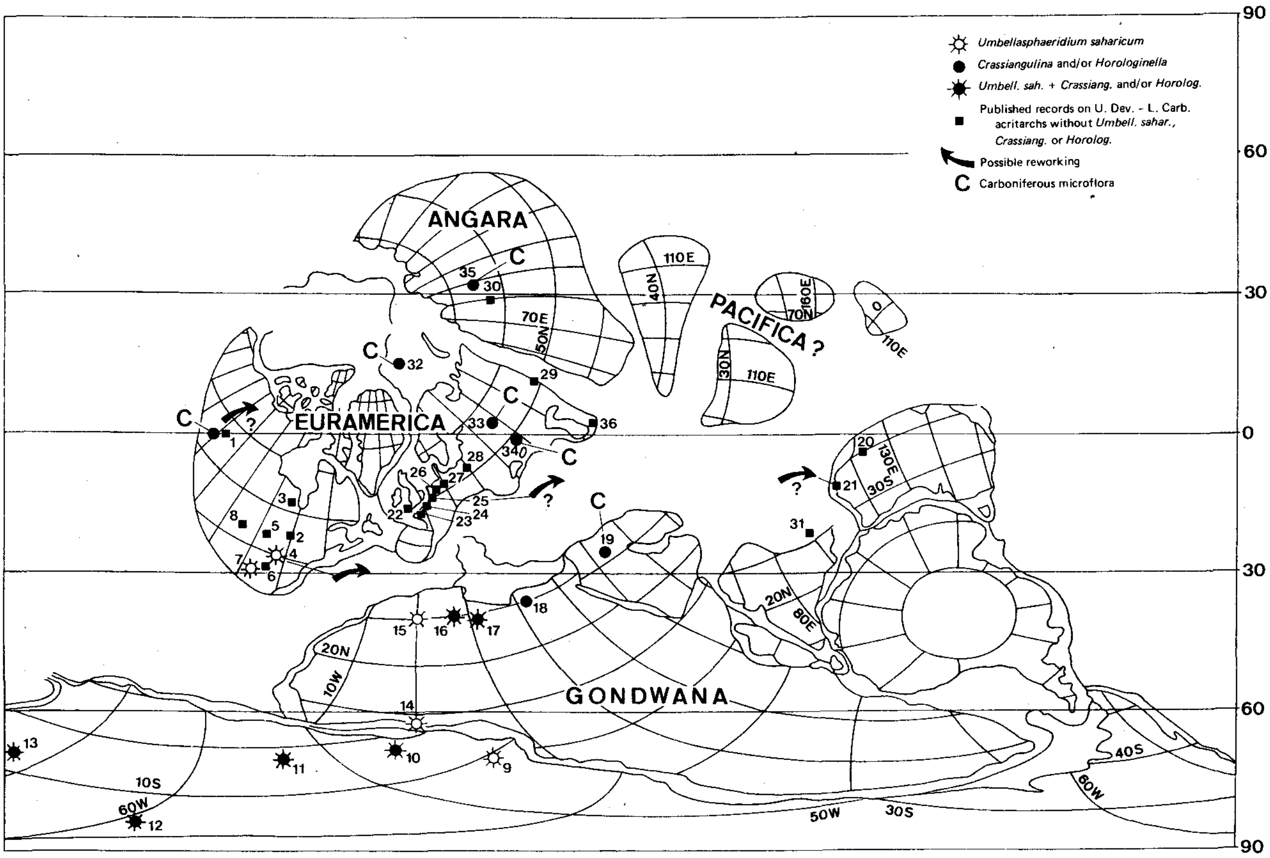

Figure 1. - Geographic location of published records of Upper Devonian and Carboniferous acritarchs.
(slightly modified cylindrical equidistant 360 m.y., Frasnian, map of Smith, Hurley and Briden, 1980, see Streel, 1986).
1. Alberta, Canada (Staplin, 1960, 1961; Staplin, Jansonius & Pocock, 1965); 2. Ontario, Canada (Deunff, 1967; McGregor *in* Wood, 1984); 3. Ontario, Canada (Legault & Norris, 1982); 4. Ohio, U.S.A. (Winslow, 1962; Wicander, 1974, 1975; Molyneux, Manger & Owens, 1984; Wood, 1984); 5. Indiana, U.S.A. (Wicander & Loeblich, 1977); 6. Kentucky, U.S.A. (Bharadwaj, Tiwari & Venkatachala, 1971); 7. Tennessee,U.S.A. (Reaugh, 1970); 8. Iowa, U.S.A. (Wicander & Playford, 1985); 9. Tucano-Jatobá basin, Brazil (Regali, 1964); 10. Parnaiba basin, Brazil (Daemon, 1974); 11. Amazon basin, Brazil (Daemon, 1974); 12. Bolivia (Boneta, 1975); 13. Oriente basin, Peru (Béju in Wood, 1984); 14. Keta basin, Ghana (Bär & Riegel, 1974; Anan-Yorke, 1974); 15. Mac-Mahon basin, Algeria (Lanzoni & Magloire, 1969); 16. Illizi-Tinrhert basin, Algeria (Jardiné & Yapaudjan, 1968; Jardiné, 1972; Jardiné *et al.,* 1972, Jardiné *et al.,* 1974; Attar *et al.,* 1980); 17. Rhadamès basin, Western Libya (Wray, 1964; Massa *et al.,* 1979; Moreau-Benoît, 1984; Massa & Moreau-Benoît, 1985); 18. Eastern Libya (Paris *et al.,* 1984); 19. Saudi Arabia (Hemer & Nygreen, 1967); 20. Carnarvon basin, Australia (Playford, 1981; Playford & Dring, 1981); 21. Canning basin, Australia (Playford, 1976); 22. England (Owens, Downie & Reynolds 1977; Le Gall *et al.,* 1985); 23. Brittany, France (Deunff, 1965); 24. Normandy, France (Rauscher, 1969); 25. Ardenne and Boulonnais, France and Belgium (several publications, see figure 5 plus Bain & Doubinger, 1965; Deunff, 1966, 1980; Brice *et al.,* 1979; Combaz & Streel, 1971; Loboziak *et al.,* 1983); 26. Western Germany (Pichler, 1971; Riegel, 1974; Jux, 1975, 1984; Amirie, 1984); 27. Eastern Germany (Burmann, 1976); 28. Poland (Gorka, 1974a and b); 29. Bashkiria, USSR (Chibrikova, 1966); 30. Siberia, USSR (Sheshegova, 1971); 31. Tibet (Gao); 32. Spitzbergen (Playford, 1963); 33. Moscow basin, USSR (Naumova, 1939, 1950); 34. Donets basin, USSR (Teteriuk, 1956, 1958); 35. Tunguska basin, USSR (Kondratjev, 1963); 36. Iran (Coquel *et al.,* 1977).

by Jardiné & Yapaudjan (1968), Lanzoni & Magloire (1969), Jardiné (1972) and Jardiné *et al.* (1972). This biozonation can be (partly) applied in the same Illizi-Tinrhert Basin (Attar *et al.,* 1980) and in the Rhadamès Basin (Wray, 1964; Moreau-Benoît, 1984; Massa & Moreau-Benoît, 1985). The association of the acritarchs *Crassiangulina tesselita* and *Horologinella quadrispina* with either Frasnian miospores (in Eastern Libya : Paris *et al.,* 1984) or with Strunian miospores (a.o. *Retispora lepidophyta* in Algeria : Jardiné *et al.,* 1974) indicates that these species range from at least the Upper Frasnian into the Strunian (fig. 2).

Remarkable is the occurrence of the genera *Crassiangulina, Horologinella* and *Umbellasphaeridium* in the Upper Devonian microflora of Northern Africa. These genera have been described also from other Devonian sediments of Gondwana (figs. 1 and 3) : in South America, *Umbellasphaeridium* and *Horologinella* (Regali, 1964; Brito, 1965, 1967 and 1976; Daemon, 1974; Boneta, 1975; Wood, 1984) and in Ghana, *Umbellasphaeridium* (Anan-Yorke, 1974; Bär & Riegel, 1974). They have not been cited from Devonian locations outside Gondwana with the exceptions of *Umbellasphaeridium* occuring in the Strunian of North America (Reaugh, 1978; Wood, 1984; Molyneux, Manger & Owens, 1984) and rarely in the Famennian of Bel-

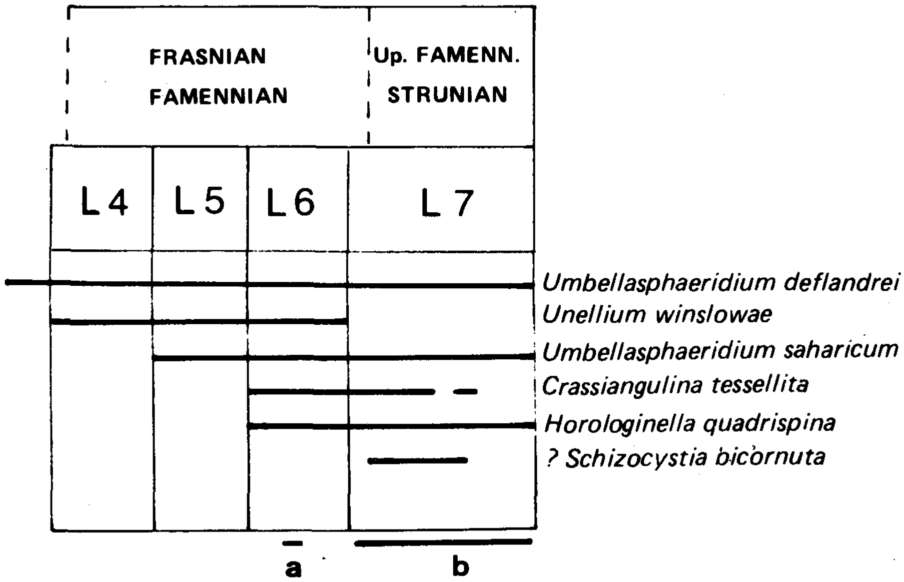

Figure 2. - Acritarch zonation in the Upper Devonian of Algeria; ranges of some guide species (after Jardiné *et al.*, 1974).
a : Strunian miospores (Jardiné *et al.*, 1974); b : Upper Frasnian miospores (Paris *et al.*, 1984).

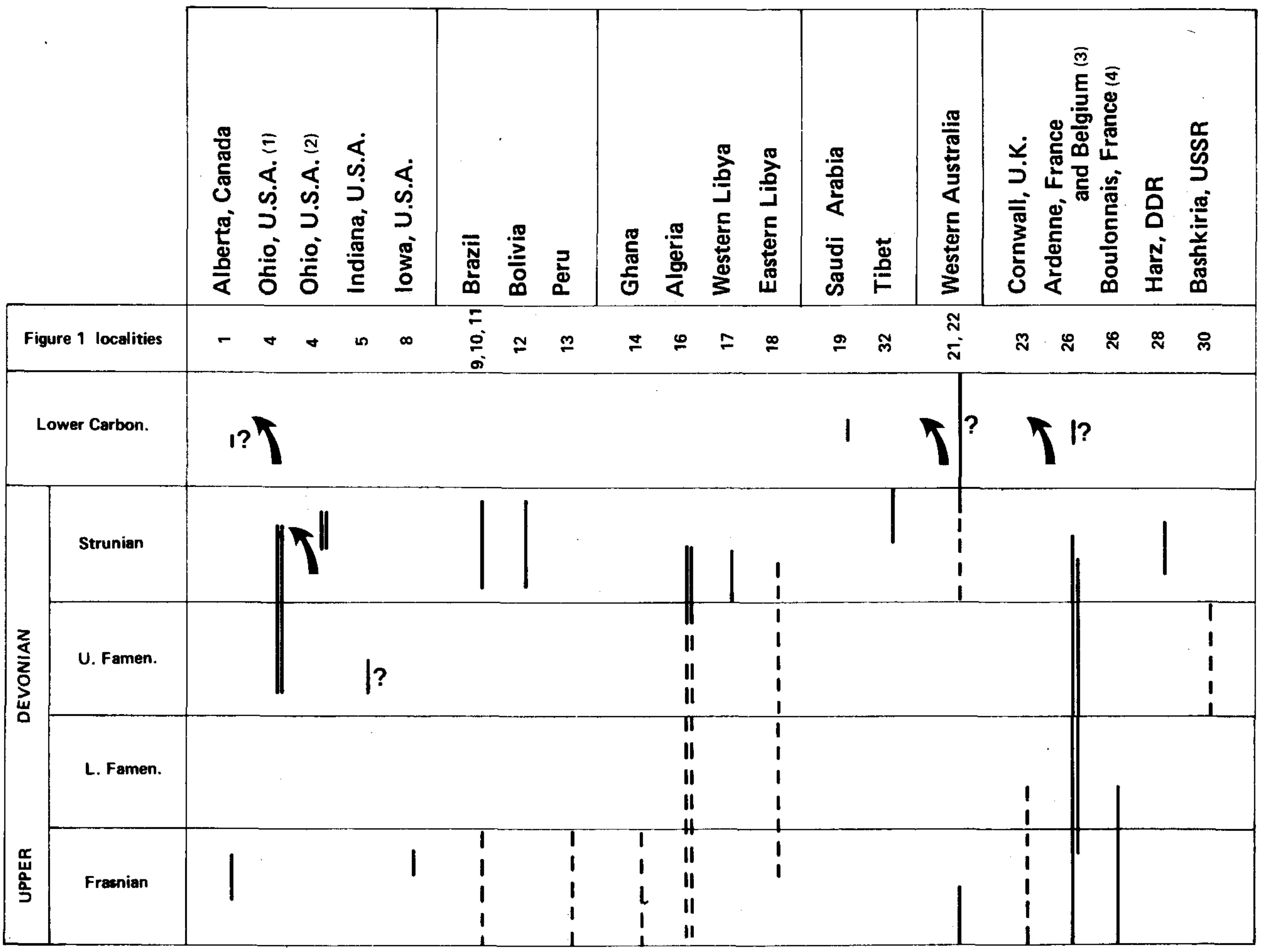

Figure 3. - Approximate stratigraphic position of sequences investigated on their acritarch contents in the Upper Devonian and Lower Carboniferous. Single line : spot samples, reduced or incompletely studied interval (no zonation proposed); double line : sequence studied in detail (zonation proposed); dashed line or question mark : poorly dated; full line : dated; arrow : possible reworking.

(1) Wicander, 1975;
(2) Molyneux *et al.*, 1984;
(3) several localities detailed on figure 5;
(4) based on Deunff, 1980 and Loboziak *et al.*, 1983.

In Alberta, Canada, the Lower Carboniferous Banff Formation only (Staplin, Jansonius & Pocock, 1965) is localised.

gium where it is found associated with a questionable *Horologinella* (Martin, 1985). *Crassiangulina* and/or *Horologinella* are also recorded, without *Umbellasphaeridium* and any acanthomorphic acritarchs, in the Carboniferous of Euramerica, Angara and Gondwana : *in* USSR by Naumova, 1939, 1950 (identified as *Tetraporina*), Teteriuk, 1956 (*Tetraporina*) and Kondratyev, 1963 (*Tetraporina*); in Spitzbergen by Playford, 1963 (*Tetraporina*); in Alberta, Canada by Staplin, 1960 (*Azonotetraporina ?*) and in Saudi Arabia by Hemer & Nygreen, 1967 (*Tetraporina, Diporina ?* and *Triporina ?*).

A general ressemblance of the Upper Devonian acritarch assemblages from Algeria with those from other parts of Gondwana has been noticed by some authors notably Nautiyal (1977), Downie (1979), Wood (1984) and Paris *et al.* (1984). The last authors have emphasized the similarity between "Frasnian-Famennian" microfloras in Libya and Frasnian ones in Western Australia (Playford, 1981; Playford & Dring, 1981). These assemblages include species unknown thus far in Euramerica.

2. - EURAMERICA

Wicander (1975) erected five acritarch biozones in the Barberton Test Core 3 of Ohio (U.S.A.) where a 175 m thick shale sequence was studied consisting of (in ascending order) the "Upper Devonian" Chagrin Shale and Cleveland Shale, and the "early Mississippian" Bedford Shale (fig. 4). However, the miospore assemblages of the Bedford Shale prove a Strunian age for the same (Streel, 1971; Vanguestaine, 1978; Molyneux, Manger & Owens, 1984). Correlation charts *in* Clendening, Eames & Wood (1980) and *in* Matthews (1983) consider the Chagrin Shale as Upper Famennian, an opinion followed here (1).

Up to now, Wicander's acritarch zonation is valid only for Ohio, whereas it can be partially applied in Indiana (correlation of basal Chagrin Shale with Antrim

(1) *Gorgonisphaeridium ohioense* (Winslow) Wicander 1974 is a common acritarch species in the Chagrin, Cleveland and Bedford units. In Belgium, this species in unknown in the Frasnian and in the Lower Famennian but occurs in the Upper Famennian and the Strunian (Vanguestaine, 1978).

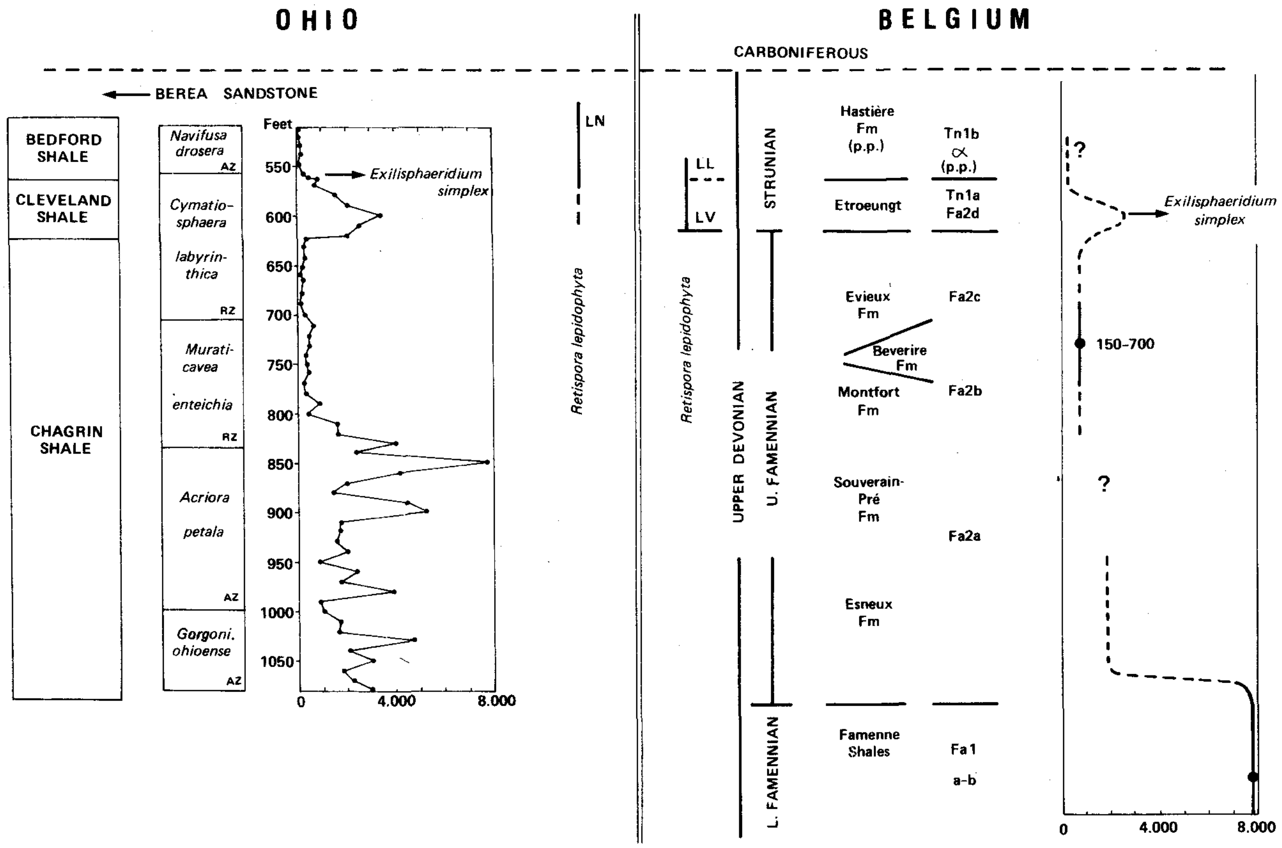

Figure 4. - Comparison of acritarch abundance profiles for the Upper Famennian-Strunian of Ohio, U.S.A. (after Wicander, 1975) and Famennian-Strunian of Belgium (profile based on Streel *in* Becker, Bless, Streel & Thorez, 1974, on Rouhart *in* Vanguestaine *et al.*, 1983, and on unpublished data).

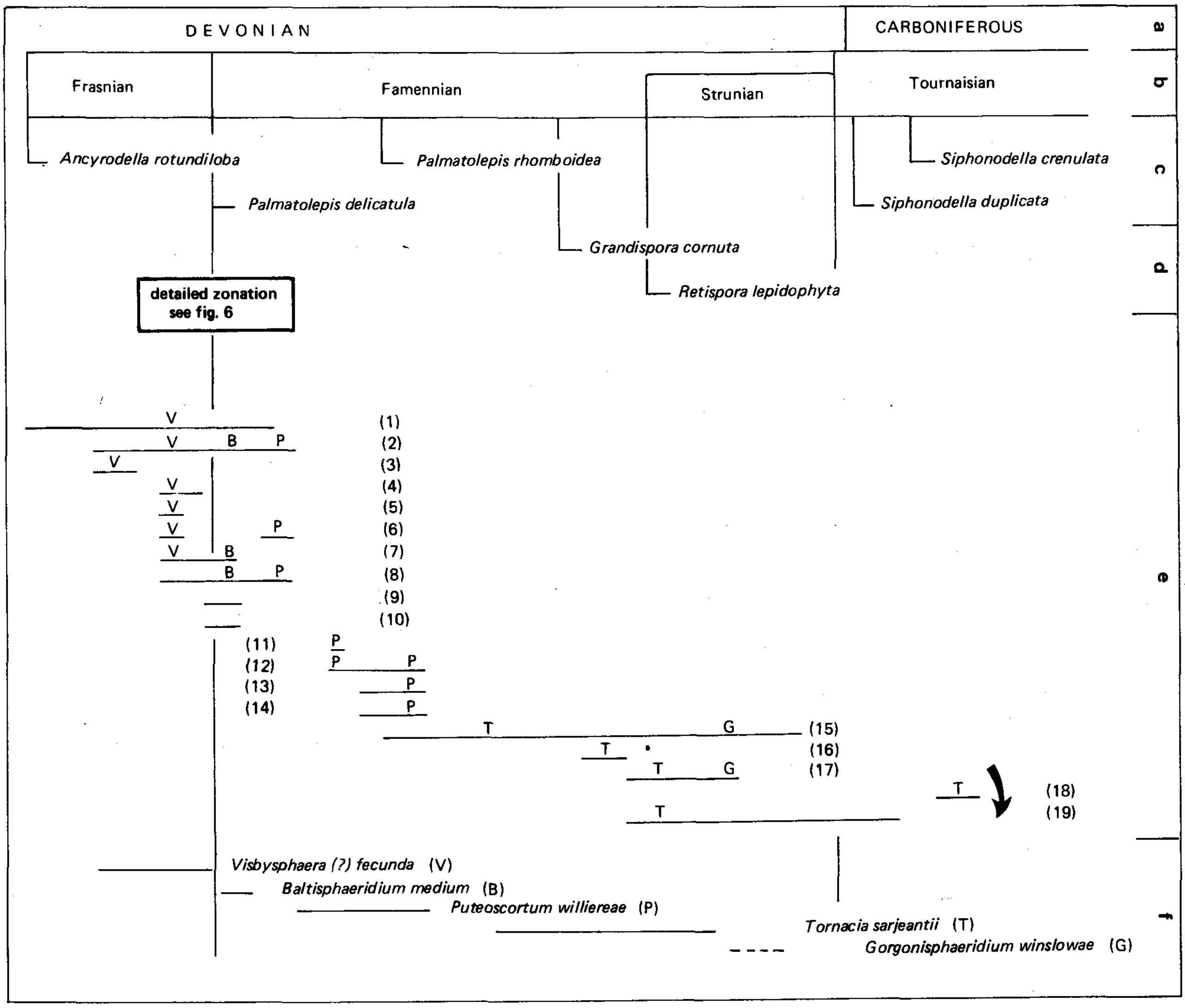

Figure 5. - Literature on late Devonian and early Carboniferous acritarchs in Belgium.

a and **b** : Systems and Stages; **c** and **d** : Relevant Conodonts and miospores marking base of successive chronostratigraphic units. **e** : Stratigraphic intervals dealt with by the following authors (1) Dricot (1965, 1968 and 1971) (a) : several sections in the Dinant and Herve basins; (2) Vanguestaine *et al.* (1983) : several sections in the Dinant, Namur, Herve and Campine basins; (3) Stockmans & Willière (1960, 1962a and 1962b) : Tournai and Wépion boreholes; (4) Vanguestaine *in* Kimpe *et al.* (1978) : Vf and Vg Zones at Visé, Campine basin; (5) Martin (1982) : north-Frasnes section; (6) Houbaille (1983)(b) : Focant borehole; (7) Blampain (1981)(c) : Aisemont and Presles sections; (8) Stockmans & Willière (1974) : Senzeilles section; (9) Streel *in* Bouckaert, Mouravieff, Streel, Thorez & Ziegler (1972) : Senzeilles and Hony sections; (10) Houbaille (1983)(b) : Havelange borehole; (11) Stockmans & Willière (1969) : Dailly section (and Senzeilles pro parte); (12) : Bragard (1984)(d) : 3 sections in the Hamoir area ranging from the middle *Crepida* to the *Rhomboidea-Marginifera* transition; (13) Houbaille (1983)(c) : Soumagne borehole; (14) Martin (1981) : Villers-sur-Lesse section; (15) : Streel *in* Becker *et al.* (1974) and *in* Bouckaert & Streel (ed.), (1974) : several sections in the Dinant basin; (16) : Kievietz (1977) (e) : Fa2c Evieux Formation and Béverire Formation at Poulseur and Comblain-au-Pont; (17) Vanguestaine (1978) : Tohogne borehole; (18) Stockmans & Willière (1966, 1967) : "Tn2a" Tournai and Leuze boreholes; (19) Di Clemente (1985)(f) : Langlier, Spontin and Yvoir-station sections (Fa2c-"Tn1b"). **f** : species range zones for the middle Frasnian to Strunian period (Vanguestaine *et al.*, 1983; Vanguestaine *in* Paproth *et al.*, 1983).

(a) DRICOT, E.M., 1971. Acritarches du Frasnien moyen et supérieur de la Belgique. PhD Thesis, Louvain University, 279 p.

(b) HOUBAILLE, C., 1983. Contributions à l'étude des caractères lithologiques, physiques et biostratigraphiques des roches au voisinage de la limite Frasnien-Famennien dans les sondages de Havelange, Focant et Soumagne. University of Liège, : 1-207.

(c) BLAMPAIN, A.,1981. Etude lithologique des roches givetiennes et frasniennes à Aisemont. University of Liège.

(d) BRAGARD, J.-M., 1984. Comparaison litho- et biostratigraphique à la limite Famennien Inférieur - Famennien Supérieur de part et d'autre de la faille de Xhoris à Hamoir. University of Liège : 1-102.

(e) KIEVIETZ, J., 1977. Relations entre Spores, Acritarches et Palynofacies et l'analyse séquentielle et pétrographique de sédiments d'âge Famennien (Fa2c) dans la vallée de l'Ourthe (Belgique). University of Liège : 1-42 and annexes.

(f) DI CLEMENTE, C., 1985. Biostratigraphie et palynofaciès de la transgression du Famennien Supérieur dans la région du Bocq. University of Liège : 1-79.

Shale : Wicander & Loeblich, 1977). A tentative correlation between Upper Devonian strata of Ohio and Belgium (where the Tohogne borehole has yielded well-dated acritarch assemblages) indicates that the upper part of Wicander's *Cymatiosphaera labyrinthica* zone is of Strunian age (upper Fa2d). This correlation is supported by miospore data (Vanguestaine, 1978). More recently, Molyneux, Manger & Owens (1984) have studied the Bedford Shale and the overlying Berea Sandstone. These authors have slightly modified some of the acritarch ranges as identified by Wicander (1974, 1975). Moreover, they have not recognized the marker species of his *Navifusa drosera* Zone (Bedford Shale).

Wicander & Playford (1985) documented an Upper Frasnian section in Iowa, U.S.A. but a detailed correlation based on acritarchs between this section and/or between Wicander's sequence in Ohio and the following areas has proved to be difficult : French Ardennes (Bain & Doubinger, 1965), Boulonnais of Northern France (Deunff, 1966, 1980; Combaz & Streel, 1971; Brice *et al.,* 1979; Loboziak *et al.,* 1983), Normandy of France (Rauscher, 1969), Brittany of France (Deunff, 1965), Western Germany (Pichler, 1971; Riegel, 1974; Jux, 1975, 1984; Amirie, 1984), Eastern Germany (Burmann, 1976), Poland (Gorka, 1974a, b), England (Owens *et al.,* 1977; Le Gall, Le Hérissé & Deunff, 1985), Iran (Coquel *et al.,* 1977), USSR (Chibrikova, 1966; Sheshegova, 1971), China (2), Canada (Staplin, 1961; Deunff, 1967; Nautiyal, 1977; Legault & Norris, 1982), U.S.A. (Bharadwaj *et al.,* 1971; Reaugh, 1978) and Belgium (see here after). This is partly explained by the fact that in many of these regions only spot samples or reduced intervals have been studied.

In Belgium, acritarch assemblages are known from many Frasnian to Tournaisian rock sequences (fig. 5e). Combining all informations, a generalized Upper Devonian acritarch succession of 5 species is here proposed (fig. 5f). Two of these 5 species are cited elsewhere : *Tornacia sarjeantii* in Western Australia (Playford, 1976; Playford & Dring, 1981), *Gorgonisphaeridium winslowae* in Canada (Staplin, Jansonius & Pocock, 1965), U.S.A. (Molyneux, Manger & Owens, 1984), Iran (Coquel *et al.,* 1977), Libya (Massa *et al.,* 1979) and China (2). A more detailed approach in the Frasnian-Famennian transitional beds has been realized by Vanguestaine *et al.,* 1983 and by Martin, 1985. Their zonations, very similar indeed, are compared at figure 6.

<table>
<tr><td rowspan="6">L. Famennian</td><td rowspan="2">crepida</td><td>m</td><td rowspan="2">Pw</td><td>V</td></tr>
<tr><td>l</td><td>IV</td></tr>
<tr><td rowspan="5">triangularis</td><td rowspan="2">u</td><td>Bb</td><td rowspan="3">III</td></tr>
<tr><td rowspan="2">Bm</td></tr>
<tr><td rowspan="2">m</td></tr>
<tr><td rowspan="3">Vg</td><td rowspan="3">II</td></tr>
<tr><td rowspan="3">U. Frasnian</td><td>l</td></tr>
<tr><td rowspan="2">gigas</td><td rowspan="2">u</td></tr>
<tr><td>Vf</td><td>I</td></tr>
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Figure 6
Comparison between the interval zones Vf-Pw (Vanguestaine *et al.,* 1983), the palynoflora I-V (Martin, 1985) and the standard conodont zonation at the Frasnian-Famennian boundary.

3. - PROBLEMS CAUSED BY POSSIBLE REWORKING

Several authors have described Strunian or Carboniferous acritarchs which, in our opinion, may have been partly or entirely reworked from older strata.

Possible reworking of *Umbellasphaeridium* species in the Strunian (*Retispora lepidophyta* bearing) Bedford Shale of Ohio, Michigan and Canada, has been suggested by Wood (1984) who recognized reworked Silurian acritarchs in the same beds.

Playford (1976) described some acritarchs from Strunian to Upper Tournaisian sediments in Western Australia. Coquel *et al.* (1977) mentioned a rich microflora in the Upper Devonian of Iran and some specimens in the Carboniferous of the same area. The question arises whether part of these assemblages had been reworked as acanthomorph acritarchs are apparently unknown up to now in the Carboniferous (see p. 96).

Staplin, Jansonius & Pocock (1965) described the species *Gorgonisphaeridium winslowae* (but not the associated species of the assemblage) in the "Lower Mississippian" Banff Formation, Alberta, Canada. Further informations are needed concerning the age of this Formation. If the Banff Formation is proved to be of true Carboniferous age, then it would have yielded the youngest *Gorgonisphaeridium winslowae* (recorded elsewhere in Strunian strata) unless the species is reworked.

The fact that acritarch assemblages in the Middle Tournaisian shales of the Tournai and Leuze boreholes in Belgium are very similar to those observed in the Upper Devonian of the Tohogne borehole has also rised the question of possible reworking of Upper Devonian

(2) GAO, L. : Discovery of Late Devonian spore assemblage from Nyalam County, Xizang (Tibet) and their stratigraphic significance : 183-218 (no date nor references).

material in the Middle Tournaisian (Vanguestaine *in* Paproth *al.*, 1983).

Other Carboniferous localities with possibly reworked acritarch specimens are listed in Streel & Bless, 1980.

4. - ABUNDANCE OF PHYTOPLANKTON IN THE LATE DEVONIAN

Wicander (1975) calculated the abundance of phytoplankton in the Barberton Test Core 3. His abundance profile is compared in figure 4 with the lithological succession and the acritarch zonation. Also the position of the Berea Sandstone is indicated. This sandstone was studied in an outcrop by Molyneux *et al.* (1983). The Berea Sandstone and the underlying Bedford Shale have yielded a miospore assemblage characterizing the LN miospore Zone (with *Retispora lepidophyta*). Although *R. lepidophyta* has not been observed in the Cleveland Shale in the Barberton Test Core 3 (Winslow, 1962), this species is known in that shale elsewhere (Vanguestaine, 1978; Wood, 1984). Therefore it is accepted here that part of the Cleveland Shale and the Bedford Shale and Berea Sandstone are of Strunian age. The Chagrin Shale is of Upper Famennian age (Clendening *et al.*, 1980; Matthews, 1983).

The abundance profile for the phytoplankton (number of specimens per gram of sediment) shows high values for the lower part of the Chagrin Shale with a clear maximum half way this shale interval. Distinctly lower values mark the upper portion of the Chagrin Shale. A sudden increase of the phytoplankton abundance characterizes the base of the Cleveland Shale, followed by gradual decrease in the upper half of the same and eventually succeeded by extremely low values for the Bedford Shale.

These fluctuations in the abundance profile are the more remarkable since these occur within an apparently homogeneous lithological succession suggesting the persistance of uniform depositional conditions during the latest Devonian (Wicander, 1985).

In Belgium, a similar abundance profile for the phytoplankton in the Famennian-Strunian may be composed. Up to now two intervals have been studied in detail, namely the Frasnian-Famennian boundary at Senzeilles (8.000 specimens per gram, Rouhart *in* Vanguestaine *et al.*, 1983) and in the Upper Famennian Beverire and Evieux Formations (150-700 specimens per gram Kievietz, 1977 (fig. 5e)). In other portions of the sequence data are missing (Souverain-Pré Formation) or based on estimations. Relatively high values are suggested for the Esneux Formation (Streel *in* Becker, Bless, Streel & Thorez, 1974; Bragard, 1984) and for the basal Strunian (Vanguestaine, 1978). Extremely low values characterize the lower part of the Hastière Formation (Di Clemente, 1985) (fig. 5e).

Accepting that the strata in Ohio have been correctly correlated with those in Belgium (fig. 4) one necessarily focuses on certain resemblances between these two phytoplankton abundance profiles. These suggest that the relative abundance of the phytoplankton has not been controlled by local or regional sedimentary conditions. Apparently, this presumably synchronic fluctuations must have been influenced by more widely extended changes in for example the paleoclimate or changes in the direction of paleocurrents (possibly causing changes in the water temperature and/or nutrient supply) or eustatic sea level changes.

If this assumption is correct these changes in the phytoplankton abundance profiles are related to/or have been induced by widespread if not global events. Therefore it is suggested that future investigations on acritarchs should not only concentrate on qualitative data but also on quantitative informations.

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