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Late Famennian Phytogeographic Provincialism: Evidence for a Limited Separation of Gondwana and Laurentia

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1 Text-Figure and 3 Plates



*Allemagne
Massif schisteux rhénan
Devonien
Corals
Tabulata
Paléogéographie*

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Phytogeographischer Provinzialismus im späten Famennium: Nachweis einer beschränkten Separation von Gondwana und Laurentia

Zusammenfassung

Acritarchen und Prasinophytenzysten sind Palynomorphe, die als marines Mikroplankton angesehen werden; sie weisen einen deutlichen Provinzialismus auf. Das Erkennen von Provinzen nach ausgewählten, Temperatur-empfindlichen Morphotypen mag dazu beitragen Paläo-kontinentallagen und Paläobreiten zu definieren. Die Verteilung des spätdevonischen Acritarchen *Umbellaspheeridium saharicum* wurde verwandt, um eine Mikroplanktongemeinschaft hoher Breitenlage zur Frasne/Famennian-Zeit auszuscheiden. *Umbellaspheeridium saharicum* dominiert im peruanischen und bolivianischen Palynospektrum des Spätdevons und tritt in vielen Lokalitäten West-Gondwanas auf, sowie auch in vermutlich südlichsten Teilen von Laurussia. Weitere palynologische Daten sind notwendig, um das restriktive Vorkommen dieses morphologisch klar zu unterscheidenden Morphotypes zu bestätigen wie auch seine Abwesenheit in spätdevonischen warmen bis tropischen Klimagürteln.

Abstract

Acritarchs and prasinophyte cysts are palynomorphs considered to be marine microplankton, and they reveal a distinct provincialism. Recognition of provinces, based on selected temperature-sensitive morphotypes, may help define paleocontinent positions and paleolatitudes. Distribution of the Late Devonian acritarch, *Umbellaspheeridium saharicum*, has been used to distinguish a high-latitude microplankton community in Frasnian and Famennian time. *Umbellaspheeridium saharicum* is dominant in Peruvian and Bolivian Late Devonian palynospectra and present in numerous western Gondwana localities, as well as in the presumed southernmost parts of Laurussia. Further palynological data are needed to confirm the restricted occurrence of this morphologically distinctive morphotype, and its absence in the Late Devonian warm to tropical climatic belts.

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1. Introduction

The distribution patterns of fossil marine microplankton cysts (acritarchs), cysts of fossil dinoflagellates (dinocysts) and of fossil phycomata of green prasinophycean algae represent an important tool for paleogeographic and paleoclimatic reconstructions. Many paleogeographic reconstructions are based on paleomagnetic data, and the potential of the non-megafaunal fossil record is still underestimated. In combination with other sedimentary data, such as development and occurrences of organic buildups, karst, glacial deposits, and temperature-sensitive calcareous algae (ROUX, 1991), fossil marine microplankton can be utilized for determination of global paleoclimatological variations and differentiation. This appears to be applicable to the Late Devonian.

Although the biological affinities of acid-resistant organic-walled microfossils attributed to the group Acritarcha are not yet well-established (SERVAIS et al., 1997), it appears that the majority of acritarchs represent abandoned cysts of unicellular marine green algae (COLBATH & GRENFELL, 1995; VAVRDOVA, 1996). The chemical composition of the polymeric and resistant wall, overall morphology, and a consistent presence of regular vesicle opening (aperture) are the most compelling arguments for their identification with resting stages of phytoplanktonic algae. Factors controlling the distribution of marine fossil microplankton are probably identical with those influencing the distribution pattern of phytoplankton in modern oceans.

Spatial distribution of recent oceanic microplankton depends on the mean annual temperatures of oceanic water masses, influenced by major currents and position of continental blocks. Major modern microplankton communities clearly show latitudinal control. Eight main planktonic bioprovinces in the Pacific Ocean (BROMWELL, 1977) form narrow, well-defined belts which parallel latitudes. The subarctic and subantarctic planktonic communities are confined to 50° and 60° latitude in each hemisphere.

The relation between acritarch biofacies and paleolatitudinal position was originally proposed by CRAMER (1971) and CRAMER & DIEZ (1972) in Silurian rocks. CRAMER's latitudinal model has been challenged (TAPPAN, 1980, FORTEY & MELLISH, 1992) and modified and complemented by many subsequent investigations (COLBATH, 1990; LE HERISSE & GOVERNNEC, 1995).

Provincialism in acritarch distributions has been demonstrated in the Ordovician (LI JUN, 1987; TONGIORGI et al., 1995) and suggested in the Early Cambrian (FATKA & VAVRDOVA, 1998). Early Ordovician acritarch bioprovinces appear to reflect cold peri-Gondwanan and temperate Baltic and warm Australo-Laurentian provinces (TONGIORGI et al., 1995).

2. Late Devonian Acritarch Provincialism

Abundant and well-preserved palynomorphs recovered from the fine-grained clastic sequences in the Madre de Dios basin, northern Bolivia (Manuripi X-1 and Pando X-1 wells) yielded a large number of acritarch and prasinophyte taxa, with diverse miospores. Over 80 species of marine microfossils were identified (VAVRDOVA et al., 1996). The assemblages document intracratonic connections between Bolivian basins (Tarija-Titicaca basin) to sub-Saharan Devonian sequences from the Murzuq Basin, Libya and the Illizi basin, Algeria. Migration routes along the

northern rim of Gondwana, reaching to Appalachian regions have been suggested (WOOD, 1995; VAVRDOVA & ISAACSON, 1997).

Although the majority of acritarchs of this age seem to show a worldwide distribution, endemic forms confined to local planktonic communities occur as well. VANGESTAINE (in STREEL et al., 1988) compared the distribution of acritarchs from the Late Devonian subsurface material from Libya with 27 palynological associations from Laurentia, Europe, and Australia. VANGESTAINE noted uneven distribution of phytoplankton forms and characterized the species as cosmopolitan, restricted, or endemic. He also recognized the Gondwanian bioprovince, marked by the presence of genus *Horologinella*, not found in the Euramerican province.

Acritarchs of Late Devonian age are still poorly documented. Despite the admittedly sparse data, four major groups of fossil microplankton taxa may be distinguished.

2.1. Ubiquitous Taxa

A majority of taxa within the Frasnian and Famennian association show a worldwide, cosmopolitan distribution. Among these, *Stellinum micropolygonale* (STOCKMANS et WILLEIRE) PLAYFORD 1977, *S. comptum* WICANDER et LOEBLICH, 1977, *Gorgonisphaeridium absitum* WICANDER, 1974, *G. ohioense* (WINSLOW) WICANDER, 1974, *Navifusa bacillum* (DEUNFF) PLAYFORD, 1977, *Veryhachium downiei* STOCKMANS et WILLIERE 1962, and *Veryhachium polyaster* STAPLIN, 1961 are the most frequently recorded ubiquitous taxa. They are known from the sedimentary basins of South and North America, Saharan North Africa, Europe, China and Australia (LU LI CHANG & WICANDER, 1988; PLAYFORD, 1976, 1993).

2.2. Taxa Common to Western Gondwana and Eastern North America

Important links between the Late Devonian-Early Carboniferous sedimentary basins of the Appalachian region (Chagrin Shale and Cleveland Shale, Ohio, in WICANDER, 1974; Antrim Shale, Indiana, WICANDER & LOEBLICH, 1977) and western Gondwana are documented by the common presence of a large number of characteristic species such as *Acriora petala* WICANDER, 1974, *Barathrisphaeridium chagrinense* WICANDER, 1974, *Diaphrochroa ganglia* WICANDER, 1974, *Gorgonisphaeridium evexispinosum* WICANDER, 1974, *Exochoderma irregulare* WICANDER, 1974, *Orygmahapsis fistulosa* (COLBATH) COLBATH, 1977, *O. craticulum* COLBATH 1977, *Pterospermella latibalteata* WICANDER, 1974, *Puteoscortum polyankistrum* WICANDER et LOEBLICH, 1977, *Veryhachium pannuceum* WICANDER et LOEBLICH, 1977, and *Veryhachium roscidum* WICANDER, 1974.

2.3. Gondwana-Wide Associations

Species confined to a peri-Gondwanan biogeographic province in the sense of VANGESTAINE (in STREEL et al., 1988) include forms common to Bolivia, Peru, Brazil, Ghana, Algeria and Libya. *Crassiangulina tessellata* JARDINE et al., 1972, *Horologinella horologia* (STAPLIN) JARDINE et al., 1972, *H. quadrispina* JARDINE et al., 1972 and *Schizocystia bicornuta* JARDINE et al., 1972, among others, are characteristic.

2.4. Species Group Endemic to Western Gondwana

Although a need for biostratigraphic correlation of Upper Devonian rocks in South America has produced signi-

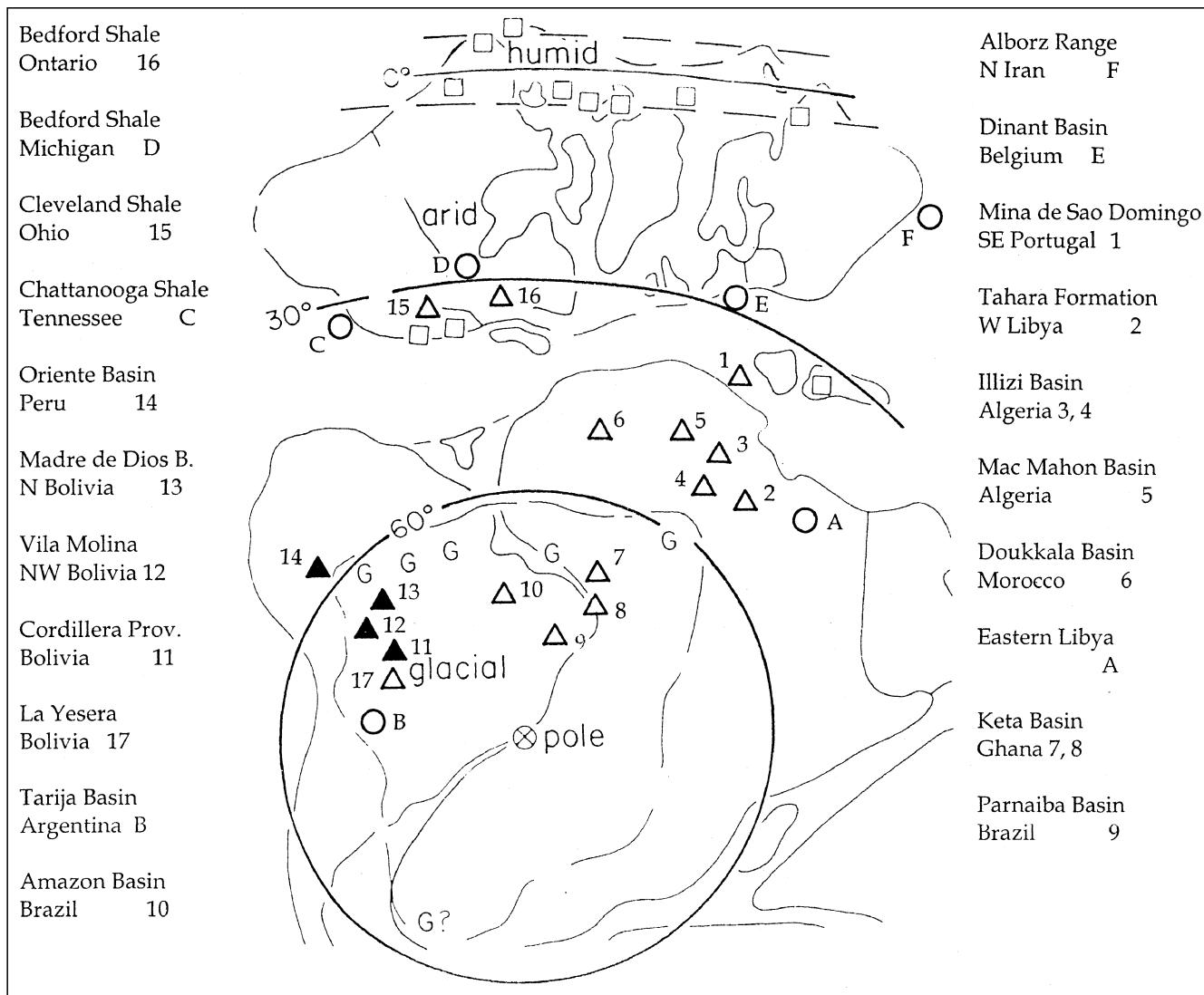
ficant new research on palynomorphs, species so far restricted to the western Gondwana region are still for the most part unknown. The palynological associations recovered in the Late Devonian Bolivian sequences and subsurface samples reveal the presence of not yet described taxa of acritarchs. Other endemic forms are described by WOOD (1995) OTTONE (1996) and others.

3. *Umbellasphaeridium Saharicum* Bioprovince

In addition to taxa considered by VANGESTAINE (in STREEL, 1988), the Famennian palynological associations from the intracratonic basins of southern America contain

a distinctive species of sphaeromorphic acritarch with characteristically expanded radial appendages. Defined by JARDINE et al. (1972) in Saharan Algeria, the genus *Umbellasphaeridium* now comprises three species and several undescribed forms. Umbrella-like expansions of the tubular processes and a firm, robust vesicle wall enables the preservation of *Umbellasphaeridium saharicum* even in assemblages strongly affected by various degradational processes.

WOOD (1984) described a recurrent species association of *Umbellasphaeridium saharicum*, *U. deflandrei*, *Stellinium octoaster*, *Navifusa bacillum* and *Maranhites brasiliensis* complex with stratigraphically important fossil miospore species *Retispora lepidophyta* (KEDO) PLAYFORD (1976). Wood noted that *Umbella-*



Text-Fig. 1.

The high-latitude *Umbellasphaeridium saharicum* acritarch bioprovince (from HECKEL & WITZKE, 1988, Fig. 4C), showing selected localities with Frasnian/Famennian age acritarch assemblages.

G = possible areal extent of glaciation. Circles (A-F) are localities with the genus *Umbellasphaeridium* present. Closed triangles indicate localities with *U. saharicum* as a frequent to dominant element of the taxa; open triangles indicate localities in which *U. saharicum* is present.

1 = Phyllite-quartzite Formation, Mina de Sao Domingos, SE Portugal (CUNHA & OLIVEIRA, 1989); 2 = Tahara Formation, Ghadamesh Basin, western Libya (MOREAU-BENOIT, 1984); 3 = Gazelle Formation, Illizi Basin, Algeria (JARDINE et al., 1972); 4 = Djebel Illerena Formation, Illizi Basin, Algeria (ATTAR et al., 1980); 5 = McMahon Basin, Algeria (LANZONI & MAGLOIRE, 1969); 6 = Doukkala Basin, central-west Morocco (RAHMANI-ANTARI, 1990); 7 = Takoradi Sandstone, Keta Basin, Ghana (BAR & RIEGEL, 1974); 8 = Well 10-1, Keta basin, Ghana (AANAN-YORKE, 1974); 9 = Longá Formation, Parnaiba Basin, Brazil (DAEMON, 1974); 10 = Curuá Formation, Amazon Basin, Brazil (DAEMON, 1974); 11 = Itacua Formation, Cordillera Province, (Lobo-BONETE, 1989); 12 = Colpacucho Formation, Vila Molina (Mina Matilde), Lake Titicaca, NW Bolivia (Vavrdova et al., 1991); 13 = Tomachi and Torequa Formations, Madre de Dios Basin, N Bolivia (Vavrdova et al., 1996); 14 = Oriente basin, Peru (WOOD, 1984); 15 = Cleveland Shale, Ohio (WOOD, 1984, MOLYNEUX et al., 1984); 16 = Bedford Shale, Ontario (WOOD, 1984).

A = Eastern Libya (STREEL et al., 1988); B = Los Monos Formation, Tarija Basin, Argentina (OTTONE, 1996); C = Chatanooga Shale, Tennessee (REAUGH, 1978); D = Bedford Shale, Michigan (WOOD, 1984); E = Geirud Formation, Central Alborz Range, N Iran (GHAVIDEL-SYOOKI, 1994); F = Dinant Basin, Belgian Ardennes, (MARTIN, 1985).

sphaeridium saharicum displays a distinct southern hemisphere endemism.

Occurrences of *Umbellasphaeridium saharicum* are plotted in Text-Fig. 1 to illustrate the common environmental conditions in the peri-Gondwanan belt rimming the margin of the paleocontinent; this distribution largely corresponds to the *Coryphidium bohemicum* bioprovince in the Early Ordovician. The presence in the glacially influenced sequences at the eastern shore of Lake Titicaca suggest the assignment to the cold, high-latitude oceanic regions. The bioprovince, originally proposed by WOOD (1984), is complemented by a new record in Portugal (CUNHA & OLIVEIRA, 1989) and occurrences of *Umbellasphaeridium* sp. (MARTIN, 1985; GHAVIDEL-SYOOKI, 1994) are considered herein as characteristic for the marginal areas outside of the *Umbellasphaeridium saharicum* bioprovince.

Text-Fig. 1 presents a map of the high-latitude *Umbellasphaeridium saharicum* acritarch bioprovince, which includes sixteen localities with assemblages of acritarchs of Frasnian/Famennian age. Associations of Early to Middle Devonian age and forms of *U. saharicum* presumably recycled into Early Carboniferous sequences are not included. The bioprovince ranges from SE Portugal across the Saharan Africa (western Libya, Algeria, Morocco) to Gulf of Guinea, Brazil, Bolivia, Peru and eastern North America. Marginal regions not included within the bioprovince are characterized by the occurrence of *U. deflandrei* (MOREAU-BENOIT) JARDINE et al. (sensu lato) without *U. saharicum*. These regions include eastern Libya, Argentina, Michigan, Tennessee, Belgium and Iran. At present, data are insufficient to decide if the absence of *U. saharicum* is caused by paleoclimatological or other factors. *U. saharicum* and other representatives of the genus were not reported from the low-latitude, warm to tropical "belt" ranging from western Canada (Alberta, Great Slave Lake region, Saskatchewan) to Poland, Siberia, and Australia (NAUTIYAL, 1977; PLAYFORD, 1993).

Selection of taxa representing the warm climatic belt is very difficult. Some taxa are mentioned by NAUTIYAL (1977) that occur in Western Gondwana as well. This could be a result of the region's movement to lower latitudes by later Devonian time (ISAACSON & DÍAZ-MRTÍNEZ, 1995). One very distinctive acritarch, *Craterisphaeridium sprucegrovense* (STAPLIN) TURNER, 1986 occurs in western Canada (NAUTIYAL, 1977), in the Dinant Basin, Belgium, and NW China

(Xinjiang, LI CHANG & WICANDER, 1988), and in NE Libya, North Africa (VANGUESTAINE in STREEL et al., 1988).

4. Comparison with the Miospore Record

Siliciclastic sediments from the Tarija-Titicaca basin and from Brazil have provided rich, diversified and well preserved terrestrial palynomorphs, which show a uniform vegetation closely similar to coeval assemblages of predominantly homosporous plants from North Africa and Euramerica (STREEL et al., 1990; LOBOZIAK et al., 1992; OTTONE, 1996). Comparison of characteristic miospore taxa from numerous drill holes has not supported existence of a wide ocean separating the paleocontinent Gondwana from Laurentia and the Armorican terranes (STREEL et al., 1990). Important vegetational bioevents, shown by the first occurrences of age-significant index species, arose in the same order of succession in all these areas. This allows an application of Devonian palynozones defined in southern Euramerica to Upper Devonian rocks of Western Gondwana.

5. Conclusions

The latest Devonian distribution of *Umbellasphaeridium saharicum* is remarkably similar to the megafossil-based Malvinokaffric Realm of the Early Devonian (ISAACSON & SABLICK, 1990), in that an endemic province that apparently paralleled high latitudes contained a restricted (highly endemic) fauna. A notable exception for the Late Devonian province is that it extends into eastern North America and North Africa, two regions assumed to be much more temperate. Yet, it appears that high latitude-generated, cooler water currents controlled acritarch distribution. In the absence of well-developed megafaunal communities at this time (as well as paleomagnetic information), it appears that insight into paleo-oceanographic surface current circulation, relative to continental positions, will be dependent upon organic microfossil distribution data.

Acknowledgments

Acknowledgement is made to the donors of The Petroleum Research Fund, administered by the American Chemical Society, for support of this research.

Plate 1

Acritarchs and prasinophytes from the Vila Molina section.
Latest Famennian, Lake Titicaca, NW Bolivia.

Fig. 1: *Umbellasphaeridium saharicum* JARDINE et al., 1974.

× 1000.

Fig. 2: *Umbellasphaeridium saharicum* JARDINE et al., 1974.

× 1200.

Fig. 3: *Gorgonisphaeridium evexispinosum* WICANDER, 1974.

× 2500.

Fig. 4: *Maranhites* sp.

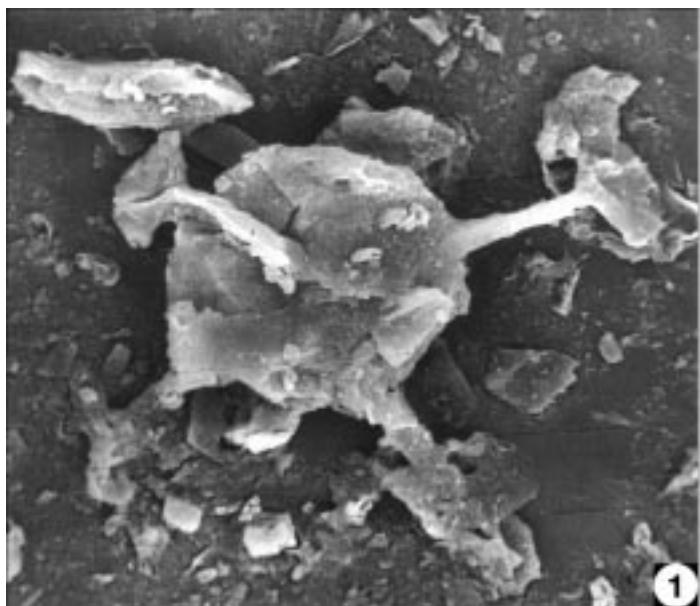
× 1000.

Fig. 5: *Gorgonisphaeridium evexispinosum* WICANDER, 1974.

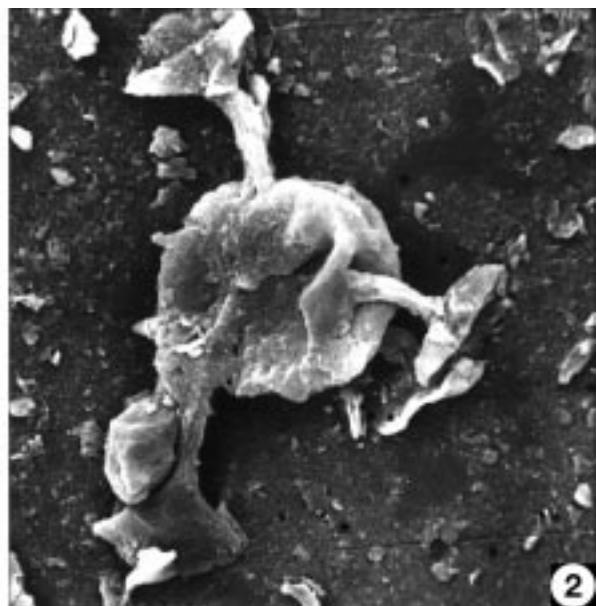
× 7000.

Fig. 6: *Pterospermella latibalteata* WICANDER, 1974.

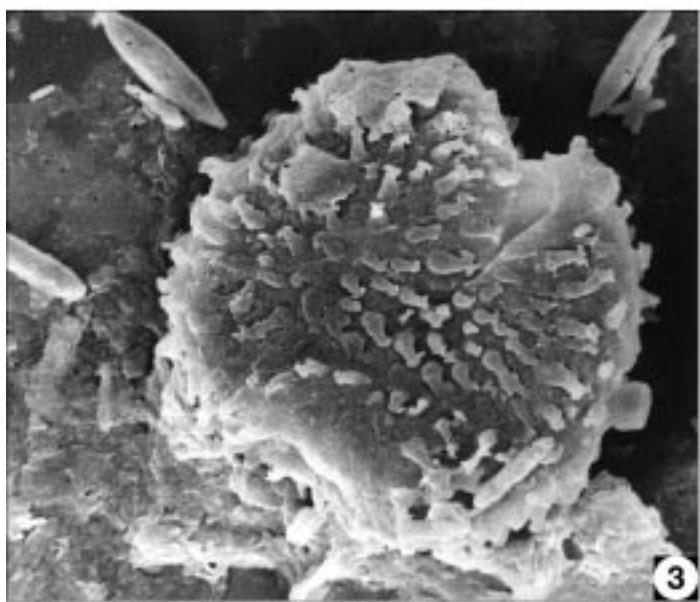
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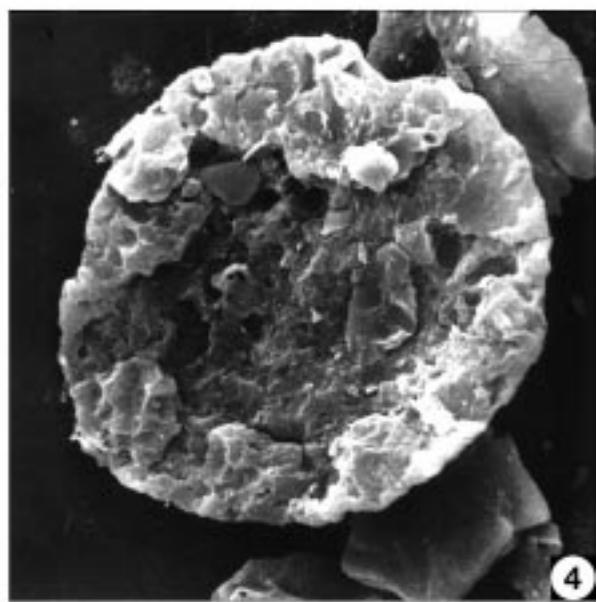
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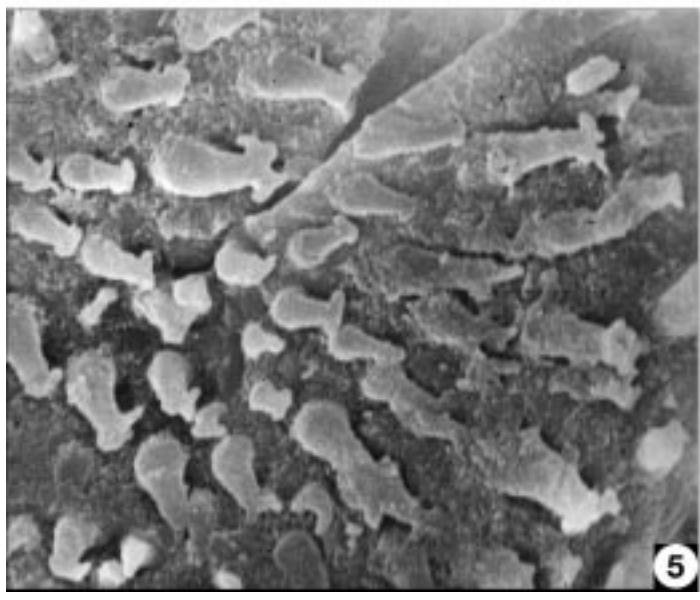
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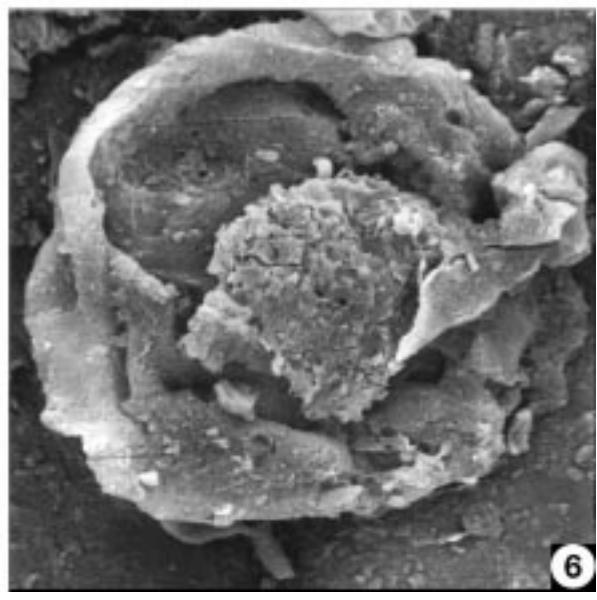
3



4



5



6

Plate 2

- Fig. 1: *Navifusa bacillum* (DEUNFF) PLAYFORD, 1977.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 2: *Veryhachium pannuceum* WICANDER & LOEBLICH, 1977.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 3: *Veryhachium roscidum* WICANDER, 1974.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 4: *Umbellaspaeidium deflandrei* (MOREAU-BENOIT) ex JARDINE et al., 1972.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 5: *Chomotriletes vedugensis* NAUMOVA, 1953.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 6: *Gorgonisphaeridium ohioense* (WINSLOW) WICANDER, 1974.
- Fig. 7: *Umbellaspaeidium deflandrei* (MOREAU-BENOIT) ex JARDINE et al., 1972.
Murzuq Basin, Libya (Ashkidah Formation, sheet Sabha).
- Fig. 8: *Exochoderma irregulare* WICANDER, 1974.
Vila Molina section, NW Bolivia.
- Fig. 9: Gen. et sp. indet.
Vila Molina section, NW Bolivia.

All $\times 1000$.

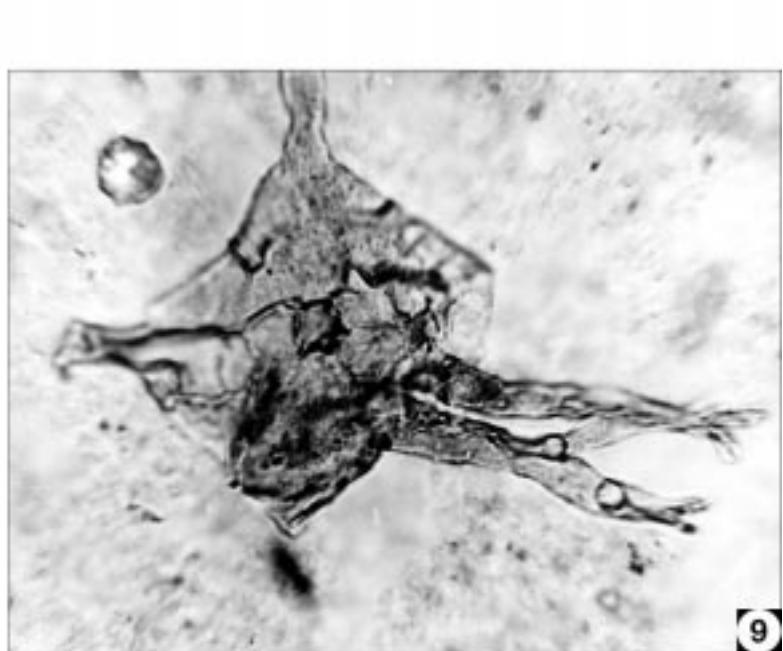
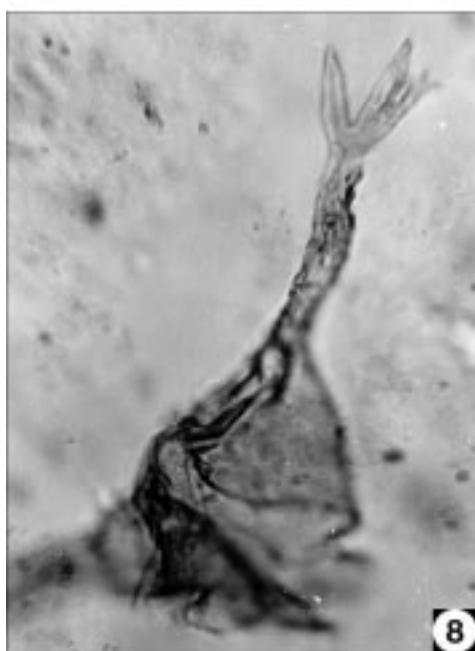
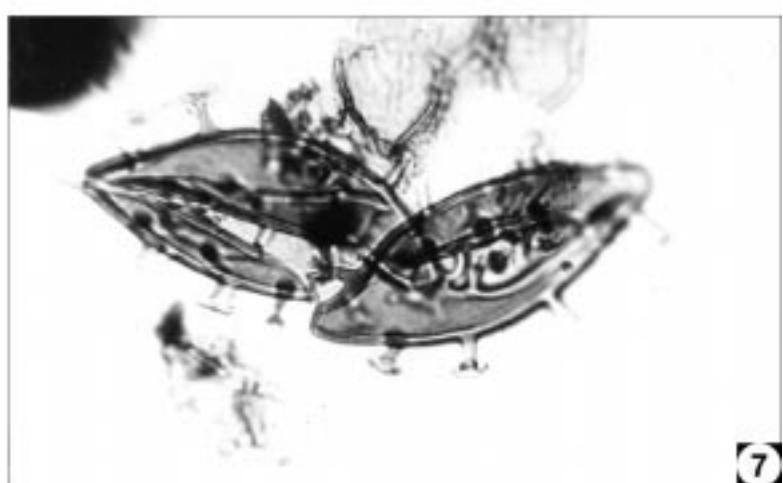
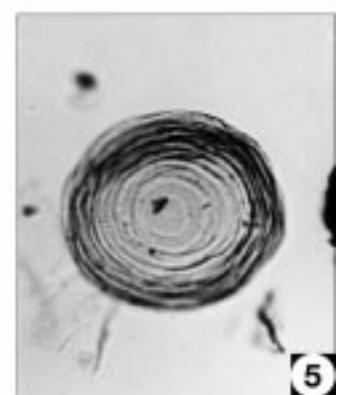
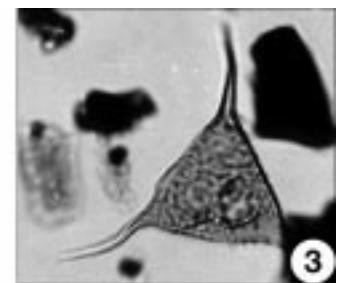
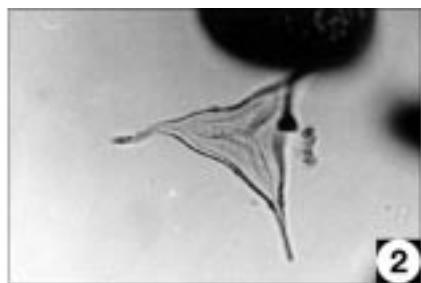
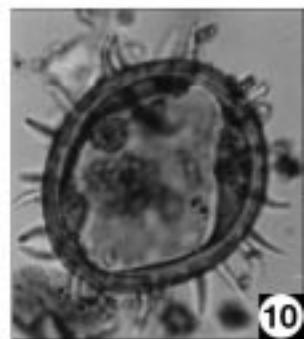
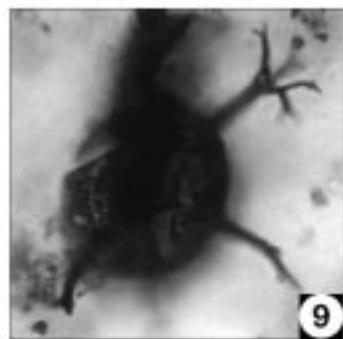
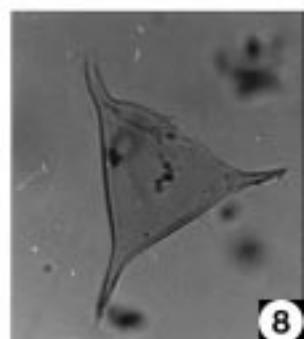
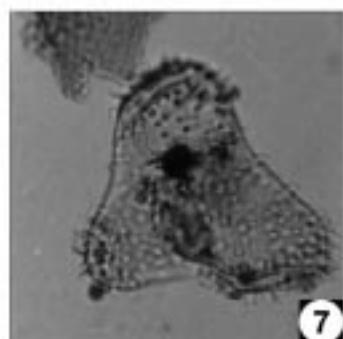
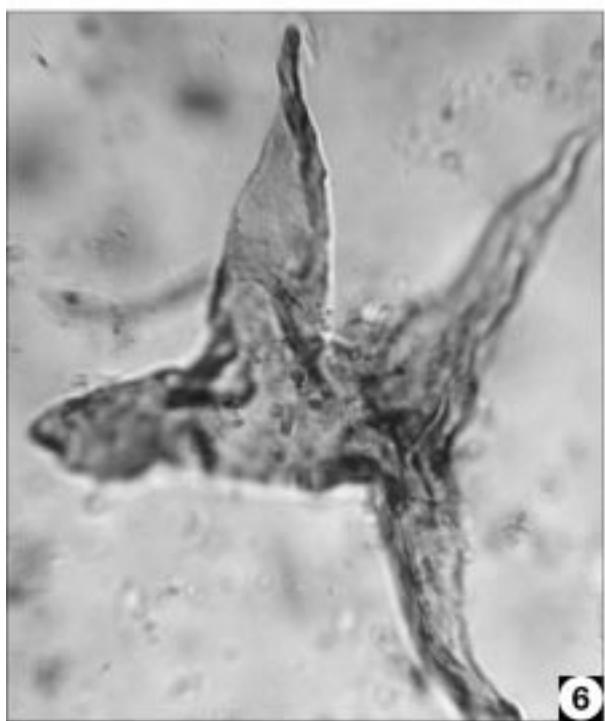
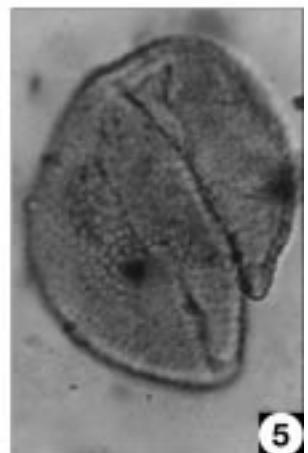
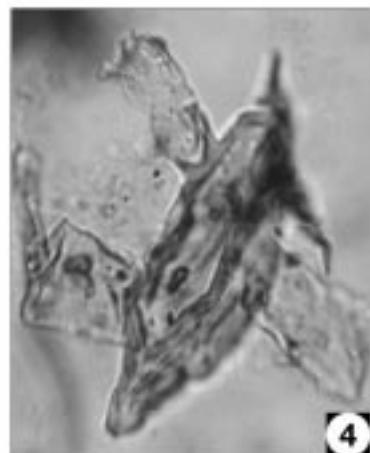
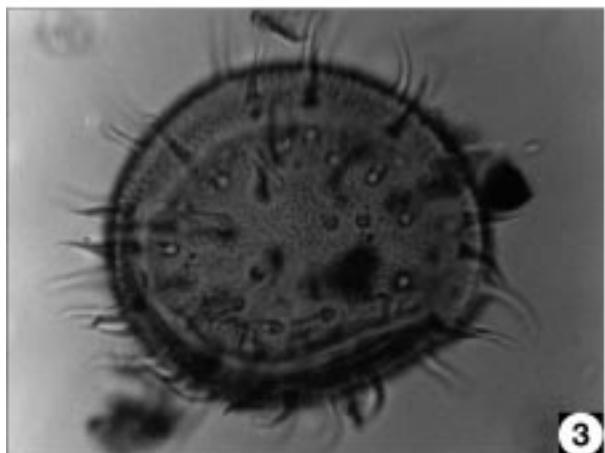
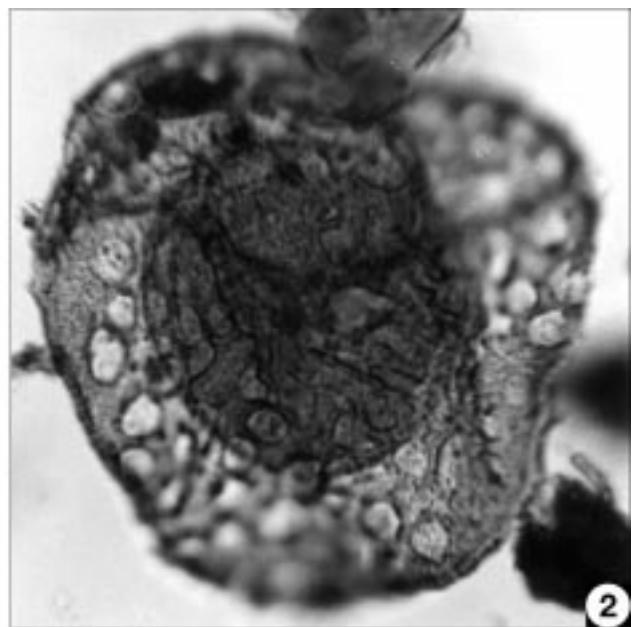


Plate 3

Palynomorphs from selected Late Devonian localities in Bolivia.

- Fig. 1: *Umbellasphaeridium saharicum* JARDINE et al., 1974.
Calamarca, early Famennian.
- Fig. 2: *Retispora lepidophyta* (KEDO) PLAYFORD, 1976.
latest Devonian of the Murzuq Basin, Libya.
- Fig. 3: *Barathrisphaeridium chagrinense* WICANDER, 1974.
latest Devonian of the Murzuq Basin, Libya.
- Fig. 4: Gen. et sp. indet.
Pando X-1 well, Madre de Dios Basin.
- Fig. 5: *Orygmahapsis fistulosa* (COLBATH), COLBATH, 1987.
La Yesera.
- Fig. 6: *Horologinella quadrispinosa* JARDINE et al., 1972.
Pando X-1 well, Madre de Dios Basin.
- Fig. 7: *Deltotosoma intonsum* PLAYFORD in PLAYFORD & DRING, 1981.
latest Devonian of the Murzuq Basin, Libya.
- Fig. 8: *Veryhachium downiei* STOCKMANS et WILLIERE, 1962.
latest Devonian of the Murzuq Basin, Libya.
- Fig. 9: *Diaphrochroa ganglia* WICANDER, 1974.
Hinchaka, late Famennian.
- Fig. 10: *Gorgonisphaeridium ohioense* (WINSLOW) WICANDER, 1974.
latest Devonian of the Murzuq Basin, Libya.

All × 1000.



References

- AANAN-YORKE, R.: Devonian chitinozoa and acritarcha from exploratory oil wells on the shelf and coastal region of Ghana West Africa. – *Ghana Geological Survey Bulletin*, **37**, Accra 1974.
- ATTAR, A., FOURNIER, J., CANDILIER, A.M. & COQUEL, R.: Etude palynologique du Devonien terminal et du Carbonifère inférieur du bassin d'Illizi (Fort Polignac), Algérie. – *Revue Institut Français Pétrole*, **35**, 585–618, Paris 1980.
- BÄR, P. & RIEGEL, W.: Les microflores des séries Paléozoïques du Ghana (Afrique Occidentale) et leurs relations paléofloristiques. – *Sciences Géologique Bulletin*, **27** (10), 39–58, Paris 1974.
- BROMWELL, M. (ed.): *Atlas of the oceans*. – Crescent Books, 1–209, New York 1977.
- COLBATH G.K.: Palaeobiogeography of Middle Palaeozoic organic-walled phytoplankton. – In: MCKERROW, W.S. & SCOTSESE, C.R. (eds.): *Palaeozoic Palaeogeography and Biogeography*, Geological Society of London Memoir, **12**, 207–213, London 1990.
- COLBATH, G.K. & GRENfell, H.R.: Review of biological affinities of Paleozoic acid-resistant, organic-walled eukaryotic algal microfossils (including acritarchs). – *Reviews of Palaeobotany and Palynology*, **86**, 287–314, Amsterdam 1995.
- CRAMER, F.H.: Distribution of selected Silurian acritarchs. – *Revue Espanola Micropaleontologia*, 1–203, Madrid 1995.
- CRAMER, F.H.: A palynostratigraphic model of Pangaea during Silurian time. – Colloque Ordovicien-Silurien, Brest, Memoirs Bureau Recherches Geologiques Minérales, **73**, 229–235, Brest 1971.
- CRAMER, F.H. & DIAZ, M.C.R.: North American Silurian palynofacies and their spatial arrangement: acritarchs. – *Palaeontographica B*, **138**, 107–180, Stuttgart 1972.
- CUNHA T.A. & OLIVEIRA J.T.: Upper Devonian palynomorphs from the Represa and Phyllite-Quartzite Formations, Mina de São Domingos, southeast Portugal: tectonostratigraphic implications. – *Bulletin Societe geologique Belgique Geologie*, **98**, 295–309, Bruxelles 1989.
- DAEMON, R.F.: Palinimorfos-Guias do Devoniano superior e Carbonífero inferior das Bacias Amazonas e Parnaíba. – Academia Brasileira Ciencias, Anais, **46** (3/4), 549–587, Rio de Janeiro 1974.
- FATKA, O. & VAVRDOVÁ, M.: Early Cambrian Acritarcha from sediments underlying Moravian Devonian (Borehole Menin 1). – *Bulletin, Czech Geological Survey*, **73** (1), 55–60, Praha 1998.
- FORTÉY, R.A. & MELLISH, C.J.T.: Are some fossils better than others for inferring palaeogeography. – *Terra Nova*, **4**, 210–216, Oxford 1992.
- GHAVIDEL-SYOOKI, M.: Upper Devonian Acritarchs and miospores from the Central Alborz Range, Northern Iran. – *Journal of Science*, **5**, 3, 103–122, Tehran 1944.
- HECKEL, P.H. & WITZKE, B.J.: Palaeoclimatic indicators and inferred Devonian paleolatitudes of Euramerica. – In: MCMILLAN, W.J., EMBRY, A.F. & GLASS, P.J.: *Devonian of the world*, Canadian Society of Petroleum Geologists Memoir, **14**, 1, 49–63, Calgary 1988.
- ISAACSON, P.E. & DÍAZ MRTÍNEZ, E.: Evidence for a Middle and Late Paleozoic Foreland Basin and Significant Paleolatitudinal Shift, Central Andes. – In: TANKARD, A.J., SUAREZ, R. & WELSINK, H.J. (eds.): *Petroleum Basins of South America*, American Association of Petroleum Geologists Memoir, **62**, 231–249, Tulsa 1995.
- ISAACSON, P.E. & SABLOCK, P.E.: Devonian palaeogeography and palaeobiogeography of the central Andes. – In: MCKERROW, W.S. and SCOTSESE, C.R. (eds.): *Palaeozoic Palaeogeography and Biogeography*, Geological Society of London Memoir, **12**, 429–433, London 1990.
- JARDINE, S., COMBAZ, A., MAGLOIRE, L., PENIGUEL, G. & VACHEY, G.: Acritarches du Silurien terminal et du Devonien du Sahara Algérien. – *Comptes Rendus, Congrès International de la stratigraphie et géologie Carbonifère*, Krefeld 1971, vol. 1, 295–311, Krefeld 1972.
- LANZONI, E. & MAGLOIRE, L.: Associations palynologiques et leurs applications stratigraphiques dans le Dévonien supérieur et Carbonifère inférieur du Grand Erg Occidental (sahara Algérien). – *Revue Institute Français Pétrole*, **23**, 441–465, Paris 1969.
- LE HERISSE, A. & GOVERNNEC, R.: Biogeography of upper Llandovery and Wenlock acritarchs. – *Reviews of Palaeobotany and Palynology*, **86**, 11–133, Amsterdam 1995.
- LI JUN: Ordovician acritarchs from the Meitan Formation of Guizhou province, southwest China. – *Palaeontology*, **30**, 613–634, London 1987.
- LOBO-BONETA, J.: El límite Devónico-Carbonífero en el Subandino Sur de Bolivia. – *Revista Técnica, Yacimientos Petrolíferos Fiscales Bolivianos*, **10** (3/4), 213–217, Santa Cruz, Bolivia 1989.
- LOBOZIAK, S. & STREEL, M.: West Gondwanan aspects of the Middle and Upper Devonian miospore zonation in North Africa and Brazil. – *Reviews of Palaeobotany and Palynology*, **86**, 147–155, Amsterdam 1995.
- LOBOZIAK, S., STREEL, M., CAPUTO, M.V. & DEMELO, J.H.G.: Middle Devonian to Lower Carboniferous miospore stratigraphy in the central Parnaíba Basin Brazil. – *Annales de la Société Géologique de Belgique*, **115**, 215–226, Brussels 1992.
- LU LI CHANG & WICANDER, R.: Upper Devonian acritarchs and spores from the Hongguleleng Formation, Hefeng district in Xinjiang, China. – *Revista Micropaleontologia*, **20**, 1, 109–148, Madrid 1988.
- MARTIN, F.: Acritarches du Frasnien supérieur et du Famennien inférieur du Bord méridional du Bassin de Dinant (Ardenne Belge). – *Bulletin Institut Royal Scientifique naturelle Belgique*, **55**, 7, 3–57, Bruxelles 1985.
- MOLYNEUX, S.G., MANGER, W.L. & OWENS, B.: Preliminary account of Late Devonian palynomorph assemblages from the Bedford Shale and Berea Sandstone formations of central Ohio, U.S.A. – *Journal of Micropaleontology*, **3**, 41–51, London 1984.
- MOREAU-BENOIT, A.: Acritarches et Chitinozoaires du Devon moyen et supérieur de Libye occidentale. – *Reviews of Palaeobotany and Palynology*, **43**, 187–216, Amsterdam 1984.
- NAUTIYAL, A.C.: The paleogeographic distribution of Devonian acritarchs and biofacies belts. – *Geological Society of India Journal*, **18** (2), 535–561, Bombay 1977.
- OTTONE, E.G.: Devonian palynomorphs from the Los Monos Formation, Tarija Basin, Argentina. – *Palynology*, **20**, 105–155, Dallas 1996.
- PLAYFORD, G.: Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia. – *Palaeontographica B*, **158**, 1–103, Stuttgart 1976.
- PLAYFORD, G.: Miospores and organic-walled microphytoplankton characteristic of strata contiguous with the Devonian-Carboniferous boundary. – *Comptes Rendus XII ICC-P*, Vol. 1, 127–160, Buenos Aires 1993.
- RAHMANI-ANTARI, K.: Etude palynologique et évaluation de l'indice d'alteration thermique du Paleozoïque de forage DOT 1 (bassin des Doukkala Centre-Ouest marocain). – *Reviews of Palaeobotany and Palynology*, **66**, 211–227, Amsterdam 1990.
- REAUGH, A.B.: Acritarch assemblages from the ?Couvinitian-Tournaisian Chattanooga black shales in northwestern Tennessee, U.S.A. (abstract). – *Palynology*, **2**, 230–231, Chicago 1978.
- ROUX, A.: Ordovician algae and global tectonics. – In: RIDING, R. (ed.): *Calcareous algae and stromatolites*. – Springer Verlag, Berlin 1991.
- SERVAIS, T., BROCKE, R., FATKA, O., LE HERISSE, A. & MOLYNEUX, S.G.: Value and meaning of the term acritarch. – *Acta Universitatis Carolinae – Geologica*, **40**, 631–643, Praha 1997.
- STREEL, M., FAIRON-DEMARET, M. & LOBOZIAK, S.: Givetian-Frasnian phytogeography of Euramerica and western Gondwana based on miospore distribution. – In: MCKERROW and SCOTSESE, C.R. (eds.): *Palaeozoic Paleogeography and Paleobiology*. – Geological Society of London Memoir, **12**, 291–296, London 1990.

- STREEL, M., PARIS, F., RIEGEL, W. & VANGUESTAINE, M.: Acritarch, chitinozoan and spore stratigraphy from the Middle and Late Devonian of northeast Libya. – In: EL-ARNAUTI, A., OWENS, B. & THUSU, B. (eds.): Subsurface palynostratigraphy of northeast Libya, Garyounis University Publication, 11–128, Benghazi, Libya 1988.
- TAPPAN, H.: The Paleobiology of plant protists. – W. H. Freeman Co., San Francisco 1980.
- TONGIORGI, M., YIN LEIMING & DI MILLIA, A.: Arenigian acritarchs from the Daping section (Yangtze Gorges area, Hubei Province, Southern China) and palaeogeographic significance. – Reviews of Palaeobotany and Palynology, **86**, 13–48, Amsterdam 1995.
- VAVRDOVÁ, M.: Excystment mechanism and the affinities of acritarchs. – Acta Universitatis Carolinae, Geologica, **3–4**, 361–383, Praha 1996.
- VAVRDOVÁ, M. & ISAACSON, P.E.: Affinities of Late Devonian acritarchs from the Madre de Dios Basin, northern Bolivia. – Acta Universitatis Carolinae, Geologica, **40**, 683–693, Praha 1997.
- VAVRDOVÁ, M., ISAACSON, P.E., DIAZ MRTÍNEZ, E. & BEK, J.: Palinología del límite Devonico-Carbonífero entorno al Lago Titikaka, Bolivia: resultados preliminares. – Revista Técnica, Yacimientos Petrolíferos Fiscales Bolivianos, **12** (2), 303–313, Santa Cruz, Bolivia 1991.
- VAVRDOVÁ, M., BEK, J., DUFKA, P. & ISAACSON, P.E.: Palynology of the Devonian (Lochkovian to Tournaisian) sequence, Madre de Dios Basin, northern Bolivia. – Vestnik Českého geologického ústavu, **71**, 4: 333–350, Praha 1996.
- WICANDER, E.R.: Upper Devonian-Lower Mississippian acritarchs and Prasinophycean algae from Ohio, USA. – Palaeontographica B, **148**, 9–43, Stuttgart 1974.
- WICANDER, E.R. & LOEBLICH, A.R.: Organic-walled microphytoplankton and its stratigraphic significance from the Upper Devonian Antrim Shale, Indiana, USA. – Palaeontographica B, **160**, 129–165, Stuttgart 1977.
- WOOD, G.: A stratigraphic, paleoecologic and paleobiologic review of the acritarchs *Umbellasphaeridium deflandrei* and *Umbellasphaeridium saharicum*. – In: SUTHERLAND, P.K. & MANGER, W.L. (eds.): 9th International Congress on Carboniferous Stratigraphy and Geology, Southern Illinois University press, 191–211, Carbondale (Illinois) 1984.
- WOOD, G.: The Gondwanan acritarch *Bimerga bensonii* gen. et sp. nov.: paleogeographic and biostratigraphic importance in the Devonian Malvinokaffric Realm. – Palynology, **19**, 221–231, Chicago 1995.

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