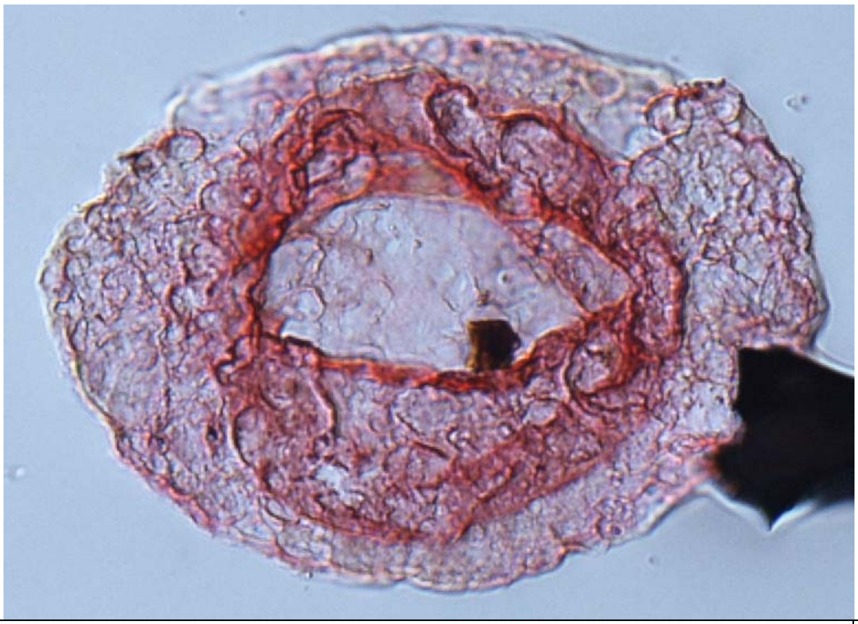
Newsletter
Summer 2008
No. 73



Potonieisporites sp. from the proposed basal Artinskian (Permian) GSSP, Dal'ny Tulkas section southern Urals; width of specimen 110 µm

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Message from the President

This CIMP Newsletter is circulated in the run-up to the Bonn IPC/IOPC and whilst we encourage all to attend and support the CIMP sponsored symposia and other events, I expect that there are a few members that are yet still undecided as to their attendance. So, we can look forward to greeting old and new colleagues in Bonn and for those of you who can't make it then we will miss you but you will be able to read all about it here in the Winter Newsletter.

We have tried to take a few initiatives to increase the profile of CIMP and its activities at the Bonn meeting. After some discussion we have offered CIMP travel scholarships to a number of students. Our funds are limited and these scholarships are modest but we hope they make the difference in attendance.

We have also sponsored a CIMP member's reception on the evening of Thursday 4th September at the Rietbrocks Weinhaus. This will be hosted by our local CIMP member Rainer Brocke. At this reception we will be formally awarding the CIMP student travel scholarships. There will also be the presentation of a festschrift to Marco Tongiori written by his friends and colleagues. So, please come and meet your CIMP colleagues in an informal atmosphere in an otherwise diverse conference. We have the venue for the evening, if we keep buying once the largesse of CIMP is exhausted.

It will be at this CIMP meeting that we will give our thanks to outgoing Secretary Mike Stephenson who has done such an excellent job in keeping the Newsletter going. We will also welcome our new Secretary Gary Mullins. Please give him your support and, more importantly, send new and interesting newsletter articles to him.

At the Bonn IPC/IOPC we have a business meeting. Here, we will be discussing the introduction of a new category of membership: Sustaining Membership for companies. We have benefited from much support over the decades from our colleagues in industry and are now trying to formalise this into a regular income stream. This would enable us to support more initiatives (i.e. spend money on Palaeozoic palynology). The concept, usually adopted by American societies, is for companies to regularly pay an enhanced yearly subscription in exchange for membership benefits for a restricted number of employees. This requires us to amend the CIMP constitution so please come, discuss, debate and give us your views.

Philippe Steemans, CIMP Treasurer also reminds you that he will be there in Bonn and willing to accept your membership subscriptions. Alternatively you can pay by Paypal before the conference.

In Bonn there are also the CIMP acritarch, chitinozoan and spore sub-commission meetings. Please also support these with your attendance. We also have a new CIMP IFPS Councillor who had to be nominated before the IPC. So, please welcome Zélia Pereira who you will know following her splendid organisation of the CIMP acritarch/spore meeting in Lisbon in 2007.

And finally….. Thomas Servais, one of our members, has been elected the new President of the IFPS. Congratulations to Thomas - and it shows that the Palaeozoic palynology remains a scientific force within the palynological community.

John Marshall, jeam@noc.soton.ac.uk

Message from the outgoing General Secretary

After several years I have decided to move on from the General Secretary job at CIMP and among other things I have taken up the challenge of palaeopalynology Editor-in-Chief of the Elsevier journal *Review of Palaeobotany and Palynology*. So you may be hearing from me again!

I'd like to say that I have really enjoyed my time on the council of CIMP, working with some of the best palynologists in the world, and on some of the most interesting problems in Earth history. The conferences: Prague, Lisbon, Seville, Lille were fantastic – great places for ideas, new papers and meeting people.

I'll obviously remain a member of CIMP and stay active in this organization but now it's time to hand over to a new Secretary.

Thanks for all your help!

Mike Stephenson; mhste@bgs.ac.uk

Meetings and conferences

12th International Palynological Congress

30 Aug - 6 Sept 2008, Bonn, Germany

International Geoscience Programme (IGCP) Project 503
Ordovician Palaeogeography and Palaeoclimate

International Congress "Palaeozoic Climates"

August 23-31, 2008, Lille, France

The Second Circular is available for download

August 23-24: Pre-conference excursion : Lower Palaeozoic of Belgium and northern France (Brabant, Condroz, Ardennes)

August 25-26: Lower Palaeozoic Climates, Sea-Levels and Biodiversity (Closing Session IGCP 503)

August 27: Plenary Session : Palaeozoic Climates, with invited keynote speakers

August 28-29: Upper Palaeozoic Climates, Sea-Levels and Biodiversity

August 30-31: Post-conference excursion : Upper Palaeozoic of Belgium and northern France (Avesnois, Meuse Valley, Ardennes)

AASP 42nd Annual Meeting,

Meadowview Convention Center, Tennessee.

September 27-30, 2009.

Organizer: Michael Zavada

Convention Center webpage: http://www.marriott.com

See announcement in AASP Newsletter.

PALYNOS

June 2008 issue of PALYNOS

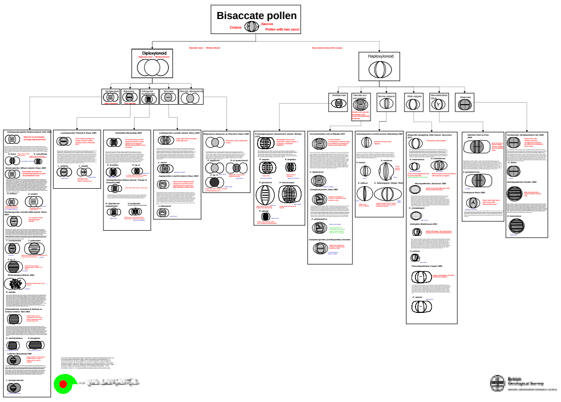
The June 2008 issue of PALYNOS, the newsletter of the “International Federation of Palynological Societies” (IFPS), is now available. IFPS members will either have received an electronic copy directly from their IFPS councillor, or they can obtain it from the IFPS website: <http://geo.arizona.edu/palynology/ifps.html>. The latest issue contains the latest information of the XIIth IPC / VIIIth IOPC that will be held in Bonn, Germany in August-September 2008.

Palynological standardisation in an oil company

Gordon Forbes, Gordon.Forbes@pdo.co.om; Mike Stephenson, mhste@bgs.ac.uk

Petroleum Development Oman (PDO) is probably one of the largest users of palynology in the petroleum industry. The company has used the discipline extensively since the 70s covering almost the entire Phanerozoic. But it has proved particularly important for correlating the subsurface Permo-Carboniferous, Al Khlata Formation, such that at present it is the chief method used due to extreme lateral variability of facies (and therefore of the wireline logs), and poor seismic resolution. The company employs four full time palynologists as well as - at present - sponsoring, two palynology PhD students. It processes all its own samples and is in the initial stages of planning a new laboratory facility.

Palynological biostratigraphy in various forms has been in operation for nearly 40 years in PDO, and has proved to be extremely robust, having been developed from a database of thousands of samples and hundreds of well sections. However, despite its well-established nature in PDO, palynology has had its pitfalls, mainly in introducing the subtle and sophisticated craft of practical palynology to new recruits and specialists working outside their area of expertise. One of the primary challenges in dealing with the Al Khlata is the confusing range of species concepts in press (Permian studies in particular). Thus a programme of standardisation and documentation was instituted between 2005 and 2007. One part of this process was the development of a series of ‘taxonomic keys’ whereby the methods used by an experienced taxonomist were captured in a flowchart showing the main ‘classification decisions’ needed to make a correct determination. Thus most of the taxa encountered in the Late Palaeozoic formations in Oman have been illustrated in relation to their near neighbours and a system of taxon determination is available to the least experienced PDO palynologist. Having been in operation for several months now this has proved a huge benefit to all, even our most experienced staff.



Taxonomic key for bisaccate pollen of the Late Palaeozoic formations in Oman

The application of biozones, again a subtle and demanding job, has been made as clear as possible to new recruits with a sequence of charts and notes, and a new handbook. Again this is particularly important to document clearly in a system that is dominated by multiple (long and short term) reworking and has the added complication of significant climate change through time. Classic zonal, top and base driven interpretations are fraught with danger in such a variable setting and clear uncertainties are written into the approach. To improve the transparency of the system, and to relate the system as much as possible to first principles, critical biozonal boundaries and events are catalogued with reference to wells in which the events or boundaries are best illustrated. In effect the system is comprehensively 'ground truthed' against a set of reference sections.

Finally the ways in which a biozonation is applied can vary considerably. In its most advanced applications in PDO it can be used to understand stratigraphy in horizontal wells, through often complex, faulted fields. To apply biostratigraphy in horizontal wells, the biostratigrapher needs a good understanding of well engineering, as well as an ability to see stratigraphy in three dimensions. Thus a part of the process in PDO has been to illustrate such complex and demanding applications of biostratigraphy in the form of case studies that can be worked through by new recruits and demonstrated practically by experienced palynologists.

The resultant handbook and microscope companion is already reaping rewards and the consistency of interpretation it will bring will benefit PDO for years to come.

The management of Petroleum Development Oman and the Ministry of Oil and Gas of the Sultanate of Oman are acknowledged for allowing publication of this article.

CIMP Lisbon 2007 Abstracts part 2

Approximately half of the abstracts from Lisbon 2007 were included in Newsletter 72. The other half are reproduced here with kind permission of the organisers of Lisbon 2007. **I apologise for the small size of some of the diagrams included in abstracts, and I realise that some of these will be difficult to read, especially in PDF form. If there is a diagram you'd like to read in more detail, you can contact me (mhste@bgs.ac.uk) and I will send it to you by email.**

ACRITARCH ASSEMBLAGES FROM THE *NORMALOGRAPTUS PERSCULPTUS* GRAPTOLITE BIOZONE (UPPER HIRNANTIAN) FROM ANTICOSTI ISLAND, QUEBEC, CANADA

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SUMMARY

New palynological data from the Ordovician-Silurian boundary at Anticosti Island (Quebec, Canada) are presented. Acritarch assemblages occur in strata correlated with the *Normalograptus persculptus* graptolite biozone (upper Hirnantian, Upper Ordovician). These sediments were deposited during the melting of the Gondwana ice cap. One of these assemblages is very abundant and diverse, and shows affinity with previously described associations from younger strata (Richmondian) in North America (U.S.A).

At the end of the Ordovician, the first and second largest of the "big five" Phanerozoic

extinctions took place, resulting in an estimated 85% of the total fauna becoming extinct (Sheehan, 2001). This extinction is thought to be directly related to a major glaciation, centered on the Gondwana megacontinent, and associated with the development of a large south polar ice-cap. We present herein new preliminary data on organic walled microphytoplankton (acritarchs) from the Upper Ordovician-Lower Silurian formations of Anticosti Island, Quebec, Canada.

During the Late Ordovician-Early Silurian, Anticosti Island was situated at low latitudes (12^o South) on the eastern margin of Laurentia (Figure 1A). Limestones, mudstones and minor sandstones were deposited during this time interval, forming a carbonate ramp to platform sequence on the western side of the Iapetus Ocean. These Ordovician-Silurian sequences comprise seven formations, which in ascending stratigraphic order are the Vaureal, Ellis Bay, Becsie, Merrimack, Gun River, Jupiter and Chicotte formations. The Ordovician-Silurian boundary lies between the Ellis Bay Formation (Hirnantian) and the Becsie Formation (Rhuddanian) (Figure 1B).

The present palynological investigation focuses on an outcrop situated at the western part of the island, known as Pointe La Framboise (Figure 1B). This outcrop is late Hirnantian in age and extends into the Early Silurian (Figure 2). It comprises the Prinsta, Lousy Cove, and La Framboise Members of the Ellis Bay Formation (late Hirnantian), and the lower part of the Fox Point Member of the Becsie Formation, dated as Rhuddanian. Most of this interval is biostratigraphically constrained to the *Normalograptus persculptus* graptolite biozone (Melchin, 2002) (Figure 2). The melting of the palaeo-south pole inlands took place during this biozone (see Wang et al., 1993, p. 62 for more references). The south pole melting is generally considered to have caused the second phase of the Late Ordovician extinction, in which a rapid rise in sea-level decimated the macrofaunal assemblages that had earlier adapted to glacial conditions (Sheehan, 2001).

Previous studies on the acritarch microflora from Anticosti Island include those of Martin (1988), Duffield and Legault (1981, 1982), and Jacobson and Achab (1985). Only sparse, albeit interesting, information exists on the acritarchs from the Ellis Bay Formation of Hirnantian age, which corresponds to the Late Ordovician glaciation interval (Martin, 1988; Duffield and Legault, 1981). The present preliminary data results from the analysis of 42 samples collected at the La Framboise section (Fig. 1B), and dated as late Hirnantian. Of the investigated samples, only seven yielded identifiable acritarchs, five of which are from the Prinsta and Lousy Cove members, and two from above the coral patch reefs of the La Framboise Member.

The Prinsta and Lousy Cove Members yield a diverse and abundant microflora (see the local extension range of acritarch taxa in Figure 2) including new species and probably a new genus. The assemblage includes *Evittia denticulata denticulata* (Cramer, 1970) Le Hérissé, 1989; *Veryhachium triangulatum* Konzalová-Mazancová, 1969; *Hogklintia visbyense* (Eisenack, 1959) Dorning, 1981; *Veryhachium oklahomense* Loeblich, 1970; *Veryhachium* sp. cf. *V. fictusistriatum* Colbath, 1979; *Leiofusa litotes*

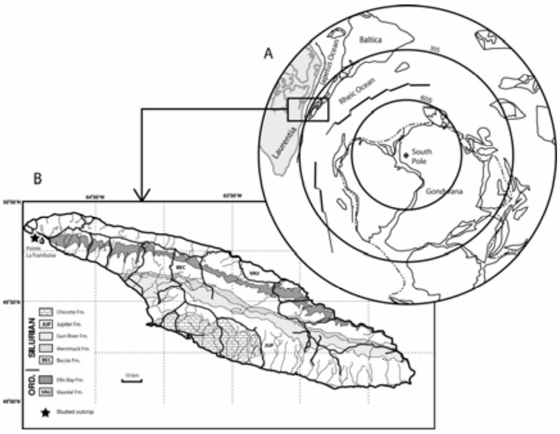

Figure 1: A. Palaeogeographical location of Anticosti Island, Canada (modified from Cocks and Torsvik, 2004). B. Geographical location of the studied outcrop (modified from Zhang et al., 2006).

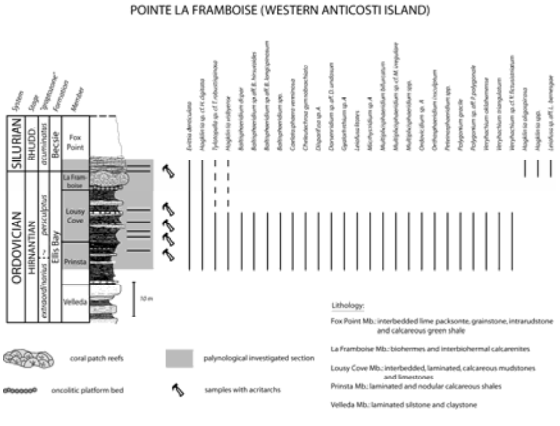

Figure 2: Investigated section of Pointe La Framboise (Anticosti Island) and local extension range of acritarch species (stratigraphic log build from field data; Petryk, 1981; Long and Copper, 1987).

Loeblich and Tappan, 1978; new species of *Multiplicisphaeridium*; *Multiplicisphaeridium bifurcatum* Staplin, Jansonius, and Pocock, 1965; *Multiplicisphaeridium* sp. cf. *M. irregulare* Staplin, Jansonius, and Pocock, 1965; *Caelatosphaera verminosa* Wicander, Playford, and Robertson, 1999; *Orthosphaeridium insculptum* Loeblich,1970; a new species of *Gyalorhethium*; *Tylotopalla* sp. cf. *T. robustispinosa* (Downie, 1959) Eisenack, Cramer, and Diez, 1973; a new species of *Micrhystridium*; *Cheleutochroa gymnobrachiata* Loeblich and Tappan, 1978; *Polygonium gracile* Vavrdová, 1966 emend. Sarjeant and Stancliffe, 1994; *Hogklintia* sp. aff. *H. digitata* (Eisenack, 1938) emend. Le Hérissé, 1989; *Baltisphaeridium* sp. aff. *B. hirsutoides* (Eisenack, 1951) Eisenack, 1959; *Baltisphaeridium dispar* (Turner, 1984) Uutela and Tynni, 1991; new species of *Peteinosphaeridium*; *Polygonium* sp. cf. *P. polygonale* (Eisenack, 1931) Wright and Meyers, 1981; *Dorsennidium* sp. cf. *D. undosum* Wicander, Playford and Robertson, 1999; and *Disparifusa* sp. A.

Acritarch floras from the La Framboise Member (latest Ordovician) and the lowermost part of the Fox Point Member (earliest Silurian) are impoverished, being only composed of *Hogklintia oligospinosa* (Eisenack, 1934) n. comb., *Hogklintia* sp. aff. *H. digitata*, *Leiofusa sp.* aff. *L. Bernesgae* Cramer, 1964, and *Evittia denticulata denticulata*.

The assemblages from the Prinsta and Lousy Cove members have a clear Upper Ordovician character (species of *Baltisphaeridium*, *Peteinosphaeridium,* and *Orthosphaeridium*) with some typical Silurian acritarch species such as *Hogklintia visbyense* and *Tylotopalla* sp. cf. *T. robustispinosa* already present. On the other hand, the La Framboise Member microfloras show a Silurian affinity.

The transition between typical Ordovician and typical Silurian phytoplankton appears to be rather abrupt in the Anticosti Island formations. The microflora change from extremely abundant and diverse in the Late Ordovician to poorly preserved, rare and poorly diversified in the Early Silurian. At first sight, this might be considered to reflect a rapid and strong crisis of the primary producers, as previously suggested by Colbath (1986) and Martin (1988). However, a different interpretation has been proposed more recently (e.g., Le Hérissé in Paris et al., 2000; Vecoli, 2006). These authors suggest that no true mass extinction occurred in the phytoplanktonic realm in association with the Late Ordovician glaciation, and that the transition from typical Ordovician to Silurian acritarch suites occurred rather gradually in the form of a turn-over. Knoll (1989) also used this hypothesis as an explanation for other Phanerozoic biological crises.

The palaeoecological interpretation of acritarch abundance variations across the O-S boundary at Anticosti Island must also take into account the lithological changes occurring in the sediments. The more abundant and diverse acritarch assemblages come from fine-grained, shaly sediments (Prinsta and Lousy Cove members), whereas the poorer (in abundance, diversity, and preservation) assemblages are associated with the more calcareous and compact sediments (La Framboise and Fox Point members) (Figure 2). This facies control on acritarch abundance and preservation gives a biased impression of a drastic "extinction" event. However, it is now evident that certain taxa previously considered typically Silurian, such as *Tylotopalla* and *Hogklintia*, first appear in latest Ordovician time. Additionally, some taxa characteristic of the Late Ordovician (*Multiplicisphaeridium*, *Veryhachium*) cross the O-S boundary. These data seems to be consistent with the gradual "turn-over" scenario.

Lithological changes also occur laterally at Anticosti Island, from more calcareous sediments in the western side to more siliciclastic in the east, where the Hirnantian bioherms of the La Framboise Member are less developed. Accurate palaeoecological analysis, including sedimentological and stable isotopic geochemical studies, of the acritarch dynamics across the O-S transition and taking into account this facies change are currently in progress.

From a palaeobiogeographic standpoint, the Prinsta and Lousy Cove acritarch assemblages have many of the same taxa (species or genus) in common with those of the Richmondian (pre-Hirnantian stage) Sylvan Shale from the Arbuckle Mountains in southern Oklahoma, U.S.A. (Loeblich and Tappan, 1978; Playford and Wicander, 2006), the Richmondian Maquoketa Shale of northeastern Missouri, U.S.A. (Wicander et al., 1999), and northeastern Kansas, U.S.A. (Wright and Meyers, 1981).

REFERENCES

Cocks, L.R.M., Torsvik, T.H., 2004. Major Terranes in the Ordovician, 61-67, *In*: Webby, B.D., Paris, F., Droser, M.L., Percival, I.D. *(*Eds.*)*, The Great Ordovician Biodiversification Event. Columbia University Press, New York.

Colbath, G.K., 1986. Abrupt terminal Ordovician extinction in phytoplankton associations, southern Appalachians. Geology 14, 943-946.

Duffield, S.L., Legault, J.A., 1981. Acritarch biostratigraphy of Upper Ordovician-Lower Silurian rocks, Anticosti Island, Québec: Preliminary results. *In*: Lespérance, P.J. (Ed.), Field Meeting, Anticosti-Gaspé, Québec 1981 (Stratigraphy and Paleontology) 2, 91-99. (I.U.G.S. Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group) Montréal.

Duffield, S.L., Legault, J.A., 1982. Gradational morphological series in Early Silurian acritarchs from Anticosti Island, Quebec. *In*: Mamet, B., Copeland, M.J. (Eds.), Proc. 3rd N. Amer. Paleont. Conv., Montréal 1, 137-141.

Jacobson, S.R., Achab, A., 1985. Acritarch biostratigraphy of the *Dicellograptus complanatus* graptolite zone from the Vaureal Formation (Ashgillian), Anticosti Island, Quebec, Canada. Palynology 9, 165-198.

Knoll, A.H., 1989. Evolution and extinction in the marine realm: some constraints imposed by phytoplankton. Phil. Trans. R. Soc. Lond. B 325, 279-290.

Loeblich, A.R., Jr., Tappan, H., 1978. Some Middle and Late Ordovician microphytoplankton from Central North America. J. Paleontol. 52, 1233-1287.

Long, D.G.F., Copper, P., 1987. Stratigraphy of the Upper Ordovician upper Vaureal and Ellis Bay formations, eastern Anticosti Island, Quebec. Can. J. Earth Sci. 24, 1807-1820.

Martin, F., 1988. Late Ordovician and Early Silurian acritarchs. Bull. Nat. Hist. Mus. Geol. 43, 299-309.

Melchin, M.J., 2002. Restudy of some Ordovician-Silurian boundary graptolites from Anticosti Island: Implications for the age and correlation of the Ellis Bay Formation. Canadian Paleontology Conference, Program and Abstracts N° 12, Ottawa, September 2002, 31-33.

Palyford, G., Wicander, R., 2006. Organic-walled microphytoplankton of the Sylvan Shale (Richmondian: Upper Ordovician), Arbuckle Mountains, Southern Oklahoma, U.S.A. Bull. Oklahoma Geol. Surv. 148, 1-116.

Paris, F., Bourahrouh, A., Le Hérissé, A., 2000. The effects of the final stages of the Late Ordovician glaciation on marine palynomorphs (chitinozoans, acritarchs, leiospheres) in well Nl-2 (NE Algerian Sahara). Rev. Palaeobot. Palynol. 113, 87-104.

Petryk, A.A., 1981. Stratigraphy, sedimentology and paleogeography of the Upper Ordovician – Lower Silurian of Anticosti Island, Quebec. *In*: Lespérance, P.J. (*Ed.),* Field Meeting, Anticosti-Gaspé, Québec, 1981 (Stratigraphy and Paleontology) 2, 11-39. (I.U.G.S. Subcommission on Silurian Stratigraphy, Ordovician-Silurian Boundary Working Group) Montréal.

Sheehan, P.M., 2001. The Late Ordovician mass extinction. Ann. Rev. Earth Planet. Sci. 29, 331-364.

Vecoli, M., 2006. Acritarch biostratigraphy and palaeoecology across the Ordovician-Silurian boundary. Geophysical Research Abstracts, Vol. 8, EGU General Assembly 2006, N° A-07599.

Wang, K., Orth, C.J., Attrep, M.Jr., Chatterton, B.D.E., Wang, X., Li, J.-j, 1993. Thre great latest Ordovician extinction on the South China Plate: Chemostratigraphic studies of the Ordovician-Silurian boundary interval on the Yangtze Platform. Palaeogeogr. Palaeoclimatol. Palaeoecol. 104, 61-79.

Wicander, R., Playford, G., Roberrtson, E.B., 1999. Stratigraphic and paleogeographic significance of an Upper Ordovician acritarch flora from the Maquoketa Shale, northeastern Missouri, U.S.A. J. Paleont. 73(6), Paleont. Soc. Mem. 51, 1-38.

Wright,R.P., Meyers, W.C., 1981. Organic-walled microplankton in the subsurface Ordovician of northeastern Kansas. Kansas Geol. Surv. Subsurface Geol. Ser. 14, 1-49.

Zhang, S., Barnes, C.R., Jowett, D.M.S., 2006. The paradox of the global standard Late Ordovician-Early Silurian sea level curve: Evidence from conodont community analysis from both Canadian Arctic and Appalachian margins. Palaeogeogr. Palaeoclimatol. Palaeoecol. 236, 246-271.

SPORE/POLLEN CHARACTERS AND LAND PLANT PHYLOGENY

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SUMMARY

It has long been recognized that spore/pollen characters are valuable in revealing the taxonomic and phylogenetic relationships of extant land plant. Increasing information on in situ spores/pollen from fossil plants, coupled with analyses of wall ultrastructure, is permitting incorporation of evidence from fossil material. This work examines the evolution of spore/pollen development during the "explosive" radiation of vascular plants that took place during the Devonian, and what it can tell us about land plant phylogeny at this critical time.

The early diversification of land plants was a rather drawn-out affair. The earliest land plants are believed to have evolved from charophycean green algal ancestors in the Mid Ordovician (Darriwilian) (e.g. Wellman & Gray 2000). They were probably bryophyte-like plants that represent stem group "bryophytes" (e.g. Edwards & Wellman 2001). Which of the extant bryophyte groups (liverworts, hornworts, mosses) is most basal is controversial, although many workers believe it may be the liverworts (e.g. Kenrick & Crane 1997). Evidence for these earliest land plants is confined to dispersed spores and rare fragments such as sporangia and their contents (Wellman *et al.* 2003). This almost certainly reflects a preservational bias, with these early bryophyte-like plants unrepresented because they lack recalcitrant tissues such as those containing lignin. Thus little is known of the earliest land plants, except information that can be deduced from study of their dispersed spores.

Somewhat surprisingly it seems that the bryophyte-like plants were palaeogeographically widespread, their spores having been reported from sediments deposited from the equator to very high latitudes (with high latitude spore occurrences persisting even during the end Ordovician glaciation). These dispersed spore assemblages exhibit very little variation both spatially and temporally. Palaeogeographical variation is very limited, although there are some subtle differences between assemblages from Gondwana and Euramerica. Intriguingly the plants (or at least their spores) appear to exhibit temporal stasis in terms of morphology, with similar spore assemblages occurring for at least 30 million years. However, this is not to say that the unrepresented vegetative parts were not evolving rapidly.

A major event took place in the dispersed spore record in the Early Silurian (Llandovery). Trilete spores become abundant in the dispersed spore record for the first time. This is often considered to represent the origin of vascular plants. Vascular plants appear to have evolved from within the "bryophytes", possibly with a moss/vascular plant sister group relationship. Shortly after this, in the Late Silurian (Late Wenlock), the earliest vascular plant fossils appear (e.g. Edwards & Wellman 2001). These are simple bifurcating plants with terminal sporangia (rhyniophytes), that are preserved due to the presence of recalcitrant lignified tissues.

During the remainder of the Late Silurian-Early Devonian vascular plants underwent an adaptive radiation. This is witnessed in both the dispersed spore (Richardson & McGregor 1986; Streel *et al.* 1987) and megafossil (e.g. Edwards & Wellman 2001) fossil records. The dispersed spore record, which probably records events with high fidelity, suggests that vascular land plants diversified (trilete spore diversity/disparity is seen to dramatically increase) while the bryophyte-like plants persist but gradually decline in relative abundance (Wellman & Gray 2000). The megaspore record shows gradually increasing diversity of the vascular plants with the occurrence of rhyniophytes, zosterophyllys, lycopsids and plants such as *Psilophyton* that have traditionally been classified in the "Trimerophyte" group (that has subsequently been shown to be polyphyletic). Plant size increases dramatically over this 40 million year period, from millimeters in height when vascular plants first appear to over a metre in height by the end of the Early Devonian (Emsian). However, one must bear in mind that the plant megafossil record is probably highly selective.

What follows is one of the most dramatic periods in the evolution of land plants. During the 39 million years of the Mid and Late Devonian vascular plants radiated rapidly and dramatically (e.g. Berry & Fairon-Demaret 2001). By the end of the Devonian essentially all of the modern vascular plant groups (except the angiosperms) had appeared. Lycopsids persisted, stem group sphenopsids/ferns appeared, and at the very end of the Devonian the earliest seed plants had evolved via intermediary groups focused on the "Progymnosperms". Maximum plant size had also increased dramatically, beginning in the latest Emsian-earliest Eifelian with the advent of arborescence in a variety of phylogenetically unrelated groups, and culminating with "Archaeopteridalean Progymnosperm" forests in the Late Devonian.

Of course these rapid and momentous evolutionary events are reflected in the dispersed fossil record, with distinct changes in disparity, diversity and patterns of palaeogeographic distribution (summarized in Richardson & McGregor 1986 and Streel *et al.* 1987).

Key to understanding early land plant evolution is integration of the dispersed spore and plant megafossil fossil records. The former is probably a fairly accurate reflection of land plant evolution because spores have an excellent fossil record. They are produced in vast numbers, dispersed large distances by wind and other vectors, and are easily fossilized. On the other hand the plant megafossil record is probably highly incomplete and extremely biased, principally due to the selective nature of sediment accumulation and the difficulty of transporting plant megafossils large distances (e.g. from an inland area to a site of sediment accumulation).

Integrating the dispersed spore and plant megafossil fossil records has been greatly facilitated in recent years due to the increasing number of reports of *in situ* spores. Thus dispersed spore taxa (be it individual species or "generic" groupings as a whole) are more easily assigned to known plant taxa. Furthermore, it is becoming increasingly clear that spore/pollen development is characteristic for different plant groups. This is based on: (i) ultrastructural studies of extant plants, with ontogenetic studies being most informative; (ii) ultrastructural studies of fossil spores/pollen (*in situ* or dispersed), although unfortunately ontogenetic information is usually not available; (iii) recent developments in the field of developmental genetics that is revealing the molecular basis for spore/pollen development. The latter is likely to be an extremely fruitful avenue of research in the foreseeable future.

In an attempt to shed light on the Ordovician-Devonian radiation of land plants information has been collated in order to characterize plant-spore/pollen type relationships and relate these to phylogenetic hypotheses. Thus information has been collated on: (i) all known *in situ* occurrences of Ordovician-Devonian spores; (ii) all known reports of wall ultrastructural analysis of Ordovician-Devonian spores/pollen. This information has been plotted on relevant cladograms to ascertain how patterns of spore/pollen evolution relate to land plant phylogeny. These patterns can then be translated back into the dispersed spore record to shed light on patterns of evolution of these early land plants. Particular emphasis has been placed on spore/pollen wall ultrastructural characters, that have been considered in light of information from studies of spore/pollen wall development in extant plants (including the increasing wealth of data from studies of developmental genetics).

A particularly informative example involves the transition from the traditional "Trimerophytes" through the "Progymnosperms" and into the seed plants. Recent cladistic analyses have demonstrated that the "Trimerophytes" are polyphyletic. Constituent taxa, however, hold key position in recently proposed phylogenies. The genus *Psilophyton* is seen as fairly basal within the Euphyllophytes. Spores in this taxon are accommodated in the dispersed spore genus *Apiculiretusispora*. They are bilayered, with an inner laminated layer and an outer (?tapetally derived) granulate layer that has a habit of sloughing off. The genus *Pertica*, that is sister group to the Lignophytes, has similar spores, although unfortunately these have yet to be sectioned. "Progymnosperms" key out as somewhat more derived in the cladogram and are paraphyletic but with a sister group relationship to the seed plants. The more basal "Aneurophytalean Progymnosperm" taxa, such as *Rellimia* and *Tetraxylopteris*, have pseudosaccate spores of *Rhabdosporites*-type. New studies of these spores demonstrate that they are ultrastructurally similar to *Apiculiretusispora* spores. Similarly, the more derived "Archaeopteridalean Progymnosperm" plants produce spores that are also ultrastructurally similar to *Rhabdosporites* and *Apiculiretusispora*. This is despite the fact that these plants are heterosporous with *Geminospora*–type microspores and *Contagisporites*–type megaspores. Thus it is easy to envisage an evolutionary transition from *Apiculiretusispora*-type spores to *Rhabdosporites*-type spores to *Geminospora*- and *Contagisporites*–type spores even though this transition breaches: (i) a morphological divide between simple bilayered spores and pesudosaccate spores; (ii) the reproductive divide between homospory and heterospory. Regarding the latter, however, one must recognize that heterospory evolved independently many times in distantly related plant groups.

"Progymnosperms" are considered to have a sister group relationship with the seed plants. Do spore characters also smoothly bridge the reproductive divide between homosporous/heterosporous free-sporing plants and seed habit? The most basal seed plants are considered to be the [Hydrasperman seed-ferns [Medullosan seed-ferns [Callistophytalean seed-ferns]]] (Hilton and

Bateman 2006). Fortunately pollen wall ultrastructure is well known in these plants (e.g. Osborn and Taylor 1994). Intriguingly, it is most simple in the most basal Hydrosperman seed-ferns becoming more complex through the Medullosan and Callistophytalean seed-ferns. In the seed plant phylogeny of Hilton and Bateman (2006) the most basal gymnosperm group with extant representatives, the cycads, key out next. These provide a wealth of information on pollen wall development that can be used to interpret spore/pollen wall ultrastructural features observed in the mature spores/pollen of the more basal, extinct "Progymnosperm" and basal seed-fern groups.

It would appear that several important developments were associated with the evolution of seed habit (though not all are confined to the seed plants). Firstly, gametophyte development occurred earlier and within the pollen grain. Secondly, germination switched from gametophyte emergence from the spore proximal surface to pollen tube emergence from the pollen distal surface. Interestingly, however, the most basal prepollen show evidence for retaining germination through a trilete mark on the proximal surface. Thirdly, pollen wall development appears to have incorporated a new developmental mechanism into its ontogeny. Spores of free-sporing plants appear to have retained a simple system of lamellae formation followed by accumulation of additional tapetally-derived sporopollenin (that accumulates on the lamellae and also on the outer surface of the lamellate layer). Spores of seed plants (excluding angiosperms) appear to have a glycocalyx-like Microspore Surface Coat, that forms a framework within which the ectexine (tectum and infratectum) precursors form. The lamellated endexine, that is presumably homologous to the lamellated inner layer in free-sporing plants, develops below the ectexine (usually, but not always, after ectexine initiation). The final stage, that is presumably equivalent to the similar stage in the development of spores of free-sporing plants, sees tapetally-derived sporopollenin accrete onto the ectexine and endexine substructures and precipitate out to form the footlayer of the ectexine. Thus evolution of the seed habit appears to have been a major event with respect to male microspore evolution (i.e. the spore to pollen transition). The occurrence of prepollen and the simplicity of wall ultrastructure in the most basal of these suggest that the transition may have been step-wise. Critically, however, at some point it involved incorporation of a new mode of pollen wall development involving a Microspore Surface Coat that forms the additional tectum/infratectum layer not seen in the free-sporing plants (e.g. Lugardon 1995).

CONCLUSION

1/ Recent advances in our understanding of spore/pollen wall development, in both extant and fossil plants, is permitting formulation of hypotheses regarding evolution of spore/pollen development through time.

2/ It is becoming clear that much of spore/pollen morphological variation is easily achieved through minor manipulation of basic developmental mechanisms, although certain major morphological transitions (such as the spore to pollen transition associated with the origin of seed plants) involves the incorporation of new developmental mechanisms (i.e. Microspore Surface Coat).

3/ Increasing knowledge of *in situ* fossil spores/pollen and wall ultrastructure in fossil spores/pollen is permitting identification of spore/pollen morphological characters/developmental mechanisms with different plant groups. Thus it is becoming increasingly possible to interpret the excellent dispersed spore/pollen record in terms of the plant producers and land plant evolution through time.

REFERENCES

Berry, C. M., Fairon-Demaret, M., 2001. The Middle Devonian flora revisted.120-139. In: Gensel, P. G.,

Edwards, D. Plants invade the land: evolutionary and environmental perspectives. Columbia University Press.

Edwards, D. Wellman, C. H., 2001. Embryophytes on land: The Ordovician to Lochkovian (Lower Devonian)

record. 3-28. In: Gensel, P. G., Edwards, D. Plants invade the land: evolutionary and environmental perspectives. Columbia University Press.

Hilton, J, Bateman, R. M. 2006. Pteridosperms are the backbone of seed-plant phylogeny. J. Torrey Bot. Soc., 133, 119-168.

Kenrick, P. K., Crane, P. R. 1997. The origin and early diversification of land plants. Smithsonian Institution Press.

Lugardon, B., 1995. Exine formation in Chamaecyparis lawsoniana (Cupressaceae) and a discussion on pteridophyte exospore and gymnosperm exine ontogeny. Rev. Palaeobot. Palynol. 85, 35-51.

Osborn, J. M., Taylor, T. N., 1994. Comparative ultrastructure of gymnosperm pollen and its phylogenetic implications. In: Kurmann, M. H., Doyle, J. A. Ultrastructure of fossil spores and pollen. The Royal Botanic Gardens Kew.

Richardson, J. B., McGregor, D. C. 1986. Silurian and Devonian spore zones of the Old Red Sandstone Continent and adjacent regions. Geol. Surv. Can. Bull. 364, 1-79.

Streel, M., Higgs, K., Loboziak, S., Riegel, W., Steemans, P. 1987. Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenish region. Rev. Palaeobot. Palynol. 50, 211-229.

Wellman, C. H., Gray, J. 2000. The microfossil record of early land plants. Phil. Trans. R. Soc. Lond. B 355, 717-732.

Wellman, C. H., Osterloff, P. L., Mohiuddin, U. 2003. Fragments of the earliest land plants. Nature 425, 282 -284.

THE EARLY CARBONIFEROUS *SPELEOTRILETES BALTEATUS-PRETIOSUS* COMPLEX: DEFINING THE BASE OF THE PC MIOSPORE BIOZONE

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SUMMARY

The early Carboniferous BP and PC miospore biozonal boundaries are defined on the first appearances of the miospore taxa Speleotriletes balteatus and Speleotriletes pretiosus respectively. The PC biozone boundary is more clearly defined based on new descriptions of these miospores using examples from the Porter's Gate Formation at Hook Head, Co. Wexford, Ireland.

Current PhD research being undertaken by the author consists of a comparative investigation into the early Carboniferous palaeoenvironments of southeast Ireland and south Wales. As part of this research it was necessary to accurately date sedimentary event horizons within the Porter's Gate Formation of Hook Head, Co. Wexford, a key reference section for the early Tournaisian in Ireland. This Formation was previously dated using miospores (Higgs et al, 1988) and conodonts (Johnston & Higgins, 1981). The miospore zonation scheme is the most suitable method of dating for the purposes of this study as the conodont zonation scheme was found to lack the detail required, given that the stratigraphic interval studied falls only within two conodont biozones, namely *Polygnathus spicatus* and *Polygnathus inornatus*.

With the intention of using the miospore zonation scheme, a detailed sampling programme was carried out at three sections of the Porter's Gate Formation, namely Lumsdin's Bay South, Woarwoy Bay North (the type section for the formation) and Woarwoy Bay South. A total of 31 palynological samples were collected and processed.

It is known from previous research (Higgs et al, 1988, for example) that the sequences samples range in age through the BP and PC miospore biozones. The boundaries of these biozones are defined on the first appearances of the miospore taxa *Speleotriletes balteatus* and *Speleotriletes pretiosus* respectively. These miospores, originally described by Playford (1964) from the Mississippian Horton Group in eastern Canada, are morphologically very similar and are mainly identified based on their ornament type, size and shape. *S. balteatus* has smaller ornament, consisting mainly of grana, coni and spinae with occasional small verrucae and mammilae whereas *S. pretiosus* has larger ornament, consisting mainly of mammilae and verrucae with occasional coni, spinae and grana. It has been found that some specimens show an overlap of these ornamental features. This makes it difficult to identify the first appearance of *S. pretiosus* and thus to define the base of the PC biozone.

The high-resolution sampling undertaken allowed for a detailed biometric analysis of a continuous succession of *S.balteatus-S. pretiosus* populations to be carried out in order to determine whether a morphological lineage exists. If such a lineage were to be established it would allow for more accurate differentiation between the two species and as a result, more clearly define the base of the PC miospore biozone. The results of this investigation will be described and discussed.

REFERENCES

Higgs, K., Clayton, G., & Keegan, J., 1988. Stratigraphic and systematic palynology of the

Tournaisian rocks of Ireland. Geol. Surv. Irel. Spec. Pap. 7., 1-93.

Johnston, I., & Higgins, A., 1981. Conodont faunas from the Lower Carboniferous rocks at Hook Head, Co. Wexford. Jour. Earth Sci., Roy. Dub. Soc. 4., 83-96

Playford, G., 1964. Miospores from the Mississippian Horton Group, Eastern Canada. Geol. Surv. Canada Bull. 107

THE DEVONIAN-CARBONIFEROUS BOUNDARY IN EAST GREENLAND REVISITED

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SUMMARY

The D-C boundary is present within a long section of Famennian terrestrial sediments in East Greenland. These sediments give a direct record of climatic changes. The palaeoclimate in this continental interior is controlled by relative insolation. Interpreting this record enables a number of cycles and megacycles to be recognised that can be used to both define Famennian time and correlate with the marine record.

In 2001 at the first CIMP Pollen and Spores meeting in Cork a preliminary account was given of the palynology of the very latest Devonian section in East Greenland. This included the Obrutschew Bjerg Formation which was coincident with the Devonian-Carboniferous boundary. This account was then amplified at the subsequent CIMP meeting in Lille. The importance of the boundary section is that it comes not from just a totally terrestrial environment but one that is sensitive to climate change. Hence, it can be used to directly determine the pattern of climate change below and across the D-C boundary. There was always a limitation originating from the fieldwork as this had been done as part of an intensive field season when some 3 km of section from the early Frasnian to latest Famennian was logged and sampled. As ever, the established biostratigraphic precision was weak within these East Greenland Devonian sections such that the importance of the Obrutschew Berg Formation as being coincident with the D-C boundary was unknown at this time. In addition, the palyniferous section through the Stensiö Bjerg Formation was composited from two sections on two separate mountain tops. This was further complicated by the presence of a post-Carboniferous sequence cutting down unconformably onto the section at different levels. This truncation removing all the overlying Carboniferous sediment apart from the immediate boundary interval.

In 2006 the opportunity arose to revisit the sections in the company of a palaeobotanist (C. Berry) and palaeoichthycologist (H. Blom) in order to make a more focussed study of the D-C boundary section. The original sections on Stensiö Bjerg and Nathorst Bjerg were revisited and relogged and resampled through several key intervals. In addition, a further correlative section was located on Celsius Bjerg, then logged and sampled. Importantly this section has a much longer preserved Carboniferous interval. At this stage the account is preliminary but the following conclusions can be drawn/reiterated.

- The Stensiö Bjerg Formation is equivalent to the Strunian and is coincident with the range of *Retispora lepidophyta*.
- The calcretic soils in the Stensiö Bjerg Group represent times of low insolation when the climate was arid. At times of high insolation the monsoon is more active and brings sustained rainfall into the basin and leads to the development of a perennial deep lake. Therefore the thick calcrete beneath the Obrutschew Bjerg Formation (i.e. the D-C boundary section) represents a time of sustained aridity that at high latitude will be a time of climatic cooling.
- The Stensiö Bjerg Formation contains some 4 megacycles. These are difficult to determine within such a heterolithic formation but are defined by the high frequency ‘precessional’cycles that have the combination of a thick calcrete unit as the arid insolation low coupled with a deep sustained lakes that represents the insolation high.
- The D-C boundary section is, in fact, a composite of two precessional cycles showing the presence of a lake that was sustained through a more arid interval. This section through the double precessional cycle

gives a high resolution palynological record through the D-C boundary.

- The D-C boundary section on Celsius Bjerg, some 30 km to the south, has a more proximal development of the Obrutschew lake. The early Carboniferous sequence on Celsius Bjerg is quite different and characterised by fluvial sandstones.
- In contrast the Britta Dal Formation, which underlies the Stensiö Bjerg Formation, is quite different in being a sequence of 6 megacycles of 120 vertisols cycles. The overall character is one of sustained aridity. Palynologically it is constrained by the GF spores in the upper Elsa Dal Formation (Marshall et al. 1999) and the LL spores at the base of the Stensiö Bjerg Formation. It is correlated to the Montfort Formation in Belgium (Bultynck & Dejonghe, 2001) which is also a time of sustained aridity (Dreesen et al. 1988). The Britta Dal and Stensiö Bjerg Formations can be recognised as representing two stages in the climatic development of the late Famennian. The Britta Dal Formation is a time of sustained aridity with only minor insolation highs. It matches a stratigraphic gap or condensed sequence at high palaeolatitudes (e.g. Loboziak et al. 1997) in the southern hemisphere and marks the time of cooling and the accumulation of ice. The Stensiö Bjerg Formation is climatically different in character with more extreme warming and cooling events. This would be the time of more obvious southern hemisphere glacial and interglacial cycles. It is these interglacials that leave a record of diamictites that contain *R. lepidophyta*. It is known that the the most extensive diamictites terminate at the D-C boundary (Streel et al. 2000; Díaz-Martínez et al. 1999) and are hence equivalent to the insolation high of the Obrutschew lake.

REFERENCES

Bultynck, P. & Dejonghe, L. 2001. Devonian lithostratigraphic units, (Belgium). *Geologica Belgica*, **4**: 39-69.

Díaz-Martínez, E., Vavrdova, M., Bek, J. & Isaacson, P.E. 1999. Late Devonian (Famennian) glaciation in western Gondwana: evidence from the Central Andes. *Abhandlungen der Geologischen Bundesanstalt* **54**: 213-237.

Dreesen, R., Paproth, E. & Thorez, J. 1988. Events documented in Famennian sediments (Ardenne-Rhenish Massif, Late Devonian, NW Europe). *CSPG Memoir* **14** (II), 295-308.

Loboziak, S. Melo, J. H.G., Matsuda, N.S. & Quadros, L.P. 1997. Miospore biostratigraphy of the type Barreirinha Formation (Curuá Group, Upper Devonian) in the Tapajós River area, Amazon Basin, North Brazil. *Bulletin du Centre de Recherches Elf Exploration Production*, **21**, 187-205.

Marshall, J.E.A. Astin, T.R. & Clack, J.A. 1999 The East Greenland tetrapods are Devonian in age. *Geology* **27**: 637-640.

Streel, M., Caputo, M.V., Loboziak, S. & Melo, J.H.G. 2000. Late Frasnian-Famennian climates based on palynomorph analysis and the question of Late Devonian glaciations. *Earth-Science Reviews* **52**: 121-173.

SILURIAN ACRITARCHS OF SOUTHEAST ANATOLIA

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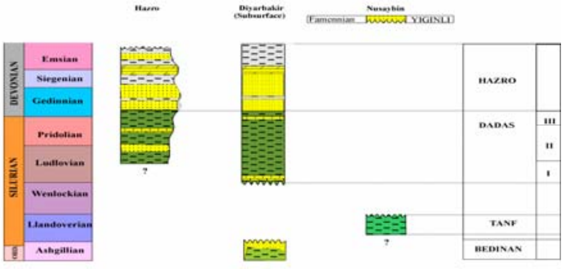
SUMMARY

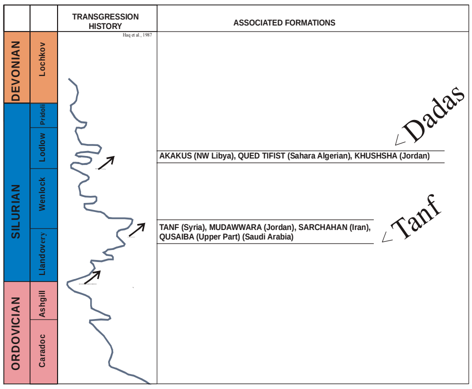
The Silurian acritarchs obtained from 5 well samples from Southeast Anatolia have been studied.

The acritarchs have been determined in 49 species belonging to 36 genera. Most of these species are well compared with other records in the world. The graptolite data also support the age and paleoenvironmental interpretation.



Stratigraphic Relationship of the Ordovician-Silurian-Devonian Formations in SE Anatolia

During the Paleozoic, the southeastern Anatolia region (northern edge of the Arabian Plate) was situated in the southern hemisphere as a part of Gondwana. Following the uppermost Ordovician glaciation, the paleogeography of the southeastern Anatolia region showed great variations during Silurian time. The Lower Silurian deposits are more restricted in the southern part of the region and are recorded in only one well in the Nusaybin area as an extension of the Lower Silurian deposits of Jordan (Tanf Formation). Lower Silurian strata were also palynologically recognized in only one well in the Koruda area in the north of the region and are well correlated by Llandoverian graptolites (Kozlu et al., 2002). Except for the Lower Silurian strata restricted to Koruda, the area is considered to be Early Silurian in age and is viewed as palynologically correlative with the Early Silurian in the Nusaybin area.



Transgression history during Silurian time on the Arabian Plate

The northern parts of the southeastern Anatolia region around the Diyarbakır and Hazro areas were generally sites of sedimentation by the Middle Silurian (Ertu and Bozdoğan, 1997). The Dada Formation was deposited during the Middle Silurian-earliest Devonian time interval which related to the marine transgressions in the north of the region, influenced the Diyarbakır and Hazro areas, but, was controlled by the Siirt uplift in the east at the Siirt area. The input flow direction of the transgressions was from north to south. This marine invasion continued in the same manner and completely regressed during the Middle Devonian.

The Silurian Tanf and Dada formations of southeastern Anatolia consist of shale, limestone, and siliciclastics that yield thermally unaltered, diverse and well-preserved acritarch assemblages.

This study documents the acritarch assemblages from these units and discusses their bio-chronostratigraphic correlations with similar Silurian successions in adjacent areas. Five wells have been studied palynologically, and 49 acritarch species assigned to 36 genera are reported. Morphology and taxonomy of some selected taxa are also discussed (Erkmen and Bozdoğan, 1979; Hill and Dorning, 1984; Le Hérissé A., 1989).

References

Erkmen, U., Bozdoğan, N., 1979. Acritarchs from the Dada Formation in southeast Turkey. Geobios 12, 445-449.

Ertuğ, K. and Bozdoğan, N., 1997, Geological evolution and paleogeography of the SE. Anatolia in the Paleozoic, Proceedings of Early Paleozoic Evolution in NW. Gondwana, TAPG Special Publication, V. 3, p. 39-49.

Hill, P.J., Dorning, K.J., 1984. The Llandovery series in the type area. Appendix 1. *In*: Cocks, L.R.M. et al. (Eds.), The Llandovery series of the type area. Bull. British Museum National History 38, 131-182.

Kozlu, H., Günay, Y., Sachanski, V., 2002. Stratigraphy and graptolite biostratigraphy of the Lower Silurian strata of Southeastern Anatoli and Taurous Belt. TPAO Report No. 4355 (In Turkish).

Le Hérissé, A., 1989. Acritarches et kystes d'alques prasinophycees du Silurien de Gotland, Suède. Palaeontographica Italica 76, 57-302.

MISSISSIPPIAN MICROFLORAS FROM THE SOUTH MUNSTER BASIN, IRELAND

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SUMMARY

A succession of spore assemblages have been recovered from the Mississippian rocks of the South Munster Basin, Ireland. The microfloras are described and correlated with the standard Carboniferous miospore zonation scheme of western Europe.

The Carboniferous (Mississippian) succession of the South Munster Basin comprises a thick (2.5km) succession of shallow to deep marine marine clastic sediments. Lithostratigraphically these rocks are referred to as the Cork Group and have been divided into four formations in the South Cork Sub-basin and into five formations in the West Cork Sub-basin. Biostratigraphically the succession has been dated using miospores, conodonts and goniatites. However, the latter two fossil groups only occur intermittently throughout the succession, whereas miospores are abundant throughout. Detailed palynological studies have recognised a continuous succession of miospore assemblages which can be assigned to the Carboniferous miospore zonation scheme for northwest Europe (Clayton et al 1977). The base of the Kinsale Formation contains the LN/VI miospore biozonal boundary which correlates closely with the base of the Carboniferous system. The Kinsale Formation and overlying Courtmacsherry / Reenydonegan Formations (Members 1-3) have yielded relatively well preserved miospores of early to late Tournaisian age (VI-CM Biozones). Member 4 of the Courtmacsherry Formation contains poorly preserved miospores of early Viséan (Pu-TC Biozones) age. The overlying Lispatrick Formation contains very poorly preserved and low diversity assemblages of mid to late Viséan age (VF - lower NC Biozone). The White Strand Formation of the South Cork Sub-basin and the East Point, Middle Battery and Kilmore Formations of the West Cork Sub-basin contain more diverse and better preserved miospore assemblages that range in age from Serpukhovian to possibly early Bashkirian age (upper NC-SO Biozones). The taxonomic diversity and preservational quality of the miospore is highly variable, particularly from the upper part of the succession. This is due to both the high thermal maturity of the organic material and to the anoxic environment of a starved deep marine basin.

REFERENCE

Clayton, G., Coquel, R., Doubinger, J., Gueinn K.J., Loboziak, S., Owens B, Streel M., 1977. Carboniferous Miospores of Western Europe: illustration and zonation. Meded. Rijks Geol. Dienst 29, 1-71.

KEROGEN STUDIES OF DEVONIAN-CARBONIFEROUS DEPOSITS FROM THE PALAEOZOIC BASEMENT OF THE CARPATHIAN FOREDEEP, POLAND

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SUMMARY

Thirty samples from Devonian-Carboniferous deposits drilled in the Upper Silesia and Małopolska Terranes contain four kerogen types. Palynofacies analysis and Amoco TAI scale were used to determine hydrocarbon potential. Thermal maturity of the organic matter is higher in the deposits of the Małopolska Terrane. The most perspective conditions for hydrocarbon generation occur in the Middle Devonian-Lower Carboniferous carbonate deposits of the Upper Silesia Terrane.

INTRODUCTION

Devonian-Carboniferous deposits occur in two regional tectonic units (terranes) distinguished in the Palaeozic basement of the Carpathian Foreland. These two units: western Upper Silesia Terrane and eastern Małopolska Terrane are separated by Kraków-Lubliniec zone. The composition and colour of the kerogen recovered from the logs drilled in the Upper Silesia and Małopolska terranes was the subject of palynological studies. The aim of these investigations was designation of the hydrocarbon potential on the basis of palynofacial analysis.

MATERIAL AND METHODS

Seventeen samples from six boreholes drilled in the Upper Silesia Terrane (Tab. 1) and thirteen samples from four boreholes drilled in the Małopolska Terrane (Tab. 2) contain the organic matter (kerogen). Most of the samples were collected from the carbonate rocks. Samples were macerated using HCl and HF acids. Cellulosize and elvacite were used as mounting media to allow observations of kerogen in slides both in transmitted and fluorescent light.

The term kerogen is used in this abstract only in palynological sense and means disseminated sedimentary organic matter, which is insoluble in non-oxidizing acids (Batten, 1982). Between the components of the organic matter three main categories have been distinguished (according to Batten, 1996) in examined slides:

- palynomorphs
- structured organic matter (SOM)
- unstructured (amorphous) organic matter (AOM)

The first category refers to all acid-resistant, organic-walled microfossils distinguished in the examined material, such as miospores, acritarchs (including leiospheres), scolecodonts.

The second category refers to all particles that have cellular organisation and clearly defined, non-amorphous outline. The majority of these particles are derived from plants (phytoclasts), while the organic particles of animal origin are zooclasts. In examined slides most of the SOM was phytoclasts, with black (melanogen) and brown wood (hylogen), black phytoclasts (charcoal), cuticles, fungal hyphae.

The third category refers to altered (bacterially, chemically, and/or otherwise) organic debris with no cellular structure preserved. AOM has no clearly defined shape and may occur in masses, sheets, or be finely dispersed. The differences in appearance of AOM is reflected in such terms as fibrous, fluffy, granular, membranous, etc; in the examined material mainly fluffy AOM occurs, subordinately membranous.

The maturation degree of kerogen was determined according to the colour of the palynomorphs, using Amoco Standard Thermal Alternation Index (TAI scale). Five divisions are used in this scale: 1 for yellow palynomorphs, 2 orange, 3 brown, 4 black, and 5 vitreous black. The various intermediate stages are designed by + and – signs; for example, 2- for yellow to light orange, 2+ for dark orange to light brown. Of course, the determination of colour is subjective, so it is very important to make all determinations in repeatable conditions (standard palynological preparation and standard microscope light settings and magnifications).

RESULTS

The occurrence, proportions and the colour of the above mentioned components of the organic matter allow to distinguish a few typical palynofacies in the examined slides. These typical palynofacies have been related to kerogen types according to Tyson (1993), and Amoco Standard Thermal Alternation Index (TAI).

Four typical palynofacies corresponding to kerogen types have been distinguished; in bolded brackets are kerogen types, and degree of thermal maturation given in terms of Amoco TAI scale.

1. Palynofacies dominated by fluffy AOM honey-brown in colour, subordinately occurring spores, phytoclasts are absent. AOM is fluorescing, sometimes strongly – which suggests its origin from algae. This is kerogen type II (oil prone amorphous kerogen).

2. Palynofacies characterized by numerous well- preserved cuticles, with rarely occurring wood fragments and spores. The domination of the phytoclasts indicates kerogen type III (gas prone structured kerogen).

3. Palynofacies containing both phytoclasts and dispersed fluffy and/or granular AOM. This is mixed kerogen (oil and gas prone kerogen).

4. Palynofacies containing only/mainly black wood fragments (melanogen), showing no fluorescence. This is kerogen type IV – unproductive (overmature organic matter).

Palynofacies analysis indicates that most perspective conditions for hydrocarbon generation occur in the boreholes drilled in the Upper Silesia Terrane, where the thermal maturity is not so high as in the Małopolska Terrane.

The stratigraphy of some gas and oil prone Devonian and Lower Carboniferous samples from study area, kerogen features and palynomorph TAI index are shown in tables, separate for Upper Silesia Terrane (Tab. 1) and Małopolska terrane (Tab. 2).

REFERENCES

Amoco Standard Thermal Alternation Index (TAI); modified by D. Engelhardt, G. Wood, G. Baker, GETS.

Batten, D. J., 1982. Palynofacies, palaeoenvironments and petroleum. Journal of Micropalaeontology, 1, 1: 107-114.

Batten, D.J., 1996. Palynofacies and palaeoenvironmental interpretation; in: Jansonius, J.,

McGregor, D.C. (ed.), Palynology: principles and applications. 3, 1011-1064.

Tyson, R.V., 1993. Palynofacies analysis; in: Jenkins, D.G. (ed.), Applied Micropaleontology, 153-191.

Borehole	Depth interval	Stratigraphy	Kerogen type /TAI
	UPPER SILESIA	**TERRANE**	
Lachowice 4	3811.4m 3819.7m	Early Visean spore zone Pu	gas prone structured TAI 4+, 5
Lachowice 4	3939.7m	Eifelian, spore zone *velata-langii*	oil prone amorphous TAI 4, 4+
Lachowice 3 a	3849.1m	Upper Carboniferous (Arnsbergian) spore zone TK	gas prone structured TAI 4, 4+
Lachowice 3 a	3874.8m	?	oil prone amorphous
Lachowice 3 a	3876.4m	Middle Eifelian-Early Givetian, spore zone devonicus-naumowii	oil & gas prone (mixed kerogen) TAI 3
Lachowice 3 a	3881.6m	?	oil prone amorphous
Lachowice 2	3819.55m	Early Eifelian	oil prone amorphous TAI 3
Lachowice 2	3837-3840m		gas prone structured TAI 3+, 4
Roczyny 3	1142-1151m, VII	Late Visean (Brigantian) spore zone VF	gas prone structured TAI 3
Roczyny 3	1190-1199m	?	oil prone amorphous
Roczyny 3	1243-1253m, VIII	Lower Carboniferous?	oil & gas prone (mixed kerogen) TAI 3+, 4
Roczyny 3	1357-1366m, III	Givetian, spore subzone *A.extensa*	TAI 3+, 4
Tarnawa 1	4623-4642m	Visean (Asbian?) undivided spore zones TC and NM	
Tarnawa 1	5158-5166m, III	Late Famenian? probably spore zone PL	TAI 4, 4+
Tarnawa 1	5449-5457m, IV	?	oil & gas prone (mixed kerogen)
Rajbrot 2	2678-2687m	Late Tournisian spore zone CM?	gas prone structured TAI 3
Rajbrot 2	3119-3122m 3182-3188m	Tournaisian spore zone PC	oil & gas prone TAI 3, 3+
Rajbrot 1	3283-3289m	Tournaisian spore zone PC	oil prone amorphous
Rajbrot 1	4129.6m	Famenian spore zone Cva	TAI 3+, 4

Table 1 – stratigraphy and hydrocrabon potential of Devonian-Carboniferous deposits from the selected boreholes drilled in the Upper Silesia Terrane

Borehole	Depth interval	Stratigraphy	Kerogen type TAI
	MAŁOPOLSKA	**TERRANE**	
Łowczów 2	3468-3477m, IV, 70cm	Visean?	TAI 4, 4+
Łowczów 2	3713.2m 3841-3847m, V, 50cm 3914.7m ?	Late Tournaisian (Ivorian/Chadian boundary) zone CM	TAI 3+, 4
Rajsko 3	1893.5m	Late Tournaisian spore zone Ma	TAI 4, 4+
Rajsko 3	1606.2m	Latest Tournaisian spore zone Cl	TAI 3+, 4
Strzelce Wielkie 1	1954-1988m	Late Visean (Brigantian) spore zone VF	gas prone structured
Strzelce Wielkie 1	3677.2m	Early Eifelian	
Strzelce Wielkie 1	3714.6m	Late Emsian	
Okulice 2	1570.0m	Upper Carboniferous (Arnsbergian) spore zone TK	TAI 3+, 4
Okulice 2	1740.45m	?	oil prone amorphous TAI 3
Okulice 2	1845.05m	Late Visean (Asbian) spore zone NM	TAI 4, 4+
Okulice 2	1853.6m	Middle Devonian?	oil prone amorphous TAI 4, 4+

Table 2 – stratigraphy and hydrocrabon potential of Devonian-Carboniferous deposits from the selected boreholes drilled in the Małopolska Terrane

POST-GLACIAL REBOUND UNCONFORMITY WITHIN THE BAQ'A MEMBER OF THE SARAH FORMATION (ASHGILL): SEQUENCE STRATIGRAPHIC IMPLICATIONS AT THE ORDOVICIAN-SILURIAN BOUNDARY IN SAUDI ARABIA

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SUMMARY

The Hawban and Baq’a members of the Sarah Formation represent the culmination of Late Ordovician glaciation in Saudi Arabia. The Hawban contains stratigraphically admixed palynomorphs in a poorly sorted, boulder-bearing diamictite. The Baq’a consists of leiosphere-bearing, pale gray silty shale with less reworking and an upper sandstone unit. No sedimentological evidence for glaciation is present in the Baq’a Member. The Baq’a sandstones of fluvial or estuarine origin are thought to have developed in response to post glacial isostatic rebound.

The recently redefined Hawban and overlying Baq’a Members of the Sarah Formation were re-examined at outcrop and in the shallow subsurface at several locations in Saudi Arabia. The Hawban Member comprises a chaotic, syn-sedimentary deformed, interval of green-gray, very poorly sorted sandy diamictites supporting large boulder-sized contorted clasts of sandstone derived from the underlying Sarah Formation. Palynologically, it is characterized by a stratigraphically admixed assemblage comprising taxa reworked from older Ordovician sediments, as well as indigenous Ashgill marine species. Thus, Hawban deposition occurred in a glaciomarine setting at the end of Gondwanan glaciation.

The overlying Baq’a Member consists of two units. The lower of these is a pale gray silty shale that passes upwards into fine-grained hummocky-stratified and wave-rippled sandstones. Palynologically, this gray shale is

characterized by marine taxa dominated by leiospheres, with only rare reworked assemblages. It has variable thickness and infills topographic lows in a post-glacial, shallow marine environment upon the post-Hawban surface. This shale unit is overlain by a Baq'a sandstone unit that comprises stacked, cross-bedded sandstones with numerous sharp, erosional basal bed contacts, of probable braided-fluvial or estuarine origin. The uppermost beds of this facies become more argillaceous and are intensely bioturbated, suggesting the onset of marine conditions. The basal contact of this Baq'a sandstone is demonstrably unconformable across both the Baq'a shale and the Hawban Member. The Baq'a sandstone is considered to have developed in response to post-glacial isostatic rebound (uplift) of underlying units. Stratigraphically, there is clearly a hiatus between it and the older units. It is proposed that the Baq'a sandstone represents the basal unit of a major new stratigraphic sequence that may ultimately extend into the Qusaiba.

PALYNOSTRATIGRAPHY AND PALAEOGEOGRAPHY OF THE GORGAN SCHISTS IN SOUTHERN GORGAN CITY (SOUTHEASTERN CASPIAN SEA), EASTERN ALBORZ RANGE, NORTHERN IRAN

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SUMMARY

The low-grade metamorphic rocks of the Gorgan Schists form high Mountains in the area to the southeast of the Caspian Sea. The Radkan study area is located, approximately 25 km to the south of Kordkuy city where the Gorgan Schist is well exposed. The Gorgan Schist is a green schist facies (prehnite-pumpellyite with temperatures 250°C). These low-grade metamorphic rocks have been considered Precambrian in age. The writer sampled a traverse in the Radkan area, in order to verify the exact age and palaeogeographic position of this part of Iran. All samples contain abundant acritarchs and chitinozoans as well as scolecodonts. In this study, 55 palynomorph taxa were recovered, consisting of 30 acritarch species assigned to 20 genera, and 25 chitinozoan species assigned to 15 genera. Based on the presence of well-known chitinozoan and acritarch species, a Late Ordovician (Caradoc-Ashgill) is assigned to the Gorgan Schists in the study area. The encountered chitinozoan species are assigned to the *Belonechitina robusta, Armoricochitina nigerica, Ancyrochitina merga, Tanuchitina elongate and Spinachitina oulebsiri* chitinozoan biozones which have been established for the North Gondwanan Domain. These chitinozoan biozones clarify affiliation of the southeastern Caspian Sea to the Gondwanan palaeo-provinces.

The low-grade metamorphic rocks of the Gorgan Schists form high mountains in the area to the southeast of the Caspian Sea. These mountains are covered by dense forests on their northern flanks, whereas the southern flanks have sparse tree coverage. Therefore, geological observations are difficult on the northern flanks. The Radkan study area where the Gorgan Schists are well exposed, locating approximately 25 km southern Kordkuy. The Gorgan Schists cover an area approximately 110-125 km long and 2-10 km wide, and extends from Gorgan to Behshahr and Aliabad.

In general, the metamorphic rocks of Iran have not been properly studied and there is very little data available regarding the age of their protoliths as well as the metamorphic age. The metamorphic rocks consist mainly of phyllites, sericite-chlorite-schists, and quartzite. These low-grade metamorphic rocks have been considered Precambrian in age. However, the Gorgan Schists have been a puzzle and mystery in geology of Iran since the early days of its reporting (see references of 1-4 and 7-11).

The Gorgan Schists are unconformably overlain by the nonmetamorphic and fossiliferous Jurassic limestone of the Lar Formation, but its lower contact is not clear because of the Radkan fault. The apparent thickness of the Gorgan Schist (considering folding and trusting) varies from place to place and ranges from 1800 to 2445 m. The author measured and sampled a traverse of the Gorgan Schists, in the Radkan area, in order to verify the exact age and palaeogeographic position of this part of Iran. One hundred ninety three surface samples were collected throughout the entire thickness of the Gorgan Schists. All samples contain abundant acritarchs and chitinozoans as well as scolecodonts. In this study, 55 palynomorph taxa were recovered, consisting of 30 acritarch species assigned to 20 genera, and 25 chitinozoan species assigned to 15 genera.

The identified acritarch taxa are geographically widespread and support the cosmopolitan nature of acritarch assemblages during the time interval representing by Gorgan Schists. Numerous diagnostic chitinozoans, including *Belonechitina robusta*, Armoricochitina *nigerica*, *Armoricochitina iranica*, *Ancyrochitina merga*, *Spinachitina bulmani*, *Hercochitina spinetum*, *Spinachitina oulebsiri*, *Tanuchitina elongata*, *Desmochitina minor*, *Plectochitina sylvanica*, and *Caplpichitina lenticularis* are present. -Therefore, based on the presence of well-known chitinozoan and acritarch species, a Late Ordovician (Caradoc-Ashgill) is assigned to the Gorgan Schists in the Radkan area. Thus, there is a major hiatus between the Gorgan Schists and the non-metamorphic, fossiliferous limestones of the Lar Formation? encompassing the Late Paleozoic and Triassic strata.

This study marks for the first time chitinozoans and acritarchs from the Gorgan Schists. The encountered chitinozoan species are assigned to the *Belonechitina robusta, Armoricochitina nigerica*, *Ancyrochitina merga*, *Tanuchitina elongate* and *Spinachitina oulebsiri* chitinozoan biozones which have been established for the North Gondwanan Domain (see references of 5-6). Based on these chitinozoan biozones, the northeastern Alborz Mountain Range (southeastern Caspian Sea) has been part of the Gondwanan supercontinent during the Late Ordovician.

REFERENCES:

1-Afshar-harb, A., 1979. The stratigraphy, tectonic and petroleum geology of Kopet-Dagh region, northern Iran. Ph.D. thesis. Petrolium Geology Section of Royal School of Mine, Imperial College London, 315p.

2-Delaloye, M.., Jenny, J. and Stampfli, G., 1981. K-Ar dating in the eastern Elburz (Iran): Tectoniphysics, v.79, p.T27-T36.

3-Gansser, A., 1951. Geological reconnaissance in the Gorgan and surrounding areas. Unpublished Geological Report no. 18 of National Iranian Oil Company.

4-Hubber, H., 1957.Geological report on the south Gorgan Mountain front between Neka and Shahpasand: National Iranian Oil Company, unpublished internal geological Report, no. 164,39p.

5-Paris, F., 1990.The Ordovician biozones of the North Gondwana Domain. Rev.Paleobot. Palynol.66, 181-209.

6-Paris., Bourahrouh,A. and Herissé,A.L,(2000a)The effects of the final stages of the Late Ordovician Glaciation on the marine palynomorph(Chitinozoans, Acritarchs and Playford, G. Leiospheres) in well NI-2(NE.Algerian).Rev.Palaeobot.Palynol. 11:87-104.

7-Salehi-Rad, M. R., 1979.Etude Geologique de la région de Gorgan (Alborz Oriental, Iran): Ph.D. thesis, Universities de Paris Sud, 162p.

8-Stahl, A. F., 1911.Handbuck der regionalen geologie – Persian: V Band 8, Hildelberg.

9-Stampfli, G., 1978.Etude géologique general de l Elburz oriental au S de Gonbad-e-Qabus, NE Iran. Thesis no.1868, 328p Univerite de Geneva.

10-Stöcklin, J., 1971.Statigraphic Lexicon of Iran (Part I). Rep.Geol.Surv.Iran, 18:1-337.

11-Tietze, E., 1877.Ein Ausflug nach dem Siahkuh (Schwarzer Berg) in Persien.Mitt.geogr. Ges.Wien.[N.F.]18/8,pp.257-267.

ICHNOSPHAERA FLEXUOSA - COMASPHAERIDIUM MOLLICULUM A NEW ACRITARCH ZONE FROM THE LOWER CAMBRIAN BIOTURBATED SANDSTONES OF THE SILESIAN-CRACOW AREA, POLAND

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SUMMARY

New Lower Cambrian acritarch assemblages from the Lower Cambrian bioturbated sandstones were described. They are morphologically distinctive, taxonomically diverse and limited to one type of Lower Cambrian sediments. Therefore, the recognition of the new acritarch zone: Ichnosphaera flexuosa-Comasphaeridium molliculum is suggested. In the investigated area new zone corresponds to the Schmidtielus mickwitzi and lower part of the Holmia zone.

The paper presents characteristic acritarch associations from the Lower Cambrian bioturbated sandstones of the Głogoczów Member recognized in the Upper Silesian Block (USB). The stability of their occurrence allows recognition of a new acritarch zone in the Lower Cambrian sediments in the studied area.

In southern Poland, two regional tectonic units are considered as blocks – the Upper Silesian Block and the Małopolska Block. These are separated by the Kraków-Lubliniec tectonic zone, and thus represent separate crustal units (Buła et. al., 1997; Buła, 2000; Buła and Żaba, 2005).

The Upper Silesian Block and the Brno Block to the south form a larger unit – Brunovistulicum. It represents a tectonic unit of Cadonian consolidation and it is built of plutonic, metamorphic, and anchimetamorphic lithologies (Dudek, 1980; Buła et al., 1997; Buła and Żaba, 2005). The Cadomian basement is overlain by stratigraphic complexes of different ages.

The Paleozoic lithologies of Variscian and Caledonian structural stages are overlain by a hermetic cover of younger deposits and they have been recognized on the basis on numerous drillings. The Upper Silesian Coal Basin o Hercynian stages is the best defined geological unit of the Upper Silesian region. Because of its economic importance, this unit has been intensively studied during the past 60 years. The development of an Early Palaeozoic sediment cover in the USB is still an open problem. According to the present interpretation, the Lower Palaeozoic sediments of the USB consist mainly of Cambrian deposits. The Lower Cambrian clastic sediments disconformably overlie a Cadonian basement and continue into the Middle Cambrian and Ordovician in the northern part of the block. According Buła, 2000, four lithostratigraphical units are distinguished within the Lower Palaeozoic section. In ascending stratigraphic order, these are: the Borzęta Formation (Lower Cambrian, Sub-Holmia Zone), Goczałkowice Formation (Lower Cambrian, Holmia Zone), Sosnowiec Formation (Middle Cambrian), Bibiela Formation (Ordovician). Owing to litholigic and facies variations, the Lower Cambrian lithostratigraphical units are subdivided into members (Mb).

The typical profile of the oldest lithostratigraphical unit – the Borzęta Formation comes from the Borzęta IG 1 borehole.Its sediments form a three-unit regressive sequence which consists of claystones and siltstones that grade upwards into sandy mudstones (the Myślenice Claystones Mb., Osieczany Siltstones Mb., and Rajbrot Sandstones Mb.). The sediments of the Borzęta Formation were documented only in the marginal eastern part of the USB.

The Goczałkowice Formation was established by Kotas (1982) while investigating Lower Cambrian lithologies in the Goczałkowice IG1 borehole. A three-unit transgressive sequence is evidenced by gradational changes in lithology of sediments. Its particular parts have been distinguished as members and have been named (from bottom to top): the Mogilany Scolithos Sandstones (Mb.), Głogoczów Bioturbated Sandstones (Mb.), Pszczyna Siltstones with Trilobites (Mb.).

The equivalents of the individual units of the Goczałkowice Formation have been reported in several boreholes located to the east of Goczałkowice, as far as the Borzęta area and northwest of Kraków. The stratigraphy of these rocks is based first of all on acritarchs. The trilobite fauna (*Holmia* Zone) was documented only in the upper part of the Lower Cambrian profile in the Goczałkowice IG 1 borehole (Orłowski, 1975).

In the Silesian region, Cambrian acritachs have been documented in single boreholes during the 1970s (Turnau, 1974; Kowalczewski et al., 1984; Brochwicz-Lewiński et al., 1986; Moczydłowska, 1993). The age interpretations of documented acritarch associations have changed several times. Different Cambrian time periods were suggested, which caused different geological interpretations in the area studied (Kowalczewski et al., 1984; Kowalczewski, 1990; Moczydłowska, 1997, Moczydłowska, 1998).

Detail palynological investigations have been carried out by this author, aimed at working out the stratigraphy of the Cambrian sediments in the USB (Buła and Jachowicz, 1996; Buła et al., 1997; Jachowicz, 1994; Jachowicz, 2005). During the course of these studies, rich and taxonomically diversified microflora assemblages were documented. Acritarchs from the Głogoczów Bioturbated Sandstones (Mb.) were documented in eight boreholes. Thickness of the investigated profiles are variously estimated from 15 m to 111m. The Głogoczów Bioturbated Sandstones (Mb.) consist of alternating layers of light-grey, grey-green quartz sandstones, and grey and grey-green sandy siltstones, and the sediments are generally heavily bioturbated. Abundant and varied trace fossil assemblages have been documented in these rocks. According to Pacześna (2005), these ichnocoenoses were typical for open, shallow shelf environment. The frequent depositional structures left by waves and storms are present. Characteristic trace fossils for this environment are: *Bergaueria, Diplocraterion*, *Scolitos lineraris*, *Monoceration tentaculatum* and *Planolites beverleyensis*.

Determinable microfloras have been found in samples from the bioturbated sandstones. The investigated samples contained rich and very well preserved acritarch populations which are dominated by the characteristic new genus *Ichnosphaera* (sometimes as much as 60% of the assemblage). This new genus and its associated new species, which are abundant in the Lower Cambrian profile, will be formally defined by the author in a work in preparation. Species described as *Skiagia ornata* type 1 (Moczydłowska and Vidal 1986), *Baltisphaeridium stipaticum* (Hagenfeldt 1989), and *Elektoriskos flexuosus* (Eklund 1990; Brück and Vanguestaine 2004) will be transferred to the new taxon – *Ichnosphaera*. The age of the described acritarchs are considered to be early Early Cambrian by various authors (Moczydłowska and Vidal, 1986; Hagenfeldt, 1989; Eklund, 1990; Brück and Vanguestaine, 2004). In the studied area they were documented only in the Głogoczów Bioturbated Sandstones (Mb.). Accordimg to Moczydłowska and Vidal (1992), these forms are unknown in the East European Platform (Volkova et. al., 1983; Moczydłowska and Vidal, 1991) but are very common among acritarchs from the *Mickwitzia* Sandstone in central Sweden, and the "Green shales" in Bornholm (Moczydłowska and Vidal, 1986).

The acritarchs assigned to *Ichnosphaera* are associated with abundant representatives of following genera and species: *Comasphaeridium molliculum*, *Asteridium lanatum*, *Asteridium tornatum*, *Lophosphaeridium dubium*, *Tasmanites bobrovskae*, *Archeodiscina* sp., and *Leiosphaeridia* sp.

The Głogoczów Bioturbated Sandstones (Mb.) is overlain by the Pszczyna Siltstones with Trilobites (Mb.) which is assigned on the basis of macrofossils to the *Holmia* Zone (Orłowski, 1974). The Mogilany Scolithos Sandstones (Mb.), which underlie the investigated rocks do not contain macrofossils. In a similar Cambrian profile documented in the Brno area (Czech Republic) acritarch assemblages assigned to the *Asteridium tornatum-Comasphaeridium velvetum* acritarch zone were recognized (Vavrdova et al., 2003). According to these data, it is necessary to interpret the age of investigated acritarch associations as embracing zones from the *Platysolenites antiquissimus*, to the *Holmia kjerulfi*.

The acritarchs recovered from the bioturbated sandstone deposits are morphologically distinctive and taxonomically diverse. In the Upper Silesia, this characteristic acritarch flora is limited to one type of Lower Cambrian sediment. Therefore, the recognition of a new acritarch zone is suggested. The *Ichnosphaera flexuosa-Comasphaeridium molliculum* Zone is evident throughout the entire Brunovistulicum area. In the Brno area, comparable microflora associations were described from the same type of Cambrian sediments by Vavrdová (Vavrdová et al., 2003).

Presently, recognition of the *Ichnosphaera flexuosa-Comasphaeridium molliculum* assemblage zone corresponds to the *Schmidtielus mickwitzi* and lower part of the *Holmia* zone in the Upper Silesian Block.

REFERENCES

Brochwicz-Lewiński, W., Vidal G., Pożaryski W., Tomczyk H., Zając, R., 1986. Posision tectonique du massif de Haute-Silesie avant le Permian à la luminere de données nouvelles sur la Cambrian de cette region. Comptes Rendus de l'Academie des Sciences de Paris. 303, Serie II, no.16, 1493-1496.

Buła Z., 2000. Dolny paleozoik Górnego Śląska i zachodniej Małopolski. Prace PIG. (English summary) 171, 1-63.

Buła Z., Jachowicz M., 1996. The Lower Paleozoic sediments in the Upper Silesian Block. Geol. Quart. 40, 299-336.

Buła Z., Jachowicz M., Żaba J., 1997. Principal characteristics of the Upper Silesian Block and Małopolska Block border zone (southern Poland). Geol. Mag. 133, 669-677.

Buła Z., Żaba J., 2005. Pozycja tektoniczna Górnośląskiego Zagłębia Węglowego na tle prekambryjskiego i dolnopaleozoicznego podłoża. Przewodnik 76 Zjazdu PTG, 14-42.

Brück, P.M, Vanguestaine, M., 2004. Acritarchs from the Lower Palaeozoic succession on the south County Wexford coast, Irleand: new age constrains for the Cullenstown Formation and the cahore and Ribband Groups. Geol. J. 39, 199-224.

Dudek A. 1980. The crystalline basement block of the Outher Carpathians in Moravia: Bruno-Vistulicum. Rozpravy Československé Akademie Věd, Řada matematyckých a přírodních Věd 90, 1-85.

Eklund, C., 1990. Lower Cambrian acritarch stratigraphy of the Bårstad 2 core, Östregötland, Sweden. Geol. Fören. Stockholm Förh. 112, 19-40.

Hagenfeld, S., 1989. Lower Cambrian acritarchs from the Baltic Depression and south-central Sweden, taxonomy and biostratigraphy. Stockholm Contr. Geol. 41, 1-176.

Jachowicz, M., 1994. Occurrence of the microfossils belonging to Acritarcha in the older Palaeozoic of the NW border of the Upper Silesia Caol Basin (SW Poland). (English summary). Prz. Geol. 42, 631-637.

Jachowicz, M. 2005. Ordowickie akritarchy bloku górnośląskiego. (English summary). Prz. Geol. 53, 756-762.

Kotas, A., 1982. Profil utworów kambru w otworze Goczałkowice IG1. Przewodnik 54 Zjazdu PTG, 193-201.

Kowalczewski Z., 1990. Grubookruchowe skały kambru na środkowym południu Polski (litostratygrafia, tektonika, paleogeografia).(English summary) Prace PIG 131, 1-82.

Kowalczewski, Z., Kuleta, M., Moczydłowska M., 1984. Uwagi o stratygrafii i tektonice skał kambryjskich nawierconych w podłożu Górnośląskiego Zagłębia Węglowego w otworze Goczałkowice IG 1, Sosnowiec IG1, Potrójna IG 1. Geol. Quart. 28, 450-451.

Moczydłowska, M.,1993. Is there caledonian deformation in the TESZ (Trans European Suture Zone) of the Upper Silesian, southern Poland? Publ.Inst.Geoph.Pol.Acad.Sc. A-20, 255, 119-122.

Moczydłowska, M., 1997. Proterozoic and Cambrian successions in the upper Silesia: an Avalonian terrane in southern Poland. Geol. Mag. 134, 679-689.

Moczydłowska, M., 1998. Cambrian acritarchs from the Upper Silesia, Poland – biochronology and tectonic implications. Fossils and Strata 46, 1-121.

Moczydłowska, M., Vidal, G., 1986. Lower Cambrian acritarch zonation in southern Scandinavia and south-eastern Poland. Geol. Fören. Stockholm Förh. 108, 201-23.

Moczydłowska, M., Vidal, G., 1992. Phytoplankton from the Lower Cambrian Læså Formation on Bornholm, Denmark: biostratigraphy and palaeoenvironmental constrains. Geol. Mag. 129, 17-40.

Orłowski , S., Lower Cambrian Trilobites from Upper Silesia (Goczałkowice Borehole). Acta Geol. Pol.. 25, 377-83.

Pacześna, J., 2005. Środowiska sedymentacji dolnokambryjskich osadów bloku górnośląskiego. *Przewodnik 76 Zjazdu PTG,* 90-98.

Turnau, E., 1974. Microflora from core samples of Palaeozoic sediments from beneath the Flysch Carpathians (Bielsko-Wadowice area, Southern Poland). Rocz.Pol.Tow.Geol. 19, 1-63.

Vavrdová, M., Mikuláš, R., Nehyba, S. 2003. Lower Cambrian siliciclastic sediments in the southern Moravia (Czech Republic) and their paleogeographical constraintts. Geol. Carpathica 54, 67-79.

Volkova, N.A., Kirjanov, V.V., Piscun, L.V., Paškevičienié, L.T., Jankauskas, T.V., 1983. Plant Microfossils. *In*: Urbanek, A. and Rozanov, A.Yu, (Eds.), Upper Precambrian and Cambrian palaeontology of the East-European Platform, 7-46. Wydawnictwa Geologiczne, Warszawa.

VEGETATION HISTORY OF THE MANGROVE IN BÉNIN DURING THE HOLOCENE : A PALYNOLOGICAL STUDY

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SUMMARY

The mangrove is a halophitic vegetation, characteristic of coasts, deltas and lagoons of tropical areas, which are especially adapted to the tide. Presently the mangrove in Bénin occurs only in the central and western parts of the coastal area while the eastern part is

occupied by fresh water swamp forests with typical especies such as *Raphia* and swampy savannas. The dynamics of the mangrove during the Quaternary attracted many studies in Western Africa, especially in Côte d'Ivoire (FREDOUX, 1994), Nigeria (SOWUNMI, 2004) and Senegal (LEZINE, 1996). In Bénin, many works related to the mangrove vegetation were concerned with its present structure and the factors that caused its degradation (PARADIS, 1980; AKOÈGNINOU *et al.*, 1997). The only study which focused on the history of the mangrove in Bénin is that of PARADIS (1976b).

The present article sums up the palynological study of three core samples taken in Benin's coastal strip within the framework of the "Dahomey-Gap" project. The major aim of this project is to contribute to an elucidation of the vegetation history of the mangrove during the last 10,000 years.

MATERIAL AND METHODS

The sites studied are located in the coastal zone (figure 1) as defined by ADJANOHOUN (1968). The climate is a subequatorial type with four seasons, two dry and two rainy seasons.

The vegetation consists of grasses and coastal thickets, meadows, mangrove, fresh water swamp forests, dense semi-deciduous forests and Guinean savannas (AKOÈGNINOU, 1984).

The samples were collected using a Livingstone modified piston corer, at the sites located in Yevié areas, north lake Nokoué; Goho, alongside the lagoon of Porto-Novo, and Dogla-Alago in the lower valley of the Ouémé river, the geographic coordinates of which are respectively, 6°32'06''N, 2° 22'42''E; 6°26'35''N, 2°34'45''E and 6°36'25''N, 2°35'43''E (figure 1).

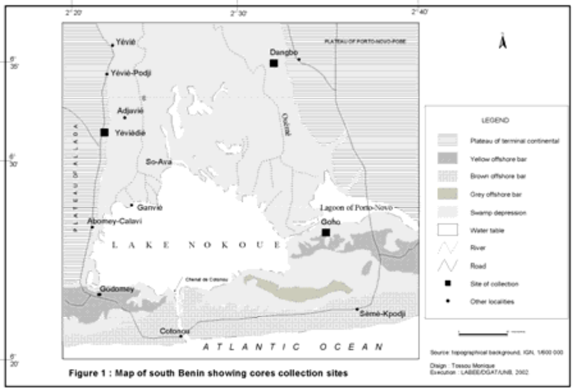

Figure 1 : Map of south Benin showing cores collection sites

In total, 212 sub-samples analysed. The pollen count was done with an Olympic® optical microscope using 200x, 400x, and 1000x magnifications.

RESULTS AND DISCUSSIONS

The pollen diagrams of the three cores show that mangrove existed around Lake Nokoué, the lagoon of Porto-Novo and in the lower valley of the Ouémé river in the middle Holocene (7500 years BP to 2500 years BP). Its abundance is clear from all of these diagrams where *Rhizophora* pollen reach values from 80 to 95% during that period. It was well developed, very dense and almost monospecific/generic because the other taxa of the mangrove such as *Avicennia* and *Acrostichum* rarely appear. The low incidence of these latter two shows that they would have occupied low areas behind the *Rhizophora* population. The pollen of other mangrove species such as *Laguncularia racemosa* (L.) Gaertn. f. and *Conocarpus erectus* L. have not been differentiated from the pollen grains of other Combretaceae. They probably existed in almost the same amounts as *Avicennia*.

These results of pollen analysis reveal an important geographic extension of mangrove with *Rhizophora* extending oven the whole of the coast of Bénin during the middle Holocene. That episode coincides with the later mangrove extension in western Africa. This took place during the Nouackchottian transgression that reached its maximum towards 5500 years BP (SOWUNMI, 1981a ; LEZINE, 1986).

In the late Holocene (towards 2500 years BP) this mangrove disappeared totally but the reduction would have started even earlier from 3000 years BP as SOWUNMI (1986) and TOSSOU (2002) noted.

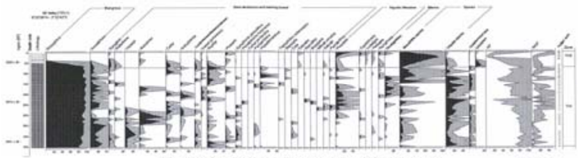

Figure 3 : Pollen diagram for YEV-I core

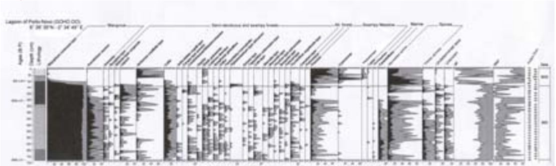

Figure 4 : Pollen diagram for GOHO.OO core

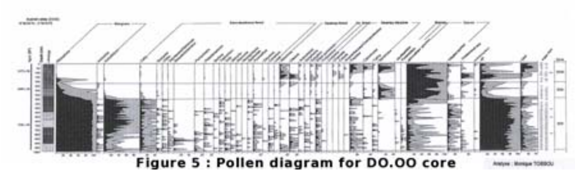

Figure 5 : Pollen diagram for DO.OO core

ABSTRACT

Pollen analysis of three core samples YEV-I, GOHO.00 and DO.00, taken in the coastal area of Bénin shows the existence of mangrove during the Holocene. This mangrove underwent a lot of physiognomic changes from the middle to the late Holocene. In the course of the middle Holocene (from 7500 years BP to 2500 years BP), it stretched over a large area from the littoral inland. It was tightly closed and almost monospecific, dominated by *Rhizophora*. During the late Holocene, this mangrove started to regress around 3000 years BP and disappeared about 2500 years BP in the studied sites. It has been replaced by swamp meadows dominated by *Paspalum vaginatum* Sw. and a fresh water environment colonised by taxa such as *Persicaria*, *Typha*, *Ludwigia*, and *Nymphaea*.

REFERENCES

Adjanohoun E., 1968**.** Le Dahomey. *Acta Phytogeogr Suec*. 54: 86-91.

Akoègninou A., 1984. Contribution à l'étude botanique des îlots de forêt dense humide semi décidue en République populaire du Bénin. Thèse de 3ème cycle. Univ. de Bordeaux III. 250 p.

Akoègninou A., Oyédé L.M., Toffi D.M., 1997. La mangrove au Bénin: environnement physique, végétation et essais de gestion. In *Mangrove Ecosystem studies in Latin*

Frédoux A., 1994. Pollen analysis of deep-sea core in the Gulf of Guinea: vegetation and climatic changes during the last 225,000 years BP. *Palaeogeography*, *Palaeoclimatology*,

Palaeoecology, 109: 317-330.

Lézine A.-M., 1986. Environnement et paléoenvironnement des Niayes depuis 12000 ans BP. Symposium « Changements globaux en Afrique » *INQUA* Dakar: 261-267.

Lézine A.-M., 1996. La mangrove ouest-africaine, signal des variations du niveau marin et des conditions régionales du climat au cours de la dernière déglaciation. *Bull. Soc. Géol.*

Paradis G., 1976b. Recherche sur le Quaternaire récent du sud de la République Populaire du Bénin: étude de thanocénoses de mollusques. Thèse de 3ème cycle de Paléontologie. Orsay. 173 p.

Paradis G., 1980. Un cas particulier de zones dénudées dans les mangroves d'Afrique de l'Ouest: celles dues à l'extraction de sel. *Bull. Mus. Nat. Hist. Nat. 4ème série 2.*

Sowunmi M. A., 1981a. Aspects of Late Quaternary vegetational changes in West-Africa. *Journal of Biogeography*, 8: 457-474.

Sowunmi M. A., 2004. Aspects f Nigerian coastal vegetation in the Holocene: some recents insignts. In : *Past climate variability through Europe and Africa*. Vol. 6, R.W.

Tossou M. G., 2002. Recherche palynologique sur la végétation holocène du Sud-Bénin (Afrique de l'Ouest). Thèse de l'Université de Lomé. 136 p.

PALYNOLOGY OF TERRESTRIAL LANDSCAPES IN THE LOWER PALEOZOIC

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SUMMARY

Tracheophytes did not evolve until the middle Silurian, yet, for decades, the search for small upright axes, preserved as carbonaceous or coalified compressions, has been the modus operandi of paleobotanists concerned with plant origins. Recent discoveries of presumed protonematal fragments add to a growing list of morphological characters that support a bryophyte origin to numerous microfossils from Cambrian through Ordovician palynological assemblages. These assemblages, from siliciclastic sequences marginal to the paleocontinent, Laurentia, contain cryptospores in addition to spore masses and cuticles, which indicate that an extensive bryophyte-grade flora occupied the surface of land during the early Paleozoic. Extant plant phylogenies all place the bryophytes basally within the Embryophyta, essentially occupying an evolutionary position between the algae and the tracheophytes. The fossil record complements this scheme, with bryophyte-related fossils occupying the stratigraphic record from late Early Cambrian through middle Silurian time. Palynology provides us with our best opportunity to sample this early terrestrial landscape.

The oldest plant spores come from the Rome Formation in eastern Tennessee, US. They are small alete spores in units of two to four cells, and may be enclosed within membranes. In the overlying Rogersville Shale (Middle

Cambrian) a wide variety of monads, dyads, paired dyads, tetrads and more-or-less irregular arrangements of polyads have been found. Some of these forms show a laminated spore-wall ultrastructure that is indistinguishable from modern liverworts (work of Wilson A. Taylor, University of Wisconsin - Eau Claire). None of these earliest topologies results in perfectly tetrahedral tetrads, so the cryptospore precursors that led to the trilete spore condition are not known until the lower Middle Ordovician. However, the somewhat irregular nature of the early cryptospore morphologies does not exclude them from the bryophytes. Most bryophyte spores today are not trilete. The double dyad condition is quite interesting. They are produced when cell wall formation in the developing sporocytic tetrad occurs serially, rather than simultaneously. Cell walls begin to form immediately after the first meiotic cytokinesis; the second cell plate forms later, resulting in a "tetrad" of two dyads which may be only loosely attached. The dyad condition persisted in the early land plant record well into the earliest Devonian. It is characteristic of some rhyniophytoid mesofossils, such as *Fusitheca fanningae*, which is somewhat enigmatic, since these plants appear to be evolutionary derived from the bryophytes (their sporophytes bifurcate, a morphological feature that had been thought to represent a tracheophyte synapomorphy). Dyads and tetrads found in the Upper Cambrian Lone Rock Formation in central Wisconsin, are morphologically similar to those found in the (~ Darriwilian of Saudi Arabia). This provides a link between the extensive Middle Cambrian Laurentian assemblages and the earliest Ordovician ones from the Arabian Plate. The second half of the Ordovician appears to be a time of evolutionary stasis, although, this may be an artifact of undersampling. The Silurian record of cryptospores shows trends in diversity and the development of sculpture, some of which matches the developing sculptural types seen in the earliest trilete spores, such a proximal radial striae and distal vermiculae.

Mesofossil fragments found in Middle and Upper Cambrian strata include wefts of filaments, some of which retain oblique cross walls - a feature long held to be unique to the protonemata of liverworts and rhizoids and protonemata of mosses. These fossils appear to be the remains of a persistent caulonematal phase of the protonema stage in gametophytes of bryophytes. Taphonomic studies on modern bryophytes support this idea that the filamentous stages in bryophytes might be resistant to decay and survive the rigors of fossilization. Spore masses with coverings (sporangial cuticles?) have also been recovered from palynological preparations from Middle and Upper Cambrian deposits in Tennessee. These fall into three categories: amorphous, ribbed and reticulate. This later form is a close match to later "pseudo-cellular" cuticles that are well known from the Silurian. Taken as a whole, these tissues appear to be of bryophyte, rather than algal, affinity.

The recovery of bryophyte remains, from Cambrian through Silurian strata lends, support to the idea that the earliest Paleozoic landscape was populated by plants at a bryophytic grade of evolution which had advanced beyond that of subaerial microbial mat communities. This conclusion may affect the way in which models of early ecosystems are constructed. For example, it is possible that the trophic links in the Cambrian, between marine and terrestrial realms, may be far more extensive than previously thought. Perhaps the so-called, "Cambrian Explosion," was fueled by the prior evolution of plants on land - certainly the marine ecosystems of today rely heavily on nutrients (N, P) flushed from estuaries and terrestrial runoff into the shallow shelf. This early terrestrial record also supports a notion of evolutionary addition to the landscape. The microbial world never went away, it was not destroyed by the evolution of plants. Rather, complex, multicellular photosynthesizers were added to a preexisting microbial landscape. This microbial/bryophyte complex was later eclipsed by root-bearing tracheophytes during the Devonian. This later evolution of tracheophytes may have pushed the bryophytes to a subdominant position in terrestrial ecosystems, but it did not cause their overall extinction.

A LATE FAMMENIAN AGE STORM-DOMINATED SUCCESSION AT BERROCAL (IBERIAN PYRITE BELT – SPAIN)

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SUMMARY

The Berrocal area is situated in the northern limb of Valverde del Camino anticlinal in the Spanish sector of the Iberian Pyrite Belt and exposes the upper part of the Phyllite-Quartzite Group. Recent studies on palynostratigraphy and sedimentology of the Berrocal section indicates that the stratigraphic succession is late Famennian age (VH miospore biozone) and was accumulated on the offshore zone of a siliciclastic shelf dominated by storm events.

INTRODUCTION

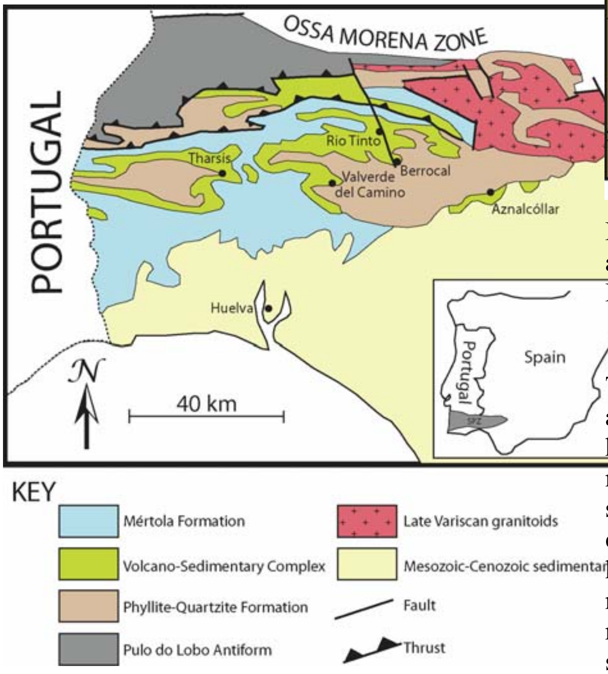

Fig. 1 Geological sketch map of the Berrocal section, Iberian Pyrite Bekt, Spain (Adapt. Oliveira et al., 1990).

The Berrocal area is located in the northern limb of Valverde del Camino anticlinal (Fig. 1) that belongs to Spanish sector of the Iberian Pyrite Belt (IPB), one of the richest and most prolific volcanic-hosted massive sulphide metallogenic provinces in the world. The IPB makes part of the South Portuguese Zone, a SW branch of the European Hercynian Orogen. The stratigraphic column of the IPB is characterized by an extremely reduced geologic record, from late Devonian to Carboniferous, and is commonly divided into three major units (Oliveira, 1990): the Phyllite Quartzite (PQ) Group, comprising the IPB´s basal detritic formation (Upper Devonian); the Volcano Sedimentary Complex, an assemblage of alternating felsic and mafic volcanic rocks within a detritic sedimentary sequence, hosting massive sulphide deposits (Late Famennian to mid Late Viséan), and the Upper Carboniferous Baixo Alentejo Flysch Group (mid Late Visean to Bashkirian).

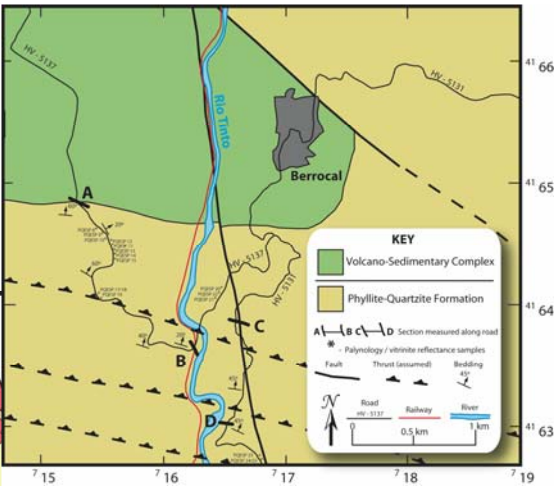

Fig. 2 Sample location and studied sections, along the HV-5137 and HV - 5131 roads in Berrocal region

The PQ group commonly lies in the core of anticlines (such as Valverde del Camino) and has been described as more than 1000m-thick monotonous sequence of shales and sandstones, deposited in epicontinental sea environment (Oliveira, 1990). The homogeneous feature of the sequence changes near the top by the increase of the sand/lutite ratio and appearance of sedimentary facies such as fan-deltas, near-shore bars, mega-debris flows and some limestone lenses, suggesting a collapse and fragmentation of the stable continental platform (Moreno et al., 1996).

The core of the Valverde del Camino anticline represents the largest exposed area of the PQ rocks throughout all IPB, which was folded and thrusted during Variscan Orogeny according to thin-skinned tectonics (Silva, 1990). The Berrocal section along the road cuts HV-5137 and HV-5131 is one of the rare places where the top succession of the local PQ sequence is well exposed. The upper PQ levels are characterized by the occurrence of intercalations of shales with sandstones. In this area the PQ rocks are conformably overlain by a thick sequence of basic rocks of the Volcano Sedimentary Complex.

SEDIMENTARY FACIES AND ENVIRONMENTAL INTERPRETATION

The stratigraphic information presented here resulted from the detailed logging of road-cuts exposed along roads HV-5137 and HV-5131 (Fig. 2). The sedimentary succession of the PQ group at Berrocal (Fig. 3) is composite with a measured thickness of *ca.* 980 m. The upper part of this succession is 695 m thick and is well exposed along road HV-5137 between points A and B (Fig. 2), whereas the bottom part of the succession, corresponding to a thickness of 275 m, is exposed along road HV-5131 between points C and D. Breaks in the sedimentary succession are frequent, especially in the part between points C and D due to intense faulting and folding. The 150 m break, observed in the upper part of the succession, starting at the depth of 416 m, corresponds to a section of the road with no outcrop, possibly due to intense tectonism.

Four principal lithofacies were recognised: Shale, Siltstone, Quartzite and Greywacke Lithofacies. The Shale Lithofacies consists of grey to black siliceous shales exhibiting parallel laminae and are interbedded with mostly nongraded, laminated grey siltitic beds with an average thickness of 1 – 2 cm. The fine grade and the parallel lamination displayed throughout this lithofacies suggest deposition from suspension in the offshore part (bellow storm wave base) of an epicontinental sea. The Siltstone Lithofacies occurs essentially in the lower part of section outcropping in road HV-5137. It consists of centimetric (1-2 cm thick) beds of nongraded silt interbedded with parallel laminae of mud.

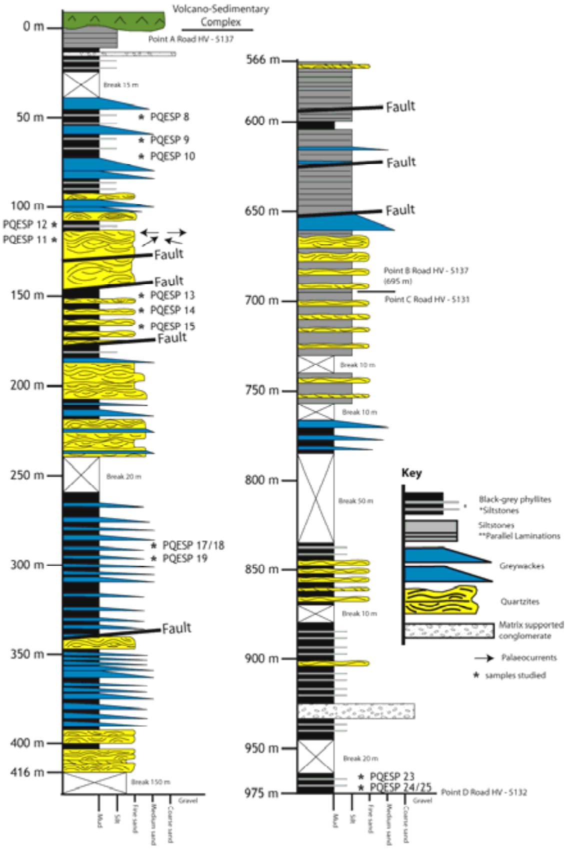

Fig. 3 Stratigraphic log of Berrocal section, with position of positive palynostratigraphic samples.

Particularly important in the Berrocal stratigraphic succession is the Quartzite Lithofacies. This lithofacies occurs throughout the succession either as single beds or as tabular bodies, with several metres thick, formed by tens to hundreds of amalgamated beds. The thickness of the quartzite beds ranges from 3 cm to 20 cm, having an average of 10 cm. This lithofacies is composed of very fine to medium sand grade. The main internal sedimentary structure exhibited by the quartzite beds is hummocky cross stratification (HCS) (figure 4). Wave ripple cross stratification (WCS) is a very rare feature in these beds and suggest that deposition occurred essentially bellow fairweather wave base. Palaeocurrents measured from WCS of 30 beds, in the interval between 120 – 135 m, indicate direction of sediment transport from E, SE, SW and W. Amalgamated quartzite beds are the dominant lithofacies in several parts of the succession (e.g. between 110 and 145 m) and are considered to represent frequent episodes of storm deposition above storm-wave base (DOTT & BOURGEOIS, 1982), typically on the lower shoreface or offshore transition zone, close to the fairweather wave base. The single beds of quartzite with HCS, which occur throughout the section, reflect the alternation of slow fairweather mud/silt deposition with storm-emplaced sands on a siliciclastic shelf between the fairweather and storm-wave bases (Dott and Bourgeois, 1982; Walker and Plint, 1992).

The Greywacke Lithofacies consists of parallel beds of sand-sized clasts, mostly quartz, and a clay-sized matrix. Bed thicknesses range from 10 cm to up 1 m, averaging about 30 cm. The beds are usually normal graded and in the ones with well-developed sedimentary structures, these are comparable to the Bouma sequence. The range of sedimentary structures described above is typical of deposition by turbidity currents. Two beds consisting of matrix-supported conglomerates, located towards the top and base of the section, were also observed, although due to its minor distribution were not described as a new lithofacies. The internal sedimentary structures suggest that they are mass flows deposited, possibly, during periods of tectonic instability.

Figure. 4 Hummocky cross stratification in several quartzite beds. Quartzite lithofacies, approximately 125 m depth.

Sediments represented in the Berrocal stratigraphic succession accumulated, generally, on the offshore zone of siliciclastic shelf below the fairweather wave base dominated by storm events. The amalgamated quartzite beds with HCS represent the shallower sediments, possible deposited by frequent storm events on the lower shoreface zone. Conversely, the greywacke beds are considered to be the sediments that accumulated in deeper waters. Intervals of the succession with quartzite beds showing HCS interbedded with siltstone and/or mudrock beds are considered to be sediments that accumulated on the offshore zone between fairweather and storm wave bases.

PALYNOSTRATIGRAPHY

The palynostratigraphic study is based on 21 rock samples collected along the road HV-5137 (Figure 1). Standard palynological laboratory procedures were employed in the extraction and concentration of the palynomorphs (Wood et al., 1996). The slides were examined with transmitted light, with a BX40 Olympus microscope equipped with an Olympus C5050 digital camera. All samples, residues and slides are stored in the Geological Survey of Portugal/INETI, S. Mamede Infesta, Portugal. The spore biozonal scheme used follows the standard Western Europe Miospore Zonation (Higgs et al., 1988; Higgs et al., 2000 and Maziane et al., 2002).

The dark shales of the PQ in the Berrocal section, along the road cut studied HV-5137, revealed moderately to well preserved miospore assemblages assigned to the VH Biozone of late Famennian age. The assemblages include *Grandispora echinata* that indicates the base of the biozone, together with *Ancyrospora sp*, *Apiculiretusispora* sp., *Auroraspora macra*, *Cristicavatispora dispersa*, *Diducites versabilis*, *D. poljessicus*, *Emphanisporites annulatus*, *Grandispora cornuta, G. famenensis*, *G. gracilis*, *Plicatispora* sp., *Punctatisporites* spp., *Retusotriletes planus*, *R. triangulatus*, *R. rugulatus*, *Rugospora explicata, R. radiata* and *Teichertospora iberica.* Rare acritarchs, prasinophytes and chitinozoans are present. Miospore tetrads are also very frequent. Palynomorph assemblages recovered are poorly sorted and larger taxa frequently occurs broken, suggesting torrential events, which substantiates the depositional environment.

The miospore assemblages recovered in shales interbedded in Quartzite Lithofacies, samples 18 and 24/25, respectively at *ca.* 280 and 970 m depth (Fig. 3), show some correspondence, marked by the presence of common miospore tetrads and chitinozoans in the assemblage. This palynostratigraphic evidence may suggest that this part of the stratigraphic sequence is tectonically repeated.

Comparison of the Berrocal section with palynostratigraphic records acquired from the South Portuguese Zone (Gonzalez, 2005; Oliveira et al., 2004; 2005; 2006; Pereira et al., 2006) indicates a number of similarities:

- PQ Formation in Berrocal Section is dated miospore biozone VH of Late Famennian age, with characteristic assemblages that contains a number of taxa, only documented in the SPZ (e g. *Cristicavatispora dispersa, Rugospora explicata* and *Teichertospora iberica*). These taxa are also common presence at the late Famennian assemblages of the Phyllite Quartzite Group in Portugal (Neves Corvo mine) and in Spain (Jarama River and Rio Tinto old Railway) in the Horta da Torre, Santa Iria and Represa Fms of the Pulo do Lobo Domain.

- miospore biozone VH of Late Famennian age was also recovered in the Volcano Sedimentary Complex of the Pyrite Belt in Portugal.

CONCLUSIONS

The following conclusions were reached from this study:

- PQ Formation in the Berrocal section is late Famennian age based on palynomorphs.
- The Berrocal stratigraphic succession accumulated, generally, on the offshore zone of siliciclastic shelf below the fairweather wave base dominated by storm events.
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ACKNOWLEDGEMENTS

This work was sponsored by the project POCI/CTE-GIN/56450/2004 (PYBE) and POCI/CTE-GEX/60278/2004 (PROVENANCE) of Fundação para a Ciência e Tecnologia, Portugal.

REFERENCES

Dott, Bourgeois, 1982. Hummocky cross stratification: significance of its variable bedding sequences. *Geological Society of América Bulletin*, 93, pp. 663-680.

Gonzalez, F., 2005. *Las pizarras negras del límiteDevónico/carbonífero de la Faja Pirítica Ibérica (S.O. de España). Estúdio bioestratigráfico e implicaciones sobre la paleogeografía de la cuenca y el origen de las mineralizaciones de sulfuros.* Tesis Doctoral. Facultad de Ciencias Experimentales, Departamento de Geologia, Área de Estratigrafia, Universidad de Huelva, 200pp.

Higgs, K., Clayton, G., Keegan, B.J., 1988. Stratigraphic and systematic palynology of the Tournaisian rocks of Ireland. Geol. Surv. Irel. Spec. Pap. **7**, pp. 1-93.

Higgs, K., Avkhimovitch, V.I., Loboziak, S., Maziane-serraj, N., Streel, M., 2000. Systematic study and stratigraphic correlation of the Grandispora *complex in the FAmennian of northwest and eastern Europe.* Review of Palaeobotany and Palynology*, 118, pp. 211-226.*

Maziane, N., Higgs, K.T. & Streel, M., 2002. Biometry and paleoenvironment of Retispora lepidophyta *(Kedo) Playford 1976 and associated miospores in the latest Famennian nearshore marine facies, eastern Ardenne (Belgium).* Review of Palaeobotany and Palynology*, 118, pp. 211-226.*

Moreno, C., Sierra, S., Sáez, R., 1996. Catastrophism evidence in the Famennian-Dinantian limit of the Iberian Pyrite Belt. *In*: *European Dinantian environments.* Strogen, P., Sommerville, I.D., Jones, G.L. (Eds.) *Geol Soc London Spec* 107, p. 153-162

Oliveira, J.T. (1990) - Stratigraphy and syn-sedimentary tectonism in the South Portuguese Zone. *In*: *Pre-Mesozoic Geology of Iberia*. Dallmeyer, R. D., Martinez Garcia, E. (Eds.). Springer Verlag. pp. 334-347.

Oliveira, J.T., Relvas, J., Pereira, Z., Matos, J., Rosa, C., Rosa; D., Munhá, J.M, Jorge, R., Pinto, A., 2006. O Complexo Vulcano-Sedimentar da Faixa Piritosa: estratigrafia, vulcanismo, mineralizações associadas e evolução tectono-estratigráfica no contexto da Zona Sul Portuguesa. *In*: *Geologia de Portugal no contexto da Ibéria.* Dias, R., Araújo, A., Terrinha, P., Kullberg, J.C. (Eds). Univ. Évora, Évora, pp. 207-243.

Oliveira, J.T., Pereira Z., Carvalho P., Pacheco N., Korn D. 2004. Stratigraphy of the tectonically imbricated lithological succession of the Neves-Corvo mine region, Iberian Pyrite Belt. Implications for the regional basin dynamics. *Min. Deposita* 34, pp. 422-436.

Oliveira, J.T., Pereira, Z., Rosa, C., Rosa, D., Matos, J. (2005) - Recent advances in the study of the stratigraphy and the magmatism of the Iberian Pyrite Belt, Portugal. *In*: *The southern Variscan belt.* Carosi, R., Dias, R., Iacopini, D., Rosenbaum, G., (Eds.,)., Journal of the Virtual Explorer, Electronic Edition, 19, 9, pp. 1441-8142.

Pereira, Z., Fernandes, P., Oliveira, J.T. (2006) - Palinoestratigrafia do Domínio Pulo do Lobo, Zona Sul Portuguesa. Resumos alargados. *Em*: *VII Congresso Nacional de Geologia*. Mirão, J., Balbino, A. (Eds.), Vol 2, pp. 649-652.

Silva J.B., Oliveira J.T. & Ribeiro A. (1990) - South Portuguese Zone. Structural outline. In: Dallmeyer R.D, Martinez Garcia E (eds)

Pre-Mesozoic geology of Iberia. Springer-Verlag, Berlin Heidelberg New York, pp. 348-362.

WALKER, PLINT, 1992. Wave and storm-dominated shallow marine systems. In: Facies Models: Response to Sea Level Change. Walker, R. G & James, N. P. (Eds.), pp. 219-238. Geological Association of Canada, St. Johns, Newfoundland.

WOOD, G.D., GABRIEL, A.M., LAWSON, J.C., 1996. Palynological techniques-processing and microscopy. *In*: *Palynology: Principles and applications.* Jansonius J., McGregor D.C, (Eds.), Am. Assoc. Strat. Palynol. Found, Vol **1**, pp. 29-50.

THE EFFECTS OF HEAT ON THE ISOTOPIC SIGNATURES OF *TASMANITES*

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The effects of heat on organic material were empirically investigated under controlled laboratory conditions. Sub-samples of a ‘tasmanite’ oil shale of earliest Permian age from the Quamby Formation, Latrobe, Northern Tasmania were furnace heated in an inert gas (Ar) at 230ºC ± 8ºC for durations of 1 - 3 weeks. The rock is dominantly composed of large specimens of the prasynophyte *Tasmanites* sp. These were carefully separated from the matrix without the use of any chemical treatment. The size and concentration of *Tasmanites* allowed stable isotope analysis of a single kerogen type, unlike previous studies which have been undertaken on bulk organic material with potentially mixed isotopic signatures. The colour change of the *Tasmanites* in response to heating was also dertermined.

Samples were analysed for 15N/14N and 13C/12C on a Thermo Delta^{plus} Continuous Flow Isotope Ratio Mass Spectrometer (CF-IRMS). In order to obtain sufficient nitrogen for reliable results, 200 specimens were used for each analysis. Preliminary results indicate that stable nitrogen isotope ratios do not change with heating ($\delta^{15}N$ = 12.41‰). A small but progressive positive shift occurs in stable carbon isotope ratios from $\delta^{13}C_{org}$ = -11.01‰ for unheated *Tasmanites* to -10.28‰ for *Tasmanites* heated for 3 weeks. These results suggest that considerable caution must be exercised when comparing $\delta^{13}C_{org}$ values from rocks of different organic maturity.

The colour of the *Tasmanites* changed rapidly during heating, suggesting that heating time is a relatively insignificant factor in the geological maturation of organic matter compared with peak temperature.

ACRITARCHS – THE SOLUTION FOR EDIACARAN BIOSTRATIGRAPHY?

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SUMMARY

This paper provides new insights into the potential of organic-walled microfossils (acritarchs) as tools in biostratigraphic correlation. Ediacaran age acritarchs studied from drillcores in South Australia are well preserved, taxonomically rich and stratigraphically constrained, and can be used for stratigraphic subdivision. Taxonomic similarities between Australia and other palaeocontinents show that intercontinental correlation is possible.

INTRODUCTION

The fossil record stretching some three billion years before the Cambrian is patchy, but shows that many of the major evolutionary innovations such as multicellularity, sexual reproduction, tissue formation, and adaptations to a variety of environments (benthic, pelagic, hot springs, high salinity, etc.), had occurred early in life history. The fossil record of the earliest prokaryotes is debated (e.g., Schopf, 1993; Brasier et al., 2002) but that of eukaryotic protists is better understood, although by no means well established. A limited diversity of protists and problematic biota, including e.g., *Grypania*, is present between 2.5 and 1.5 Ga. Rock successions between 1.5 Ga and 750 Ma in age include more complex fossils such as *Chuaria* and *Tawuia* as well as the possible red algae *Bangiomorpha* (see Knoll et al., 2006 for a review of Proterozoic eukaryotes). However, it is not until the Ediacaran that organisms of undoubtedly metazoan affinities appear (e.g., Narbonne, 2005). On the other hand, despite the irregular distribution of the fossil record, organic-walled microfossils of unknown affinities, referred to as acritarchs, are recorded throughout Meso- and Neoproterozoic rock successions from all over the world.

The Neoproterozoic was a time of major environmental change. At least two, possibly three, and even four global glaciations have been suggested to cover the entire Earth with thick ice during the Cryogenian Period (e.g., Hoffman et al., 1998). Following the last glaciation, the Marinoan glaciation, greenhouse conditions prevailed during the Ediacaran and caused major shifts in ocean geochemistry, oceanic stratification and oxygenation, and evolution of the marine biosphere (Kirschvink, 1992; Canfield, 1998; Shields et al., 1998; Grey, 2005; Fike et al., 2006; Canfield et al., 2007). It was during the Ediacaran that the first major diversification of organic-walled acritarchs occurred. This diversification is preserved in rock successions worldwide, including Siberia, China, Baltica, India and, especially, in the Centralian Superbasin in Australia. Grey et al. (2003) noted that the first appearance of acanthomorphic (ornamented) acritarchs in samples from drillcores in the Officer and Amadeus Basins and the Adelaide Rift Complex, occurred stratigraphically above a bolide ejecta layer, the result of a large impact some 580 Ma years ago (the Acraman impact; Walter et al., 2000). Geochemical analyses of the sediments surrounding the ejecta layer shows a striking negative excursion in carbon isotope fractionation that was followed by a steady rise of values coinciding with the transition from the pre-Acraman to post-Acraman intervals. Consequently, Grey et al. (2003) argued that the impact could have provided a link to the subsequent diversification of acritarchs.

Dating of the Neoproterozoic is problematic and anything that can aid in the correlation of Ediacaran successions is especially sought after. Ediacaran acritarchs are stratigraphically restricted, have complex morphologies, and some also occurred globally. This suggests that they can be used for biostratigraphic analysis and correlation because other fossils are too scarce, too geographically restricted, or too difficult to interpret.

GEOLOGICAL SETTING AND PALAEOENVIRONMENT

The Officer Basin in South Australia is an intracratonic basin that extends some 1400 km in an east-west trend across Western and South Australia. Stratigraphic correlation of the Officer Basin has been based mainly on seismic, magnetic, and gravity studies but was recently reviewed by Grey (2005). The succession studied here (and in Grey, 2005) is the largely siliciclastic lower Ungoolya Group which, in ascending stratigraphic order, consists of the Dey Dey Mudstone, the Karlaya Limestone, and the Tanana Formation. The Dey Dey Mudstone is divided into two units separated by a bed of dolomitic intraclasts; the lower unit is mainly red-brown and occasionally green-grey silty mudstone that was deposited in a fluvial environment and the upper unit is a laminated dolomitic or calcareous siltstone and mudstone deposited in slightly deeper, prodelta and shelf environments (Zang, 1995; Morton, 1997). The Karlaya Limestone consists mainly of thin-bedded micritic limestone with dark grey silty mudstone layers and some limestone intraclasts, deposited on a subtidal shelf, probably below fair-weather wave base (Zang, 1995). The Tanana Formation overlies the Karlaya Limestone and consists of micritic limestone with silty mudstone interbeds deposited in a prodelta and distal delta front to shelf settings (Morton, 1997)

Microfossils were derived from unevenly sampled intervals in the Giles 1, Murnaroo 1, Lake Maurice West 1, WWD 1, Observatory Hill 1, and Munta 1 drillcores. Samples were selected from lithologies that are suitable for palynological preservation (i.e., unoxidized mudstones, shales, and carbonaceous rocks) and collected from both sides of the Acraman impact ejecta layer. The microfossils are permanently fixed in strew mounts and were observed under transmitted light, and documented using a digital camera.

RESULTS AND CONCLUSIONS

The results of micropalaeontological studies reported herein provide further evidence for the acritarch diversification that was so typical for parts of the Ediacaran. Many of the acritarch taxa are stratigraphically constrained and the patterns observed in various drillholes match the patterns first reported by Grey (2005). The new palynological record further supports and enhances the subdivision and stratigraphic correlation of the Ediacaran System in Australia and potentially on a more interregional scale. Acritarchs are well-preserved and diverse, change over short stratigraphic intervals, and allow the recognition of the previously established zones by use of certain acanthomorphic species. The presence of common species and taxonomic similarities between entire assemblages from Australia, Siberia, Baltica and South China provide a means for global correlation of the Ediacaran System using palynology. Portions of the Ediacaran System can be confidently proved to be coeval by the occurrence of discrete species distributed across various palaeocontinents and ranging stratigraphically no longer than a few million years.

Organic-walled microfossils from Ediacaran successions in Australia are morphologically diverse and taxonomically rich and the diversity may suggest that the acritarchs possible represent several different types of organisms, such as green algae, stem-group dinoflagellates, fungi or even egg-cases.

REFERENCES

Brasier, M.D., Green, O.R., Jephcoat, A.P., Kleppe, A.K., Van Kranendonk, M.J., Lindsay, J.F., Steele, A., Grassineau, N.V., 2005. Questioning the evidence for Earth's oldest fossils. Nature 416, 76-81.

Canfield, D.E., 1998. A new model for Proterozoic ocean chemistry. Nature 396, 450-453.

Canfield, D.E., Poulton, S.W., Narbonne, G.M., 2007. Late-Neoproterozoic deep-ocean oxygenation and the rise of animal life. Science 315, 92-95.

Fike, D.A., Grotzinger, J.P., Pratt, L.M., Summons, R.E., 2006. Oxidation of the Ediacaran Ocean. Nature 444, 744-747.

Grey, K., 2005. Ediacaran Palynology of Australia. Australasian Association of Palaeontologists Memoir 31, 1-439.

Grey, K., Walter, M.R., Calver C.R., 2003. Neoproterozoic biotic diversification: Snowball Earth or aftermath of the Acraman impact? Geology 31, 459-462.

Hoffman, P.F., Kaufman, A.J., Halverson, G.P., Schrag, D.P., 1998. A Neoproterozoic Snowball Earth. Science 281, 1342-1346.

Kirschvink, J.L., 1992. Late Proterozoic low-latitude global-glaciation: the Snowball Earth. *In*: Achopf, J.W., Klein, C. (Eds.), The Proterozoic biosphere. Cambridge University Press, 51-52.

Knoll, A.H., Javaux, E.J., Hewitt, D., Cohen, P., 2006. Eukaryotic organisms in Proterozoic oceans. Philosophical Transactions of the Royal Society B 361, 1023-1038.

Morton, J.G.G., 1997. Chapter 6: Lithostratigraphy and environments of deposition. *In*: Morton, J.G.G., Drexel, J.F. (Eds.), Petroleum Geology of South Australia, Vol. 3: Officer Basin. South Australia, Department of Mines and Energy Resources Report Book 19, 47-86.

Narbonne, G.M., 2005. The Ediacara biota: Neoproterozoic origin of animals and their ecosystems. Annual Review of Earth and Planetary Sciences 33, 421-442.

Schopf, J.W., 1993. Microfossils of the Early Archean Apex chert: new evidence of the antiquity of life. Science 260, 640-646.

Shields, G.A., Stille, P., Brasier, M.D., Atudorei, V., 1998. Ocean stratification and oxygenation of the Late Precambrian environment: a post-glacial geochemical record from a Neoproterozoic section in W. Mongolia. Terra Nova 9, 218-222.

Walter, M.R., Veevers, J.J., Calver, C.R., Gorjan, P., Hill, A.C., 2000. Dating the 840–544 Ma Neoproterozoic interval by isotopes of strontium, carbon, and sulfur in seawater, and some interpretative models. Precambrian Research 100, 371-433.

Willman, S., Moczydłowska, M., Grey, K., 2006. Neoproterozoic (Ediacaran) diversification of acritarchs – A new record from the Murnaroo 1 drillcore, eastern Officer Basin, Australia. Review of Palaeobotany and Palynology 139, 17-39.

Zang, W-L., 1995b. Neoproterozoic depositional sequences and tectonics, eastern Officer Basin, South Australia. South Australia. Department of Mines and Energy. Report Book, 1-21.

THE PALYNOLOGY OF THE SYDNEY COALFIELD, CAPE BRETON, CANADA

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SUMMARY

The Sydney Coalfield is a fault-bounded area of mainly late Westphalian coal-bearing strata lying in the eastern part of the Cape Breton Island, Canada. The present report proposes a Cantabrian age from the assemblage (BD 87 section) below Lloyd Cove Seams.

The Sydney Coalfield is a fault-bounded area of mainly late Westphalian coal-bearing strata lying in the eastern part of the Cape Breton Island, Canada.

The Carboniferous succession is referred to the Morien Group, which is divided into three formations: the South Bar Formation; the Waddens Cove Formation; and the Sydney Mines Formation.

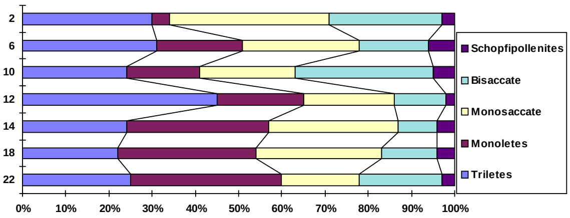
The first palynological reports on Pennsylvanian spores of Nova Scotia are those of Grace Somers in 1952. Graham Dolby (unpubl., 1988, 1989) reported for the palynology of the Morien Group, Sydney Basin, Cape Breton Island, Nova Scotia and also presents detailed correlation between the sections.

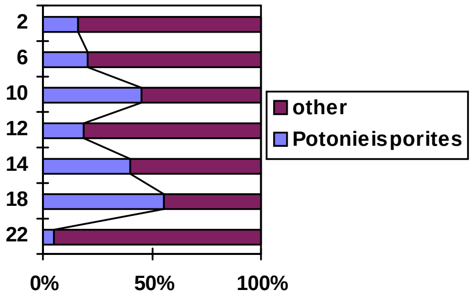
This present report summarises the biostratigraphical significance of the fossil spores and pollen from some of the coal seams in the Sydney Coalfield sequence, based partly on a re-assessment of the palynological preparations made by Dolby. An additional five samples from the Sydney Mines Formation were prepared from hand-specimens in the palaeontological collection of E. Zodrow.

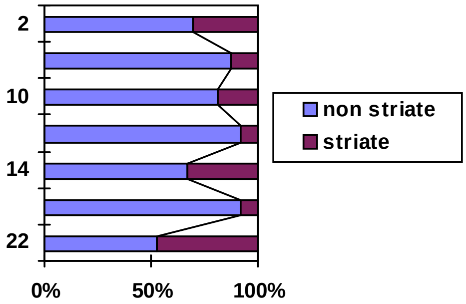
The microflora from Zodrow Sample 1 (991295) is dominated by monosaccate pollen (15-30 %) and bisaccate pollen. Notable is the appearance here of *Columinisporites ovalis*.

The stratigraphical range for the palynoflora found in the Sydney Mines Formation is proposed based on selected taxa (preparations made by Dolby, section 87) such as Thymospora spp., Schopfites spp., Vestispora laevigata, Vestispora pseudoreticulata, Spackmanites facierugosus, Spinosporites spp., Columinisporites ovalis . The genus Schopfites is locally rare in the Backpit seam, the genus Columinisporites first appears between the Point Aconi and the Lloyd Cove seams. Proportions in the miospore assemblage are show on the next figure.

SYDNEY MINES FORMATION BD 87- NOVA SCOTIA, CANADA







The samples were between the Point Aconi and the Lloyd Cove Seams give the most significant evidence of change in vegetational composition between pollen and spores (sample 12) and between Monosaccate and Bisaccate pollen grains (sample 22, striate and non striate pollen).

The Asturian (Westphalian D) species of the Sydney Coalfield were reviewed by Zodrow & Cleal (1985), Zodrow (1986) and Cleal & Zodrow (1989). Dolby considered the oldest part of the sequence in Sydney 82-1 to be probably no older than Duckmantian in age. The highest productive sample in the Grace Bay, H-1A borehole is no younger than Stephanian. The present report proposes a Cantabrian age from the assemblage (BD 87 section) below Lloyd Cove Seams.

REFERENCES

Cleal C. J.& Zodrow, E. L. 1989. Epidermal structure of some medullosan *Neuropteris* foliage from the middle and upper

Carboniferous of Canada and Germany. *Palaeontology*, **32**, 837-882.

Dolby G., 1988: The palynology of the Morien Group, Sydney Basin, Cape Breton Island, Nova Scotia. Nova Scotia Department of Mines and Energy, Open File Report 88-061, 30 p.

Dolby G., 1989: The palynology of the Morien Group, Sydney Basin, Cape Breton Island, Nova Scotia. Nova Scotia Department of Mines and Energy, Open File Report 88-061, 32 p.

Zodrow, E. L.1986. Succession of paleobotanical events: evidence for mid-Westphalian D floral changes, Morien Group (Late Pennsylvanian, Nova Scotia). *Review of Palaeobotany and Palynology*, **47**, 293-326

Zodrow, E. L. & Cleal, C. J. 1985. Phyto- and chronostratigraphical correlations between the late Pennsylvanian Morien Group (Sydney, Nova Scotia) and the Silesian Pennant Measures (south Wales). *Canadian Journal of Earth Sciences*, **22**, 1465-1473.

REVISION OF THE PALAEOBOTANICAL AND PALYNOLOGICAL INTERPRETATION OF THE LATE CARBONIFEROUS INTERVAL OF THE DE LUTTE-6 WELL, THE NETHERLANDS

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SUMMARY

The borehole “De Lutte” contains the type section of the Upper Carboniferous of the Netherlands. In this study the original biostratigraphy based on Palaeobotany and Palynology is reviewed and re-analysed. A revision of the Palaeobotany and Palynology of this core suggests a much younger age for these deposits, ranging from Late Westphalian D to Stephanian in age. This is the first encounter of deposits of Stephanian age in the Netherlands and has important implications for Late Carboniferous oil and gas play-concepts.

In 1989 the De Lutte-6 borehole (eastern Netherlands) was deepened into the Carboniferous deposits by the NAM (Nederlandse Aardolie Maatschappij B.V.) in co-operation with the RGD (Geological Survey of the Netherlands). This well is of stratigraphic importance as it represents the type section of the Late Carboniferous deposits in the Netherlands. In the original publications regarding the biostratigraphy of this core a controversy was noticed between the palaeobotanical and the palynological age interpretations (van Amerom, 1996; van der Laar and van der Zwan, 1996). The palaeobotanical biostratigraphy suggested a late Westphalian C to Westphalian-D (Stephanian ?) age (van Amerom, 1996) while the palynological associations (van der Laar and van der Zwan, 1996) indicated that the Westphalian D Stephanian transition was to be found higher in the core. Nevertheless it was decided to hold the palaeobotanical results as leading in the interpretation of the age of the deposits because at the time the palynofloral transition from the Westphalian into the Stephanian was still insufficiently elucidated.

Palaeobotanical samples from the De Lutte-6 core are presently stored at the National Museum of Natural History, in Leiden. In order to resolve the controversy between palaeobotanical and palynological age interpretation, new sampling of plant macro- and micro-fossils along the core was conducted which resulted in several new palaeobotanical specimens. The stratigraphic age evaluation of the De Lutte-6 was conducted anew by the reassessment of palaeobotanical identifications and sampling new horizons for palynological analysis. New palaeobotanical results indicate that the identification as *Annularia spicata* was preferred above *A. galioides*, as *Sphenophyllum verticillatum* was preferred above *Sph. cuneifolium*. Both new identifications indicate a Stephanian range, while the older identifications indicated a Westphalian D range. New insights on the range of the pecopterids also suggest a revision of the age-interpretation of the Lutte-6 core. New palynological analyses reveal the same associations previously observed by van der Laar and van der Zwan (1996). The revised age interpretation of the De Lutte-6 well suggests this type section represents a gradual transition from the Lower Westphalian D to the Upper Stephanian.

REFERENCES

Amerom, H.W.J. van, 1996. The biostratigraphy of borehole “de Lutte-6” (East Twente, the Netherlands). Medelingen Rijks Geologische Dienst, no 55: 83-105.

Laar, J. G. M. van de, and Zwan C. J. van der, 1996. Palynostratigraphy and palynofacies reconstruction of the Carboniferous of borehole “ de Lutte-6” (East Twente, the Netherlands). Medelingen Rijks Geologische Dienst, no 55: 61-82.

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CIMP Treasurer's statement: 2006-2008 (Euros)

- Expenses:
  - 2007
    - Software (Developers4web) creation of forms: 23.99
    - Software (Developers4web) internet security: 15.99
    - IFPS fees (½ 2004 - 2005-2008): 339
  - 2008
    - IFPS fees (2009-2010): 177
    - Charges for the IFPS payment: 9.68
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    - Bonn CIMP reception: 800 (estimate)

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  - 2006 (since the Prague CIMP meeting)
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