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Welcome to CIMP Warsaw 2010

During the previous CIMP General Meeting in Prague, several delegates have suggested that the next General Meeting should be organized in Poland for the first time. A group of the Polish palynologists working in the Palaeozoic decided to accept this challenge and via mail correspondence with CIMP authorities proposed to organize the CIMP 2010 General Meeting in Warsaw, Poland. The CIMP President John Marshall and CIMP secretary Mike Stephenson had accepted our proposal. During the Joint Meeting on Spores/Pollen and Acritarchs Subcommisions in Lisbon, 2007 the representative of the Organizing Committee – dr Marzena Oliwkiewicz-Miklasierska had invited Palaeozoic palynologists to Poland and presented some important information about the organizers and post-conference field trip in the Holy Cross Mountains.

The CIMP General Meeting is organized by the Institute of Geological Sciences of Polish Academy of Sciences, Polish Geological Institute – National Research Institute, Institute of Geological Sciences of Wroclaw University, in Warsaw, Poland, from the 13th to the 16th of September 2010. All persons interested in any aspect of the Palaeozoic palynology are welcome. The program includes a scientific meeting consisting of three days of technical and scientific sessions, a poster session, a microscopic workshop sponsored by Precoptic Co., and will be followed by a post-conference field trip of three days in the Holy Cross Mountains.

The main organizer - Institute of Geological Sciences of Polish Academy of Sciences was established in 1956 as the Research Centre of Geological Sciences in Warsaw. The Palaeozoic palynology is one of the most important research activities carried out over the past decades as a part of geological investigations conducted in the Institute. This activity is demonstrated by publications, issued in the foreign and Polish scientific journals as well as regular participation in palynological and palaeobotanical conferences and scientific collaboration within International projects, like IGCP 469 or IGCP 575. The palynological staff of the Institute is often invited to consulting jobs for the oil industry.

A special thanks are due to conference guests Prof. Józef Kaźmierczak, dr Barbara Kremer and dr Øyvind Hammer that accepted to collaborate, preparing web presentations of invited talks that greatly improve the CIMP General Meeting Warsaw 2010 programme.

And, last but not least, a word to the CIMP General Meeting Warsaw 2010 participants. We express out thanks to all the authors for their invaluable contributions that are now published in this Abstracts volume.

The Editors
September 2010
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Detailed palynological analysis of the Middle Ordovician-Early Silurian (Llandovery) Safiq Group of Oman enables precise dating, correlation, and facilitates palaeoenvironmental and sequence stratigraphic interpretations. Most of the studied 245 subsurface sample of the Saih Nihayda, Hasirah and Sahmah formations proved palyniferous, yielding abundant, moderately to well-preserved acritarchs (51 species), chitinozoans (33 species) and cryptospores (13 species). Four new chitinozoan species, *Euconochitina sheridani*, *Belonechitina ghabaensis*, *Desmochitina omanensis* and *Desmochitina mortoni*, were proposed and described by Al-Ghammari *et al.* (2010) from Darriwilian core samples in the Saih Nihayda Formation. Three acritarch assemblage zones are recognised and informally designated: Ac1 (middle-late Darriwilian), Ac2 (early-middle Katian) and Ac3 (early Rhuddanian). These zones stratigraphically coincide with four chitinozoan assemblage zones which are also informally designated: Ch1 (middle Darriwilian), Ch2 (late Darriwilian), Ch3 (early-middle Katian) and Ch4 (early Rhuddanian). Chronostratigraphic assignments are based principally on comparison with previously established acritarch and chitinozoan zones in the Arabian Plate and Gondwana. The present palynozonation scheme confirms and refines previous palynological datings proposed for the Safiq Group (e.g. Droste, 1997; Molyneux *et al.*, 2006). The three formations of the Safiq Group represent three major transgressive-regressive cycles separated by two unconformities, corresponding to the Sandbian and the late Katian-Hirnantian. The shales with diverse and abundant acritarchs and chitinozoans at the bases of the Saih Nihayda and the Hasirah formations were deposited in relatively deep-marine environments and are, respectively, correlated with the middle Darriwilian O30 and the early Katian O40 maximum flooding surfaces of Sharland *et al.* (2001). These horizons are overlain by generally coarsening upward sequences of
siltstones and fine-grained sandstones, representing highstand systems tracts in an up-section regressive shallowing facies reflected by decreasing abundance and diversity of marine palynomorphs and increasing abundance and diversity of cryptospores. In accordance with Molyneux et al. (2006), the early Rhuddanian shales of the Sahmah Formation is related to a marine flooding event that predates the middle Aeronian S10 maximum flooding surface of Sharland et al. (2001).

<table>
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</table>

Stratigraphy, biostratigraphy, chronostratigraphy and maximum flooding surfaces (MFS) of the Safiq Group.

REFERENCES


TAXONOMY AND STRATIGRAPHIC IMPORTANCE OF THE CARBONIFEROUS MIOspore Genus Vestispora

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Authors revised stratigraphical ranges of the miospore genus Vestispora from USA, Canada, UK, Poland, Belgium, France, Germany, Turkey, Netherlands, Spain, Bulgaria and the Czech Republic. Palynologists regard vestispores as useful biostratigraphic indicators (e.g. Smith and Butterworth 1967, Clayton et al. 1977). Special focus was concentrated on stratigraphical occurrences of vestispores and their parent plants.

Now the genus consists of about 25 species. It is possible to divide vestispores into a few morphological groups according to the sculpture of outer perisporial layer which can be laevigate, costate, reticulate to foveolate.

The first group is represented by laevigate vestispores of the Vestispora laevigata-type. The second group consists of vestispores with simple primary costae of the Vestispora costata-type. The third group is characteristic by primary reticulum (e.g. Vestispora profunda-type). Vestispores of the fourth group possesses primary and secondary reticulum like e.g. Vestispora magna or V. pseudoreticulata. The fifth group is typical by simply foveolate exine, e.g. Vestispora fenestrata-type. The last, sixth group consists by vestispores with the combination of costate and foveolate sculpture (Vestispora tortuosa-type).

Stratigraphically oldest occurrence of vestispores is Vestispora lucida reported by Smith and Butterworth (1967) from Namurian A of UK. The latest record is represented by Vestispora fenestrata from the Stephanian B of France (Alpern et al. 1969).

 Majority of vestispores were produced by one group of sphenophyllalean cones of the Bowmanites-type.
Morphologically similar spore type is represented by operculate genus *Pteroretis* which was produced also by sphenophyllalean cones of the *Bowmanites*-type. The gross morphology of *Pteroretis* is very similar to vestispores. The genera *Glomospora, Cancellatisporites, Novisporites, Foveolatisporites* (part) and *Reticulatasporites* can be considered as synonymous.

The only non-sphenophyllalean *in situ* record of vestispores is from noeggerathialens cones of the *Discinites*-type (Bek and Šimůnek 2005) that may suggest hypothetical relationships of some shenophylls and some noeggerathialens.

Authors proved the role of vestispores in the coal seems for the first time. The distribution of microfloristic species is partly based on our observations of palynological collections. These new data confirm that taphonomical effect has been taken into account of the species when interpreting in coal seams. There is significant difference in the species diversity between ecological conditions and the levels in the coal.

The analysis of the dynamics of the change of the species destitutions and quantitative changes provides a basis for a detailed stratigraphy and also each type of the spore species is the source in concrete facies setting. The individual taphomicrofloras in the level of coals have been influenced by different depositional setting of the taphonomic histories of the petrographic of the individual coal seem. Despite taphonomic differences between the individual localities considered by the study, possible reasons for the position of the species of the genus *Vestispora* in the coal seems and clastic material.

**REFERENCES**


Tournaisian successions of southern Ireland and South Wales were deposited in transgressive shallow marine, tempestitic shelf environments, undergoing constant palaeoenvironmental change. Palynological samples from eight locations across the region (a palaeogeographic area of ~300km²) were analysed. A detailed palynological study found that the successions range in age from the Cristatisporites hibernicus - Umbonatisporites distinctus to the Spelaeotriletes pretiosus - Raistrickia clavata (HD - PC) Miospore Biozones. As part of this study, comprehensive biometric analysis of the biostratigraphically important Spelaeotriletes balteatus - S. pretiosus complex was undertaken resulting in the description of one new species - Spelaeotriletes galearis Brittain & Higgs 2007, and one new name combination, Indotriradites faciatus (Higgs) comb. nov.

As a result of the detailed miospore biostratigraphy of the successions, the occurrence of major synsedimentary deformation events across the region were, in some cases, found to have occurred simultaneously. In the sections studied, four separate levels of regional deformation were identified. These are (in stratigraphic order): within in the HD Biozone in South Wales; close to the HD-BP Biozonal boundary in both southern Ireland and South Wales; within the BP Biozone in South Wales; and at the BP-PC Biozonal boundary in both Southern Ireland and South Wales. The sedimentology of these simultaneous events was documented and analysed in detail, and compared to modern analogues. As a result, these events are thought to be associated with the effects of seismic shock waves on unconsolidated storm-deposited sediments on a regional scale at specific times in the Tournaisian and a particularly major, regional deformation event was found to have occurred at the BP - PC Miospore Biozone boundary.
A reworked Ordovician-Silurian acritarch assemblage was also discovered in the lower PC Biozone towards the top of the Houseland Sandstone Member of the Porter’s Gate Formation (at Hook Head, Co. Wexford, Ireland), and proven, by means of the detailed miospore biostratigraphy of the successions, to be much older than previously recorded Lower Palaeozoic reworking events from the Irish Tournaisian, such as that in the upper PC Biozone Ballyvergin Shale Formation. Further investigation of the systematic palynology of the acritarch assemblage found is ongoing.
The Palaeozoic inlier of the Holy Cross Mountains (Central Poland) is the only outcrop area of the Silurian rocks in the southern part of the Trans-European Suture Zone. Silurian sediments are the infill of the Caledonian foreland basin that developed on the Baltica shelf area. Investigated Late Silurian marginal marine sediments are composed of limestones intercalated by clastic deposits rich in organic particles.

Examined samples represent Jadowniki Member of Winnica Formation. The Winnica Formation lies above the spot findings of the graptolite *Bohemograptus bohemicus* (in the Trzcianka Formation) and below Sarnia Zwola Formation, the Pridolian age of which is documented by graptolite *Istrograptus transgrediens* sp. l, and trilobite *Acaste dayiana*. The rocks of the Jadowniki Member of the Winnica Formation yield the following trilobites: *Proetus signatus*, *Acastella spinosa*, *Homalonotus knighti*, *Calymene beyieri*, that indicate upper Ludlowian age. The distinct regressive facial record, along with C isotope excursion in the Jadowniki Member indicate that the studied sediments have been deposited during N. kozlowski - M. latilobus interzone (i.e. middle part of the upper Ludfordian).

Examined samples yield rather poorly diversified organic microremains assemblage. It is dominated by dark brown and black AOM particles. The dominant palynomorphs are acritarchs with diacrodi ans showing Uppermost Cambrian - Lower Ordovician age. This feature, along with the regressive character of the sediments, clearly shows redeposition. Among other palynomorphs the most frequent are nematophyte cuticles. Less frequent are cryptospores, fungal hyphae and invertebrate cuticles. Very rare are trilete spores. As a matter of fact, only two were found by now. No higher land plant cuticles, stomata or tracheids were found.
THE MEASUREMENT OF VITRINITE REFLECTANCE USING MATLAB

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The measurement of vitrinite reflectance is widely used as an indicator of coal rank and organic maturation in source-rock studies. This is due to the regular change in reflectance properties of the vitrinite group during coalification. Traditional coal petrographic studies¹, including rank determination, uses transmitted light microscopy. Vitrinite is differentiated from other macerals microscopically under an oil immersion lens using incident light on polished surfaces and taking into account properties, such as, colour, shape, relief, hardness and principally, reflectivity. The accurate measurements of vitrinite reflectance are achieved with the calibration of the microscope with, at least, two standards of known reflectance. The values of vitrinite reflectance are then registered analogically in a photo-multiplier apparatus or more recently in software packages that deal with image analysis treatment.

In this work we propose a method for vitrinite reflectance measurement that uses the techniques of image processing ready available in Matlab . We developed a dedicated graphical tool that runs within the Mirone suite (also written in Matlab, Luis, 2007), that calibrates a scale of 256 grey levels with standards of known reflectivity. The black and white images of the vitrinite particles are imported to this routine and its reflectance values are measured. In order to test the reliability of this method, several coal samples with a known rank, ranging from lignite to meta-anthracite (Flores, 2002; Marques 1993; Suarez et al., 2006; Marques et al., 2009), were re-studied and its vitrinite reflectance were measured using the new tool . The results of
this test (table 1 and figure 1) show that there is a very good correlation between the vitrinite reflectance measurements made with traditional methods (%Rm Literature) and the new Vitrinite tool. Although more tests are needed to ascertain the consistency of this new method, these results show that this method can be a more affordable alternative to the commercial vitrinite reflectance software packages.

<table>
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<td>6.25</td>
<td>6.21</td>
<td>0.36</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1. Values attained for the coal samples. %Rm Literature indicates the vitrinite reflectance values for the coals measured with traditional methods; %Rm MatLab the vitrinite reflectance values measured with the new Vitrinite tool routine; SD – standard deviation and the number of points measured.

**Figure 1.** Correlation chart between the vitrinite reflectance values measured with the traditional methods and with the new Vitrinite tool. Note the very good correlation between the two sets of values with a regression line of $R^2 = 0.9988$.

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Examined material is derived from the 10 boreholes located in the Kielce region of the Holy Cross Mountains. Productive samples were mainly obtained from grey claystones and mudstones as well as fine-grained sandstones representing the nearshore and rarely continental, alluvial sedimentation (Tarnowska, 1996). The palynostrigraphic scheme introduced by Streel et. al. (1987) has been applied here. The succession of four palynological assemblages belong to the Oppel Zones: *polygonalis* – *wetteldorfenis* (PW), *annulatus* – *bellatulus* (AB), *foveolatus* – *dubia* (FD) and *apiculatus* – *protea* (AP) has been recognized. Presence of the interval Zones: *subgranifer* (Su and *corystus* (Cor.)) was also ascertained in the upper part of PW Zone and the lower part of AP Zone respectively. The assemblages of Su. and AB Zones occur within the Haliszka Formation whereas the assemblage of FD zone – in the top of the Haliszka Formation and within the Winna Formation. The assemblage of Cor. Zone was found in the top of the Winna Formation. Therefore the Upper Pragian (Siegenian) – Lower Emsian boundary can be placed in the lower part of the Haliszka Formation, between the Su. and AB Zone assemblages (see Turnau et al., 2003). The Lower - Upper Emsian boundary, however, is more problematic. It is diachronous to the lithostratigraphical units and can be drawn in the lower part of FD Zone. For that reason, it can be only generally accepted that the Lower – Upper Emsian boundary lies in the lower part of the Winna Formation. The Cor. Zone assemblage confirms the late Emsian age of the upper part of the Winna Formation. This succession of palynospectra corresponds to palynological assemblages presented by Turnau (Turnau & Tarnowska, 1997, Turnau et al., 2003).

All the assemblages are strongly dominated by apiculate spores, mostly representatives of Rhyniophyta, Trimerophyta and Pteridophyta. They can be well
compared to the contemporaneous spectra from the West and East Europe. Thus the Holy Cross Mts. build a natural platform in floristic correlation between these areas. Relative strong similarity between the late Pragian (Siegenian) and Emsian palynoassemblages suggests that flora of the “Old Red” continent was poorly differentiated.

REFERENCES
ULTRASTRUCTURE OF IN SITU SPORES OF EARLY DEVONIAN LYCOPHYTINA

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Studies of the wall ultrastructure of extant and fossil spores illustrate features that might be diagnostic of major plant lineages as well as improved understanding of wall organization. We specifically are examining the ultrastructure of in situ spores of selected Early Devonian (Emsian) vascular plants in order to understand the organization of their walls and to investigate if there are any features that might be distinctive for the lineages they represent. We report here on TEM studies of spore walls for the following Early Devonian taxa currently classified as Lycophytina sensu Kenrick and Crane (1997): 1) the stem taxon Renalia hueberi; 2) the zosterophyllopsid Zostephyllum divaricatum; and 3) the lycophyte Leclercqia (Early Devonian L. complexa and L. andrewsii). Basic features of spore walls in these taxa are compared to what is known among extant lycopsida and other extant and extinct plant groups.

Renalia hueberi spores, comparable to the sporae dispersae taxon Retusotriletes, exhibit a mostly homogeneous wall, sometimes with tiny voids or faint lamellae scattered throughout. Sections through the trilete aperture demonstrate that the inner wall may be more granular in that region. Abundant globules, possibly representing tapetal residue, are present over the surfaces of spores, being densest on those still in spore masses or sporangia.

Zostephyllum divaricatum spores also are comparable to Retusotriletes or if faintly granular, perhaps Apiculiretusispora. TEM sections show that these spore walls are very strongly lamellate, particularly in the inner wall region, and covered
with globules. The globules often are ornamented. Again the inner wall below and adjacent to the aperture appears more strongly granular.

Spore wall ultrastructure of the Emsian *Leclercqia* species is more complex in having two distinct layers, interpreted as a homogeneous to laminate inner exospore (evident as an “inner body” by LM and SEM) and outer paraexospore which forms the ornament. A region below and adjacent to the proximal aperture forms a multilamellated zone. Features of this wall are reminiscent of ultrastructure in microspores of fossil and extant heterosporous lycopsids such as extinct *Cirratriradites* and extant *Selaginella* microspores. Their presence in homosporous *Leclercqia* might indicate stepwise acquisition of characters during evolution of heterospory.

One feature present in all of these taxa, and also in extant lycopsids, is a differentiation of the inner wall beneath apertures, either as a granular or multilamellate region. The presence of laminae in mature exospores is frequent in both the fossils and in extant Lycopodiaceae. Such features are not common if at all present in extant ferns or horsetails. To determine if these might be distinctive for lycopsids and not generally present in all early plants, more studies of spore ultrastructure from extinct basal euphylllophytes are needed.

![Spore sections of Early Devonian Renalia hueberi (left) and Zosterophyllum divaricatum (right)](image-url)
BIOSTRATIGRAPHY AND PALEOGEOGRAPHY OF ORDOVICIAN STRATA, IN KABIRKUH WELL#1, IN LURESTAN AREA, SOUTHWESTERN IRAN

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The Kabirkuh well #1 is located on the crest of Kabirkuh anticline which is the largest structure in the Lurestan area (Fig.1). The Kabirkuh anticline is 220km long and 10-12km wide with more than 2438m closure. The Kabirkuh well #1 is an exploration well which was spudded on the Lower Cretaceous Garau Formation in 1972 and completed in the Ordovician strata (= Seyahou Formation) by Oil Service Company of Iran in 1973. The purpose of drilling was to test the hydrocarbon potential of the Permian-Triassic strata in the Lurestan area and to ascertain the nature of subsurface stratigraphic column for further regional exploration requirements.

The relationships of the drilled rock units from the Garau Formation (Lower Cretaceous) down to Dalan Formation (Permian) can be determined by diagnostic microfauna, whereas from depth of 2963m to 3157m are without foraminifers. Therefore, fifty three core and cutting samples were treated for palynomorph entitities in order to determine the precise age of this interval. All samples contain well-preserved acritarch and chitinozoan assemblages. The acritarchs include 25 genera and 42 species. The diagnostic acritarch taxa consist of Cristallinium dentatum, Cymatiogalea granulata, Cymatiogalea deunffii, Cymatiogalea philippotii, Pirea ornata, Dactylofusa velifera, Aureotesta clathrata var. simplex, Dasydiacrodium ancoriforme, Coryphidium bohemicum, Coryphidium persianense, Veryhachium trispinosum, Frankea sartbernardensis, Arbusculidium filamentosum, Arbusculidium iranensis, Striatotheca triangulata, Striatotheca trapziformis, Striatotheca transformata, Striatotheca quieta, Striatotheca principalis, Stellechinatum uncinatum, Aremoricanium deflandrei, Orthosphaeridium tematum, Orthosphaeridium bispinum, Orthosphaeridium inflatum, Orthosphaeridium insculptum, Gorgonisphaeridium antiquum, Ordovicidium elegantulum, Multiplicisphaeridium bifurcatum, Multiplicisphaeridium irregularare, Diexapllophasis denticulata denticulata,
Dactylofusa spinata, Rhopaliophora palmata, Voglandia flosmaris, Balisphaeridium christoferi, Polygonium gracile, Balisphaeridium perclarum, Veryhachium hamii, Tunisphaeridium eisenackii, Leiofusa fusiformis, Aremoricanium squarrosum, Actinotodissus crassus and Batisphaeridium constrictum. The chitinozoan taxa comprise of 17 genera, and 20 species including of Eremochitina brevis, Linochitina pissotensis, Siphonochitina formosa, Cyathochitina campanulaeformis, Cyathochitina kukersiana, Laufeldochitina clavata, Eisenackitina sp., Hercochitina sp., Acanthochitina barbata, Desmochitina minor, Belenochitina micracantha, Lagenochitina baltica, Euconochitina lepta, Armoricochitina fistulosa, Rhabdochitina usitata, Rhabdochitina gracilis, Armoricochitina nigerica, Pogonochitina spinifera, Ancyrochitina merga and Tanuchitina elongata. So far the above-mentioned acritarch and chitinozoan taxa have been recorded from Early (Floan), Middle (Dapingian-Darriwillian) and Late Ordovician (Sandbian-Hirnantian) strata elsewhere. Therefore, the drilled Ordovician interval of depth 2963m to 3157m in Kabirkuk well #1 is assigned to Early-Late Ordovician. Based on chitinozoan and acritarch taxa, the Lurestan area looks like Khuzestan and Fars areas can be assigned to North Gondwana Domain. Likewise, the Ordovician strata were investigated as source rock. As a result, 85-90% of organic matter is amorphous with TOC 1-1.5 % values. The acritarch taxa are also brown to gray with thermal alteration index 3.5-3.9 levels, suggesting generation of wet gas and condensates for Permian reservoirs (Faraghan and Dalan formations) which disconformably rest on Ordovician strata. Likewise, the presence of acritarch and chitinozoan taxonomically diverse assemblages, suggests a relatively shallow marine, platformal depositional environment, locating in medium-high palaeolatitudes.
Fig. 1. Location map of studied area.
The siliciclastic rocks of the Paprotnia Series from the vicinity of Czerwieńczyce village were palynologically studied. These Upper Viséan rocks belong to the autochthonous/parautochthonous succession of the Bardo Unit (Polish Sudetes) and are interpreted as a shallower-water equivalent of the pelagic *crenistria* Limestone (Haydukiewicz & Muszer, 2002).

The palynological studies provided diverse miospore assemblages and abundant palynological material, in which the amorphous organic matter was not observed. The preservation of miospores was rather poor and the main destructive factor was pyrite.

The miospore assemblages found in 15 m thick rock section allow to distinguish two miospore zones. The miospore assemblage found in the lower and middle part of the section contains *Waltzispora planiangularata, Raistrickia nigra, Microreticulatisporites concavus, Rotaspora knoxi, Triquiritites marginatus, Savitisporites nux, Crassispora maculosa, Kraeuselisporites echinatus, Remysporites magnificus* and *Schulzospora spp*. This assemblage is characteristic to the *T. vetustus-R. fracta* (VF) miospore biozone.

In the upper part of the section some important taxa appear: *Bellisporites nitidus, Reticulatisporites carnosus* and *Cingulizonates capistratus*. Their occurrence indicate that this part of the section should be included to the *B. nitidus - R. carnosus* (NC) miospore biozone.

The boundary between these two zones was established on the base of the IV taphocoenose distinguished by Haydukiewicz & Muszer (2002).

Above results confirm Asbian age of the lower and middle part of the section, which was supported on the micro- and macrofaunistic studies and suggested for whole section of the Paprotnia Series (Haydukiewicz & Muszer, 2002). The Asbian
age was suggested also by the radiometric dating on 334±3 Ma of the bentonite level from the lower part of the section (Kryza et al., 2010).

The palynological data indicate that the upper part of the Paprotnia Series belongs to Brigantian. These rocks had not provided any faunistic fossils and they appeared to be younger than it was believed earlier.

REFERENCES


The Silurian rocks of the Dunquin inlier comprise a 1500m thick succession of shallow marine and minor coastal plain sediments interbedded with a range of volcaniclastic deposits and lavas. The lower part of the Silurian succession (Coosglass and Foilnamahagh Formations) was previously undated, however the middle and upper parts of the succession (Ferriter’s Cove to Croaghmarhin Formations) have yielded Wenlock and Ludlow macrofaunas. An ongoing palynological study of the Dunquin Group succession has recovered a variety of palynomorph groups, such as, acritarchs, prasinophyte cysts, chitinozoans, scolecodonts, miospores and cryptospores. Preliminary palynological results indicate the biostratigraphic age of the Coosglass Formation is now considered to be late Llandovery to early Wenlock. Palynological data from the overlying formations are consistent with the Wenlock-Ludlow ages given by the macrofaunal evidence. The diversity and distribution of acritarchs and spores within the Ferriter’s Cove Formation is very variable and is considered to be palaeoenvironmentally controlled. The different palynological assemblages are closely correlated with regressive shallowing upward cycles that range from siliciclastic shallow shelf, shoreface, back barrier intertidal and lagoonal depositional environments. The sediments of the Ferriter’s Cove Formation were repeatedly affected by sea level change, variable rates of sediment supply and volcano-tectonic activity.
The Małopolska Block definition is not easy. It borders as well as the age of the consolidation have not been so far defined. The Małopolska Block is situated near the southwestern boundary of the Eastern European Platform where together with other units form Teisseyre-Tornquist Terrane Assemblages (TTA) (Nawrocki & Poprawa, 2006). The Małopolska Block from the southwest border of the Upper Silesian Block, the northeastern boundary is drawn along the Holy Cross Dislocation (Pożaryski et al., 1992; Pożaryski & Tomczyk, 1993). The anchimetamorphic clastic rocks of flysch character are the oldest rocks recognized in the Małopolska block. Results of palynological investigations in several boreholes from the Małopolska Block indicate that they are Ediacaran in age (Moryc & Jachowicz, 2000).

The Cambrian clastic complex of Małopolska Block is known from outcrops and drillings in northern and eastern part of the Małopolska Block. Its stratigraphy in the Kielce region of Holy Cross Mts. based on trilobites and acritarchs (Żylińska & Szczepanik, 2009). These rocks continues within the basement into Carpathian Foredeep where were penetrated by deep drillings (Dziadzio & Jachowicz, 1996). The detailed palynological analyses allow to document microflora assemblages typical of the Lower, Middle and Upper Cambrian.

The Lower Cambrian deposits contain characteristic acritarch associations predominated with *Skiagia* genus represented by some species and accompanied by representatives of other, typical Lower Cambrian genera and species such as: *Archeodiscina umbonulata*, *Estiastra minima*, *Heliosphaeridium dissimilare*, *Michrystridium xianum* and *Granomarginata*. The typical Middle Cambrian genus - *Adara* and species of *Cristallinium cambriense*, *Eliasum IIaniscum*, *Heliosphaeridium notatum* i *Comasphaeridium longispinosum* are particularly numerous represented among the obtained Middle Cambrian microflora assemblages. Microflora with
characteristic members of Herkomorphitae and Diacromorphitae subgroups has been recognized in the Upper Cambrian deposits. The obtained data show that Cambrian rocks recognized in the Kielce region of Holy Cross Mts., continue within the Carpathian Foredeep basement.

REFERENCES
Until now the precise age and nature of the ?glacigene Tobra Formation (Salt Range, Pakistan), and its relationship to palaeogeographically-nearby sequences in Arabia and the Middle East have been uncertain. Samples from a 125 metre-thick section of the Tobra Formation at Zaluch Nala, western Salt Range, Pakistan yielded 38 palynomorph taxa including the spores *Horriditriletes* spp., and *Microbaculispora tentula*; abundant monosaccate pollen including *Barakarites* cf. *rotatus*, *Cannanoropollis janakii* and *Plicatipollenites malabarensis*, and rare taeniate and non-taeniate bisaccate pollen. *Converrucosisporites grandegranulatus*, *Cycadopites cymbatus*, *Horriditriletes ramosus*, *Horriditriletes tereteangulatus* and *Microbaculispora tentula* indicate the south Oman 2165B Biozone (Pennsylvanian), suggesting that the Tobra Formation in Zaluch Nala is equivalent to the middle part of the Al Khlata Formation of Oman (PDO production unit P1). *Brevitriletes leptoaicina*, *Brevitriletes parmatus*, *Horriditriletes ramosus* and *Microbaculispora tentula* indicate the lower part of the Oman Saudi Arabia Palynological Zone 2 (OSPZ2). The Tobra Formation assemblages are also correlated to western Australian Stage 2 (*sensu* Backhouse 1991) and the eastern Australian *Microbaculispora tentula* Oppel-zone, based on the occurrence of *Brevitriletes cornutus*, *Brevitriletes parmatus*, *Cycadopites cymbatus*, *Horriditriletes ramosus*, *Horriditriletes tereteangulatus* and *Microbaculispora tentula*. The Tobra Formation in Zaluch Nala lacks the deglaciation sequence that is present in several other palaeogeographically-nearby basins such as those of south Arabia and Western Australia indicating either non-deposition during the deglaciation period, or erosion associated with the unconformity between the Tobra Formation and the overlying Warchha Formation.
The Carboniferous-Permian succession of Pakistan comprises approximately 610m thick sedimentary strata and crops out in the Salt Range and Trans-Indus Khisor and Marwat ranges and partly in the Surghar Range (Fig. 1). The succession is divided into two groups: the lower largely terrestrial Gondwana succession, represented by the Nilwahan Group, and the upper shallow marine Tethyan succession, represented by the Zaluch Group (Wardlaw and Pogue, 1995; Jan et al., 2009). The oldest of the Carboniferous-Permian units of the Nilwahan Group in the Salt Range is the Tobra Formation, the type locality of which is located near the Tobra Village in the eastern Salt Range (Fig. 1).

For present investigation, forty samples were studied for palynology from the Tobra Formation at Zaluch Nala, Western Salt Range, Pakistan (Fig. 1), which yielded significant palynomorph taxa, including Microbaculispora tentula, Horriditriletes tereteangulatus, Horriditriletes ramosus, Horriditriletes uruguaiensis, Brevitriletes parvatus, Brevitriletes comutus and Brevitriletes leptoacaina. The monosaccate pollen represented, are Plicatipollenites malabarensis, Barakarites cf. rotatus and Cannanoropollis janakii.

The assemblage also represented considerable numbers of taeniate and non-taeniate bisaccate pollen. The palynological assemblages from the Tobra Formation show close similarity with the assemblage of the OSPZ2 biozone of Arabian Peninsula (Stephenson et al., 2003) and 2165B biozone of south Oman (Penney et al., 2008). The Tobra Formation which is correlative with the middle part of the Al-
khla Formation of Oman and Unayzah B of central Saudi Arabia, based on the palynological assemblages from these sections, hence can be dated as Pennsylvanian; Gzhelian, equivalent to the PDO production units P1.

REFERENCES


The Neoproterozoic is seen as a time of extreme climatic changes. At least two global glaciations, known as ‘Snowball Earth’, are proposed for the Neoproterozoic. Evidence for low latitude glaciations is based on widespread palaeogeographic distribution of diamictites reaching out to low palaeolatitudes, overlain by Cap Carbonates showing negative δ13C excursions. The negative δ13C excursion is interpreted as a result of the collapse in organic productivity in the ocean, due to the decoupling of global oceans from the atmosphere by a global ice cover. Cap Carbonates are interpreted as anorganic precipitates produced by the switch from ‘Snowball Earth’ into a super hot green-house – the Neoproterozoic climatic paradox. In opposite, the waxing and waning of glaciers and the coexistence of open oceans with low latitude sea-ice is proposed based on sedimentary evidence, contradicting essential requirements of ‘Snowball Earth’. The controversial debate on ‘Snowball Earth’ is focussed mainly on geochemical data and secondarily on sedimentological analyses. The input from palaeontology is very marginal, because macro- and microfossils are not recorded from these intervals until now.

Palynological studies of the late Neoproterozoic Ghaub glaciation (Marinoan) in NE-Namibia show a continuous microfossil record throughout this interval for the first time. Therefore palynology presents essential new data for the analysis of palaeoenvironments during Neoproterozoic glaciations and the debate on ‘Snowball Earth’.

(1) A continuous record of life is observed from pre-glacial carbonate platform deposits throughout the glacial diamictites and Cap Carbonates into post-glacial highstand platform deposits. The microbial assemblages in the Cap Carbonates are dominated by filamentous cyanobacteria / algae accompanied by coccoidal bacteria /
algae and few acritarchs. In pre- and post-glacial strata filamentous microbiota disappear and partially highly carbonized organic debris and acritarchs become more frequent. The decrease of the total organic matter in the Cap Carbonates in some sections is most probably related to the facies change towards extremely shallow, marginal marine conditions of a proximal carbonate platform and not to less organic productivity in the ocean. The continuous biogenic productivity shown by palynology gives clear evidence for areas of open oceans and ice-free shelves during this glacial interval, which contradicts a crucial requirement for 'Snowball Earth'.

(2) Palynology also proves, that Marinoan Cap Carbonates are mainly biogenic, with microbial assemblages typical for very shallow marine algal mat deposits. Microbial life during the glaciation shows no major differences to pre- and postglacial assemblages, questioning a rapid change to extremely high temperatures, proposed by 'Snowball Earth' hypothesis. Dolomitization of Cap Carbonates seems to be at least partially biomediated, leading to changes in δ13C as observed in Cap Carbonates.

(3) Palynofacies analysis shows rhythmical changes in the proportions of benthic organisms like filamentous cyanobacteria / algae just as coccoidal bacteria / algae and planctonic organisms like acritarchs. It gives clear evidence for changes in water depth and therefore sea-level variations within the generally very shallow, marginal marine environment of the Cap Carbonates. Therefore palynofacies shows continued climatic variability during Cap Carbonate deposition, contradicting its interpretation as a deposit of a continuous marine transgression at the end of the global glaciation, proposed by the ‘Snowball Earth’.

The continuous record of fluctuations in relative sea-level from pre- to post-glacial deposits indicated by palynofacies analysis contradicts the rapid change from a ‘Snowball Earth’ to an extremely hot green-house during the Cap Carbonate deposition, but supports a model of long term waxing and waning of glaciers within a relatively slow escape from a widely glaciated Neoproterozoic world. Latest palynological studies of the Chuos glacial interval (Sturtian) in NE-Namibia show very similar results to the Ghaub glaciation. This hardly questions the existence of global glaciations in the Neoproterozoic as proposed by ‘Snowball Earth’ and supports an alternative model of widespread glaciations merged with open oceans in between.
PALYNOMORPHS FROM THE GORSTIAN (SILURIAN) OF SAZES FORMATION
(BUÇACO SYNLINCE), CENTRAL IBERIAN ZONE, PORTUGAL – PRELIMINARY
RESULTS

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Occurring in a complex syncline that extends from Buçaco to Penedo de Góis, the
studied area is located in the Central Iberian Zone of the Iberian Massif. In this region
outcrops a well-preserved and complete stratigraphic succession of Lower Paleozoic
age. At the top of the Buçaco Syncline stratigraphic succession, the Silurian Sazes
Formation (Paris, 1981), is currently being studied at a palynological (miospores and
chitinozoans) and macrofossil (graptolites) level, allowing a preliminary revision and
completion of the initial biostratigraphy of this area. This studies will also provide
information to support the undergoing surveying mapping project (1:50 000) that is
being undertaken by the “Laboratário Nacional de Energia e Geologia”
(Portuguese Geological Survey) (Sequeira, in prep). The Silurian age of the Sazes
Formation was provided by graptolites faunas (e.g. Piçarra & Sequeira, in press),
and consists of highly deformed dark carbonaceous shales with nodules
intercalated with quartzites beds. The

Figure 1 – Simplified geological map of the Sazes area (N Buçaco Syncline) showing the
studies trench (A). Adapt. Piçarra & Sequeira (in press) from original geology of N. Delgado
published by Costa (1950).
samples for the present work were collected in the road cuts of EN 235 (km 51.6 – km 51.7) where the Sazes Formation contacts by fault with the Upper Ordovician Porto de Santa Ana Formation (Fig. 1) (Young, 1988).

From the seven samples that were studied, six of them were barren in miospores and acritarchs and only sample BU.H/S7 yielded a very poor preserved miospore assemblage, which allowed the identification of the *Synorisporites libycus – Lophozonotriletes? poecilomorphus* Miospore Biozone (Richardson & McGregor, 1986), and *Chelinospora obscura* Sub-zone of Burgess & Richardson (1995), that indicates an upper Gorstian age. In this study no index species of chitinozoans were recovered, but it was identified a species that first occurs in the Gorstian (Verniers *et al.*, 1995), *Angochitina echinata* Eisenack, 1931. For the first time cryptospores were identified in this section. The graptolites samples collected at base of the stratigraphic succession, allowed the confirmation of the *Monograptus belophorus*, *Gothograptus nassa* and *Colonograptus praedeubeli - Colonograptus deubeli* Biozones of Wenlock age. A more detailed palynostratigraphic study from this road cut and other sections of Ordovician and Silurian ages of the Buçaco region is currently in progress.

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INTRODUCTION

The Albergaria-a-Velha Unit (AVU) constitutes one of the several tectonostratigraphic out-of-sequence units of the metamorphic belt along the Porto-Tomar shear zone (Ossa-Morena Zone, Iberian Massif, W Portugal) (Chaminé et al., 2003). It is imbricated in the Late Proterozoic (Beetsma, 1995) black-greenish phyllites of this metamorphic belt (Arada Unit). The AVU is a metasedimentary unit composed by shales, siltstones and rare sandstones. The metamorphic degree is low to very low, as indicated by Illite crystallinity analysis (Chaminé et al., 2003; Vazquez et al., 2007).

Fig. 1 – Simplified Geological map of the Espinho-Miranda do Corvo sector of the Porto-Tomar shear zone and associated metamorphic belt. Sampled localities are shown
STRATIGRAPHY AND PALYNOLGY

Continuous stratigraphic sequences are very rare and restricted to coarser sediments (siltstones and sandstones). Most known outcrops are heavily deformed and standard stratigraphical procedure is not applicable. Palynology is one of the few methods that allows the paleoenvironmental interpretation of the unit and the only providing some biostratigraphical control.

The coarser sediments represent, in vast majority of the observed outcrops, low density turbidites. Bouma sequences are incomplete, but the dm- to m-thick beds often present a massive coarser base, a laminated (occasionally with cross lamination) siltstone interval and finely laminated shaly top. This lithotype is restricted to the Serpukhovian. Other siltstone-dominated lithotypes include cm- to dm- thick beds of finely laminated pelitic sediments. These are commonly Serpukhovian in age, but Viséan spore assemblages have been found in this lithotype. Other lithotypes include black shales with few or none lighter or coarser sediment intercalations. These are mostly Famenian-Early Tournaisian in age, but a few localities also provided Viséan and Serpukhovian miospore assemblages. This data, together with detrital framework analysis and palynofacies indicate that a significantly large basin persisted from the Frasnian to at least the Serpukhovian where sedimentation was controlled by a generally prograding turbidite system close to the fine-grained end member (sensu Bouma, 2000). The post-sedimentary tectonic evolution of the area, clearly associated with the Porto-Tomar shear zone (Chaminé et al., 2003), destroyed most of the sedimentary record and preserved only a few discrete portions of a much larger basin, as nappes over older rocks.

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Archaepolisaccus is a distinctive Devonian monolet spore. It was first described from the northern hemisphere and was notable for being found only in the Frasnian of northern Laurasia. Archaepolisaccus is the microspore of the heterosporous lycopod Kryshtofovitchia (McGregor, 1969). The megaspore is Nikitinsporites which is very different from Archaepolisaccus in being trilete with prominent labra and long processes surmounted by small bifurcate tips.

This unity of the biogeographic and stratigraphic distribution of Archaepolisaccus was questioned by the discovery in the Givetian of Yunnan, China (Lu, 1980) of both Archaepolisaccus and Nikitinsporites. Further records from China then extended both its geographical extent and its age (Eifelian - Famennian). In addition, similar spores were reported from Australia (Grey, 1992; McGregor & Playford, 1993) including a new species A. rhacodes Hashemi & Playford 2005. These southern hemisphere Archaepolisaccus species differ in possessing a ‘camerate’ structure with scattered small processes that is more similar to Grandispora whereas the ‘northern’ Laurasian forms generally have more in common with Cristatisporites. A significant question is whether the similarity between these two groups is fortuitous and a consequence of a morphological system or has the potential to reveal much about Devonian plant evolution and palaeogeography.

The records of the different species of Archaepolisaccus from China have been reviewed and species redescribed made using new material from Longhuashan, Yunnan. This locality (Lu, 1980) is a direct correlative of the now covered type locality for Archaepolisaccus indistinctus Lu 1988. We can report here...
that most of the species of *Archaeoperisaccus* described from China can be
catered within *A. indistinctus*. In addition, the range of sculptural variation
includes the scattered coni and folds used to define *A. rhacodes*. A review of the
independent age evidence of the records from China indicates that the oldest
specimens are Givetian.

The specimens described by Grey (1992) as cf. *Calyptosporites* and
*Rhabdosporites* from the Canning Basin we place within *A. indistinctus* as
populations from China show individual specimens with a circular amb with both, or
either, a monolete mark and a modified or vestigial trilete mark. If unaware of *A.
indistinctus* we would regard these as aberrant *Grandispora*.

Also present within the Longhuashan assemblages are specimens we can
confidently attribute to *A. scabratus* and *A. opiparus*. Hence, we have the co-
occurrence of both groups.

Importantly, we have also discovered many specimens of unequivocal *A.
indistinctus* in several samples within a 200 m thick section of Frasnian age Kap
Kolthoff Group sediments from Ymer Ø, East Greenland. This is palaeogeographically within the interior of the ORS continent. These forms are, as
yet, unknown within European Russia.

The significant question is whether the distribution of *Archaeoperisaccus*
simply represents the co-occurrences of a morphologically similar spore or whether
there is a phylogenetic relationship between the two groups. Clearly both groups of
*Archaeoperisaccus* are independently associated with the megaspore *Nikitinsporites.*
In addition, the populations within East Greenland show significant morphological
variation between *A. indistinctus* and northern hemisphere *Archaeoperisaccus*
indicating transitional populations.

The age evidence shows a Givetian origin within the area of China and
Australasia followed by migration between continents, despite the encumbrance of a
large megaspore. The key palaeogeographic record (Zhu et al., 2008) is that from the
Junggar Basin, Xinjiang that during the Devonian moved towards Siberia. Hence,
migration could have been via the chain of moving microcontinents present within the
Panthalassic Ocean.

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The discovery of palynomorphs within the older Palaeozoic of the Saxothuringian zone (SE-Germany) is commonly hindered by the bad preservation of its organic interior. Tectonic shear [1] and thermal overprint at temperatures corresponding to a CAI of up to 6, as specified for the Silurian Ockerkalk limestone [2], often restrict successful identification of taxa to thin-sections of their source rocks. Ignoring this fact, samples from 14 thin marl slate layers intercalated in the Ockerkalk taken from a 24 m thick section of the well Lippelsdorf 17/64 located in the Schwarzburg anticline were solved and processed in conventional manner. Strong coalification and pyritisation of the macerates throughout the whole collection of sample preparations and the yield of only two (!) poorly preserved acritarchs from more than 100 preparations seem to confirm the above-mentioned problem. Instead acritarchs, several apparently ligneous fragments were found in one single layer around 1,2 m below the suprarregional spread “Scyphocrinus-Horizont” marker bed, which separates the Silurian Ockerkalk from the overlying Upper Graptolite shale which is, for the most part, early Devonian in age. The dark brown opaque fragments reach 100 μm extension. Their surface is characterised by patterns of more or less parallel arranged fibres resembling the pyritised xylem strands with tracheids illustrated by Edwards [3]. In some places this fibres additionally enclosure spindle shaped depressions or openings. Nevertheless, with 2..3 μm the width of these fibres is two orders of magnitude lesser than tracheids usually should be. Whether they still represent residua from early vascular plants, as guessed by the author, shall be matter of a discussion. The biostratigraphic position of the Ockerkalk section examined has been determined by conodonts to the interval from the latest Ludlow to the latest Přidolí [2], corresponding to the epoch, when the first higher plants (Tracheophyta) appeared on land. The interpretation of the Ockerkalk as a
succession of limestone-clay-turbidites [4], however, is not in conflict with this guess. The marl layer bearing the ligneous fragments is also rich in well-rounded bioclastic carbonate pebbles, shell detritus and crinoid stem fragments underlining its provenance from a shallow marine, probably land-proximal environment which could serve as its source area. The transport of this debris to the depositional realm of the Ockerkalk could be associated with a regressive regime triggered by the sea-level fall postulated for the period of the Silurian-Devonian transition.

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The morphology of microfossils with resistant cell walls, their ornamentation and functionally identifiable structures are the first source of information used to assess their biological affinities. Difficulties in relying on morphology alone due to the problem of convergent morphology may be resolved by the ultrastructure of the cell wall and its biochemistry.

The cell walls of microfossils, which are acid-resistant and thus extractable by chemical processing from the host rocks, are composed of biopolymers that show the properties of the sporopollenin/algaenan classes of biomolecules synthesized by green algae, the green lineages of dinoflagellates, and the reproductive cells of higher plants (spores and pollen). These biota share primary biochemical pathways of organic synthesis of biopolymers for constructing cell walls, and show a common early lineage in their phylogeny. The geochronologic sequence of appearance of microfossils with diagnostic traits of phycoma-like cysts, zygotic cysts with ornamentation, pylomes, double-walled vesicles and endocysts, and spheroidal vegetative cells and /or aplanospores with trilaminar sheath structure (TLS), which are interpreted to be green microalgae, is aligned on the phylogenetic tree of the Viridiplantae. The radiometric datings of the first appearance datum of these taxa provide the minimum age of the origin of the classes to which they are assigned. According to the affinities of microfossils inferred herein, the sequence of evolutionary events is as it follows.

The stem-group of the Viridiplantae extends in time prior to c. 1800 Ma, and the major branching nodes in a common lineage are at c. 1800 Ma for the Chlorophytes, c. 1650 Ma for the Prasinophyceae, and at c. 1450 Ma for the Chlorophyceae-Ulvophyceae lineage. The divergence of the Ulvophyceae might have occurred before c. 950 Ma. The origin of the Chlorophytes is constrained by the earliest record of the Leiosphaeridia-type microfossils from the Changzhougou Formation. The
“leiosphaerid” morphology, which is recognized among the prasinophyceae or chlorophyceae microalgae, has deep roots in their common ancestral group and it is not only the result of a convergent morphology expressed later on.

The prasinophyceae lineage is recognized by *Tasmanites rifejicus* and co-occurring species with phycoma-like, double-walled cysts: *Pterospermella*, *Simia*, *Pterospermopsimorpha*, and striated *Valeria*. *Valeria* appears at c. 1650 Ma in the Mallapunyah Formation, and it marks the minimum age at which the Prasinophyceae lineage split from the basal Chlorophytes. Phycoma-like microfossils are subsequently recorded at c. 950 Ma (*Octoedryxium*), c. 580 Ma (*Tasmanites*, *Simia*, *Octoedryxium*, *Pterospermopsimorpha*), and since c. 540 Ma through the Cambrian (*Tasmanites*, *Granomarginata*, *Pterospermella*, *Cymatosphaera*).

The chlorophyceae lineage is recognized by various species of *Leiosphaeridia* showing the TLS in their cell walls, which are likely the early members of the orders Volvocales and/or Chlorococcales. Leiosphaerids with such traits are present at c. 1450 Ma, 650 Ma and 520 Ma. The divergence of the Ulvophyceae prior to c. 950 Ma is suggested by the dasycladacean *Archaeoclada* and *Variacutada* in the Lakhanda Group, and the siphonocladacean *Proterocladus* from the c. 700-750 Ma Svanbergfjellet Formation.

The presented minimum ages of the origin of the Viridiplantae and the divergence of the major microalgal clades differ from the molecular clocks estimates. They also suggest that previously inferred time of the origin of Chlorophytes at c. 1 Ga or 1.5 Ga is too young. The molecular clocks estimates of these events are in conflict with microfossil records, and the interpretation of some of them as being photosynthesizing biota, and seem to be delayed in time.

Following the Great Oxygenation Event at c. 2.2 Ga, the oxygen pressure in the ocean-atmosphere system has been apparently increasing although with significant fluctuations through time. This was due to the variation in carbon cycles and carbonate formation, assembly and breaking off the supercontinents and weathering rate change, and hydrological cycle and stratification of the oceans. The Palaeo-Mesoproterozoic oceans were stratified with deep layers anoxic and only the surface layer oxygenated by photosynthesis within the photic zone. The late Neoproterozoic oxygenation event resulted in full oxygenation of the oceans and deep currents circulation.
The increasing pressure of oxygen in marine environments is argued to have played a decisive role in the evolution of metazoans in the Ediacaran and Cambrian, yet the cause-effect relationships may be in reverse as it comes to photosynthetic organisms diversification and growing abundance observed through the Proterozoic. The recorded diversification of green microalgae (acritarchs) must have enhanced the rates of primary productivity in the surface ocean layers and organic carbon burial in shelf sediments. Photosynthesis most profoundly increased the oxygen pressure in the global ocean. Precise correlation in time of the geochemical signatures and radiations of photosynthetic biota may reveal critical relationships between biotic and environmental evolution.
In Neuville-sous-Huy, central Condroz Inlier, Belgium there are three long, parallel sections through Silurian sediments: the Parc de la Neuville, the ravine 700 m east (of the Parc de la Neuville) and the ravine 1200 m east. These sections were first described by Michot (1932, 1934) as blackish, bluish and greenish shales with graptolites and levels with red shales. He found also four volcanic beds. Maes et al. (1978) restudied the sections and collected and described graptolites from 17 levels. They have shown that the three sections contain a larger part of the Silurian as previously accepted and probably form together a nearly continuous composite section covering the Telychian, Sheinwoodian and parts of the Homerian and Gorstian. In total 12 volcanic layers were described by them, but the detailed correlation of the three sections failed.

We restudied in detail these sections starting with the ravine 700 m east of the Parc de la Neuville. Lithostratigraphically this section could be divided by us into 6 units (from top to base):

Unit 6: Grey shales to fine siltstones.
Unit 5: Dark grey, finely laminated shales with some calcareous levels similar as unit 3.
Unit 4: Alternation of red fine siltstones and olive green, greenish grey to dark grey, sometimes laminated fine siltstones. Higher up the red fine siltstones disappear and passes into green to greyish green fine shales.
Unit 3: Dark grey, finely laminated shales with some calcareous levels.
Unit 2: Olive green, greenish grey to grey and dark grey fine siltstones intercalated
with grey medium-grained to coarse siltstones. Red fine siltstones occur only in the finer part of the section.

Unit 1: Grey, greenish grey to olive green, compact fine siltstones alternating with dark grey and greenish grey, laminated fine siltstones. At the base these fine siltstones are hard and quartzitic. Higher up red fine siltstones appear. The transition to unit 2 is gradual.

In between the sedimentary layers there are 11 volcanic or volcanoclastic layers. Almost each of them has his own characteristics that distinguish them from the other volcanic layers.

Chitinozoans were sampled from 54 samples. Although some beds contain only badly preserved chitinozoans, other beds contain a diverse and moderately to sometimes well preserved chitinozoan assemblages. The biostratigraphical results of the chitinozoans and calibration with the graptolite biozonation will be presented.

Fig. 1: Simplified geological map of Belgium with localisation of the study area. Adapted from Fielitz & Mansy, 1999.

Fig. 2: Topographic map of Neuville-sous-Huy with the location of the three sections.

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Prospecting borehole M-1 of 4500m depth was drilled in NW part of Lublin Basin in order to recognize the lithological-facial development of Devonian and Carboniferous deposits and their hydrocarbon potential. 11 samples from the interval 2724-3809m were collected for the palynological analysis. Preliminary stratigraphy based on comparisons with data from surrounding area indicate the Fammenian – Upper Carboniferous age of this interval.

All the samples contain organic matter, but two of them lack palynomorphs. The sample from the deepest examined interval (3800-3809m, V) contain abundant carbonised phytoclasts (melanogen) and rare palynomorphs with evidence of pyritization. In the depth interval 3586-3595m three examined samples contain miospores indicating Arnsbergian palynozone Stenozonotriletes triangulus – Rotaspora knoxi TK (Clayton et al., 1977) or revised Mooreisporites trigallerus – Rotaspora knoxi TK (Owens et al., 2004) with index species Rotaspora knoxi and Stenozonotriletes triangulus? and numerous specimens of Tripartites and Schulzospora. The succeeding palynozone Lycospora subtriquetra – Kraeuselisporites ornatus SO was distinguished in the depth interval 3482-3491m, VIII based on the occurrence of index species Kraeuselisporites ornatus and K. echinatus, Remysporites magnificus, Crassispora kosankei.

Higher in profile (depth interval 2855-2865m, II) such specimens like Cirratriradites saturni, Reticulatisporites reticulatus and Crassispora kosankei indicate younger age of the miospore assemblage, but the state of preservation and frequency of spores didn’t allow to establish palynozone. The highest examined
depth interval (2724-2734m) contain rare, badly preserved Upper Carboniferous miospores or only overmature organic matter.

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Cambrian rocks of the Cantabrian Mountains contain a great diversity of acritarchs that were the subject of pioneering studies on Middle Cambrian acritarchs (Cramer & Diez, 1972; Fombella, 1978), although their calibration has been controversial (e.g. Vanguestaine & Van Loy, 1983). Recent studies of acritarchs in the sections previously calibrated with trilobites, and new data on acritarchs and trilobites in the sections studied by Palacios (2008) confirm that the Oville Formation and lower levels of the Barrios Formation (La Matosa Mb.) yields the basis for the most detailed Middle Cambrian acritarch zonation in northwestern Gondwana known to date. Six acritarchs zones (IMC1-IMC6) are recognized in the Middle Cambrian and one Lower Furongian acritarch assemblage is identified in the middle part of the Matosa Mb. of the Barrios Formation in the Barrios de Luna Section. The co-occurrence of acritarchs and trilobites makes it possible to correlate, in part, the two types of biozones.

A detailed outline of the acritarch zones with the stratigraphic distribution of species and a new correlation schema is shown in Figure 1. Of particular interest is comparison to the Middle Cambrian acritarch studies realized in Newfoundland (Martin & Dean 1988) and EEP (Volkova & Kirjanov 1995). The IMC1-IMC3 zones and their correlations is described in Palacios (2008). Here three new zones are recognized in the Cantabrian Mountains, two of these (IMC4 and IMC5) have no comparisons in the zonations erected in Newfoundland and EEP, likely as results of important hiatus in those areas. This explains the absence of *Eliasum ilaniscum* in the lower A2 zone in Newfoundland, while in IMC4 and lower IMC5 this species is very abundant, decreasing sharply in abundance in the upper part of IMC5, to disappear at the base of IMC6. The upper part of the IMC5 zone which record the first appearance of *Cristallinium dubium* is equivalent to the VK2 zone of Volkova &
Kirjanov (1995). An important problem to the correlation is the incorrect identification of species diagnostic of the Middle Cambrian, as is the case of *Timofeevia lancarae*, or species of *Cristallinium* (Palacios et al. 2009). For example, the diagnostic characters of the specimens assigned to *T. lancarae* in the Lower A2 zone in Martin & Dean (1988), do not correspond to *T. lancarae* sensu Cramer & Diaz de Cramer (1972), whose first appearance defines the IMC4 zone. Palacios et al. (2009) includes most of the specimens of *T. lancarae* illustrated in Martin & Dean (1988) in the synonymy of *Stelliferidium magnum*, a form that appears in the younger IMC6 Zone. The IMC6 zone is characterized by the first appearance of *Stelliferidium magnum*, *Timofeevia microretis* and *T. phosphoritica*. In Newfoundland *T. microretis* appears near the base of the Elliot Cove Fm., in levels with *Agnostus pisiformis* (Martin & Dean, 1988). In the Mira area, Nova Scotia, the first appearance of *S. magnum* occurs in levels that contains *Paradoxides forchhammeri* (Palacios et al. 2009 and personal observations). The base of this zone is located in Barrios the Luna section at the top of the La Barca Mb of the Oville Fm. This assemblage is correlated (Fig. 1) with the Lower A2 zone of Martin & Dean (1988) and part of SK2 of Volkova & Kirjanov (1995).

Upper Cambrian (Furongian) assemblages. The uppermost positive sample of the La Matosa Mb. of the Barrios Formation contains a diverse assemblage that includes several diagnostic acritarchs (Fig. 1). The presence of *Stelliferidium cortinulum*, *Stelliferidium pingiculum* and *Leiofusa staumonensis* allows to correlate this assemblage with the A3 Zone of Martin & Dean (1988) and VK2a of Volkova & Kirjanov (1995). In Barrios de Luna section this association appears below levels with *Skolithos*, which at the top includes a K-bentonite, dated in other areas of the Cantabrian Mountains as latest Tremadoc-basal Floian (477,47 ± 0,93 Ma, Gutiérrez Alonso et al, 2007). This probably means that the base of *Skolithos* level include a major hiatus that represent the Sardic unconformity.
Figure 1. Stratigraphical ranges of acritarchs in Oville and Barrios formations and correlations with Eastern Newfoundland and East European Platform.

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The palynology of Cambrian sediments from the USA has been largely, and sadly, overlooked with only four papers having been published on the subject. In each of these papers, however, new species and genera have been described suggesting the possibility that the coastal waters of Cambrian Laurentia harboured communities of plankton distinct from those found elsewhere in the Cambrian world. Recently collected Upper Cambrian samples from the Nolichucky Shale in Tennessee and the Upper Gros Ventre Formation in Wyoming, USA, have not disappointed and have yielded a widely varying array of palynomorphs. These include the more familiar arthropod spines, sphaeromorphs, small acanthomorphs (spiny acritarchs) and filaments. However, alongside these are a group of unknown (to the Cambrian) and anomalously large spinose acritarchs (LSAs) (Figure 1).

(Figure 1. Two large spinose acritarchs from the USA: LSA 1 from the Nolichucky Shale in Tennessee; LSA 3 from the Gros Ventre Formation in Wyoming.)

Four new LSA species (LSAs 1-4) have come to light, possibly representing three genera. They all range in size from 90µ-140µ, which is large for the Cambrian; most
Cambrian acanthomorphs are <50μ. And although very well preserved they occur in low numbers of roughly <0.5 specimens per gram. Whole specimens are rare.

The determination of their provenance is ongoing and their presence prompts a number of questions: Why have LSAs not been found previously in the Cambrian? Are they phytoplankton or something else? One LSA species, in size and general morphology, more resembles the diapause eggs of a modern copepod than any Palaeozoic acritarch. Are they related to the large ornamented acritarchs of the Ediacaran which seemingly disappeared at the end of that period? This talk will address all these questions and discuss the possible origins of these seemingly rare and enigmatic microfossils.
PALAEOBOTANICAL INVESTIGATION OF A NEGLECTED COALFIELD: THE COALPIT HEATH BASIN OF THE BRISTOL COALFIELD

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At the Late Carboniferous (Westphalian-Stephanian) boundary a dramatic turnover event is evident in the floral record of the tropical Euramerica peat mires. Lycopsid diversity and abundance is severely reduced, and the more tolerant tree ferns became dominant. This is believed to coincide with the mires contracting to nearly half their pre-Stephanian size. The causes of this floral event are uncertain, but probably relate to substrates drying out due to tectonic uplift, that possibly also coincided with a period of global climate change.

This study focuses on the palynology and palaeobotany of the much overlooked Upper Coal Measures of the Bristol coal field. The Bristol coal measures have so far yielded well preserved examples of some very rare and unusual palynomorphs, some of which have never before been recorded in Britain. Cyclicity in the dominant flora is seen in the sequence, likely driven by fluctuations in the moisture levels in the mires. Superimposed onto these “humid-dry” cycles, a progressive switch to a more dry-tolerant flora can be seen. Well preserved conifer and pteridosperms pollen in the Westphalian coal seams indicate that the coal swamps of Bristol were dominated by a more xerophytic flora than the surrounding coal fields. The thin and sporadic nature of most of the coal seams and rare associated Lycopsid megafossils are also strong indicators that this relatively small area of the Westphalian aged Euramerica forest may have been drier than previously thought.
PALYNOSTRATIGRAPHIC STUDY OF THE CAVEIRA MINE  
(NW SECTOR OF THE IBERIAN PYRITE BELT, PORTUGAL) 

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In the NW sector of Iberian Pyrite Belt, the geology is dominated by complex antiformal structures, as we can observe in the Lousal and Caveira old massive sulphide mines, both located at the Azinheira de Barros region. The age of the lithostratigraphic units of these structures is still poorly constrained and subsequently palynostratigraphy revisions are being undertaken. The Caveira mine is located in a complex N-S trending antiformal structure, with a core composed of shales and quartzites belonging to the Phyllite-Quartzite Group (PQG), surrounded by felsic volcanics and volcanoclastics of the Volcano-Sedimentary Complex (VSC) (Oliveira et al. 2006, Matos, 2006, Figure 1). Several massive sulphides, <10m thick lenses, occur near the PQG/VSC boundary, forming two main ore horizons: the Helena Shaft and the Luísa Shaft. The structure is affected by N-S and NE-SW late Variscan reverse faults. The Grândola Fault limits the Palaeozoic basement in the northern sector of the Caveira mine. The borehole CAV 02 (SMRA 2001 exploration project, 301 m length, 60°,Az 270°, M= -32042, P= -172321) was selected to illustrate the lithological succession and support the palynostratigraphic study.

The following units were identified in the CAV 02 hole from the top to the base: dark shales with thin-bedded siltstones and quartzites (Xn1); felsic porphyritic volcanics (Va); black shales (Xn2) with massive sulphide intercalations (Luisa Shaft orebodies); dark shales with siltstones and quartzitic beds (PQG). The Unit Xn1, interpreted as a PQG equivalent, is thrusted over the felsic volcanics Va and the contact between unit

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Xn2 and the PQG lithologies is faulted (probable shear zone). The black shales of unit Xn1 and also those intercalated in the massive sulphides (Xn2), both gave rich miospore associations of the LN Biozone, of upper Strunnian age, characterized by abundant specimens of *Auroraspora macra*, *Cristatisporites triangulatus*, *Densosporites spitsbergensis*, *Dictyotriletes fimbriatus*, *Discernisporites* sp., *Geminospora spongiata*, *Grandispora comuta*, *G. echinata*, *Knoxisporites literatus*, *Punctatisporites irrasus*, *Retispora lepidophyta*, *Retusotriletes incohatus*, *Rugospora flexuosa*, *Vallatisporites pusillites* and *Vallatisporites verrucosus* together with the index species *Verrucosisporites niditus*. *Maranhites* spp. are also present.

**Figure 1** Simplified Caveira mine geology (adapt. Matos, 2006): FBA - Mértola Fm. Flysch; VSC - Volcano-Sedimentary Complex; PQG - Phyllite-Quartzite Group; T - Tertiary sediments; E - Mine waste tailings. Hayford-Gauss coordenate in km.

The black shales interbedded in the PQG quartzites revealed the presence of moderately preserved miospores indicating the AD miospore Biozone, subzone Lem, of Lower Givetian age. This biozone shows moderately preserved species of *Cristatisporites* sp., *Geminospora lemurata*, *Cymbosporites magnificus*, *Aneurospora greggsii*, *Emphanisporites annulatus*, *Grandispora* sp., *Retusotriletes rugulatus*, *Verrucosisporites premnus* and *V. scurrus*. Reworked older miospores of Lower Devonian make part of the assemblage (e.g. *Camarozonotrilestes sextantii* and *Diatomozonotriletes* sp.).

The time gap between unit Xn2 and the PQG covering the Famennian, the Frasnian and part of the Givetian is probably due to the effect of the extensional fault between
the two units. Recent U-Pb geochronology data in zircons recovered from felsic volcanics ca. 300m SSE of Luisa Shaft indicates an age of 361±4Ma (Rosa et al., 2008), e.g. upper Famennian. Available palynological data suggest that the age of the Caveira massive sulphides is upper Strunian. This new age achieved, together with the same age determined for the PQG lithologies in the near São Francisco Anticline, located 14 km westward (Pereira et al., 2009; 2010) indicates that these are the oldest sediments of the PQG, ever found at the South Portuguese Zone, were the Iberian Pyrite Belt is included. Other sedimentary units can be older but no fossil record was found until now.

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The Lower Palaeozoic sedimentary basins of India occur mainly in the Tethyan Himalayan region. These sedimentary basins are divided into several sub basins, between the Indus-Tsangpo Suture Zone (ITSZ) in the north and the South Tibetan Detachment Zone (STDZ) in the south. The present study is confined to the Garhwal-Kumaon Tethyan Himalaya of the Chamoli district of Uttarakhand, India. The Lower Palaeozoic rocks are well-exposed close to the boundary with Tibet. The geological formations of interest are, in an ascending order, the Garbyang (Precambrian-Cambrian), Shiala (Ordovician-Silurian), Yong Limestone (Silurian), Variegated (Silurian) and Muth Quartzite (Silurian-Devonian) formations. The Shiala Formation consists of shales, sandstones and limestones and has been extensively sampled for chitinozoans. The greenish-grey silty shale at the lower horizon of the Shiala Formation yielded an abundant but low-diverse assemblage of relatively well-preserved chitinozoans. The assemblage is dominated by two species, i.e. *Belonechitina capitata* and *Belonechitina micracantha*. These have a rather long range in the Middle and Upper Ordovician. This is consistent with available conodont evidence, and with the inferred position of the Ordovician-Silurian boundary higher in the same formation, as suggested by an earlier acritarch study. We thus document the first undisputable evidence for the occurrence of Ordovician chitinozoans in India and, as far as we are aware of, in low-latitudinal Gondwana.
To better understand the biological affinities of cryptospores, micro-FTIR (Fourier transform infrared) spectroscopy analysis has been carried out on isolated specimens from the Late Silurian of Gotland. The geobiochemical results have been compared to spectra of trilete spores, chitinozoans and leiospheres from the same sample. The palynomorphs are all very well preserved as attested by their pale yellow to orange colour indicative of a low thermal maturity. Micro-FTIR spectroscopy indicates that cryptospores display very similar spectra to those of the trilete spores, which are composed of sporopollenin characterised by absorption bands from aliphatic C-H in methylene (CH$_2$) and methyl (CH$_3$) groups, aromatic (C=C and C-H) groups and C=O groups of carboxylic acids. The sporopollenin composition of the cryptospore wall observed here is additional evidence demonstrating the embryophytic affinity of the cryptospores. In addition, several variations in other bands in the spectra of the different miospore morphospecies are evidenced and may be linked to their biological affinity or palaeoecological history.
The main purpose of this study was to determine, using palynological methods, the stratigraphical position of the Radok Conglomerate - the lowest accessible unit of the Amery Group exposed in Prince Charles Mountains (East Antarctica). The existence of late Paleozoic rock in that area is recognized by Ravich (1974 as Early Permian) and Fielding & Webb (1995 as Middle to Late Permian). Radok Conglomerate is composed of olive green and brown, fine to medium grained conglomerates and coarse sandstones. Minor intercalations of finer sediments are present and lenses of coal and coal shales are occurring in the section (Ostrowski & Gola, 2008). This unit is intruded by two anolit sills of Cretaceous age (McKelvey & Stephenson, 1990). Sediments bellow and above these sills is thermally alternated.

Palynological results from Prince Charles Mountains, from sediments bellow the Radok Conglomerate were presented by Lingström in McLoughlin et al., (1997). Her work deals with the palynomorphs of the Permian - Triassic transition (Amery Group, Uppermost Bainmedart Coal Measures and overlying Flagstone Bench Formation).

The palynological samples from the Radoc Conglomerate were from black, dark grey and grey shales, mudstones, coals and coal shales, which were intercalations within sandstones and conglomerate.

Identifiable palynomorphs are present in seventeen from twenty four analyzed samples. The samples yielded a relatively rich, but very poorly preserved palynoflora dominated by spores and pollen grains, among which eighty palynomorph taxa have been recognized. Fifty taxa are placed in open nomenclature. Twenty four spore species and six pollen are illustrated. Three palynological assemblages, new in this region, have been temporarily distinguished (Assemblage I, Assemblage II and Assemblage III).
The Assemblage I contains probably Upper Carboniferous palynomorphs and does not contain palynomorphs typical for Autunian. The Assemblage II may indicate the transition between the Upper Carboniferous and the Autunian, and Assemblage III contains probably Lower Permian palynomorphs and does not contain palynomorphs typical for Upper Carboniferous.

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Permian mixed clastics and carbonates of SE Anatolia (SE Turkey, northern Arabian Plate margin, Fig. 1) were dated by foraminifers in previous studies and also the palynological record can be chronostratigraphically related to the geological timescale (e.g. Stolle 2010). The deposits are in this study correlated over a long distance with Australian strata, the latter dated by brachiopod zonations (details in Fig.2). The palynological assemblages from the Kas Formation (SE Turkey) can be correlated with those of the upper D. ericianus Zone of Western Australia. Pollen and spores of around 20 species were dispersed and embedded approximately at the same time in rocks of the Kas Formation and of the upper Collieburn Member (Western Australia). A similar LOD in the late Wordian and earliest Capitanian of the distinct miospore Corisaccites alutas Venkatachala and Kar has been observed in SE Anatolia (earliest Capitanian) and in Western Australia (late Wordian).
REFERENCES (SELECTED)


Figure 2: Modified from Stolle 2010. The correlation of stratigraphical units and biozones of SE Turkey, the Arabian area and Australia.

Australia: The western Australian brachiopod zones (Archbold 2003) were already related to the Permian international subdivisions (IUGS – International Union of Geological Sciences Global Chronostratigraphy and ICS – International Commission on Stratigraphy). The western and eastern Australian palynozones (= APP, Australian Permian palynostratigraphic units) were well correlated with the same brachiopod zones of former studies, but before Archbold (2003) the brachiopod zones were only erected with relation to the Russian regional stages. In this chart the Australian palynozones are correlated to the brachiopod zones of Archbold (2003) – and each palynozone in relation to the respective brachiopod zones.

Central and southern Arabian Plate: The OSPZ biozones (Oman and Saudi Arabia Palynological Zone) were already related to the Permian international subdivisions (IUGS, ICS) (e.g. Stephenson et al. 2003).

Iraq: Strata and palynozones were already related to the Permian international subdivisions (IUGS, ICS) (Al-Hadidy 2007; Al-Juboury and Al-Hadidy 2008; Stolle 2007).

SE Turkey: Foraminifer zones (Köylüoglu and Altiner 1989) have originally been erected in relation to the Tethyan stage division. Altiner et al. (2000) and Stolle (2007; unpublished data) related SE Turkey strata and biozones to the Permian international subdivisions (IUGS, ICS). The boundary between the Eopolydiexodina and the Chusenella zones could not be defined exactly (Köylüoglu and Altiner 1989). The boundary is related to the earliest or early Capitanian.

The Last Occurrence Datum of Corisaccites alutas in SE Turkey is therefore an approximate datum. The LOD of C. alutas in SE Turkey lies somewhere between the latest Wordian and earliest Capitanian (IUGS, ICS, chronostratigraphic framework of GTS 2004). The LOD of C. alutas in the Collie Basin of West Australia (Backhouse 1991) may also range stratigraphically a little higher (into the latest Wordian) because the zones equivalent to the D. ericianus and P. rugatus zones (APP 4.2 and APP 4.3, see in Backhouse 1991) have not clearly defined boundaries.
In coal-bearing subsurface and surface samples from the Zonguldak Basin of northwestern Turkey and the Dobrudzha Basin, northeastern Bulgaria, well preserved specimens of the species *Torispora securis* (Balme) Alpern, Doubinger & Horst 1965, *T. laevigata* Bhardwaj 1957 and *T. verrucosa* Alpern 1959 occur. The appearance of *Torispora* is related to wet areas, for example to the huge coal swamp forests of the Pennsylvanian. For Moscovian strata, *T. securis* and *T. laevigata* are used as index fossils over wide areas in Western Europe (Clayton et al. 1977, and updates). Both species form a palynozone (SL Zone, Clayton et al. 1977), which is assigned today to the early Moscovian. The established zonal scheme is now also applicable in the southeastern European coal basins of Dobrudzha and Zonguldak, among other spores due to the occurrence of these *Torispora* species. *Torispora* is according to our re-investigations recorded in Turkey up to the Kasimovian. Afterwards a hiatus follows.

In Southeast Anatolia (northern margin of the Arabian Plate), deposition began after a hiatus again in the mid-Permian (Wordian, Guadalupian). Because of the frequent occurrence of spores such as *Torispora*, the Guadalupian deposits were in the past in most studies palynostratigraphically assigned to be older (e.g. Cisuralian, Early Permian). *Torispora* was considered for a long time only as characteristic for the Pennsylvanian. *Torispora* is present in Southeast Anatolia with the species *T. securis*, *T. laevigata*, *T. verrucosa*.

*Torispora verrucosa*, related verrucate forms, and other ornamented forms of *Torispora* show distinctive morphological changes during the period from Pennsylvanian to Lopingian (Late Permian). *T. verrucosa* has in Pennsylvanian times an equatorial total diameter of 20 µm - 30 µm (average). The exine is relatively uniformly ornamented with low verrucae, rounded at the ends. In the Guadalupian, *T. verrucosa* and related verrucate forms have in all the palynological assemblages
(from core material of five wells and outcrops) an average equatorial total diameter of up to around 50 µm. The verrucae are in width and height more prominent and the exine can bear some spinose elements (spinules and spines, Fig. 1). Towards the Lopingian (Late Permian) forms can have a constant spinose ornamentation. Spines are long tapering elements exceeding 1 µm. On the basis of these morphological features, a new species can be defined. Close to the end of the Permian Period, shortly before the last appearance of the genus, verrucate and spinose forms of *Torispora* reach in SE Turkey an average size of up to 65 µm.

Reference


Fig. 1: A specimen of *Torispora* from the Guadalupian of Southeast Anatolia (Turkey) bearing verrucae, spinules and spines.
The age of the oldest Cambrian rocks in the Holy Cross Mountains (HCM) is the matter of discussion. The dark shale succession of the Czarna Formation in the southern HCM were regarded as the oldest Cambrian rock in the HCM, correlated with Terreneuvian Series (Orłowski, 1992). However, Moczydłowska (in Lendzion et al., 1982 and Kowalczewski et al., 1987) basing on the acritarch data postulated that these rocks belong to the Cambrian Series II, i.e., the Holmia and Protolenus zones in the Baltic subdivision.

The oldest Cambrian acritarch zone, i.e., *Asteridium – Comasphaeridium* (Moczydłowska, 1991) correlated with Terreneuvian Series is represented by simple acritarchs without processes. This assemblages is difficult to unequivocal identification, especially in the case of not numerous and badly preserved assemblages because this kind of microflora can be very similar to the poor assemblages of the younger rocks. Unfortunately this zone has not been unequivocally identified in the Holy Cross Mountains. It seems possible that the part of very poor palynological assemblages reported in some boreholes of southern east margins of HCM (Szczepanik 2009) belongs to the Terreneuvian Series.

The occurrence of acritarchs showing diversified morphology (e.g. characteristic *Skiagia* species) appears to be related to the next stage in development of the Cambrian microflora in the HCM. This worldwide noted microflora is common in the sedimentary record of the Cambrian Series II (e.g. Downie 1982; Volkova et al., 1983; Hagenfeldt 1989; Moczydłowska 1991, 1998; Szczepanik 2000). In the HCM this assemblage was reported in the Lower Cambrian rocks of the Kielce Region, i.e., the Kamieniec, Czarna and Ociesięki Formations (Lendzion et al., 1982; Kowalczewski et al., 1987; Żylińska and Szczepanik, 2009). The recognized specimens may be related to the *Skiagia - Fimbriaglomerella, Heliosphaeridium* -

It is noteworthy that in samples from HCM assemblages in which Lophosphaeridium dubium and Globosphaeridium cerinum without acritarchs belonging to Skiagia genera are present (Szczepanik 2009). Moreover, it is interesting that acritarchs of S. ornata and S. orbiculare always occur together with S. ciliosa indexed for Heliosphaeridium- Skiagia zone. Those information can be useful for more precise acritarch subdivision in the future (Szczepanik 2008).

It is noteworthy that in the HCM numerous Volkovia dentifera, Liepaina plana and Skiagia insigne are detected in outcrops and boreholes. All of those forms are characteristic for upper part of Cambrian Series II (acritarch zone Volkovia - Liepaina) but rare in the other areas of the world (Żylińska, Szczepanik 2009). The conspicuous acritarch extinction recognized at the Series II/III boundary is manifested by replacement of characteristic Lower Cambrian forms by a new specimens represented by: Eliasum, Adara, Cristallinium and Timofeevia. Their gradual appearing allowed to distinguish dozen of acritarchs zones (M-I - M-XII).

The M-I zone is characterized by co-occurrence of acritarchs from the transition between Series II and III: Liepaina plana, Skiagia insigne, Heliosphaeridium notatum, Eliasum llaniscum, Volkovia dentifera together with forms which until present day were considered to be typical for the Middle Cambrian: Comasphaeridium silesiense, Adara alea and Adara cf. undulate. This assemblage lacks of Cristallinium which is very numerous in the younger parts of the Middle Cambrian. The assemblage M-I can be probably correlated with lower part of trilobite zone A. oelandicus.

The M-II zone was distinguished due to numerous forms of Cristallinium cambriense as well as first appearances of Cymatiosphaera cramerii. In microfloral assemblages, spherical forms of Leiosphaeridia dominate. Acritarchs from informal assemblage Herkomorhitae (genera: Cristallinium, Cymatiosphaera, Dictyotidium, Retisphaeridium and Eliasum) are also very numerous. Acanthomorphitae are represented by taxonomically diversified genera Heliosphaeridium. In the considered zone the most popular are: C. cambriense, C. cramerii, Eliasum llaniscum and Eliasum sp. It’s noteworthy that microflora of M-II zone, is devoided of Timofeevia. This zone may be correlated with the A. oelandicus trilobite zone up to middle part of the P. paradoxissimus zone.
The next microfloral M-III zone is defined by the appearance of Timofeevia sp., T. phosphoritica and less common T. cf. lancaræ, accompanied by Cristallinium cambriense, Cymatiosphaera, Dictyotidium, Retisphaeridium, Acanthomorphitae. The last group is represented by Heliosphaeridium and Multiplicisphaeridium. The latter form occurs first time in the Cambrian section. The considered acritarch zone appears to be correlated with the P. paradoxissimus and middle (?upper) part of P. forchhammeri trilobite zone.

The M-IV zone is defined by the first appearance of acritarch with completely new type of morphology. Acritarchs from the „galeate” (informal group) were found for the first time in the Cambrian sections and they are represented by: Cymatigalea cf. C. cristata, Cymatigalea velifera and Stelliferidium glabrum, accompanied by numerous Vulcanisphaera. The latter form is represented only by specimens with short processes belonging to Vulcanisphaera spinulifera. Numerous acritarchs of the older zones were found in the assemblage of this zone as well, mostly species of Timofeevia (T. phosphoritica and T. lancaræ) and Multiplicisphaeridium. The first occurrence of Pirea orbicularis was also noticed in this zone. The chronostratigraphic position of this microfloral zone can be related to the lowermost Furongian what is supported by comparisons of acritarch and trilobite data from the borehole Narol PIG 2 nearby Lublin (SE Poland). This comparison indicates that the M-IV acritarch zone is coeval to the Homagnostus obesus trilobites zone (Lendzion in: Jendryka-Fuglewicz 1995) which correlates with the lowermost Furongian Glyptagnostus reticulatus zone.

The acritarch assemblage of the M-V zone is represented by Vulcanisphaera turbata, Cymatigalea bellicose, V. spinulifera and morphologically diversified Multiplicisphaeridium. The gradual decreasing of acritarch specimens and final disappearance of Timofeevia lancaræ was reported in this zone. The lack of precise trilobite data impedes the correlation of the M-V zone with trilobite subdivision, however, scarce data suggest that this acritarch zone may correspond to the Scandinavian Olenus zone.

The M-VI zone was recognized in the Narol PIG 2 borehole. In the HCM it was found only in few samples from the Wiśniówka quarry and it is characterized by presence of Vulcanisphaera africana. Rocks of this zone are dated by trilobites of Protopeltura aciculata (Żylińska et al., 2006). This trilobite taxa proves the presence
of the Parabolina brevispina subzone in the lower part of the Parabolina spinulosa superzone.

The M-VII and M-VIII zones are present only in the Narol PIG 2 borehole whereas in the HCM they were not identified.

The assemblage of the next M-IX zone, is completely different from the mentioned above assemblages. This zone reveals the co-occurrence of numerous Polygonium, and Diacromorphitae forms which have equal number of processes on the poles. The type forms of this community are: Actinotodissus achrassii, Dasydiacrodium obsonum, Lusatia and less common Stelliferidium and Solisphaeridium. Acritarchs belonging to Diacromorphitae, which have unequal number of processes on the poles, are rare and are represented by Ladogella rommelearei. Rocks yielding the considered microfloral assemblage are dated by trilobites of the Protopeltura praecursor zone, however, partially it may correspond to the Leptoplastus trilobite zone.

The M-X acritarch assemblage is characterized by the presence of a numerous and large forms, represented by Solisphaeridium sp. 1, Solisphaeridium sp. 2 and Veryhachium mutabile. The first appearances of Calyxiella izhoriensis and Ellenia armilata were also noticed. Other palynological features of this assemblage remain the same as in the M-IX zone. Perhaps this presence of the microflora is not stratigraphically conditioned, nevertheless it is the effect of good environmental conditions. The M-X assemblage is accompanied by numerous trilobites of the Ctenopyge tumida and C. affinis zones (Żylińska 2002).

The M-XI zone was defined by the first occurrence of Ladogella rotundiformis that appears together with Acanthodiacrodium snookense, Arbusculidium sp. cf. A. polypus, Ocidium div. sp. and Vogtlandia notabilis. The most of acritarch taxa reported in these assemblages belong to the species and genera existing in older zones. It seems that the high taxonomic diversity and significant dynamic of changes in taxonomical composition of assemblages may in future be the basis for more precise biostratigraphic subdivision of this zone. Nowadays, it is possible to notice two characteristic acritarch populations in the discussed microflora. They may be the basis for distinction of two sub-zones: M-XIa and M-XIb. The former is characterised by the first appearance and numerous presence of Acanthodiacrodium snookense, whereas the latter sub-zone is defined by the first appearance of Arbusculidium sp. cf. A. polypus and A. polypus. Acritachs from sub-zone M-XIa are
present in rocks dated by trilobites of the *Ctenopyge linnarsoni* zone ( Żylińska 2002). The sub-zone M-XIb is not precisely dated and can be related to trilobite superzone *Peltura s.l.*

The *M-XII* zone is the last distinguished microfloral assemblage characteristic for the Cambrian/Ordovician boundary. It is defined by the presence of *Arbusculidium destombesii*, *Acanthodiacrodium cf. angustum*, *Nellia sukatschevii*, *Cymatiogalea cristata*, *Poikilofusa* sp. 1, *Trichosphaeridium* div. sp., ?*Baltisphaeridium* sp., *Vogtlandia notabilis*. This assemblage is accompanied by trilobites of the uppermost Cambrian *Acerocare* zone but it can not be excluded that the considered acritarch community represents the lowermost Tremadocian. The latter seems highly plausible since the *M-XII* assemblage is commonly reported worldwide in sections of the Cambrian/Ordovician boundary.

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Sandy mudstones and sandstones of the Zalesie Formation (up to 6 m thick) intercalated by thin shales and marls delineate the top of the Ordovician succession in some localities of the Holy Cross Mountains (HCM, SE Poland). These deposits are dated by trilobite species of *Mucronaspis* and brachiopods of the Hirnantia fauna (Kielan, 1959; Temple, 1965). The sedimentary record indicates that reworking and redeposition were important processes during the deposition of the Zalesie Formation. It is enhanced by the textural and compositional immature of mudstones and sandstones. This formation records the final stage in the upward progradation of the Upper Ordovician mudrock facies, related to the early Hirnantian glacio-eustatic regressive event (Trela, 2007).

In the southern margin of the HCM (Zbrza and the Szumsko Kolonia 2 well) the sandy mudstones of the Zalesie Formation yielded the acritarch assemblage displaying predominance of *Veryhachium* (more than 70%) accompanied by *Domasia, Deunfia, Leiofusa, Polygonium, Cheleutochroa, Multiplicisphaeridium* and *Polygonium*. It is noteworthy that these forms occur together with *Acanthodiacrodium angustum, Timofevia phosphoritica, Vulcanisphaera africana, V. turbata* and species of *Frankea, Cymatiogalea, Actinotodissus*. The latter forms are commonly reported in the Furongian to Lower Ordovician deposits apart from *Frankea* that was recognized hitherto only in the Middle Ordovician of the peri-Gondvanan provinces (Servais, 1993).

The pre-Hirnantian acritarch community in the Holy Cross Mountains consists of *Baltisphaeridium, Excultibranchium, Multiplicisphaeridium, Ordovicidium, Orthosphaeridium, Peteinosphaeridium, Polygonium* with subordinate *Veryhachium* detected in the lower Katian mudstones/shales of the Stawy Formation in the Szumsko Kolonia 2 well. The increasing frequency of *Veryhachium* was reported in

The Middle Ordovician acritarch community in the HCM is of the Baltic type (Szczepanik, unpublished data) since in Ordovician the HCM area was positioned at the margin of Baltica. Thus, the occurrence of the Middle Ordovician peri-Gondwanan exotic acritarchs in the Hirnantian microphytoplankton assemblage of the Zalesie Formation appears to be associated with their redeposition from an area located outside the HCM. Basing on the palaeogeographic reconstruction of Baltica in Late Ordovician it seems feasible that the most plausible source area for *Frankea* in the Zalesie Formation was Avalonia that collided with Baltica during the considered time interval. The Furongian – Lower Ordovician acritarchs in the Hirnantian community might have been delivered from the HCM localities subjected to erosion in Late Ordovician.

**REFERENCES**


WHAT CAN SPORE WALL ULTRASTRUCTURE TELL US ABOUT AFFINITY AND EVOLUTION OF THE DEVONIAN FORM GENERA *EMPHANISPORITES* AND *CAMAROZONOTRILETES*?

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Prior to the evolution of extensive recalcitrant tissue in the bodies of land dwelling plants, spores represent the most widespread evidence of plant biodiversity. In some cases, a particular type of spore may be widespread and distinctive, but the organism(s) that produced it may be completely obscure. The genus *Emphanisporites* is one such type, its members possessing radiating sculptural patterns on their proximal surfaces. We used transmission electron microscopy (TEM) to examine several species in an attempt to assess variability within the genus. The species examined include *E. rotatus*, *E. annulatus*, and *E. schultzii*, all obtained from the Emsian of Gaspé, Canada. One specimen is also morphologically very similar to *E. erraticus*. A certain degree of ultrastructural variability exists both between taxa and within taxa. This is unexpected, and suggests that different plant groups may have produced these spores, seemingly converging on a common structural theme that is apparent when viewed under light microscopy. It is possible that some of the differences seen may be attributable to natural variation, developmental stage, or preservational vagaries, but we discount these as the only agents. Two characteristic ultrastructural features were noted in specimens of *E. rotatus* and *E. schultzii* that are found among extant plants only in the hornworts. This small group of extant bryophytes produces very little in the way of decay resistant tissues, which is consistent with its absence in the fossil record. These two Devonian spores would represent the earliest record of this group by several
geologic periods. Some specimens exhibit aperture and wall features similar to spores of fossil and extant lycophytes, again suggesting the possibility these spores were produced by more than one parent plant taxon. *Camarozonotriletes sextantii* has a two-layered wall (based on staining reactions), and a well-developed cingulum. There is some suggestion of lamellae and spaces within the wall, including within the cingulum. Possible affinities suggested by ultrastructure in this spore type are less certain, though parallel research suggests an association with the enigmatic Lower Devonian genus *Chaleuria*.

Left: Light micrograph of two specimens of *Emphanisporites rotatus*. White lines show locations of cross sections shown in middle (white line in upper left) and right (white line at lower left) of page. Size bar = 10µm.
Middle: TEM cross-section at upper left white line in light micrograph (at left).
Right: TEM cross section at lower right white line in light micrograph.
Size bar = 100nm for both TEM images.
TEM STUDY OF THE MELANOSCLERITE MIRACHITINA QUADRUPEDIS
EISENACK, 1932

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The term ‘melanosclerite’, coming from Greek meaning ‘dark’ and ‘hard’, was introduced by Eisenack (1942) for specimens he described as ‘black rodlets of uncertain origin’ and refers to an artificial group of palynomorphs. The group includes any small (mostly 50-1500 microns), organic-walled microfossils that cannot be assigned to any natural group. Previously, Eisenack (1932) had conducted analysis of microtome slices of melanosclerites, stating that the internal structures in ‘all Melanoskleritoiden show no cell construction in cuts’. Eisenack (1942) published the first picture of a melanosclerite cross section from a 2x2 cm microtome slice of Melanocladus sp., though this did not reveal any internal structure. He recognized a concentric construction on appositionelles wax. The absence of a typical cell structure was proof for Eisenack (1942) that the melanosclerites were not animal fossils, though the illustration is not of a high quality and may therefore be misleading. Górka (1971) also examined microtome slices of melanosclerites and likewise did not find any cellular structures, but she did observe an internal concentric nature to the specimens. Górka (1971) also observed an axially eccentric canal in some specimens of Melanoskleritoites anceptiferus Eisenack though these illustrations are also not particularly clear. Interestingly, the specimens of Eisenack (1942) also show canals that occur off-axis. Schallreuter (1981) illustrated transmission electron microscope (TEM) studies of melanosclerites. He described the internal construction as being similar to bone and distinguished two layers: a condensed, thick and relatively even outside layer which he termed ‘kompakta’, and a less stable, spongy inside layer, termed as ‘spongiosa’. The spongiosa layer can be penetrated by a central hollow canal shown by reflection electron microscope (REM) images of Menola os Schallreuter, 1981 and Melanoporella clava Schallreuter,
1981. The material for the present work exclusively comes from the unweathered Gotländer type. For the processing 120gs of the material were chopped up and laid in 40 % hydrofluoric acid for 3 days. The indissoluble remains were washed out with water and sieved afterwards. The fossils were isolated individually from the floating by means of pipettes. Additionally, special ergonomically crooked short pipettes were used. With those pipettes the desired objects can be drawn with relatively low loss rate (<5%) and then be blown out in a Peter’s bowl. The TEM admissions of *Mirachitina quadrupedis* Eisenack, 1932 were made in the Institute of Microbiology, University of Greifswald, Germany. After a fixation step (2 hours in 3 % glutaraldehyde), samples were treated with 1 % osmium tetroxide for 3 hours and 2 % uranyl acetate for 2 hours with washing steps in between. The samples were dehydrated in a graded series of aqueous ethanol solutions (10 – 100 %) and then embedded in Spurr’s resin. Ultra-thin sections were stained with 4 % uranyl acetate and Reynold’s lead citrate, and examined using a Zeiss EM 906 electron microscope (Zeiss, Oberkochen, Germany). *Mirachitina quadrupedis* is a long rod-shaped melanosclerite with a distal end displaying four rounded prongs (the proximal end being broken off), and sections were made through both the distal and the damaged proximal ends. In the cross section of the distal area the four prongs can be distinguished, although they are weakly separated. The internal area of the distal end is filled with a large-pored spongy material. This spongy mass is also apparent in the interior of the proximal end, though it is finer-pored and more compact. The centre of the proximal end shows a more or less hollow central canal that runs through the specimen but stops before the distal part with the four prongs begins and the proximal parts closes. In contrast to Eisenack (1942), Górka (1971) and Schallreuter (1981) could not clearly observe a concentric internal structure. Therefore, the new TEM images produced for this study do not provide unequivocal data concerning the internal structure of the melanosclerites, though they do reveal a difference between different genera and species.

**References**


A: distal part of Mirachitina quadrupedis

B: proximal part of Mirachitina quadrupedis
Recently, it has been shown that Ordovician chitinozoans, like graptolites, were “mixed layer” marine zooplankton and that their global distribution was primarily controlled by variations in Sea Surface Temperature. Here, we present new data on the palaeobiogeographical distribution of chitinozoan biotopes during the end-Ordovician Hirnantian glacial maximum (440Ma). These are compared to those from the Sandbian (460Ma). We demonstrate that severe cooling towards the Hirnantian glacial maximum resulted in (i) a steeper latitudinal temperature gradient and (ii) an equator-ward shift in the position of the Hirnantian austral Polar Front from 55-70°S to 40°S. This is deduced from an expansion and diversification of the Polar fauna. These changes are equivalent to those in Pleistocene glacial maxima. Our data show that Late Ordovician surface ocean temperature gradients, and their response to climatological changes, may have been much more similar to modern oceans than hypothesized before. This information critically affects how we conceptualize Late
Ordovician climate change and how we should define boundary conditions for numerical climate models. Significantly, our data suggest that a disruption of marine habitats and net reduction in ecospace in mid-latitude biotopes, in front of the advancing Polar Front and as a consequence of rapid climate change, resolves as a likely cause of the mass extinction in the zooplankton at the end of the Ordovician.
CHITINOZOANS IN $\Delta^{13}C_{\text{org}}$ STUDIES: A REVISION OF METHODOLOGY

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$\delta^{13}C$ isotope-event stratigraphy is of growing importance for correlation in the Early Palaeozoic. Paris et al. (2008) criticized $\delta^{13}C_{\text{org}}$ analyses on Early Palaeozoic bulk whole-rock samples, because reworked organic compounds, undetected in the bulk sample, can alter the $\delta^{13}C_{\text{org}}$ signal. On the other hand, $\delta^{13}C$ analyses on selected chitinozoans were thought to require 1000 to 1500 hand-picked and cleaned specimens per analysis, which was considered too labour intensive for routine analyses.

We have conducted a series of experiments, aimed at developing and refining a protocol for $\delta^{13}C$ analyses on selected chitinozoan species and specimens. Chitinozoan samples were analysed using a Costech EA connected to a ThermoFinnigan Delta V Advantage isotope-ratio mass-spectrometer. Isotopic analyses ($^{13}C/^{12}C$ and $^{15}N/^{14}N$) were performed on chitinozoan samples in tin cups, based on the number of specimens within each sample and species. The newly established protocol allows the analysis of 10 to 300 specimens, depending on size (which is species specific). This means that $\delta^{13}C$ on selected (medium-sized) chitinozoan species can become a routine technique. We consider this an important advancement in using chitinozoan-specific $\delta^{13}C_{\text{org}}$ for isotope stratigraphy purposes.

A second aspect of our work involves a test of the hypothesis that fine fraction (<53 microns) organic residues from palynological samples can be used as carbon sources for $\delta^{13}C_{\text{org}}$ analyses, and that these results can be used as a proxy for whole-rock samples (Vanmeirhaeghe et al. 2005). Here, we present and compare $\delta^{13}C_{\text{org}}$ curves from whole-rock samples and palynological fine fraction residues from key Upper Ordovician sections in the Anglo-Welsh Basin (UK) and the Scottish
Southern Uplands (UK). This also results in the first comprehensive $\delta^{13}C_{\text{org}}$ isotope-event stratigraphic framework for the Caradoc and Ashgill in their historic type areas.

REFERENCES


The sequence of Silurian age of central Portugal outcropping in Amêndoa-Mação Syncline (figure 1) comprises four formations: Vale da Ursa, Aboboreira, Castelo and Chão Lopes (Cooper, 1980, Romão et al., 1998 and Romão, 2000).

Vale da Ursa Formation was characterized by dark, pyritic and micaceous quartzites and sandstones, a age Rhuddanian to Aeronian is accept for the top of formation based in graptolites (Piçarra, 2007).

The Aboboreira Formation is a micaceous black shale sequence with sandstone intercalations, that grade upwards into dark silstones, a age Aeronian to basal Homerian is accept based in graptolites (Piçarra, 2007).

The Castelo Formation was characterized by shales and siltstones intercalated with grey quartzites, an age upper Wenlock to Ludlow is accepted because the stratigraphical position.

The Chão Lopes Formation was characterized by shales with nodules intercalated with centimetric levels of shales and micaceous siltstones, an age upper Ludlow to lower Pridoli is accepted by lateral correlation with Foz da Sertã Formation (Cooper, 1980) in Dornes sector.

We collected 10 samples in Castelo Formation and 6 in Chão Lopes Formation. These formations yield moderately well-preserved chitinozoans.

The samples from Castelo Formation yield a chitinozoan association with Cingulochitina convexa (Laufeld, 1974) and Angochitina echinata Eisenack, 1931, suggesting the elongata and philipi Biozones of Ludlow age (upper Gorstian to early Ludfordian). The samples of Chão Lopes Formation yield a chitinozoan association with Urnochitina urna Eisenack 1934, which is the chitinozoan index of the Pridoli.
That data indicating a Ludlow age for the Castelo Formation and a Pridoli age for the Chão Lopes Formation. These biostratigraphic results are in agreement with the age of the graptolites recovered by Piçarra (2007) in the underlying Vale da Ursa and Aboboreira Formations.

Fig. 1 – Localization of samples and Amêndoa – Mação Syncline (Adapt. Geological Map of Portugal, 1/50,000 (28-A Mação), IGM, 2000, (Romão, 2000a)).

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The Pragowiec Ravine in Holy Cross Mountains, Poland, is considered a standard section for the Silurian of southern Baltica in its deeper shelf facies with black graptolithic mudstones. The well preserved graptolites have attracted since long many researchers as well as collectors. They were studied and Tomczyk (1962), Tomczykowa & Tomczyk (1981) and Kowalczewski & Tomczyk (1981) established a stratigraphical division. Recently, graptolites were recollected and restudied in more detail by Porębska (in Masiak 2007). Masiak (2007) has studied the acritarchs of the section and she found an assemblage, that diversification and frequency varies during the interval from lundgreni-testis biozone to nilssoni biozone. Samples from younger zones are moderate frequent, but more diversified.

Because the ravine is a standard section for a part of the Silurian succession in southern Baltica and the graptolite biozonation is now well established, especially for the entire interval from the Homerian to lower Ludfordian (upper Wenlock to Ludlow), we conducted a preliminary study of the chitinozoans of this section in order to calibrate the three biozonations versus one another.

Chitinozoans have been extracted in this preliminary study from 20 samples collected by one of the authors (M.M.) and prepared according to the standard palynological techniques. One sample comes from the Ludfordian leintwardinensis biozone (PR27/1), ten samples from the Gorstian: hemiaversus biozone (PR26/1, PR26/5), scanicus biozone (PR25/4), nilssoni biozone (PR23/3, PR22/3, PR21/3, PR20/3, PR19/4, PR17/4, PR16/2); nine from the Homerian: gerhardi biozone (PR15/3); ludensis biozone (PR13/2); deubeli biozone (PR11/1); praedeubeli
The recovered chitinozoans from the 20 samples are rather moderately preserved and often broken. The assemblages are dominated by Eisenackitina spp., Conochitina spp. and Sphaerocritina spp. and furthermore Ancyrochitininae with often broken appendices. In some levels the index species or other characteristic species for certain biozones as Cingulochitina cingulata, C. serrata and C. convexa is observed.

The chitinozoan biozonation in this newly studied section will be compared with the global biozonation of the Silurian (Verniers et al. 1995) and with regional biozonations as in Gotland situated in a shallower facies of Baltica (Laufeld 1974; Nestor 1994), with the type area of the Wenlock and Ludlow in the Wales and the Welsh Borderland (Sutherland 1994; Verniers 1999), and with the Silurian section in the Brabant Massif and Condroz Inlier (Verniers 1983) (all areas belonging to Avalonia and with other sections in other palaeocontinents.

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CHITINOZOANS IN *ADELOGRAPTUS TENELLUS* GRAPTOLOITE ZONE OF THE LATE TREMADOCIAN (EARLY ORDOVICIAN) FROM YIYANG, SOUTH CHINA

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The Lower Ordovician argillaceous succession of Nanba Section, Yiyang area, Hunan Province, South China (South China terrane) belongs to the Jiangnan Region, which is characteristic of slope facies sediments (Fig.1). A rich assemblage of chitinozoans is recorded from the *Adelograptus tenellus* Graptolite Zone which is the lowest graptolite biozone of the Upper Tremadocian (Fig.1). This chitinozoan assemblage occurs in the lowest level discovered in China so far.

Figure 1 - Location map of Nanba area (according to Feng et al., 2009); Legend: Q=Quaternary; K=Cretaceous; C=Carboniferous; D=Devonian; S=Silurian; O=Ordovician; Cam.=Cambrian; Z=Neo-Proterozoic; Pt2=Mesoproterozoic; Pt3= Neo-Proterozoic; α, andesite; β, basalt; γ, granite. Inset: location of study area within larger structural units of South China. From west to east shows an increasing depth of water.
The chitinozoans are moderately well preserved, in low abundance (between 0.1 and 3.3 chitinozoans per gram of rock) but the assemblage is characterized by high diversity. Two genera and ten species at five different stratigraphical levels were identified (the other 15 samples were found to be barren). They include five *Lagenochitina* species and five *Conochitina* species (Fig. 2). For global correlation purpose, the important Ordovician chitinozoan index species *Lagenochitina esthonica* Eisenack, 1955 has its FAD in the *Adelograptus tenellus* Graptolite Zone (Fig. 2). *L. esthonica* is also the index species of the third chitinozoan biozone in Laurentia. However, the systematic position of our specimens need further study, because in literature three different forms have been determined in *L. esthonica*.

Figure 2- Chitinozoans from the Yinzhubu Formation, Nanba section (L-Dp-Dc).


The new South China material allows calibrating the lowest chitinozoan assemblage versus the lowest Upper Tremadocian graptolite biozone in South China. The finding that chitinozoan assemblage of Nanba includes several taxa in common with coeval ones in Baltoscandia during the late Tremadocian is also significant with respect to palaeobiogeography of early chitinozoans and the early start of the chitinozoan diversification.
Analysis of dispersed spore assemblages from the Late Silurian-Early Devonian indicates pronounced palaeophytogeographical differentiation between dispersed spore assemblages from Euramerica (‘Old Red Sandstone Continent’) and Gondwana. Recently these differences have been quantified in terms of dispersed spore assemblage taxonomic composition, taxon diversity and morphological disparity (e.g. Steemans et al. 2010, in press). A striking difference is the presence of a highly distinctive group of spores reported from PeriGondwana (Cantabrian Mountains of Spain and Massif Armoricain of France) (e.g. Cramer & Diez 1975; Le Herisse 1983; Rodriguez 1983; Richardson et al. 2000) with occasional reports extending south into Northern Gondwana (e.g. Jardine & Yapaudejian 1968). These highly distinctive spores are characterized by a combination of the following morphological features: (i) cingulate structure; (ii) crenulation associated with the trilete mark; (iii) interradial papillae and/or various inspissations of the proximal wall; (iv) distal annuli or similar prominent constructions. Unfortunately few land plant megafossils have been described from Late Silurian-Early Devonian deposits of PeriGondwana and Gondwana. Consequently nothing is known of the plant group(s) that produced these spores and their palaeophytogeographical significance. In an attempt to shed light on their affinities we have undertaken an analysis of spore wall ultrastucture in a selection of these characteristic spore types. In this talk we will discuss our findings and their implications. A further enigma is the report of typical ‘Cantabrian/Armoricain’ spores in South China (Gao Lianda 1978). We will explore...
the intriguing possibility that their occurrence is a consequence of tectonic assembly rather than palaeophytogeographical distribution.

A typical Cantabrian/Armorican spore (Iberoespora cantabrica Cramer & Diez 1975) from the Lochkovian (Early Devonian) of the Cantabrian Mountains of Spain (spore diameter = 35 μm)

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Three Ordovician Global Stratotype Section and Points (GSSPs) have been defined in South China. The divisions of graptolite biozones provide a precise frame for biostratigraphical correlation in South China. Six Lower - Middle Ordovician sections and four Middle - Upper Ordovician sections were investigated with the aim of discussing the biostratigraphical of acritarch assemblages for the recognition of the acritarch biostratigraphical sequence in South China.

Based on their First Appearance Datum (FAD), some of the taxa recorded might be useful for recognition of the boundary of Ordovician Series in sections where conodonts, graptolites or other fossils are absent. The genera Barakella and Liliiosphaeridium would be indicators of the base of the Dapingian. Ampullula, Orthosphaeridium and Dicrodiacrodium are useful for Early - Middle Ordovician stratigraphical correlation, while Baltisphaeridium dispar, Gyalorhethium chondrodes, Leprotolypa evexa, Lophosphaeridium edenense, and Navifusa anicepsipuncta are useful for Upper Ordovician stratigraphical correlation. Several of the stratigraphically significant taxa are typical of the peri-Gondwanan palaeobioprovince, while others also occur outside of the Gondwana palaeocontinent. The acritarch successions recovered from the South China Plate can therefore be correlated with sequences observed from other peri-Gondwanan areas. In addition, correlations are also possible with other palaeocontinents, in particular with Baltica.

Six acritarch Assemblage Zones (A-F) are established based on the FAD of characteristic acritarch species. The Assemblage Zone A corresponding to the approximatus graptolite biozone is characterized by the FADs of Pachysphaeridium
rhabdocladium, Petaloferidium bulliferum, P. florigerum, Striatotheca pricipalis parva, Veryhachium lairdii, and V. trispinosum. The Assemblage Zone B corresponding to filiformis graptolite biozone is characterized by the FADs of Coryphidium bohemicum, Sacculidium. The Assemblage Zone C corresponding to the eobifidus graptolite biozone is characterized by the FADs of Arbusculidium filamentosum, Dasydorus cirritus, Liliosphaeridium, Pirea sinensis, Ampullula, and Tongzia meitana. The Assemblage Zone D corresponding to deflexus graptolite biozone is characterized by the FADs of Arkonia tenuata, Barakella rara, and Loeblichia heterorhabda. The Assemblage Zone E corresponding to the suecis - intersitus graptolite biozone is characterized by the FADs of Coryphidium elegans, Dasydorus microcephalus, and Dicrodiacrodium ancoriforme. The Assemblage Zone F corresponding to the linnarssoni - gracilis graptolite biozone is characterized by the FADs of Baltisphaeridium dispar, B. onniense, Gyalorhethium chondrodes, Leiosphaeridia caradocensis, Lophosphaeridium edenense, Navifusa ancepsipuncta. Four of six acritarch biostratigraphic zones appear in the Floian Stage, reflecting the rapid evolution of acritarchs in the Early Ordovician.