CIMP Meeting 2015

Abstract book

Sept. 17.-18. 2015

UNIVERSITY OF BERGEN
Department of Earth Science

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Editors: Gunn Mangerud (UoB); Gilda Lopes (UoB); Marco Vecoli (Saudi Aramco); Reed Wicander (CMU)
Date: September 2015

ORGANIZING INSTITUTION
UoB – University of Bergen

Dear fellow palynologists,

On behalf of the Organizing Committee it is with great pleasure I welcome you all to the CIMP conference hosted by CIMP and the University of Bergen, Norway.

This conference, along with its predecessors, has the goal to bring together specialists in Palaeozoic Palynology in order to present their work and to discuss various topics that are relevant within this scientific field. The sessions will be focused on various aspects of Palaeozoic Palynology and we think we have managed to put together an interesting program demonstrating the width, depth and the varied fields within Paleozoic palynology. We also hope the field excursions offered will add some local flavor in addition to complement knowledge and perspectives in order to understand the Paleozoic world even better. Last, but not least, we hope that this type of focused, small conference would encourage open sharing of knowledge and fruitful discussions.

I would like to thank all the colleagues who helped with the logistics and the technical support.
A special thanks to all the participants and authors for their invaluable contributions to this Abstract Book.

We hope you have time to enjoy the meeting and the social events provided and wish you all an enjoyable stay and a great meeting!

Gunn Mangerud

Professor, Department of Earth Science, University of Bergen

The Organizing Committee: Gunn Mangerud, Gilda Lopes (co-organizers), Marco Vecoli (past CIMP president), Reed Wicander (CIMP president).

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LATE ORDOVICIAN (KATIAN) CHITINOZOANS FROM NORTHWEST SAUDI ARABIA: BIOSTRATIGRAPHIC AND PALEOENVIRONMENTAL IMPLICATIONS

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Investigation of 37 samples from continuously cored intervals of the upper part of the Quwarah Member of the Qasim Formation yielded diverse chitinozoan assemblages. Two biozones previously defined from the North Gondwanan Domain were recognized in the examined cores: the *Tanuchitina elongata* and *Ancyrochitina merga* biozones. Detailed sampling within the intervals represented by these biozones allows recognition of five new subzones. They are, in descending stratigraphic order:

- Post-*Hyalochitina* n. sp. 1 Interval Subzone
- *Hyalochitina* n. sp. 1 Total Range Subzone
- *Tanuchitina* sp. 1 - *Belonechitina* sp. 2 Concurrent Range Subzone
- *Tanuchitina* sp. 2 - *Belonechitina* aff. *robusta* Concurrent Range Subzone
- *Tanuchitina ontariensis* Total Range Subzone

Additionally, the total range of *Angochitina* cf. *curvata* is presented here as a potential subzone, occurring below the cored interval. These subzones have the potential to improve regional and local stratigraphic correlations, and the recognition of the degree of the Hirnantian glacial erosion at the top of the Quwarah Member.

Chitinozoan diversity fluctuations in the examined section are not very pronounced. Several subtle trends may be present in the 180-3 well. Three minor diversity and abundance increases are recognized within the uppermost part of the section. These events could represent pulses of sea level rise within a progressive, overall sea level drawdown. For this upper part of the core, a general trend of upward shallowing is suggested. It could be speculated that fluctuations in sea level were caused by ice advance and retreat during the initiation of Hirnantian continental glaciation south of the study area.

A potential evolutionary lineage, based on chamber shape, is proposed. This lineage begins with *Lagenochitina dalbyensis* in the Sandbian (early Late Ordovician), and is represented in the Katian by a new species ("*Haplochitina* n.sp. P" of Al-Hajri, 1995), culminating with *L. nuayyimensis* in the Rhuddanian (Early Silurian). Taxonomic revision of the members of this lineage is proposed.

PALYNOLOGY OF THE CARBONIFEROUS (LATE VISÉAN-PENNSYLVANIAN) SARDAR FORMATION FROM THE HOWZ-E-DORAH AREA, CENTRAL IRANIAN BASIN

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A palynological study has been yielded from the Sardar Formation in one of the best exposures at the Howz-e-Dorah area, Central Iran Basin. Due to the scarcity of biomineralized content, the age of this formation was strongly debated in the geological literature. This study aims to resolve these age discrepancies by palynology. Accordingly, due to the promising lithology, palynomorphs could be the best microfossils to determine the age and the stratigraphic position of the Sardar Formation. By the recorded microflora three palynoassemblages were established. The first one is characterized by palynoelements as *Perotriletes tessellatus, Schulzospora compyloptera, Cordylosporites magnidictyus, Spelaeotriletes owensii, Cyclogranisporites palaeophytus, Verrucosisporites congestus, V. gobbettii, Indotriradites dolianitii* and *Convolutispora circumvallata*. The second one is marked by the appearance of monosaccate pollen grains as *Potonieisporites novicus*, *Plicatipollenites malabarensis* and *Florinites pellucidus*. Acavate and laevigate spores occur in the assemblage with ornamented spores as *Tumulispora rarituberculata* and *Densosporites spitsbergensis*. The last microfloristic assemblage recognized is marked on its base by the abundance of *Punctatisporites* spp. Other forms as *Crassispora kosankei* and *Spelaeotriletes triangulus, Caheniasaccites densus, C. flavatus*, *Florinites junior*, *F. medipudens*, *Plicatipollenites gondwanensis*, *Potonieisporites* spp., *Cannanoropollis* sp. are also present. The last level sampled in the Sardar Formation also yielded sporomorphs as *Vallatisporites arcuatus*, *Barakarites* cf. *rotatus* and *Stotersporites* cf. *indicus*. On the basis of a comparison with coeval microfloristic assemblages from Northern Gondwana regions (i.e. North Africa and Middle East), the Sardar Formation has been attributed to the Upper Viséan-Gzhelian time interval.

PALYNOLOGICAL ANALYSIS OF THE MIDDLE DEVONIAN OF NORTHERN SPAIN: HUNTING FOR THE KAČÁK EVENT

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Northern Spain contains one of the most complete Devonian sequences in Western Europe, with numerous lithologies and formations present, chronicling widely varying depositional environments in a Peri-Gondwana setting. This project aims to describe palynomorph assemblages from the Eifelian and Givetian age Huergas and Naranco formations of Asturias and Castilla y León provinces. These laterally equivalent formations are comprised of large sandstone bodies, interspersed with black shales, positioned between thick limestone sequences. Sites from across the lateral extents of the two formations have been isolated and their palynological assemblages quantitatively analysed to reveal changes in the terrestrial flora and marine biota through time and space. Samples already studied have revealed rich assemblages of land-derived spores and marine palynomorphs (acritarchs and chitinozoans with occasional scolecodonts). The Kačák event is believed to be represented in the upper part of the formations. This event is not well characterised in the Iberian peninsula and its effect on terrestrial floras is very little known. This work is beginning to fill this knowledge gap.

PRELIMINARY CHITINOZOAN DATA FROM THE HLÁSNÁ TŘEBAŇ SECTION, CZECH REPUBLIC – A POTENTIAL REPLACEMENT GSSP FOR THE BASE OF THE AERONIAN STAGE (LLANDOVERY SERIES, SILURIAN)

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The current Global Stratotype Section and Point (GSSP) for the base of the Aeronian, the Trefawr Track Section (Wales, UK), has known limitations in terms of its biostratigraphical constraint. As such, a working group of the International Subcommission on Silurian Stratigraphy (ISSS) is currently assessing potential candidate sites as replacements for this stratotype section.

One such section, at Hlásná Třebaň on the south-eastern margin of the Prague Basin (Czech Republic), has been proposed by a team of Czech researchers headed by Petr Štorch. Graptolite biostratigraphical data (for which the section is particularly well-known), have allowed for precise identification of the Rhuddanian-Aeronian boundary within the section, with all key index taxa present. Carbon isotope data have also been analysed recently, alongside other geochemical analyses for the section. Palynological samples were processed in order to provide biostratigraphical data based upon chitinozoans, which have been recorded previously from the section.

The preliminary results from the first six samples processed are presented herein – in total forty-two samples will be analysed, from each of which diagnostic graptolites had been recovered. Samples were processed using the 'standard' HCl-HF-HCl process, sieved through 500µm, 53µm, and 10µm nylon meshes respectively, and the organic material separated using sodium polytungstate at a specific gravity of 2.0. The organic residues from these preliminary samples yielded a moderate diversity of chitinozoans, in reasonable abundance, amongst large amounts of structured organic matter (predominantly graptolite fragments). Quantitative analyses (i.e. chitinozoans per gramme) have not yet been calculated.

The Rhuddanian-Aeronian boundary is situated within the lower part of an existing global chitinozoan biozone (the *Spinachitina maennili* biozone), and as such it is not marked elsewhere by the appearance of a particular chitinozoan taxon – the base of the Aeronian is defined by the first appearance datum (FAD) of the graptolite *Demirastrites triangulatus*. Fourteen taxa have been identified so far, that show an affinity with Baltic and northern Gondwanan assemblages. The characteristic early Silurian species *Belonechitina postrobusta* and *Spinachitina fragilis* have been recovered from the lower samples, though the occurrence of the latter is unusually high stratigraphically – more specimens must be recovered and analysed from the samples, however, before definitive ranges can be established. Two other taxa recovered, *Conochitina edjelensis* and *Ancyrochitina convexa*, may help to position the Rhuddanian-Aeronian boundary, as both were recorded by Viiu Nestor as having their FAD within the *S. maennili* biozone, at the base of the Aeronian. More data, and analyses of global records must be assessed before the true value of these taxa as markers for the boundary can be established.

PALYNOMORPH DARKNESS INDEX (PDI) — A CASE STUDY FROM THE CARBONIFEROUS OF NORTHERN SAUDI ARABIA

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Palynomorph Darkness Index (PDI) is a fully quantitative method for assessing the darkness of palynomorphs in transmitted light using standard palynological microscopes and digital cameras. It provides a rapid and inexpensive means of estimating thermal maturity that can be deployed during routine palynostratigraphic investigations.

Saudi Aramco Well A is a cored stratigraphic borehole drilled in Northern Saudi Arabia that penetrated the Carboniferous uppermost Jubah, Berwath and Unayzah formations. The stratigraphic interval studied is *ca.* 1,900 feet thick and covers the critical maturity range of submature to the top of the oil window. A detailed investigation of the thermal maturity of this section has been completed as part of a joint study between Saudi Aramco and C.I.M.P. This has comprised determination of Palynomorph Darkness Index (PDI) calibrated against vitrinite reflectance (R_{oran}).

Numerous palynomorph taxa have been assessed with regard to their suitability for PDI determination. The smooth, simple miospores *Retusotriletes* spp. and *Waltzispora* spp. with the prasinophyte *Tasmanites* spp. proved most useful. PDI measurements on these taxa indicate a gradual increase in thermal maturity with increasing depth through the Carboniferous section, fully consistent with R_{oran}. Considerations such as the minimum number of PDI determinations needed to produce reliable results and the main sources of errors are discussed, together with the correlation of PDI with other maturity indicators, such as Spore Color Index (SCI).

NEW PALYNOLOGICAL DATA AT THE PERMIAN-TRIASSIC TRANSITION IN THE MOATIZE-MINJOVA BASIN, MOZAMBIQUE

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The Permian-Triassic transition has been identified for the first time in the Karoo Supergroup at the Moatize-Minjova Basin in Mozambique. This transition was recognized in the subsurface in deep (*ca*. 500 m) coal exploration boreholes that penetrated the base of the Matinde Formation and the top of the coal bearing Moatize Formation (Boreholes DW 123 and DW 321).

Two palynomorph assemblages (assemblage 1 and assemblage 2) assigned to the latest Permian were defined for the Moatize and Matinde formations. These assemblages are dominated by striate taeniate pollen, cavate trilete spores of *Kraeuselisporites* spp., associated with conifer (*Lueckisporites virkkiae*) and pteridosperm pollen (*Guttulapollenites hannonicus* and *Weylandites lucifer)*. A third palynological assemblage (assemblage 3) documents for the first time in the Moatize – Minjova Basin, rare specimens of *Lunatisporites pellucidus*, in a group associated with common spores of the taxa, *Kraeuselisporites* spp., *Indotriradites* spp., *Laevigatosporites vulgaris*, *L. collensis*, *Polypodiisporites mutabilis, Polypodiidites* sp. and *Reticuloidosporites warchianus*, together with a few new spore *taxa*, that are observed for the first time at the base of assemblage 3, including *Indospora clara*, *Lophotriletes novicus*, *Lundbladispora brevicula*, *Lundbladispora* sp. and *Triquitrites* sp.. This assemblage was assigned to the Early Triassic and occurs at the top of borehole DW 132 within the Matinde Formation.

Assemblages 2 and 3 also present specimens of organic-walled microphytoplankton assigned to the species *Peltacystia venosa* (Zygnemataceae) and *Leiosphaeridia* (Prasinophyceae). Common to abundant *incertae sedis* algal remains were recognized, assigned to *Reduviasporonites chalastrus* (frequently were observed cells, ranging in shape from rectangular to ovoid and spherical) and *R. catenulatus* (mainly single cells or pairs of cells).

The palynostratigraphic signature obtained for the Permian-Triassic transition places the Moatize-Minjova Basin in the central Gondwana palaeobiogeographic province with strong affinities with the Karoo basins of Madagascar and the Salt Range Basin, in Pakistan. These new data indicates

that coal deposits accumulated in the Moatize-Minjova Basin until the latest Permian and that these are possibly more extensive temporally than previously described, opening new perspectives for coal and unconventional hydrocarbon exploration in this basin.

HYDROCARBON POTENTIAL AND MATURITY OF CARBONIFEROUS SHALE IN THE SOUTHERN NORTH GERMAN BASIN – NEW INSIGHTS FROM DETAILED PALYNOLOGICAL ANALYSIS

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The North German Basin (NGB) covers northern Germany into the North Sea with a complex polyphase basin development, including huge Mesozoic and Upper Palaeozoic sediment infill. In the upper Palaeozoic sediments derived mainly from the south, the prograding active continental margin. In the Carboniferous three organic rich shale units were deposited basinwide, also in the flysch dominated southern part of the NGB, which is known as a highly mature basin (upper gas-window to overmature). This indicates good conditions for the development of shale gas plays in the southern NGB, getting the Carboniferous shales in the center of shale gas exploration in Germany. Detailed palynological investigations should provide new insights about the organic matter in the shales to further assess their hydrocarbon potential. The focus was on the composition and preservation just as the maturation of the organic matter in the different shale units, not on palynostratigraphical analysis. The high-resolution, component-specific optical analysis of the organic matter provides detailed information on the origin, distribution and secondary alteration / maturation and transformation of the organic matter in the studied shales, which is linked directly to their hydrocarbon potential.

Palynological analysis shows a huge dominance of highly carbonized organic matter (inertinite) supporting the proposed high maturity. But in most samples a small amount (mostly < 5%) of less mature brownish organic matter is observed too. It is made of plant debris, mostly vitrinite with very few spores, indicating good gas-potential of the shales. But it questions the proposed high maturity of the basin, which is essentially needed for a productive gas play. Vitrinite reflectance performed on few samples with well preserved vitrinite shows high maturity (upper gas-window) for the whole samples, fitting to the high maturity of the established regional model. But selective analysis of brownish vitrinite indicates much lower maturation (upper oil-window) in the southern NGB. Highly mature organic matter (inertinite) is recycled, while less mature organic matter indicates the in-situ basin maturation. This is supported by conodont colours, which indicate upper oil window maturation also. Due to the low maturation no shale gas plays can be expected in the southern NGB, but for shale oil plays the composition of the organic matter does not fit. Thus a proposed highly prolific unconventional hydrocarbon province is turned into an almost non-prolific hydrocarbon province by detailed palynological analysis.

LATE SILURIAN (PRIDOLI) PALYNOMORPHS FROM THE FRESHWATER EAST FORMATION, PEMBROKESHIRE SOUTH WALES

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The Freshwater East Formation is the stratigraphically oldest unit in the Lower Old Red Sandstone succession south of the Ritec Fault in Pembrokeshire, South Wales. At the type section at Freshwater East it is 50.25m in thickness and lies with erosional unconformity on the Silurian (Wenlock) Grey Sandstone Formation. The Freshwater East Formation comprises a predominately red bed succession composed of sheet sandstones, laminated mudstones and red calcretised siltstones. This alluvial flood plain sequence also contains four inter-bedded fine grained green – grey heterothithic units composed of grey lenticular bedded, wave rippled sandstones and laminated mudstones that were deposited in a tide influenced coastal plain environment. Some of the grey sandstones contain lingulid brachiopods, fish spines, trace fossils together with a diverse Cooksonia flora. A late Silurian age for the formation has been inferred from its stratigraphical position below the Townsend Tuff Bed, a regional marker bed that approximates the level of the Silurian – Devonian boundary in the Anglo Welsh Basin. A previous record of some very dark carbonised spores from the formation suggested a Downtonian (Pridoli) age, however, no details of the spore assemblage were given. The present study provides the first description of palynomorphs from the Freshwater East Formation. Seven productive grey mudstone samples collected from the grey-green heterothithic units have yielded a microflora of cryptospores, trilete spores and rare prasinophytes and acritarchs. The palynomorphs are relatively well preserved despite their high thermal maturity. The microflora is dominated by diverse cryptospore taxa which consititute over 67% of the assemblages. However it is the ornamented trilete spore taxa (<10%) that provide the principal means of dating the Freshwater East microflora. Comparison of the trilete spore assemblages with the late Silurian spore zonation scheme of the Cantabrian Mountains of northern Spain indicates the Freshwater East microflora can be correlated with the Chelinospora. hemiesferica (H) Zone of early to mid Pridoli age. The rare presence of prasinophytes and acritarchs in some of the grey –green heterolithic samples supports the interpretation of restricted marine to brackish water influence in these beds.

MIOSPORE STRATIGRAPHY OF THE SILURIAN AND DEVONIAN OF THE WESTERN AND EASTERN ALGERIAN SYNCLINES

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Eighty nine palynological samples were collected from the Silurian and Devonian exposures of Oued Saoura between Béni Abbès in the north and Kerzaz in the south of the south-western Algerian Sahara for the first time, and seventeen samples from Stah 1, Illizi Basin. Of these forty-seven samples were productive. The productive samples are derived from the Grzime, Djable el Kahlo and Monger Debad km 30 exposures and from unnamed lower Devonian sediments of petroleum well Stah 1. They yielded palynomorphs that are mainly mature to highly mature in character and poorly preserved, although a small number of individual forms are moderately to well preserved. The palynomorphs are dominated by miospores and phytodebris and also contain rare phytoplankton and arthropod cuticles. Miospore assemblages are correlated with established palynostratigraphic miospore assemblage biozones of the Tidikelt Plateau, Central Algerian Sahara of Hassan Kermandji *et al*. (2008), Hassan Kermandji (2007). The new palynological data provide, for the first time, a reliable biostratigraphic determination, indicating a Pridolian to early Eifelian age for the studied deposits, and confirm previously established but limited faunal ages. The miospore assemblages and the level of structural complexity of the taxa do not show significant differences in composition when correlated with coeval palynofloras of the uppermost Silurian to Eifelian sections from the Illizi, Ghadamès and Hammadah Basins of Algeria, Tunisia, Libya and with other Gondwanan regions. Conversely, those Late Silurian-early Mid Devonian Gondwana miospore assemblages can only be correlated with difficulty with the well established spore zones of Richardson and Mcregor (1986), Richardson (1984) and oppel zones of the Ardenne-Rhenish regions of Streel et al. (1987). The lack of productive samples makes the precise determination of the Silurian and Devonian boundary and the position of the Devonian stage boundaries difficult to establish.

Miospore biostratigraphy and sedimentary studies of Oauli Mehadji et al. (2011) improve the correlation of the tectonically complex deposits and shed light on other features of the geological development of the region.

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SILURIAN ACRITARCHS AND ASSOCIATED FRESHWATER AND MARINE MICROFLORAS FROM SAUDI ARABIA: COMPREHENSIVE REVIEW AND NEW INSIGHTS

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Acritarchs and prasinophyte algae, associated with more enigmatic freshwater and marine organic-walled microfossils, are a major component of the Silurian palynofloras of the Arabian Peninsula. Significant advances in the knowledge of the palynological associations and their distribution have been made since the initial phase of the joint Saudi Aramco-CIMP project in the 90's, revealing their indispensable role in refining the Paleozoic palynostratigraphy of the Arabian Plate. Organic-walled microfossils can also be applied as paleoenvironmental and paleoclimatic indicators, although their full potential in this respect has yet to be achieved.

The Silurian System of Saudi Arabia is composed of the Qusaiba and Sharawra members of the Qalibah Formation, of Llandovery-Wenlock age, and the lower part of the Tawil Formation, which includes the Ludlow-Pridoli. The Qalibah Formation is a coarsening-upward progradational marine sequence. The Qusaiba Member is composed mostly of claystone and organic-rich shale with interbeds of siltstone and sandstone. Depositionally, the Qusaiba Member is interpreted to represent the delta-toe clays, whereas the Sharawra Member was deposited as pro-delta siltstones and sandstones of an immense fluviodeltaic system. The sand-dominated Tawil Formation mostly accumulated in marginal marine environment and fluvial settings. The contact between the Sharawra Member and the Tawil Formation is marked by a sharp unconformity, which represents a mid-Silurian regional hiatus due to a severe period of uplift and erosion in Arabia, probably related to the Caledonian movement.

Globally, well preserved acritarch assemblages were recovered from core and cuttings samples investigated in 15 wells in central and northwestern Saudi Arabia. More than 200 species have been recovered in the entire Silurian, including several new species in association with well-known species. Some of the latter are documented for the first time in Saudi Arabia.

The proposed biozonation is based on acritarchs and associated microfloras according to First Appearance Datums (FADs) of selected index taxa, and concurrent associations of species; it is correlated with the regional Silurian chitinozoan zonation published by Al-Hajri and Paris (1998), Paris et al. (1995), and Paris et al. (2015).

Notable taxonomic similarities exist among Silurian acritarch assemblages of Western Gondwana (e.g. Argentina, Brazil, Bolivia and Paraguay), Northern Gondwana (Algeria, Ghana, Libya, Tunisia), and Saudi Arabia, showing that there was no significant paleolatitudinal bio-provincialism within the group during Silurian times. Interesting relationships are also discussed between Aeronian and Telychian Saudi Arabian and Baltic assemblages.

MIDDLE ORDOVICIAN ACRITARCHS AND PROBLEMATIC FORMS FROM THE SAQ-HANADIR TRANSITIONAL BEDS IN THE QSIM-801 WELL, SAUDI ARABIA

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Core samples from the QSIM-801 water well, drilled in central Saudi Arabia, concern a 93 Feet interval in the Middle Ordovician, to the transition between the Sajir Member of the Saq Formation that consist mainly of sandstones of tidal sand flat environment, and the Hanadir Member of the Qasim Formation, with argillaceous graptolitic mudstones, corresponding to a tidal delta front. They contains well preserved palynomorphs which include some cryptospores, acritarchs, chitinozoa, cuticle-like fragments, and other problematic organic-walled microfossils. The studied interval is biostratigraphically well constrained by the presence of chitinozoans of the successive *formosa* and *pissotensis* Zones of early (not earliest) to late Darriwilian age. Ichnofossil *Phycodes fusiforme* has been found in the uppermost Saq of the cored section. Acritarch assemblages from the Sajir Member of the Saq Formation are dominated by sphaeromorphs and veryhachids. More diverse assemblages of acritarchs associated with enigmatic forms occur in the Hanadir Member of the Qasim Formation. The contact is sharp between the two formations and suggest a small discontinuity. Among diagnostic acritarch taxa observed in the studied interval are *Frankea Breviuscula, F. longiuscula* very sensitive to malformations, *Baltisphaeridium ternatum*, *Dasydorus cirritus*, *Dicrodiacrodium ancoriforme, Poikilofusa ciliaris, Pterospermopsis colbathii* and *Uncinisphaera fusticula.* They are associated to other typical forms known to range across the Lower-Middle Ordovician boundary, e.g. *Aremoricanium rigaudiae*, *Aureotesta clathrata*, *Barakella fortunata*, *B. rara, Baltisphaeridium klabavense.* The *Striatotheca* spp., the galeate and peteinoids acritarchs are also well represented. Problematic microfossils such as organic filaments, cuticle-like tissues, possible algal spores, striated and pigmented leiospheres, suggest recurrent terrestrial and freshwater inputs all along the section. The studies performed using Confocal Laser Scanning Microscopy, revealed significative differences in fluorescence emission spectra useful to discuss and separate the enigmatic form *Tyrannus? proteus* nov. sp., from the classical acritarchs.

EPISODIC PERTURBATIONS OF END PERMIAN ATMOSPHERE RECORDED IN PLANT SPORE CHEMISTRY

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The end-Permian mass extinction, 251 Myr ago, is the largest of all marine Phanerozoic extinction events and is accompanied by a major reorganization of terrestrial vegetation and the destruction of Palaeozoic tropical rainforest ecosysytems. The event is temporally linked to the eruption and emplacement of the Siberian Traps large igneous province (LIP). The vast Siberian traps (areal extent of ~5million km^2 and volume totaling ~4 million km^3) were rapidly emplaced by flood basalt mechanisms, possibly enhanced explosive eruptions, through a sedimentary sequence of evaporites coal and rocks rich In dispersed organic carbon. When heated this would have facilitated the production of large quantities of organohalogens. These factors when combined with the high latitude location suggest that large quantities of ozone depleting chemicals could have been delivered into the atmosphere, resulting in a partial collapse of the stratospheric ozone layer and a commensurate increase in UV-B radiation at the Earth's surface. To date indirect evidence supports this chain of events but full elucidation remains elusive. Here we use a newly developed proxy for UV-B radiation and apply it to clubmoss (Lycophyta) megaspores to track changes in the UV-B flux over this interval. In contrast to recent hypotheses, our data show three episodes of marked relative decreases in ultraviolet screening compounds during the latest Permian and one large relative decrease in the earliest Triassic. When combined with evidence of spore and pollen mutations, our chemistry data evidence a highly dynamic system oscillating between episodes of high UV-B flux, and conditions more attuned to 'normal' background UV-B flux during the end Permian extinction.

TOWARDS A PALYNOZONATION OF THE EARLY CARBONIFEROUS OF THE BARENTS SEA AREA

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During the late Paleozoic the Barents Sea was part of a vast E-W oriented intra-cratonic basin located on the northern margin of the Euramerican Supercontinent. Numerous structural basins and highs reflect a complex tectonic development which controlled the deposition of clastic terrestrial sediments derived from braided rivers, swamps and large prograding fans, resulting in the formation of several tectonical provinces. The Finnmark Platform was located on the northern margin of the Fennoscandian Shield during the late Paleozoic. The oldest sedimentary unit comprises mainly continental siliciclastic sediments of the Billefjorden Group, ranging in age from Late Devonian to Early Carboniferous. Its regional development throughout the Barents Sea is still relatively poorly known (Larssen et al., 2005). Few palynological papers have been published on this area, where palynology has proven to be the only applicable tool for dating these parts of the successions. More work is needed in order to fully understand the stratigraphic ranges and quantitative distribution of all palynomorph taxa present.

A miospore biozonal scheme for the Mississippian Billefjorden Group is currently being developed. So far, three shallow cores (7127/10-U-2; 7127/10-U-3; 7029/3-U-1) and cores and cuttings from one exploration well (7128/6-1), drilled on the Finnmark Platform, have been analyzed for palynology; all yielded relatively rich and well preserved palynofloras. A detailed palynological analysis has been performed and a preliminary palynological correlation with the Western Europe Biozonal Scheme has been attempted. Preliminary results from this study will be presented.

This project is partially supported by the FORCE Industry Consortium sponsored by BG Group, Chevron, Detnorske, E-On, Faroe Petroleum and VNG Norge.

PALYNOLOGICAL RECORD OF PALEOVEGETATION CHANGES DURING THE VISEAN AGE FROM THE MOSCOW SYNECLISE (RUSSIA)

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Paleoecological research of the Visean miospore assemblages from the different localities of the south and north-west wings of the Moscow Syneclise has been carried out. The age of studied palyno assemblages was assigned to Bobrikian (Lower Visean), Tulian, Aleksinian and Mikhaylovian (all of the Upper Visean) regional stages of the Carboniferous Regional Scheme of East European Platform. The palynological material was obtained from the coaly clays, siltstones and stigmarian limestone beds. The abundant miospore associations are a good source of data about the parent vegetation types and its alteration through time. The paleoecological analysis is based on the miospore natural affinity determined by the comparison of the dispersed material with the *in situ* spore data. Accordingly, the miospore genera of the studied palyno assemblages were grouped into several paleobotanical units: arborescent lycopsids, sub-arborescent lycopsids, miospores of fern-like plants (ferns and seed ferns), spores of the sphenopsids and miospores of uncertain botanical affinity. The natural groups were associated with the two vegetation types: forest mire (all lycopsids) and non-forest mire (fern-like plants, sphenopsids). The significant differences in the vegetation types from the south wing of the Moscow Syneclise and the north-west one during Visean times has been indicated. On one hand, both regions are dominated by arborescent lycopsids (54 – 93%) which are general elements of the forest mire type. Additionally no prominent variations of the sub-arborescent lycopsids (3 – 9%) and sphenopsids (1 – 4 %) has been observed in the regions. On the other hand, the value of both ferns and seed ferns (up to 21%) was constantly increased upward the stratigraphical sequence in the southern part of the Moscow Syneclise. The forest mire elements were slow replaced by the non-forest ones. In contrast, the fern-like plants (up to 6%) were obviously diminished during the Visean in the north-west wing of the region. Apparently, the inverse changes of the Visean vegetation types, of the same age, from various parts of the Moscow Syneclise can be explained by different influences of local environmental factors such as periods of standing water, clastic sedimentation and brackish conditions.

The research was supported by Russian Foundation for Basic Researches, project No 15–04–09067.

A PRELIMINARY $\delta^{13}C_{TOC}$ ISOTOPE CURVE FROM THE EMSIAN OF SAUDI ARABIA AND ITS INTEGRATION WITH THE PALYNOLOGICAL ZONATION

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Spores have a key role in international correlation. But there are inevitably questions regarding their application for intercontinental correlation by the differing ability of spores to travel freely between dispersed land masses separated by wide seaways. This is simply expressed as the gross palynological assemblage differences between Gondwana and Euramerica. It is also seen in the differential inception of key taxa that are used to define the palynological zonation. An example would be *Geminospora lemurata*, which originates in Euramerica in the early Givetian but only gets to Australia by the late Givetian. A time difference of some 5 million years. To attempt a higher resolution correlation there are a number of apparently global trends in stable isotopes that have been widely applied in post Palaeozoic sequences. An established and widely applied curve is that of $\delta^{13}C$ from carbonates. These are more difficult to routinely apply in the Palaeozoic because of the generally higher levels of diagenetic alteration. A complementary and related curve is that of $\delta^{13}C$ from bulk organic matter. This result is controlled by both the organic matter present and biologically driven fractionation processes in the immediate water column. There is also secular variation in the curve through geological time. These often represent global perturbation in biogeochemical cycles and represent correlative time planes or narrow intervals of time. We know from the established $\delta^{13}C_{CaCO3}$ curve that there is an Emsian minimum with the low point coincident with the mid Emsian Zlichov Event.

In the Emsian Hammamiyat Member from the Jauf Formation there are a series of leiospheres-rich event levels that were used to define the D3B Palynosubzone within the *lindlarensis-sextantii* Assemblage Zone. A series of high resolution samples were taken through the interval through a series of kerogen types. These form the ideal opportunity to test the application of a $\delta^{13}C$ isotope curve from a location on the Arabian Plate.

A MID FAMENNIAN (LATE DEVONIAN) SPORE ASSEMBLAGE FROM SVALBARD AND ITS SIGNIFICANCE

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A new fish- and tetrapod bearing locality at Triungen (Dickson Land, Spitsbergen) has been dated as mid Famennian (Late Devonian) based on spores. It contains a very distinctive assemblage including *Cyrtospora cristifer, Cornispora monocornata, Cornispora bicornata, Cornispora tricornata, Lophozonotriletes lebedianensis*, *Knoxisporites dedaleus*, *Grandispora gracilis*, *Spelaeotriletes papulosus*, *Cristatisporites lupinovitchi*, *Lagenosisporites* sp., *Grandispora famensis* and *Tergobulasporites immensus.* This assemblage has been recorded widely from Russia (west of the Urals) and Arctic Canada. It has been documented previously from Bjørnøya (Kaiser, 1971) but only briefly noted from Dickson Land. It was also discovered recently by Scheibner et al. (2012) in NE Spitsbergen. The Triungen mid Famennian spore assemblage is abundant, diverse, internally consistent in assemblage and present in 30 separate samples. There is no evidence that it is reworked as suggested by Piepjohn et al. (2014).

The Triungen mid Famennian interval is thin (45m) and rests with a strong angular unconformity on the early Devonian Wood Bay Formation, thus forming the lower part of the Triungen Member (Hørbyebreen Formation). The lithology is dominantly mudstone with sandstones and conglomerate and represents deposition in a humid climate. It is separated from the remaining part of the member by a subtle unconformity, which may warrant a subdivision of the Triungen Member. It was the spores from these overlying sediments (Hoelbreen Member and younger) that were monographed by Playford (1962, 1963).

Combining these results with revised spore dates from Mimerdalen now enables us to better understand the timing of movements along the Billefjorden Fault, a major strike slip system that has been identified as part of a continental scale transform fault. In Mimerdalen the late Givetian - early Frasnian Plantekløfta Formation includes *in situ* lycopod forests with direct evidence for syndepositional deformation including tectonically shortened megaspores. The new evidence from Triungen shows that deposition was renewed in the mid Famennian but that there was then a further tectonic event before deposition of the Tournaisian coal bearing sediments. This sequence of strike slip movements from Svalbard informs us as to the timing of tectonic events that may have affected the British Isles for which we otherwise have no direct age evidence.

Recent research on structural geology in the Hornsund and Mimerdalen area (Bergh et al., 2011) has identified similarities in the structural geology of these areas but used this to imply that palynologically dated Devonian and Carboniferous units are in fact age correlatives. Clearly the structural history is more complex with more discrete tectonic events (at least four) and stratigraphic palynology still remains an essential for any integrated geological interpretation.

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PENNSYLVANIAN PALYNOMORPHS FROM THE PIESBERG, NORTHWEST GERMANY

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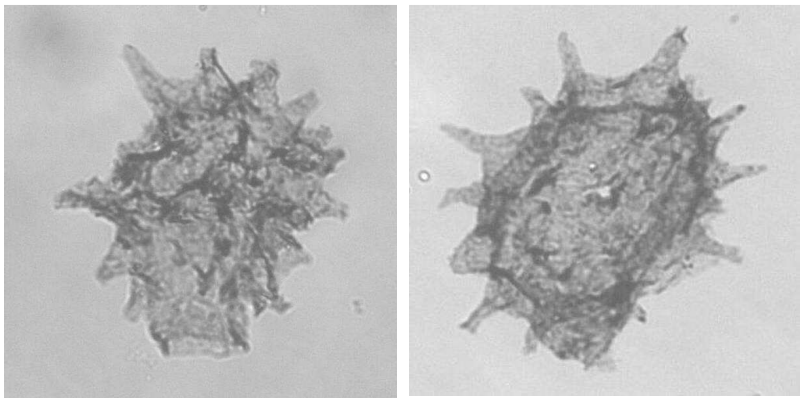
The Piesberg Quarry in Lower Saxony, northwest Germany works late Bolsovian to Asturian fluvio-deltaic, conglomeratic sandstones. These have interbedded coals and associated fine-grained clastic sediments. The strata are thermally mature (R_o>3). However, although the anthracitic coal material is devoid of recoverable miospores, some of the mudstones and siltstones provide well preserved, but dark miospores. Those finer-grained clastics that are massive or laminated and are without any palaeosol textures or sulphur staining provide the best miospore recovery. Presence or absence of macroscopic plant material does not seem to correlate with palynological productivity.

The base of the Asturian is recognised by macroflora at the horizon of the Zweibänke Coal. Samples from the mudstones above this provide diverse miospore assemblages including the typical Asturian taxa *Thymospora obscura, T. pseudothiessenii, Torispora laevigata, T. securis, Triquitrites sculptilis, Vesicaspora wilsonii, Vestispora fenestrata, V. magna, V. wanlessii, V. witneyensis* and *Wilsonites* spp. Taxa less typical of the Asturian include *Cycadopites* sp., *Cingulizonates loricatus, Scutasporites ?* sp., *Raistrickia abdita, R.* cf. *fulva, Spelaeotriletes* sp. and *Vittatina?* sp. An unusual form of *Peromonolites* is recorded.

Mudstones also provided examples of an unnamed, acanthomorph acritarch, superficially similar to *Polygonium* sp. It has processes that are fairly regular in shape and size, but with a single process that is much broader than the others, and which may be open distally (see below). The acritarchs are recovered from marine strata identified by records of the xiphosuran *Euproops.*



Unnamed acritarch.

THE EVOLUTION OF THE UPPER ORDOVICIAN TO SILURIAN BASIN IN THE CONDROZ INLIER: LITHO- AND BIOSTRATIGRAPHY WITH CHITINOZOANS

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Verniers et al. (2002a) summarized the knowledge on the Cambrian to Middle Devonian basin evolution and deformation history of Belgium, eastern England and surrounding areas. The PhD dissertation, presented here, considers the third of their three megasequences: from middle Katian to upper Silurian, and mostly in the Condroz Inlier in Belgium. The area was poorly studied before, in contrast with the knowledge on that megasequence in the Brabant Massif. Vanmeirhaeghe (2006), in his PhD study revised the stratigraphy of the second megasequence of the Condroz Inlier (Ordovician and parts of the lower Silurian) in combination with a chitinozoan biostratigraphy.

We propose a new lithostratigraphy and dating of the units mostly with chitinozoans but also with graptolites and brachiopods. Once the stratigraphy of the Condroz Inlier established, correlation with the Brabant Massif becomes possible.

During megasequence 3 the sediments of the Condroz Inlier were deposited on the shelf, but the sedimentation changed through time. In contrast during the same megasequence sedimentation in the Brabant Massif started with a shelf deposition, but slope conditions with deposition of turbidites soon prevailed most of the Silurian. The thickness of the lithostratigraphical units generally increases upwards through the Llandovery with thick units in the upper Telychian. The basin in the Brabant Massif began to deepen in the upper Katian and we can place the start of the development of the foreland basin at the onset of the deepening in the upper Katian.

From the lower Telychian onwards, oxic-anoxic alternation are noted in the stratigraphical column of the Condroz Inlier. From the upper Telychian onwards until the end of the Wenlock anoxic sedimentation takes place almost continuously, with deposition of dark grey, finely laminated mudstone and with limited amount of oxic intervals. Those laminated hemipelagites, already recorded previously in the Brabant Massif in the same time range, are discovered here for the first time in the Condroz Inlier.

THE PALEOZOIC OF NORWAY – A BRIEF INTRODUCTION

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Mainland Norway is part of the Baltica paleocontinent, which encompasses a major portion of northern Europe. The core of this continent consists of Archaean and Proterozoic rocks of the East European Craton. Tectonic phases have in varying extent preserved younger sedimentary (and fossiliferous) successions. The Lower Paleozoic succession in the Oslo Region is approximately 2 500 m thick, and extends out into the fiord to the south (the Skagerrak Graben). The rocks here were folded, faulted and thrusted during the Caledonian orogeny, as well as rifted during the Late Paleozoic rifting phase. The late Carboniferous to early Permian rifting created the graben structure which is the main reason for the preservation of Lower Paleozoic rocks in the Oslo Region. Local and regional thermal metamorphism is evident due to the Late Paleozoic magmatic activity. The Oslo Region is famous for its Cambrian to Silurian succession, rich in fossils, and has attracted international research for more than 170 years. Smaller Paleozoic outcrops are preserved near Stavanger, Bergen, Trondheim, and in Northern Norway, especially in Finnmark. Some of these areas have more or less continuous Late Proterozoic to Early Paleozoic sedimentary successions preserved.

The **Svalbard** archipelago comprises all the islands between 74° and 81° N latitude and from 10° to 35° E longitude. The basement of Svalbard formed during Precambrian to Silurian time and has experienced several periods of folding and metamorphism. The last largescale folding and metamorphism took place during the Caledonian Orogeny, a major mountain building episode in the Silurian. Pre-Caledonian rocks are generally heavily metamorphosed, but some areas, e.g. to the NE have well preserved fossiliferous sedimentary successions. Sedimentary rocks from the Devonian onwards are well preserved in most areas, although being faulted and folded during the plate movement that started at the end of Mesozoic culminating in the Early Tertiary with formation of a new mountain belt along the west coast of Spitsbergen.

Devonian strata consist mainly of silt- and sandstone and conglomerate alternating with small amounts of shale and carbonate rocks. Many fossils of primitive fish have been found in the estuarian deposits, whereas fossils of primitive spore plants that grew on river plains and in shallow lakes are also common. The lowermost Carboniferous sandstones contain coal seams which were mined in the Russian settlement of Pyramiden. The horizontal Carboniferous– Permian strata contain fossiliferous carbonates with white layers of gypsum and anhydrite. These Upper Paleozoic units are very fossiliferous with a fauna dominated by brachiopods, siliceous sponges and bryozoans. Locally bioherms are developed. The Permian-Triassic transition in Svalbard is

currently under intense study, and the P-T-extinction is event is scrutinized using sedimentological, paleontological as well as various geochemical (isotopes) studies.
Highlights of the geological and evolutionary history of the Paleozoic of mainland Norway and Svalbard will be the focus of the lecture.

Further reading:

Dallmann, W.K. 2015 (Ed.). *Geoscience Atlas of Svalbard*. Norsk Polarinstitutt Rapport 148, 292 pp. Tromsø.

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DISPERSE MEGASPORES OF THE LOWER CARBONIFEROUS DEPOSITS (LOWER VISEAN SUBSTAGE) OF PENZA REGION (RUSSIA)

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Numerous disperse megaspores were found in the Lower Carboniferous deposits of borehole 6, near the Obval village, Penza region, Russia. Samples (aleurolites and clays) were macerated using concentrated hydrogen nitrate. 15 species of 7 genera of disperse megaspores were defined. Abundant megaspores of the genus *Aphanozonatisporites* (*A. triglobatus*, *A. trilobatus* and *A. grandiosus*) were found in the lower part of the section. Disperse megaspores of *Zonalesporites brasserti* were usually recorded in small numbers in all studied samples. Abundant megaspores of *Setosisporites brevispinosus* were obtained from the middle-upper part of the section. Megaspores of genus *Crassilagenicula* were defined in small numbers in 5 samples, notably *C. simplex,* C. *angina* and *C. pseudoagnina* were found only in the lower part of the studied section and *C. furia* was recorded in the upper one. The other taxa were sporadically found in small numbers (*Cystosporites* sp., *Sublagenicula hirsutoida*, *S. nuda, Lagenicula horrida*, *L. acuminata,* etc.) Megaspore assemblages of Penza region are similar to coeval megaspore assemblages of Moscow Syneclise but taxonomical composition of studied assemblages is slightly different.

The research is supported by the Russian Foundation for Basic Research, project no. 15-04-09067.

ACRITARCHS FROM THE DUOLBAGÁISA AND KISTEDALEN FORMATIONS (CAMBRIAN SERIES 2-3), DIGERMULEN PENINSULA, NORTHERN NORWAY

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New information on acritarchs from the upper part of the Duolbagáisa Fm., and the lower part of the Kistedalen Fm., on SE Digermulen Peninsula, northern Norway, adds biostratigraphical control to previous studies on trilobites and acritarchs. Levels with *Kjerulfia lata*, *Kjerulfia* sp. and *Elliptocephala* sp., in the upper part of the Duolbagáisa Fm., yield abundant *Skiagia ciliosa,* indicative of the *H. dissimilare-S. ciliosa* Zone (Cambrian Series 2, Stage 4). Higher in the Duolbagáisa Fm., some ten metres above an unidentified ellipsocephalid*, Liepaina plana* occurs with single specimens of *Comasphaeridum longispinosum* and *Sagatum priscum. L. plana* and *S. priscum* indicate the *Volkovia-Liepaina* Zone, which spans the traditional lower-middle Cambrian boundary; *C. longispinosum* is known only from the middle Cambrian. The basal part of the K1 Mbr of the Kistedalen Fm., yields *Retisphaeridium dichamerum*, *Multiplicisphaeridium parvum* and *Eliasum llaniscum;* on the NW side of the peninsula trilobites from this interval include *Ellipsocephalus* cf. *hoffii* and *Eccaparadoxides* cf. *pusillus.* Higher in the K1 Mbr, a second acritarch assemblage includes *Cristallinium cambriense, Adara undulata and Vulcanisphaera* sp., and close to the top of this member appears *Adara alea.* In the K2 Mbr there is a successive appearance of *Timofeevia lancarae* (*sensu* Palacios 2015), *Symplassosphaeridium cambriense* and *Cristallinium dubium.* The highest record of *Eliasum llaniscum* is close to the top of the member. Acritarchs from the lower part of the Kistedalen Fm. can be readily assigned to Cambrian Series 3 acritarch zones established in northern Gondwana and Avalonia, and allows for a more precise calibration of Welsch's (1986) AI and AII acritarch zones.

CAMBRIAN SERIES 2-SERIES 3 ACRITARCH ASSEMBLAGES FROM THE IBERIAN PENINSULA

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Acritarch assemblages from the lower-middle Cambrian of the Cantabrian Zone (CZ) and Celtiberian Chains, northern Spain, and the Ossa Morena Zone (OMZ), southern Spain, allow to establish a detailed lower-middle Cambrian (Cambrian Series 2-3) acritarch biozonation. The lower Cambrian *Skiagia ornata-Fimbriaglomerella membranacea* and *Heliosphaeridium dissimilare-Skiagia ciliosa* zones are recorded in Cantabrian Zone (CZ), and *S. ciliosa* and *Heliosphaeridium notatum* in the Celtiberian Chains and Ossa Morena Zone (OMZ). In the middle Cambrian of the CZ have been established six acritarch zones (IMC1-IMC6) correlated with previously established trilobites zones. In the Celtiberian Chains the record is restricted to the upper part of Cambrian Series 3 (IMC5 and IMC6 Zones). In the OMZ a thick volcanosedimentary succession, with a sporadic record of trilobites, yields a continuous record of acritarchs across the Cambrian Series 2-3 transition, and the recognition of all CZ zones (IMC1-IMC6). The recent discovery of a paradoxidid near the base of the La Albuera Member of the Vallehondo Formation, classically assigned to the Upper Marianian-Lower Bilbilian, allows calibration of the IMC1 Zone. The IMC1 Zone can be divided into two subzones. The IMC1a Subzone includes the first appearance of *Comasphaeridium silesiense, C. longispilosum*, *Tubulosphaera perfecta*, *Eliasum* sp.. *E. llaniscum*. *C. silesiensis*, *T. perfecta*, and *Eliasum* sp., appear about 100 m below the first record of paradoxidids, and *C longispilosum* and *E. llaniscum* very close to this level. The IMCb Subzone is characterized by the appearance of *Comasphaeridium francinae* and *Adara undulata* in the upper part of La Albuera Member, in levels that overlies the occurrence of *Parasolenopleura* sp..

ARE LARGE SPINOSE ACRITARCHS CRUSTACEAN EGG CASES? A CONSIDERATION AND CASE STUDY FROM THE CAMBRIAN (FURONGIAN) OF TENNESSEE, USA

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The hypothesis that some of the larger (>100 µm) spinose acritarchs are egg cases of arthropods is not a new one, but the supporting evidence for it, often represented by simple comparisons of size, general morphology and ornament, is circumstantial and far from conclusive. Other criteria, in particular a consideration of preservational potential and comparisons of cell wall ultrastructure, are also required.

Today numerous arthropods utilise diapause as part of their life cycle. Diapause involves the suspension of development of an organism in response to seasonal heterogeneity of environments. In the case of many copepods and branchiopods (aquatic crustaceans) diapause occurs at the embryonic stage when the nascent animal is still contained within the egg case, and can last for decades. In order that an embryo might survive such prolonged periods of time, diapause egg cases have evolved a number of structural and biochemical characteristics. These include complex trilaminar wall ultrastructures and the incorporation of chitinous or complex lipo-protein components to increase strength and provide protection against harsh and fluctuating environmental conditions. These characteristics make crustacean diapause egg cases good candidates for fossilization.

A large (60-155 μm) Cambrian (Furongian) spinose acritarch species recovered from the Nolichucky Shale in Tennessee, USA, possesses a trilaminar wall ultrastructure comparible to that of some extant branchiopod egg cases, and there is evidence of co-occurrence of branchiopod-type crustaceans. Furthermore, its large size, overall morphology and ornament all suggest a possible crustacean provenance.

But is it enough?

MEGASPORES OF THE WEST MAINS FARM BOREHOLE, TOURNAISIAN, ENGLAND

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Following the end Devonian Mass Extinction event, tetrapods seemed to disappear from the fossil record for a significant time interval (Romer's Gap). However, many have been discovered within intact ecosystems from a number of Tournaisian localities in Nova Scotia, Canada and in the Scottish Borders, UK. These tetrapods, and associated environments, are now being studied by the NERC funded TW:eed project.

The UK tetrapod sites are from a number of scattered localities in the poorly exposed Ballagan Formation. In an attempt to tie these localities together stratigraphically, the Ballagan Formation has been cored (501.33 m) in the West Mains Farm borehole at Norham, just inside the England border. This is a preliminary account of the megaspores from the borehole. Although megaspores are well known from a number of localities in the region, this is the first time they can be studied stratigraphically within a continuous section.

After standard palynological processing, megaspores were hand-picked from the >150 µm fraction. The distribution of the megaspores through the Ballagan Formation shows that they occur in discrete zones that highlights an episodic return to a lycopod forested landscape. Abundant *Didymosporites scottii* megaspores together with rarer lycopods (*Setosisporites* sp.) support an environmental reconstruction of a low-level vegetation of the fern *Stauropteris* with higher, more distant lycopods.

LOWER PALEOZOIC ACRITARCHS FROM THE SHIALA AND YONG LIMESTONE FORMATIONS OF NORTHEASTERN GARHWAL-KUMAON TETHYS HIMALAY, PITHORAGARH DISTRICT, UTTRAKHAND, INDIA

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In India, the Lower Paleozoic marine sedimentary basins are exposed in patches. These are Kashmir, Zanskar-Spiti and Kinnaur-Uttarakhand basins and popularly known as the Tethyan-Tibetan sedimentary sequence. The sedimentary sequences of these basins range in age from Late Proterozoic to Cretaceous except in Zanskar where it extends to Eocene. These sedimentary basins are intercalated between the Central Crystalline Complex in the south and the sequence of Indus-Tsangpo Suture Zone in the north.

Prolific and diverse acritarch forms have been, for the first time, recovered from the right bank of Kali River of northeasten Kumaon region which is a part of Garhwal-Kumaon (Uttarakhand) Tethys basin of the Himalaya, India. These acritarch assemblages have been recovered from the Lower Paleozoic sequences of the Shiala and Yong Limestone formations which include brown to opaque vesicles of sphaeromorphs, acanthomorphs, polygonomorphs and diacromorphs. The assemblage recovered from the Yong Limestone Formation is assigned to Llandovery-Ludlow age based on biostratigraphically potential forms. The other associated forms with acritrarchs are chitinozoa and melanosclerites. Some cuticles and trilete spores are also found probably of reworked nature. The paper describes the high resolution biostratigraphy and a comparative study with Garhwal assemblage as far as acritarch is concerned.

The study area during Lower Paleozoic was the part of a low palaeolatiudinal Gondwana region in contrast to high latitude northern Gondwana (Morocco, Libya, Algerian Sahara) and western Gondwana (Argentina).

ORDOVICIAN CHITINOZOANS FROM RONKON VILLAGE OF PITHORAGARH DISTRICT, GARHWAL-KUMAON TETHYS HIMALAYA, INDIA

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Chitinozoans have been reported for the first time from Ronkon village of Pithoragarh, district of Kumaon province, a part of eastern peri-Gondwana margin. However, our eastern peri-Gondwana chitinozoan assemblage lacks the better quality of preservation in comparison with much of the western peri-Gondwana margins known assemblages such as Middle East, North Africa and South America.

Ronkon village is situated at the right bank of Kuti River in the Pithoragarh district of Kumaon province. Along the right bank the Lower Paleozoic formations such as upper part of Shiala and Lower part of Yong Limestone formations are well exposed. Recovered chitinozoans are strongly thermally altered, and often opaque, attributed to intense tectonic activity in the Himalaya. The macerated samples from the Shiala Formation yields *Conochitina* sp., *Desmochitina* sp., and *Belonechitina capitata,* a potential Mid to Late Ordovician chitinozoans index taxon. Furthermore, *B. capitata* has already been described from high palaeolatitudinal Gondwana during the Ordovician, whereas our study shows its presence also in low-paleolatitudinal Gondwana region.

CHITINOZOAN BIOSTRATIGRAPHY OF THE SILURIAN WENLOCK–LUDLOW BOUNDARY SUCCESSION OF THE LONG MOUNTAIN, POWYS, WALES

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Systematic collecting through the upper Wenlock (upper Homerian) and lower Ludlow (Gorstian and lowermost Ludfordian) Silurian rock succession of the Long Mountain, Powys, Wales, identifies some 48 chitinozoan species that distinguish four biozones, two subzones and an interregnum. Consideration of the chitinozoan biozones together with those of the graptolites enables a local threefold subdivision of the late Homerian *lundgreni* graptolite Biozone, and the distinction of lower and upper intervals for the Gorstian *incipiens* graptolite Biozone. The base of the Ludlow Series in the Long Mountain more or less equates to the base of the *Cingulochitina* acme chitinozoan Biozone, although no key chitinozoan first or last appearance datums are associated with the series boundary itself. The new graptolite–chitinozoan biozonation allows enhanced correlation between upper Wenlock and lower Ludlow sedimentary deposits of the Lower Palaeozoic Welsh depositional basin and those of the palaeo-shelf in the stratotype Wenlock and Ludlow areas of Shropshire. Chitinozoans seem affected by the phenomena that caused the late Wenlock 'Mulde extinction' in graptolites but, with the final disappearance of 9 species and re-appearance of 11 species following an interval of overall low diversity, they seem to have suffered less severely than their macro-zooplanktonic contemporaries.

MIDDLE ORDOVICIAN CRYPTOSPORES AND OTHER PLANT REMAINS FROM THE SAQ-HANADIR TRANSITIONAL BEDS IN THE QSIM-801 WELL, SAUDI ARABIA

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The QSIM-801 well from Central Saudi Arabia contains beds transitional between the Sajir Member of the Saq Formation and the Hanadir Member of the Qasim Formation. Core samples from these beds yielded rich assemblages of well-preserved palynomorphs of low thermal maturity. They are dominated by marine forms (acritarchs, chitinozoans and scolecodonts) but also include relatively abundant and diversified terrestrial forms (cryptospores), especially in samples from the upper part of the Sajir Member. The cryptospore assemblage is taxonomically consistent with other Middle Ordovician assemblages previously reported from the region, and is concordant with the Darriwillian (Llanvirn) age indicated by acritarch and chitinozoan biostratigraphy (*Siphochitina formosa* chitinozoan zone). It includes a variety of monads and permanent dyads and tetrads, which are often characterized by well-developed surface ornamentation such as microgranulation, as well as, in some instances, by thick walls displaying distinct layering. An interesting feature of the palynological preparations is the presence of large (> 200 µm) fragments of plant material. These include spore masses and a fragment of pluri-layered parenchymatous tissue consisting of thin-walled, abundantly pitted, rectangular cells which is possibly indicative of bryophytic affinities for the parent plants.

CREATING A TAXONOMY OF CAMBRIAN CRYPTOSPORES

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Problematic palynomorphs extracted from shales from the Lower Cambrian Rome Formation and the Middle Cambrian Conasauga Group in eastern Tennessee are classified as cryptospores: they possess laminated wall ultrastructure, and were shed in polyads that reflect successive meiosis during endosporogenesis. Similar lamellated spore-wall ultrastructure, which is found in Ordovician – Devonian cryptospore dyads, has recently been confirmed in the living basal liverwort, *Haplomitrium gibbisae* (Steph.) Schust., the only living land plant known to produce spore dyads. The Cambrian cryptospores are highly plesomorphic, which has made initial attempts at creating a taxonomy somewhat taxing. Spore wall surfaces are generally smooth, without ornamentation; some new taxa are characterized by mottled walls which reflect their underlying multilaminate ultrastructure. In some instances both dyads and tetrads occur within a single spore mother cell (SMC) wall. It is also clear, from cryptospore packets that are attached in regular geometries, that the same plant was producing differing numbers of spores as the end result of reduction division. This fact, in combination with populations of cryptospore packets that have retained their SMC walls, provides a basis for establishing a highly-lumped taxonomy. The weight of evidence indicates that the Cambrian cryptospores were shed by thalloid sporophytes belonging to lineages of (aeroterrestrial) charophytes that were actively evolving in subaerial settings. This conclusion is consistent with Bower's theory of the antithetic origin of the plant sporophyte and with recent studies in bryophyte sporogenesis which predict that spores evolved prior to the evolution of a somatic sporophyte phase.

ON SOME PROPOSED CHANGES IN THE SUPRAGENERIC CLASSIFICATION OF THE ACRITARCHS

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When the term *acritarch* was first proposed, it represented a solution intended to provide a label for Palæozoic organic-walled microfossils (OWMs) that largely appear to represent the cysts of marine phytoplankton. There is increasing evidence, especially from recent studies of Precambrian OWMs, that acritarchs comprise microfossils of various eukaryotic protists, which can be of either marine or non-marine provenance. It is also possible that many Precambrian and Palaeozoic OWMs were benthic and/or non-photosynthetic. Therefore, as the study of Precambrian OWMs increasingly pertains to questions surrounding the topology of the basal eukaryotic supergroup phylogeny, it seems appropriate to revisit the question of suprageneric classifications of the acritarchs. We have proposed two taxa in the suprageneric classification: *Superornamenti* and *Operculate Acritarchs*. In addition, we have emended the *Sphæromorphitae* to exclude sphæromorphs, which possess surface ornament or inner bodies. These distinctions within the sphæromorphs help to distinguish wall *structure* from wall *ornamentation*. The possession of an operculum is a feature that requires a level of cytoskeletal control that, in general, exceeds that required for simple slits, or other ill-defined apertures. As a result, we expect *Operculate Acritarchs* to represent a discrete grade of evolutionary development within one or more eukaryotic supergroups. The continued recognition of *Moyeria* as eugleniod justifies its classification within supergroup Excavata. It seems obvious that *Moyeria* and morphologically related OWMs should be placed in their own suprageneric acritarch taxon. The recognition of a greater ecological and systematic range of the acritarchs also has important implications, in geological applications, for palæoenvironmental interpretations of Palæozoic acritarch assemblages.

INTERRADIAL PAPILLAE IN MICROSPORES AND MEGASPORES OF *OXROADIA GRACILIS* FROM THE LOWER CARBONIFEROUS OF OXROAD BAY, SCOTLAND

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Isoetalean lycopsid spores are characterized by the presence of interradial papillae. The ultrastructure of these papillae was first investigated by Lugardon in spores of the extant genera *Isoëtes* and *Selaginella*. He demonstrated that the papillae are polylamellated when viewed in cross-section under the transmission electron microscope (TEM). Subsequent workers recognized a similar feature in Carboniferous lycopsid spores (*Cirratriradites annulatus* from cones produced by *Paurodendron*), demonstrating a 300 million-year persistence of this feature. This range was extended back even further when polylamellated layers were discovered in the wall of *Acinosporites lindlarensis* recovered from sporangia of the Lower Devonian lycophyte *Leclercqia*. This was also the first time a taxon considered to be homosporous was shown to possess these structures. Placement of this trait on the lycophyte phylogeny supports a clade that includes the Protolepidodendrales + rhizomorphic lycopsids (including *Isoetes*) + Selaginellales. Papillae with polylamellated ultrastructure are found in both the microspores and megaspores of the Lower Carboniferous lycopsid *Oxroadia gracilis*. This is the earliest occurrence of the structures in megaspores as well as the only Paleozoic instance known where the structures have been demonstrated with TEM to be present in both types of spores. The discovery of this feature in *Oxroadia*, which plugs a 100 million year gap in existing knowledge of its occurrence, may allow refinement of the group's phylogeny. This may include the previously proposed existence of a separate clade of pseudo-herbaceous lycopsids in the Lower Carboniferous.

PALYNOLOGY OF THE PERMIAN-TRIASSIC TRANSITION IN EAST GREENLAND

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The Permian-Triassic boundary (PTB) in Jameson Land, East Greenland, is unique in that it is one of the most extended sections containing both terrestrial and marine palynomorphs. Furthermore, because there have been no igneous intrusions in the area, the material has undergone no thermal alteration. The end Permian mass extinction and Triassic recovery are contained in two lithostratigraphical formations, the Schuchert Dal Formation and Wordie Creek Formation. The PTB, defined by the first occurrence of the conodont *H. parvus*, is located ~23.5 m above the boundary formation of the Schuchert Dal and Wordie Creek formations. In an earlier palynological study, Looy et al., (2001) defined five pollen-zones describing vegetational changes occurring during the end Permian extinction, which are from oldest to youngest: a) decline of cordaite–pteridosperm woodland; b) proliferation of herbaceous lycopsids; c) establishment of diverse gymnosperm shrubland communities; d) renewed lycopsid proliferation; and e) extinction of typical Late-Permian Subangaran gymnosperms. To study the changes in the terrestrial and marine ecosystems in more detail, we are increasing the resolution of the palynological record, with special interest in the intervals at the start of the end Permian extinction (zone a and b), the formation boundary (zone b and c) and the early Triassic (following zone e). The well preserved acritarchs will be used to shed further light on paleo-environmental changes and biological stress occurring in the marine realm.

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CHITINOZOANS ASSEMBLAGES OF BREJO FUNDEIRO FORMATION, AMÊNDOA MAÇÃO SYNCLINE (MIDDLE ORDOVICIAN, PORTUGAL)

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The Brejo Fundeiro Formation (Middle Ordovician, Portugal) was defined by Cooper (1980) about 500 m north of the village with the same name, in Dornes region. Succeeds in concordance with previous formation, Armorican Quartzite Formation. Locally the base is underlined by a lenticular level of a microconglomerate with brachiopods.

It is characterized by a fossiliferous sequence with mudstones and siltstones, showing in this area an ooidal ironstone level with fragments of fossils, oolithic iron, concentrations of heavy minerals, phosphates, black mudstones and siltstones.

The present research shows the biostratigraphic results with chitinozoans obtained in samples from the Brejo Fundeiro Formation in Amêndoa-Mação syncline. The studied samples provided moderately preserved chitinozoans, assigned to *Calix* and *Protocalix* Biozones, which allowed dating the lower part of the formation of lower Darriwilian (Upper Arenigian to the lowest Oretanian), and the upper part of lower to middle Darriwilian (Lower Oretanian).

AN ORGANIC-WALLED MICROPHYTOPLANKTON ASSEMBLAGE FROM THE MIDDLE DEVONIAN GRAVEL POINT FORMATION, MICHIGAN, U.S.A.

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A moderately diverse and abundant organic-walled microphytoplankton assemblage was recovered from two outcrop locations of the Middle Devonian (Givetian) Gravel Point Formation along the shore of Little Traverse Bay, Michigan. The Gravel Point Formation exposed along the shoreline consists of 11 – 15 m of fossiliferous cryptocrystalline limestone and argillaceous limestone beds, as well as interbedded carbonaceous and calcareous shale layers. Although both shale lithotopes were palyniferous, two samples of calcareous shale at different stratigraphic horizons yielded the best-preserved specimens of organic-walled microphytoplankton taxa, as well as associated scolecodonts, chitinozoans, and miospores.

The Gravel Point Formation acritarch and prasinophyte assemblage reported herein is the first Middle Devonian organic-walled microphytoplankton assemblage described from Michigan. Other published Givetian organic-walled microphytoplankton assemblages from North America include those recovered from the Arkona, Hungry Hollow, and Widder formations of the Hamilton Group, Ontario, Canada; the Silica Shale, Ohio; the Columbus Limestone and Delaware Limestone, Ohio; the Boyle Dolomite, Kentucky; and the Rapid Member of the Cedar Valley Formation, Iowa.

Although sharing many taxa in common with the aforementioned organic-walled microphytoplankton assemblages, the composition and diversity of the Gravel Point Formation assemblage differs from those assemblages in being generally less diverse. The most abundant Gravel Point Formation taxa are *Multiplicisphaeridium ramusculosum*, *Veryhachium* spp., and *Stellinium micropolygonale*. Although the previously mentioned taxa dominate the palynoflora, such characteristic Middle Devonian species as *Duvernayspahera tenuicingulata, Diexallophasis simplex, Exochoderma arca, Muraticavea munifica,* and *Polyedryxium pharaonis* are also present in lesser numbers. However, other typical Middle Devonian taxa that are common elsewhere in Laurentia, as well as cosmopolitan in their distribution, are lacking in the Gravel Point Formation. This could be the result of preservation or paleoenvironmental factors, given that the Gravel Point Formation is interpreted as having been deposited in a near shore, marine environment.

SILURIAN (LLANDOVERY–LUDLOW) PALYNOSTRATIGRAPHY AND PALYNOFACIES OF THE CINCINNATI ARCH REGION, MID-CONTINENT (INDIANA, OHIO, KENTUCKY, TENNESSEE), USA

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Silurian rocks are exposed on the flanks of the Cincinnati Arch in the mid-continent United States. The exposures yielding palynomorphs represent a relatively broad low-gradient ramp having predominately dolomitic carbonates on the western side of the arch (Brassfield Formation, Osgood Formation, Waldron Formation, Mississinewa Shale), and a mix of shales and dolomitic carbonates and on the eastern side (Brassfield Formation, Noland Formation, Estill Formation, Waldron Formation). The palynomorph assemblage is well preserved, thermally immature, and dominated by acritarchs, prasinophytes, and chitinozoans, with an occasional influx of spores and chlorococalean algae.

The Brassfield Formation (Llandovery) is primarily a dolomite that contains a low diversity assemblage. The chitinozoans include Ancyrochitina *ancyrea*, *Ancyrochitina primitiva*, *Angochitina longicollis*, *Conochitina maennili*, and *Cyathochitina campanulaeformis*. The acritarch assemblage consists mainly of veryhachids, micrhystrids, and multiplicisphaerids that are not age diagnostic.

The shales of the Noland Formation (Llandovery) yield a diverse and well preserved acritarch and chitinozoan and assemblage. The palynomorphs include Ancyrochitina *ancyrea*, *Ancyrochitina primitiva*, *Angochitina longicollis*, *Beromia rexroadii*, *Conochitina probosifera*, *Cyathochitina campanulaeformis*, *Carminella maplewoodensis*, *Domasia* spp., *Neoveryhachium carminae*, *Tetrahedraletes medinensis*, *Tunisphaeridium tentaculiferum*, *Tylotopalla caelamenicutis*, *T. deerlijkianum*, and *Visbysphaera* spp.

The shales from the Estill and Osgood have similar upper Llandovery–lower Wenlock assemblages. The palynomorphs include *Angochitina longicollis, Ammodinium microcladum*, *Conochitina probosifera*, *Cymatiosphaera wenlockia*, *C. cornifera*, *Deflandastrum millepiedii*, *Deunffia ramusculosa*, *Domasia bispinosa*, *Domasia quadrispinosa*, *Domasia rochesterensis*, *Domasia trispinosa*, *Duvernaysphaera aranaides*, *Eisenackidium ranaemanum, Eupoikilofusa cantabrica*, *E. striatifera*, *Gracilisphaeridium encantador*, *Hogklintia digitata*, *Khafia circularis*, *Margachitina margaritina*, *Pulvinosphaeridium* spp., *Schismatosphaeridium algerense*, *S. guttulaferum*, *Visbysphaera erratica*, and *Visbysphaera pirifera.*

The Bisher Formation (Wenlock) is predominately a dolomite, but argillaceous intervals yield palynomorphs. The assemblage includes *Deunffia* cf. *D. ramusculosa*, *Diexallophasis denticulata*, *Domasia trispinosa*, *Leiofusa bernesgae*, and *Multiplicisphaeridium* spp.

The Waldron Formation (Wenlock) is a shale in the southern Cincinnati Arch area and yields an assemblage that includes *Ambitisporites avitus*, *Dictyotidium dictyotum*, *Leiofusa algerensis*, *L.*

tumida, *Psenotopus chondrocheus*, *Oppilatala insolita*, *Ozotobrachion dactylos*, *Synorisporites verrucatus*, *Synorisporites* spp., *Tetrahedraletes medinensis*. In north–central Ohio, the Waldron consists of interbedded dolomites and shales associated with reefs. The assemblage from this area contains abundant netromorph acritarchs, including aberrant *Leiofusa* spp. and variants of *Deunffia eisenackii*.

Mississinewa Shale (Ludlow) of northern Indiana represents an intereef environment with dolomite and interbedded argillaceous beds. The assemblage includes *Ambitisporites avitus*, *Emphanisporites protophanus*, *Deunffia eisenackii, Micrhystridium* spp., *Multiplicisphaeridium* spp., *Synorisporites verrucatus*, *Synorisporites* spp., *Tetrahedraletes medinensis* and *Veryhachium* spp..

PALYNOLOGY AND DETRITAL ZIRCONS OF THE SILURIAN CANCAÑIRI FORMATION FROM THE BOLIVIAN ALTIPLANO

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Samples from the Lower Paleozoic Cancañiri Formation at la Cumbre (La Paz-Bolivia), were analysed for petrography, geochemistry, dating of detrital zircons and palynology. This unit was interpreted as recycled from previous glaciogenic deposits probably from the latest Ashgilian and the early Llandoverian. First results of U-Pb ages of detrital zircons (n= 93 < 10% discordance) do not reveal the maximum depositional age as the so far dated sample is affected by sorting. The youngest zircons are of Ediacaran age and are the most abundant group. A significant population (c. 10%) is of Paleoproterozoic (1.9-2.1 Ga) age. Although the rocks are dark to even black the content of organic carbon is minute (< 0.05 %). Trace element geochemistry does not support an anoxic glacial depositional environment with only slight enrichment of some redox-sensitive base metals (Cr, Ni, V), which also could be related to provenance. From sixteen samples processed for palynology, six yielded acritarchs (40 species), chitinozoans (14 species), cryptospores (10 species), chlorophycean algae (*Quadrisporites* sp.), and scolecodonts (2 species), poorly preserved and with high thermal maturation (grey to black colour, TAI 3+ to 4). The biostratigraphic analysis of the species revealed three groups, one of autochthonous species from the Silurian (cryptospores *Imperfectotriletes vardovae,* acritarchs *Ammonidium* ?*cladum, Baiomeniscus camerus, Cymatiosphaera* cf. *franjada*, *Domasia limaciformis, Eupoikilofusa striatifera*, *Fractoricornula* sp., *Helosphaeridium citrinipeltatum*, *Leiofusa cucumis, Leiofusa thomissa, Leiofusa parvitatis, Leiofusa* cf. *estrecha*, *Neoveryhachium carminae, Onondagaella* sp., *Veryhachium strangulatum,* chitinozoans *Cyathochitina* sp. B sensu Paris, *Cyathochitina campanulaeformis*, *Conochitina elongata, Conochitina* cf. *armillata, Desmochitina acollare, Sphaerochitina* sp. C Grahn et al.), others from the Ordovician (*Acanthodiacrodium crassus, Orthosphaeridium* spp., *Vulcanisphaera tuberata, Focusphaera elongata, Lagenochitina cilindrica*, *Lagenochitina baltica*, *Lagenochitina obeligis*), and a third one with long stratigraphic range from Ordovician to younger ages (*Leiofusa tumida, Polygonium gracile, Veryhachium trispinosum, V. downiei, Villosacapsula irrorata*). The autochthonous species suggest for this unit an Aeronian (middle Llandovery) to Telychian (late Llandovery). A correlation with other Early Silurian units such as the Lipeón, Zapla and Cachipunco

formations in northwestern Argentina, Los Espejos Formation of Central Argentina, and the Vargas Peña Formation from Paraguay, and the Vila María Formation in southern Brazil, is supported on the basis of common species (cryptospores *Imperfectotriletes vardovae,* chitinozoans *Conochitina elongata*, *Conochitina* cf. *armillata*, *Cyathochitina campanulaeformis*, *Sphaerochitina* sp. C Grahn et al., acritarchs *Baiomeniscus camerus, Fractoricornula* sp., *Neoverhyachium carminae, Onondagaella* sp.).


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