Absolutely final meeting of IGCP 503: Ordovician palaeogeography and palaeoclimate
Copenhagen 2009

Abstracts

Compiled and edited by
David A.T. Harper and Maureen McCorry

STATENS NATURHISTORISKE MUSEUM - GEOLOGISK MUSEUM
DET NATURVIDENSKABELIGE FAKULTET
KØBENHAVNS UNIVERSITET

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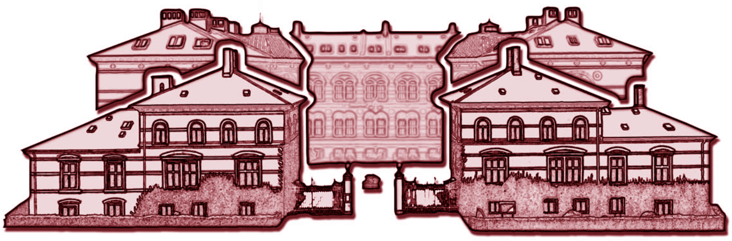

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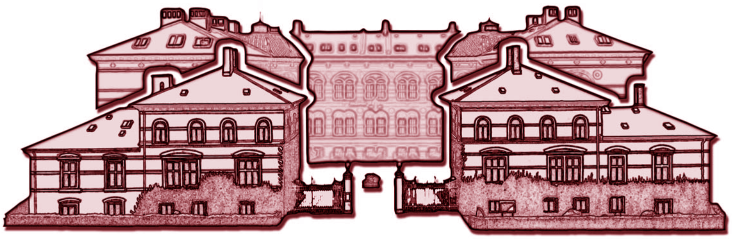
Introduction



Welcome to the absolutely final meeting of IGCP 503, **Ordovician palaeogeography and palaeoclimate**. This is the sixth and final year of one of UNESCO's most successful scientific programmes. During these six exciting years the programme has developed a large, global network of active scientists, generated a substantial number of scientifically significant publications and we have met regularly at many formal and informal international meetings. The formal meetings of the programme in Erlangen (2004), Milwaukee (2005), Glasgow (2006), Nanjing (2007) and Lille (2008), set the agenda for research in our field and each generated thematic publications based on both oral and poster presentations. Copenhagen will be no exception. A volume based principally on the bio- and palaeogeography of the Early Palaeozoic will be published by the Geological Society.

At the time of writing almost 70 delegates have registered for the conference. We welcome colleagues from Australia, Belgium, China, Czech Republic, Estonia, France, Germany, Holland, India, Italy, Lithuania, Norway, Portugal, Russia, Spain, Sweden, Turkey, the United Kingdom and the USA. Some 20 delegates will participate in the pre-conference field excursion to Norway and Sweden. During the three days of technical sessions much new data will be communicated in over 35 oral presentations and through some 25 posters and discussed at a number of business meetings. Over 50 delegates will participate in the conference banquet in Tivoli Gardens and the mid-conference excursion to the classic localities at Stevns Klint and Fakse Quarry together with a tour of the new geological museum at Fakse. Despite the large number of talks we have avoided parallel sessions. All oral presentations are scheduled for the auditorium in the Geological Museum. Posters will be displayed in the canteen at the Geological Museum.

We are very grateful to the following organizations for financial support: The Carlsberg Foundation, the Department of Geology, Natural History Museum of Denmark, University of Copenhagen and the Palaeontological Association. We are also very grateful to the staff at the Geological Museum for their enthusiasm and generous help. In particular Annemarie Brantsen is thanked for her work with the abstract book and together with Anne Haastrup Ross set up the conference web pages; Lene Bentzen and Birgitte Keldsbo Pedersen have helped with the conference accounts. Students associated with the museum have also made significant contributions to the organization of the conference.

We hope you enjoy not only the conference, but also the environs of the lively city of Copenhagen with its many attractions.

David Harper

Copenhagen, August 2009

David Harper, Maria Liljeroth, Arne Thorshøj Nielsen, Jan Audun Rasmussen and Svend Stouge

THE ABSTRACTS

TALKS

Ordovician trilobite biogeography and biodiversity patterns

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Trilobites have played a fundamental role in the understanding of Ordovician palaeogeography. The ordination of faunas by Whittington & Hughes in the early 1970s identified the broad biogeographical units within which Ordovician trilobites were distributed. More recent biogeographical work, including the use of other multivariate and cladistic techniques and the differentiation between the signals from different palaeoenvironments has greatly refined our understanding of the spatial relationships between the major plates and, increasingly, the smaller and more enigmatic terranes. The palaeogeographical setting of Ordovician trilobite faunas provides a framework for documenting and interpreting biodiversity changes through the Period. Preliminary analysis of 5,411 records of valid Ordovician species belonging to 1,021 genera in a global species database of trilobites reveals the changing biogeographical patterns through eight time slices. Palaeocontinents were scored for raw species occurrence by taxon (families or subfamilies) and shared patterns of distribution during each interval were explored using grouping and ordination techniques. Cluster analysis was performed using Pearson's product-moment correlation coefficient and Ward's method to form clusters. Gradient analysis was carried out using detrended correspondence analysis and non-metric multidimensional scaling. The secular global pattern of genus first appearance was also calculated and the geographical pattern was mapped to each palaeocontinent by time slice.

Biostratigraphic and palaeogeographic significance of Paibian (Cambrian) conodonts from the Zhangxia-Rushan section, Shandong, North China

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Some 600 m of Cambrian clastic and carbonate sediments are exposed at the Zhangxia-Rushan section (Shandong Province, North China). The succession encompasses most of the Cambrian Period. The studied interval presented here, ranging from the Guzhangian to the Paibian stages, includes the Kushan Formation and part of the Chaomidian Formation. The trilobite biostratigraphy of the section is well-established, whereas detailed investigations of conodont succession are in progress.

The well-preserved (CAI = 1) and diverse conodont fauna consists mostly of paraconodonts, whereas protoconodonts are only a minor component of the assemblage. According to the biozonal scheme introduced by An in 1982, the *Westergaardodina orygma*, the *Westergaardodina matsushitai* and the *Muellerodus*? *erectus* zones are recognized. Several taxa are endemic but some species can be used for international correlation, and among these *Furnishina quadrata* and *Furnishina longibasis* are especially useful for the recognition of the base of the Paibian Stage and Furongian Series.

The same taxa have a distinct palaeogeographic distribution. They have been recorded from different depositional settings, from different palaeoplates, and at different palaeolatitudes, such as South China and Baltica. As a result, these "vagabond" species allow a confident correlation not only between North and South China, but also give a good tie with the conodont associations I, II and III introduced by Müller and Hinz in 1991 for the Baltica succession.

The Hirnantian oolites in Baltoscandia – part of the terminal Ordovician anachronistic period

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Widespread oolite formations can be considered as anomalous in the marine carbonate ecosystem. Such occurrences have more recently been interpreted as 'disaster-sediments' typical for the early aftermath of extinction events, e.g. in the Silurian and in the earliest Triassic (Groves and Calner, 2004). They are frequently associated with 'pre-Cambrian-style' anachronistic facies such as wrinkle structures, flat-pebble conglomerates and microbialites. This underlines the significance of oolites as marker beds for unusual environmental conditions and ecological demise in shallow subtidal platforms as well as in deeper marine environments. In this presentation we stress the importance of oolites from these perspectives and note also their widespread distribution during the terminal Ordovician anachronistic period of Sheehan and Harris (2004). The Hirnantian of Baltoscandia is characterized by intense oolite formation across vast areas. The oolites in the Ärina, Saldus (East Baltic area) and Loka formations (Sweden) are variously related to the existing carbon isotope stratigraphy but seem to have formed mainly during the peak interval and falling limb of the HICE. Ancient oolites are generally of transgressive origin and based on sedimentary facies and published data; this is likely also the origin for the Hirnantian oolites in Baltoscandia. We will also review contemporaneous oolite formations in remote areas, e.g. in South China and Laurentia.

Was Arctida a reality in the Palaeozoic?

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The pioneer Russian plate tectonicists Lev Zonenshain and Lev Natapov postulated in 1989 that there was a substantial Arctida continent in the Palaeozoic, which consisted of various parts of modern Siberia, including North Taimyr, Severnaya Zemlya, the New Siberian Islands, Wrangel Island and the Chukotka Peninsula, as well as some parts of Alaska. Since then, from continuing studies of tectonics, faunas and palaeomagnetism, it has become clear that North Taimyr and Severnaya Zemlya formed the independent Kara Terrane. In addition, because the New Siberian Islands contain parts of the 250 Ma Siberian Traps Large Igneous Province, they must have been part of the old continent of Siberia rather than part of "Arctida". However, Wrangel Island and the Chukotka Peninsula, both in Siberia, as well as the substantial and composite Arctic-Alaska Terrane and the Seward and York Terranes in Alaska, apparently together did form an independent palaeocontinent. From the varied data we conclude that at the start of the Cambrian that continent, which had a Neoproterozoic core, was situated in the ocean between Siberia, Baltica and Laurentia, but drifted towards the latter, and that movement was reflected in the changing provincial faunas. Eventually, during the Devonian, the eastern end of the Chukotka-Arctic-Alaska continent collided with today's northwestern Laurentian/Laurussian margin, giving rise to the Ellesmerian Orogeny in Alaska and northern Canada. However, it was not until further tectonism in Cretaceous time that the Chukotka-Arctic-Alaska area rotated to its modern position to become welded to the North America Plate (which lies under today's north-eastern political Siberia).

Ordovician palaeogeography: Laurentia-Gondwana separation or intimacy?

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The traditional view of early Palaeozoic Earth opposes the proto-Appalachian margin of Laurentia and the northwest African margin of Gondwanaland. Palaeomagnetic data then require an Ordovician Iapetus

Ocean ~5000 km wide. Recognition that Laurentia may originally have broken out from between East and West Gondwanaland and travelled to its docking position within Pangea around the proto-Andean margin during the Palaeozoic, led to the alternative view of a narrow Ordovician Iapetus (Dalziel, 1997); also palaeomagnetically acceptable given lack of palaeolongitudinal control. In their recent review of the "Great Ordovician Biodiversity Event (GOBE)," Servais *et al*. (2009) take the traditional 'wide Iapetus' approach describing the peak of GOBE as coinciding with "the greatest continental dispersal of the Palaeozoic." However, the reconstruction used (Early Ordovician, 480 Ma, Cocks and Torsvik, 2002) has a separation of >7000 km between the location of the Argentine Precordillera within Gondwanaland and its widely accepted Laurentian point of origin in the Ouachita embayment. As the Cuyania terrane, which makes up the Precordillera only moved beyond the range of benthic faunal exchange with Laurentia during the Sandbian, ~460 Ma, and docked in Gondwanaland prior to the Hirnantian glaciation, 445 Ma, this illustrates a major problem with the traditional view. I will attempt to demonstrate that the data from the Precordillera and the present North Atlantic margins can be reconciled, but only with intimate interaction between Laurentia and Gondwanaland during the Ordovician rather than wide separation.

Trilobites of the genus *Lonchodomas* in the Middle and Upper Ordovician of Baltoscandia

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Trilobites of the genus *Lonchodomas* are rare to fairly common in the Middle and Upper Ordovician (Floian to Katian) of North Estonia, Leningrad region (Russia), Central and South Sweden and Norway. The genus is an important element of Ordovician trilobite faunas of Eurasia, North and South America, and Australia, including over 55 species from 37 regions/localities. The area of origin of the genus was probably Baltoscandia. Three species are described in the lower and middle Floian; they are widespread in the Baltoscandian region and probably occur also in Kazakhstan. Six species are described from late Floian, Dapingian and early-middle Darriwilian of Eastern Australia, Baltica, south-east North America and South America. Nineteen species are known in the upper Darriwilian and Sandbian, where the genus occurs worldwide. The area of distribution was reduced again in Katian, with most species being confined to England and southwestern Baltica, whereas the number of species reduced from twenty to nine.

A number of consecutive morphological changes can be traced in the genus *Lonchodomas* throughout the Floian to Katian. During Floian and Early Darriwilian, the glabella became more narrow and elongated. Pygidial rachis became longer and the form of pygidium changed from triangular to elongated and rounded.

Seven species of *Lonchodomas* are known in the Middle and Upper Ordovician of Baltoscandia, but the validity of some of them (*L. affinis* and *L. jugatus*) remains unclear.

Long-term palaeoceanographic change in the Middle and Upper Ordovician of the Siberian craton

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The Middle and Upper Ordovician deposits of the Siberian craton are represented by cool-water carbonates. Onset of the cool-water carbonate sedimentation starts at the base of the Volginian Regional Stage (mid-Darriwilian) and is associated with widespread phosphatization especially in the Volginian, Kirensko-Kudrinian and Chertovskian Regional Stages (mid-Darriwilian – lower Sandbian). The shift from tropical-type to temperate-type carbonates was preceded by the destruction of the warm-water "carbonate factory" and a large input of siliciclastic material (Baikit Sandstone) during the Vikhorevian and Mukteian Regional Stages (lower to mid-Darriwilian). Wide distribution of the temperate-type carbonates over the Siberian platform located in the low latitudes in the Ordovician can be explained by upwelling of cold oceanic waters and their penetration into epicontinental seas. The same situation was recorded for the North American platform. The transgression and associated upwelling took place after a large regression and tectonic rearrangement related to the initial attachment of the Taconic island arc to the North American continent (Holland &

Patzkowsky, 1996). In Siberia, a similar succession of events was realized slightly earlier. As a result, waste territories of epicontinental seas all over the world including those situated in the tropics were converted into the temperate climate shelves. This conversion probably played a significant role in suppression of pre-existing cyanobacterial sedimentary systems and increasing biodiversification. Upwelling also seems to play an important role in a global later Ordovician cooling terminated by the Hirnantian glaciation.

Biogeography of Ordovician – Devonian tergomyans and gastropods: outline of project

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Analyses of distribution and occurrences of both trilobites and brachiopods have been pivotal for the current understanding of Lower Palaeozoic biogeography. A fruitful coupling with palaeomagnetic studies has recently produced highly accurate palaeomaps for the Ordovician and Silurian. Tergomyan molluscs and gastropods represent abundant and diverse marine benthos with a huge potential for further detailing of Lower Palaeozoic biogeography. In the present project we aim at analysis of Ordovican – Devonian members of these groups, on a stage by stage level. The analysis will be at the generic level, because very few species seem to be common between the various palaeo terranes. This is especially true for the Ordovician. Although a number of important contributions on diversity and distribution exist, these molluscs have never been subjected to a large-scale numerical analysis. In the literature, Ordovican taxa such as *Peelerophon* (Tergomya), *Tritonophon* (Gastropoda), and the widespread macluritid gastropods have been recognized as useful for biogeographical studies. For Silurian, and particularly Devonian taxa, a much better understanding of biogoeographical distribution exists. Devonian gastropods have for instance been used to formalize distinct biogeographical realms. The current project involves several experts, with the two authors as principal coordinators.

Polychaetes from the Kukruse (early Late Ordovician) post-impact event strata of Tvären, southeastern Sweden

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The post-impact Dalby Limestone (Kukruse; Upper Ordovician) of the Tvären crater, southeastern Sweden, has been analyzed with regards to polychaetes, as represented by scolecodonts. A palaeoecological succession is observed in the Tvären-2 drill core sequence, as the vacant ecospace was successively filled by a range of benthonic, nektonic and planktonic organisms. Scolecodonts belong to the first non-planktonic groups to appear and is one of the most abundant fossil elements. The assemblage recorded has an overall composition characteristic of the Upper Ordovician of Baltoscandia. *Oenonites*, *Vistulella*, *Mochtyella*, and the enigmatic "*Xanioprion*" represent the most common genera whereas *Pteropelta*, *Protarabellites*?, *Atraktoprion*, and *Xanioprion* are considerably more rare. The assemblage differs from coeval ones particularly in its poorly represented ramphoprionid fauna and the high relative frequency of "*Xanioprion*". A taxonomic succession and changes in abundance and relative frequency of different taxa is observed from the deepest part of the crater and upwards towards inferably more shallow water environments. The initial post-impact assemblage does not, however, necessarily represent a benthonic colonization of the crater floor. Instead it may be transported, as indicated by its taxonomic correspondence to the rim facies fauna recovered from Dalby erratics of the Ringsön island. Whether or not the impact had destructive or beneficial effects on the polychaete faunas cannot be assessed as pre-impact strata are lacking from the region. Nonetheless, these strata have yielded considerably richer scolecodont assemblages than hitherto recorded from the approximately coeval Lockne crater, probably as a consequence of shallower water settings in the former area.

Late Ordovician brachiopod distribution and ecospace partitioning in the Tvären crater system, Sweden

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Patterns of distribution and ecospace utilization of Late Ordovician brachiopods in a recently formed, contemporary meteorite crater are described and analyzed. On the crater rim, rhynchonelliformean brachiopod communities, dominated by a wide range of orthides and strophomenides, were established at an early stage, although in the crater depression rhynchonelliformean brachiopods, merely represented by strophomenides, are not present until the upper third of the remaining crater fill. The crater formed a protected but restricted microenvironment where sediments four times the thickness of the nearby basinal succession accumulated. Within this narrow space, environments varied from shallow and reef-like to over 200 m in depth and from well oxygenated to hypoxic. Such varied environments generated a rough ecological landscape, facilitating niche partitioning across a relatively small geographic area. Analysis of the guild structure of the fauna permits explanation of the local biodiversity hotspot in otherwise low-diversity strata elsewhere in the Scandinavian region. The Tvären impact event had an important palaeobiologic effect upon the fossil record as it served as a local pump and reservoir for biodiversity. Moreover, the development of new community types and narrowly-defined niches helped further drive both α and β biodiversity during a critical phase of the Great Ordovician Biodiversification Event.

Biogeographical patterns in the rhynchonelliform brachiopod fauna through the Ordovician Period

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The Ordovician Period was pivotal in the evolution of the Brachiopoda. During the period there was an overall reduction in the provinciality of its brachiopod faunas as many of the major continental basins and shelves converged and habitats were destroyed. Multivariate analyses of brachiopod-range data using clustering and ordination techniques through the system indicate at least five recognizeable groups corresponding to the Tremadocian-lower Floian, upper Floian-Dapingian, Darriwilian-Sandbian, Katian and the Hirnantian. Statistical analyses of presence-absence data, anchored to GPS coordinates and plotted on BugPlates dynamic palaeogeographic reconstructions, through an interval of some 25 myr, monitor the evolution of brachiopod provinces during the period. High diversities are apparent amongst the upper Floian-Dapingian benthic faunas belonging to well-defined Celtic, peri-Gondwanan and the Toquima-Table Head, peri-Laurentian marginal and oceanic provinces, reflecting the dispersal of the continents and the high frequency of volcanic arcs and microcontinents. During the subsequent Darriwilian-Sandbian, biogeographic patterns are more diffuse and less easy to define against a background of climatic change and fluctuating sea level; nevertheless, continental, marginal and oceanic faunas can be differentiated. The abundant and diverse faunas of the Katian show well-defined provincial patterns together with a distinction between shallower-water assemblages and the deeper-water *Foliomena* fauna. Distributional patterns were modified during the Boda Warming Event, with more endemism and biotic migrations. Although less diverse, the Hirnantian faunas, developed during the transition from greenhouse-icehouse-greenhouse conditions, demonstrate a strong provincial polarity, with fewer recognizable, but more tightly constrained, provinces against a background of biotic extinction and recovery.

Biodiversity patterns of Ordovician acritarchs in Baltica: comparison with marine invertebrates and sea level changes

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Based on extensive literature on Ordovician acritarchs, biodiversity curves of the marine microphytoplankton of the palaeocontinent Baltica are compiled. The data set includes over 600 species whose ranges can be used in diversity analysis. Stratigraphically well-constrained data from the Rapla and Männamaa boreholes, northern Estonia, are analysed separately in order to provide additional information on the Middle to Late Ordovician phytoplankton evolution on shallow shelf settings.

A continuous increase in diversity from the base of the Ordovician to the late Darriwilian – early Katian can be observed, with highest total diversity approaching 250 species in the Keila Regional Stage. Diversity diminished progressively after the early Katian with a more pronounced decrease in the upper Ordovician Porkuni Regional Stage, corresponding to the Hirnantian.

The phytoplankton diversity curves match rather well with those of several other fossil groups in Baltica. The diversity changes can be analysed and discussed in the context of palaeogeographical (northwards drifting of Baltica) and palaeoclimatological (rising sea levels up to the middle part of the Upper Ordovician) changes. The increasing diversity of the phytoplankton not only rawly correlates with the Baltic and global sea level changes, but also with the diversification of marine invertebrate groups. This corroborates the assumption that the diversification and abundance of the organic-walled microphytoplankton may have had an important role in triggering the Ordovician Biodiversification.

Aspects of Ordovician glacial deposits in southern Saudi Arabia

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In southern Saudi Arabia, the Sanamah Formation is of Ordovician or Early Silurian age. Its deposits are mainly found in channels incised into the underlying Cambrian – Ordovician sediments. The channel fill consists of red conglomeratic sandstone with rounded to well-rounded quartz pebbles and cobbles. Repeatedly, large angular clasts of friable, coarse-grained sandstone have been observed in the conglomerates. Above these sediments, there is a succession of light-coloured sandstones, which show almost no internal structure. On outcrop scale, however, it is evident that the sandstones and the conglomerates were deposited in giant foresets comparable to coarse-grained deltas. Above this succession and onlapping the confining borderlands of the valleys are conglomeratic sandstones, badly sorted and with striated clasts. In several sections, striations have been found in the friable sandstones, locally 5 horizons within 40 m of section, that closely resemble glacial striations carved onto hard rock such as basement. We question whether such striations are evidence of direct glacial contact with the sediment.

Although there is no doubt that the Sanamah Formation represents a proglacial to periglacial depositional environment, we will discuss the general palaeogeography in which the Sanamah Formation was deposited, why so many features are different from the modern analogues, and why the Sanamah Formation is restricted to broad channels probably draining the Arabian Shield as a hinterland. Finally, we will propose a new model for the generation and preservation of multiple levels of glacial striations in soft sediment.

Palaeobiogeography of Ordovician echinoderms

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Echinoderms underwent a major diversification in Ordovician times, with a regular increase in diversity from the Tremadocian to the late Sandbian – early Katian, followed by a sharp decrease in latest Ordovician times. The detailed patterns of palaeobiogeographic distribution of all main clades of echinoderms are described here: for example, asterozoans (asteroids, ophiuroids, ...), blastozoans (aristocystitids, glyptocystitids, pleurocystitids, ...), crinoids, cyclocystoids, echinoids, edrioasteroids, and stylophorans (cornutes, mitrates). At a global scale, endemicity is higher in Early to Middle Ordovician assemblages, whereas Late Ordovician faunas are more cosmopolitan. This progressive shift from endemic to more cosmopolitan assemblages probably largely results from both a large scale transgressive trend from the Tremadocian to the late Sandbian, and dramatic changes in global palaeogeography (e.g., drift of Avalonia away from Gondwana towards Baltica and Laurentia). At a more regional scale, changing palaeoenvironmental conditions probably played a key role in the composition of Late Ordovician echinoderm assemblages and their more cosmopolitan character. For example, the first appearance of cool-adapted taxa (solutes, stylophorans) on the eastern margin of Laurentia coincides with the drowning of this region (taconic orogeny) in the late Sandbian. In late Katian times, high-latitude, cool-adapted assemblages are suddenly replaced by more temperate faunas in most regions of the Mediterranean Province. This dramatic shift in the composition of echinoderm communities was possibly driven by palaeoceanographic changes. Finally, the few documented Hirnantian assemblages of echinoderms are dominated by cosmopolitan, cool-adapted taxa.

The Katian Slandrom glaciation: an example of faunal change and peaks in diversity related to glacial intervals in the Late Ordovician

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There has been much discussion about the timing of Early Palaeozoic glaciations other than the well-established Hirnantian glaciations, based on faunal extinctions and marked changes in the carbon isotope record. The Mid-Katian Slandrom Glaciation commenced in the upper *Amorphognathus superbus* Zone and was first discussed by Calner *et al*. (submitted, PPP) based on profound facies changes and an associated, widespread palaeokarst horizon at the Slandrom Limestone-Fjäcka Shale boundary in Baltoscandia. Together with sedimentary changes in the tropics (Laurentia) as well as in high latitude peri-Gondwana (e.g., Prague Basin) there are also marked faunal changes in different palaeobasins during this interval; these data suggest that this is an environmental perturbation that deserves global recognition based on sedimentological and faunal criteria.

Study of the classic Sepkoski curves, together with diversity curves for specific faunal groups, indicates that diversity peaks compare well with the Late Ordovician cold periods or glacials and diversity apparently falls during the warmer intervals or 'interglacials'. The time slice for the Slandrom Glaciation corresponds well with a major peak in diversity, not only in the Palaeozoic but also in the Modern Fauna of Sepkoski. This mid-Katian interval is related to a time of maximum biodiversity in several groups and the cooling was possibly the main trigger. Many groups, like brachiopods and gastropods, appreciated cooler conditions and, in general, faunas seem to flourish during colder periods. The interval also corresponds to the climax offshore development of many groups of benthic organisms, creating a maximum for β diversity during the mid-Katian.

Conodont faunas and carbon isotopes of the Oslobreen Group, Ny Friesland (NE Spitsbergen): correlation along the Laurentian margin

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The remotely located Cambro – Ordovician strata in Ny Friesland, Spitsbergen are referred to the Oslobreen Group, composed of the Tokammane (Cambrian), Kirtonryggen (Lower Ordovician) and Valhallfonna (Middle Ordovician) formations. The Ordovician conodont succession of Ny Friesland deposits is newly recorded and well-preserved collections of conodonts (CAI 1) have been recovered from the Lower and Middle Ordovician interval in the region.

The yield is relatively poor for the Kirtonryggen Formation, but the oldest Ordovician conodont faunas span the *Rossodus manitouesis* through *Macerodus dianae* zones (Tremadocian) followed by the Floian *Oepikodus communis* Zone. The taxa are typical of the tropical North American Midcontinent faunal province, and dominated the region until open marine associations invaded the shallow shelf (i.e. *Evae* transgression). The pandemic *Oepikodus evae* becomes frequent and is succeeded by *O. intermedius* in abundance in the Olenidsletta Member, i.e. the lower member of the Valhallfonna Formation. The upper strata are characterized by the *Periodon-Paroistodus* assemblage characteristic for outer shelf and slope environments around Laurentia.

In total, this formation comprises the Floian and Dapingian stages and ends in the early Darriwilian *Lenodus variabilis* Zone. The Ny Friesland fauna show affinities to coeval assemblages from North-East Greenland and West Newfoundland; the presence of early Darriwilian *Phragmodus spicatus* and *Juanognathus leptosomatus* known from Australo-Asian peri-Gondwana allows for precise correlation to the areas.

The conodont succession is closely tied to the newly established $\delta^{13}C$ isotope curve from Ny Friesland. Correlation $\delta^{13}C$ curves from North East Greenland, Newfoundland and Argentine Precordillera is presented.

Quantifying the biogeographical patterns of Ordovician ostracods

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The biogeographical occurrence and patterns of distribution of shelf marine ostracod genera are analyzed quantitatively for two Ordovician time slices, thought to reflect global greenhouse and icehouse climate states respectively. These correspond to the earliest Late Ordovician and to the latest Ordovician. The earlier time slice is equivalent to the *Nemagraptus gracilis* interval, and is defined as the total range of the eponymous graptolite species. In reality the limits of stratigraphical resolution means that some ostracod-bearing strata from immediately below and immediately above this interval may have been incorporated into the dataset. The Hirnantian time slice includes data from some areas, in particular Anticosti Island, where the exact age of the terminal Ordovician strata has still to be resolved.

The results from the *N. gracilis* interval reveal a subdivision into four broad biogeographical areas, namely Laurentia, Peri-Gondwana (with Ibero-Armorica, Saudi-Arabia and Bohemia at the center), Baltoscandia and Russian Siberia, while the position of the Precordillera, Kazakhstan, Holy Cross Mountains and Norway remains poorly resolved. The Hirnantian interval contains data from a limited number of localities, mainly in Baltoscandia and North America. A decrease of provincialism is suggested by an increase in ostracod faunal affinities between Baltoscandian and Peri-Gondwanan areas. However, a response to global cooling is not identified in the analyses of the distribution patterns.

As the taxonomic status of many of the taxa - published over the last fifty years - is still in flux, the results of these analyses must be regarded as provisional.

The Boda event and the start of glaciation in Perunica: rise and fall of brachiopod diversity at the top of the Králův Dvůr Formation

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The Králův Dvůr Formation (KDF) is characterized by deficiency of black-shale lithofacies indicating sufficiently aerated waters near the basin floor. This is reflected by the deep-water, well-established and widespread assemblage of *Chonetoidea*, *Dedzetina,* and *Foliomena* (*Foliomena* Fauna). The rich fauna with *Leptaena*, *Hindella*, *Eoanastrophia, Jezercia, Epitomyonia,* and minute rhynchonelliformeans derived from the *Foliomena* fauna indicates the first drop in sea level drop following the influence of climatic amelioration during the Boda Event. Succeeding climatic deterioration brought a high-latitude *Mucronaspis* Fauna leaving only one minute orthid species apart from a poor trilobite, ostracod and bivalve fauna. Diamictites bearing “exotic” and probably reworked brachiopod fossils terminated the KDF. Cooling, shallowing and deposition of diamictites led to the temporary extinction of brachiopod shelly fauna on the basinal floor.

Lower Palaeozoic phytoplankton biogeography

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The distribution patterns of modern organic-walled phytoplankton (dinoflagellates) are regulated by environmental signals such as temperature, salinity, water depth, nutrient supply, and water chemistry. One of the more important parameters is the climatic signal which is mainly related to latitude. Published models on Recent dinoflagellate distribution patterns show that selected dinoflagellate species occupy different climatic zones (e.g., arctic to cool-temperate, temperate, cool-temperate to tropical). On the other hand, distribution maps of modern microphytoplankton illustrate some “provinces” that are clearly latitudinally controlled, while others are partly located along the margin of a continent. It is also evident that surface water currents partly control the distribution of the modern assemblages.

Similar palaeogeographical distribution patterns are also known for fossil dinoflagellates in the Mesozoic, and it would be logical to find the same scenario for Lower Palaeozoic acritarchs, which were mostly the cysts of organic-walled microphytoplankton.

Analysis of the distribution of Lower Palaeozoic acritarchs shows no apparent palaeobiogeographical differentiation during the Cambrian, and species or assemblages appear to have had a cosmopolitan distribution. A "provincialism" is clearly present in the late Early and Middle Ordovician, with an obvious distinction between peri-Gondwanan assemblages and Laurentian or Baltic associations. The global distribution of Ordovician acritarchs was probably the result of an interdependence of continental arrangement, latitudinal position, environmental conditions and oceanic currents, although the exact impact of the latter is far from understood. During the Late Ordovician, the provincial distribution became less evident, but it developed more fully again during the Silurian.

Exploration of biodiversification signals: the example of the Early Palaeozoic blastozoans (Echinodermata)

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What has governed changes in taxonomic diversity of the marine fauna over the entire Phanerozoic? The documentation and interpretation of this question and the dynamics of diversification have motivated palaeontological research on a global, temporal and taxonomic scale for more than 30 years. Numerous quantitative methods have recently been developed to dissect the different signals (e.g., diversity metrics, evolutionary and diversification rates, longevity) and their associated biases (e.g., preservation, sampling effort, methods). They mostly concern the possible relationships between taxic geographic ranges and many of theirs characteristics, such as diversity, longevity and occurrences, at large taxonomic and stratigraphic scales. Major results suggest that 1) diversity changes tend to result from changes in origination and/or in extinction, 2) taxonomic diversity is positively correlated to the taxic longevity, and 3) taxonomic diversity could be also influenced by some other factors, such as the onshore-offshore pattern or the palaeolatitudinal gradient. Do the same factors contribute with the same strength to the diversity or the diversification signals at a smaller taxonomic scale? This question will be investigated on the biodiversification events of one echinoderm subphylum (Blastozoa). The compilation of the published papers dealing with Early Palaeozoic blastozoans has allowed the construction of a quasi-exhaustive database, which includes stratigraphic, geographic, and environmental occurrences for each genus. Preliminary results suggest that Early Palaeozoic blastozoan diversification may be mostly driven by the origination rate. Moreover, the Ordovician diversity rise could be due to the increase of generic longevity related to the increase of their geographic extension and the decrease of their eurytopy.

Cambrian sea-level changes: new evidence from Scandinavia

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In Scandinavia the last Precambrian orogeny took place at around 1 billion yrs ago. Thereafter the area underwent intensive peneplainisation and thus was exceptionally flat at the dawn of the Cambrian. Scandinavia was progressively flooded during the early Cambrian and was totally submerged from the mid Cambrian onwards. The increasing submersion was associated with progressive clastic starvation of the epicontinental sea and average depositional accumulation rates eventually diminished to 2-4 mm/1000 yrs during the Furongian. From the mid Cambrian onwards dysoxic conditions prevailed in the sea, probably as a result of restricted water circulation. The continent was located in relatively cool water and carbonate production was minimal throughout the Cambrian, despite the pronounced clastic starvation. Carbonate production was probably also hampered by the widespread mid-late Cambrian dysoxic conditions, preventing a calcareous producing shelly fauna from settling on the sea floor.

Deposition thus did not influence local depth in the sea to any significant degree except in the earliest Cambrian, where transgressive events were followed by extensive and probably rapid progradation. The craton was overall tectonically quiescent with passive continental margins to the west and south (present day geography). The Cambrian succession of Scandinavia therefore provides a condensed sedimentary record of Cambrian sea level changes, strongly controlled by eustasy, and a detailed sea level curve has been reconstructed based on the distribution of lithofacies in combination with analyses of faunal data from the monotonous Alum Shale. The 1st order sea level rose significantly during the early Cambrian and more slowly during the mid and late Cambrian. Five 2nd order cycles area recognized. The analysis of 3rd order fluctuations is only completed up to the mid mid Cambrian and the total number of cycles is as yet undetermined.

Variability of a dalmanitid trilobite *Mucronaspis mucronata* (Brogniart) in Stirnas-18 core, Latvia

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The cosmopolitan dalmanitid trilobite *Mucronaspis mucronata* (Brongniart) is known from the Hirnantian of Avalonia, Laurentia, Baltica, Siberia, Kazakhstan, South China, Sibumasu and and peri-Gondwana. In the Baltoscandian palaeobasin it is previously recorded from Poland, Oslo-Asker district, Skåne, Västergötland, and drill cores of Lithuania, Latvia, and southern Estonia, not reaching the near-shore facies of the North Estonian Confacies Belt. Previous studies of the Baltoscandian collections have concluded that *M. mucronata* is a rather variable species.

A morphometric study of the collection of *M. mucronata* from the interval of 14 m of the uppermost Ordovician Kuldiga Formation in the Stirnas-18 core, eastern Latvia, shows very little variability, although this interval of the core is characterized by variable lithologies and stable isotope composition. The morphology of the Latvian specimens is closely similar to that of *Mucronaspis mucronata* (Brongniart) *kiaeri* Owen, characterized as a geographical subspecies from the Oslo-Asker district.

Biogeographic affinities of a new Middle Ordovician (Darriwilian) shelly fauna from the South Island of New Zealand

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A well preserved Middle Ordovician shelly fauna, including conodonts, lingulate brachiopods and trilobites, is documented from an allochthonous limestone lens exposed in Thompson Creek, northwest of Nelson, on the South Island of New Zealand. The stratigraphic setting is unclear as the limestone is situated in the Takaka Terrane adjacent to the Anatoki Fault, separating this terrane from the Buller Terrane. Biostratigraphically significant conodonts among the 24 species recognized include *Histiodella holodentata, Baltoniodus*? sp.*, Paroistodus originalis, P. horridus, Periodon macrodentatus, Protopanderodus* sp. cf. *P. varicostatus*, *Costiconus ethingtoni* and *Venoistodus balticus* which indicate a Darriwilian (late Da2 to mid Da3) age. Occurrence of *Ansella jemtlandica*, *Baltoniodus*? sp., *Periodon macrodentatus, Spinodus* sp. and *Histiodella holodentata* suggests arelatively deeper-water (outer shelf to slope) setting, comparable with contemporaneous faunas from central New South Wales, described from the lower part of the Weemalla Formation and from allochthonous limestones within the Oakdale Formation. The lingulate brachiopods include new species of *Broeggeria*, *Cyrtonotreta*, *Scaphelasma*, *Torynelasma* and *Nushbiella*, together with representatives of *Spinilingula*, *Schizotreta*, *Trematis*, *Lurgiticoma*? and *Undiferina*, plus several indeterminate acrotretoids. The brachiopods show strong affinities with late Middle Ordovician faunas from Kazakhstan, with a contemporaneous assemblage from Meiklejohn Peak in Nevada, and to a slightly younger assemblage from the Pratt Ferry Formation of Alabama. Incomplete remains of several trilobites are known from Thompson Creek, though only one is identifiable; it is tentatively assigned to *Gogoella*, a genus previously described from Western Australia and Argentina.

Percival publishes with the permission of the Director, Geological Survey of New South Wales, NSW Department of Primary Industries.

So, where did they go? Brachiopod refuges during the End Ordovician crisis interval

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The End Ordovician mass extinction event was a major disaster with respect to taxonomic loss. An estimated 85% of all species were eradicated during the event (Jablonski, 1991). The rhynchonelliformean brachiopods experienced a taxonomic loss of about 60% at the generic level and, thus, were severely targeted by the catastrophe (Rasmussen, 2009).

Using GIS-software, a large, geo-referenced database was compiled encompassing global brachiopod occurrences through the crisis interval. A survey was conducted based on this database to track fluctuations in brachiopod α- and β-diversity through the crisis interval. Furthermore, each brachiopod species within the database was ecologically coded to assess its bathymetrical preferences during the crisis.

When split up regionally it appears that the greatest taxonomic loss was situated within the Iapetus region and in particular on the peri-Laurentian terranes. The variations in diversity and ecological preferences of the brachiopod faunas through the crisis interval indicate that Baltica was a particularly good refuge for the shallow water forms, whereas on the South China Plate, mid-shelf to deep-water faunas were better protected.

In the recovery interval, Avalonia, Baltica, Laurentia and South China experienced increased diversity in shallow-water settings. Most regions experienced increased diversity among deeper-water faunas, although this appears to have been delayed until the Late Rhuddanian on Laurentia. At this time the deeper-water faunas disappeared from the peri-Laurentian terranes (as did the terranes themselves), probably as a consequence of the progressively narrowing Iapetus Ocean. As these terranes were the focal point for taxonomic reduction it is suggested that here the End Ordovician mass extinction event is clearly linked to a major loss in habitats.

Biogeographic significance of the cephalopod fauna of the Ordovician Otta Conglomerate, Central Norway

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Cephalopods from the Otta serpentinite conglomerate of the Upper Allochthonous Køli Nappe, Norwegian Caledonides, have been known since Hedström reported elements of the fauna almost eighty years ago. Other fossil groups such as gastropods, brachiopods and trilobites have been studied in greater detail and have shown that taxa with Baltic and Laurentian affinities occur together with endemic taxa and indicate a relationship with the Celtic Province of the Iapetus Ocean. Preliminary investigations of the cephalopod fauna from the Otta serpentinite conglomerate indicate that it is dominated by *Discoceras*, while *Endoceras*, *Ctenoceras*, *Plectoceras* species of the family Orthoceratidae and a specimen questionably belonging to *Allumetoceras* occur in lower numbers. A coiled form with a characteristic deep, ventral, longitudinal furrow, probably represents a new genus. The preliminary identifications support an intra-Iapetus location of the Otta area during the Mid Ordovician.

Eocrinoids and paracrinoids of the Baltic Ordovician basin: a biogeographical aspect

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Eocrinoids are represented by at least 12 genera in the Baltic Ordovician Basin. Representatives of the rhipidocystid-cryptocrinitid lineage of eocrinoids (six genera) were often dominant in Middle Ordovician echinoderm communities. This lineage originated from outside the Baltic Region. Although eocrinoid genera similar to these Baltic taxa are found only in Laurentia, morphological differences between the Baltic and American taxa suggest the presence of a third biogeographical region inhabited by their ancestors that gave rise to parallel lineages of the main rhipidocystid-cryptocrinitid stem in Laurentia and Baltica. It is possible that this province was situated in the South China Region. The phylogenetic and biogeographical roots of the unusual eocrinoid *Bolboporites* are unknown, but its center of diversification was certainly in the Baltic Region. From here, at the end of the Darriwilian, this genus migrated to North America. Plates of Rhopalocystidae are abundant in the Volkhovian (Dapingian). The Baltic genus originated from Gondwanan rhopalocystids. Three other genera have unusual morphology, uncertain systematic position among eocrinoids and are endemic for the Baltic Region. Their phylogenetic and biogeographic roots are unknown. Eleven genera mostly occurred in the Middle Ordovician and had completely disappeared by the end of the Kukruze. Only one eocrinoid genus (new) is known from the Sandbian. Both paracrinoid genera *Achradocystites* (Keila-Oandu) and *Heckerites* (Keila) are endemic for Baltica. The genus *Heckerites* is somewhat similar to the typical Laurentian amygdalocystitid paracrinoids. The genus *Achradocystites* is significantly different from all other paracrinoids, primarily in the arm morphology. Therefore its phylogenetic roots and biogeographical origin remain uncertain.

The Hirnantian stratigraphy of Portugal, with notes on the Trás-os-Montes and Valongo-Arouca areas

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The Hirnantian succession in Portugal is characterized by the occurrence of widespread glaciomarine diamictites and shallow-water sandstone deposits, which crop out in the Amêndoa-Mação and Buçaco synclines, as well as in the Valongo anticline of the Central-Iberian Zone. Additional outcrops occur to the north in the region of Trás-os-Montes. A generalized stratigraphic sucession, from base to top, consists of: a) a basal hiatus of variable extent (from a part of the late Katian to earliest Hirnantian, to a late Darriwilian to early Hirnantian long ?erosional gap); b) basal sandstones and quartzites (Maceiras Fm., Ribeira Cimeira Fm., lower part of the Sobrido Fm., upper part of Ribeira da Laje Fm.); c) massive diamictites (e.g. Guadramil and Casal Carvalhal formations, upper part of the Sobrido Fm.); and d) terminal siltstones (upper part of the Guadramil Fm.) or local quartzite (e.g. Vale da Ursa Fm. and equivalents, transitional with the Silurian). A probable Hirnantia Fauna was reported from basal beds in southern Buçaco. Correlations between the main Central-Iberian sequences of Portugal and Spain reveal a very incomplete record of Hinantian rocks in comparison to the main glacial cycles in the glaciated areas of African Gondwana. Of significance, true dropstone textures were discovered for the first time in glaciomarine diamictites from northern Portugal (Guadramil Fm.), as well as associated pebbles in varve-like laminated mudstones in the middle part of the Sobrido Formation (Valongo-Arouca inlier).

Palaeogeographical and palaeobiogeographical nomenclature in the Early Palaeozoic

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Terms such as terrane, micro-continent, and micro-plate are commonly used in geodynamical models by structural geologists and tectonicians. On the other hand, terms such as realm, province, and biochors are used by palaeontologists and palaeobiogeographers to describe the geographical distribution of living or fossil organisms.

In recent decades, it has become fashionable to create new terranes or microcontinents or new provinces. Selected palaeontological or palaeomagnetic data, not necessarily placed in a general context, have led to the creation of numerous new palaeogeographical units around the world. Moreover, there is often a conceptual confusion between palaeogeographical units (physical entities) and biogeographical units (biotic entities) that has resulted in a circular reasoning when one wishes to use biogeographical data to test palaeogeographical reconstructions based on geological and palaeomagnetic data.

For the Early Palaeozoic periods the palaeogeographical and palaeobiogeographical terminology has often been used indiscriminately and inconsistently in publications concerning palaeogeographical reconstructions, plate tectonic configurations, and palaeobiogeographical distributions. The confusion of terms has led to a mixing of terminology and palaeogeographical concepts. This is particularly valid for the peri-Gondwanan margin during the Early Palaeozoic and the discussion between palaeobiogeographers and palaeogeographers, where terms such as terranes and provinces, for example, have been confused.

In the present paper, we discuss the different palaeobiogeographical concepts in the Early Palaeozoic, by comparing different models and reconstructions, with the major aim of clarifying the conceptual differences in terminology used by palaeobiogeographers and palaeogeographers.

We advocate the use of distinct and consistent terminologies for both palaeogeographic and palaeobiogeographic units, following the guidelines of the group 'Friends of Paleobiogeography' with a coherent palaeobiogeographic classification and nomenclature of palaeobiogeographic units (biochoremas) as proposed by Westermann (2000) and Cecca and Westermann (2003).

Comparison of the relative ecological impact of the end-Ordovician and other mass extinctions

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Loss of taxa during the end-Ordovician extinction may have been exceeded only by the end-Permian extinction. However, ecologic structures of the dominant Ordovician animal groups were little changed compared to the other mass extinctions. Features that differentiate these extinctions most likely are related to the primary causes of the extinctions. The greatest Ordovician losses to the benthic fauna were in the epeiric seas, which were drained during glacio-eustatic sea level decline. The key to the relatively minor changes of ecological structure was that there was little preferential extinction and few niches were completely vacated. Nearly all niches were repopulated by survivors of groups that had filled these niches prior to the extinction. Conversely, many niches were vacated during the great Permian extinction. Although the Devonian, end Triassic and K/Pg extinctions had much less taxonomic loss than the Permian Extinction these events also preferentially culled many groups and produced many vacated niches into which new groups of animals evolved. Siberian Trap volcanism was likely involved with the end-Permian extinction, and effects of volcanism have been suggested for the Devonian and end-Triassic extinctions. The K/Pg extinction was caused by an asteroid impact. It may now be possible to assess the relative effect of the three types of perturbation that caused mass extinctions. Volcanism was most likely to cause the most severe mass extinction over the last 500 MY. Asteroid impact is second and climate change (glaciation) is third. Any of the three mechanisms could produce much larger extinctions (e.g. 20 km asteroid or a snowball Earth would produce larger events), but since the 5 major events did happen during the Phanerozoic, and smaller examples of each did occur, the rankings are a reasonable approximations of worst case occurrences. The Ordovician extinction, caused by climate change with a brief interval of glacial maximum and rapid melting of glaciers, provides the best analog for the modern ecological crisis. We might be led to predict that the current climate changes will not produce the most severe type of disruption. However, the modern event differs from the Ordovician in that many keystone species are already in trouble; the oceans have been degraded by pollution, over fishing and acidification, and the land has been degraded by deforestation, pollution and loss of wildlife habitat.

Lower to Middle Ordovician conodont faunal diversity on the South China palaeoplate in comparison to the Baltica palaeocontinent

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A survey on the palaeodiversity of the Lower to lower Upper Ordovician conodont faunas from central South China and Baltica is presented. Comparison of the palaeodiversity curves from the two areas demonstrates that the development of diversification is similar. Analysis of α diversification (species richness) through time shows two large conodont diversity peaks in the investigated interval, i.e. the Upper Floian and mid Darriwilian. The highest α diversity is observed in the mid to upper Floian Stage (*Oepikodus evae* Zone, Lower Ordovician). Lower maxima in species richness or diversification are recorded in the early Tremadocian, late Tremadocian, early Dapingian and in late Darriwilian stages.

Changes of the conodont faunas through time do not resemble the diversification pattern displayed by brachiopods from South China and Baltica. They rather correlate with sea-level changes and facies development in the regions. High α diversity abundance in conodonts corresponds to carbonates, whereas conodonts are rare to nearly absent in siliceous facies.

Latitudinal distribution of bryozoan limestones in the Ordovician

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The benthic colonies of most recent bryozoans have calcite skeletons that locally contribute significant amounts of carbonate sediment to the sea floor. Whereas recent bryozoans are diverse in shelf seas all around the world, only outside the tropics are they potential limestone producers – tropical bryozoans have too small a biomass relative to other carbonate producers (corals, algae and molluscs) to be important. However, bryozoan limestones were formed at all palaeolatitudes, including the tropics, during the Palaeozoic. Indeed, many Ordovician bryozoan limestones accumulated in the palaeotropics, such as those from the type Cincinnatian. Therefore, straightforward uniformitarianism cannot be applied to infer palaeolatitude from the occurrence of bryozoan limestones in the Ordovician. A key question that remains to be answered is whether low and high latitude bryozoan limestones of the Ordovician differ in the taxonomic composition of the bryozoans or associated biotic and sedimentary facies. Differences are not immediately obvious. For example, Ordovician biohermal bryozoan limestones were not restricted to low latitudes but may also occur in high latitude settings. A possible explanation for the broader palaeolatitudinal distribution of bryozoan limestones in the Ordovician compared to the present day is that durophagous predators were insignificant in the Ordovician, allowing large erect bryozoan colonies to grow in the tropics where today they are vulnerable to grazing fishes and echinoderms etc.

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New palaeogeographical base maps for the Lower Palaeozoic

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New global maps for the conference and subsequent book from 540 Ma (Lower Cambrian) to 400 Ma (Lower Devonian) are presented at 10 my intervals. They show continental crustal fragments and intervening oceanic crust through time (not lands and seas), with appropriate kinematic continuity between successive maps. Gondwana was the dominating supercontinent throughout the period, covering much of the southern hemisphere, and the northern hemisphere contained the vast Panthalassic Ocean. The relative positions of the major continents of Gondwana, Baltica, Siberia and Laurentia/Laurussia and South China are well constrained. Their latitudes and rotations are now well known, largely through palaeomagnetic analysis, together with subsidiary evidence from faunas and facies. There are also a few preliminary palaeolongitudinal indications from the positions of old Large Igneous Provinces (Australia, Siberia) with respect to the Earth's core-mantle boundary. Siberia was inverted throughout the Lower Palaeozoic, and Baltica was initially inverted, but rotated through 120° between the Late Cambrian and Late Ordovician. In addition, through reconstructions of the Caledonide and some other orogenies, the progressive history of the Iapetus Ocean is well constrained. Smaller continents whose positions are well known include Avalonia (initially peri-Gondwanan but migrating in the Early Ordovician to join Baltica by the end of the Ordovician), Perunica (Bohemia), Sibumasu, and Mongolia, and many others are plotted. The Armorican areas of France and Iberia remained parts of Gondwana through most of the period. Less well constrained are North China (Sinokorea) and Annamia (Indochina). The maps and reconstruction software (BugPlates) may be downloaded freely (with acknowledgement) from www.geodynamics.no.

Epipelagic chitinozoan and graptolite biotopes map a steep latitudinal temperature gradient for earliest Late Ordovician seas: implications for a cooling Late Ordovician climate

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The pre-Katian Ordovician has long been considered a super-greenhouse world, based largely on high relative global sea levels and depleted stable oxygen isotope data from carbonates. An alternative and largely untested hypothesis has suggested that, at least in equatorial palaeolatitudes, there was a steady cooling trend through the Early Ordovician reaching the range of modern equatorial sea surface temperatures by the Mid Ordovician. Here, we present palaeobiogeographical data of the early Late Ordovician (460Ma) zooplankton that is in support of the latter hypothesis. The planktonic graptolites and chitinozoans of the Ordovician occupied the 'mixed surface layer' of the oceans and were indicative of temperature-controlled ocean water masses, in much the same way as the modern plankton. Applying multivariate statistical analysis to the Sandbian fossil presence/absence data, tropical to polar chitinozoan and graptolite biotopes are recognized. Their distribution allows us to identify the Subtropical-Subpolar Transition at ~35°S and the Polar Front at ~55°-70°S. Strikingly, early late Ordovician biotopes map a steep latitudinal temperature gradient from equator to pole that is comparable to that of modern seas. This strongly questions the notion that this interval of Earth history had an intense greenhouse climate, and suggests that cooling towards the Hirnantian glacial maximum may have started before (or during) the early Sandbian. Furthermore, these pre-glacial Sandbian distribution patterns will be compared to those from the glacial Hirnantian (440Ma) in order to test the narrowing of climate belts and the expansion of the Polar fauna through time, predicted by General Circulation Models.

Palaeophytogeographical patterns during Ordovician – Silurian times: a review of data and interpretations

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In the last fifteen years, the origin of land plants has been commonly considered to have occurred during Ordovician times, based on dispersed spore records from Middle Ordovician (Darriwillian) strata of Saudi Arabia. These primitive spores have been termed crytpospores, highlighting their anomalous morphology relative to trilete spore monads as well as the uncertainty regarding their palaeobotanical affinity. Notwithstanding, there is now a general consensus for considering Middle Ordovician and younger cryptospores as proxies for land plants at a bryophytic grade of organization. This commonly shared view among palynologists has led to the *a priori* exclusion of all pre-Middle Ordovician cryptospore-like microfossils from being considered as possible evidence for the existence of older land plants. However, there is increasing evidence for Middle and Late Cambrian palynomorphs from North American as well as Gondwanan localities, which could represent land-plant cryptospores, thus significantly pre-dating the origin of land plants as currently accepted. Indirect support for a possible older origin of land plants comes also from the recent findings of complexly sculptured trilete spores from early Hirnantian sediments in Saudi Arabia. The often-proposed scenario of a high-latitude Gondwanan origin and subsequent spread of vegetation towards regions of lower latitudes appears consistent if based on a "conservative" concept of cryptospore definition. New findings of cryptospores from low latitude areas – up to now less intensively studied than Gondwanan localities – suggest that such a scenario might essentially result from a database of miospores occurrence which is significantly biased by sampling and observational effects.

Brachiopods, bryozoans and the palaeolatitudinal change of the Mediterranean margin of Gondwana during the Ordovician

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The exctinction of several brachiopod and bryozoan genera in tropical palaeocontinents, simultaneously with their immigration into Mediterranean cool waters during the late Katian, adds new arguments in favour of the model for global warming postulated for the pre-Hirnantian Late Ordovician. A temperature increment in the tropics, beyond the tolerance threshold of some taxa, would have driven them to extinction. Simultaneously, similar temperatures to those in the tropics in previous times would have developed at intermediate latitudes, allowing the more strictly stenothermic genera to take refuge there.

Nevertheless, the temperature increase of the Mediterranean margin of Gondwana during the late Katian cannot be linked only to that global climate change, but also to a continuous latitudinal displacement during the Ordovician, beginning at polar latitudes and ending the Period at intermediate latitudes. An accessible way to quantify that proposed movement of the Mediterranean region is to compare it with other Gondwanan margins, which should have followed equivalent shifts. Since the present Australia is considered to have lain in tropical latitudes all through the Ordovician, the Gondwana displacement should have been a clockwise rotation, with the equatorial side of the palaeocontinent (the present Australia) acting as the pivot region. If this had been so, the approach of the Mediterranean margin of Gondwana towards the equator would be opposed to the movement of the opposite continental side, i.e. the pre-

Andean Gondwana margin, which would have shifted toward the South Pole. If the Precordillera Argentina occupied the margin of Gondwana during the Ordovician, in the proximities of the Antarctic Peninsula and South Africa, as considered by those authors defending its continuous Gondwanan nature, the Precordillera terrane could be the clue to test the suggested rotation of Gondwana.

Early Ordovician (Floian) biogeography of *Serratognathus* (Conodonta) in eastern Gondwana

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The bizarre conodont *Serratognathus* has a trimembrate apparatus of modified pectiniform elements, including symmetrical Sa, asymmetrical Sb and strongly asymmetrical Sc elements, and is restricted stratigraphically to the lower Floian (upper *P. proteus* to lower *P. elegans* biozones) of eastern Gondwana and peri-Gondwana. Just three species are known to belong to *Serratognathus*. *Serratognathus bilobatus* is most widespread, occurring in the Dumugol Formation (South Korea), Liangjiashan Formation (North China Platform), Qianzhongliangzi Formation (Ordos Basin, North China), Honghuayuan Formation (lower Yangtze Platform), Dakui Formation (subsurface southern Hainan Island), Setul Limestone (Malaysia), Mooroongga Formation (subsurface Arafura Basin, northern Australia), and in the Emanuel Formation (Canning Basin, Western Australia). *Serratognathus diversus* is recorded in the Honghuayuan Formation and equivalents (South China), Qiulitag Group (Tarim Basin), and in the Liangjiashan Formation (North China). *Serratognathus extensus* is reported only from the Liangjiashan Formation.

Serratognathus is a characteristic component of the earliest development (latest Tremadocian and early Floian) of the Ordovician conodont “Australasian Province”. Restriction of *S. diversus* to the South China and Tarim indicates the close biogeographic relationship between these two plates. Occurrence of *S. bilobatus* in northern and Western Australia implies strong biogeographic linkages to North China via intervening terranes (Sibumasu and Indochina) in the early Floian. The temporal and spatial distribution pattern of *Serratognathus* species enhances correlation in shallow water successions across the three main Chinese plates and in peri-Gondwanan terranes through an interval when age-diagnostic pandemic conodonts are rare. The initial appearance of *Serratognathus* in such environments coincides with the base of the Floian.

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POSTERS

Lau Event in the carbonate successions from the Timan-northern Ural region: new sedimentological and isotopic records

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The Gerd’’yu and Greben’ formational boundary is a sequence boundary that is well correlated through the Timan-northern Ural region and is located within the Lau Event succession. Intensive dolomitization and formation of an erosional surface in the Gerd’yu Fm top beds show a substantial sea-level drop. Facies curves show that deposits of the Gerd’’yu Fm upper member are characteristic of lagoon–supratidal environments. The lower part of the Greben’ Fm is characterized by argillites and mudstones/wackestones with siliciclastics (up to 31%) that reflect an abrupt sea level rise, with deposition in deep subtidal environments. There is intensive weathering and wide distribution of the argillites and mudstones on a shallow-water shelf. Clay minerals in various argillites are represented by hydromica (consistently present), chlorite (fluctuates slightly) and illite/kaolinite (consistently present). The Homerian – early Ludfordian reef growth was eventually terminated. Isotopic $\delta^{13}C$ PDB values in dolostones and microbial limestones of the Gerd’’yu Fm’s uppermost member fluctuates from –5.4 to –3.2‰ and increases in clay limestones of the

Greben' Fm's lowermost member up to –2.1 to –1.4‰. Changes in $\delta^{18}O$ SMOW coincide with a significant positive excursion in $\delta^{13}C$. Distinct variations in the $\delta^{18}O$ value from 25.6 to 21.4‰ in the Greben' Fm member are observed. Quite probably this fact reflects not fluctuations of sea water temperature but alos the lithological features of these successions.

Furongian (Cambrian) fossil associations from Dayangcha (China): a warming up for the Great Ordovician Radiation

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The Dayangcha section, Jilin Province, North China, consists of marginal deposits with cyclic sedimentation that offer the unique opportunity to investigate Furongian associations of conodonts and acritarchs from a biostratigraphic and palaeoecological point of view. We focus on an interval comprising the *Cambroistodus* and the *Cordylodus proavus* conodont zones. In this interval, *Cordylodus andresi* makes its first appearance 0.80 m below a stromatolite bed. The lowest occurrence of *Cordylodus andresi* has been proposed as a marker for the topmost stage/substage of the Cambrian System.

In the interval under consideration, conodonts invented white matter, well-differentiated apparatuses and denticulated processes, while acritarchs, with the galeate group, introduced specialized excystment structures and double walls. These are important novelties that were to be very successful later during the great Ordovician radiation.

The relative abundance of the different taxa varies through the investigated interval, probably reflecting cyclic environmental changes.

Palaeobiogeography of Late Ordovician and Silurian brachiopod faunas of the European North-East

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New data on the biostratigraphy and studied $\delta^{13}C$ isotopes of the Upper Ordovician and Silurian of the Timan-Northern Urals region allowed definition of regional boundaries between Ordovician and Silurian, Llandovery and Wenlock, gave deeper insight into the biogeography of Early Palaeozoic brachiopods and determined the interval corresponding to Hirnantian in the Upper Ordovician. Two pentamerid taxa – *Holorhynchus giganteus* and *Proconchidium muensteri* – are known in the Western Ural marine palaeobasin in the Late Ordovician, relating to the Norway-Kazakhstan biogeographic super-region. Their appearance and development was connected with the onset of reef formation in the Urals in the pre-Hirnantian. The absence of a cold water Hirnantian brachiopod fauna suggests that a regional climatic gradient at the end-Ordovician, prevented its development. In the end-Llandovery (Rhuddanian-Aeronian), *Rafinesquina, Coolinia, Borealis, Virgianella, Pseudoconchidium, Becscia, Zygospiraella, Nalivkinia* were widely distributed and characteristic of a Tropical biogeographic area or the Northern Silurian kingdom. Brachiopods *Virgianella* and *Pseudoconchidium* were described first as provincial taxa. Furthermore, *V. vaigatschensis* was found in the Tien Shan, Russian North-East, Southern China and Western Siberia. In Telychian, brachiopod communities were dominated by Atrypa and Fardenia. The expansion of connections of the Timan-Northern Urals basin in the Wenlockian is confirmed by genera *Atrypoidea, Spirinella, Eoreticularia, Hyattidina* and *Howellella*. In the Ludlow reef strata, *Conchidium* are abundant on the greater area of the Tropical biogeographical area. The Pridolian time is characterized by the appearance of endemic genera *Collarothyris, Grebenella, Pseudohomeospira* in the Timan-Northern Urals marine basin, which became extinct by the beginning of the Devonian. Despite the endemism of Late Silurian brachiopods the genus *Atrypoidea* had a remarkably wide distribution.

Late Ordovician shelly faunas from Jämtland: palaeocommunity development along the margin of the Swedish Caledonides

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Late Ordovician shelly faunas occur at several localities in the Östersund area of Jämtland (Sweden) developed against a background of intense and rapid global climate change; in the eastern part, approximately in the middle parts of the Kyrkås Quartzite, and in the western part in the uppermost Kogsta Siltstone, changes in faunas and sedimentary parts provide regional evidence of these global events. In both areas the faunas occur in shale and siltstone facies and the brachiopods and trilobites are used to effect correlations between the eastern and western parts of the region, which show major differences in facies development. These sub basins, situated on the margins of a developing mountain belt, reacted differently to global signals and contain contrasting faunas, providing further evidence of the heterogenous responses to climate change at the end of the Ordovician Period. Moreover here the *Hirnantia* brachiopod fauna apparently persisted through the stage in deeper-water, clastic facies on the margins of Baltoscandia when elsewhere on Baltica shallower-water, carbonate facies was occupied by the American Mid Continent, Edgewood fauna.

Archaeocyath palaeobiogeography

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Archaeocyaths were widespread during the first half of Cambrian time, and are found on all present continents except South America. They reached their acme in the interval equivalent to the Botoman stage of Siberia. Global archaeocyathan distribution was fundamentally controlled by the deposition of normal-marine carbonate sediments, as well as tectonic changes and evolution within the group, leading to the frequent appearance of short-lived, specialized endemic taxa.

Published analyses have employed the Jaccard and Ochiai similarity coefficients to deduce faunal provinces from compilations of taxonomic and geographic data. Some of these have relied on comprehensive compilations of a range of fossil groups including archaeocyaths, and others on archaeocyth data only. The latter type of analysis has outlined Siberia-Mongolia, Central-East Asia, Europe-Morocco, Australia-Antarctica and North America-Koryakia provinces. The first three provinces have been grouped as the Eurasian Realm, and the last two as the Lauraustral Realm.

These analyses support hypotheses regarding the rifting of Laurentia from the Australian-Antarctic margin, and the drift of suspect terranes toward Siberia during the early Cambrian. Further analysis using a palaeocommunity concept based on sedimentological and taxonomic factors have modified these conclusions.

Upper Ordovician carbon isotope records in the Siljan district, Sweden

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The Upper Ordovician Boda Limestone and the unconformably overlying Glisstjärn Formation in the Siljan district, Sweden, were sampled for carbon isotope analysis. The aim is to combine chemo- and biostratigraphy for detailed regional correlation. This may help further studies of the time interval spanning the two-phased end Ordovician extinction. Expanding upon the study by Schmitz & Bergström (2007), five quarries, eight sections (669 samples) were studied; two sections each in Kallholn, Osmundsberget, and Solberga, and one section each in Östbjörka and Jutjärn. The Glisstjärn Formation is exposed only in one section at Kallholn, both sections at Osmundsberget, and possibly at one section in Solberga. A cephalopod event bed is recognized in one section in Kallholn and the two sections in Osmundsberget. Additionally, a thick coquina consisting of the brachiopod *Hindella* is found in all quarries except Solberga. The Hirnantian Isotope Carbon Excursion (HICE) was positively identified in seven of the eight sections. The peak occurs at the *Hindella* bed in all sections. The beginning of the excursion in Osmundsberget is placed slightly higher than in the previous study, at about 14 m from the top of the Boda Limestone, which means it is above the level with the brachiopod *Holorhynchus* (identified both in Osmundsberget and Solberga). In Osmundsberget, Östbjörka and Jutjärn, sampling of the deeper parts of the Boda Limestone yielded δ13C values between + 1 and + 3 ‰, with two or three peaks higher than + 3 ‰, that may be correlated between the sections.

Tergomyans, gastropods, and biogeography in the Upper Ordovician of the Fågelsång district, southern Sweden

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During the Ordovician, deep-water graptolitic mudstone and shale formed in what is now the classical succession at Fågelsång, southern Sweden. Previously, only one gastropod species was described from the succession, but during this study diverse tergomyan and gastropod assemblages have been recognized both from outcrop and drill-core collections. The material spans the Sularp Shale through the Lindegård Mudstone (*Nemagraptus gracilis − Dicellograptus complanatus* Zones; Sandbian − Katian, Viru − Harju regional stages). Altogether 14 species are described; two tergomyan, five bellerophontoid gastropods, and six anisostrophically coiled gastropods. Three taxa (*Tritonophon*, *Tetranota* and *Holopea*) are found in the Lindegård mudstone. The first record of *Tritonophon* in the Ordovician of Baltoscandia occurs in the Fågelsång and nearby Röstånga area. The remaining taxa are from the Sularp, Skagen, and Mossen formations. Specimens may have been transported into the area from shallower settings, while species of *Peelerophon*, *Cyrtodiscus*, *Joleaudella,* and *Sinuites*, are interpreted as having been part of the local benthos. With the exception of *Bucania* and *Deaechospira*, no other taxa are common to the hitherto described gastropod fauna of the coeval Dalby Limestone in other parts of Sweden. The Fågelsång assemblages have more in common with the slightly older or coeval fauna of the Elnes to Arnestad formations in the Oslo Region (e.g. *Joleaudella*, *Sinuites*, *Mestoronema*, *Pararaphistoma*). The Sandbian taxa show similarities with peri-Gondwanan faunas (e.g. *Peelerophon*, *Cyrtodiscus*). Both *Peelerophon* and *Cyrtodiscus* are for the first time recorded from Baltoscandia. The hitherto endemic Baltoscandian taxon *Deaechospira* may also be recognized in Bohemia and Morocco.

Early Palaeozoic polychaete diversity and biogeography

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Jawed polychaetes formed a significant part of the Ordovician and Silurian marine invertebrate communities as shown by the abundance of scolecodonts in the fossil record. They appeared in the latest Cambrian, but it was not until the Mid Ordovician that these metazoans diversified significantly. The earliest representatives had primitive, usually symmetrical, placognath/ctenognath-type jaw apparatuses. The first more advanced taxa, possessing labidognath-type jaw apparatuses or placognath apparatuses with compound maxillae, are first recorded in the Middle Ordovician. The most significant increase in global generic diversity occurred in the late Mid Ordovician, when many common taxa appeared. In total, more than 50 Ordovician genera are known. However, because of the relatively limited number of taxonomic studies published, this figure should be considered only as a conservative estimate. Information available from their Ordovician and Silurian occurrences allows some palaeobiogeographical patterns to be explored. Most of the current data derive from successions in Baltica and Laurentia. That information, together with records from other palaeocontinents, reveals a wide distribution for the most frequent and species-rich genera and families. Preliminary data indicate that the Ordovician polychaete faunas of Gondwana (northern Africa, Arabian Peninsula, Perunica) were linked to those of Laurentia rather than Baltica. This is different from most other fossil groups and requires further assessment. Like many other benthic and pelagic fossil groups, scolecodonts show an increased cosmopolitan character in the Silurian as compared to the Ordovician. Endemism is common at the species level, which signals the potential of scolecodonts as biogeographical indicators.

The palaeogeography of the Baltic Palaeobasin in the Early Ordovician: new insight

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The palaeogeography of the Baltic Palaeobasin has been reinterpreted for the Varanguan and Latorpian (Early Ordovician) in the light of new data discovered in Russia.

The successions of the "Glauconitic Sandstone" and the lower part of the "Glauconitic Limestone" were studied along the Russian part of the Baltic – Ladoga Glint. More than 40 sections were described and sampled for lithology and conodonts. Correlation of investigated sections indicate:

1) Thickness of the Varanguan - Latorpian deposits increases northward
2) Conodont distribution shows increasing stratigraphical completeness to the north
3) Total volume of clastic material decreases to the north
4) The Varanguan − Latorpian deposits contain several phosphorite layers formed by shallow-water upwellings.

These new data show a different palaeogeographical situation than previous research had indicated. They reveal the presence of a relatively deep basin with transgression from the north to a depressed area with its summit located southward of Glint during the Varanguan-Latorpian. This land separated a northern (Pre-Finland) basin from the Moscow basin.

Contours of the land were traced using published descriptions of outcrops and boreholes in Russia, Estonia, Latvia and Sweden. All reliable data reveal a huge Early Ordovician island extending from Gotland (Sweden) in the west to the Syas' River (Russia) in the east; we have, therefore, named this Early Ordovician island as "Gotland-Syas' Elevation".

The Pre-Finland Basin was destroyed by Quaternary glacial erosion. In the Varanguan – Latorpian it probably connected the Scandinavian Shelf between Östergotland and Öland and with the Moscow Basin to the east of Lake Ladoga.

Shallow-water *Chonetoidea* (*Sericoidea*) shell concentrations from the Ordovician impact crater fill in Tvären, Sweden

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Numerous studies report the presence of the small thin-shelled cosmopolitan rhynchonelliformean *Chonetoidea* (*Sericoidea*) as being environmentally controlled and characteristic of deep water/distal clastic

Ordovician and Silurian environments. It has been suggested that *Chonetoidea* occupied a proximal habitat to the widespread and deep water *Foliomena* type assemblages, although it has been concluded that they rarely exist within the distinctive *Foliomena* fauna. Assemblages of *Chonetoidea* have been analyzed from post-impact layers in a newly formed Upper Ordovician crater. In the crater succession, colonization of benthic faunas can be followed throughout the post-impact limestone, showing a number of environmental preferences. Consequently the crater, because of its restricted area, is useful as an experimental basis for faunal characteristics to be correlated to specific environments. Continuous infilling of the crater after it was formed reveals deposition of argillaceous mudstones to carbonates from a deeper environment to a shallower regime. Rhynchonelliformean brachiopods inhabited the crater depression very late following the impact and are entirely represented by *Chonetoidea*, which are abundant in the upper third of the existing crater infill. It appears that *Chonetoidea* preferred the crater environment only after it had become less restricted in the course of infilling of sediments and the consequent reduction of water depth. The deep water regime that existed in the depression during the initial part after the crater's formation had been substantially reduced by this time with shallower-water conditions. Evidently *Chonetoidea*-bearing associations associated with a shaly substrate did not, or did not only, favour and occupy deep water environments as previous studies suggest. The shell beds analyzed are related to shallower water and this may unravel the dilemma of why they generally do not occur with the deeper water *Foliomena* fauna.

Morphological characters of cystoids of systematic value: Spanish samples

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In the Middle Ordovician of the ***Hesperic Massif***, abundant echinoderms are found in siliciclastic rocks. Our study focuses on the thecae of cystoids (diploporids). Taxonomic determinations of diploporids are usually based on incomplete specimens. Aboral characters have been used frequently to make systematic determinations. These highly variable characters can indicate adaptations to particular modes of life. Whereas different genera or species may have similar aboral structures, their oral structures may differ. Therefore, taxonomic diagnoses should be based preferably on features observed on the oral sides of the thecae.

Diploporids from Navas de Estena are dominantly Sphaeronitidae and Arystocystitidae. The genus *Calix* (Arystocystitidae) is the most cited diploporid in the Spanish palaeontological literature. Taxonomical features used in its determination are mainly based on (a) shape and size of the theca; (b) shape, size and disposition of thecal plates; (c) structure and disposition of the respiratory pores; and (d) additional thecal elements.

As the taxonomy of diploporids has hitherto been based on characters showing high variabilities and little difference among species, it is of doubtful reliability. Instead, it is advisable to study the different components of the oral sides of thecae, as well as other thecal characters such as tubercles and protuberances and their arrangement into lines, size and design.

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Ordovician – Lower Silurian successions of different Gondwanan terranes in Anatolia: palaeogeographic constraints

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In Anatolia, the Ordovician and Lower Silurian successions are observed in the basement of different terranes, successively rifted off the NW Gondwana-margin and amalgamated with Laurussia during the Cadomian, Variscan, Cimmerian and finally Alpine events.

In the SE Anatolian terrane in the northern Arabian Peninsula, the Arenig siliciclastics (Seydisehir Fm) unconformably rest on the Middle Cambrian. It is followed by dark shales and siltstones (Bedinan Fm.) and glacio-marine sediments (Halevikdere Fm.) of Hirnantian age. They are followed by graptolitic shales of Late Sheinwoodian and Homerian in the subsurface.

In the Taurides, the Tremadoc and Arenig series (Seydisehir Fm) include nodular limestones followed by tempestides. They are conformably overlain by carbonate tempestide bands of early, middle and upper Darriwilian age. Transgressive Caradoc red clastics above them grade into dark green siltstones and mudstones (Bedinan Fm). The following Sort Tepe Fm. consists of brown-grey-reddish siltstones and silty shales with Early Ashgill trilobites. The uppermost Ordovician is represented by the glacio-marine/glacial sediments (Halevikdere Fm.). The transgressive Lower Silurian includes graptolitic shales starting with Rhuddonian and reaching the Homerian with an Orthoceras limestone interval of latest Llandovery-earliest Sheinwoodian dated by conodonts.

In the Avalonian-type Zonguldak Terrane, middle Tremadoc graptolitic shales with N Gondwanan acritarchs and cryptospores disconformably rest on a crystalline basement with Cadomian arc-assemblages. The Upper Tremadoc – Arenig is characterized by arkosic sandstones, conglomerates and quartzites. They are followed by Darriwillian black shales and Caradoc – Early Ashgill limestones. Ashgill is not yet confirmed and the succession continues with Llandovary black argillites. In the Balkan-type Istanbul Terrane, the Ordovician includes arkosic sandstones and conglomerates, followed by quartzites and q-siltstones (Aydos Fm.). The end-Ordovician glacio-marine sediments are missing here and the lower part of the overlying grey shales (Gozdag Fm.) yielded Telychian acritarchs.

Late Telychian maximum highstand in NW Anatolian Istanbul-Zonguldak Terrane Assemblage

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Telychian (late Llandovery – Early Silurian) is a period of global sea level rise with a maximum in *spiralis* Zone, recorded with black graptolitic shale or red beds. In NW Anatolia, Early Silurian was yet only known from the Istanbul Terrane and represented by shallow-marine carbonates. Recent studies in the Zonguldak Terrane further E, however, showed the presence of Llandoverian black shales in the Findikli Formation in Camdag, Catak and Karadere (Ovacık) areas. In the Camdag area, the “Black Shale Mb.” yielded numerous well preserved (some in relief) specimens, identified as *Oktavites spiralis*, *Diversograptus ramosus* and *Retiolites geinitzianus.* It is suggested that the deposition of graptolitic shales in this area corresponds to *spiralis*–lower *lapworthi* Zone. In the Çatak and Ovacık areas, black shales intercalated by yellow shales yielded *O. spiralis* and *R. geinitzianus*. The deposition of black shales is related with time of maximum Silurian sea level, whereas the yellow layers correspond to an interval of lowered sea level in the late *lapworthi* Zone. The graptolitic shales in the Zonguldak are time-equivalents of the (late Llandoverian) violet shales with green layers from a less deep basin in E Istanbul Terrane. In the W Istanbul Terrane reddish sandstones with Fe-oolithic minerals and brachiopod-bearing carbonates deposited during the late Llandovery maximum transgression. By this, the Early Silurian deposits in the Zonguldak Terrane are more akin to the E Avalonian successions, whereas those of the Istanbul terrane correlate with the Gondwanan periphery. Moreover, the studied sections enable the recognition of the regressive trend (or part of it) in this high level stand, as indicated by the deposition of pale and grey-greenish mudstone layers, carbonates and shell beds.

Diversity fluctuations and biogeography of Lower Palaeozoic brachiopod faunas in Northeastern Spitsbergen: a preliminary report

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Preliminary investigations of Lower and Middle Ordovician brachiopods in Northeastern Spitsbergen have on the generic level revealed strong ties to faunas in Laurentia, though the fauna appears rather endemic on the species level. Five out of a total of about 35 taxa are identified to species level. All five are previously described from the Floian and Dapingian of Nevada. Two of these are also described from Newfoundland and Kazakhstan respectively.

The archipelago of Svalbard, including Spitsbergen, consists of small terranes which during the early Palaeozoic were located at equatorial latitudes along the northeastern margin of Laurentia. The northeastern part of Spitsbergen experienced significant sea level changes, shifting from very shallow water in the Tremadocian to deep in the Floian and back again to shallow water carbonate environments in the Dapingian. The brachiopod fauna was low diverse with a high proportion of cosmopolitan genera during the Tremadocian and early Floian, but in late Floian there was an abrupt change to a highly diverse partly endemic Laurentian fauna which remained into the Dapingian. This change is seen in the upper part of the *D. bifidus* graptolite biozone in time slice 2C. A similar change is seen in North America, but here the abruptly increasing diversity occurs later, in Dapingian.

Preliminary report on isolated Ludlow retiolitids from West Lithuania

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Well-preserved, isolated retiolitids (Graptolithina) are investigated for the first time from Lithuania. Some flattened retiolitids have been described previously. Together with isolated retiolitids, a great quantity of monograptids were discovered and previously described. The retiolitids came from Šiupyliai-69, Priekule-20, and Virbalis-5 boreholes, Rusnė Formation (Dubysa regional stage), and represent upper Homerian and Gorstian. Typical upper Wenlock retiolitids were found in the *ludensis* biozone: *Spinograptus spinosus* and *S. munchi*. The *S. spinosus* continues to the lower Ludlow *nilssoni* biozone, together with three *Neogothograptus* species, *N. purus*, *N. alatiformis*, *N. balticus*, and *Holoretiolites manckoides*. In the lower part of *scanicus* biozone there is *Plectograptus mobergi* and *N*. sp. The investigation of retiolitids under scanning electron microscope shows their extremely good preservation and presence of similar ultrastructures as described before. The retiolitids diversity is similar to other places on the East European Platform.

Giant *Rusophycus* trace fossils from the Middle Ordovician of Siberia

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During field work in Siberia in 2008 giant trace fossils *Rusophycus* Hall, 1842 were found for the first time in the Middle Ordovician Baikit Sandstone (Vikhorevian and Mukteian Regional Stages). The two best preserved examples were found on the basal surface of the overturned fallen blocks of quartz sandstone in the locality on the right bank of the Podkamennaya Tunguska River about 3 km downstream from the mouth of the Stolbovaya River. They are represented by big buckle-like bilobate forms with the lobes transversely wrinkled by anterolaterally directed coarse striae. *Rusophycus* are widely accepted as excavations normally made by trilobites. The size of the traces allows estimating size of the animal that produced them. In our case the size is 20x32cm and 21x31cm with a depth of about 12cm. On the bottom surface of the other big block of sandstone, 11 bilobate horseshoe-shaped excavations of a similar size were found. The trace fossils are from 36 to 53cm long and from 19 to 24cm wide. Distribution of giant *Rusophycus* and *Cruziana* known as “trilobite traces” is limited almost exclusively to fragments of the former Gondwana continent (Seilacher, 2007). Appearance of these characteristic trace fossils in the Siberian craton coincides with dramatic changes in lithology that can be related to global oceanographic changes and introduction of upwelling of the cooler waters into the epicontinental seaways of the Siberian palaeocontinent.

The Late Ordovician cooling: a continental basalt flooding tested with a numerical carbon cycle model

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The cause or causes of the well-known Late Ordovician glaciation remain unclear. This global cooling is generally attributed to a decrease of atmospheric pCO_2 during a time of greenhouse climate but its duration is not yet determined. This perturbation is synchronous with one of the biggest biotic crisis of Earth history. Some authors have shown that, under the Ashgillian palaeogeography, a drop in pCO_2 up to a threshold of 8x to 10x PAL (Present Atmospheric Level) may induce a decrease in temperature in high latitudes and supports the installation of an ice-sheet on Gondwana. The intensification of silicate weathering and enhanced organic carbon burial are the two major processes that lead to a decrease in atmospheric pCO_2.

As the Ordovician is known to be a period with high mantle activity marked by a lack of reversal magnetic field and high volcanic activity, several authors linked the Late Ordovician cooling to a superplume event that may have given rise to continental basalt flooding.

Here we have tested this hypothesis with a global carbon cycle numerical box-model coupled with an Energy Balance Model. Our model calculates the evolution of carbon, phosphorous and oxygen concentration and alkalinity. It also calculates atmospheric pCO_2, atmospheric and oceanic ⍰^{13}C and oceanic ^{87}Sr/^{86}Sr.

We have tested different scenarios of trap emplacements and organic carbon cycle interactions that could lead to the Hiranatian glaciation. Our model indicates that the hypothesis of a low latitude basalt flooding matches with a Late Ordovician global warming event, that could be the Boda Event, followed by a drop in atmospheric pCO_2 allowing the installation of the Hirnantian glaciation. The model shows that a 600 000 km^2 continental basaltic province localized between 5°S and 5°S is the minimum area required to reach the 8x PAL atmospheric pCO_2 threshold.

Cruziana? *almadenensis* Seilacher: its ichnotaxonomy and a review of its type locality in the Ordovician of Spain

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Since its discovery by Dolf Seilacher in 1970, “*Cruziana*” *almadenensis* constitutes the nominal icnotaxon of a problematic group attributed to *Cruziana*, but whose trace markers were possibly chelicerates rather than trilobites. The original material of this ichnospecies comes from beds of early Sandbian age located in the upper part of the “Canteras Quartzite” (= Botella Formation), directly south of the classic locality of Almadén (province of Ciudad Real). The only figured material consists of two Spanish specimens (a typical stationary burrow with high degree of heteropody and a cruzianiform trace), but according to Seilacher the ichnospecies is apparently widespread in Upper Ordovician Gondwanan sandstones from Jordan, Algeria, Tunisia, Saudi Arabia and Benin, where however it was never described or figured. In the Central Iberian Zone of Spain, *C.*? *almadenensis* was later recorded from two additional areas, being badly illustrated only by Lauret in an unpublished thesis of 1974. In this work we report newly obtained material of both the resting and cruzianiform morphotypes of *C.*? *almadenensis* from the original locality at Sierra de la Cárcel. This ichnospecies should be restricted to the procline stationary burrows of doubtful ichnogeneric assignment, never observed so far in direct prolongation of the parallel-scratched bilobed trace supposedly ploughed in an opistocline position by the same trace marker. Both forms belong to a diversified trace fossil assemblage which comprises another ten different ichnogenera, among them some of trilobitic origin such as *Rusophycus* and *Cruziana*.

Ancient travertines on Ordovician – Silurian transition

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The Upper Ordovician stratotype section in the Polar Urals exposes the most complete and section of Yunkoshor strata – an equivalent of the Hirnantian, correlated, mainly, by characteristic positive trends in $\delta^{13}C$ values. The strata are represented by secondary dolomites with shadow structures of microbial, microbial-algal, biomorphous micrites and small detrital sparites. At the top, the rocks are irregularly stratified, the original fabric destroyed and include small ambiguously delineated “stromatolite-like” bodies composed of white porcelain-like dolomite. They are connected to a small “positive shift” in the values of $\delta^{13}C$ marking a positive anomaly. The upper boundary of the strata is fixed by a transgressive, overlying black silty dolomite practically devoid of organic remains. The morphology of the carbonate bodies and their structural-textural features are close to known tuffs – travertines, differing from the latter by a dolomitic (not calcitic) structure and lack of visible inclusions of mineralized organic remains. It is known that travertines formed in discharge areas of thermal or cold sources of carbonic, rarer nitric-carbonic waters. Together with fresh water stromatolites they represent characteristic littoral facies of soda lakes. Also the fact that modern calcareous tuffs are enriched by heavy carbon isotope $\delta^{13}C_{carb}$ positive excursions supports this interpretation. Conditions of travertine formation are confined to moderately arid and semiarid climates. Hence, their appearance in the tropical and subtropical palaeobasin sediments can indicate not only subaerial exposure and continental settings, but also development of an arid climate in those zones suffereing maximum Late Ordovician cooling.

Silurian rocks of Chios Island, Greece

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Chios Island is located in the eastern Aegean Sea, only a few kilometres west of the Turkish mainland. It can be subdivided into two tectonostratigraphic units: an ‘autochthonous’ Lower Unit and a tectonically overlying ‘allochthonous’ Upper Unit. The analysis of fossiliferous Silurian olistoliths from the Lower Unit has important implications for our more detailed understanding of the evolution of North Gondwana-derived terranes and consequently for an alternative plate-tectonic reconstruction for this part of the Eastern Mediterranean in Palaeozoic time. The conodont fauna recovered from an *Orthoceras*-bearing limestone lens from the Carboniferous succession of the Lower Unit indicates a Late Silurian age. The fauna is typical of the Ludfordian *Polygnathoides siluricus* conodont zone (Upper Ludlow). The material shows a conodont colour alteration index (CAI) of about 1–2, indicating very low-grade thermal alteration (less than 100 °C). The closest localities with similar conodont-bearing limestones are in the Balkan region and in the Istanbul Zone of northern Turkey. The occurrence of the *Orthoceras* Limestone can be used as an indicator of palaeosource reconstruction. The provenance analysis of Silurian olistoliths in conjunction with detrital zircon ages (Meinhold *et al*., 2008) strongly suggest that the Carboniferous clastic succession of Chios received its detritus from basement rocks of the Sakarya microcontinent in western Turkey and time and facies equivalents of Palaeozoic units of the Istanbul Zone in northern Turkey and the Balkan region due to subduction of a branch of the Palaeotethys Ocean close to the southern active margin of Eurasia in the Late Palaeozoic.

Linguliform brachiopods from the terminal Cambrian to lower Ordovician Tiñu section, Mexico

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The fossiliferous sediments of the lower Palaeozoic Tiñu Formation of Oaxaca State (Mexico) rest nonconformably on middle Proterozoic basement representing the lowest sedimentary unit of the microcontinent Oaxaquia. The formation is divided into two members, the uppermost Cambrian Yudachica Member and the Tremadocian Río Salinas Member. Recent investigations of the fossil content (chiefly trilobites and conodonts) and the depositional environment of the formation have shown that the Tiñu section is a condensed passive margin succession with Gondwanan character.

Our investigation focused on the taxonomy and biogeographic characterization of the linguliform brachiopods of the Tiñu Formation and their stratigraphic distribution within the formation. About 1000 specimens have been studied, all derived from acid residues of twelve limestone horizons sampled throughout the formation. The fauna comprises eight acrotretid taxa (preliminary assigned to *Eurytreta* spp., *Neotreta*? sp. and *Quadrisonia*? sp.), a new siphonotretid species (*Schizambon* sp. nov.), and a potential representative of the family Ceratretidae. Obolids are rare and only represented by a few indeterminable fragments. These preliminary results seem to contradict the newly suggested Gondwanan character of the Tiñu Formation, but rather agree with a previous view that during the lower Palaeozoic the area had a provincially mixed fauna including Laurentian, Avalonian and Gondwanan elements. However, more precise taxonomic allocations of the various brachiopod taxa are needed to provide a reliable biogeographic affinity of the Tiñu brachiopod fauna. This work is currently in progress.

Conodont faunal dynamics through the Kinnekulle 'Täljsten' interval: untangling a palaeoecological event in the Darriwilian (Mid Ordovician) of Baltoscandia

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The anomalous 'Täljsten' interval, present within the orthoceratite limestone at Mount Kinnekulle, Sweden, has been investigated regarding conodont faunal changes and high resolution biostratigraphy. The study was based on a 2.5 m thick succession in the Hällekis quarry comprising the grey 'Täljsten' and the enclosing red strata yielding fossil meteorites and elevated levels of extraterrestrial chromite. Biostratigraphically it spans the Darriwilian *Lenodus variabilis–Yangtzeplacognathus crassus* conodont zonal boundary. This interval has previously been suggested to reflect a regression, a theory supported by the occurrence of specific conodont taxa and element abundance patterns. The regression initiated in the pre-'Täljsten' strata as indicated by the disappearance of e.g. *Periodon*, whereas a more apparent faunal re-arrangement can be correlated to the red-to-grey limestone transition. The succeeding lower half of the 'Täljsten' reflects a gradual shallowing, favourable for certain taxa that became abundant, like the platform-equipped *Lenodus*. Moreover, the changing conditions promoted temporary occurrences of species from other areas, such as *Microzarkodina* cf. *ozarkodella* and *Histiodella holodentata*. Mid-way through the 'Täljsten', conditions became less hospitable for conodonts, coinciding with the appearance of abundant cystoids. A low diversity and abundance fauna prevailed until the uppermost part where conditions changed again, consistent with a deepening of the basin. The reappearing red strata attest to the returning of pre-'Täljsten' conditions, albeit, with a re-organized conodont fauna. The precise correlations between the shifting lithologies and responding conodont fauna demonstrate the applicability of conodonts as palaeoenvironmental indicators. Furthermore, the high-resolution biostratigraphy rendered has proven useful for identifying contemporaneous Baltoscandian strata.

Taphonomical loss of diversity in the early Ordovician fossil faunas of Perunica

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A compilation of new and existing data on the benthic biota of the Prague Basin indicates that there is important taphonomical loss of diversity data in fossils associations of the Tremadocian to Dapingian ages. Red-coloured siltstone and oolitic ironstone locally abound with phosphatic-shelled fauna, whereas calcareous fossils are missing. Similarly, some shales are devoid of calcareous and siliceous fossils, with only organic-walled and phosphatic-shelled fossils preserved. Some of these “low” diversity association have formerly been interpreted as examples of originally low diversity “communities”. However, there is good evidence now that the low diversity “communities” were very diverse. These examples clearly demonstrate underestimation of the original diversity and the risks of subsequent incorrect interpretations.

Biogeography of Ordovician – Silurian Stromatoporoidea

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Stromatoporoids appeared during the Mid-Ordovician (mid-late Darriwilian) accompanying an important “Chazy” reef-building event. Representatives of order Labechiida appeared first, initially splitting into two sister groups; North China (nine genera) and Laurentia (four genera). Two genera were common to the two regions, but some others in North China and Siberia were endemic. This initial provincialism was not maintained into the Late Ordovician (Sandbian) as labechiids attained a wider dispersal, across Laurentia, Scotland, Siberia, Urals, Chukchi Peninsula, Tarim, North China, New South Wales and Tasmania, and only a few endemics were present (three in Laurentia, and one in Tarim). In the Katian, the maximum diversification of labechiids occurred (19 genera, including a genus possibly transitional to first actinostromatids), also the Clathrodictyida (four genera) first appeared, and the overall distribution became still wider. Hirnantian marked a dramatic narrowing of the distribution (only Anticosti, Manitoba, Norway, Estonia), and diversity decline of labechiids. Altogether ~70% of stromatoporoid species disappeared in response to end-Ordovician global cooling events.

The Llandovery stromatoporoids were widespread in Laurentia, Baltica and Siberia, with clathrodictyids dominant and labechiids accessory (the latter group being more common in Siberia and China). Gradual diversification and expansion of stromatoporoids followed in the “upper” Llandovery, with appearances of orders Actinostromatida and Stromatoporida. The stromatoporoids became most widespread and most diversified during the Wenlock transgression, with clathrodictyids maintaining their leading position, and appearances of earliest Stromatoporellida and Syringostromatida. Rapid spread of new phylogenetic stocks indicates good intercommunication existed among Wenlock stromatoporoids and lack of provincialism. The Ludlow was characterized by final closure of the Iapetus Ocean, accompanying upheaval of palaeocontinents and decline in prominence of stromatoporid-bearing shallow shelves. However, clathrodictyids and actinostromatids remained dominant, though appearances of Amphiporida in several regions, and restricted distribution of some other forms suggests emergence of provincialism. With regression in many parts of the world and stratigraphic hiatuses, stromatoporoids (mostly hangovers from Ludlow) became less common in the Pridoli, and apparently entirely absent from Gondwana and Siberia.

Biodiversity of the Ludlow monograptids fauna in Lithuania

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Lithuania is situated in the western part of the East European Platform or western part of the Baltica palaeocontinent. Three Ludlow facies occur in Lithuanian territory: starting with lagoon deposits, such as dolomite with gypsum in the eastern part and ending with marine facies, which consists of argillite and marl, in the west.

Nilssoni, *progenitor*, *scanicus*, and *hemiaversus* biozones are distinguished at Gorstian and *leintwardinensis*, *praecornutus*, *cornutus*, *bohemicus tenuis*, *balticus* and *formosusu – valleculosus* biozones at Ludfordian in Lithuania.

The first graptolite fauna, which is typical of Ludlow, appears at the end of the Wenlock. At the beginning of the Ludlow absolutely new monograptids groups appear, such as *Bohemograptus*, *Saetograptus*, *Neodiversograptus*, *Lobograptus* and *Monograptus uncinatus*. These groups also existed with Wenlock graptolites such as *Colonograptus gerhardi*, *Pristiograptus auctus* and older ones, more conservative *Pristiograptus* ex. gr. *dubius* graptolites. On the sicula of *dubius* group pristiograptids sicula rings emerge. These sicula rings are typical only of Ludlow *dubius* pristiograptids. At the beginning of the Ludfordian series, *leintwardenenis* Biozone monograptids were significantly decreasing. At this biozone all *Labograptus* and *Cucullograptus* species became extinct, but *Pristiograptus* genus were greatly increasing. Monograptids again thrived after this graptolite fauna crisis. New specialized species such as *Bohemograptus cornutus* appeared, but at the *tenuis* biozone a number of graptolite species were decreasing in Lithuania suggesting that it is related to the sinking of the Baltic basin. On the other hand there is a small outspread of graptolite species at the Ludlow *formosus* biozone.

Cambrian acritarchs from the southwestern part of East Siberia: the first record

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Middle to late Cambrian acritarchs are reported for the first time from the southwestern part of East Siberia. The new material originates from claystone interbeds of the upper part of the Ust'-Tagul Formation, exposed along the Biryusa River of Tayshet area. Their finding has important implications for stratigraphy, regional and interregional correlation, and biogeography.

The first record of Echinoderms in the Ordovician of Mongolia: biogeographical significance

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Until recently no Ordovician echinoderms were known from Mongolia. Fossil remains from the previously studied Ordovician beds showed a close connection of these basins with the Siberian and Altai-Sayan Basins. Recently two Upper Ordovician localities with a fossil echinoderm fauna were discovered in the South of Mongolia, suggesting a former biogeographical connection between these basins and the Baltic Basin. The first locality is in southwestern Mongolia, in Mongolo-Altai, in the valley of the Chigertey, where Ordovician beds with brachiopods, cephalopods, trilobites, sponges, bryozoans and echinoderms are exposed. The locality is dated as Sandbian to Katian based on conodonts. The assemblage contains two genera of rhombiform echinoderms *Echinosphaerites* sp. nov. and *Stichocystis* sp. nov. The state of preservation of these fossils is poor, but their pore system, number of plates and general outline of the theca allow positive identification of the genera and recognition of new species. The distribution of these genera suggests a possible biogeographical connection between South Mongolia and the Baltic Region and South China. The second locality with echinoderms is in the southeast of Mongolia (Eastern Gobi Depression) near Sayshand chuduk well. Here a thin limestone bed within a silt series contained numerous fragments of crinoids, among which specialized stems of *Ristnacrinus* sp. were dominant. Species of this genus, with an easily recognizable highly specialized stem, are known from the Upper Ordovician (Sandbian and Lower Katian) of the Baltic, Kazakhstan, Central Asia, (Kara-Kum, Pamir, Zeravshan-Gissar Region, northern fringes of the Turkestan and Alai Ranges) and France.

A review of Ordovician fauna and flora of the Northwest Himalaya, India

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In the Zanskar-Spiti-Kinnaur Basin (Tethyan Himalaya), the top part of the Haimanta Group (?Precambrian-Cambrian) is variably eroded due to an untraced orogenic/epiorogenic event (tentatively dated as Late Cambrian-?Early Ordovician) and unconformably overlain by the sediments of the Sanugba Group (Ordovician-Silurian – early Devonian), consisting of the Thango/Thaple and Tanze/Takche (= Pin Formation) formations. The Thango/Thaple Formation comprises polygenic red to brown conglomerate, sandstone beds with shale partings. The Ordovician conglomerate is calcareous mud-supported, indicating the terrigenous supply derived from the underlying sedimentary sequences (dolomites and terrigenous rocks fragments of the underlying rocks) and also from the phyllites, quartzite and crystalline rocks.
In Zanskar region the Thaple Formation unconformably rests on the latest Middle Cambrian Kurgiakh Formation and assumed to be of Dapingian Stage (early Middle Ordovician age) based on the Orthids and pelmetazoan columnals (Singh, 2008). In the Spiti-Kinnaur regions, the lower part of the Thango Formation yielded casts of brachiopods and marine algae *Prismocorollina* sp., (Sinha & Mishra, 2006). The calcareous algae *Salpingoporella sp., Dasyporella sp., Vermiporella sp.,* and *Moniliporella sp.,* (Parcha & Pandey, 2008), and brachiopods *Leptena trachealis, Orthis testudinaria, Orthis thakli, Orthis porcata*, *Refinesquina muthensis* and corals *Streptelasma* sp., gastropod *Bellerophon* sp. (Misra *et al.*, 1995) have been reported from different parts of the Thango Formation. In the Kinnaur region, the Early Ordovician trace fossils *Phycodes circinatum* have been reported from the basal part of the Thango Formation; however, the pentamerids casts in the upper part indicate Silurian age. In the Spiti region, the Takche Formation has yielded *Vermiporella* sp.; tabulate corals; trilobites; crinoids; *Tentaculites*; *Girvanella* sp., *Girvanella* cf. *problematicus*, *Girvanella* cf. *tasmaniaensis*, *Renalcis* sp., *Rothpletzella* sp.; *Apidium indicum*, *Coelosphaeridium shianense*, *Dasyporella* sp., ?*Plexa* sp.; ?*Graticula* sp., *Favosites* sp., *Halysites* sp., *Heliolites* sp., *Euomphalus* sp., *Allumettoceras pinense*, *Cyrtogomphoceras centrifugum*, *Lambeoceras farkamuthense*, *Orthoceras* cf. *annulatum* and *Oxygonioceras latum*; *Glossomorphites himalayaensis*, *Krausella* ? *shianensis*, *Pilla pinensis*, *Pinpilla u-formis Steusloffina cuneata* and *Vendona crassiplicata*); orthids, strophomenids, *Leptaena* sp., *Calloporella harrisi*, *Ceramopora* sp., *Cladodictya markhensis*, *Corynotrypa* sp., *Cyphotrypa yak*, *Dekayia gregaria*, *Dekayia* sp., *Discotrypa* aff. *elegans*, *Enallopora ulrichi*, *Eridotrypa suecica*, *Kukersella borealis*, *Lichenalia concentrica*, *Oanduellina himalayaica*, *Orbignyella* aff. *lamellosa*, *Pesnastylus*? *vesiculosum*, *Phaenopora ordinarius*, *Phaenopora* sp. *Pinocladia triangulata*, *Prasopora yushanensis*, *Ptilodictya exiliformis*, *Ralfina*? *originalis*, *Revalotrypa*? sp., *Stellatodictya plana*, *Trematopora minima*, *Ulrichostylus bhargavai*); graptolites; conodonts (*Amorphognathus ordovicicus*, *Belodina confluens*, *Icriodella superba*, *Panderodus* sp. and lingulids brachiopods (Suttner, 2006, 2005, 2007, Schallreuter *et al.*, 2008). The Thango/Thaple Formation records a break in sedimentary development: after a long period of offshore marine to shoreface to fluvial setting (Parahio Formation), a phase of shallowing caused by retarded subsidence (Karsha Formation) and renewed innershelf and shoreline settings (Kurgiakh Formation). The Thaple Formation (Early – Middle Ordovician) records a subaerial alluvial environment passing from alluvial fan to braid-plain. The Takche Formation (Late Ordovician – Early Devonian) indicates regressive shallow shelf conditions of deposition.

The Ordovician radiation of the acritarch *Veryhachium*

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The acritarch genus *Veryhachium*, originally described by Deunff (1954) from the Ordovician of Britanny, western France, is one of the most frequently recorded organic-walled microphytoplankton genera. The revision by Servais *et al*. (2007) indicates that the genus first appeared in the lowermost Ordovician, and had established a worldwide distribution by the Middle Ordovician.

Detailed analyses of the first occurrences of *Veryhachium* in different localities from different palaeocontinents elucidate the palaeobiogeographical radiation of the genus from the South Pole to all Ordovician palaeocontinents: the first *Veryhachium* specimens appeared in the middle part of the Tremadocian, and possibly earlier in the early Tremadocian, at levels where graptolites of the *R. flabelliformis* group occur, in North Africa, which was located at the South Pole during the earliest Ordovician. Later Tremadocian records of *Veryhachium* are from localities on the Gondwanan margin that are all considered to have been located at high latitudes (> 60°) in the southern hemisphere. In China, located at intermediate latitudes (between 30° and 60° S), *Veryhachium* has not been recorded below the lowermost Floian, and in Argentina, located at similar latitudes, not below the middle Floian. The first occurrence of *Veryhachium* on another palaeocontinent, Baltica, is also in the lower Floian, but the genus did not become common there until the Darriwilian.

This suggests that *Veryhachium* first appeared in the Tremadocian at high latitudes before radiating to lower latitudes of the Gondwanan margin (China and Argentina) and Baltica during the Floian, to become cosmopolitan by the Middle Ordovician.

A revision of the Ordovician *Ampullula/Stelomorpha* acritarch plexus : palaeogeographical implications

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After the initial description of *Ampullula* Righi 1991 and *Stelomorpha* Yin 1995, Brocke (1997) revised the genus *Ampullula* to include *Stelomorpha,* while Uutela and Sarjeant (2000) retained and emended *Stelomorpha* and considered *Ampullula suetica* as a junior synonym of *Tranvikium polygonale.* Subsequently, Ribecai *et al*. (2002) suggested an additional new genus, *Sacculidium,* and included it in a "*Stelomorpha – Tranvikium - Sacculidium* plexus".

Based on a detailed taxonomical revision, it appears evident that the Ordovician acritarch genera *Ampullula, Sacculidium, Stelomorpha* and *Tranvikium* belong to a larger acritarch plexus with a great morphological variability. The *Ampullula - Stelomorpha* plexus is characterized by a morphological variation of specimens with one single (*Ampullula*) or several (*Stelomorpha*) neck-like tubes on the central body.

In the present study, the biostratigraphical ranges of these genera and their species are revised, and the palaeogeographical distribution and palaeobiogeographical significance is highlighted. While most previously described species of the *Ampullula - Stelomorpha* plexus are present in the Ordovician of South China (Yangtze Platform), several taxa of the plexus also occur on other palaeocontinents at localities at low to intermediate latitudes, e.g. on Baltica. It therefore appears that the plexus is possibly indicative of warm water environments. The plexus was first present in South China, where it has possibly its origin, and subsequently morphotypes of the plexus were also present on Baltica and on peri-Gondwana.

BUSINESS MEETING

The International Subcommission on the Ordovician System: towards a new decade and a new agenda

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[1]Chair, [2]Vice Chair and [3]Secretary of the International Subcommission on the Ordovician System

The first phase of the Commissions' work has provided an enviable and robust international chronostratigraphic scheme at the stage level. This framework together with some of the intensive work on the boundary levels within the system and those with the adjacent Cambrian and Silurian systems has helped generate much new data for major research programmes such as the Great Ordovician Biodiversification Event (GOBE) and the end-Ordovician extinction events. It is clear that to maintain the influence and usefulness of the Subcommission we will have to develop some new areas of infrastructure and some new products. We have listed eight areas that the Subcommission should see as future priorities and a focus for a number of active working groups.

1. There will be requirement to evaluate the efficacy and utility of the Ordovician international stages and stage boundaries. Where appropriate and/or necessary we will have to move to establish some small advisory groups.

2. The Subcommission can now move towards confirming and establishing finer divisions of Ordovician time. In this respect Bergström *et al.* (2009: *Lethaia*) have already divided our international stages into stage slices based mainly on existing biozones. Finer time slices were also proposed by Webby (2004: *The Great Ordovician Biodiversification Event*, Columbia University Press) and used effectively in developing data for the GOBE. As these time divisions are more widely adopted, it would be useful to confirm their definition and status.

3. Over the last few years we have neglected the role of the regional groups and the many important regional and diverse stratigraphies that make our system so exciting. A number of the key regional successions were included in the correlation charts provided by Bergström *et al.* (2009), but there more that require calibration with our new stages. Moreover a few regions such as Baltoscandia and SE Asia were never formally published. This is a priority for our system and work that can involve all our colleagues.

4. Work is now far advanced on a Carbon stable isotope curve for the Ordovician. Consistent results have been already achieved for parts of the column. There are of course other stable isotopes and it will be appropriate and useful to evaluate if we can help develop these curves not least as one of our nonbiologic means of correlation. There are other nonbiologic techniques that we could also consider.

5. A more difficult area is sea-level or water-depth curves for the period. There have been a number of curves for the Ordovician and many more for particular parts of the period. It would be useful to move towards examining these curves more carefully and the criteria upon which they are based towards developing more standardised curves for the Ordovician.

6. We now have a number of accurate palaeogeographic maps for our period. Not everyone agrees with all the reconstructions and perhaps they never will. But it is possible to engage in cooperation with some of the groups to develop a more standard set of base maps for the period.

7. We already have a number of robust absolute dates for parts of the system but it would useful to develop more, not least to be able to calibrate the true rates of biological and geological process occurring during the period.

8. We have tended as a group to ignore the economic potential of our system. But, for example in New South Wales, nearly all the gold and copper mines are hosted in Ordovician volcanics of the Macquarie Arc and in China considerable funding is being made available through SINOPET (the hydrocarbon exploration company) to support research into Ordovician biostratigraphy.

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