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Bernard Mottequin, Julien Denayer,
Peter Königshof, Cyrille Prestianni & Sébastien Olive

IGCP 596 - SDS SYMPOSIUM
Climate change and Biodiversity patterns in the Mid-Palaeozoic

ABSTRACTS

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International Geoscience Programme (IGCP) Project 596: Climate change and biodiversity patterns in the Mid-Palaeozoic

Subcommission on Devonian Stratigraphy (SDS)

Contents

Preface

Dear colleagues and friends,

We cordially welcome you, some ninety participants from 19 countries around the globe, to the IGCP 596–SDS International Symposium in Brussels, 20–22 September 2015.

This symposium is the final meeting of the 4-year International Geoscience Programme (IGCP) Project 596 (climate change and biodiversity patterns in the Mid-Palaeozoic; 2011-2015), which is associated for the fourth time to the Subcommission on Devonian Stratigraphy (SDS), after a first joint meeting in Russia (2011), a second in Morocco (2013), and a third in Argentina (2014).

Organizing this meeting in Belgium was obvious as this small country has a long history of research dedicated to the Devonian and Carboniferous. This is mainly due to the fact that Belgium is the cradle of the internationally recognized Frasnian, Famennian, Tournaisian and Viséan stages. Although disused nowadays, terms such as Gedinnian and Couvinian, which sound probably familiar to many of us, were also first defined in southern Belgium. The symposium is flanked by a pre-symposium field trip dedicated to the Devonian–Mississippian succession of the Namur–Dinant Basin organized by the Royal Belgian Institute of Natural Sciences and the University of Liège (Belgium), and a post-symposium field trip devoted to the Devonian–Tournaisian succession of the Eifel area and the Rhenish Massif (Germany) organized by the University of Münster and the Senckenberg Research Institute and Natural History Museum.

The symposium is organized around 10 sessions (45 talks and 40 posters):

S1: Lower to Upper Devonian palaeontology and sedimentology
S2: Lower and Middle Devonian events and biostratigraphy
S3: Tetrapod World: early evolution and diversification (TW:eed)
S4: Devonian continental flora and fauna
S5: Devonian–Carboniferous boundary
S6: Devonian of Mongolia
S7: Devonian marine fauna
S8: Devonian climates
S9: Upper Devonian stratigraphy
S10: Frasnian–Famennian boundary

We would like to express our sincere thanks to the organizations, which have contributed to this symposium, namely the Royal Belgian Institute of Natural Sciences, the Fonds National de la Recherche Scientifique (FNRS), Carmeuse S.A., STRATA and the University of Liège. Moreover, we would like to use this opportunity to honor the memory of Paul Sartenaer, a former voting member of the SDS, who passed away on 1st July 2015, at the age of 90. He was a famous specialist of the Devonian rhynchonellide brachiopods and his death is a great loss for our Devonian worker community.

We hope that this symposium will be a successful and enjoyable meeting providing you with new insights, ideas and friends. We wish you an excellent stay in the capital of Europe!

Bernard Mottequin, Julien Denayer, Xavier Devleeschouwer, Valentin Fischer, Vincent Hallet, Jean-Marc Marion, Edouard Poty, Sébastien Olive and Cyrille Prestianni

Brussels, September 2015

Introduction

The International Union of Geological Sciences (IUGS) is one of the largest and most active non-governmental scientific organizations in the world. Founded in 1961, IUGS is a member of the International Council of Science. IUGS fosters dialogue and communication among the various specialists in earth sciences around the world. IUGS, amongst other tasks, features the International Commission on Stratigraphy (ICS), which is composed of individual Subcommissions on individual Geological Periods and the Precambrian that build the formal, officially and internationally defined time units (chronostratigraphic units) of Earth History. The Subcommission on Devonian Stratigraphy (SDS) has been one of the most active Subcommissions of ICS since it formed in 1973, which is mostly based on a highly successful integration of all leading specialists of Devonian stratigraphy, regardless of their specialization or their origin.

For forty years, UNESCO (United Nations, Educational, Scientific and Cultural Organization) has worked with IUGS to mobilize global cooperation in the Earth sciences through the International Geoscience Programme (IGCP). This Programme has provided a platform for scientists from across the world to push the frontiers of knowledge forward through concrete projects.

IGCP and SDS locking back on a long-lasting, fruitful cooperation (*e.g.*, IGCP, 216, 293, 421, 499 and, currently 596). IGCP 596-SDS are specifically interested in the interaction between climate change and biodiversity in the mid-Palaeozoic (Devonian and Carboniferous Periods, 416–299 million years ago) when the terrestrial ecosystems experienced a biodiversity boom and oceanic ecosystems suffered catastrophic extinctions of different magnitudes such as in the Devonian Period with the two 1st order mass extinctions at the Frasnian-Famennian boundary (Upper Kellwasser Event) and in the latest Famennian (Hangenberg Events). Greenhouse climates dominated the Early and Mid Devonian (416–385 Ma) world, but changed to icehouse conditions in the latest Devonian (~385–380 Ma). The Early Carboniferous world was relatively warm until cooling in the early Late Carboniferous (318–299 Ma) resulted in a huge polar southern hemisphere ice shield that covered most of Gondwana. The Mid-Palaeozoic was also a time of very active plate tectonics that caused major palaeogeographic changes. During the Devonian two supercontinents, Euramerica and Gondwana, together with Siberia formed the biggest landmasses of our planet. They successively amalgamated into the supercontinent Pangaea during the Late Carboniferous. As the continental landmass grew, vascular plants, arthropods, hexapods and first tetrapods spread on land. Their radiation formed the base of new terrestrial ecosystems unknown before the Devonian Period. The unique rise among the land plants and the formation of biogeochemical soil profiles led to distinctive changes in environmental conditions. Based on proxy-data, we can show that the rapid rise of land plants was coupled with strongly decreasing atmospheric CO_2 values from 4000 ppm to nearly present day values of about 350 ppm during the latest Devonian. Increased weathering activity and soil formation by rooted plants lead to intensified run-off and changed water chemistry, which seriously affected marine communities globally.

IGCP 596 in cooperation with SDS have focused within their joint symposia, conferences, and field trips on sudden extinctions, anoxic, climatic and eustatic events, building up a detailed event stratigraphy that enables non-biostratigraphic correlations. Results of IGCP 596 project should help to clarify whether climate change (*e.g.* interaction of CO_2 and temperature) from greenhouse conditions during the Early–Mid Devonian to icehouse conditions during the Late Devonian–Early Carboniferous represents a major trigger for variations in biodiversity or if a combination of multiple factors is responsible for such changes. During the last years of research knowledge on the above topics increased fundamentally even if there are many scientific questions still unanswered. We are looking forward to seeing a good number of interesting presentations as summarized in this abstract volume.

First, on behalf of the IGCP 596 and SDS we would like to thank the organizers for their tremendous work to prepare the Conference in Brussels and field trips to Belgium and Germany. We welcome all participants to Brussels and wish you stimulating discussions, and a successful and pleasant stay both in Brussels and during the field trips.

Kind regards,

Peter Königshof (Chairman of the IGCP 596) & John Marshall (Chairman of the SDS)

Upper Devonian bryozoans from western Mongolia

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Bryozoans rank among the more widespread and taxonomically diverse invertebrate fossils in the Palaeozoic deposits. The first discovery of bryozoans within Devonian deposits from Mongolia was reported in 1926. Until now, 127 species from 66 genera, 27 families and 5 orders have been recognized and described on the basis of Devonian material from Mongolia. Incomplete bryozoan distribution in the sections makes it nevertheless difficult to distinguish uninterrupted bryozoan associations. On the basis of a study of the bryozoans from well-known Devonian type sections (Fig. 1), and on an analysis of their distribution, we are here able to establish eight associations of bryozoans among which two are upper Devonian in age.

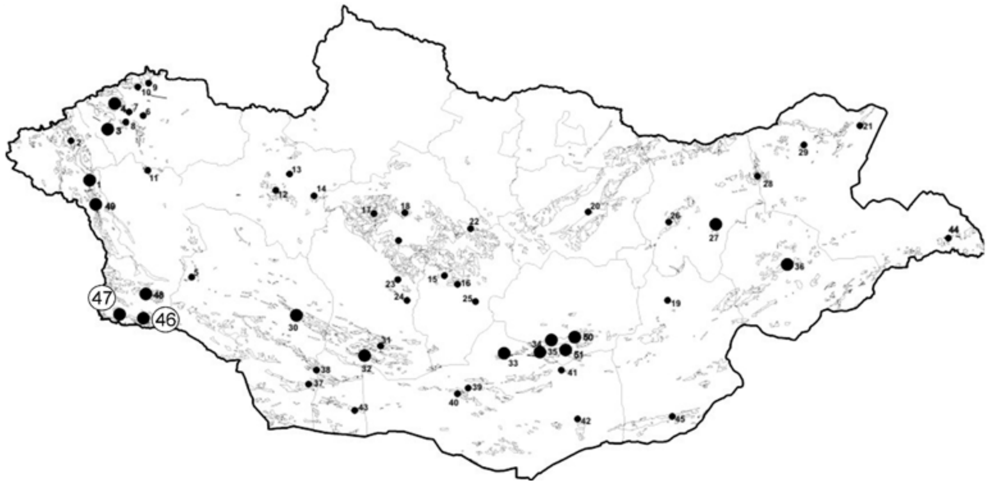

Fig. 1: Schematic map of Mongolia with indication of the Devonian deposits. Upper Devonian bryozoans were recovered from the Baruunhuurai (46) and Samnuuruul (47) formations (western Mongolia).

The Frasnian bryozoan associations are represented by 9 species belonging to 9 genera: *Pileotrypella lautissima*, *Boardmanella richardi*, *Bactropora granistriata*, *Semicoscinium* sp., *Mirifenestella* sp., *Sulcoretepora consona*, *Shulgapora devonica*, *Reteporidra* sp. and *Narynella* sp. (Goryunova, 1993; Ariunchimeg, 2010). The bryozoans come from the Middle–Upper Devonian Baruunhuurai Formation.

The Famennian bryozoan association consists of 12 species from 12 genera (Ariunchimeg, 2000, 2003): *Cyclotrypa gigantea*, *Cheilotrypa subtilis*, *Neotrematopora baitagensis*, *Pseudonematopora hextolgayensis*, *Nemacanthopora cellaris*, *Orthopora tomensis*, *Intrapora lanceolata*, *Streblotrypa* sp., *Nikiforovella* sp., *Fenestella* sp., *Alternifenestella* sp., and *Minilya* sp. Bryozoans come from the Upper Devonian Samnuuruul Formation.

Upper Devonian invertebrates are known only from the Baruunhuurai terrane in the south-western part of Mongolia and, except bryozoans, are represented by brachiopods, corals, trilobites, gastropods and rare conodonts (Ruzhentsev, 2001).

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Lower Devonian red pelagic carbonates of the Barrandian area, Czech Republic: how red is red and why to bother about?

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Carbonate successions in the Barrandian area, a classical region for Lower Devonian stratigraphy, contain a marked, more than 15 m thick band of red pelagic carbonate of Early Devonian (earliest Emsian) age. Situated in the upper levels of the Praha Formation, the red band can traced on several tens of kilometres providing an important local stratigraphic key level. Red coloured deep-marine sediments are known from many Phanerozoic stratigraphic levels. The best known examples are perhaps the Upper Cretaceous ocean red beds (CORB) which feature a conspicuous spatial and temporal coincidence with the Cretaceous ocean anoxic events (OAS) and thus represent time specific facies of palaeoceanographic / palaeoclimatic significance.

To make an insight into the genesis of the Devonian pelagic red beds and their palaeoclimatic meaning, we have made a detailed study of the red horizon and its stratigraphic context. The aim was to find the mineral carriers of the red colour and to investigate the conditions of their genesis, to examine the prerequisites for the red pigmentation, to locate the red horizon in the sea-level cycle and to interpret the local paleogeographic/bathymetric context of their formation. In this effort, we used detailed facies logging at 7 large sections (17 to 255 m thick) in the Prague basin, accompanied with field spectral gamma-ray logging (> 1600 points with 0.25 to 1.0 m vertical step), quantitative colorimetry (spectral reflectance in visible light, *ca.* 3500 samples), quantitative microfacies analysis (*ca.* 90 samples), element geochemistry (EDXRF, 215 samples), total organic carbon concentrations (80 samples), magneto-mineralogical analysis (12 samples) and electron microprobe analysis (WDX SEM, 12 samples).

The best exposure of the red band is provided in a 120 m thick section of the Branžovy quarry located *ca.* 20 km WSW of the Prague city centre. Bound to the underlying Lochkov Formation by a basal unconformity, the basal layers of the Praha Formation are composed of coarse-grained crinoidal calcarenite (grainstone) that pass upward into dark nodular calcisiltite and calcilutite (lime mudstone / wacke-packstone) with abundant dacryoconarid tentaculites, trilobites, bryozoans and ostracods, and with stromatactis-like structures (sheet cracks) forming an upward fining (transgressive) sequence. The upper parts of the Praha Formation contain the target layer of deep red limestone, which is overlain by about 1m thick interval of light-grey limestone, followed by a regionally significant interval of eight limestone layers sandwiched with black shale laminae (so called Bohemian Graptolite Event). The Praha Formation is then overlain by grey platy calcarenites and calcilutites of the Zlíchov Formation. The Lochkov/Praha Formation boundary and the Praha/Zlíchov Formation boundary can be correlated all over the Barrandian area based on their gamma-ray patterns, namely U/Th ratios. The computed gamma-ray (CGR) values based on K and Th concentrations are low at the base of the Praha Formation, but they markedly increase upwards consistently with the facies and microfacies trends constituting a prominent deepening-upward (transgressive) trend. Element geochemistry data indicate a gradual decrease in Ca (calcium carbonate) at the expense of terrigenous elements such as Al, K, Ti, Rb and Fe. Consistently with the microfacies data, this pattern is interpreted as gradually decreasing marine carbonate production on the background of steady influx of suspended clay minerals from dry land.

The red carbonates fall within the peak transgressive strata (as documented by CGR, EDXRF and microfacies). The intensity of the red pigmentation was expressed in such colorimetric parameters as CIEa* (dimensionless), percentage of red reflectance (%) and red/yellow reflectance ratios. The red colour intensity was found to be highest in the most distal sections of the Prague basin (Branžovy, Požár 3 and Na Chlumu quarries) where the thickness of the Praha Formation is extremely low. However, the red coloration quickly fades away towards the thicker and more-shallow water parts of the basin fill suggesting that its intensity is closely related to low sediment accumulation rates. The red colour is mainly carried by hematite, as indicated by magneto-mineralogy study and prominent peaks at 565 nm wavelength band on the 1st derivatives of reflectance curves. The red coloration is well visible in thin sections under plane polarized light, often inside the dacryoconarid shells, fenestrate bryozoans or echinoderm fragments. Under WDX SEM, the red fields are characterized by domains enriched in Fe-bearing clay minerals but hematite crystal individuals were never found. This suggests that hematite forms a dispersed mass of submicronic crystals associated with clays. The EDXRF analyses show that Al and Fe concentrations are well correlated ($R^2 = 0.8$) but the red colour intensity is uncorrelated with the Fe concentrations. There is no Fe enrichment associated with the hematite-rich red carbonates so we infer that the hematite formed *in situ* by mineral transformation of Fe-bearing clays. The red band is characterized by extremely low concentrations of TOC (0.02 to 0.03 %) while TOC values are slightly higher in the remaining, non-red parts of the Praha Formation (0.02 to 0.05 %). This indicates a very good bottom oxygenation during deposition.

In summary, the red coloured band formed in deep-water, distal parts of the Lower Devonian carbonate system of the Praha Formation during peak transgression and minimum calcium carbonate supply. Hematite as the main carrier of the red colour formed by mineral transformation of clays under oxidizing conditions, presumably during very early diagenesis (as indicated by hematite impregnation inside echinoderm shells, which tend to be obstructed by blocky calcite during very early diagenesis). The red carbonates are confined to a specific stratigraphic level, which quickly passes into the Bohemian Graptolite Event horizon enriched in black shales. Interestingly, there are more black shale/carbonate levels (*e.g.*, Kačák Event) and more red carbonate horizons (*e.g.*, Suchomasty Limestone) in the Lower–Middle Devonian of the Barrandian area. In many respects, the Devonian red carbonates conform to the Cretaceous CORB and may indicate a similar palaeoclimatic regime of atmospheric CO_2-driven switching between dysoxic and super-oxic sea-bottom conditions.

Acknowledgements: This study was supported by Czech Science Foundation (GACR) project GA 14-18183S.

Biostratigraphy of the Late Devonian (Famennian) deposits of the Kuh-e-Kaftar section (Chah-Riseh area), Central Iran

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The studied section is located southwest of the Chah-Riseh village (Kuh-e-Kaftar mountains), 55 km northeast of Isfahan, Central Iran. Middle to latest Famennian deposits of the 110 m-thick Shishtu Formation correspond to limestone, sandy limestone, marly limestone, shale and sandstone levels mainly reflecting shallow-water environments (Fig. 1). The fossiliferous levels yield diverse macro- and microfaunas such as bivalves, brachiopods, invertebrate micro-remains, bryozoans, crinoid stems and conodonts (Djafarian & Brice, 1973; Golamalian, 2003, 2007).

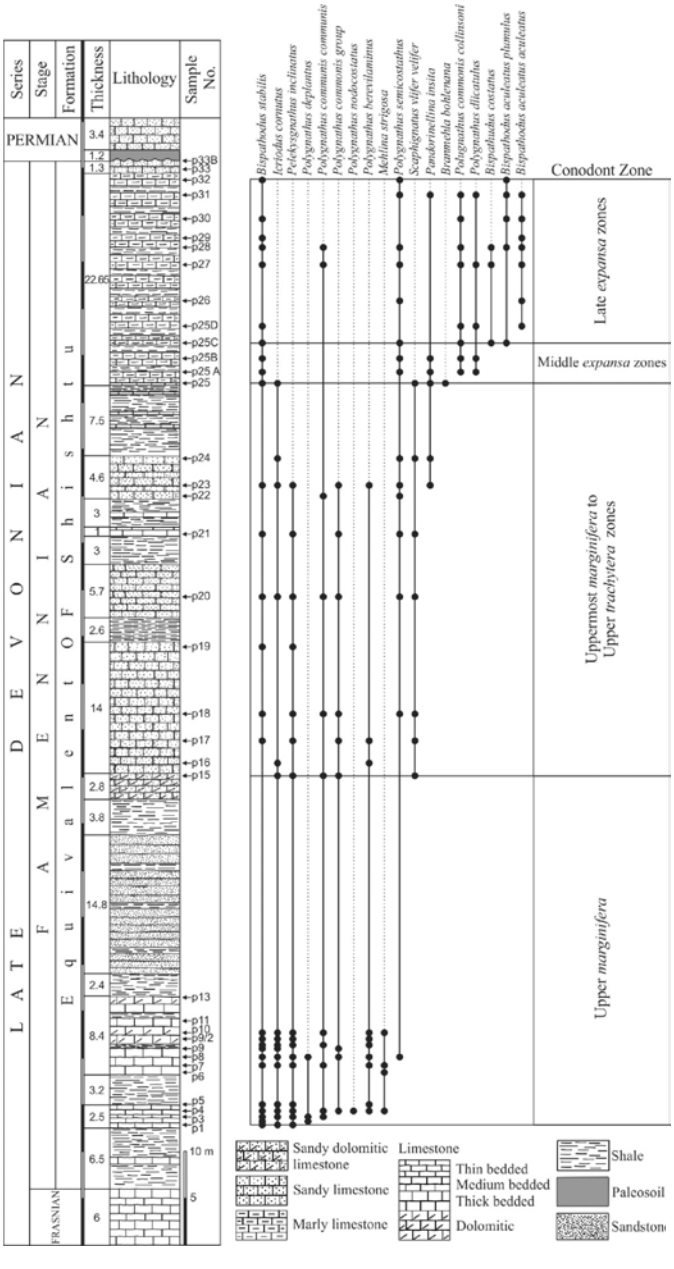

Fig. 1: Biostratigraphic column of the Chah-Riseh section.

An alternation of black shales and medium-bedded limestones at the base of the section is assigned to the Frasnian–Famennian boundary. The Shishtu Formation is disconformably overlain by the Permian Jamal Formation. In order to establish the biostratigraphical framework for the Shishtu Formation, 44 samples were collected systematically and yielded the following conodonts: *Bispathodus aculeatus aculeatus, Bispathodus aculeatus plumulus*, *Bispathodus costatus*, *Bispathodus stabilis*, *Branmehla bohlenana*, *Icriodus cornutus*, *Mehlina strigosa*, *Pandorinellina insita*, *Pelekysgnathus inclinatus*, *Polygnathus delicatulus*, *Polygnathus deplanatus*, *Polygnathus nodocostatus nodocostatus*, *Polygnathus berevilaminus*, *Polygnathus semicostathus*, *Polygnathus communis* group, and *Scaphignatus velifer velifer.*

The abundance and distribution of conodont elements as well as the sedimentary record suggest fully marine conditions of an inner shelf environment. The conodonts are related to the following conodont biozones as: Upper *marginifera*, Uppermost *marginifera*, Upper *trachytera*, Middle *expansa*, and Upper *expansa* zones. In terms of biofacies, the conodonts can be assigned to the icriodid–polygnatid, polygnatid–bispathodid and bispatodid–polygnatid biofacies.

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Constraining the ages of Late Devonian Extinction events in the Central Asian Orogenic Belt (COAB): U-Pb zircon ages and igneous petrology

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The Late Devonian was a time of extreme ecological crisis containing two of the top six most devastating extinction events in Earth's history. The Kellwasser Anoxia Event at the Frasnian–Famennian (F–F) boundary and the Hangenberg Anoxia Event at the Devonian–Carboniferous (D–C) boundary decimated coral reefs, changed the evolutionary trajectory of fishes, and negatively impacted colonization of land by animals. Most studies of these mass extinction events have been conducted on the continental margins of Europe and North America, but evidence of these extinction events have also been identified in sediments located in an understudied area: the Central Asian Orogenic Belt (CAOB). In the Late Devonian, the CAOB consisted of a series of island arcs in an open oceanic setting far from continental-driven sediments, and represents an ideal location to study these events as they are outside of well-studied epeiric sea environments or shallow carbonate platforms associated with cratonic blocks.

Late Devonian sediments from the CAOB have been collected from both China and Mongolia. In China, sediments include the Zhulumute, Hongguleleng, Hebukehe, and Heishantou Formations, which are from the Boulongour Reservoir section of the Junggar Basin in Xinjiang Province, China. Tectonic models for the Late Devonian suggest that these sediments formed as part of the West Junggar/Balkash accretionary wedge, deposited on a Marianas Island type island arc complex, which is consistent with sedimentary geochemical signatures in the Boulongour Reservoir sediments (Carmichael *et al.*, 2015). Mongolian samples are from the Samnuuruul Formation, which is located at the Gerelt Hoshoo site, the Mongolia-China Border locality and the Hushoot Shiveetiin Gol site, all in the southwest end of the Gobi fold megazone in the Baruunhuurai Terrane, Mongolia. Trace element concentrations associated with these Mongolian basalts and mudstones suggest that the sediments collected in Mongolia also have an island arc volcanic signature (Fig. 1), consistent with tectonic models of the CAOB.

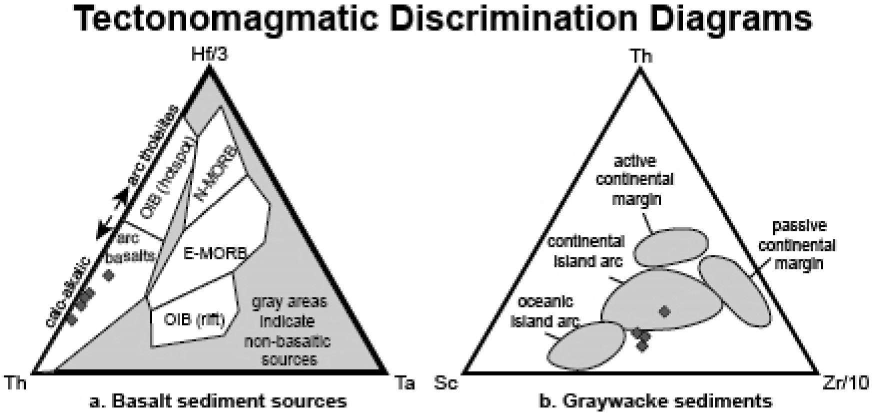

Fig. 1: Trace element discrimination diagrams of basalts, sandstones, and mudstones from the Mongolia-China Border locality and the Hushoot Shiveetiin Gol site show an island arc geochemical signature, consistent with the Devonian tectonic models of the region.

At the base of the Boulongour Reservoir, the lowermost Zhulumute Formation contains volcanicalastic sandstones and conglomerates that grade upwards towards the base of the Hongguleleng Formation.

Prominent porphyritic basalt pebbles are also evident in the Zhulumute Formation with albite sand and detrital zircons in the matrix. Fieldwork conducted in western Mongolia during the summer of 2014 revealed a fossiliferous Samnuuruul Formation that exposed what was tentatively identified in this field as the F–F boundary, and possibly the D–C boundary. The Samnuuruul Formation consists mainly of conglomerate beds with interbedded limestone beds that grade into sandstone, siltstone, and tuffite layers. Pillow basalts (Fig. 2) and lava flows are also found within the Samnuuruul Formation in the Hushoot Shiveetiin gol and the Mongolian Border localities.

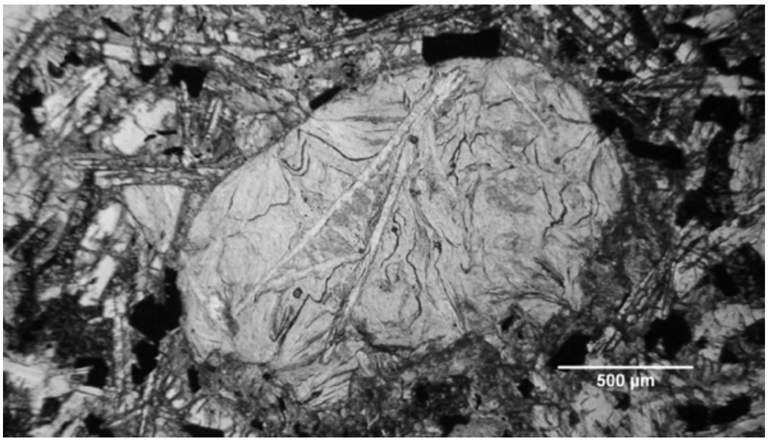

Fig. 2: Image of a transmitted light microscopy photomicrograph of sample MBL 7 from the Mongolian Border locality that shows a filled amygdule containing serpentine and needle-like white mica flakes with surrounding plagioclase and altered pyroxene.

In the summer of 2014, sample ZH01-10 from the Zhulumute Formation in China was selected for U/Pb geochronology at the University of North Carolina at Chapel Hill (UNC-CH) using standard hydrodynamic and heavy-liquid techniques, using a VG Sector 54 Thermal Ionization Mass Spectrometer (TIMS). Initial results from sample ZH01-10 suggest an age of 452 ± 2 Ma, which fits in the Middle Ordovician and is consistent with tectonic models of Marianas-type island arc development around the Hongguleleng Ocean (Choulet *et al*., 2012), but results cannot be confirmed until more zircons are dated for comparison.

Two samples from within the Samnuuruul Formation in Mongolia have been selected for zircon analysis at UNC-CH during the summer of 2015. The first sample, SAM 4/8, was collected from the Gerelt Hoshoo locality and consists of a coarse sandstone bed that fines slightly upwards. The second sample, MBL 7, was collected from the Mongolian Border locality and consists of a pillow basalt showing minor hydrothermal alteration (Fig. 2).

The Kellwasser and Hangenberg Events are both present in the Boulongour Reservoir sediments in China, and have been detected via multiproxy geochemical evidence rather than visible black shales commonly associated with these intervals (Carmichael *et. al*., 2014; Carmichael *et al*., 2015), but the presence of anoxic events have not yet been confirmed for the analogous Mongolian sections at this time. Zircon analysis will be used to constrain the ages of the Kellwasser and Hangenberg ocean anoxia events in China, and to constrain the biostratigraphy of the fossils in the Mongolian sections. These results will be the first radiometric ages for Late Devonian sediments in the CAOB thought to contain both the F–F boundary and the D–C boundary in an open oceanic setting.

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The timing of Eovariscan block faulting, reworking and re-deposition in the Moroccan Meseta

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The Moroccan Meseta, including some outcrops in tectonic windows of the High Atlas and small belts just to the South (*e.g.*, Tinerhir region), forms the southern external Variscides, which were continuous in the Devonian with the much less deformed Anti-Atlas region of stable cratonic NW Gondwana. Understanding the palaeogeographic and synsedimentary tectonic evolution of the Moroccan Hercynides is crucial for the plate tectonic reconstruction of the western Prototethys between Gondwana and the more internal Variscides (southern European and Armorica terrain assemblages). Beyond, a comparison with the external Variscides at the southern margin of Laurussia/Avalonia (Rhenohercynian Zone), N of the Rheic Ocean, gives fundamental insights into the history of a highly complex and controversial (very wide or rather narrow) ocean system, which controlled the migration/distribution of marine and terrestrial biota and, potentially, globally significant palaeoceanographical, climatic, and geochemical patterns. Within the frame of a joint DFG Germany-CNRST Maroc research programme, we focused on the Eovariscan interval (upper Emsian to Tournaisian), the time when the Rheic Ocean was largely subducted under Avalonia Terrains and before the Viséan onset of the main, oblique Variscan Gondwana-Laurussia collision.

The Meseta is a complex patchwork of individual autochthonous blocks and of partly allochthonous units (nappes, "Klippen"), each with a distinctive history of faunas, facies; and synsedimentary tectonics (*e.g.*, Piqué & Michard, 1981, 1989; Michard *et al.*, 2008). An overall extensional tectonic regime, at least of the western Meseta N/NW of the Middle Atlas, lead to significant block faulting and tilting, which resulted in uplift, erosion, reworking, and re-deposition in adjacent basins, often as mass-flows and olistolites. Piqué (1975) coined the term "Famennian Revolution" because this was the time when the rapidly subsiding Sidi Bettache Basin opened and when Eovariscan reworking units were most wide-spread. However, the reconstruction of palaeogeography and block movements in space and time suffered badly from a very imprecise stratigraphy, with common age assignments based on superficial lithological similarities and a lack of reliable biostratigraphic ages. Therefore, our programme concentrated on the precise dating of major facies and subsidence changes and especially of reworking units with the help of conodonts and, to a lesser extent, of ammonoids and brachiopods (identifications by D. Brice).

New data from *ca.* 30 different successions provide a refined and complex picture of polyphase reworking in the Meseta, which can be assigned to five synsedimentary tectonic phases of the Devonian-Tournaisian, an interval of 65 Ma duration. Block movements can be identified variably by intraformational breccias and slump units (without reworking from significantly older strata), polymict breccias and conglomerates with clasts of very different age (often increasing upsection) and lithology, olistostromes and isolated olistolites in basinal facies, often with evidence of double reworking (cannibalized conglomerates preserved as isolated olistolites), angular unconformities with evidence of basal reworking, sudden lateral facies differentiation, sudden long-term non-deposition or extreme condensation, especially when not correlated with major eustatic falls, onset of thick flyschoid sedimentation with turbidites and debris flows, and evidence of rapid deepening and increased subsidence, especially when not correlated with known eustatic rises. Dating of reworking units was variably achieved by samples from in-situ underlying, interbedded and overlying carbonates, by sampling individual components of conglomerates/breccias (searching for the youngest clasts), by whole rock samples of fine-grained units, and by the local/regional geological context. A range of literature records had to be incorporated and was partly revised. Not all reworking units could be dated with sufficient precision and some contradictions are still to be solved.

A general and very distinctive feature of the Meseta is the fact that all successions were affected by Eovariscan movements. The most stable region was the Coastal Block near Oulad Abbou, S of Casablanca, which also received the least post-sedimentary overprint. However, the local Eifelian and Frasnian are rather condensed, as in most other successions.

The first Middle Palaeozoic tectonic phase of the Meseta comprises the Lochkovian to Eifelian, an “Eovariscan prelude” or “Antevariscan Interval” with restricted and often localized uplift events. Still limited evidence comes from a coarse conglomerate of Taliouine with late lower Lochkovian conodonts (large *Ancyrodelloides*), which overlies upper Silurian black shales. It belongs to the Skoura succession just S of the High Atlas, which, in the absence of typical Variscan deformation, can be regarded as a northern Anti-Atlas extension. But Lochkovian breccias/conglomerates have also been reported from the High Atlas basement and eastern Rehamna, which gives a common pattern restricted to the southern margin of the Variscides. Thin lower Emsian breccias and small olistolites were found at Jebel ben Arab (between Azrou and Meknes). The thick conglomerate of Immouzer-du-Kandar (S of Fes) ranges from the lower to upper Emsian. The supposed Emsian polymict, coarse conglomerate at the base of the Jebel Ardouz (western Jebilet) is much younger. It yielded a middle Frasnian *Ancyrodella* and includes Middle Devonian reefal clasts. Alleged Eifelian conglomerates and reworked carbonates from the Khatouat Massif require a restudy.

The first true Eovariscan phase, the middle/upper Givetian, can be recognized almost throughout the Meseta as a highly important time of brecciation, reworking, and of a subsequent hiatus, caused by non-deposition due to submarine uplift and long-lasting current exposure. This lower main Eovariscan phase may have been masked by subsequent, renewed reworking in the Famennian. For example, recycled conglomeratic clasts within the olistolites of the Oued Cherrat Zone and Khatouat (“Biar Setla Conglomerate”) yielded Givetian or mixed Eifelian-Givetian conodonts. In the Al Attamna region a Givetian red conglomerate with colonial corals is partly overlain by a more massive second unit with mostly reworked Givetian conodonts (*ansatus* Zone) and very rare Famennian palmatolepids, probably from the matrix. Middle Givetian conglomerate successions are especially well preserved NW of Benahmed and, as an exception, are followed by an upper Givetian deepening interval that lead eventually to a Frasnian hypoxic goniatite shale succession.

Apart from this subsiding block, the third phase, the Frasnian and lower Famennian, is characterized in the western successions by wide-spread gaps (non-deposition) or extreme condensation. Middle Frasnian polymict conglomerates occur in the western Jebilet (see above) and characterize the eastern Mrirt-Azrou region. This is the area with the most intensive reworking and re-deposition, persisting at Dechra-Ait-Abdallah and N of Azrou (Bab-el-Ari) into the lower Famennian and higher.

The peak episode of Eovariscan block faulting was the middle/early upper Famennian (phase four). A precise dating is often difficult (*e.g.*, in the case of the famous Oued Tiflet conglomerate) since limestone conglomerates/breccias yield mostly reworked conodonts. Elsewhere (Oued Cherrat, Khatouat, Sidi Bettache Basin) the shale matrix of olistolites or debris flows has provided a few miospore ages. The main reworking clearly predates the LL Zone. It is still middle Famennian in age at Azrou (*velifer* Zone) and Ziyyar (Lower *trachytera* Zone) but partly older (*rhomboidea-marginifera* Zone) and partly younger (“Etrœungt conglomerates”) in the allochthonous Mrirt sucession. Last movements extended into the uppermost Famennian in the autochthonous Famennian at Dechra-Ait-Abdallah (*ultimus* Zone). Stable pelagic basins developed contemporaneously only in the Coastal Block (Oulad Abbou) and southern Mdakra Massive (Oued Aricha).

Phase 5 is the “Eo-Variscan 2 Event” of Michard *et al.* (2008) and falls in the Tournaisian. Impressive, very thick mass flow and olistolite successions of this age are well exposed N of Oulmes (Ta´araft) and lie above the Hangenberg Sandstone equivalents of Ain Jemaa. In the allochthonous successions between Azrou and Mrirt (Bou Khedra), Tournaisian shales transgressed with angular unconformity above a deeply eroded Lower Devonian sequence and contain reworked middle Givetian clasts (*ansatus* Zone) at the base.

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An Early Devonian peak of biodiversity: the case of heterostracan vertebrates

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The Pteraspidomorphi are jawless vertebrates that lived from the Middle Ordovician to the Late Devonian (470-370 My). Their head is covered by a bony dermal armour organized into dorsal, lateral and ventral plates, and the trunk and tail by scales. The histology of both their head carapace and the scales typically includes acellular bone (aspidine). They had no paired or midline fins, except the caudal one. Four clades are included in the Pteraspidomorphi: the Arandaspida, Astraspida, Eriptychiida and Heterostraci. Here I focus on the Heterostraci that are known from the Early Silurian to the Late Devonian (Frasnian) and were mostly living on Laurentia, Avalonia and Baltica in the Silurian, and the Old Red Sandstone Continent (ORSC) and Siberia in the Devonian. They are characterised by the occurrence of a single paired external branchial opening and the honeycomb structure of their bone. More than 300 species have been described to date. They inhabited all environments of the Silurian marine platforms, and various environments from shallow marine to intermediate (coastal, estuarian, "brackish") around the Devonian ORSC (refs in Blieck & Elliott, in press). The head carapace of Heterostraci consists of a series of plates, the number and morphology of which varies among their different taxa. Basically there are a large median dorsal and a large median ventral plate, plus anterior and lateral plates and platelets (oral, branchial, etc.). The two main groups of heterostracans are Cyathaspidiformes (including amphiaspids) and Pteraspidiformes (including psammosteids). Other more problematical groups include the traquairaspids, cardipeltids, corvaspids, ctenaspids, *Nahanniaspis*, and various tessellated forms (tesseraspids, *Lepidaspis*, etc.) (Janvier, 1996). The Cyathaspidiformes (*Cyathaspis*, *Poraspis*, *Anglaspis, Ariaspis, Capitaspis*, etc.) had a head armour composed of a large median dorsal plate and a large median ventral plate separated by a pair of elongated branchial plates, plus a series of plates in the oral cover (refs in Lundgren & Blom, 2013). Amphiaspids are derived cyathaspids where the head carapace is fused into a single bony element. The Pteraspidiformes (*Pteraspis*, *Althaspis*, *Rhinopteraspis*, *Doryaspis*, *Protaspis*, etc.) had a head armour composed of a more complex arrangement of plates, basically a median dorsal disc, rostral, pineal and spinal plates, bordered by paired orbital, branchial and cornual plates, plus the small plates of the oral cover (refs in Pernègre & Elliott, 2008). Psammosteids are derived pteraspids where the armour includes additional platelets ("tesserae") in between the various plates of the head. In this communication, the most recent data on Late Silurian to Middle Devonian heterostracans are presented after a selection of papers from 2010 to 2015. They include two cyathaspids from the Přidoli of the Canadian Arctic (*Ariaspis arctata*, *Capitaspis giblingi*); a series of faunas from the Lochkovian of Chukotka, Arctic far-eastern Russia (traquairaspids, *Lepidaspis*?, *Oniscolepis*?, poraspids), of northern France (*Rhinopteraspis crouchi* and traquairaspids), from the Lochkovian and Pragian of Belgium (*Althaspis leachi, Europrotaspis*? *wiheriesiensis*, *Rhinopteraspis dunensis*); a review of Lochkovian and Pragian heterostracans of Podolia, Ukraine (cyathaspids, *Ctenaspis*, tesseraspids, corvaspids, pteraspids, traquairaspids); *Zaphoctenaspis meemannae* and *Poraspis thomasi* in the Emsian of Nevada and California, USA, respectively; a "*Drepanaspis*-like " species in the Emsian of Germany; and psammosteids in the Givetian of the Leningrad Region, Russia (*Pycnosteus palaeformis, Psammolepis proia, Schizosteus?* sp. and *Tartuosteus giganteus*).

These results are in accordance with various diversity curves that have been published for early vertebrates in general, and heterostracans in particular: the Cyathaspidiformes, amphiaspids and Pteraspidiformes (excl. psammosteids) (Ludlow to Givetian) show all a peak of diversity in the Lochkovian, and a second one in the Pragian for pteraspids (Blieck, 1984; Novitskaya, 2007, 2008); the heterostracans show a peak in the late Lochkovian of Severnaya Zemlya (Blieck *et al.*, 2002) and Spitsbergen (Blieck *et al.*, 1987), and in the "middle" Lochkovian of northern France (Blieck *et al.*, 1995). This corresponds to the Lochkovian peak of biodiversity shown at a global scale for heterostracans (pteraspidomorphs, Klug *et al.*, 2010) and for agnathan (ostracoderm) vertebrates, both at the family- and genus-level (Blieck, 2011; Friedman & Sallan, 2012; Sansom *et al.*, 2015). It is thus a component of the genus-level Early Devonian diversity peak shown for marine organisms (metazoans less tetrapods) by Alroy *et al.* (2008; also Alroy, 2010), a result of both a high origination rate (Aberhan & Kiessling, 2012: fig. 4a) and a low extinction rate (*ibid*.: fig. 4b). This Early Devonian peak marks the beginning of the Devonian Nekton Revolution for both demersal organisms (such as most heterostracans as, *e.g.*, amphiaspids, *Drepanaspis*) and nektonic organisms (such as some heterostracans as, *e.g.*, poraspids, *Torpedaspis*) (Klug *et al.*, 2010, fig. 1). It may be related to various physical characteristics of the Earth dynamics of that time, viz., a rise in both atmospheric (Dahl *et al.*, 2010) and oceanic oxygen (Joachimski *et al.*, 2009), and a rise in mean annual continental temperature (Nardin *et al.*, 2011). This kind of correlation has been hypothesized for the occurrence of new arthropod orders, the number of genera of autotrophic reefs, the body volume and genus-level diversity of marine invertebrates, in relation with an increasing oxygen level (refs in George & Blieck, 2011) — but bizarrely with a rather low eustatic level (Haq & Schutter, 2008). It is thus suggested "*that the co-occurrence of a series of bio-events and physical properties of the oceans on Earth during the Early Devonian is not merely a coincidence, but reflects a global rearrangement of the biosphere*" (George & Blieck, 2011) which would have triggered the diversity of vertebrates, including the ostracoderms (in particular the heterostracans) and tetrapods (*ibid.*). And I propose to name that series of bio-events the "Great Eodevonian Biodiversification Event".

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Devonian deposits of Bahram Formation in the Kuh-e-Reza-Abad and the Kuh-e-Shorab sections (southwest Damghan), Central Iran

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The studied sections belong to the northern border of Central Iranian Structural Domain (Alavi-Naini, 1972; 1975). The area is characterised by strong tectonic deformation, and consequently, sedimentary sequences exhibit many thrusts and faults leading to thickness differences and lateral facies changes. The sections exhibit mainly Late Devonian sediments of the Bahram Formation, but also Middle Devonian, which is proven by conodont stratigraphy. The studied sections are located close to the Reza-Abad village and to the north of the Shorab village, 55 km southwest from Damghan city.

The Kuh-e-Reza-Abad section has a thickness of 166 m. Based on field observations and sedimentological criteria, this section can be subdivided into three lithological units. The unit A consists of gray to dark grey limestones, rich in brachiopods and ostracods. The unit B is mainly composed of gypsum levels with some marly intercalations. The unit C is composed of grey limestones, rich in fossils. Among the conodonts, the following species have been identified (Fig. 1): *Icriodus excavatus*, *I. arkonensis*, *I. expansus*, *I. iowaensis*, *Polygnathus politus*, *P. webbi*, *P. aequalis*, *P. pollocki*, and *P. xylus.*

The Kuh-e-Shorab section is about 307 m thick and is mainly composed of an alternation of limestones, sandstones and dolomites. The sediments contain a number of fossils such as brachiopods, corals, crinoid stems, holothurian remains, sponge spicules and conodonts. Four genera and 29 conodont species have been identified: *Icriodus excavatus*, *I. expansus*, *I. cedarensis*, *I. subterminus*, *I. iowaensis*, *I. alternatus*, *I. tafilaltensis*, *I. brevis*, *Polygnathus brevilaminus*, *P. angustidiscus*, *P. pollocki*, *P.* cf. *webbi*, *P.* cf. *aequalis*, *P. politus*, *P. prepolitus*, *P. brevilamiformis*, *P.* cf. *olgae*, *P. dubius*, *P. xylus*, *P. zinaidae*, *Pelekysgnathus inclinatus*, *Pel. serradentattus*, *Ancyrodella pristina*, and *A.* cf. *pristina*

The identified taxa provide a stratigraphic range from Upper Givetian (*subterminus* Zone) into Lower Frasnian (*transitans* Zone). Based on the studied fauna, it was possible to prove the presence of uppermost Givetian at the base of the sections. The Middle Devonian is continuously overlain by Late Devonian sediments, which can be assigned to the Bahram Formation in the Kuh-e-Shorab and the Kuh-e-Raza-Abad sections.

The sections exhibit shallow-marine sediments that led to discontinuous conodont successions. Thus, the biostratigraphic interpretation of the conodont fauna requires the application of an alternative conodont zonation for neritic facies settings because the Standard Conodont Zonation by Ziegler & Sandberg (1990) is not useful. This problem is well known in Central Iran (*e.g.*, Bahrami *et al.*, 2015) and the future challenge might be to establish a shallow-water conodont zonation, which is mainly based on icriodontids.

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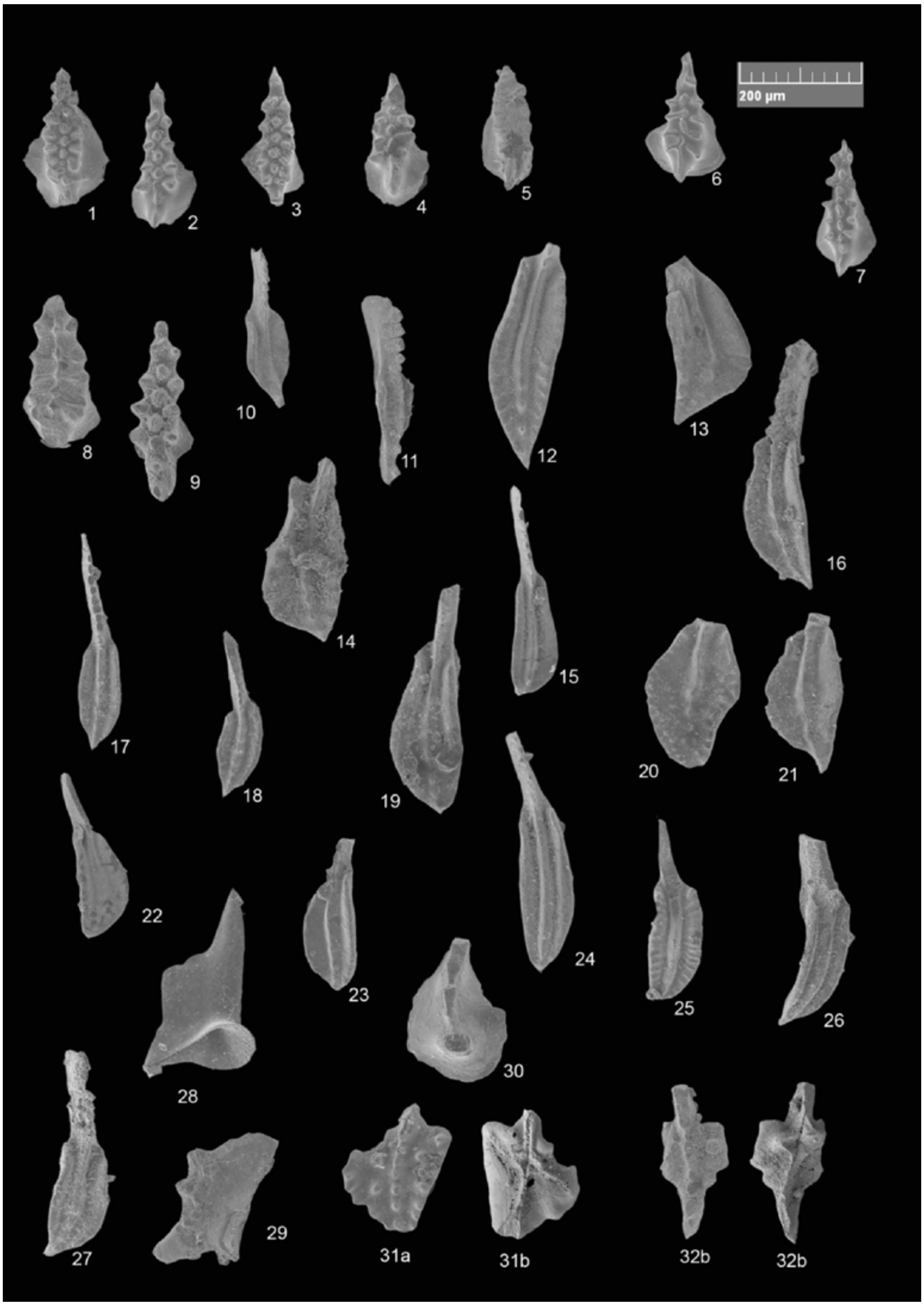

Fig. 1: Conodonts from the Barham Formation. (1) *Icriodus excavatus* Weddige, 1984; sample. (=s.) H 23. (2) *I. expansus* Branson & Mehl, 1938; s. H 23. (3) *I. cedarensis* Narkiewicz & Bultynck 2010; s. H 23. (4) *I. subterminus* Youngquist, 1947; s. H 22. (5) *I.* sp. indet.; s. H 22. (6). *I. iowaensis* Youngquist & Peterson, 1947; s. H 21. (7) *I. alternatus* Branson & Mehl, 1934; s. H 21. (8) *I. tafilaltensis* Narkiewicz & Bultynck, 2010; s. H 08. (9) *I. brevis* Stauffer, 1940; s. H 03. (10) *Polygnathus brevilaminus* Branson & Mehl, 1934; s. H 22. (11) *Pol. angustidiscus* Youngquist, 1947; s. H 22. (12) *Pol. pollocki* Druce, 1976; s. H 20. (13) *Pol.* cf. *webbi* Stauffer, 1938; s. H 16. (14) *Pol.* cf. *aequalis* Klapper & Lane, 1985; s. H 16. (15) *Pol. politus* Ovnatanova, 1969; s. H 09. (16) *Pol. prepolitus* Kononova, Alekseev, Barskov & Reimers, 1996; s. H 08. (17) *Pol. brevilamiformis* Ovnatanova, 1976; s. H 08. (18)- *Pol. aspelundi* Savage & Funai, 1980; s. H 08. (19) *Pol.* cf. *webbi* Stauffer, 1938; s. H 08. (20) *Pol.* sp.; s. H 08. (21) *Pol. alatus* Hinde, 1934; s. H 08. (22) *Pol.* cf. *webbi* Stauffer, 1938; s. H 07. (23) *Pol.* cf. *olgae* Ovnatanova & Kuzmin, 1991; s. H 07. (24) *Pol. pollocki* Druce, 1976; s. H 04. (25) *Pol .dubius sensu* Kapper & Philip, 1971; s. H 04. (26) *Pol. xylus* Stauffer, 1940; s. H 04. (27) *Pol. zinaidae* Kononova, Alekseev, Barskov & Reimers, 1996; s. H 08. (28) *Pelekysgnathus planus* Sanneman, 1955a: s. H 23. (29) *Pel. inclinatus* Thomas, 1949; s. H 23. (30) *Pel. serradentattus* Capkinoglu, 1991; s. H 22. (31a-b) *Ancyrodella pristina* Khalymbadzha & Tchernyshova, 1970; s. H 09. (32a-b) *Anc.* cf. *pristina* Khalymbadzha & Tchernyshova, 1970; s. H 05.

Devonian vertebrates of Mongolia

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The Devonian is a particularly important time as it records a turnover from faunas dominated by jawless fishes to those dominated by jawed vertebrates, as well as the rise of tetrapods. Much of our knowledge of vertebrate evolution during this time is derived from Euramerican deposits, and increasing numbers of exceptional discoveries from Australia and China. The Siberian palaeocontinent and related terranes are underrepresented in phylogenetic studies of early jawed vertebrate evolution, leaving a major palaeobiogeographic gap in these studies. Devonian vertebrates from Mongolia, which formed part of the Siberian palaeocontinent, have been poorly documented, even though extensive Devonian outcrops are known in the region. To date, published records are limited to fragmentary placoderm remains from eastern Mongolia, although diverse vertebrate microremains are known from the Silurian of western Mongolia. To address this gap, we have been undertaking a multi-year field project in Mongolia to prospect for Palaeozoic vertebrate localities, with a particular focus on the Devonian of western Mongolia. Mongolia has extensive Devonian marine and near-shore sequences which should yield vertebrate remains. Our work has uncovered new Devonian vertebrate localities in Early, Middle, and Late Devonian deposits. Early Devonian deposits yield acanthothoracid placoderms and acanthodian remains. Acanthothoriacids comprise at least three distinct genera, at least two of which are new, highly unusual forms. The Early-Middle Devonian yields a diverse assemblage of placoderms and osteichthyans. The Late Devonian has produced abundant *Bothriolepis* remains and rare osteolepidid material. Most significantly is a lack of jawless vertebrate macroremains. These new records have the potential to inform our understanding of vertebrate diversification and distribution during the Devonian period. Jawed vertebrate records in Mongolia are characterised by groups with global or palaeobiogeographically very broad distributions. The absence of jawless vertebrates is consistent with their presumed low rates of dispersal and high levels of endemism.

Revised Devonian time scales and evidence for variable eustatic, climatic, and biotic volatility: example from the Lower-Middle Devonian of the Appalachian Basin

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Revised time-scales for the Devonian Period (*e.g.*, Becker *et al.*, 2012), together with increasingly precise studies of oxygen isotopes and correlated sea level fluctuations has brought major discrepancies in the frequency and amplitude of eustatic, isotopic, physical and biotic fluctuations through various parts of the Devonian into sharp focus. Revised correlation charts for the Lower-Middle Devonian of the Appalachian Basin highlight these anomalies.

The record of eustatic events is highly uneven. Thus, the relatively minor evidence of sea level variation in the Emsian (five rather minor fluctuations over ~17 million years) contrasts sharply with the high-frequency and strong definition of sea level fluctuations during the late Eifelian to early Frasnian interval (some 10 recognized third order sequences over about 10 million years as well as many recognized fourth- and fifth-order sequences; Brett *et al*., 2011).

Recent studies of carbon isotopes in Devonian brachiopods and whole-rock carbonates (Buggisch & Mann, 2004; Buggisch & Joachimski, 2006; Becker *et al*., 2012) have led to refined understanding of isotopic trends: there are about 15 positive $\delta^{13}C_{carb}$ excursions and about six stronger negative excursions in the Devonian. The volatility is again very low during the long Emsian interval (no major excursions), and strongest in the late Eifelian to early Famennian (9 major positive excursions and 6 fairly pronounced negative excursions). This evidence of variable volatility of the global carbon cycle roughly parallels the reduced sea level, climatic and biotic variability of the Emsian as compared to the Middle Devonian. Perhaps the abrupt positive isotopic shifts are related to intervals of eutrophication and burial of organic carbon. The rising phases of these shifts may be associated with bioevents.

Many studies have focused on hypoxic events and their close association with minor and major extinctions, and biotic turnovers, typically identified as “bioevents” (for summary see House, 2002; Becker & Kirchgasser, 2007). The Lower-Middle Devonian record of the Appalachian Basin and elsewhere, provides strong evidence that widespread hypoxic conditions and abrupt bioevents are linked. At present, there some 12 named global bioevents in the Early to Middle Devonian and three of these are doublets (*i.e.*, two closely spaced events). Of named bioevents, one is in the Lochkovian, four minor ones in the Pragian-Emsian, three in the Eifelian, and four in the Givetian. These are variably recorded in the Appalachian Basin. Those of the Emsian are relatively minor, in contrast to those of the subsequent Middle Devonian (*e.g.*, Kacak, Taghanic), which bound ecological-evolutionary subunits and are nearly as strong as the better known Late Devonian events (Brett *et al*., 2009).

Together, the strong evidence for a change in environmental and biotic volatility in the Appalachian Basin record may well reflect a transition from strong greenhouse, (Pragian to Emsian), to transitional or moderate icehouse conditions in the Middle Devonian. The development of an oxygen isotopic curve for the Devonian based largely on conodont apatite values (Joachimski *et al*., 2009) appears to give more reasonable temperature estimates than brachiopod shell values and outlines a broad trend of cooling from high oceanic temperatures in the Lochkovian-Emsian into the Middle Devonian followed by warming into the Frasnian. Superimposed on this general curve are a series of peaks, especially warming spikes, associated with the global late Lochkovian, Bakoven (late Eifelian), and Taghanic (late Givetian) extinction and hypoxic events. These fluctuations suggest a connection between brief episodes of abrupt warming (during a generally cool period), intervals of sea level rise, hypoxia recorded in black shale, and biotic turnovers. The widespread, probably global, nature of these events suggests a eustatic connection. Elrick et *al.* (2009) have argued that high-resolution variation in $\delta^{18}O$ values in Middle Devonian suggests not only fluctuations consistent with sea level variations (high values during lowstands and vice versa), but also a glacial "reservoir" effect based on Rayleigh distillation. This provides indirect proxy evidence for glacioeustasy at a time interval for which actual glacial deposits are as yet unknown. The recent discovery of these deposits in a very well known area in very recent years suggests that our knowledge of glacial deposits remains very incomplete.

Regardless of mechanism, there appear to be prolonged intervals characterized by weak fluctuations in sea level, oxygenation, carbon isotopes, and biotic change. In contrast, are intervals of much stronger environmental volatility. The latter show a series of relatively quasi-stable conditions punctuated by major turnovers with abrupt sea level rise, widespread hypoxia, and changes in the carbon cycle. It is during these intervals that much net evolutionary and ecological change appears to take place.

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New insights on Uppermost Famennian brachiopods from north-western France (Avesnois)

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The uppermost Famennian is characterized by radiations among several brachiopod orders such as the Productida, Rhynchonellida and Spiriferida, which developed morphological features heralding the Carboniferous brachiopod faunas (*e.g.*, Gosselet, 1857; Simakov, 1990; Mottequin *et al.*, 2014). In common with other groups such as ammonoids (Kullmann, 2002), fishes (Friedman & Sallan, 2012), rugose corals (Poty, 1999) and stromatoporoids (Fagerstrom, 1994), brachiopods suffered extinctions during the Hangenberg Crisis such as the disappearance of the last cyrtospiriferoids that were so abundant during the Late Devonian. However, judging from the stratigraphical record of brachiopods, the Hangenberg Crisis seems to have been less severe than the end Frasnian Crisis as no extinction of brachiopod orders occurs at the Devonian–Carboniferous boundary. Significant post-crisis recovery took place during the Tournaisian (Sun & Baliński, 2011), especially within the spiriferides and the productidines.

Brice *et al.* (2013) recently stressed that the brachiopod data related to the uppermost Famennian (Etrœungt Formation) of the Avesnois (north-western France), which is the historical type area of the "Strunian" (Streel *et al.*, 2006), strongly need to be updated in order to detail the aftermath of the Hangenberg Crisis. In this area, the last comprehensive study on uppermost Famennian brachiopods dates back to Dehée (1929) and has been subsequently partly revised (*e.g.*, Legrand-Blain, 1995; Brice *et al.*, 2013).

Due to the poor state of preservation of the material collected notably in the Parcq quarry, which is the historical section of the Etrœungt Formation (*e.g.*, Gosselet, 1857; Mistiaen *et al.*, 2013), it is presently difficult to assess the real diversity of the brachiopod fauna recovered from the mixed siliciclastic-carbonate Etrœungt Formation, but the major orders are represented among the brachiopod fauna: athyridides (*Cleiothyridina?*, *Composita*), orthides (*Aulacella*, *Schizophoria*), orthotetides (*Schellwienella?*, Orthotetida gen. indet.), productides (*Rugosochonetes?*, *Semiproductus*), rhynchonellides (*Araratella*, *Centrorhynchus*), spiriferides (*e.g.*, *Prospira*, *Sphenospira* (Fig. 1)), and spiriferinides (*Cyrtina*).

Fig. 1: Two emblematic species of the uppermost Famennian succession of the Avesnois. (1-3) *Prospira struniana* (Gosselet) in ventral, lateral and posterior views (Dehée, 1929: pl. 3, fig. 4). (4) *Sphenospira julii* (Dehée), ventral valve (Dehée, 1929: pl. 2, fig. 2). Scale bars: 5 mm.

The Hangenberg Event *sensu stricto* is located at the boundary between the Etrœungt and the Avesnelles formations (Hubert *et al.*, 2013). The latter, which consists of dark, thin-bedded limestones devoid of corals and stromatoporoids, rests abruptly on the Etrœungt Formation. Legrand-Blain (1995) reported the presence of an abundant, but poorly documented brachiopod fauna dominated by the productidines within the Avesnelles Formation but, in the absence of conodonts, its age still remains imprecise (Hance *et al.*, 2001; Poty *et al.*, 2006).

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The Lower Devonian "Hunsrückschiefer" of the Rheinisches Schiefergebirge: new insights from palynology

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The exceptional preservation of fossils from the Hunsrückschiefer offers rare insights into the unique biota of oxygen-deficient environments of early Devonian seas, but provides little conclusive evidence of the precise age and age range of the Hunsrückschiefer and its facies equivalents. Besides, controversies still exist regarding interpretations of the depositional environment. Several attempts have been undertaken in the past to find solutions to existing problems from a palynological viewpoint. But palynological studies in the Hunsrückschiefer are severely limited by high thermal alteration, tectonic deformation, pyrite precipitation and high sedimentation rate. Our current knowledge has, thus far, been obtained from isolated samples and marginal sites.

New palynological information has now been received from a section at Siesbach near Idar-Oberstein. The section exposes fine grained siliciclastics across more than 400 m along a forest road cut including volcanics and a thin unfossiliferous carbonate horizon. It is situated at the southeastern limb of an anticline representing the southwestern extension of the Soonwald anticlinorium. Three units can be distinguished from base to top: a quartzite/siltstone sequence, a quartzite/siltstone/shale sequence and a siltstone/shale sequence. Within a superposed fining-upward trend a distal turbidite sequence can locally be recognized at a decimetre scale.

From the upper part of the section relatively diverse and reasonably well-preserved palynomorph assemblages allowing identifications by means of SEM and infrared microscopy have been isolated. Studied samples are characterized by land derived spores including species of the genera *Retusotriletes, Apiculiretusispora, Emphanisporites, Dictyotriletes, Streelispora* and *Camptozonotriletes* in addition to some obligate tetrads. They appear to alternate with assemblages abounding in marine phytoplankton represented by rather long ranging genera such as *Veryhachium, Micrhystridium, Baltisphaeridium*, *Multiplicisphaeridium, Cymatiosphaera* and *Dictyotidium*.

Biostratigraphically, the spore assemblages suggest a late Siegenian to deep early Emsian age. A younger Emsian age is unlikely for the Siesbach section since the marker species of the Emsian Klerf Formation, *Verruciretusispora dubia*, has not been found so far. The latter, however, has previously been recorded from other sites, *e.g.* near Bundenbach, suggesting that the Hunsrückschiefer *sensu lato* ranges from the late Siegenian through the lower Emsian and possibly into the upper Emsian.

Future palynological studies will be combined with lithofacies analysis and the geochemistry of MORB-type metabasites and will explore the possible correlation of the Siesbach section with the classical "Fossillagerstätten" near Bundenbach and Gemünden.

New data on Middle Devonian conodonts from New York State with emphasis on the Icriodontidae

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Klapper (1971, 1981) was the first author who studied accurately Middle Devonian conodonts from New York, mainly Polygnathidae. He recognized 28 species, including 20 *Polygnathus* species and only 4 *Icriodus*: *Icriodus latericrescens robustus, I. latericrescens latericrescens, I. brevis* and *I. difficilis*. In the present contribution we describe for the first time all Icriodontidae and their stratigraphic distribution from the base of the Nedrow Limestone to the top of the Tully Limestone. Four new *Icriodus* species are recognized in the interval Nedrow Limestone–Cherry Valley Limestone. Three of those new species are well represented in the faunas, but their stratigraphic extension is relatively short, Nedrow Limestone to Cherry Valley. This may be due to a local regression. Until now similar forms or species have not been recognized in conodont faunas from other regions. *Icriodus brevis* and *I. difficilis* occurring above in Tully Limestone are well known outside New York and have a nearly cosmopolitan distribution.

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A decade of deciphering the Late Devonian: more answers, but many more questions

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The dynamic shifts in the Late Devonian climate are thought by many to be the causal mechanisms of two of the top six major mass extinctions in Earth's history: the Frasnian–Famennian (F–F) boundary at ~375 Ma and the Devonian–Carboniferous (D–C) boundary at ~354 Ma. The F–F extinction event decimated coral-stromatoporoid reef ecosystems, and the D–C boundary extinction primarily affected pelagic marine communities including fish and cephalopods. Both of these extinction events are closely correlated with major ocean anoxia events: the Upper and Lower Kellwasser Events (at the F–F boundary) and the Hangenberg Event (at the D–C boundary). Although the correlation of anoxia with extinction is generally well established, the causes and trigger mechanisms for anoxia development are not. Despite the numerous detailed studies from a variety of disciplines conducted in the decade since Racki (2005) noted that the Late Devonian was rife with "few answers, many questions," there are still disagreements on whether or not the Kellwasser Events and the Hangenberg Event were regional or global in scope, and whether or not they had similar or disparate causes. This intent of this abstract is to summarize the copious new research of the last decade to show what is known about Late Devonian anoxia events, what is still unknown, and present some promising new (as well as tried and true) geochemical techniques that can be used to test established hypotheses.

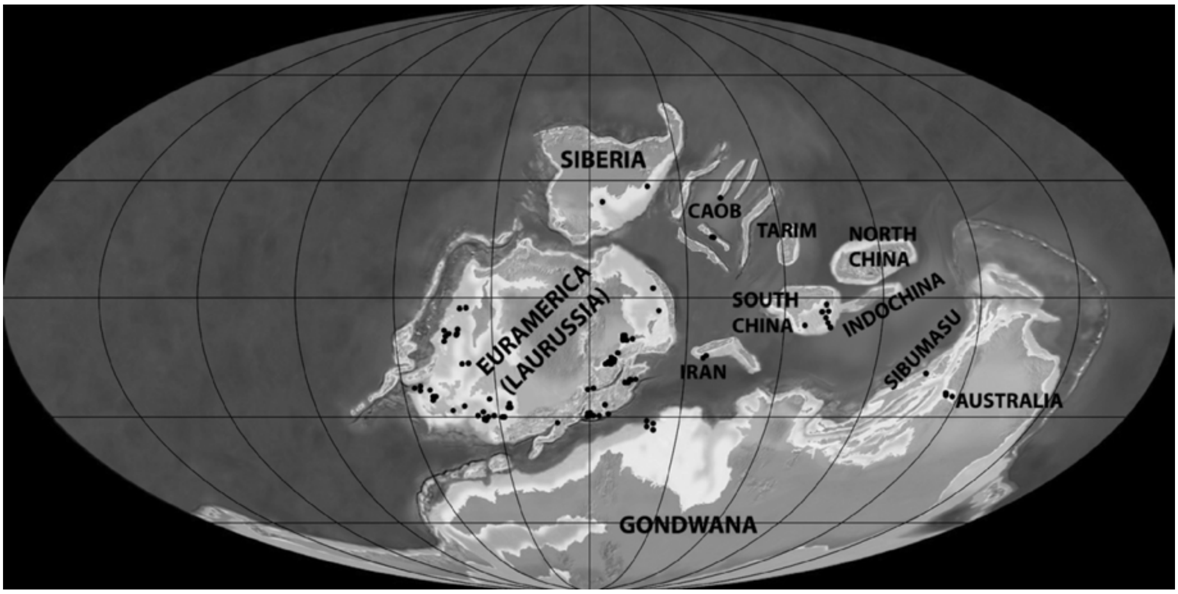

Fig. 1: Late Devonian paleogeographic map showing black dots for the approximate locations of 116 detailed studies of both the F–F and D–C boundary extinction events. Of these, 89 studies are associated with the epeiric seas and restricted basins of the Euramerican continent, and 22 are located on carbonate platforms associated with cratonic blocks. Only 5 studies are located in Marianas-type island arc environments (in the CAOB), indicative of open oceanic conditions, although new field sites in southeast Asia (see Königshof *et al.*, 2015) may possibly represent isolated island arc environments as well. Map modified from Blakey (2008) with updated paleogeographic data from Metcalfe (2011) and Xiao *et al.* (2010).

Sample Bias

One of the major stumbling blocks to understanding these Late Devonian anoxia and extinction events is sample bias (Fig. 1). Nearly 77% of our current information about the Kellwasser and Hangenberg Events and the extinctions associated with them comes from studies in epicontinental basins or continental shelf deposits in sites across Europe and North America, which may exhibit a tectonic megabias from the rising Appalachian Mountains. While other studies have been conducted in locations that would presumably not be affected by the Appalachian orogenic events, nearly all of these locations are associated with sediments derived from large cratonic blocks and may not be representative of global oceanic conditions. Only the Marianas-type island arcs in the Central Asian Orogenic Belt (CAOB) are representative of open oceanic conditions in the Late Devonian, but they represent <5% of Late Devonian studies. A better understanding of global oceanic conditions in these intervals requires additional work in understudied areas, particularly in Asia.

Causes of Anoxia

Late Devonian ecosystems were under several long-term stresses including falling atmospheric CO_2 levels and the transition from a greenhouse to an icehouse climate, the development of soils, increased biomechanical weathering and nutrient leaching, and changing ocean circulation patterns due to the rise of a major mountain chain in the tropics (the Appalachian/Variscan orogeny). These long term stresses alone were unlikely to have caused the abrupt onset of anoxia, which would have to involve some sort of external trigger that caused rapid fluctuations in climate (either caused by orbital forcing, large igneous provinces, or a bolide impact). Bolide impacts have for now been ruled out as causal mechanisms, but recent work has suggested correlations between major igneous activity (in a variety of places) with both the Kellwasser and Hangenberg Events. Cyclostratigraphy analysis of several Late Devonian units likewise indicates that both Middle and Late Devonian anoxia events are correlated with climate change induced by orbital forcing.

Mechanisms of Anoxia

For many years, the established mechanism for Late Devonian anoxia was “bottom up”, *i.e.* upwelling of anoxic bottom waters into shallow marine ecosystems. In the last decade, however, work in new field sites as well as the use of new techniques in well-studied sites has called the upwelling model into question. One new model includes transgression of oxic water with later stagnation in epicontinental basins, although this model does not work in all studied systems. A “top down” model involving shallow water eutrophication and changes in primary productivity is an additional model that works in many systems in a variety of environments, although it is not yet known if this model is representative only of near-shore environments (due to nutrient influx, similar to what is seen in the hypoxic dead zones of coastlines today), or is more global in scope due to changes in plankton communities.

Tried and True *versus* New Geochemical Techniques

Stable isotopes of carbon and oxygen have long provided much of the information we have about paleoclimate and paleooceanographic conditions during the Late Devonian. Limitations of these techniques, however, are well established: diagenetic alteration, sample type, fossil type, and sample location (epeiric sea *versus* open carbonate platform) can all affect the outcome of C/O stable isotope signatures. These limitations, in combination with the sheer number and variety of field sites and difficulties in stratigraphic correlation, have led to conflicting interpretations about whether global cooling or short pulses of global warming were responsible for Late Devonian anoxia. Other stable isotope techniques include ε_{Nd} for reconstructing changes in sea level, $^{87}Sr/^{86}Sr$ for chemostratigraphic correlation where biostratigraphy is not well constrained (as well as for determining the extent of diagenetic alteration in carbonates), $\delta^{15}N$ to asses changes in primary productivity, and $\delta^{34}S$ for tracking seawater mixing and mineral speciation dynamics in anoxic/dysoxic waters.

Organic geochemistry is a useful tool that has been used to decipher the specific origins of the high levels of TOC within Kellwasser and Hangenberg black shale sequences, yet these signatures indicate that either terrestrial- or marine-derived organic matter are causal agents of shallow water eutrophication-driven anoxia, depending on the study site. Trace element geochemistry has been used frequently to better constrain anoxic/dysoxic conditions in units (which may or may not contain visible black shale beds), but their use is limited by sediment type, the paleogeography of the field site, and the degree of diagenetic alteration. Framboidal pyrite distribution is a useful (albeit time consuming) analytical tool that can be used to determine the degree of oxygen deficiency in mudrocks, and can be extremely useful in sites where black shale development is limited, particularly when used in conjunction with other techniques. It does not, however, provide any information about the causes or mechanisms of anoxia, only the presence and severity of anoxia.

Summary

Despite the numerous studies and new developments in the last decade studying Late Devonian sequences, we are still left with "few answers, many questions." However, it is clear that relying on single methodologies to explain these events is no longer feasible, and that new field sites in understudied areas will be key in understanding the complex Late Devonian world.

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Wildfire activity as a proxy for atmospheric oxygen content during Romer's Gap

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Following the End Devonian Mass Extinction Event (EDME, or Hangenberg Crisis), tetrapods disappear almost completely from the fossil record for 10–15 million years. Latest Devonian forms such as *Acanthostega* were primarily aquatic and equipped with a variable number of digits, front and back; after the gap, Viséan tetrapods were essentially terrestrial and five-fingered (*e.g.*, *Eucritta*). Clearly, "Romer's Gap" (named for Alfred Romer, who first drew attention to it (Romer, 1956)) obscures an important stage of vertebrate terrestrialisation.

The cause of the hiatus is unclear. One hypothesis (Ward *et al.*, 2006), in part based on Palaeozoic atmosphere models (Berner, 2006), is that the concentration of atmospheric O_2 was abnormally low at this time, making a terrestrial mode of life untenable for early limbed vertebrates. However, such models are highly complex and require a number of assumptions which are difficult to test; disagreement over how to incorporate these into the models in a realistic way has led to widely diverging outputs that are difficult to reconcile. An alternative interpretation is that Romer's Gap is an artefact, either of collection failure or taphonomic bias; proponents of this view note that rare finds of tetrapod material have progressively narrowed the gap over the last 50 years (Smithson *et al.*, 2012; Anderson *et al.*, 2015).

A high-resolution Famennian - Viséan record of wildfire activity, based on the relative abundance of microscopic charcoal (inertinite) within dispersed organic matter extracted from sedimentary rocks, is providing new insights into biosphere flammability and hence an independent constraint on atmospheric O_2 during this critical interval. Results indicate no significant suppression of wildfire activity, implying that reduced atmospheric O_2 is not a viable explanation for Romer's Gap. Indeed, on the basis of charcoal occurrence in modern (pre-industrial) sediments, Tournaisian O_2 levels appear to have been similar to those of today.

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Ostracods from the Emsian–Eifelian and Eifelian–Givetian boundaries in the Dinant Synclinorium: paleoenvironmental implications

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1. The Emsian–Eifelian boundary

Ostracods present close to the Emsian–Eifelian boundary are studied for the first time in the Dinant Synclinorium (Ardenne). The studied section is located along the Eau Noire River close to Couvin, at a place named "La Foulerie". The Eau Noire section exposes the upper part of the Saint-Joseph Formation (Fm), the stratotype of the Eau Noire Fm and the La Foulerie Member (Mbr), the lower member of the Couvin Fm. The Emsian–Eifelian boundary is marked in this section by the appearance of conodonts belonging to the *partitus* Zone, 50 m above the base of the Eau Noire Fm (Bultynck *et al.*, 1991). The Eau Noire section has been described by Bultynck (1970), Bultynck *et al.* (1991) and Mamet & Préat (1994).

From 66 samples collected in the studied section, 1,077 carapaces, valves and fragments of ostracods were extracted by the hot acetolysis method. Only 42 taxa were identified through the series, implying a low diversity in regard to the total thickness (230 m) of the outcrop. Ostracods belong to the Eifelian Mega-Assemblage, and the great abundance of Podocopids coupled to the rarity of Paleocopids and Metacopids indicate shallow open-marine environments close to the fair-weather wave-base. *Bairdia cultrijugati* is present in almost all samples, as also abundant ostracods with thick carapaces belonging to the genera *Bairdiocypris, Tubulibairdia* and *Microcheilinella* pointing to a general agitated environment. No assemblage indicative of semi-restricted or of lagoonal water conditions has been observed. The sedimentation conditions and the climate were certainly relatively stable during the deposition of the studied series.

2. The Eifelian–Givetian boundary

Ostracods of the Hanonet and Trois-Fontaines Fms have been subject of several studies in the Dinant Synclinorium, at Glageon, Mont d'Haurs and Fromelennes, in France, Couvin and Resteigne, in Belgium (Casier & Préat, 1990, 1991; Casier *et al.*, 1992, 1995, 2011; Milhau *in* Hubert *et al.*, 2007). More recently ostracods present in the Hanonet and Trois-Fontaines Fms exposed in four sections located in three quarries at Wellin, On-Jemelle and Hotton, have been studied in order to complete their inventory across the Eifelian–Givetian transition (Casier *et al.,* in press). From 168 samples collected in these 4 sections, 3,430 carapaces, valves and fragments were extracted by the hot acetolysis method and 75 taxa were recognized. Our study confirms that ostracods were particularly abundant and diversified close to the Eifelian–Givetian boundary in the Ardenne.

The exact position of the Eifelian–Givetian boundary in the southern border of the Dinant Synclinorium is still in debate. The conodont *Polygnathus hemiansatus* is infrequently present in the shallow deposits exposed in this region; consequently the base of the Givetian is fixed by the first occurrence of *Icriodus obliquimarginatus* (Bultynck, 1987). In the historical stratotype of the Givetian, *I. obliquimarginatus* has been found 4 meters below the base of the Givet Group but up to 18 meters in other sections (Bultynck, *ibid.*). Consequently, we can estimate that a great part of the Hanonet Fm belongs to the Early Givetian. The Trois-Fontaines Fm belongs entirely to the *hemiansatus* conodont Zone (Bultynck & Dejonghe, 2001).

Ostracods also belong to the Eifelian Mega-Assemblage close to the Eifelian–Givetian boundary in the Dinant Synclinorium. The succession of assemblages records a shallowing of the marine environments, which were open-marine and agitated during the deposition of the Hanonet Fm and became semi-restricted and then lagoonal in the Trois-Fontaines Fm. This confirms the results obtained by the sedimentological analysis which displays a progressive evolution from an outer mixed siliciclastic carbonate ramp to a carbonate platform around the Eifelian–Givetian boundary.

Particularly interesting is the occurrence of a monospecific leperditicopid ostracod assemblage in the upper part of the Trois-Fontaines Fm. Both the abundance of leperditicopid and this monospecificity indicate lagoonal environments confirmed by the sedimentological analysis. But leperditicopid ostracods are present only for a short time interval during the Givetian in the Dinant Synclinorium, whereas lagoonal environments are frequent during all this period and up to the Givetian–Frasnian boundary. This absence of leperditicopids in younger Givetian deposits of the Ardennes may be explained as follows: (*1*) leperditicopid ostracods are sometimes associated with some Characea and this association may indicate brackish waters (such association has also been reported from the Givetian of the Holy Cross Mountains by Malec *et al.* (1987) but only a stratigraphic value of this association was pointed out by these authors); (*2*) the climatic conditions were probably wet and warm during the Early Givetian and became arid in the Late Givetian (Casier *et al.*, 2013), perhaps in relation to the Taghanic Biocrisis. In reality, no evaporitic episodes are known in the Dinant Synclinorium before the Late Givetian.

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Tetrapod diverstity in the Tournaisian

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Following the end-Devonian mass extinction, the fossil record of tetrapods has been almost blank for the subsequent 15–20 million years, barring two exceptions. Those were the isolated bones from Blue Beach, Horton Bluff, Nova Scotia, first described briefly in Clack & Carroll (2000), reviewed along with trackways from the same site by Mansky & Lucas (2013) but described and illustrated in more detail by Anderson *et al.* (2015). The other instance was the discovery of a single articulated tetrapod specimen from Dumbarton in Scotland, *Pederpes finneyae*, described by Clack (2002) and Clack & Finney (2004). These remains hinted at the potential diversity that existed among tetrapods in the earliest Carboniferous, but each was limited in its own way, the isolated limbs because they could only be attributed to a broad taxonomic group rather than a specific taxon, and *Pederpes* because it was a single nodular specimen with little environmental context.

A project to study Tournaisian fauna and ecosystems of the Ballagan Formation was initiated in 2012, introduced by Smithson *et al.* (2012), in which the discovery of several new tetrapod taxa as well as a suite of actinopterygians and arthropods was announced. Since then, further collecting has revealed several more new tetrapod taxa, as well as a diversity of lungfish tooth plates (Smithson *et al.*, in press) and an unpredicted richness of chondrichthyan teeth (Smithson (Smithson *et al.*, 2015; Richards *et al.*, in review).

We present here some of the tetrapod material that has been discovered from a number of sites in the Borders Region of Scotland and other localities, to show its range of sizes and morphologies. Four of our specimens were briefly described in Smithson *et al.* (2012), but there are representatives of at least two other large taxa in the collection (Figs 1, 2). The most productive localities are in Willie's Hole, near Chirnside and Burnmouth.

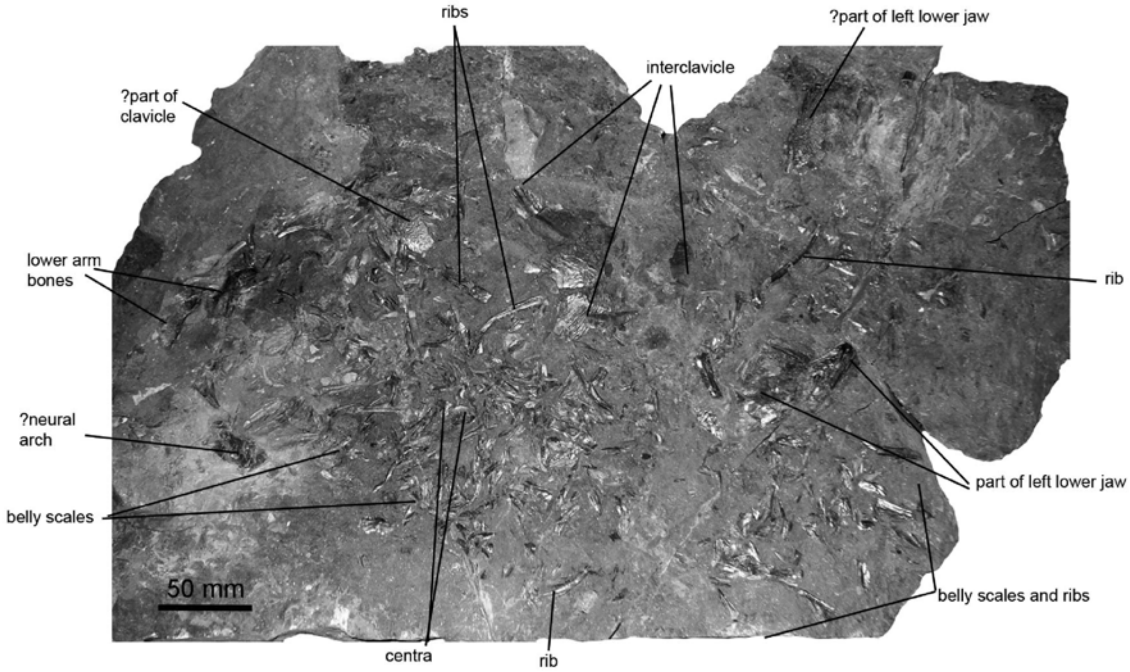

Fig. 1: Scattered elements of a large tetrapod from Willlie's Hole, showing interclavicle, ribs, ulna and radius, body scales, parts of a lower jaw, and other elements. UMZC 2011.7A.

Among the most interesting of our finds are several small tetrapod skulls, the largest no more than 75 mm in length. Small early Carboniferous tetrapods have been rare in the past, notable exceptions being *Lethiscus* and *Casineria*, from the Holkerian and Asbian respectively. We now have at least five from the Tournaisian. They show different combinations of primitive and derived characters, and none is a close relative of any of the others. Some of these taxa cluster with Devonian forms, but one appears as a basal member of a later appearing Carboniferous clade, the colosteids. The presence of more primitive taxa that appear among Devonian forms suggests the blurring of the Devonian–Carboniferous boundary and a less severe effect on tetrapods than on many fish groups. A more detailed presentation of the small taxa is being prepared for publication elsewhere.

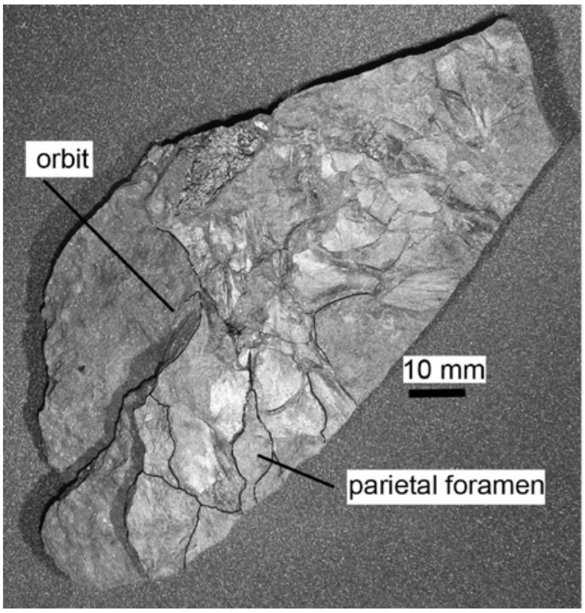

Fig. 2: Skull roof from Willie's Hole showing parietal foramen, part of skull table and orbits, and part of snout. NMS G 2012.39.95.

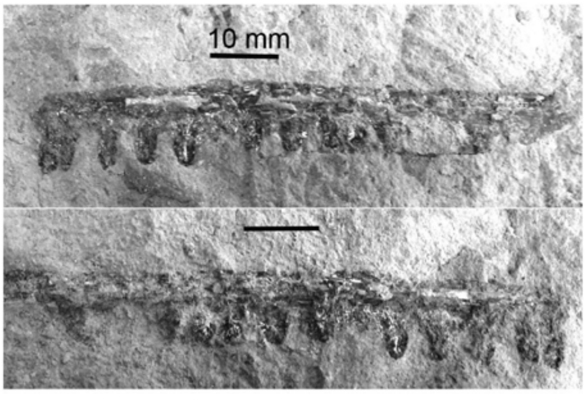

Fig. 3: Maxilla in part and counterpart.

We have discovered a range of different femora from two of our localities, all different from those described from Blue Beach, and a maxilla from a previously little-explored locality at the Heads of Ayr in western Scotland (Fig. 3).

Our discoveries imply that there was considerable diversity among tetrapods, as well as lungfishes and chondrichthyans, during the Tournaisian, and that the so-called "Romer's Gap" resulted in the past from a lack of collecting in appropriate sedimentary sequences. We suspect that this was because, lacking lithologies with significant commercial potential, the Ballagan Formation, and other Tournaisian sequences, were never exploited for mining or quarrying. Hence, no fossil finds were made as accidental "by-catch".

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Assessment on the Late Devonian fauna of Strud, Belgium

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The Late Devonian Strud locality from the Namur Province, Belgium, was known for over a century for its faunal and floral content (Hock, 1879; Lohest, 1888; Leriche, 1931; Stockmans, 1948). Then forgotten, this locality was rediscovered in 2004 by geologists of the Liege University and regular field collecting for the last 10 years has resulted in a unique continental floral and faunal assemblage which give a glimpse of Euramerican environment and biogeography during the Late Devonian phase of the processes of tetrapod and arthropod terrestrializations. Fieldwork at the Strud locality has now come to its end.

The Strud locality has yielded a diversified flora including seed-plants (Prestianni *et al.*, 2007) and fauna including crustaceans (anostracans, notostracans, conchostracans, and decapods), eurypterids, a putative insect, placoderms (groenlandaspids, phyllolepidids, antiarchs), actinopterygians, acanthodians, sarcopterygian fishes (porolepiformes, osteolepiformes, lungfishes) and tetrapods. This fossil assemblage is one of the oldest continental – probably freshwater – ecosystems with a consequent vertebrate and invertebrate diversity.

The exceptional preservation of arthropods and plants in the main fossiliferous layers is explained by a quick burial in the fine-grained sediment of a calm and confined flood plain and temporary ponds environment. Recent stratigraphic correlations allow to review the age of the fossiliferous horizon that is now definitely considered to be Late Famennian (VCo "rad" zone) (Denayer *et al.*, 2015).

Invertebrate fauna: The crustacean fauna is composed of two decapod shrimps (Gueriau *et al.*, 2014a, 2014b). *Tealliocaris walloniensis* documents the earliest occurrence of continental decapod crustaceans and indicates that decapods are part of continental ecosystems at least since the Late Devonian. *Schramidontus labasensis* documents the first occurrence of angustidontids in continental environment whereas it was previously only known from marine (pelagic) environments and enlarges the geographical distribution of angustidontids from North America and Eastern Europe to Western Europe. Angustidontida fills the gap between Amphionidacea and Decapoda *sensu stricto*.

The Strud locality also yielded an ephemeral pool branchiopod community comprised of anostracan (fairy shrimps), notostracan (tadpole shrimps) and spinicaudatan (clam shrimps). The fossil notostracan *Strudops goldenbergi* bears a close resemblance to modern notostracans in possessing a large, simple head shield covering almost half of the whole body, a set of phyllopodous thoracic appendages and a legless posterior abdomen with a telson bearing a caudal furca. The differentiation and relative size of mouthparts and limbs suggest that these specimens are all adults (Lagebro *et al.*, 2015). These notostracans are the earliest clear members of the total group Notostraca.

A unique complete insect, *Strudiella devonica*, which was probably a terrestrial species, was recently discovered associated with notostracans (Garrouste *et al.*, 2012, 2013). Its dicondylic mandibles are of an omnivorous type, clearly not modified for a solely carnivorous diet. This discovery narrows the 45-Myr gap in the fossil record of Hexapoda, and demonstrates further a first Devonian phase of diversification for the Hexapoda, as in vertebrates, and suggests that the Pterygota diversified before and during Romer's gap.

Vertebrate fauna: The placoderm fauna includes the antiarch *Grossilepis rikiki*, the groenlandaspidid *Turrisaspis strudensis* and the actinolepidoideid *Phyllolepis undulata* (Olive, 2015; Olive *et al.*, 2015). Based on morphological and morphometric evidences, this material is characterized, with rare exceptions, as juvenile material. Since the abundant placoderm material from Strud did not suffer of size sorting and is nearly exclusively composed of juvenile individual remains, this locality may be identified as a fish nursery. This nursery from Belgium, one of the rare known placoderm nurseries so far, sheds light on the ecology of the earliest fish nurseries.

Remains attributed to the sarcopterygian rhynchodipterid lungfishes *Soederberghia groenlandica* and ?*Jarvikia*, two taxa previously known in the late Devonian of East Greenland, have also been recovered from Strud (Clément & Boisvert, 2006).

A tetrapod jaw, found in the nineteenth century at Strud, was initially presumed to be from a fish (Lohest, 1888; Clément *et al.*, 2004). It shows typical tetrapod characters in its bone ornamentation and chamfered ventral margin of the dentary. The teeth are widely spaced and strongly curved posteriorly, as in the corresponding jaw portion of *Ichthyostega* from East Greenland. Although the find cannot be referred with certainty to *Ichthyostega*, it is strong evidence for the existence of a close relative of this tetrapod genus outside Greenland.

Supplementary tetrapod material from Strud has been recently collected. It consists of an isolated postorbital, fragment of two maxillae and one cleithrum.

The vertebrate occurrences, especially of placoderms, lungfishes and tetrapods, provide additional evidence for paleobiogeographical links between East Greenland and the central southern coast (Pennsylvania, Belgium) of the Euramerican continent during the Late Devonian.

Our knowledge of the paleoenvironment of the Strud locality is crucial because it recorded the earliest phase of tetrapod evolution that took place after their emergence and before their terrestrialization. It raises the question of the environmental and ecological conditions for the Devonian aquatic ecosystem and the selection pressures occurring at the onset of the tetrapod and hexapod terrestrializations.

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The redefinition of the Devonian–Carboniferous boundary: recent developments

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Since in the GSSP section at La Serre, southern France, the marker fossil for the base of the Carboniferous, the conodont *Siphonodella sulcata*, was found below the boundary just above a facies change, the definition of the base of the Carboniferous has been back on the agendas of the Devonian and Carboniferous subcommissions. A joined SDS/SCCS Task group was established in 2009 to redefine the base of the Carboniferous and thus to regain stratigraphical stability in this critical interval of Earth history. Task group members have been active in various aspects related to the boundary definition and a wealth of new data has become available. Characteristic for many studies are multi-disciplinary approaches, which combine palaeontological, sedimentological, geochemical and petrophysical methods and data.

It is not the aim to report all task group activities of the last years herein, but to summarize some and especially to present a brief summary on the discussions and results, which will arise just before the congress at Brussels. At the 2nd International Congress on Stratigraphy (Strati 2015) in July the task group organized a session on the Devonian/Carboniferous Boundary, and discussions were scheduled at the XVIII International Congress on the Carboniferous and Permian in August. Given the fact, that not many people who attended meetings in Graz and Kazan are in Brussels, it is important for the success of the task group that a summary of exchange of ideas and opinions will be given.

The task group is still gathering data and no decision has so far been made on a suitable level, an index taxon or a section. There are still many options to check. The task group is committed to stratigraphical stability, but also to a user-friendly definition of the base of the Carboniferous. In this respect the extinction events in the global Hangenberg Crises, which in the current definition predates the boundary, have been among many others one focus of our work.

In any case, the recent works demonstrated that the GSSP section and the auxiliary stratotype sections in China and Germany are not suitable for the definition of a new boundary. Hence the discussions are open in all directions and they require the input from all interested researchers.

Biodiversity and palaeobiogeographical affinities of Lower Devonian trilobites from Algeria

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Trilobites are widespread in Lower Devonian deposits of north Gondwana and some have been collected from two known sections of the Saoura Valley in SW Algeria, from the "Chefar el Ahmar" Formation. This formation is considered from Upper Emsian to Frasnian in age but only lower parts of this formation have yielded trilobites. Nevertheless no detailed studies have focused on their biodiversity and their morphological variability. New occurrences of phacopids including *Barrandeops chattertoni* Khaldi *et al.*, 2015, *Geesops fabrei* Khaldi *et al.*, 2015, *Austerops legrandi* Khaldi *et al.*, 2015, and *Phacops boudjemaai* Khaldi *et al.*, 2015, are described from this area and comparisons are made with closely allied species. These new occurrences have been integrated into analyses of intra- and inter-specific variability and biodiversity.

As observed in other areas from the northern peri-Gondwanan margin such as Morocco, the trilobite and especially phacopid remains are relatively abundant and well preserved. Trilobites include mostly complete and enrolled specimens. At generic and specific scales, the Algerian faunule may be regarded as diversified and cosmopolitan without marked original features and, as expected from its geographic position, is particularly closely related to Moroccan faunas (*e.g.*, presence of *Barrandeops granulops* (Chatterton *et al.*, 2006), *Hollardops mesocristata* (Le Maître, 1952), *Erbenochile erbeni* Alberti, 1981, *Gerastos tuberculatus marocensis* Chatterton *et al.*, 2006, etc.).

Next, a biometric study of Phacopidae enabled us to visualize and quantify partially the variability of the identified individuals and appears complementary to the descriptive systematic study. It especially enabled us to show that the new species *Austerops legrandi* differs from *A. menchikoffi* in having different cephalic proportions.

New samples in the Saoura Valley corroborate the distribution patterns of Phacopida and Proetida as mentioned by Le Maître (1952). Lower Devonian strata are characterized by abundant Phacopidae. Additional fieldwork is required to revise, complete and find rare representatives of other families such as Scutelluidae previously reported by Le Maître (1952) in the Saoura Valley.

Finally, two types of assemblages were recognized from the late Emsian: Ed4-biota dominated by *Austerops legrandi* (40%) and *Barrandeops granulops* (25%) that represents a "pioneer" community with opportunistic species; Ed3-biota characterized by a relatively moderate diversity and evenness that can represent almost "equilibrium" communities. Changes in species richness and ecological diversity of trilobites are in relation to physical environmental gradients. Changes in climate and topography limit most species ranges, resulting in considerable spatial turnover in species richness and ecological structure.

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Unravelling orbital climatic cycles from Devonian magnetic susceptibility signal – The quest for a better age model for the Lochkovian and Pragian stages (Czech Republic)

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The uncertainties on the Devonian stage boundaries are currently in the order of several millions of years. When shown to reflect a detrital signal, which is influenced by climatic variations, magnetic susceptibility (MS) has been proven as a useful tool for identifying climatic cycles; which can subsequently be used to improve the time scale.

Here, we focus on two sections from the Prague Synform (Czech Republic) cutting through the Lochkovian, Pragian and the lower part of the Emsian. Sedimentation is rhythmic, dominated by slightly clayey offshore limestones, being mostly calciturbidites and hemipelagites. We provide hysteresis analysis in order to get insight into the nature and the origin of the magnetic minerals driving the variation in the MS signal. The results point to a MS signal mostly carried by clay minerals.

Subsequently, to improve estimation of the duration of the stages, we apply different spectral analysis techniques on this MS signal. From the continuous wavelet transform (CWT), evolutive harmonic analysis (EHA) and field observations, we subdivide the section into portions with a steady sedimentation rate (a first estimate of this rate is also delivered by these analyzes). Then, we apply multitaper method (MTM) and multitaper harmonic analysis (F-test) and extract the frequencies reaching 95% confidence level. These frequencies are then implemented into the average spectral misfit procedures (ASM) which enables comparison with orbital targets. By combining these different techniques, 405 kyr cyclicty is identifed, a powerful duration paleochronometer. These new results indicate a duration of 7.7 ± 2 Myr for the Lochkovian stage and of 1.7 Myr ± 1.4 for the Pragian stage, compared to respectively 8.4 ± 6 Myr and 3.2 ± 5.4 Myr in the 2012 geological time scale.

Middle and Upper Devonian Events in Belgium: review and new insights

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Numerous events (bioevents or global sedimentary events) have been defined in the Devonian (for a recent summary, see Becker *et al*., 2012). Most of them were defined in basinal facies, based on extinction of pelagic fauna such as ammonoids and conodonts and have a global scale. However, few of these events have been recognized in neritic settings. In southern Belgium, the Upper Devonian bioevents, particularly the Kellwasser (Late Frasnian) and Hangenberg (Latest Famennian) events, received much attention (*e.g.*, Mottequin & Poty, 2014; 2015) because they are associated with stage or system boundaries. Conversely, Middle Devonian events inspired very few studies. Here we provide a review of expression of the main events recognized in the Middle and Upper Devonian through the lithostratigraphic succession of southern Belgium (Fig. 1).

The Choteč Event, situated in the upper part of the Eifelian *partitus* zone falls within the lower part of the Foulerie Member (Mbr) of the Couvin Formation (Fm) and theoretically within the Station Mbr of the Jemelle Fm. Gouwy & Bultynck (2003) postulated that the event could be recorded as a transgressive pulse ending the development of the first biostrome occurring within the Foulerie Mbr in the type area. No significant extinction corresponding to this event has been highlighted so far. The Bakoven Event within the *australis* Zone should fall within the Chavées Mbr of the Jemelle Fm. De Santis & Brett (2011) correlated it with a large-scale transgression leading to the deposition of black shale and disappearance of the Onondaga fauna. No black shale is known in the Chavées Mbr but the sudden dismiss of the limestones of the Couvin Fm, covered by the shaly Chavées Mbr is not incompatible with the Bakoven Event. Moreover, the transgression led to small-scale extinctions in the coral fauna (Tsien, 1969). The Stony Hollow Event, in the *kockelianus* Zone is marked by the expansion of tropical faunas into subtropical areas that may correspond to a rise in sea-level and temperature (De Santis & Brett, 2011). In Belgium, it could correspond to the onset of bioherms in the upper part of the Jemelle Fm but neither extinction nor dysoxic facies are known to date at this level (Bultynck *et al*., 1998). At the end of the Eifelian, in the *ensensis* Zone, siliciclastic deposits reappeared in the basin (the Lomme Fm and its lateral equivalent, the Pepinster Fm), witnessing a regression, have been interpreted by Bultynck & Hollevoet (1999) as the expression of "Struve's Great Gap" which corresponds to a period with many hiatuses in the sedimentary record in shallow environments. The following transgression led to the deposition of the carbonate Hanonet Fm (*ensensis* Zone), which took place within the Kačák event succession but the Lower Kačák Event (*otomari* Event) left no trace in Belgium after Gouwy & Bultynck (2003). Similarly, the Upper Kačák Event (*ostiolatus* Event) should be located in the basal Hanonet Fm but Bultynck & Hollevoet (1999) highlighted the lack of significant extinction and typical facies.

Within the lower part of the Trois-Fontaines Fm (Lower Givetian *hemiansatus* Zone) coral genera suffered a minor extinction (Coen-Aubert, 2004) which does not seem to be related to any yet recognized global extinction event. The Pumilio events (middle and upper *varcus*) are possibly correlated to two shelly beds rich in brachiopods in the Flohimont Mbr of the Fromelennes Fm (Maillet *et al.* 2013). As noted by Gouwy & Bultynck (2003), the Taghanic Event (and the Geneseo Transgression) does not appear as a single unit but covers the *ansatus* to *semialternans* zones and is consequently spread along the whole Fromelennes Fm with decoupled extinctions within ostracods (Maillet *et al*., 2013), corals (Coen-Aubert 2004), brachiopods (Brice *et al*., 2008). The last occurrence of stringocephalid brachiopods in the Moulin Boreux Mbr of the Fromelennes Fm is regarded by Bultynck *et al.* (2001) and Coen-Aubert (2004) as a marker of the Taghanic Event.

Frasnian events are rather well-situated stratigraphically. The Frasnes Event corresponds to the development of shaly facies at the base of the Frasnian (La Prée Mbr of the Nismes Fm; Becker, 1993) and possibly with the deposition of the chamositic and haematitic ironstone horizons of the Presles Fm. The *punctata* Event, close to the Lower–Middle Frasnian boundary has been located in the Ermitage Mbr of the Moulin Liénaux Fm but no significant extinction has been observed (Casier & Olempska, 2008). The Timan, Middlesex and Rhinestreet events (*punctata* to *hassi* zones) are theoretically situated within the Moulin Liénaux and Grands Breux formations and their lateral equivalents (Pont-de-la-Folle, Philippeville and Lustin formations) but have not been highlighted so far in Belgium. The Upper Frasnian Crisis is the best known as it is responsible for both extinctions within benthic and pelagic faunas. Extinctions of macrofauna started near the Middle–Upper Frasnian boundary (close to the base of the Lower *rhenana* Zone), at the top of the Grands Breux, Philippeville and Lustin formations (Poty & Chevalier, 2007). The Lower Kellwasser Event has been proven to be related to a third order transgression (*semichatovae* Transgression) bringing anoxic water onto the platform but extinctions are diachronic and clearly linked to the progression of the anoxia (Mottequin & Poty, 2015). The Lower Kellwasser Event is recognized at the base of the Matagne and the Les Valisettes formations and within the middle member of the Aisemont Fm (Bultynck *et al*., 1998; Poty & Chevalier, 2007). The Upper Kellwasser Event covers the upper part of the Matagne and Barvaux formations and the middle part of the Lambermont Fm within the *linguiformis* Zone (Bultynck *et al*., 2000).

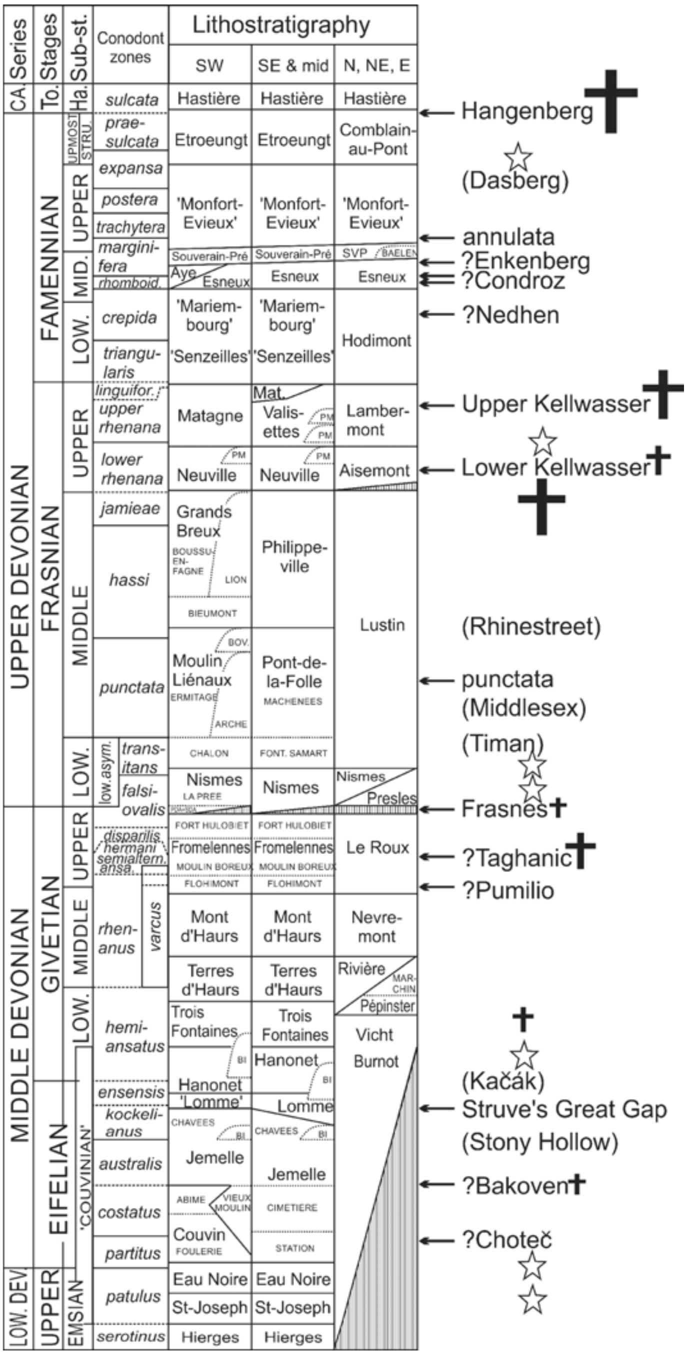

Fig. 1: Synthetic simplified stratigraphic scale of the Middle-Upper Devonian of southern Belgium with position of the bioevents. Names between brackets indicates the theoretical position events not recognized in Belgium, named preceded by a question marks indicates events hypothetically situated. Crosses indicates extinctions in macrofauna, stars indicate diversification or colonisation events. Strongly modified from Bultynck *et al*. (2001) and Thorez *et al*. (2006). Abbreviations: BI, bioherm; Bov., La Boverie Mbr; Ca., Carboniferous; Font. Samart, Fontaine Samart Fm; Ha., Hastarian; PDA + SDA, Pont d'Avignon and Sourd d'Ave members; PM, Petit-Mont Mbr; Stru., Strunian; To., Tournaisian

Because the Famennian is dominantly represented by proximal siliciclastic facies, the events defined on the basis of ammonoid extinctions are not obvious. Three oolithic ironstone horizons described by Dreesen (1982) have been correlated by Becker (1993) respectively to the Nedhen Event (horizon IIa within the Famenne Fm, upper *triangularis* zone) and the Condroz Event (horizons IIIa and IIIb in the Esneux Fm, Lower *marginifera* Zone) that questionably recorded a drop in sea level and the development of coarser siliciclastic sediments after the monotonous deposition of the lower Famennian shales. The Enkenberg pulse is questionably correlated with the transgressive limestone of the Souverain-Pré Fm starting by the IV horizon of oolithic ironstone and associated to carbonate mounds of the Baelen Mbr. The *annulata* Event, marked by the shaly Bon Mariage Mbr of the Evieux Fm (Thorez *et al*., 2006). The Dasberg Event remains unrecognized in Belgium. Finally, the Hangenberg Event (*praesulcata* Zone) has been recognized in the uppermost Famennian Comblain-au-Pont and Etrœungt formations with the record of several decimetre-thick dysoxic shales whereas the very base of the Hastière Fm is correlated with the Hangenberg Sandstone.

In conclusion, it has to be noted that (1) the Upper Devonian bioevents clearly received more attention than the Middle Devonian ones, the latter are consequently in a preliminary state of knowledge; and (2) preliminary data seems to indicate that the Eifelian–Givetian Choteč, Kačák and Taghanic events had few effect on shallow neritic environment biotas.

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Post-extinction recovery of the earliest Carboniferous rugose corals, a glimpse from eastern Australia

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After the crises and extinctions associated with the Frasnian-Famennian boundary and Devonian-Carboniferous boundary, the marine ecosystem underwent a slow recovery. This is particularly true for corals and very few genera generally occur in the basal Tournaisian (Poty, 1999)."

In Western Europe, the basal Tournaisian solitary rugose corals belong to the genera *Conilophyllum*, *Hebukophyllum* and *Kizilia* (Poty *et al*., 2006; Korn & Weyer, 2003; Chwieduk, 2005). The first two are post-disaster genera showing a wide morphological malleability and an unkown origin but are most probably close relative. *Kizilia* is a Lazarus taxon, related to the Mid Devonian stringophyllids that suddenly reappeared at the Devonian–Carboniferous boundary then disappeared from the fossil record before reappearing in the Viséan (Poty *et al*., 2006). The genus is also known in the basal Tournaisian of SE China (Poty & Xu, 1996). The basinal facies of Western Europe (Montagne Noire, Rhenish Mts, NE Germany, Semenoff-Tian-Chansky, 1988; Korn & Weyer, 2003) yield only small non-dissepimented solitary rugose corals among which are mostly long-ranging taxa. In N America, *Vesiculophyllum*, a genus very similar to and probably related to *Kizilia* occurs together with non-dissepimented long-ranging corals (Sando & Bamber, 1985). The only colonial genus in the basal Tournaisian is *Melanophyllidium*, a colonial kiziliid that occurs in NE Siberia beside *Conilophyllum* and *Parasiphonophyllia* (Poty & Onoprienko, 1984).

Like most of the basal Tournaisian dissepimented rugose corals, the two genera known from the basal Tournaisian of Eastern Australia are considered as post-disaster fauna representatives. One is solitary and develops a cystimorphic trend whereas the other is a colonial genus characterized by very large corallites, which is extremely uncommon for a Tournaisian genus. Their origin is not understood to date and they seemingly left no descent in the Carboniferous. Their stratigraphic range is extremely limited as they only occur at the base of the lower Tournaisian Gudman Formation in the type area (Webb, 2005). They show a wide morphological malleability despite their dependency to microbialithic buildup facies that might be explained by their rapid colonization of empty niches after the faunal extinction associated with the Devonian–Carboniferous boundary.

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Palaeoenvironmental input of new faunas from Upper Famennian levels at Ouarourout (Ougarta, Algeria)

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New benthic marine faunas of the northern Gondwanan margin are documented from the Famennian deposits of the Marhouma Formation at Ouarourout section (Saoura, Ougarta range, Algeria). Facies are characterized by reddish limestones of "griottes" type. The fauna encountered in 15 samples encompasses (*1*) 27 foraminiferal taxa including only mono- and bilocular forms like "saccamminids", parathuramminids, earlandiids and "tolypamminids"; (*2*) 41 ostracod taxa recognized through all the series and belonging to Paleocopina, Eridostracina, Metacopina, Podocopina and Myodocopina suborders; (*3*) one phacopid trilobite with a reduced visual complex assigned to *Weyerites* and reported for the first time in Algeria; and (*4*) four conodont taxa.

Foraminiferal and ostracod assemblages date the Ouarourout section from *trachytera* to *expansa* zones of the standard conodont zonation. Indeed, the foraminiferal assemblages probably belong to the Fa 2b-Fa 2d or DFZ4-DFZ6 of the stratotypic area of Belgium (*e.g.*, Poty *et al.*, 2006). In the entomozoidean ostracod biozonation (Rabien, 1954; Groos-Uffenorde *et al.*, 2000; Becker *et al.*, 2012), the entire section extends from the upper part of the *R. intercostata* Zone to the Lower *M. dichotoma-hemisphaerica* Zone. Moreover, entomozoidean ostracods allow precisely correlating the Ouarourout series with the well-known Km 30 section (Casier, 1985). With the lack of the key biostratigraphic taxa, conodonts date the Ouarourout section from *marginifera-expansa* up to *praesulcata* zones.

Most of the benthic foraminifers of Ouarourout were infaunal in the uppermost centimetres of the bottom sediment (earlandiids) or lived on the sea bottom ("saccamminids"), and belonged to the morphogroups B and C (Jones & Charnock, 1985). The "tolypamminids" are the unique attached forms on hard or firm substrates, either on scarce intraclasts or directly on the indurated surfaces and are representative of the Late Devonian microfaunas of hardgrounds (Vachard, 1974). These modes of life of the foraminifers indicate quiet waters, low rate of sedimentation with accumulation of soft sediments by decantation, and their rapid induration. A mixed ostracod fauna composed of taxa representative of the Thuringian and the Myodocopida Mega-Assemblages (*e.g.*, Bandel & Becker, 1975; Becker & Bless, 1990; Casier, 1987, 2008) has been identified in the Famennian of Ouarourout. Myodocopida are always overwhelmingly dominant in ostracod assemblages (frequently > 80%) but low diversified (only Entomozoidea, with 7 taxa through all the series). Ostracod assemblages are also composed of less abundant but well diversified Thuringian ostracods (34 taxa recognized through the series). All these ostracod taxa are typical of offshore marine environments. Both Thuringian and Entomozoidean taxa are thin-shelled ostracods, indicating very low-energy deep palaeoenvironments (*i.e.* at least below the storm wave base to deeper basinal settings). The presence of a small-sized phacopid trilobite with a reduced visual complex is consistent with a life in deep-water, in disphotic to aphotic habitats.

Conodonts are mostly bispathodids and palmatolepids; these taxa being also characteristic of offshore marine environments. Through the entire series, palaeoenvironments probably oscillated from circalittoral (*i.e.* very distal platform) to epi-bathyal depths, with a location on the top of the continental slope.

Such microfaunal assemblages were reported in all the "griottes" limestones from the Pyrenees (Spain-France border) to the Istanbul Terrane in northern Turkey. For instance, a remarkable similarity exists between the foraminiferal taxa of Ouarourout and those of Germany, the Carnic Alps and Poland. The Ouarourout ostracods show the closest relationships with the late Famennian faunas from the Thuringia and Rhenish areas (Germany) and also from the French Pyrenees. Strong affinities also exist with the Istanbul area (Turkey) and the Holy Cross Mountains (Poland). Finally, closest localities like the Tafilalt (Morocco) and the northern Spain show lesser faunal relationships with Ouarourout.

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The Red Marble of Baelen, an exceptional mid-Famennian mud mound complex in a carbonate ramp setting from Eastern Belgium

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The Red Marble of Baelen from the Limbourg area (Vesdre Basin, Eastern Belgium) represents a member of the middle Famennian (late Upper Devonian) Souverain-Pré Formation (Late *marginifera* conodont Zone). It corresponds to a short-term transgressive event and eustatic rise during the Famennian, interrupting the regressive megasequence on the Condroz shelf in Belgium. It is the only known or at least the only well-documented mid-Famennian carbonate mud mound complex worldwide (Dreesen *et al*., 1985, 2013), after the end-Frasnian mass extinction that wiped out numerous invertebrate taxa. In contrast with the better-known Belgian red-stained Upper Frasnian mud mounds, the Famennian Baelen mud mounds are totally devoid of corals and stromatoporoids. Instead, crinoids, hexactinellid sponges and *incertae sedis* algae (Algospongia issinellaceans; Vachard & Cózar, 2010) have occupied here the ecological niche left behind. The macrofauna is clearly dominated by crinoids, which are generally represented by large fragments of stems and more rarely by calyxes, but also includes rare brachiopods (Athyridida, Productida and Spiriferida), bryozoans, and ? oncocerid cephalopods.

Four main laterally and/or vertically carbonate microfacies and corresponding palaeoenvironments succeed: (1) Wackestones/packstones with cyanobacteria (*Girvanella* sp), algosponges (*Serrisinella* ex gr. *melekessensis* (Kulik)), kamaenaceans, plurilocular foraminifera (*Septabrunsiina baeleni* Conil) and primitive heterocorallia (*Oligophylloides* sp.). This microfacies is interpreted as being deposited in the lowermost part of an inner ramp, just above fair weather wave base (FWB); (2) Wackestones/packstones with closely associated *Serrisinella* ex gr. *melekessensis* and *Baculella* (or *Dreesenulella* Vachard) *gemina* Conil & Dreesen, evolving into packstones/boundstones. The former two algosponges either correspond to two different genera, or either represent different generations of a same organism: actually sterile (*Serrisinella*) and fertile (*Baculella*) stages. This assemblage probably thrives in the upper part of a mid-ramp, below the FWB, in a disphotic zone; (3) Encrinitic grainstones/rudstones, probably corresponding to tempestites that accumulated in the lower part of the mid-ramp in the aphotic zone. Locally, this microfacies becomes more bioclastic containing brachiopods and conodonts; (4) Red spiculitic microbial mudstones/wackestones with stromatactis locally displaying zebra structures: these represent outer ramp deposits above storm weather wave base (SWWB), whereas coeval more pelitic and silty deposits occur in the deeper shelf area. The co-existence of shallow marine shelf (Paraparchitacean-type) and deep marine shelf (Thuringen-type) ostracods (Dreesen *et al*., 1985) confirms this lateral zonation of palaeoenvironments. Pressure solution strongly affected most of the above microfacies, producing conspicuous stylocumulate and stylonodular fabrics.

Furthermore, the sudden occurrence of these particular kinds of carbonate deposits within an otherwise overall siliciclastic shelf depositional environment (micaceous silt- and sandstones of the Condroz Sandstones Group), the preferential or pre-destinated location of the mounds on supposedly deep-seated faults (Marion, 1985), the occurrence of unusual biota and the presence of zebra-like stromatactis structures, could all point to "cold seep carbonates" or "methane-derived carbonates" produced near former methane leaks at the sea-bottom (Peckman & Thiel, 2004; Krause *et al*., 2004). Unfortunately, due to strong tectonic disturbances (faulting), a complex diagenetic history and hydrothermal overprinting, the stable C- and O-isotopic signature of the Baelen microbial carbonates is not yet supporting this hypothesis and needs to be investigated further.

Besides its geological importance, the Red Marble of Baelen is also a famous building stone from the Limbourg area (Vesdre Basin, Eastern Belgium), where it has been quarried probably since Roman times. Two varieties exist: a cherry-red crinoidal limestone displaying numerous white crinoid ossicles (so-called "peastone") and a grey, pink to red stromatactis limestone. Both have been used for a large spectrum of building and decorative purposes, mostly within a short radius of the extraction sites in the former Duchy of Limbourg. Its usage was rather rural and vernacular, although it has been exceptionally employed in prestigious buildings such as the 16th century Antwerp town hall. Baelen Marble has been encountered in adjacent regions of the Limbourg area as well, including Aachen (Germany) and Southern Limburg (The Netherlands). Its earliest usage dates back from Roman times, as proven by the occurrence of marble slabs in decorations of the harbor temple in Xanten, Germany (Ruppiene, 2015). The last marble quarries to be active were those of Les Forges in Baelen: they closed shortly after World War II. Red Baelen Marble represents an important and less-known historical but highly valued building stone from Eastern Belgium, adding to the reputation of the better-known Belgian red marbles of Frasnian age. It is a silent witness of the former glory of the Duchy of Limbourg. At least one historical quarry still exists at Limbourg that should urgently be protected as an important Belgian geological heritage site.

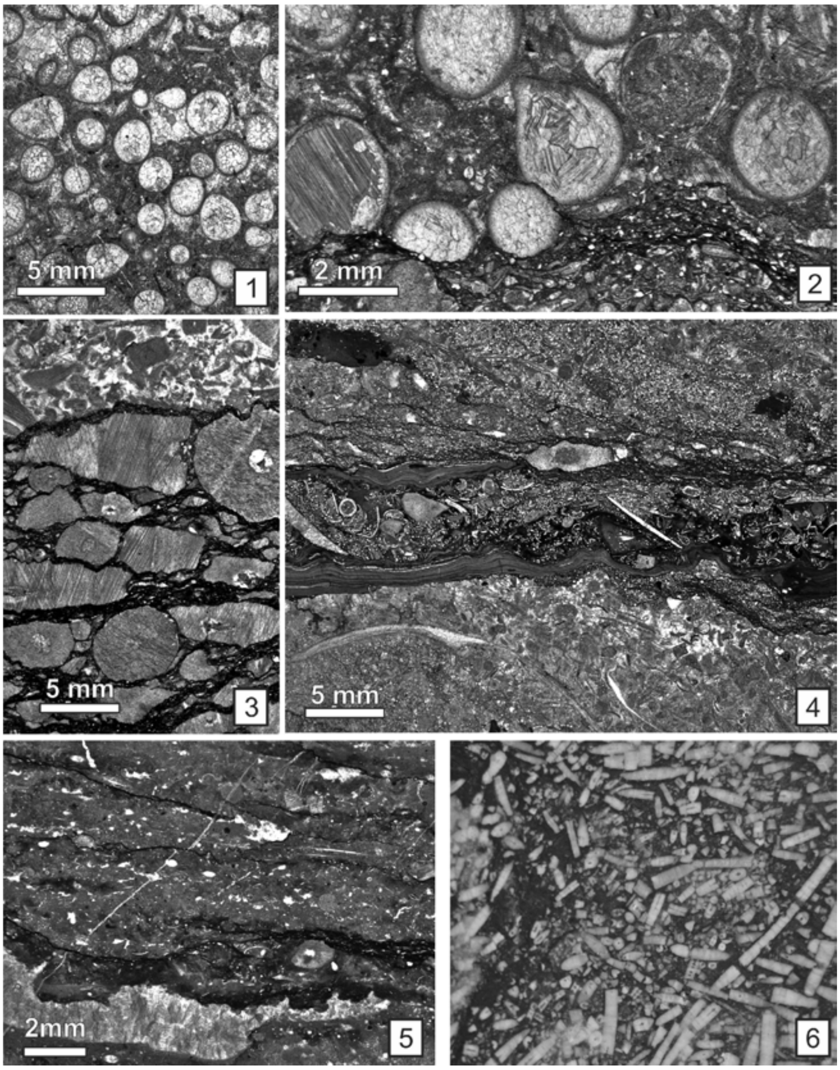

Fig. 1: Characteristic microfacies. (1) Algospongal wackestone/ packstone with numerous sections of *Baculella gemina.* (2) Floatstone with *Baculella* (top) and packstone with *Serrisinella* (bottom). (3) Two types of encrinitic limestone; crinoidal rudstone (top) and stylocumulate crinoidal floatstone (bottom). (4) Silty bioclastic packstone/grainstone with important bioaccumulations (tempestites and/or contourites) separated by bacterial endostromatolites. (5) Red wackestone with *Stromatactis*, sponge spicules, crinoids, and ostracods. (6) Polished slab of red argillaceous limestone ("peastone" variety), with numerous crinoid stems (width of crinoid stems: 5 mm). All figures are micrographs of thin sections in transmitted light, except 6.

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New data on the Frasnian ostracods from the Middle Timan Region, Russia: taxonomy, biostratigraphy, palaeoecology

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Frasnian rocks in the Middle Timan Region are mostly composed of siliciclastics in the Lower and Upper Frasnian and are represented by an alternation of carbonate and terrigenous sediments in the Middle Frasnian. These deposits are subdivided into a set of lithologic units that are from base to top: Tsilma, Ust'-Chirka, Ust'-Yarega, Kraypole, Beryozovy, and Kamenny Ruchey formations (Tsaplin & Sorokin, 1988). Our work has focused on the study of the sections along the Pechorskaya Pizhma River. Ostracods have been obtained from clays of the Ust'-Yarega and Kraypole formations, correlated with the Sargaevian (Early Frasnian) and Domanikian (Middle Frasnian) subregional stages respectively. The Ust'-Yarega Fm is composed of rhythmical alternation of sands, silts and predominant clays. The middle and upper parts include bioclastic limestone layers. The Kraypole Fm is characterized by clayey-carbonate facies. In its upper part stromatoporoid-coral bioherms occur.

Some data on the Frasnian ostracods of the Middle Timan have been treated in a few numbers of publications with the main emphasis on biostratigraphy (Orlov & Fokin, 1991, as a summary). A number of species were established, but not described. According new data, no drastic changes in the ostracode associations occur at the Ust'-Yarega and Kraypole Fms boundary. In the upper part of the Ust'yarega Fm, some species appear and are known from the Middle Frasnian of the central and northwestern parts of the Russian Platform (Central and Main Devonian Fields, CDF and MDF), *e.g. Tetracornella ornata formosa* Zasp. and *Neodrepanella tichomirovi* Zasp. The ostracod faunas of the lower part of the Kraypole Fm display close affinities with those known from the Middle Frasnian shallow marine strata of the MDF and CDF. Some renewal of the ostracod associations at both the species and generic levels can be observed in the upper part of the Kraypole Fm. This association includes a numerous of species that are considered to be “Late Frasnian” because of theirs occurrences in the Voronegian and Evlanovian deposits of the CDF (*e.g.*, *Bicornellina* cf. *bolchovitinovae* Zasp., *Knoxites bolchovitinovae* Eg., *Evlanovia tichonovitchi* Eg., *E*. cf. *cornigellaformis* Eg., *Donellina grandis* Eg.). Nevertheless, these ostracod data need a further careful biostratigraphic evaluation because they do not correspond to the official regional stratigraphic framework.

In a palaeoecological context, the composition of the ostracod association from the Ust'-Yarega Fm is of special interest as rare entomozoids occur with diverse benthic ostracods (Fig. 1).

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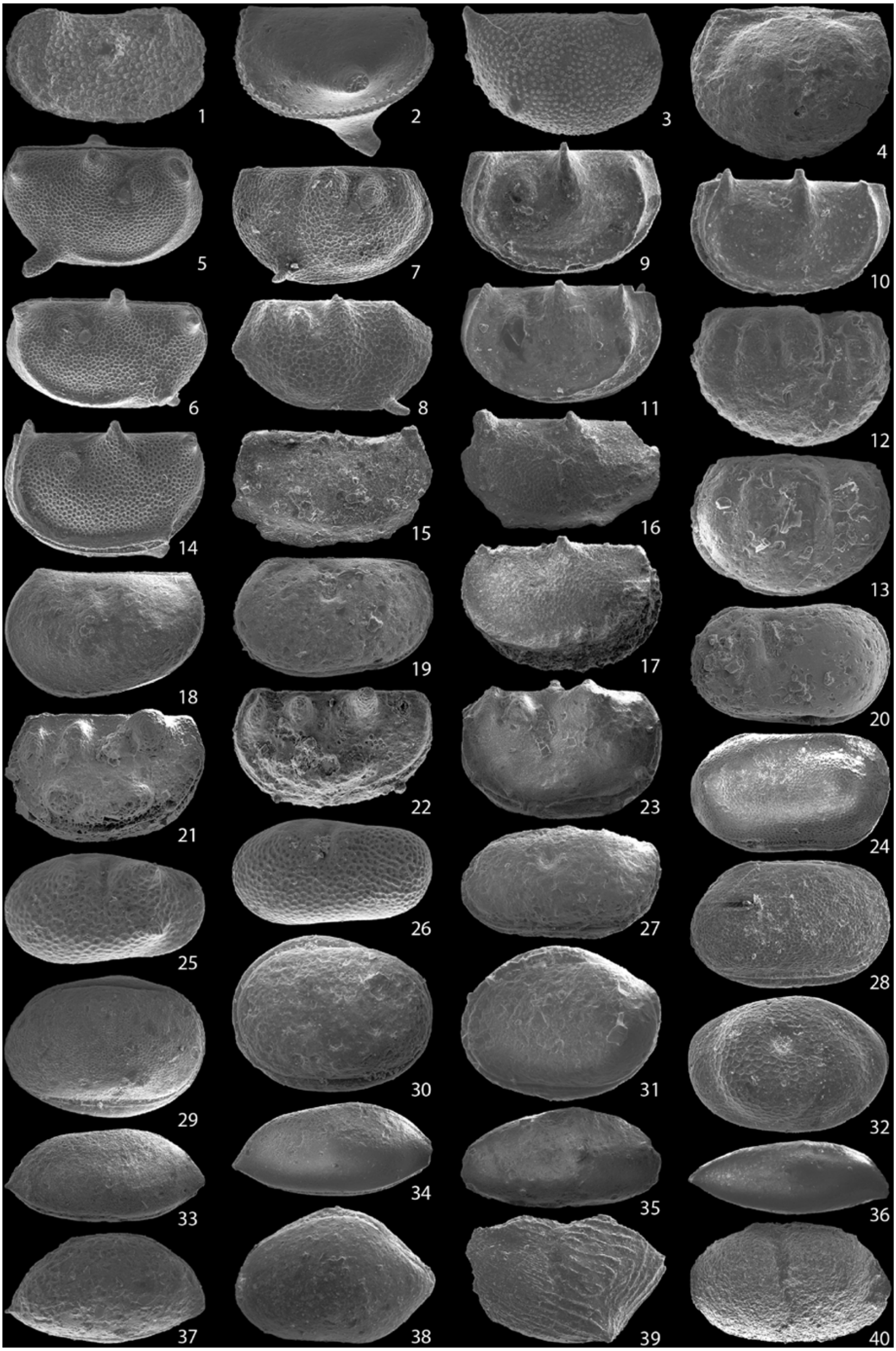
Fig. 1 (next page): Sample numbers with the prefix H-402 and H-421 – Ust'-Yarega; H-430 – Kraypole Fm. (1) *Amphissites irinae* Gleb. & Zasp., H-430/15, x49. (2) *Gravia* cf. *fabra* Zasp., H-402/2, x51. (3) *Selebratina dentata* Pol., H-402/2, 48. (4) *Paraparchites calculus* (Gleb. et Zasp.), H-430/3, 82. (5, 6) *Tetracornella ornata formosa* Zasp., H-402/2, x48. (7, 8) *Nodella* sp., H-421/2, x61, x 68. (9, 10) *Limbatula* sp., H-421/4, x90. (11) *Limbatula* sp., H-421/5, x88. (12, 13) *Nodella* cf. *svinordensis solciensis* Zasp., H-430/1, x79, x74. (14) *Neodrepanella tichomirovi* Zasp., H-402/2, x54. (15) *Bicornellina* cf. *bolchovitinovae* Zasp., H-430/2, x44. (16, 17) *Limbatula* cf. *zaspelovae* Sam., H-430/15, x64, x58. (18) Palaeocopida indet., H-430/13, x64. (19) *Knoxiella* sp., H-430/13, x82. (20) *Knoxiella* cf. *semilukiana* Eg., H-430/13, x53. (21) *Evlanovia* aff. *tichonovitchi* Eg., H-430/3, x82. (22) *Evlanovia* cf. *cornigellaformis* Eg., H-430/1, x56. (23) *Knoxites bolchovitinovae* Eg., H-430/2, x58. (24) *Indivisia* sp., H-430/15, x51. (25, 26) *Uchtovia* sp., H-421/2, x44, x35. (27) *Sulcella* sp., H-430/3, x42. (28) *Knoxiella*? sp., H-430/12, x54. (29) *Timanella* aff. *eureka* Casier & Olempska, H-430/1, x41. (30, 31) *Timanella*? sp., H-430/15, x103, H-430/13, x83. (32) *Donellina grandis* Eg., H-430/15, x80. (33) *Acratia* (*Cooperuna*) *schelonica* Zasp., H-430/2, x56. (34) *Acratia* (*Cooperuna*) cf. *gassanovae* Eg., H-430/13, x56. (35) *Famenella* sp., H-430/2, x57. (36) *Acratia* (*Cooperuna*) cf. *tichonovitchi* Eg., H-421/4, x53. (37) *Acratia* cf. *gibba* Zasp., H-430/1, x33. (38) *Olentangiella* cf. *fobosi* (Eg.), H-421/4, x71. (39) *Franklinella (F.)* cf. *jaregae* (Mart.), H-421/5, x59. (40) *Richteria* sp., H-421/9, x23.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Physical and biological events across the Frasnian–Famennian boundary in oxic carbonate successions in the Carnic Alps (Italy–Austria)

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Two continuous carbonate sequences across the Frasnian–Famennian boundary in the Carnic Alps (Italy and Austria) have been studied intensively. According to conodont data, the sampled part of the Pramosio A section (Italy), ranges from Frasnian Zone 12 to Upper *trachytera* Zone. Around the F–F boundary this sequence, which is easily accessible for sampling, reflects a rather high sedimentation rate (centimetric scale per thousand years) in facies typical of an open shallow marine environment (shelf–shore) with a well ventilated bottom. The Freikofel T section (Austria–Italy border), ranging from Frasnian Zone 13a to Middle *crepida* Zone, is characterized by shallow-water to pelagic facies. Oxygen isotopes—measured on whole-rock and on conodont apatite—display conspicuous variations up-sequence conceivably corresponding to short- and medium-term climate changes.

Famennian–Tournaisian boundary on the western slope of the South Urals, Russia: new look

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The Famennian and Tournaisian strata are well-known on the western slope of the South Urals. The Zigan, Sikaza and Ryauzyak sections are the best documented ones (Kulagina *et al*., 2003; Artyushkova *et al*., 2011). These sections show continuous sequences of shallow-water marine carbonates with different faunal groups. The Famennian and Tournaisian are subdivided into regional substages in accordance with stratigraphic scheme of the Urals. The Lytvian substage (Beds Abiyuskan and Zigan) is correlated with the upper part of the Famennian whereas the Gumerovian, Malevkian and Upian substages with the lower part of the Tournaisian. The base of the Gumerovian coincides with the Famennian and Tournaisian (Fm–Tn) boundary and is characterized by typical Carboniferous ostracods of the *Pseudoleperditia tuberculifera, Coryella alba* and *Cribroconcha primaris* zones (Sinitsyna *et al.*, 1995; Pazukhin, 2008). The Gumerovian is subdivided into two parts, of which the lower one, including the LE and PLE miospore zones and containing conodonts of the *praesulcata* Zone, is referred to the Upper Devonian, and the upper part, which corresponds to the PM miospore Zone and to the *sulcata* conodont Zone, is referred to the Lower Carboniferous (Pazukhin *et al*., 2009).

Although the boundary is correctly determined in the some sections of South Urals, many questions remain unsolved. New lithological and conodont data give us a new look at the problem of Fm–Tn boundary in the South Urals. The Sikaza section is found to be the most representative in this aspect. The global Hangenberg Event and the eustatic history associated with the Fm–Tn boundary have been recognized in this section. The Lytvian includes the beds 4−6a (dark-grey bioclastic limestones), the Gumerovian (beds 6b−d, brown argillaceous limestones), the Malevkian (beds 7−8, grey bioclastic, crinoidal limestones) and Upian (beds 9−10, white dolomitized limestones). The Lytvian (beds 4−6a, thickness: 10.7 m) is a highstand system tract (HST). There is a gradual shallowing upward trends of depositional environments in the upper part of the Lytvian. A lowstand system tract (LST) with a sharp base may also represent a sequence boundary (SB). The base of the Gumerovian includes reworked conodonts and oolites. The beds 6b−c (thickness: 0.5 m) corresponds to a transgressive system tract (TST), which coincides with climatic warming and is accompanied by the widespread deposition of black shale on the shelves of different continents (Kaiser *et al*., 2011). An argillaceous limestone is the equivalent of the Rhenish Hangenberg Black Shale (phase of maximum flooding). This is a global event in the middle *praesulcata* Zone. A subsequent lowstand phase (6d, thickness: 0.5 m) is represented by oolitic limestones and reworked conodonts. The appearance of *Siphonodella sulcata* is recognized at the base of the bed 6d. Perhaps on this stratigraphical level we have a hiatus correlated with the major regression and the Hangenberg Sandstone. The upper part of the *praesulcata* Zone is absent. This period corresponds to a glaciation pulse in Gondwana. The Malevkian (beds 7−8, thickness: 2.9 m) and Upian (9−10, thickness: 17.5 m) are a new TST and post-event warming time.

The same situation is observed in the nearby Zigan section. The Lytvian (bed 19, thickness: 1.3 m) is a HST. The base of the Gumerovian is a SB and the bed 20a (0.2 m-thick) represents a LST. The bed 20b (0.4 m-thick) is a TST (argillaceous limestones). The interval of the beds 20c−f (thickness: 1.6 m) is a HST. The Malevkian (bed 21, thickness: 1.6 m) and Upian (beds 22−24, thickness: 5.4 m) correspond to a TST. In this section the first appearance of *Siphonodella sulcata* is a little above the bed 20c. It is nearly on the appearance of the miospore *Vallatisporites pusillites.* The more prominent hiatus is in the Ryauzyak section (Kochetkova *et al*., 1988). Two conodont zones (upper *praesulcata* and *sulcata*) are absent.

The Hangenberg Event is a global anoxic and transgressive-regressive event. It has been recognized in many sections of the western slope of the South Urals. The major regression during the Uppermost Famennian is time-equivalent to a glaciation pulse in Gondwana. In the South Urals neritic successions, the hiatuses take place at this stratigraphic level. The Fm–Tn boundary is proposed on the first occurrence of the conodont species *Siphonodella sulcata* and spores *Vallatisporites pusillites*. The Hangenberg Event can be considered as a marker for this boundary. For the definition of the boundary I suggest not to change the present stratigraphic position and keep the present FAD *Siphonodella sulcata* (*=Protognathodus kuehni*).

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A reassessment of the Lindlar Flora (Devonian, Mid Eifelian), Germany

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Fossil plants are well known from the Lindlar locality (Bergisches Land, Rhineland, Germany), based on collections made in the 1960's by H.-J. Schweitzer. Schweitzer provided detailed monographic descriptions of six taxa (*Leclercqia complexa*, *Duisbergia mirabilis*, *Calamophyton primaevum*, *Hyenia elegans*, *Weylandia rhenana*, *Lycopodites*/?*Protobarinophyton lindlarensis*) and a well-known reconstruction of the Lindlar landscape and vegetation, this work being summarised by Schweitzer (2009).

The principal plant-bearing bed was an horizon at great height in the high wall of the Schiffarth Quarry, from sandstones of the Mühlenberg beds. The level was only briefly exposed as the working bench in the high wall cut down through it. Schweitzer's collections, and other smaller collections from the same time, were located in several repositories, and subsequently further dispersed, many of the most important being now located in the Natural History Museum in Stockholm; others are in the Goldfuß Museum, Bonn and the Ruhr Museum.

The age, as determined by palynostratigraphy, is Mid Eifelian (Riegel, 1968).

In late 2008 Giesen revisited the quarry, fortunately at a time when the working bench was once again cutting through the plant bearing beds, and collected there for some months. In subsequent years his collections have extended to the same horizon in the neighbouring Bergische Grauwacke quarry.

Notable amongst the new discoveries are spectacular plant fossils including large articulated specimens showing roots, base, trunk, branches, and appendages in organic connection which allow us to not only understand true morphology of individual plants without relying on conceptual whole-plant reconstructions, but also allow us to explore true diversity, growth patterns and populations. The exceptional number of complete specimens makes the Lindlar flora the most important plant locality of Eifelian age worldwide. Most specimens are preserved lying parallel to bedding planes, although some are preserved upright but drifted. Some specimens, including exceptional, complete trees, are preserved mixed with marine invertebrates including disarticulated crinoid ossicles. This suggests a catastrophic event bed, perhaps generated by tsunami, deposited in a shallow marine environment (Giesen & Berry, 2013).

The exceptionally complete specimens allow us to better delimit individual plant species, and make it clear that Schweitzer's descriptions of species mostly include material from more than one taxon.

Calamophyton primaveum Kräusel & Weyland is a cladoxylopsid tree which incorporates the trunk formerly known as *Duisbergia mirabilis* (Giesen & Berry, 2013). We have found complete specimens up to 2 m length from trunk base to apex. The enlarged base, narrow roots and trunk supported a dense crown of digitately-divided branches. The lower branches were abscised as the plant grew upwards. Studies of the several complete specimens suggested that the trunk expanded by a process of secondary growth during the life of the plant.

Weylandia rhenana Schweitzer now includes some material formerly placed in *Calamophyton* and *Hyenia*. *Weylandia* is also represented by spectacular complete specimens with upwards-tapering stems up to 1.15m high. Anatomy is poorly preserved but also suggests cladoxylopsid affinity. Notable is the fact that the lower branches, which are not digitate, were apparently more permanently attached than in *Calamophyton*, and may have been leafy. The top of the stem supports a zone of insertion of branches bearing fertile appendages. This evidence suggests a life of the plant which was determinate and of largely primary growth.

Our study of the enigmatic *Hyenia elegans* Kräusel & Weyland is only just beginning, but is informed by the transfer of many of Schweitzer's specimens to the two taxa above, and by the discovery of new large specimens. Main axes are broad, usually curved, and were presumably partly recumbent. Distinctive digitate branches were attached, and again suggest a cladoxylopsid affinity.

The herbaceous lycopsid *Leclercqia* and the probable zosterophyll *Thursophyton* form numerically small elements of the flora. The aneurophytalean progymnosperm *Rellimia* is also extremely rare and only represented by fragmentary specimens.

The Mid Eifelian Lindlar flora therefore gives an unprecedented insight into the plants and vegetation in the early phase of the transition to a forested planet. In comparison to the Late Eifelian assemblages of Goé, Belgium, there is a similar diversity of cladoxylopsid taxa but aneurophytes are much less prominent (Berry & Fairon-Demaret, 2001). So far, most of the individual plants lack evidence for the size of the largest trees at Goé, but one isolated cladopsylopsid trunk fragment of 20 cm in diameter was found, which equals the largest trunks found at Goe. The *in situ* Gilboa forest of New York (Late Givetian) includes giant cladoxylopsid trees and rhizomatous aneurophytes (Stein *et al.*, 2012).

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Paleoenvironmental trends in two Famennian sections of "Galantian" Superterranes: Col des Tribes (Montagne Noire, France) and Buschteich (Thuringia, Germany)

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Two carbonate successions with a complete record through the late Frasnian–early Tournaisian interval have been investigated in details for paleoenvironmental reconstructions. For each section we conducted concomitant conodont biodiversity and paleoenvironmental studies. The conodonts provided a fine-scale biostratigraphical framework. Even if the two sections were not deposited in the same paleogeographical area of the "Galatian" superterranes between the Laurussia and Gondwana (Stampfli *et al.*, 2013), they display some common features at first order.

We found:

- In both sections the 18 Famennian zones have been identified, indicating that no major hiatus exists;
- The Col des Tribes section deposited in carbonate mid-ramp to outer ramp setting and the Buschteich section in carbonate mid-ramp to upper slope setting;
- Microfauna is poorly abundant in thin-sections;
- Conodont assemblages are rich and well-preserved;
- A major change in conodont assemblages occurred during the upper *trachytera* Zone, coincident with the *annulata* event. Before the event the conodont genus *Palmatolepis* is dominant, after it is *Bispathodus*;
- Based on conodont biofacies and microfacies, a shallowing upward trend is recorded during the *trachytera* Zone and the lower *praesulcata* Zone;
- Black shales are rare in both sections. The only anoxic event recorded in the two sections is the Hangenberg black shales, at the Devonian–Carboniferous boundary.

The main differences between the sections are:

- The thickness of the Famennian deposits, 30 m at Buschteich and 75 m at Col des Tribes. The Buschteich section displays a global condensation without major hiatuses, probably because it was located at the outer margin of the shelf. The Col des Tribes section was emplaced in a more subsiding area in the shelf;
- The absence of the typical reddish griottes facies at Buschteich, probably because this section was in more distal location than the Col des Tribes one.

The paleoenvironmental trends recorded in both sections are, at first order, similar to those found in other areas:

- Elsewhere in the Galatian terranes, as Sardinia, a major change in conodont assemblages is also recorded between the *trachytera* and *postera* zones (Corradini, 2003);
- In Laurussia (Johnson & Sandberg, 1989) and Gondwana (Wendt & Belka, 1991), a shallowing upward trend occurred during the upper Famennian.Such data suggest that, at first order, the major

paleoenvironmental changes recorded in both sections are the witnesses of global events (sea-level changes, anoxic deposits).

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The assemblages of psammosteid agnathans from the Middle-Late Devonian of the Andoma Hill (Russia)

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In the Main Devonian Field (MDF, including Baltic States and north-western Russia, East European Platform), the Andoma Hill displays a more complete Devonian sequence than other sections of the surrounding area. This section is about 1 km long and 1.5 km wide and is located on a peninsula at the south-eastern coast of the Onega Lake, Vologda Region, Russia. Three formations, Pavlikovskaya, Andoma and Klimovskaya, consisting of siliciclastic deposits with numerous layers, yielded abundant agnathans and non-agnathan fishes. These formations are Upper Givetian–Frasnian in age (Ivanov *et al.*, 2006). The remains of psammosteid agnathans are very numerous and taxonomically diverse. The assemblage containing *Psammolepis venyukovi* Obruchev, *Psammosteus* cf. *Ps. cuneatus* Obruchev, *Ps.* cf. *Ps. praecursor* Obruchev and *Ps.* sp. nov. 1 occurs in the lower part of the Pavlikovskaya Fm. Diverse psammosteids such as *Psammolepis undulata* (Agassiz), *Psammosteus* cf. *Ps. cuneatus* Obruchev, *Psammosteus livonicus* Obruchev, *Ps. praecursor*, *Ps.* sp. nov. 2 were recorded from the lower level of the lower part of the Andoma Fm. The upper level of the lower part of the Andoma Fm. yielded *Psammosteus asper* Obruchev, *Ps. cuneatus, Ps. maeandrinus* Agassiz and *Karelosteus weberi* Obruchev (Fig. 1). The psammosteids *Psammosteus asper, Ps. cuneatus, Ps.* cf. *Ps. kiaeri* Tarlo*, Ps. levis* Obruchev, *Ps. maeandrinus* have been found in the upper part of the Andoma Fm. and the lower part of the Klimovskaya Fm. Two levels of the upper part of the Klimovskaya Fm. yielded the remains of *Psammosteus megalopteryx* (Trautschold), *Ps. pectinatus* Obruchev, as well as *Ps.* cf. *Ps. falcatus* Gross, *Ps.* sp. nov. 3.

Some layers of the Andoma and Klimovskaya Fm. contain five taxa of psammosteids found jointly. Such findings rarely occur in the Devonian of the MDF, especially in the Late Devonian. *Psammosteus* sp. nov. 1 and 3 have only been found in the Andoma Hill but *Ps.* sp. nov. 2 is reported also from the Amata Regional Stage of the Borschovo locality, Leningrad Region. This taxon considerably differs from the known species of *Psammosteus* in the presence of both microtubercles and fine plumose wrinkles passing into ramifications on the sides of crenulations on dentine tubercles. *Psammosteus maeandrinus* is the most abundant species, among the psammosteids, in the section and is wide distributed in the Snetnaya Gora – Pskov interval of the Pļaviņas Regional Stage in the MDF; their branchial plates are the most common. *Psammosteus* cf. *Ps. kiaeri* is recorded on the East European Platform for the first time. *Ps. kiaeri* was already known from the middle and upper parts of the Fram Formation, Upper Devonian of Ellesmere Island, Canada (Kiaer, 1915) which may be correlated with the Early-Middle Frasnian of the Baltic Region (Elliott *et al.*, 2005) or with the Early Frasnian Amata interval (Halstead Tarlo, 1964). *Psammosteus levis* was mentioned earlier from the Andoma Hill as well as from some localities of the Syas River (Obruchev & Mark-Kurik, 1965). A squamation fragment of *Ps. levis* has been found for the first time in the Late Devonian of the MDF. Branchial plates of juvenile individuals of that species have been found in the section. They possess the incurved distal part which distinguishes them from the branchial plates of adults. *Karelosteus weberi* was reported from the Andoma Hill in association with *Ps. maeandrinus.* This association has also been reported from the Svyatukha River locality (Obruchev & Mark-Kurik, 1965). The cyclomorial tesserae of this taxon and their position on the ventral side of the branchial plates allow to specify the systematic position of this genus in the family Psammosteidae (Glinskiy, 2014). The co-occurrence of *Psammosteus megalopteryx* and *Ps. pectinatus* was not known before in one locality of the MDF. *Ps. pectinatus* occurs in the Dubnik Regional Stage but *Ps. megalopteryx* – in the Dubnik and Daugava Regional Stages of the MDF (Obruchev & Mark-Kurik, 1965). *Psammosteus falcatus* has been found in the Snezha and Prilovat Regional Stages. The analysis of the psammosteid distribution in the Middle–Upper Devonian of the Andoma Hill allows to clarify the stratigraphical ranges of many taxa.

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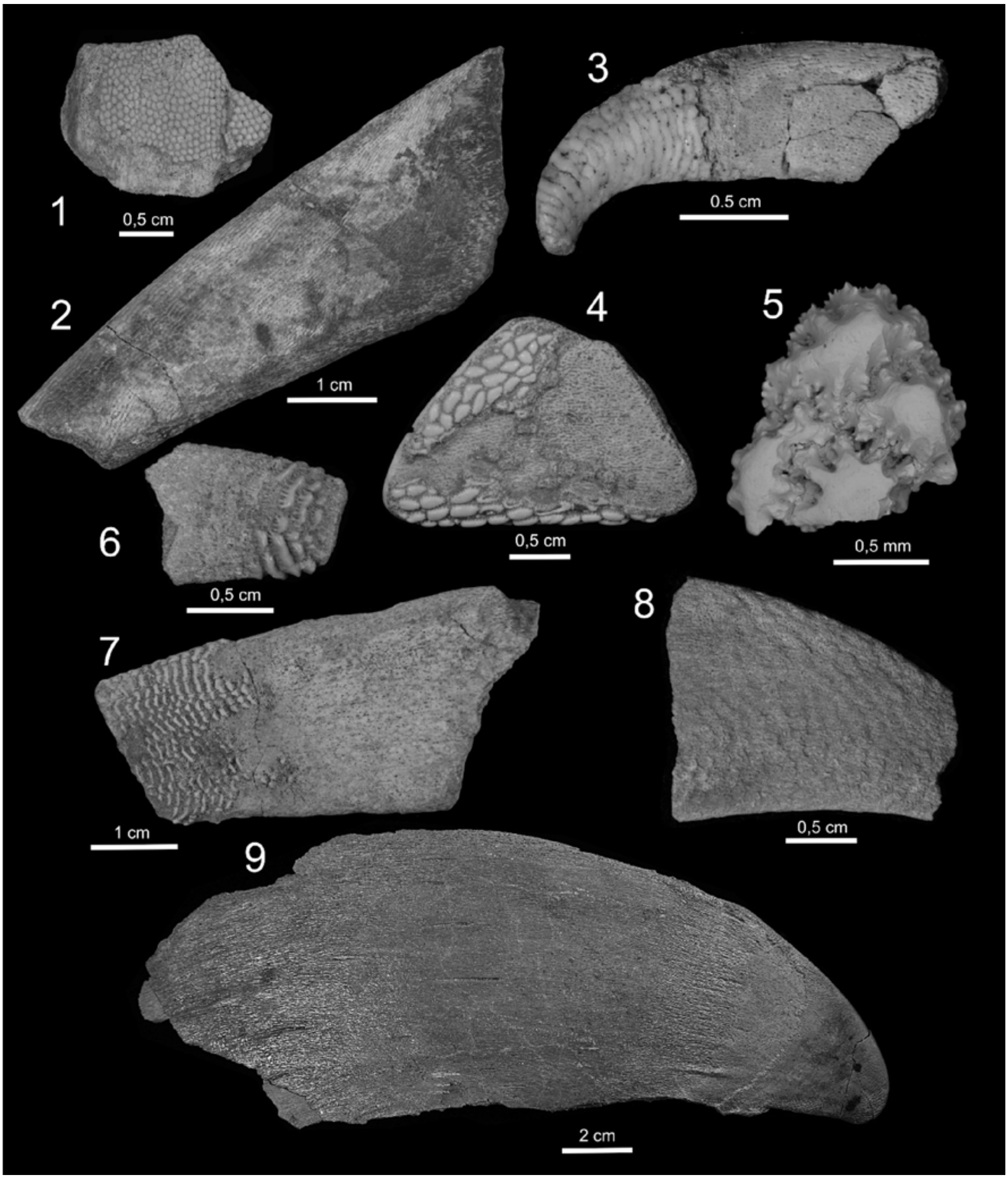

Fig. 1: Psammosteid remains from the Devonian of the Andoma Hill. (1) *Psammolepis venyukovi* Obruchev, fragment of branchial plate, ventral view. (2) *Psammosteus maeandrinus* Agassiz, fragment of right branchial plate, ventral view. (3) *Psammosteus levis* Obruchev, fragment of left branchial plate (juvenile), dorsal view. (4) *Karelosteus weberi* Obruchev, fragment of left branchial plate, dorsal view. (5) *Psammosteus asper* Obruchev, fragment of tessera, top view. (6) *Psammosteus pectinatus* Obruchev, fragment of left branchial plate, ventral view. (7) *Psammosteus* cf. *Ps. kiaeri* Tarlo, fragment of right branchial plate, ventral view. (8) *Psammosteus* cf. *Ps. falcatus* Gross, fragment of right branchial plate, dorsal view. (9) *Psammosteus megalopteryx* (Trautschold), right branchial plate, dorsal view.

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Tabulate corals from the Samnuuruul Formation (Upper Devonian) in southwestern Mongolia

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The Upper Devonian type-section of the Samnuuruul Formation at the Gerelt Hoshoo site, which belongs to the Baruunhuurai Terrane in southwestern Mongolia (Davaa, 1992) is rich in macrofossils. As a result of the field survey in 2012 within the frame of the project IGCP 596, a detailed stratigraphic profile (SAM1 to SAM4) of the Samnuuruul Formation was constructed (Kido *et al*., 2013).

Branching tabulate corals were collected and studied from beds 22, 23 and 29 (N45°17’06” E90°57’31”) of unit SAM3. As the entire section is strongly folded and sediments are extensively fractured, complete specimens cannot be obtained from bedding planes. Most of materials occur as clasts reaching 14-20 mm in diameter and 40-50 mm in length. Taxonomic study of tabulate corals clarified that Samnuuruul specimens are similar to *Thamnopora rudis* Chudinova, 1959 in colonial size, diameter of corallites, wall thickness, tabulae, the interspaces between tabulae, and one row of pores and their diameter. Chudinova’s specimen was described from the Frasnian of the Kuznetsk Basin (Kuzbass, Russia).

Previously, a Famennian age was suggested for the Samnuuruul Formation based on brachiopods (*Cyrtospirifer ivanovae* Besnosova*, Sphenospira* sp.), bryozoans (*Cyclotrypa laminata* Nekhoroshev)*,* rugose corals (*Amplexus echinatus* Bol’shakova *et al*.), conodonts (*Polygnathus communis* Branson & Mehl, *Bispathodus stabilis* (Branson & Mehl)) and foraminifera (*Quasiendothyra dentata* (Durkina)). Most significant is the occurrence of *Quasiendothyra dentata* which is known as index fossil of the uppermost Famennian of Europe (Ariunchimeg, 2000). The age of the sediments and their palaeoenvironmental interpretation as well as the palaeogeography of this part of Mongolia will be accurately determined in future thanks to further studies on palynomorphs and other microfossils and on chemostratigraphy, which are currently carried out by the members of the Mongolian working group within the frame of IGCP 596.

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The Lahonry quarry at Lompret, Belgium: an extraordinary new site to study Upper Frasnian cephalopods during the onset of anoxia in the Dinant Basin

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About four years ago, quarrying operations at the Lahonry quarry at Lompret, 10 km west of Frasnes, Belgium, moved northwards towards the old railroad, exposing the upper Frasnian reefal limestones of the Petit-Mont Member. Somewhat later, from the summer of 2013 onwards, also the surrounding and partially overlying peri-reefal Neuville Formation and younger Matagne Formation became progressively more exposed. Regular visits to this fast evolving quarry allowed to recognize several cephalopod bearing beds and intervals, so that today, without doubt, the Lompret quarry has become one of the most extraordinary and richest sites to study cephalopods, as well as other invertebrates and vertebrates, during the onset of anoxia in the Dinant basin. These anoxia are frequently cited to have been linked to the upper Frasnian mass-extinction (Kellwasser events).

From the reefal Petit Mont Member, only a very limited number of nautiloid cephalopods have yet been collected. The succession of the Neuville Formation varies significantly at Lompret: from predominantly barren shales with bentonites, up to highly fossiliferous nodular limestones with abundant crinoids and corals. Cephalopods were found only in one of the studied outcrops, related to a fault zone in the northeastern corner of the quarry. Up to 30 large Gephuroceratoids (*Manticoceras*) and three fragments of large nautiloids were found during the second half of 2013. The absence of small specimens and Tornoceratoids, plus the nearly complete absence of in-situ benthic fauna, may suggest these are drifted shells. All these finds however predate the onset of anoxia in (this part) the Dinant basin, but they do give some clues to understand the "normal" cephalopod fauna composition prior to the end Devonian extinction.

The most intriguing part of the Lompret succession is found near the base and within the lower part of the Matagne Formation, where cephalopod rich beds are found both below and above the first (visible) arrival of dysoxic-anoxic bottom water conditions. This interval was observed three times in the quarry.

The highest limestone bed below the arrival is 10-15 cm thick, and contains a concentration of small goniatites (mostly < 20 mm) and orthocones in the middle and upper part of the bed, plus an enrichment of medium sized (70-150mm) Gephuroceratoids (*Manticoceras*) on top of the bed, about one every 2 m^2 (Fig. 1).

The arrival of dysoxic-anoxic bottom-water conditions is interpreted to be positioned 30 cm above this limestone bed, when darker colored shales appear for the very first time. The change from lighter to darker colored shales also coincides with a thin (only a few mm thick) orange colored level that (presumably) originally existed of pyrite. Except for one conspicuous bed, all limestone beds above this level are also considerably darker colored. Benthic fauna above this level is also very scarce and poor in taxa. For its largest part, it is composed of juvenile brachiopod shells.

The highest concentration of cephalopods situates in a limestone nodule level about 30 cm above the change from lighter to darker colored shales. Careful collecting and splitting open of these nodules delivered hundreds of juveniles, only a few mm in size, next to dozens of subadult shells of a few cm in size. Larger specimens, up to 8 cm in size, are very rare, and relate to incomplete shells of Gephuroceratoids. Within this level, Tornoceratoids and bactritids are far more abundant than Gephuroceratoids (cf. *Manticoceras*) and orthocone nautiloids. Other fauna elements found in these nodules relate to rare occurrences of juvenile brachiopods and buchiolids, plus some extremely rare occurrences of other bivalves and vertebrate remains.

A few cm above this cephalopod bearing nodule bed, a mass-occurrence of juvenile brachiopods is found. A smaller concentration of these juvenile brachiopods was found in the top cm of the limestone bed right below the nodule level. These occurrences point to short-term colonization events, when environmental conditions allowed it, interrupted by new periods of anoxia. These changing conditions may also explain the presence of the much thicker (and vary variable in size) limestone bed above the nodule level, in which crinoid debris (isolated ossicles), larger sized brachiopods of more taxa and some coral remains are found.

This could indicate that "normal" bottom water conditions would have returned for a short period in time. Alternatively, these larger fossils represent allochtonous material that is slumped into the basin. Directly above this bed, darker colored and (almost) barren shales return.

Some meters up section, cephalopods are chiefly preserved as pyritic internal molds in the shales. Here, Gephuroceratoids return to be far more abundant than Tornoceratoids. Within this interval, a 5 cm thick layer of weathered calcareous shale holds hundreds of juvenile and subadult shells of goniatites, bactritids and orthocone nautiloids. In this layer, Gephuroceratoids are more abundant than Tornoceratoids. But more surprisingly, this level also preserves anaptychi, which are broadly curved, scoop-like univalved carbonaceous structures, that represent the lower jaw of the goniatites.

At this point in time, the true nature and context of all the observed changes in cephalopod and other invertebrate and vertebrate faunas are far from being well understood. However, the combined reduction in benthic diversity and the darkening of the sediment evidence the installation of reduced oxygen conditions at the seafloor within the late Frasnian. Also, the observed short-term re-colonizations of the seafloor by brachiopods, as well as the changes from dominant Gephuroceratoid to dominant Tornoceratoid and then back to dominant Gephuroceratoid within the goniatites faunas, seem to indicate that the installation of anoxia in (this part of) the Dinant basin is complex and occurred in several pulses. The abundance of cephalopods in the section, the possibility to collect bed-by-bed at large scale and to observe the same stratigraphic interval in several corners of the quarry make from the Lompret quarry one of the most extraordinary and richest upper Frasnian cephalopod sites in the Dinant basin.

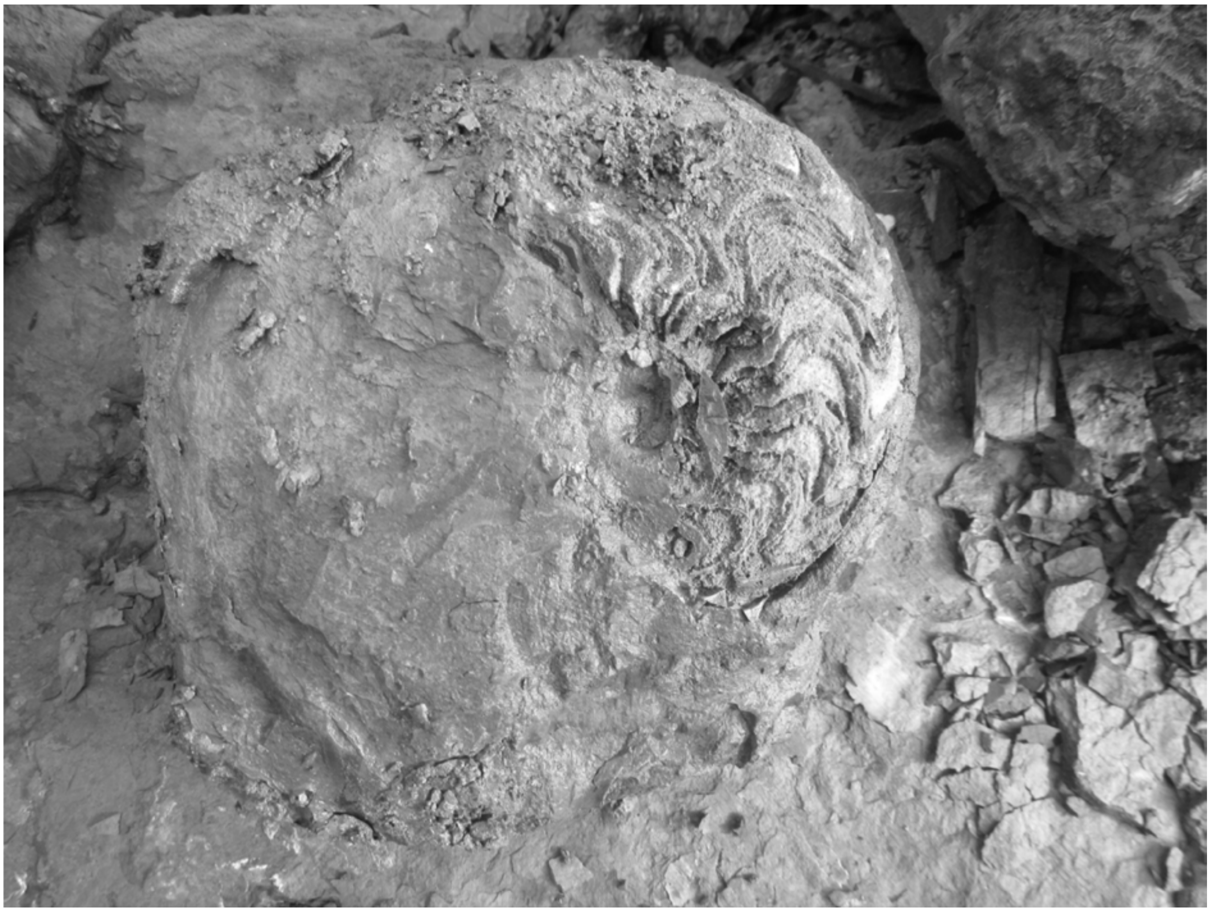

Fig. 1: Field photo of a partly weathered *Manticoceras* (Gephyroceratoid) (diameter 13 cm) from the highest limestone bed 30 cm below the first occurrence of darker coloured shales.

Upper Frasnian deposits at the Lahonry quarry (Lompret, Belgium): conodont biostratigraphy, microvertebrates and bentonites

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Excavation in the Lahonry quarry at Lompret, about 10 km east of Frasnes (Ardenne, Belgium) expanded northward during the last four years, revealing reefal limestone deposits of the Upper Frasnian Petit Mont Member close to the old railroad (Fig. 1).

Fig. 1: View on the Lahonry quarry at Lompret (see cars for scale).

The reefal unit has a general dip of about 30° in NNE direction and consists in its thickest part of at least 60 meters of middle grey bioclastic limestone alternating with dark grey levels and crowned with coral-rich irregular limestone deposits of about half a meter. The limestone body lies enclosed within the nodular limestones and shales of the peri-reefal Neuville Formation. The latter is overlain by the younger black shales of the Matagne Formation exposed in the northeastern and southeastern part of the quarry. A WSW-ENE directed fault delimits the south side of the limestone outcrop preventing disclosure of its base. Several subparallel NNW-SSE directed faults affected the limestone body and complicate mapping of the structure. In contrast to the typical reefal limestone bodies of the Petit Mont Member, this outcrop shows only rare small patches of pinkish limestone in the upper parts of the lens. The macrofauna in the main part of the limestone body is restricted to crinoid fragments, small brachiopods, rare cephalopods and receptaculites.

Several small sections in the Neuville and Matagne formations around the reefal lens have been sampled for conodonts, in addition to a few samples from the uppermost part and the lowermost accessible part of the limestone lens. The resulting conodont faunas position the limestone reefal lens and the Neuville shales covering the limestone body within the Lower *rhenana* Zone, the base of the overlying Matagne shales coincides with the base of the Upper *rhenana* Zone. The conodont biofacies in the limestone is dominated by polygnathids while the conodont biofacies of the overlying shales mainly consists of palmatolepids. Microfossil residues in the upper part of the reefal limestone and surrounding nodular limestones and shales also contained chondrichthyan microremains (teeth and scales). A similar fauna has been found in the Neuville Formation at the Nismes railway section, about 10 km to the east. The Neuville shales exposed in the southernmost part of the new quarry include three pale-yellow bentonite layers. Previously, bentonite layers in the Neuville Formation were already recognized in outcrops at Frasnes, Neuville and Givet (Gouwy, 2004).

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Upper Eifelian–Lower Frasnian (Middle–Upper Devonian) conodont biostratigraphy improved by graphic correlation in the Spanish Central Pyrenees

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Three Eifelian to Lower Frasnian (Middle to Upper Devonian) sections belonging to the Compte subfacies area (*sensu* Mey, 1967 and Valenzuela-Ríos & Liao, 2006) in the Devonian of the Spanish Central Pyrenees are compared in detail by analysing their conodont content and, subsequently, applying the Graphic Correlation Method. Detailed conodont reports were presented individually for each section: Compte section (Liao & Valenzuela-Ríos, 2008); Villech section (Gouwy *et al.,* 2013) and La Guardia d'Àres section (Liao & Valenzuela-Ríos, 2013). These sections were correlated for the first time by Liao (2014) based on the detailed comparison of the conodont successions. These works demonstrate that the conodont record spans from the lower Eifelian, *costatus* Zone to the Lower Frasnian MN3 Zone and that all Givetian conodont zones are present in the Compte Subfacies area.

In the Spanish Central Pyrenees correlation project, the Compte section was taken as the reference due to its most complete and detailed Givetian conodont sequence and highest sample resolution (29 m thick section, 142 samples). The second section was La Guardia d'Àres (about 40 m and 129 samples). The third section is the thickest one (54 m) but contains several covered intervals and the sample density is the lowest (52 samples). The conodont framework is excellent and correlation of some intervals is of the highest resolution power; however, for some other intervals the biostratigraphic correlation does not reach not the desired high-resolution. Consequently, we try to improve this situation by applying the graphic correlation to these sections. One of the advantages of this method is the potential of testing the synchronicity of each first entry of a given taxon in all the sections by its plotted position in the field of the graph. The distance to the Line of correlation is a direct indication of the diachronicity of the first entry.

In many cases, by traditional biostratigraphical methods this synchronicity cannot be demonstrated or at least the degree of uncertainty is higher than by graphic correlation.

Eighty-two taxa were considered in the construction of the Composite Section for the Spanish Central Pyrenees. Future data might expand ranges of some conodont taxa as only three rounds of correlation have been made, and the data we have obtained are far from being "mature". The Pyrenean composite can be correlated with other Middle Devonian Composite Standard, mainly Ardennes, Morocco (Anti-Atlas), Montagne Noire and contribute to the continuous improvement and construction of the Middle Devonian Global Composite Standard.

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The early continental aquatic arthropod fauna from the Late Devonian of Strud, Belgium: implications for terrestrialization strategies

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Arthropods were the first animals to colonize land, with myriapods and arachnids at least during the Silurian (443.4–419.2 Ma; Dunlop *et al.*, 2013), and hexapods during the Early Devonian (c. 410 Ma; Hirst & Maulik, 1926; Scourfield, 1940; Engel & Grimaldi, 2004). Much later at least four groups of crustaceans also literally ventured on land, most probably independently, namely isopods, amphipods, ostracods and decapods (Dunlop *et al.*, 2013), whereas other groups such as copepods and branchiopods colonized almost every terrestrial aquatic habitats. All faced a series of challenges, in particular gas exchanges, desiccation, reproduction, osmoregulation and exposure to ultraviolet radiation (Little, 1990), resulting in many morphological, physiological and ecological adaptations. Nonetheless, whether they reached land via salt or fresh water remains poorly documented, mainly because relevant localities are few. Here, I present two assemblages of continental aquatic crustaceans recently described from the Late Famennian (Late Devonian, c. 365 Ma) locality of Strud, which represents an exceptional source of information on early aquatic terrestrial ecosystems (Denayer *et al.*, 2015). Firstly, an assemblage of early decapod crustaceans has been recovered from fine shales witnessing a calm and confined floodplain habitat, indicating that decapods have been part of continental ecosystems at least since the Late Devonian (Gueriau *et al.*, 2014a, 2014b). Secondly, fresh to brackish temporary pools seasonally dried and flooded yielded a modern-looking community of branchiopod crustaceans comprised of notostracan (Lagebro *et al.*, 2015), anostracan and spinicaudatan. Insight into their reproductive strategies and life cycles show how these crustaceans adapted to invade land successfully at the onset of terrestrialization.

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Revised conodont stratigraphy of the famous Ballberg section (Famennian, Rhenish Massive, Germany)

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The northern Rhenish Slate Mountains represent one of the classic regions for studying Upper Devonian strata in central Europe. Famennian sediments are exposed in a small belt along the northern flank of the Remscheid-Altena Anticline. These outcrops extend from Hagen eastwards and disappear with the plunging fault axis to the north and northeast of Balve (Fig. 1). Further to the northeast, the Famennian re-appears on the top of horst structures. To the west, large parts of the Upper Devonian are suppressed by the Ennepe Thrust Fault and re-emerge near Wuppertal. Following early work by Denckmann (1901, 1903, 1905), the Famennian of the northern Sauerland has been described by Schmidt (1924), Paeckelmann (1924, 1938), Gallwitz (1928), and, more recently by Ziegler (1962), Paproth (1986), Becker (1992), Korn & Luppold (1987), and Hartenfels (2011).

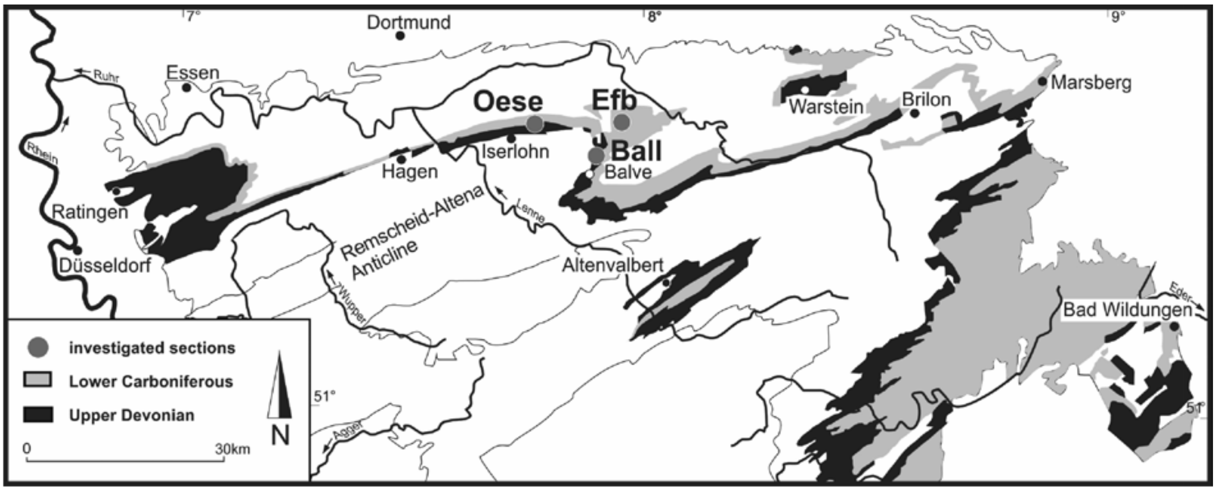

Fig. 1: Simplified geological map of the northern Rhenish Slate Mountains and the position of investigated sections (Ball = Ballberg, Efb = Effenberg, and Oese).

The Ballberg section (map sheet 4613 Balve) crops out approximately 4.5 km to the northeast of Balve, at the road B229 between Balve and Enkhausen. The sequence of the abandoned quarry was first described by Paeckelmann (1924). Ziegler (1962) added a rough conodont biostratigraphy based on 14 samples. A repeated sampling in 1964 provided 24 additional conodont samples. But, until now, these faunas are not published. Subsequently, a first section log of the entire section was given in a field guidebook by Ziegler (1971). Unfortunately, the lowermost beds, which were sampled by Ziegler (1962), are now covered by debris, a fact that was already mentioned in Ziegler (1971).

The Ballberg section became famous, because it was one, on which Ziegler (1962) based his standard conodont zonation for the middle to upper/uppermost Famennian. The entire sequence possesses a thickness of *ca.* 550 cm and consists of grey nodular to solid micritic limestones. It is interrupted in the lower part by a 5.5 cm-thick black shale, overlain by a 3 cm-thick marl, with carbonate nodules at the bottom. This marker bed can be recognized in various sections throughout the northern Sauerland and represents the *Annulata* Event at the base of UD IV.

Our re-investigation of the Ballberg section started with a B.Sc. thesis by Temmesfeld (2011). We measured the entire sequence bed-by-bed. Until now, 53 of 80 possible conodont layers were sampled. This enables a revision of the conodont stratigraphy of the section, including a precise location of zonal boundaries. The new conodont zonation scheme for the middle to upper Famennian, introduced by Hartenfels (2011), is applied.

A typical conodont association, including *Scaphignathus velifer velifer*, *Palmatolepis minuta minuta*, *Pa. minuta schleizia*, *Pa. glabra lepta* late morphotype, as well as alternognathids, such as *Al. beulensis* and *Al.*

regularis continuus, dates the lower part of the succession as *Sc. velifer velifer* Zone. The entry of *Pa. rugosa trachytera* in Bed 8, associated with the first *Polygnathus perplexus*, marks the base of the subsequent *Pa. rugosa trachytera* Zone. The next zonal marker, *Pseudopolygnathus granulosus*, starts in Bed 20b. A regional subdivision of the *Ps. granulosus* Zone is given by the entry of *Pa. gracilis sigmoidalis* (Bed 21b, *Pa. gracilis sigmoidalis* Subzone) and the extinction of *Pa. rugosa trachytera* (top Bed 25b, *trachytera-styriacus* Interregnum). In contrast to other sections of the Remscheid-Altena Anticline (*e.g.*, Effenberg, Oese: Hartenfels, 2011, Oberrödinghausen: unpublished data), the *Annulata* Event Interval (Bed 26) consists only of single black shale layer, instead of two. Slightly below and with the black shale, there is a stepwise loss of five partly important conodont species/subspecies: *Pa. perlobata grossi* (Bed 25a), *Sc. velifer velifer*, *Pa. rugosa trachytera*, *Pa. glabra lepta* late morphotype, and *Pa. minuta minuta* (all top Bed 25b). Sample 14 *sensu* Ziegler (1962, 1971), which was allegedly taken "immediately above the aforementioned shale layer" yielded *Po. styriacus*. Unfortunately, there is so far no detailed documentation or illustration of these first *Po. styriacus* of the Ballberg section. In contrast, this marker species enters in our samples five solid carbonate layers above the black shale in Bed 31b. Possibly, Ziegler's oldest *Po. styriacus* are related to *Po. protostyriacus*, a species which is intermediate between *Po. granulosus* and *Po. styriacus* (Tragelehn & Hartenfels, 2011). Within the northern Sauerland, there is no evidence of an entry of *Po. styriacus* immediately above the *Annulata* Event(s).

There is no conodont data published for the higher part of the Ballberg succession in Ziegler (1962, 1971). In Bed 50b, the entry *Pa. gracilis manca* marks the beginning of the subsequent conodont zone. Within the uppermost part of the section, an association of *Bispathodus stabilis stabilis*, *Pa. gracilis expansa* Morphotype 1, *Po. experplexus*, and *Ps. brevipennatus* dates Bed 72b as the base of the *B. stabilis stabilis* (*Pa. gracilis expansa*) Zone.

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A new Pragian trilobite assemblage from Aïn-Al-Aliliga (western Meseta, NW Morocco)

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Morocco is long known by professional palaeontologists as well as private collectors for its excellent and highly diverse trilobite faunas, mainly from the Lower and Middle Devonian of the Tafilalt and Maider Regions of the eastern Anti-Atlas. Equally important are contemporaneous faunas from the geologically complex and strongly tectonized Meseta Region, especially in the context of palaeobiogeographic relationships between the southern Variscides and stable northern Gondwana. Here we introduce a new collection of Lower Devonian trilobites from the locality Aïn-Al-Aliliga (= Aïn Aliliga).

The outcrop is situated in the western Meseta of NW Morocco in the Oued Cherrat Zone, a north-south running fault zone beginning roughly between Rabat and Casablanca (Fig. 1a). The regional geology and stratigraphy of the area is based on Chalouan & Hollard (1979), Chalouan (1981), and Zahraoui *et al.* (2000). Aïn Aliliga is the name for a W-E running valley and spring between the two localities Aïn Dakhla in the north and Aïn-as-Seffah in the south, *ca.* 13 km SE of Bouznika. GPS coordinates are: N33°37’16,3’’ W007°00’48,9’’.

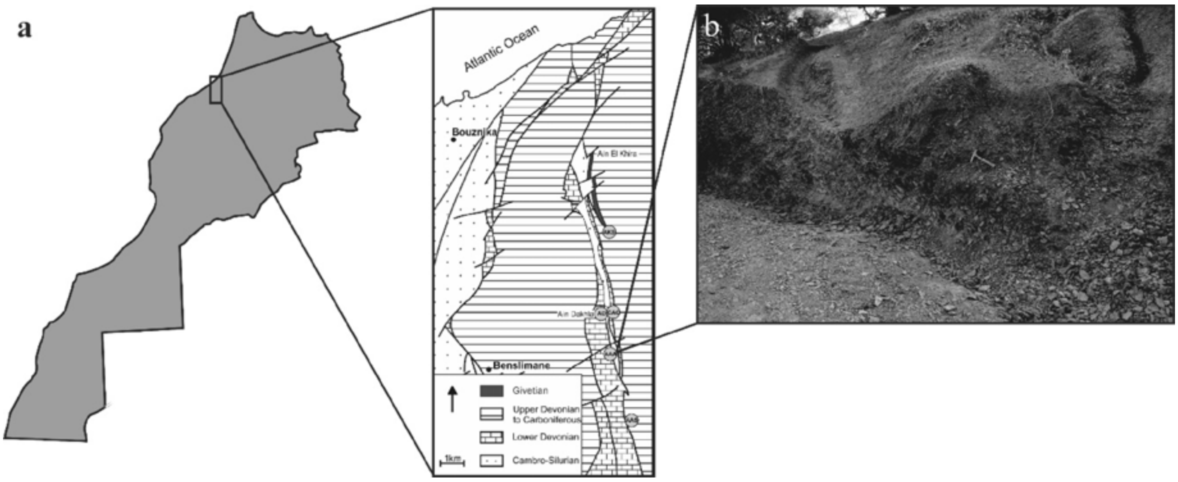

Fig. 1: (a) Geographic position of Aïn Aliliga within Morocco and within the Oued Cherrat Zone (AAA= Aïn Aliga; from Eichholt & Becker, in rev.). (b) Outcrop of the Aïn-al-Dakhla Formation at the eastern hill slope of Aïn Aliliga.

The locality exposes at its western end a thick lower Emsian biostromal succession (Cakhrat-ach-Chleh Member of Dhar-es-Smene Formation). It is underlain by phacopid-rich neritic limestones (new, un-named member), which represents the Pragian-Emsian transition that is currently subject of revision. The upper Emsiand and Eifelian are missing towards the E in the erosional contact to the Givetian represented by reefal limestones, thick, massive, partly polymict breccia units, and a few crinoidal limestones of the Aïn-Al-Aliga Formation (Eichholt & Becker, in rev.).

Previously, the Lochkovian to Pragian strata of Aïn Aliliga have not been well documented because of poor outcrop conditions. Due to mining activities the old track leading downslope into the Cherrat valley was restored and widened in 2014, cutting just E of the steep slope formed by the Aïn-Al-Aliga Formation through Pragian slates of the Ain-al-Dakhla Formation (Fig. 1b). As noted by Chalouan (1981) both units must be separated by a steep fault. The fresh outcrop enabled us to collect a new Pragian trilobite assemblage during a student fieldtrip in spring 2015. Previous regional records of *Nowakia acuaria* support the age assignment.

So far only little is known about the trilobites of the Aïn-al-Dakhla Formation. Chalouan & Hollard (1979) and Chalouan (1981) listed without any description or illustration the following Pragian taxa: *Reedops cephalotes*, *R.* ex gr. *sternbergi*, *Phacops* sp., *Odontochile* cf. *cristata*, *Odontochile reussi*, Asteropyginae undef., ? *Paracryphaeus* sp., *Pilletina* sp. aff. *anatolica*, and *Pseudocryphaeus* sp. aff. *munieri*. Zahraoui *et al.* (2000) just mentioned *Phacops*.

Our work on the Aïn Aliliga trilobites is in an initial stage and, therefore, only a short preview can be presented. The associated assemblage preserved on slate surfaces comprises relatively common, macroscopically visible ostracods (with a maximum length of 8 mm), rare brachiopods (chonetids and spiriferids), and very rare solitary rugose corals. The biofacies is deeper neritic.

Trilobites are quite common but only found disarticulated, either in shell preservation or as imprint. While the numbers of pygidia and cephala are more or less the same, thoracic pleurae are comparatively rare. Many of the specimens are elongated along the sagittal axis due to tectonic processes; this complicates the taxonomic work. All specimens retrieved so far belong to the Asteropyginae, Odontochilinae, and Homalonotinae; representatives of the Phacopinae have not yet been collected.

So far it is clear, that the fauna comprises at least two species of *Metacanthina* Pillet, 1953, a genus that comprises so far four species from Lower Devonian strata of the Moroccan Maider Region, Dra Valley as well as from the Meseta (Basse, 2012).

There are three genera from Lower Devonian strata of Morocco belonging to the Odontochilinae: *Odontochile* Hawle & Corda, 1847, *Erbenochile* Alberti, 1981, and *Spinodontonchile* Šnajdr, 1985. While lateral pygidial spines are typical for *Erbenochile*, this feature is not developed in the other two genera nor in the available material from Aïn Aliliga. *Spinodontonchile* can be distinguished from *Odontochile*, besides other morphological features, by a tuberculate pygidial axis. This feature is also not developed in the investigated material. Therefore, our specimens belong to *Odontochile*, which fits the species lists given in Chalouan & Hollard (1979) and Chalouan (1981). Species identifications have to incorporate recent revisions of the genus.

The remains assigned to the Homalonotinae are semi-circular pleurae, which fit best to this subfamily. Pygidia or cephala are not yet known from the locality, so the classification is somewhat uncertain. The morphological features of the pleurae are comparable with the genus *Wenndorfia* Sandford, 2005, known from the Lower Devonian of the Dra Valley. A better taxonomic classification requires better specimens.

The currently restricted knowledge supports faunal links with the Maider and Dra-Valley of southern Morocco, a fact that was already shown by Helling & Becker (2013) for a neritic (crinoidal limestone) Pragian trilobite assemblage from Taourirt n´Khellil at the southern margin of the Variscides (Tinerhir region). But the Aïn Aliliga assemblage will contribute to document facies influences on Moroccan Pragian trilobite assemblages.

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Late Devonian conodonts of western Mongolia: preliminary results

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The Baruunhuurai Terrane in Khovd Province, western Mongolia is one of the least studied regions in Mongolia. Late Devonian deposits in the Baruunhuurai Terrane are dominated by volcaniclastic rocks intercalated with minor cm-thick fossil-rich marl and limestone beds. To better understand the biostratigraphic control on the Late Devonian sequences in this region, conodont samples were collected from two sections, the Gerelt Hoshoo (GH) (type section) and the Hoshoot Shiveetiin gol (HS) section of the Samnuuruul Formation in western Mongolia in 2012 (Kido *et al*., 2013) and 2014. Of more than 100 samples collected (0.5 to 4.5 kg per sample), 86 samples were processed for conodonts and treated with formic acid at the University of Graz (Austria). At this time, 10 of 16 samples taken from the HS section yield conodonts. Pa-elements are sometimes fragmentary, but otherwise very well preserved. Taxa obtained from insoluble residues belong to four genera: *Ancyrognathus*, *Icriodus*, *Palmatolepis*, *Polygnathus*. Samples from the GH type section at Samnuuruul have not yielded conodonts, likely due to a higher diagenetic overprint of rocks with significant silicic cementation compared to deposits at the HS section.

These conodont assemblages represent the first record known from Late Devonian deposits of western Mongolia and the joint occurrence of these four genera will enable independent control of current Frasnian and Famennian biozonations (Montagne Noire *versus* "Late Devonian Standard Conodont Zonation"). Although our results are still preliminary we recognized affinity to the conodont assemblage documented from NW-Xinjiang in China (Xia, 1997). A detailed taxonomic study on the Mongolian conodont assemblage and its stratigraphical distribution is in progress.

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Brachiopod diversity, biofacies and events of the Rhenish Lower Devonian (Germany)

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The Lower Devonian in the Rhenish Massif (Rheinisches Schiefergebirge, Germany) contains a succession of rhynchonelliformean (“articulate”) brachiopod faunas which reflect palaeoenvironments in a tropical epeiric sea during a time span of approximately 30 million years (Jansen, subm.). These faunas, sets of assemblages named after characteristic spiriferide species, are separated by events discernible by facies changes, faunal turnovers and diversity fluctuations; the events are related to palaeoenvironmental changes caused by the interplay of eustatic sea-level variations (Johnson *et al.*, 1985; T-R cycles mentioned below) and varying rates of regional crustal subsidence and sedimentation. The present study in connection with the still ongoing monographic revision of the Rhenish faunas is an attempt to elucidate these interrelationships.

Distribution and composition of the Rhenish brachiopod faunas are dependent on spatio-temporal variations of the shallow-marine, largely siliciclastic rhenotypic (“Rhenish”) facies, which is subdivided into three newly defined larger subfacies (Jansen, subm.), each characterised by a specific faunal composition and more or less terrigenous influence: (1) eurhenotypic, (2) pararhenotypic and (3) allorhenotypic facies. These facies reflect (1) shallow marine, arenaceous palaeoenvironments with turbid water, (2) marginal marine, deltaic, coastal-lagoonal or intertidal palaeoenvironments with strongly changeable conditions and (3) more calcareous, open shelf palaeoenvironments with clear water. The rhenotypic facies as a whole is typically developed in neritic strata of Lochkovian to Frasnian age in Europe and North Africa.

The first brachiopod assemblages of the Mid-Palaeozoic (“Variscan”) succession belong to the earliest Gedinnian (late Pridolian) *Quadrifarius dumontianus* Fauna, which includes 18 species of rhynchonelliformean brachiopods (species numbers below refer to this group). Ecological effects of the transgressive Klonk Event (Jeppsson, 1998) may have caused its extinction near the Silurian-Devonian boundary.

With the Hüinghausen Event in the early Gedinnian (early Lochkovian), shallow marine conditions suitable for the eurhenotypic *Howellella mercurii* Fauna arose, which contains 16 species with only one or two surviving species from the preceding fauna. This fauna went extinct still within Gedinnian (Lochkovian) time, with the onset of the “Rhenish Gap”, a strong regressive interval during the late Gedinnian to early Siegenian with a duration of 6–8 Ma, only partly reflected by the global sea-level curve and presumably caused mainly by strong siliciclastic input from the Old Red Continent; continental, lagoonal, deltaic or intertidal conditions expanded in wide parts of the Ardenno-Rhenish region. Still within this phase, a weak marine influence near the beginning of the Rhenish Siegenian (approximately Lochkovian-Pragian boundary level or early Pragian), probably caused by increasing subsidence and decreasing sedimentary supply or already linked to an early Pragian transgressive pulse within T-R Cycle I a, is described as the Hermeskeil Event (Mittmeyer, 2008). It led to the local establishment of conditions of the pararhenotypic facies characterised by representatives of *Crassirensselaeria*.

Environmental conditions of the normal marine, eurhenotypic facies widely spread with the Gensberg Event at the beginning of the middle Siegenian, documenting a transgression of supraregional importance. It introduced the completely new, highly diverse *Acrospirifer primaevus* Fauna including 44 species in the middle Siegenian and 30 species in the upper Siegenian. It is still a working hypothesis that this development could correspond to the transgressive Zinzilban Event documented in Uzbekistan (Yolkin *et al.*, 1994) or a (corresponding?) transgressive pulse of the mid Pragian. In contrast, the faunal turnover at the beginning of the late Siegenian Kürrenberg Event (Mittmeyer, 2008) was mainly governed by increased supply of siliciclastics and higher sedimentation rates probably in combination with an eustatic sea-level fall during the late T-R Cycle I a. Organisms with clear water preference diminished so that faunas with reduced diversity and turbidicolous species (*e.g.*, *Hysterolites hystericus*) became dominant.

The late Siegenian Saxler Event (Mittmeyer, 2008) marks the beginning of a transgression, which may coincide with the onset of T-R Cycle I b of the global sea-level curve (Johnson *et al.*, 1985) and the “Basal Zlíchov Event” *sensu* García-Alcalde (1997). It resulted in the onset of a brachiopod-dominated eurhenotypic facies. The transgressive phase continued into the early Emsian and led to the facies change from the pararhenotypic and eurhenotypic Taunusquarzit Group to the largely hercynotypic Hunsrück Slate Group in the southern Rhenish Massif. The early Emsian *Arduspirifer antecedens* Fauna with 50 species, of which only about 5 survived from the Siegenian, shows a gradual evolution of the rhenotypic brachiopods within the Ardenno-Rhenish Shelf region, exemplified by the genera *Euryspirifer* and *Arduspirifer*. A peak of marine influence is reached with the transgressive Stadtfeld Event (Mittmeyer, 2008) in the late early Emsian. Regressive tendencies in the latest early Emsian, mainly caused by very high sedimentation rates, accommodated by concomitant strong subsidence, led to local extinctions and conditions of the pararhenotypic to continental-fluvial facies.

After the system of rapid subsidence and high sedimentation rates had ceased, the rising sea-level in connection with the earliest late Emsian Berlé Event (Mittmeyer, 2008) provided a more continuous connection to the sea and allowed the immigration of many taxa. The eurhenotypic facies with the late Emsian *Euryspirifer paradoxus* Fauna (86 species) developed. It is possible that the Berlé Event was linked to the global Daleje Event (*e.g.*, Walliser, 1996), which was merely a transgressive phase (Ferrová *et al.*, 2012). The overall transgressive trend during the late Emsian was accompanied by a modest, stepwise faunal change. One of the most conspicuous features is the radiation of the genus *Paraspirifer*. The beginning of T-R Cycle I c may correspond with a transgressive pulse within the Kondel (latest Emsian) time. While the eurhenotypic Kondel fauna died out in the central and eastern Rhenish Massif near the Emsian-Eifelian boundary, resulting from the onset of deep water, hercynotypic conditions, allorhenotypic late Kondel faunas lived on in the Eifel and Sauerland regions and survived into the Eifelian. With the transgression, the genus *Intermedites* appeared near the lower boundary of this stage; it was probably an immigrant from the South China region (Schemm-Gregory, 2010). The *Paraspirifer cultrijugatus* Fauna went extinct with the Kirberg Event (Struve, 1990) within the *Polygnathus costatus costatus* Biochron at the end of the Lauch time, following with some delay after the Basal Choteč Event.

To conclude, the Pridolian to early Eifelian sedimentary successions of the Rhenish Massif exemplify the dependence of the faunal development on the interplay of eustatic sea-level changes in combination with varying subsidence and sedimentation rates in the Ardenno-Rhenish Shelf area. The effects of climate changes are still unclear. Extinction, habitat-tracking, emigration and immigration of brachiopod species in connection with major events governed the composition of faunas. The evolutionary change partly took place in small, isolated populations within or outside the Ardenno-Rhenish region; it is not necessarily documented in the fossil record. With the onset of more suitable conditions after the events, faunas immigrated from outside or spread over the shelf from isolated habitats, and benthic assemblages could re-establish. Relatively modest or minor evolutionary change took place in the more stable palaeoenvironments between the events and possibly within the Ardenno-Rhenish Shelf.

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Aneurophytalean plants from the Middle Devonian of North Xinjiang, China and their ecosystematic inference in the associated Hujiersite flora

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Aneurophytalean plants are reported from the late Mid Devonian (Givetian) Hujiersite Formation, North Xinjiang, China, including *Aneurophyton doui* and a new genus which resembles *Tetraxylopteris*. *Aneurophyton doui* is endemic to the area and exhibits a more complexe organisation than *Aneurophyton* plants from elsewhere. The new genus has alternate or decussate arrangement of the axes, vegetative appendages and large reproductive organs. The vegetative appendages are once to five times dichotomous. The reproductive organs dichotomize twice then pinnately branch once with the ultimate axes further dichotomizing twice to three times, each terminating in a single sporangium. The specimens of the new genus differ from the well-recognized species *T. schmidtii* and *T. reposana* in the shape and organization of vegetative appendages, the median sporangium size and the structure of reproductive organs following branching. No specimens possess both vegetative and reproductive parts, although each kind is well-preserved separately.

Progymnosperms are an important group emerging in the Mid Devonian and prevailing through the Late Devonian world. The Aneurophytales occur throughout this stratigraphic range in Eurasia and northern Gondwana. It is not until the early Late Devonian (Frasnian) that petrified *Callixylon*, the dominant progymnosperm tree, is documented in Xinjiang. Before this, the aneurophytaleans, which in China are represented by the newly studied compressions and impressions in the Hujiersite Flora, shed some light on the ecology of local progymnosperms, which are probably shrub-like based on stem size. Recent research on the Hujiersite Flora reveals a probably Mid Devonian forest with a canopy of tree-like lycopsids (*e.g.*, *Hoxtolgaya*). Palynological analysis demonstrates a predominance of lycopsids. Aneurophytalean spores are almost absent or contribute only a small percentage in a limited area (such as 251 Hill locality). Thus, the aneurophytaleans in this early forest are interpreted as shrub-like plants that were a comparatively rare component of the understory, which was dominated by other herbaceous groups (*e.g.*, lycopsids and early fern relatives).

Middle to Late Devonian carbonate ramp sedimentation in Central Iran (Zefreh section, NE Isfahan)

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The studied section is located 6 km northeast from the Zefreh village, 60 km northeast from Isfahan. Middle- to Late Devonian deposits of the Bahram Formation are exposed in a several hundred meters thick section in Central Iran. The section shows an overall regressive trend from the base to the top and can be subdivided in several lithological units. The sedimentological record covers outer ramp- (deepest part) to inner ramp deposits as well as intertidal to supratidal deposits (shallowest part). The lower siliciclastic unit consists of an alternation of quartzites, tuffaceous sandstones, and quartzitic sandstones. Occasionally, thin bedded black shales occur. The fossil content is poor in that part of the sequence, although a good number of trace fossils occur. The next unit is composed of shales and sandstones with intercalations of thin-bedded limestones. In distinct layers, many fossils occur, such as gastropods, trilobites, and bryozoans. Very common in those mid-ramp deposits are brachiopods which have been described earlier by Brice *et al.* (2006). The third unit is composed of thick- to thin-bedded grey limestones with dolomitic intercalations and thin shale layers. Very common are intraclastic grainstones-packstones. The upper part of the section is mainly composed of thick- to thin-bedded grey limestones with dolomitic horizons. The transition from distal to proximal environments is accompanied by a relative increase in the abundance of fossils, such as stromatoporoids, bryozoans, brachiopods, sponges, and gastropods. The upper part of the section shows many facies changes within the upper inner ramp to supratidal deposits. Oncoids, ooliths, intertidal mat deposits, desiccation cracks, and evaporitic pseudomorphes occur in this part of the section. Occasionally, the occurrence of large moderately oriented ostracods in mudstones could represent a depositional setting ranging from ponds to an evaporation supratidal zone which suggests a shallow, semi-restricted lagoonal depositional environment. The Bahram Formation is disconformably overlain by the white quartzitic sandstone of the Permian Jamal Formation. The established conodont biozones are related to the Middle- to Late Devonian stratigraphic interval in the Bahram Formation. The presentation will provide a first sedimentological and stratigraphical overview of this newly sampled section in shallow-water facies.

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Events in the Mid-Palaeozoic: examples from the eastern Palaeotethys (NE Vietnam)

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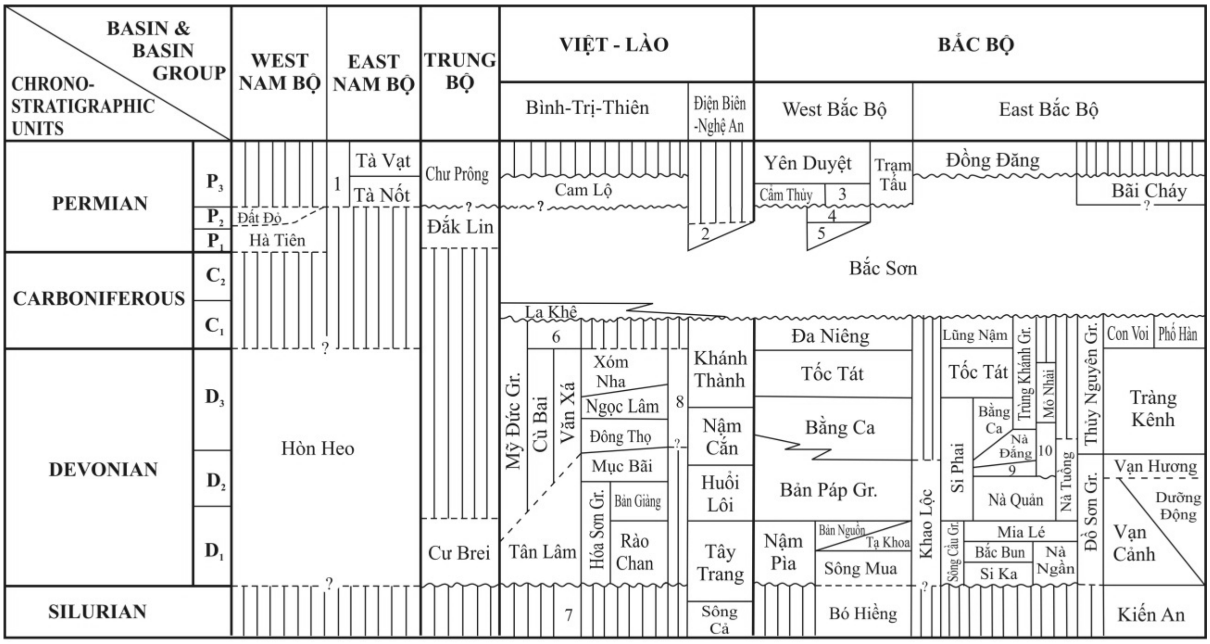
During the mid-Paleozoic a number of global events occurred which were associated with faunal changes in marine and terrestrial environments. Subsequent work has shown that a number of biodiversity crises occurred in the Middle and Late Devonian including the Givetian–Frasnian Event, the Frasnian–Famennian Event and the Devonian–Carboniferous Event. These biological and environmental fluctuations resulted in extinction events that left not only biological modifications in the geologic record, but also geochemical signals of change in Devonian sediments. Most studies of mass extinction events are located around the Rheic Ocean, while other areas such as the Paleotethys remain poorly documented. In the frame of a running project we investigate different Devonian and Carboniferous sections in northern and northeastern Vietnam, and Cat Ba Island.



1. Tà Thiết Group *2. Sông Đà Fm.* *3. Viên Nam Fm.* *4. Na Vang Fm.* *5. Bản Diệt Fm.*
6. Phong Nha Fm. *7. Đại Giang Fm.* *8. Thiên Nhẫn Fm.* *9. Bản Cỏng Fm.* *10. Tân Lập Fm.*

Fig. 1: Stratigraphic correlation of the Devonian–Upper Permian (Wuchiapingian) Supersequence (after Tran Van Tri *et al.*, 2011; Thanh *et al.*, 2013).

Based on a detailed stratigraphy, sedimentology, microfacies and geochemical proxies we try to evaluate the presence of anoxic events associated with important extinctions in the mid-Paleozoic in basinal settings. The investigated formations are composed mainly of ramp platform carbonates and slope deposits yielding a number of fossils, such as conodonts, foraminifera, tentaculitids among others. Generally, the event layers are characterized by an alternation of thin, dark gray limestones and black shales containing abundant organic carbon.

In this presentation we will report on first results on the Devonian and Carboniferous conodont stratigraphy, depositional environments, and stable isotopes of Devonian and Carboniferous rocks in northeastern Vietnam.

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High-resolution stratigraphy of the Devonian-Carboniferous boundary in Europe: multidisciplinary approach

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The Devonian–Carboniferous system boundary (DCB), as defined by the GSSP at La Serre, southern France, has been critically revised in recent years (*e.g.*, Kaiser, 2009). The general consensus is that the entry of *Siphonodella sulcata* in the lineage from *S. praesulcata* to *S. sulcata* should no longer be retained as the marker of the base of the Carboniferous as its practical application has been shown to be difficult (Kaiser, 2009). Currently, there is ongoing debate on the choice of better criteria for the DCB redefinition. As neither conodonts nor foraminifers can provide a satisfactory candidate, a cyclo- and event stratigraphic approach, based on petrophysical and geochemical proxies, can provide an auxiliary solution. The global extent and abrupt nature of the end-Famennian Hangenberg Events (HE) led Walliser (1984) to propose the events as a natural DCB. However, his proposal was abandoned during the subsequent definition of the DCB. The HE can be subdivided into two phases. The first is the Hangenberg Black Shale Event (HBSE; Hangenberg Event s.s.), which is manifested by black shale deposition, carbon isotopic anomaly and mass extinction (*e.g.*, Walliser, 1984; Becker, 1996; Caplan & Bustin, 1999; Kaiser *et al.*, 2006, 2008, 2011). The second phase of the HE, the Hangenberg Shale and Sandstone Event (HSE), is represented by deposition of siliciclastic sediments in the marine environment and/or gaps in sedimentary records all over the world (Van Steenwinkel, 1993; Hance *et al.*, 1994; Becker, 1996; Kaiser *et al.*, 2011; Kumpan *et al.*, 2014a), and related to the rapid cooling step.

Our working group has focused on the biostratigraphic (conodonts, foraminifers), petrophysical (field gamma-ray spectrometry) and chemostratigraphic (element analysis by XRF, $\delta^{13}C_{carb}$) high-resolution survey of thirteen DCB sections across Europe. They are located in the Montagne Noire, France (sections La Serre, Puech de la Suque), Rhenish Slate Mountains, Germany (Oese, Oberrödinghausen, Drewer), Ardennes, Belgium and France (Gendron-Celles, Rivage, Les Ardennes), Carnic Alps, Austria (Grüne Schneid, Kronhofgraben) and Moravian Karst, Czech Republic (Lesní lom, Mokrá and Křtiny quarries). The aim of the study was to supplement biostratigraphic framework and investigate various geochemical proxies as possible tools for correlation between shallow- and deep-water depositional settings.

The conodont biostratigraphic research took place in the Moravian Karst. The most important feature is the FAD of the *S. sulcata* morphotype (Group 1 *sensu* Kaiser & Corradini, 2011, with features close to “nov. gen. nov. sp. 1” of Tragelehn, 2010) below the Hangenberg Event, which underlines the problems with the current definition. Promising tools in terms of foraminiferal biostratigraphy are represented by the sequence of bioevents calibrated by conodont zones. It starts with FAD of *Tournayellina pseudobeata* just above the Hangenberg Event, followed by FAD of *Eochernyshinella crassitheca* and *Neoseptaglomospiranella endothyroides*, *N. rauserae*, *Endochernyshinella* ex gr. *gelida*, *Prochernyshinella oldae* in the lower Tournaisian and FAD of *Palaeospiroplectammina tchernyshinensis*, *Chernyshinella glomiformis*, *Septabrunsiina krainica* and *Crassiseptella* at the base of the middle Tournaisian.

The HBSE was chemostratigraphically characterised by $\delta^{13}C$ positive excursion, which was documented in the studied sections by previous studies from Carnic Alps and Rhenish Slate Mountains (Kaiser *et al.*, 2006), Ardennes and Montagne Noire (Buggisch & Joachimski, 2006) and recently also from the Moravian Karst (Kumpan *et al.*, 2014b). Furthermore, the HBSE horizon displays an increase in U/Th redox proxy, as well as increase in such redox and palaeoproductivity proxies as Zn, Pb, Cu or Ni, which reveal oxygen depletion trend also in sections without black shales (*e.g.*, in the Moravian Karst). Increase in Mn was documented in several pelagic sections (in Moravian Karst, Carnic Alps, Rhenish Slate Mountains) just below or within the

HBSE. We interpret this as a record of a fluctuating oxidation front, in which mobile Mn species, dissolved and transported into reductive deep water, were precipitated and buried in carbonates just above the hypoxic-oxic interface.

In relatively shallow-marine carbonate ramp settings (Ardennes) and mixed carbonate-siliciclastic settings (Rhenish Slate Mountains), well-traceable facies tracts indicate a prominent interval of forced regression in the latest Devonian (upper parts of the *costatus-kockeli* Interregnum), equivalent to the HSE (Kumpan *et al.*, 2014a). This forced regression is associated with sharp increase in detrital supply proxies (*e.g.*, Zr/Al and Computed Gamma-ray) and/or stratigraphic gap and is well correlatable and traceable even in very distal pelagic (Carnic Alps, Montagne Noire, Moravian Karst) and turbidite settings (Moravian Karst). The geochemical record in the deep-water sections with otherwise indistinct facies shifts therefore suggests that the latest Famennian sea-level fall affected all these marine environments ranging from shallow water into the pelagic.

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The correlation of Devonian deposits of Eastern and Western Transbaikal (Eastern Russia)

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The Transbaikal in the south of Russia stretches from the Lake Baikal as far as the upper reaches of the Amur River. The Devonian deposits of Eastern Transbaikal are widely distributed in the Agin, Argun and Upper Amur structural-formational zones (Fig. 1), each having different geological development history. They are represented by two lithofacies of the geological section: carbonate-volcanogenic-terrigenous (Agin zone) and terrigenous-carbonate (Argun and Upper Amur zones). The Argun and Upper Amur zones are composed of rocks which were deposited in the shelf zone of a paleobasin. All strata are characterized by abundant paleontological remains. Crinoids and brachiopods are very numerous. A crinoid biostratigraphic zonation is proposed within the Mongol-Okhotsk fold belt as follows: *Scyphocrinites mariannae*, *Costatocrinus bicostatus* and *Tastjicrinus paucicostatus* (Lower Lochkovian); *Amazaricrinus ildicanensis* (Pragian); *Paradecacrinus orientalis* (Emsian); *Raricrinus minimus* and *Vasticrinus vastus* (Eifelian); *Ononicrinus gracilis* (Givetian); *Hexacrinites? stukalinae* (Frasnian) and *Platycrinites? subtuberosus* (Upper Famennian). All strata of Transbaikal Devonian are characterized by brachiopod assemblages. Local and regional crinoid ages accord rather well with that of brachiopods. Lateral distribution of faunal assemblages allows to correlate the deposits which contain the equivalent fauna in other regions (Kurilenko *et al.*, 2002; Kurilenko & Kulkov, 2008).

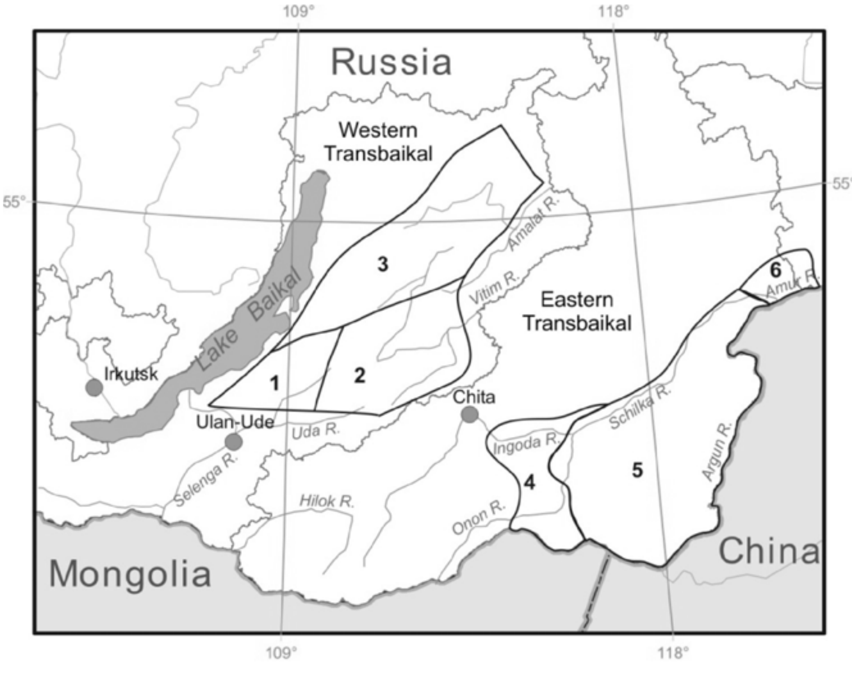

Fig. 1: The scheme of tectonic zonality in the Transbaikal. 1, Turba–Kurba zone; 2, Uda–Vitim zone; 3, Vitimkan–Tsipa zone; 4, Agin zone; 5, Argun zone; 6, Upper Amur zone.

The Devonian deposits of the Agin zone are widely distributed, but they only yielded rare faunal and floral remains. They are comparatively homogeneous in lithologic composition and are in some sections faunalistically characterized. The lower and upper boundary sequences of the Devonian are also missing in this region. In addition these rocks are poorly exposed. In the past, the stratigraphic scheme had been based on the rythmostratigraphic principle. For the first time, we here date the Givetian–Famennian deposits using numerous miospores (identifications by L. Nebericutina). They were discovered everywhere in the sections.

Two formations were distinguished. Each has its own miospore assemblage. The first is dated (Ustborzya Suite) as Givetian to Early Frasnian by the discovery of: *Iugispora impolitus* (Naum.) Oshurk., *Hymenozonotriletes spinosus* Naum., *H. abynatus* Tschibr. var. *plesius* Tschibr., *Geminospora extensa* (Naum.) Gao, *Cristatisporites triangulatus* (Allen) McGr. & Cam., *Archaeoperisaccus verrucosus* Pashk. *et* *al*. Moreover, these deposits also include tetracorals (identifications by Yu. Onoprienko: *Xistriphyllum* ex gr. *spinulosum* (Soshkina), *Betanyphyllum* cf. *soetenicum* (Schluter)), crinoid stems (identifications by A. Kurilenko: *Vasticrinus vastus* (Yeltyshewa & Dubatolova), algae (identifications by V. Luchinina: *Rothpletzella devonica* (Maslov)), foraminifers (identifications by R. Ivanova: Moravammina?), siliceous sponge spicules (identifications by O. Obut: tetractines and pentactines), radiolarians (identifications by O. Obut: *Trilonche davidi* (Hinde), *T.* cf. *obtusa* Hinde), and conodonts (identifications by V. Aristov and N. Izoch: *Icriodus* ex gr. *symmetricus* Br. & Mehl., *Ancyrognathus* cf. *triangularis* Young., *Mesotaxis* sp., *Panderodus* sp., *Polygnathus* sp., *Palmatolepis* sp.). The Overlying Tsagan-Nor Suite yields abundant Famennian miospores: *Coverrucosisporites megalothelis* (Naum.) Oshurk., *Apiculatisporis famenensis* (Naum.) Oshurk., *Iugisporis pullus* (Naum.) Oshurk., *I. vulgaris* (Naum.) Oshurk., *Geminospora micromanifesta* (Naum.) Owens var. *famennensis* Naum., *Diducites radiatus* (Kedo) Obukh., *D. versabilis* (Kedo) Van Veen, *Hymenozonotriletes luteolus* (Naum.) Kedo, *H. echinatus* Naum., *Stenozonotriletes supragrandis* Kedo, and *Laevigatosporites ovalis* Kos.

Before 2003, the Devonian deposits of Western Transbaikal were not known. They were identified by O. Minina and S. Ruzhentsev among deposits formerly considered as Riphean–Ordovician in age (Minina & Nebericutina, 2012; Ruzhentsev & Minina in Ruzhentsev *et al*., 2012). The Baikal-Vitim fold system includes the Vitimkan-Tsipa, Uda-Vitim and Turka-Kurba structural-formational zones (Fig. 1). Flyshoid greywacke sediments of Givetian–Tournaisian age were found in these zones. The best known Devonian deposits are in the Vitimkan-Tsipa zone. Their age was determined by miospore assemblages and rare remains of fauna and flora. There is a rich complex of miospores in the Lower Yaksha Subsuite: *Geminospora micromanifesta* (Naum.) Owens *var. limbatus* Tschibr., *G. micromanifesta* (Naum.) Owens *var. crispus* Tschibr., *G. compta* (Naum.) Owens *var. densispinosus* Tschibr., *Cristatisporites triangulatus* (Allen) McGr. & Cam., *Calyptosporites krestovnikovii* (Naum.) Oshurk., and *Archaeoperisaccus verrucosus* Pashk. They are characteristic of the Givetian–Early Frasnian deposits of numerous regions of Russia. In addition corals (identifications by L. Ulitina and T. Sharkova: *Graciolopora* sp., *Pachypora* sp., *Chaetetes* sp.), bryozoans (identifications by R. Gorjunova: *Geramopora* sp.), algae (identifications by V. Luchinina: *Rothpletzella devonica* (Maslov)), conodonts (identifications by V. Aristov: *Spathognathodus* sp., *Mesotaxis asymmetricus* Bisch. & Ziegl.) co-occur with spores in the Lower Yaksha Subsuite. The Upper Yaksha Subsuite contains stromatoporoids (identifications by V. Chromych: *Actinostroma* cf. *guasifenestratum* Khromych) and a Famennian palynocomplex. The lower part of the overlying Tocher Suite yields conodonts (*Palmatolepis* cf. *triangularis* San., *Pa. perlobata schindewolfi* Mull., *Pa.* cf. *marginifera* Helms, *Polygnathus glaber* Ulr. & Bass., etc.), tentaculites (Nowakiida) and palynocomplex: *Hymenozonotriletes subdiamphidus* Kedo, *Geminospora micromanifesta* (Naum.) Owens var. *famennensis* Naum., *Stenozonotriletes supragrandis* Kedo, *Lophozonotriletes lebedianensis* Naum., *Punctatisporites typicus* (Naum.) Oshurk., *Reticulatisporites varius* (Naum.) Oshurk., *Hymenozonotriletes subdiamphidus* Kedo, *H. luteolus* (Naum.) Kedo. The general interval of their distribution is Early and Middle Famennian. The Middle Subsuite of the Tocher Suite is characterized by the Famennian miospore assemblage. The Upper Tocher Subsuite has the Tournaisian palynocomplex. Conodonts (*Neopolygnathus communis* Brans. & Mehl, *Pseudopolygnathus triangulus* Voges) and stromatoporoids (*Kyklopora* sp.) occur with miospores within the Upper Tocher Subsuite.

The same deposits were recognized in the Uda-Vitim and Turka-Kurba structural-formational zones.

Thus Lower Yaksha Subsuite of the Vitimkan-Tsipa zone (Western Transbaikal) corresponds well with Ustborzya Suite of the Onon terrane (Eastern Transbaikal) in composition and age. The Upper Yaksha Subsuite, Lower Tocher and Middle Tocher subsuites of Western Transbaikal correlate with the Tsagan-Nor Suite of Eastern Transbaikal (Kurilenko & Minina, 2013).

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The latest Famennian vertebrate and trace fossils from the Ketleri site, Latvia

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The environmental conditions in habitats of early tetrapods and paleoecological aspects of the origin and early diversification of limbed vertebrates are still disputable problems of vertebrate evolution. Taphonomic studies of fossil vertebrate sites provide some clues to the problem. One of the best known Famennian tetrapods *Ventastega curonica* Ahlberg, Lukševičs & Lebedev, 1994 has been found in two localities from the south-western Latvia: the Pavāri (or Ciecere) site at the left bank of the Ciecere River close to the former Pavāri hamlet, and the Ketleri site, outcrops along the right bank of the Venta River close to the former Ketleri hamlet. The remains of *Ventastega curonica* together with abundant fish remains have been found in sandstone of the upper Famennian (Upper Devonian) Ketleri Formation which is preliminary dated as corresponding to the interval of the end of postera – beginning of expansa conodont zone (Lukševičs, 2001; Blieck *et al.*, 2010). Sedimentological, environmental and taphonomic studies of the Pavāri site (Lukševičs & Zupiņš, 2004) demonstrated that the vertebrate remains were winnowed by water transport in a low concentration flow after short transportation of the remains before final burial, and that the oryctocoenosis was formed in relatively shallow conditions dominated by stream and weak wave influence, probably representing a low-tidal near-shore depositional environment. Most likely, vertebrates from the Pavāri site dwelled in a marine coastal environment.

A new study concerning the sedimentological, environmental and taphonomic context of the Ketleri site was carried out in the summer of 2013. Excavations provided more than two thousand specimens of fossil fish and primitive tetrapod, and for the first time the trace fossil assemblage has been recognised in the same bed where fossil fishes came from. The list of identified vertebrate taxa is almost identical to that from the Pavāri site (Lukševičs & Zupiņš, 2004) and it includes the antiarch fish *Bothriolepis ciecere* Lyarskaja, at least three taxa of acanthodians ("*Devononchus*" *tenuispinus* Gross, "*D.*" *ketleriensis* Gross, and *Haplacanthus*? sp.), undetermined species of "paleoniscid" actinopterygians, various sarcopterygians including a new species of *Holoptychius*, another porolepiform fish *Ventalepis ketleriensis* Schultze, dipnoan *Orlovichthys* cf. *limnatis* Krupina, two species of osteolepiform fishes *Cryptolepis grossi* Vorobyeva and *Glyptopomus bystrowi* (Gross), as well as the tetrapod *Ventastega curonica*. The assemblage from the Ketleri site is dominated by the remains of *Holoptychius* sp., following by the scales of *Ventalepis* and *Glyptopomus*, contrary to the Pavāri site, which is dominated by *Bothriolepis* remains. The minimal number of individuals counted from the collected specimens also differs significantly from that from the Pavāri site. At the Ketleri site almost all vertebrate remains are represented by fully disarticulated plates of antiarchs, separate teeth, scales or rarely bones of bony fishes and tetrapod, but very rarely by articulated portions of head or lower jaw of sarcopterygian fishes. Many remains (> 50% of all remains) are fragmented, and almost each specimen shows traces of wearing, sometimes even to very high degree. This is also in a marked contrast to the Pavāri site, where the broken bones are comparatively rare, composing less than 2% of all specimens, and only a few of about 800 fossils show traces of wearing.

The trace fossils are distributed within the same fossiliferous bed and are represented by two ichnotaxa: *Planolites* Nicholson isp. and *Palaeophycus* Hall isp. (Lukševičs *et al.*, 2015). Trace fossils are distributed sporadically in a thin interval close to the water table of the Venta River. Burrow systems are filled with the fine-grained sandstone with mica, strongly cemented by fine- to medium crystalline dolomite. Sometimes burrows contain small vertebrate remains like scales of *Glyptopomus* or acanthodian spines. The larger burrows reaching 12 mm in diameter are rarely branching, they form horizontal network. These traces might be interpreted as combined domichnia and fodinichnia produced by deposit-feeder or predatory worm-like organisms similar to acorn worms (enteropneusts). In places these larger burrows have been found together with the systems of smaller meandering burrows (3-5 mm in diameter), which are oriented horizontally or inclined against the bed surface and have been determined as *Planolites* isp. Sometimes these smaller burrows wreathe the largest ones. Usually traces of *Planolites* are interpreted as fodinichnia produced by worm-like detritofagous animals. Possibly the *Planolites*-producers dwelled in the *Palaeophycus*-burrows or around them using the remains of food of animals resembling the acorn worms.

The analysis of taphonomic peculiarities of the Ketleri site shows that the accumulation of vertebrate remains took place in the tidally dominated deltaic or estuarine environment under influence of weak currents, but the final burial took place after relatively long transportation. Most probably the initial vertebrate assemblage characteristic for both fossil sites from the Ketleri Formation is the same, and differences between the Pavāri and Ketleri site are mainly determined by the distance of transportation of the remains and conditions of final burial.

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Signatures of biotic crisis in the Frasnian–Famennian boundary beds from Latvia

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During last decades many works explaining the causes of the biotic crisis close to the Frasnian–Famennian boundary have been published, concerning mainly marine invertebrates and plants (*e.g.*, Marshall *et al.*, 2011). Significant changes of vertebrate diversity close to this boundary also have been discussed (*e.g.*, Long, 1993; Lebedev *et al.*, 2010). Abundant vertebrate fossils occur throughout the whole Middle and Upper Devonian sequence of the Baltic Devonian Basin or the Main Devonian Field of the East European Platform (East Baltic area: Estonia, Latvia, Lithuania, north-western part of Russia and Belarus). However, the most complete sections of the Frasnian–Famennian boundary beds corresponding to the *linguiformis* and *triangularis* conodont zones are distributed only in Latvia and Lithuania. The Frasnian–Famennian boundary in Latvia until recently has been traced between the Amula Formation (Fm) below and the Eleja Fm above (Savvaitova & Žeiba, 1981), but the exact position of the boundary is still disputable since no conodonts have been found here. First data on the Late Devonian vertebrate fossils from this interval have been reported by Gross (1942). Later, in 1970- and 1980-ies, the results of stratigraphic and paleontological studies of the Amula and Eleja formations cropping out in a narrow belt in the Abava River basin were partly described including data on the distribution of miospores and vertebrates (Savvaitova & Žeiba, 1981). However, the detailed analysis of facies distribution and taphonomical peculiarities of vertebrate assemblages close to the supposed boundary has not been done. In the same time the comparison of various species of antiarch fish *Bothriolepis* from former Euramerica has demonstrated the wide geographic range of one particular species, namely *B. leptocheira* Traquair which has been reported from Scotland, Latvia, Central Russia and possibly South Timan where the very poorly described *B. jeremejevi* Rohon probably conspecific to *B. leptocheira* is known (Lukševičs, 2001).

Aiming to precise the composition of vertebrate assemblage and sedimentary environment of taphocoenosis from the Eleja Fm, the detailed sedimentological and taphonomical studies were performed in the outcrop at the left bank of the Amula River upstream Kalnamuiža mill in 2012. The upper part of the Stipinai Fm, complete section of the Amula and Eleja formations and the lowermost part of the Joniškis Fm crops out here; except the Stipinai Fm, all other intervals yield vertebrate remains (Lukševičs, 2001) as well as are well characterised by miospore assemblages (Savvaitova & Žeiba, 1981). The Imula Member of the Stipinai Fm is composed of alternating dolomite, clayey dolomite and dolomitic marl; it contains abundant bryozoan remains, rare charred pieces of the green algae *Chaetocladus*, very rare articulated brachiopods *Theodossia semgalensis* in the lower part, and rare lingulids, vermiculate trace fossils and heavily dolomitised round concretions possibly originated from bryozoan bioherms (Sorokin, 1981). Vertebrate remains generally are very rare in the deposits of the Stipinai Fm yielding only ptyctodontid "*Ptyctodus*" sp. (Esin *et al.*, 2000); no vertebrate remains have been found from the Stipinai dolomite in the Kalnamuiža site. The Amula Fm in the Kalnamuiža outcrop is composed of cyclically alternating sandstone with dolomitic or/and gypsum cement, siltstone and silty dolomite with variegated clay and clayey siltstone. The Amula Fm contains at least two differing vertebrate and spore assemblages. The lower members of the Amula Fm contains the youngest species of psammosteid heterostracans *Psammosteus tenuis* Obruchev, antiarch fish *Bothriolepis* sp., acanthodian *Devononchus laevis* (Gross), sarcopterygians *Holoptychius* cf. *nobilissimus* Agassiz and Dipnoi gen. indet. (Esin *et al.*, 2000), as well as a very rich miospore assemblage reaching 68 taxa studied in details by S. Starikova (Sorokin, 1981). The top-most sandstone with dolomitic and gypsum cement of the upper member of the Amula Fm yields fragments of antiarch fish *Bothriolepis leptocheira*, large undetermined arthrodire and scales of *Holoptychius*. Besides, the upper member of the Amula Fm contains about 50 miospore taxa, but only about half of them are similar to the taxa from the lower member (Sorokin, 1981). Lithology and sedimentary structures indicate a lagoon-like environment (Sorokin, 1981).

Clayey, silty and sandy deposits, intercalating with rhythmically layered carbonates, dominate the section of the Eleja Fm at Kalnamuiža showing increased input of clay and sand in the northern part of the sedimentary basin. Facies vertical stacking and interpretation of sedimentary facies associations evidence subtidal to intertidal flat with dominated siliciclastic deposition and intertidal to supratidal flat with mixed siliciclastic and carbonate deposition during the formation of deposits of the Eleja Fm. Various features including tidal rhythmites demonstrate domination of tidal processes on the formation of sediments. Accumulations of vertebrate fossils in the lower part of the Eleja Fm coincide with the supposed local shallow depressions. Accumulations consists of abundant mainly disarticulated but also partially articulated plates and complete head shields of antiarch *Bothriolepis leptocheira* (syn. *B. curonica* Gross: Esin *et al*., 2000), rare scales and teeth of *Holoptychius* sp., very rare bones of undetermined dipnoan of medium size (only one specimen among 535 discovered fossils) and two acanthodian spines. Taphonomical peculiarities evidence short transportation, fast disarticulation of carcasses and two stages of orientation of vertebrate remains in the subtidal to intertidal flat, most probably due to tidal currents. The remaining part of the Eleja Fm sequence contains only very rare microfossil "*Acanthodes*"-type scales. All three members (Purviņi, Sesava and Cimmermaņi) of the Eleja Fm are well characterised by miospores studied in detail by S. Starikova and V. Avkhimovich; miospore assemblages differ from those of the Amula Fm in many aspects (Savvaitova & Žeiba, 1981).

Facies analysis of the section of the Eleja Fm demonstrates the signs of maximum regression within the lower part of the Eleja Fm, the Purviņi and Sesava members, and deepening at the end of Eleja time, evidenced by the facies of the Cimmermaņi Member (Mb). It is also probably demonstrate the climatic signal, changing from the arid (Purviņi Mb) to wetter climate (Cimmermaņi Mb). Miospore assemblages show most dramatic changes and decrease of number of species very close to the boundary of the Amula and Eleja formations, but changes within the assemblages of vertebrates took place a bit earlier, the taxonomic composition of vertebrate assemblage changes already in the uppermost Amula. Composition of vertebrate assemblage of the Eleja Fm is very restricted consisting of small number of geographically very widely distributed taxa, thus possibly mirroring the biotic crisis close to the Frasnian–Famennian boundary in Latvia.

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Biodiversity changes of ostracods across the late Mid-Devonian global Taghanic biocrisis

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The Middle–Late Givetian Taghanic Biocrisis, recognized in both marine and continental palaeoenvironmental settings, was one of the most severe bioevents of the Devonian and preludes to the end-Devonian mass extinction (e.g., House, 2002; Aboussalam, 2003; Aboussalam & Becker, 2011; Marshall *et al.*, 2011; Zambito *et al.*, 2012). The polyphased Taghanic Biocrisis is worldwidely characterized by a faunal extinction interval bracketed by two major transgressive episodes: the IIa–Tagh, located in the middle *P. varcus* conodont Zone and the IIa–Gen, at the base of the *S. hermanni* conodont Zone. In the marine realm, the progressive sea-level rise coupled to the crisis led to the reduction of geographic barriers, and therefore to the reduction of faunal provincialism. Consequently, numerous shallow marine invertebrate groups were affected by the crisis. Although surprising, the biotic response of ostracods to the Taghanic Biocrisis has never been studied to date. Consequently, the present study focuses on neritic benthic ostracod faunas and their paleobiodiversity dynamics through the Givetian. For this purpose, Givetian sedimentary sequences cropping out in three different countries have been studied: the Ardenne (France: Givet area; Belgium: Durbuy and Namur areas), the Asturias (Spain: Candás area) and the Saoura (Algeria: Saoura area). During the Middle Devonian, these areas belonged to three distinct carbonate platforms located in the southern hemisphere tropical zone (Stampfli *et al.*, 2002): the Ardennean one, along the Laurussian southern margin, the Asturian one, along the western margin of the European Hunic Superterrane, and the Algerian one, along the Gondwanan northern margin. More than 20,000 ostracods were extracted from 834 calcareous samples using the hot acetolysis method (*e.g.*, Crasquin-Soleau *et al.*, 2005). 339 neritic taxa, almost all benthic, were recognized (see Maillet, 2013; Maillet *et al.*, 2013a, b, in press). A taxonomic database was compiled, covering the entire Givetian stage and where each taxon occurrence was assigned to a conodont zone in order to obtain the finest time-partitioning. The biodiversity of ostracod faunas was quantitatively analyzed via the computation of diversity curves and indices. Thus, evolution of taxonomic richness, biodiversity (diversity, dominance and equitability indices), extinction and origination rates and turnover and taxonomic similarity were assessed both at generic and specific levels through the Givetian times. Poly-cohort analyses have also been performed.

From the *P. hemiansatus* to the middle *P. varcus* zones, *i.e.* before the Taghanic biocrisis, the ostracod fauna of each platform is characterized by high diversity, high equitability and high taxonomic richness both at generic and specific levels. A high turnover rate is also observed with high extinction and origination rates at specific level. During this time-interval, the fauna is relatively endemic and is also composed of some long-ranging taxa known from the Eifelian in each studied country (Maillet *et al.*, 2013a, b, in press).

Between the middle *P. varcus* to the *S. hermanni* zones, *i.e.* the crisis interval, all the studied areas show the same trends. From the middle to the upper *P. varcus* zones, the diversity (taxonomic richness and diversity indices) strongly decreases both at generic and specific levels. This phenomenon is coupled to high extinction rates and a marked drop of origination rates. Poly-cohort analyses also show a major peak of extinction, both at the generic and specific levels. Indeed, about 70% of the species known during the Early Givetian to the early Middle Givetian persist into the middle *P. varcus* Zone, while only 30% still survive in the upper *P. varcus* Zone. Only 45% of the species known during the middle *P. varcus* Zone persist into the upper *P. varcus* Zone. In the upper *P. varcus* and *S. hermanni* zones, a high dominance characterizes the ostracod assemblages.

From the *S. hermanni* to the lower *M. falsiovalis* zones, *i.e.* the post-crisis interval, different phases can be pointed out. The *S. hermanni* and *K. disparilis* zones show a very low specific richness and a high dominance. Maillet *et al.* (2013b, c) reported low diversified ostracod assemblages with a high individual abundance, and sometimes monospecific beds during this time interval in the Givet area. In the Saoura, entomozoidean ostracods clearly dominate assemblages (Maillet *et al.*, 2013a). From the *K. disparilis* Zone, diversity and equitability progressively increase and poly-cohort analyses show a peak of origination at the specific level. About 40% of new species appear, which are more cosmopolitan (Lethiers, 1983; Maillet *et al.*, 2013a, b, in press). In the Saoura, no ostracods were found above the *S. hermanni* Zone; however, a faunal turnover could be supported by an Early Frasnian ostracod fauna different from the Mid-Devonian one (Casier, 1982, 1985).

At specific level especially, the evolution of the neritic ostracods diversity was characterized by a major decline resulting from a reduction of the provincialism and some local disappearance of taxa (as Leperditicopids in the Ardenne; Casier *et al.*, 2015) caused by the global Taghanic Biocrisis. The disturbance in ostracod faunas extends from the middle *P. varcus* to the beginning of the *K. disparilis* zones. In all the studied areas, a post-crisis phase occurred from the *S. hermanni* to the *K. disparilis* zones, characterized by low diversified ostracod assemblages with a high individual abundance. Predominant short-ranging Eridostracina and Platycopina species always occurred in such assemblages (Maillet *et al.*, 2013b, 2013c, in press) and could be opportunistic taxa settling in disturbed environments. A late recovery of the ostracod fauna occurred between the *K. disparilis* Zone and the Early Frasnian with a major turnover at the specific level characterised by taxa more cosmopolitan than previously.

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Givetian ostracods of the Candás Formation (Asturias, north-western Spain): taxonomy, stratigraphy, palaeoecology, relationship to global events and palaeogeographical implications

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During the Middle Devonian, the Cantabrian Zone (*i.e.* Asturian, Leonese and Palentian domains) was a wide reefal carbonate platform belonging to the western part of the European Hunic superterrane (Stampfli *et al.*, 2002), a set of terranes drifting in the southern hemisphere tropical area between the Laurussian and Gondwanan supercontinents. For the first time, ostracods of the carbonate Candás Formation (= Fm) are documented, thus completing the knowledge on Givetian ostracod faunas from Asturias, too little known to date. The Peran–Perlora and Carranques key-sections constitute the stratotype of the Candás Fm (Truyóls & García-Alcalde, 1981; García-López *et al.*, 2002). These two sections are complementary and well expose the whole formation, subdivided into four members (= Mb) named A, B, C and D, and reaching a total thickness of about 200 m. The base of the formation belongs to the lower *P. varcus* conodont Zone and refers to a Middle Givetian age; its top belongs to the lower *M. falsiovalis* Zone and is Early Frasnian (García-López *et al.*, 2002). About 1,230 carapaces, valves and fragments of ostracods were extracted from 44 samples by means of the hot acetolysis method. In all, 75 taxa have been identified, of which 22 are in formal description and one is new: *Evlanella* n. sp. These taxa belong to the suborders Paleocopina (19), Platycopina (10), Eridostracina (4), Metacopina (18) and Podocopina (24). All these taxa are marine benthic and belong to the Eifelian Mega–Assemblage (= "Eifelian ecotype" *in* Bandel & Becker, 1975; Casier, 1987, 2008). Through all the formation, ostracod assemblages are representative of environments fluctuating from semi–restricted conditions to shallow open–marine settings above the storm wave base. Changes in ostracod assemblages well reflect the general transgressive–regressive cycles through the series. The most part of the lower half of the formation (Mb A and B) provided ostracod assemblages with dominant podocopids, of which some thick–shelled ostracods (*Tubulibairdia* and *Bairdiocypris*), associated to abundant debris of reefal organisms, indicative of fore–reef shallow environments, with periodically very agitated waters. In these members, the depth periodically lightly increases up to below the FWWB, as attested by a diversification within paleocopids, platycopids and metacopids. The base of the Mb C shows a deepening of the environment, exhibiting assemblages with diversified Podocopina, Platycopina, and Metacopina, of which *Polyzygia* and *Jenningsina*. Above, a couple of samples of the Mb C show an overwhelming abundance of Platycopids, with especially *Uchtovia refrathensis* and *Evlanella* n. sp. sometimes representing up to 60% of the ostracod assemblage, always associated to Eridostracina. Such assemblages are indicative of a back–reef semi–restricted environment. The overwhelming abundance of platycopids coupled to low diversity of ostracods suggest instability of the environment, as salinity fluctuations (Benson, 1973), oligotrophy (Horne *et al.*, 2011), hypoxic conditions (Lethiers & Whatley, 1995), or both. From the top of the Mb C to the top of the formation, ostracod assemblages become more diversified and indicate a progressive deepening of the environment. Environments are open–marine, with a water depth always below the FWWB and sometimes to below the SWB. Stratigraphical distribution of the ostracod taxa shows a deep faunal renewal in the upper part of the Candás Fm. The Mb A provided 34 taxa, of which 21 still exist at the base of the Mb B and 15 are still present at the base of the Mb C. Although some new taxa also progressively appear through this entire time interval, the set of ostracod taxa is rather stable in the 110 basal meters of the formation and is composed of long–ranging taxa, of which many, such as *Loquitzella mesodevonica* and *Praepilatina praepilata,* are known from the late Emsian to the Eifelian in the Cantabrian Zone (Becker & Sánchez de Posada, 1977; Becker, 1988, 1989, 1998, 2000, 2001). The ostracod assemblage differs at the top of the formation (upper part of the Mb C and Mb D). The base of the Mb D shows only 1 of the 34 taxa found in the Mb A and only 3 of the taxa found in the Mb B. In the upper half of the Mb C, 19 new taxa appear, and then 3 other in the Mb D. Almost all the long–ranging taxa found at the base of the Candás Fm disappear at the base of the Mb C. The lower half of this member is characterized both by unstable environments and occurrence of some short–ranging opportunistic ostracod taxa, as *Evlanella* n. sp., *Cryptophyllus* sp. P2 and *Uchtovia refrathensis.* Then, all the previous species are replaced above, around the Middle–Late Givetian boundary, by more cosmopolitan taxa characteristic of the Frasnian, as *Jenningsina lethiersi, Jenningsina paffrathensis, Quasillites quasillitiformis* and *Polyzygia beckmanni beckmanni.* This renewal within shallow water ostracods communities is a consequence of the global Taghanic Biocrisis, world–widely leading to extinctions in several faunal groups (*e.g.*, Aboussalam, 2003). The same phenomenon has been reported in ostracod faunas, with a similar faunal succession through time, from the Ardennes and the Saoura (Maillet *et al.*, 2013a, 2013b). Faunal affinities with Givetian taxa reported in other areas of the world reflect the commonly accepted palaeogeographical patterns. Close relations between the Cantabrian Zone (NW–Spain), the Armorican Massif (W–France), the Mouthoumet Massif (S–France) and the North Africa suggest a narrow oceanic space between the western European terranes and the northern Gondwanan margin that consequently involves an advanced phase of closure of the Medio–European Ocean already during the Givetian.

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The Devonian–Carboniferous boundary in the Saoura Valley (western Algerian Sahara)

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In order to locate the Devonian–Carboniferous boundary in the Saoura Valley (Ougarta Basin), we have only studied the Ouarourout section in its northern part, and the Béchir and Tamtert-Zereg sections in its southern part.

The identification of macrofaunas was made by C. Crônier for the trilobites, D. Brice and B. Mottequin for the Devonian brachiopods (rhynchonellides), D. Korn for the ammonoids, and M. Legrand-Blain for the early Tournaisian brachiopods. Concerning the microfaunas, L. Samar and C. Randon identified the palynomorphs and the conodonts, respectively.

In the Saoura Valley, the Marhouma Formation (*e.g.*, Crônier *et al.*, 2013; Mottequin *et al.*, 2015) is subdivided into four members extending from the Frasnian up to the late Famennian. It is followed by the latest Famennian Ouarourout Formation. The latter is overlaid by the Tournaisian Ouled Bou-Hadid Formation.

This study is focused on the interval ranging from the Member 4 of the Marhouma Formation to the end of the Ouled Bou-Hadid Formation. The Member 4 consists of shales with some "griotte" levels, but also sandy and silty deposits of turbiditic origin. The latter are more developed than the "griottes" due to the sedimentary supply rate, which was higher than the increase of the relative sea level. The "griottes" are represented by thin levels, and sometimes only by nodules.

The *Goniclymenia* Zone, which has already been recognized in the upper part of the Member 3 of the Marhouma Formation, is also reported in the Member 4 in the Tamtert-Zereg and Béchir areas. In the Ouarourout area, the Famennian V is identified only on the basis of the occurrence of *Pugnaria* sp. within the lower part the Member 4 (Mottequin *et al.*, 2015). Nevertheless, in the Tamtert-Zereg area, the *Gonioclymenia* Zone is followed probably by the *Wocklumeria* Zone as indicated by the presence of numerous *Cymaclymenia* sp. associated to dwarf forms of *Rabienops wedekindi*, confirming a do VI age. Moreover, Petter (1960) already reported ammonoids of the *Wocklumeria* Zone from a shale layer underlying this level of "griotte" limestones. The dwarfism of these trilobites heralds their extinction, linked to the Hagenberg Event.

The turbiditic character of the deposits of the Member 4 predominates in the south-eastern part of the Saoura Valley and reflects a deepening phase of the basin. The last level of griotte limestones with *Cymaclymenia* sp. crops out only at Tamtert-Zereg and marks the end of the Marhouma Formation. This "griotte" level corresponds to a marine incursion in this area. At Ouarourout, the shales of the upper part of this member yielded late Famennian palynomorphs whereas in the Tamtert-Zereg section, the palynomorphs also include species that are typical of the D–C boundary.

From NW to SE, shales alternating with slumped sandstones succeeded the turbiditic deposits and belong to the Ouarourout Formation. They have always been interpreted as regression deposits in all the Saharan basins. In the Ouarourout area, *Vallatusporites pusillites* (Kedo) Dolby & Neves, *Umbellasphaeridium saharicum* Jardiné *et al.* and *Umbellasphaeridium* sp. have been recovered from the upper part of the Ouarourout Formation and indicate a late Famennian age. Therefore, we cannot affirm the existence of a sharp regression, because this assemblage of miospores and acritarchs already indicates a marine environment with continental influences. In this area, the transgression took place at the end of the latest Famennian and not at the base of the Tournaisian.

The early Tournaisian conformably lies on the latest Famennian only to the north of Ouarourout, whereas in some boreholes located northernmost of the Saoura Valley, an angular unconformity was detected between the Devonian and the Carboniferous strata. This unconformity is a proof of the Breton phase of the Variscan orogeny (Malti *et al.*, 2008). The base of the Tournaisian is indicated by the appearance of a thin limestone bed (named here "Conrad level"), which is rich in reworked conodonts of the upper *expensa* Zone that are associated to other conodonts characteristic of the early Tournaisian *sulcata* Zone. The "Conrad level" is overlaid by clear shales that include a single occurrence of numerous *Acutimoceras* sp. and *Gattendorfia* sp. of the *Gattendortfia* Zone (or Zone VII). Conversely, in the contemporaneous Kahla Formation (Timimoun Basin), ammonoid occurrences belonging to the same zone are more numerous in shaly intercalations (Ebbighausen *et al.*, 2004).

The Ouled Bou-Hadid Formation is notably characterized by thick red shale deposits, interrupted by two thin levels of limestones rich in basal Hastarian brachiopods (Pareyn, 1961; Malti *et al*., 2008). These deposits are capped by a thin limestone bed, which yields numerous late Hastarian brachiopods. Their thickness shows the importance of the basin filling phase, interrupted by some marine incursions during this period.

In the Saoura Valley, the D–C boundary is located in the upper part of the Member 4 of the Marhouma Formation in the Tamtert-Zereg area, whereas, in the Ouarourout area, this boundary has to be placed in the upper part of the Ouarourout Formation, 10 m below the “Conrad level”. We have thus identified a clear diachronism in this part of Ougarta Basin. Contrary to the previous workers, we have concluded that, during the D–C transition, the sea first invaded the south-eastern part of the basin and reached later its north-western part.

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The Siluro-Devonian age confirmation based on radiolarian biostratigraphy and zircon dating

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The dating of radiolarian biostratigraphic zones from the Silurian to the Devonian has only partially been established even on a world-wide scale. Dating zircons in radiolarian-bearing tuffaceous rocks has enabled us to show absolute ages in comparison to the radiolarian zones. To precisely date the previously disputed ages of the local formations and to establish an age-constraint for the radiolarians, radiometric dating of magmatic zircons within the radiolarian-bearing Hitoegane, Yoshiki and Shibasudani formations in the Hida-Gaien belt, central Japan was undertaken. These formations are mainly composed of alternating beds of tuffaceous sandstones, tuffaceous mudstones and felsic tuff. The felsic tuff and tuffaceous mudstones yield well-preserved radiolarian fossils.

In total, 50 zircon grains were analyzed by U-Pb LA-ICP-MS and the age of *ca*. 426 Ma was obtained from the horizons between the *Pseudospongoprunum tauversi* to *Futobari solidus–Zadrappolus tenuis* assemblage zones in the Hitoegane Formation (Manchuk *et al*., 2013b). The result shows that the boundary of the two assemblage zones is around the Ludlow.

Radiolarians and zircons were collected from the Yoshiki Formation. The radiolarian species are assigned to the *F. solidus–Z. tenuis* assemblage, and U-Pb SHRIMP ages of *ca.* 420 Ma were obtained from 67 zircon grains (Manchuk *et al*., 2013a). Thus the *F. solidus–Z. tenuis* assemblage survived up to the Pridoli age in the Yoshiki Formation.

Zircons showing the U-Pb SHRIMP age of *ca.* 408 Ma (Aichison *et al*., 1996) were reported from a horizon of 20 m above of the last occurrence of *F. solidus* at Kurosegawa belt, southwest Japan. Thus the range of the *F. solidus–Z. tenuis* radiolarian assemblage Zone can be assigned to be from Ludlow to Pragian or Emsian.

The results shown here bear the possibility to extend the revision and to refine the previous dating of many biozones worldwide, and in particular can be a promising method for the entire study of radiolarian biostratigraphy.

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An early Carboniferous palaeoclimate record from East Greenland

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A significant question in Romer's Gap is the interaction of the tetrapods with the prevailing climate. In other words, was the climate sufficiently extreme or with significant short time scale perturbations to be acting as a driver for tetrapod evolution. The TW:eed project tetrapods are largely from the Scottish Borders with smaller numbers of specimens from both Nova Scotia and West Virginia. A palaeoclimate record is being compiled in the Borders from both the Burnmouth shore section and the West Mains Farm Borehole at Norham. However, both these sections still lack a proven Devonian–Carboniferous (D–C) boundary and have been generally inferred to lack an identifiable the early Tournaisian section. Much of the climatic information is also somewhat indirect as it involves interpreting the interplay of fluvial, lagoonal and marginal marine environments.

In the East Greenland Devonian Basin tetrapods have disappeared from the record by the latest Famennian. However, there are a number of sections that have stratigraphic continuity from an identifiable D–C boundary through to the Viséan and hence encompass the entirety of Romer's Gap. In addition, East Greenland was in a central location within the ORS Continent and within the southern hemisphere arid zone. Hence, it gives us a very direct palaeoclimate record derived entirely from a long lived fluvial system and can be calibrated using palynology. The preserved parts of the Devonian Basin are also very significant in size (350 x 150 km) and this permits a number of contrasting sections to be measured that enable us to better understand the stratigraphy and palaeoclimate.

Sections have been measured on Stensiö Bjerg, Gauss Halvø; Celsius Bjerg, Ymer Ø; Backlund Ridge, Geographical Society Ø and Rebild Bakker, Traill Ø.

From these Stensiö Bjerg, which has the best developed D–C boundary section can be discounted since the overlying "Harderbjerg Formation" is almost certainly the continental Permian that has truncated the post-Devonian sequence.

The section on Celsius Bjerg is the most complete but unfortunately is entirely devoid of palynomorphs above the D–C boundary. However, comparisons with the sections at Backlund Ridge and Rebild Bakker enable a base Viséan to be picked. The Celsius Bjerg section shows a clear evolution of climatic events from the lacustrine flooding at the D–C boundary. This is followed by an interval dominated by a very active fluvial system but with seasonal aridity. Climatically this is not too dissimilar to the D–C boundary lake system. There is then a second shorter and less intensive aridity/lacustrine cycle. By analogy with the calcrete-lacustrine cycle that is the far-field record of the D–C boundary glaciation this return to a shallow lacustrine system is interpreted as the mid–late Tournaisian Alaunschiefer black shale and matched in South Africa by the Miller Diamictite and overlying Soutkloof Shale. This is then followed by an episode of rather intense aridity before the system changes to the coarser less mature sandstone, fossil plants return and the age by correlation is probably Viséan.

Backlund Ridge has an excellently exposed latest Famennian Stensiö Bjerg section that is dominated by lake cycles. However, coincident with the D–C boundary there is a 40m gap in the section that covers the key earliest Carboniferous interval. However, intermittent exposure above this level reveals a section dominated by sediments showing seasonal aridity. The return of near complete exposure marks the switch to a much wetter climate with thin coals and large lycopod stems. These sediments contain *Lycospora pusilla* which palynologically defines the base of the Viséan.

The section at Rebild Bakker is the thickest and most proximal. Unfortunately there are structural complications that make it difficult to recognise a complete sequence. But importantly there is a palynological record through the lower part of the sequence (Harderbjerg Formation) that represents a seasonally wet climate and contains key palynological inceptions (*Umbonatisporites distinctus*, *Spelaeotriletes obtusus*, *Grandispora uncata* and a lycopod megaspore) and enables recognition of a similar flora to that found in the Scottish Borders. The palaeoclimate was sufficiently wet to form small shallow lakes. After this there is a profound episode of late Tournaisian aridity with intensive and sustained vertisols indicating a dry climate with low seasonality. This is followed by a rather sudden change to much wetter climates characterised by coarse immature sandstone with thin coal seams and large and conspicuous lycopod stems. Again this is accompanied by *Lycospora pusilla* and is Viséan in age.

In summary, the Tournaisian in East Greenland (Vigran *et al.*, 2009) represents an initially wet but seasonally arid climate followed by minor lacustrine conditions before a prolonged interval of aridity. This was not an intense aridity but rather low seasonality without an intensely hot summer that would have driven monsoonal rains into the system. The switch to the warm ever wet Viséan conditions is quite marked. Currently this is interpreted as a chronostratigraphic event coincident with the regional spread of large lycopods with *Lycospora pusilla*. A pertinent question is whether the inception of *Lycospora pusilla* which is used to palynologically define the base Viséan is a chronostratigraphic datum rather than the diachronous migration of large lycopods. There is a palaeo-equatorial Tournaisian section on Svalbard where the spores were documented by Playford (1962, 1963). Here there is a lower interval of Tournaisian that predates the inception of *Lycospora* and is arid in character. The inception of *Lycospora* (as *L. uber*) is coincident with a change to wetter conditions. This implies both that the late Tournaisian aridity extends into the palaeoequatorial regions and that its amelioration may be controlling the spread of the large *Lycospora* lycopods.

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The expression of the Hangenberg Event (Latest Devonian) in a relatively shallow-marine succession in Poland

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Much activity is currently directed towards precise documentation of the Hangenberg Event/crisis interval at the end of the Devonian Period. The advances in fine-scale stratigraphic studies have been dependent upon integration of information from a wide range of stratigraphic techniques, in particular those combining high-resolution microfossil biostratigraphy with different instrumental methods, *e.g.* geochemical and petrophysical analyses. Most investigations focused on deeper marine facies where the Hangenberg Event/crisis interval manifests by the presence of the Hangenberg Black Shale horizon, often overlain by sandstones, synchronous in widely separated regions. Their presence is explained by short-term global climatic fluctuations at the end of the Devonian Period. By contrast, relatively shallow-water sequences have rarely been studied comprehensively, and few records of organic, inorganic and rock magnetic proxies have been obtained.

The uppermost part of the Famennian and lowermost part of the Tournaisian deposits in the Pomeranian Basin (NW Poland) belong to the Sąpolno Calcareous Shale Formation, which is a succession of open-marine carbonate and clayey deposits (Matyja, 1993, 2009). The Devonian–Carboniferous (D–C) boundary interval is marked by monotonous, thin-bedded, dark grey marls, marly claystones and claystones, with only thin marly lime mudstone intercalations, which show a general absence of fauna (Matyja, 1993, 2009). Only well-preserved miospores are common.

The transition from the Devonian to the Carboniferous in a reference section of the relatively shallow carbonate ramp environment within the Pomeranian Basin has been analysed in detail within two miospore interval zones, the Famennian *Retispora lepidophyta–Verrucosisporites nitidus* (LN) and Tournaisian *Vallatisporites verrucosus–Retusotriletes incohatus* (VI). Few changes in depositional conditions in macroscale are observed close to the D–C boundary interval and the stratigraphically important Hangenberg Black Shale horizon is not developed here. To constrain the nature of the Hangenberg Event in such facies, some complementary methods as the inorganic (major and trace elements and stable isotopes) and organic geochemistry as well as analysis of the magnetic properties of rocks, have been employed to infer the redox, sea-level and palaeoclimatic history of the Pomeranian Basin (Matyja *et al.*, 2015). The sedimentary succession analysed and specific phenomena recognized close to the D–C boundary, such as fluctuations in water column euxinia, wildfire evidence, perturbations of the carbon cycle reflected in positive carbon excursions and relative sea-level changes, display a pattern partly similar to that observed in many areas of Europe and even in Poland, although the Hangenberg Black Shale horizon within the LN miospore Zone, the important latest Famennian correlative horizon, is not developed here.

Some important microscale environmental perturbations recognized have been observed not only within the LN miospore Zone but also in a wide interval between the LN and VI miospore zones. It is still questionable whether the recognized event(s) was (were) connected with the Hangenberg Event/crisis, which possibly was more complex and multi-phased then has been suggested, or whether it was a series of regionally limited, post-Hangenberg events.

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Conodonts from Pragian and Emsian boundary intervals in different facies of the South Urals

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Pragian deposits from the western South Urals correspond to reefal facies (Hercynian limestones). They are present in the classic sections of the West Zilair Zone in the latitudinal segment of the Belaya River. Their subdivisions, which are traditionally based on diverse brachiopods and corals, are well correlated with those established on identical fauna in other Russian regions but also with the Barrandian area (Tyazsheva *et al.*, 1976). Thirteen brachiopod species from Kulamat and Tutulen horizons also occur in Czech Republic and *Latonotoechia latona* (Barr.) and *Cymostrophia stephani* (Barr.) are the most important ones (Tyazsheva *et al.*, 1976). Nevertheless, Pragian–Emsian boundary deposits still remain poorly known.

The first study of conodonts from the typical Hercynian sections in the West Zilair zone (Mavrinskaya & Slavík, 2013), as well as in deep-water bathyal facies in Mayak-Tau Klippe located south to Ufimian Amphitheatre (Fig. 1), revealed the characteristic conodont associations of the Lower Pragian–Lower Emsian interval.

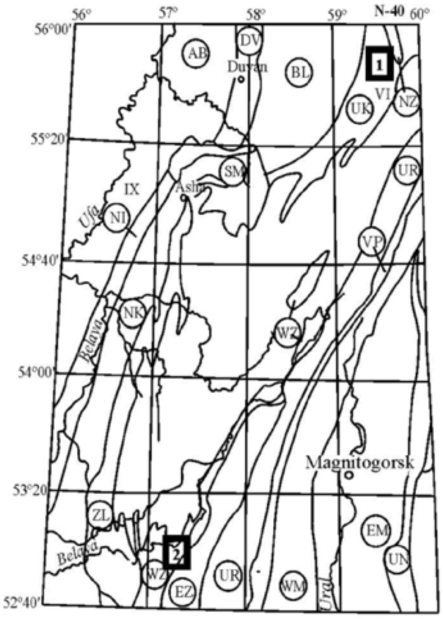

Fig. 1: Zonation scheme of the Palaeozoic deposits from the South Urals (Legend, 1999). Structural zones are marked with capital letters in circles: AB, Abdullino zone; DV, Duvan zone; BL, Belokatay zone; UK, Unkurdan zone; NZ, Nyazepetrovsk zone; SM, Sim zone; NI, Nezhinsk-Ishimbai zone; NK, Nikol'sk-Krasnousol'sk zone; ZL, Zilim-Zigan zone; AB, Abzanovo zone; WZ, West Zilair zone; EZ, East Zilair zone; UR, Uraltau zone; VP, Voznesenka–Pre-Sakmara zone; WM, West Magnitogorsk zone; EM, East Magnitogorsk zone; UN, Ui–Novoorenburg zone. Rectangles with a bold outline mark the studied areas: (1) Mayak-Tau Klippe; (2) Mindigulovo.

Lochkovian–Pragian boundary deposits in Mindigulovo section (eastern latitudinal length of the Belaya River) are composed of organogenic and bioclastic grey and dark-grey limestones that yield brachiopods, crinoids, ichtyofauna and rare conodonts. The *ca.* 2,85 m-thick interval belongs to the *gilberti* conodont Zone in which *Pedavis gilberti* V.-Ríos, *Pandorinellina optima* (Mosk.), *P. exigua philipi* (Kl.), *Masaraella pandora* (M., Matti & Wall.), and *Eognathodus sulcatus* (Phil.) have been recovered. Incumbent ca. 20 m-thick interval includes thick-bedded, light dolomitic limestones with rare macrofaunal remains such as crinoids and brachiopods. The presence of lenticular interlayer of plicated black shales is noteworthy (Fig. 2A). The Early Pragian age of this interval is based on the identification of conodonts of the *irregularis* conodont Zone such as *Eognathodus irregularis* M. associated with *E. sulcatus* morphotype *eta* (?) M., Matti & Wall., *Icriodus steinachensis* (Al-Rawi) morphotype *eta* Kl. & John., *Pelekysgnathus* cf. *serratus serratus* Jent., and *Pandorinellina* cf. *miae* (Bult.)

Because the reefal limestones do not contain stratigraphically significant conodonts, the dating and correlation of the Upper Pragian deposits in the Hercynian-type sections (Tutulen Horizon) remain problematic. An analogous situation occurs with the overlying sandy-carbonate deposits of Emsian age (Irgizla Horizon). Lower Emsian conodonts were only recovered from the Malyi Ik section (Maslov *et al.*,

1983) where *Polygnathus dehiscens* and *Pol. gronbergi* occur together in reefal limestones. The age and the stratigraphic position of the regional stratigraphic chart are not quite clear.

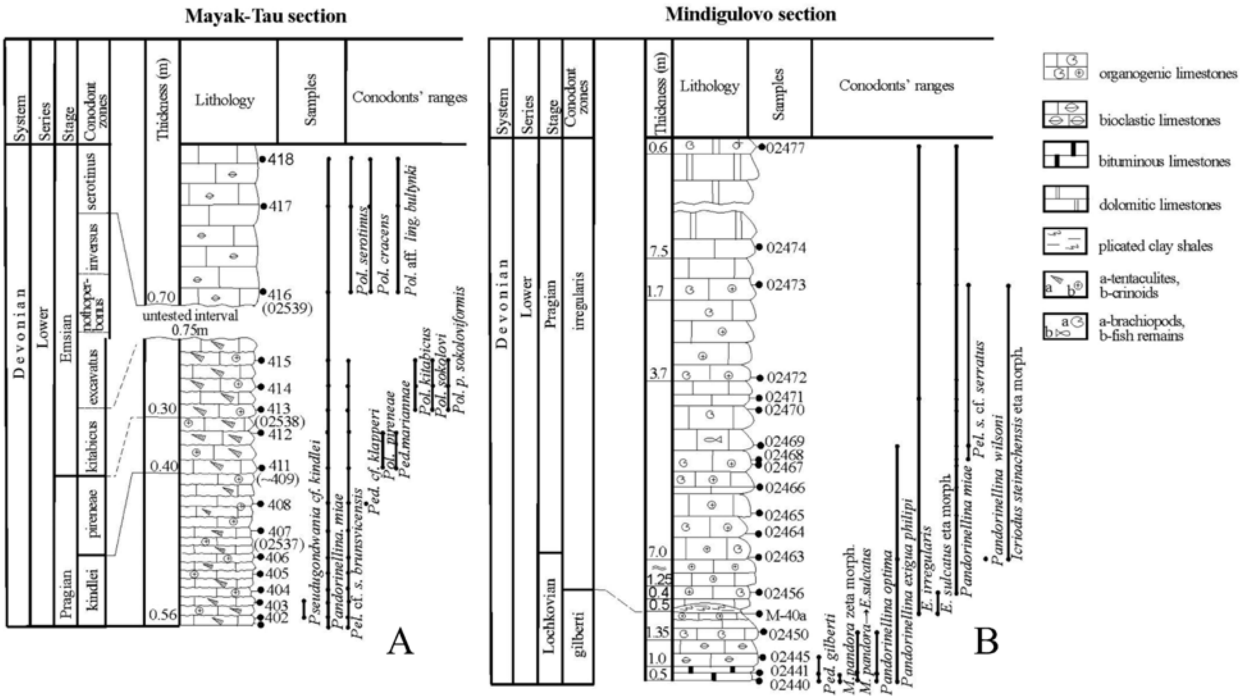

Fig. 2: Distribution of the most relevant conodont taxa in the uppermost Lochkovian to the Lower Pragian in the Mindigulovo section (A) and in the Upper Pragian to the lowermost Emsian in the Mayak-Tau section (B).

The biostratigraphical succession of the Pragian–Emsian interval is currently studied in the deep-water facies of the northern part of the western South Urals (south to Nyazepetrovsk zone) (Fig. 1). In Mayak-Tau Klippe, the Upper Pragian and Lower Emsian deposits correspond to a siliceous-carbonate succession (Zastavka suite) visible in a single outcrop (light grey and grey feebly bedded microbioclastic limestones). They usually contain abundant but poorly preserved tentaculites and fragments of crinoids and brachiopods. The Upper Pragian interval is characterized by conodont association of *kindlei* Zone with *Belodella resima* (Phil), *Pseudogondwania* cf. *kindlei* (Lane & Orm.), *Pandorinellina* cf. *miae* (Bult.), *Pedavis* cf. *klapperi* (Bard.), *Pelekysgnathus serratus brunsvicensis* V.-Rios, and *Pseudooneotodus beckmanni* (Bisch. et Sann.) (M-401–408, see Fig. 2A, 3).

The Pragian–Emsian boundary interval includes the uppermost Pragian conodont complex with *Pandorinellina* cf. *miae* (Bult.), *Pedavis mariannae* Lane and Orm., *Polygnathus pireneae* (Boer.) (M-409, M-411, 412) whereas the basal Emsian association corresponds to *P.* cf. *miae* (Bult,), *Pol. kitabicus* Yolk. *et al.*, *Pol. sokolovi* Yolk. *et al.*, and *Pol. pireneae* Boer. *sokoloviformis* morph (M-413–415, 02538, see Fig. 2A, 3). After a untested 0.75 m-thick interval, the limestones, which become thick-bedded, bioclastic and silicified, contain a Upper Emsian conodont complex: *Belodella* cf. *devonica* Stauff., *Pol.* cf. *cracens* Ziegl. *et al.*, *Pol. foliformis* Sn., *Pol.* aff. *linguiformis bultyncki* Wedd., and *Pol. serotinus* Telf. (M-416-418, 02539, see Fig. 2A).

Thus, in the South Urals, the Pragian and Emsian boundary interval, in shallow- and deep-water settings, can be characterized by the conodonts. The Lower Pragian boundary is fixed in shallow-water shelf facies in the West-Zilair zone. It contains abundant and diverse benthic macrofauna and to a lesser extent, nektonic and planktonic microfauna such as fish remains and rare, poorly diverse conodonts. The Lower Emsian is recognized within the bathyal deposits of the Bardym zone (Ufimian Amphiteatre) in Mayak-Tau Klippe (Fig. 2B), where conodonts and tentaculites are abundant and diverse. Specifically, the conodont associations occurring in deep-water facies in the South Urals are correlated quite accurately with the standard conodont zonation. The Mindigulovo section is important for the correlations between shallow- and deep-water sections due to the distribution of eognathodontid taxa and the presence of *I. steinachensis* marking the Pragian boundary in shallow-water facies like in the stratotype area.

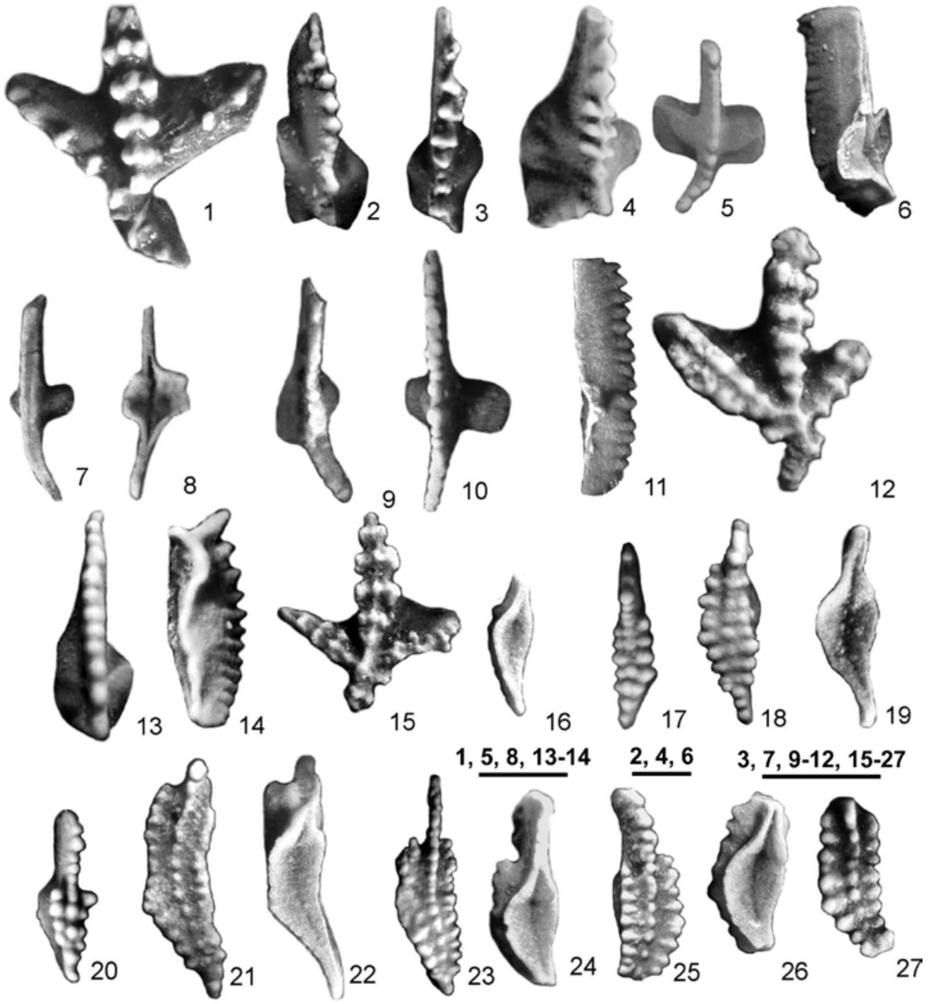

Fig. 3: Selected Upper Pragian and Lower Emsian conodonts from the Mindigulovo (1–6) and the Mayak-Tau sections (7–27). (1) *Pedavis gilberti* Valenzuela-Ríos, upper view of I-element, sample 02440. (2) *Pelekysgnathus* cf. *serratus serratus* Jentzsch, upper view of I-element, sample 02467. (3) *Eognathodus* cf. *irregularis* Murphy, upper view of Pa-element, sample M-40a. (4) *Icriodus steinachensis* (Al-Rawi) morphotype *eta* Klapper & Johnson, upper view of I-element, sample 02463. (5, 6) *Masaraella* cf. *pandora* morphotype *zeta* Murphy, Matti & Wallizer: (5) upper view of Pa-element, (6) lower-lateral view of Pa-element, sample 02440. (7–9). *Pseudogondwania* cf. *kindlei* (Lane & Ormiston,): (7, 9) upper view of Pa-element, sample 402, (8) lower view of Pa-element, sample 02537. (10–11). *Pandorinellina* cf. *miae* (Bultynck): (10) upper view of Pa-element, sample 02538, (11) lateral view of Pa-element, sample 408. (12) *Pedavis* cf. *klapperi* (Bardashev), upper view of I-element, sample 408. (13–14) *Pelekysgnathus* cf. *serratus brunsvicensis* Valenzuela-Ríos: (13) upper view of I-element, 14 – lateral view of I-element, sample 409. (15) *Pedavis mariannae* Lane and Ormiston, upper view of I-element, sample 412. (16–19) *Polygnathus pireneae* Boersma *sokoloviformis* morph: (16, 19) lower view of Pa-element, (17, 18) upper view of Pa-element, sample 2538. (20) *Polygnathus* cf. *pireneae* (Boersma), upper view of Pa-element, sample 412. (21–23) *Polygnathus sokolovi* Yolkin, Weddige, Izokh et Erina: (21, 23) upper view of Pa-element, (22) lower view of Pa-element, sample 2538. (24–27) *Polygnathus kitabicus* Yolkin, Weddige, Izokh. et Erina: (24, 26) lower view of Pa-element, (25, 27) upper view of Pa-element, sample 2538. Scale bars: 0.5 mm.

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New Middle to early Late Devonian aneurophytales showing dissected appendages from southeastern Australia

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The progymnosperm Aneurophytales were abundant and diverse in Laurussia during the Middle to early Late Devonian time interval. They were rare and poorly known elsewhere. Two genera, *Rellimia* and *Aneurophyton,* have been recorded from the Siberian and Kazakhstan paleoblocks, and terranes in-between. Three genera have been described from Gondwana, *Tetraxylopteris* in Venezuela, *Rellimia* and *Aneurophyton* in central Morocco. Evolutionarily, the Aneurophytales are the most ancient group of euphyllophytic plants possessing secondary phloem, a vascular tissue involved in the long-distance transport of photosynthates and other substances such as hormones and proteins. This new character may have been of special importance for euphyllophytes gaining height/length in the Devonian. Morphologically, it is one of the most ancient group of plants in which branching was both profuse and entirely pseudomonopodial (*i.e.* resulting in two unequally developed branches). Ecologically, the aneurophytaleans preserved in the famous Givetian paleosol of Riverside Quarry (New York State) have been interpreted as rhizomatous and forming the understorey of a cladoxylopsid (ferns *sensu lato*) forest.

A plant assemblage consisting of lycopsids and aneurophytalean progymnosperms is documented for the first time in Australia. Plants occur at Bunga Pinch Quarry, on the south coast of New South Wales. They are associated with fishes in the Bunga beds, a sedimentary unit corresponding to freshwater deposits at the base of the Boyd volcanic complex. Age constraints on the Bunga beds have been discussed with no consensus reached yet.

The aneurophytalean remains from Bunga Pinch Quarry are represented by one fertile and several vegetative specimens which all show the decussate pattern of branching characterizing the genus *Tetraxylopteris*. The shape and arrangement of the ultimate appendages suggest that the vegetative specimens, at least, may belong to a new species. The association of *Tetraxylopteris* with large lycopsids at Bunga Pinch Quarry constrains the age of the Bunga beds to the Givetian – Frasnian interval. The diversification of a dissected type of ultimate appendages in the genus *Tetraxylopteris* is noteworthy when considering that some supposedly more basal euphyllophytes from South China had evolved laminate ultimate appendages as early as the Early Devonian. The functional significance of this character and the possibility that *Tetraxylopteris* was adapted to xeric conditions are evaluated.

Environment and habitat variation on the Tournaisian (early Carboniferous) coastal plain of northern Great Britain

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Recently discovered vertebrate fossils from the early Carboniferous (Tournaisian) of south-east Scotland provide insights into the terrestrialisation of tetrapods during the rebuilding of ecosystems in the early Carboniferous, following mass extinction events towards the end of the Devonian. An understanding of the sedimentary environments in which these tetrapods lived provides a wealth of information about the range of potential habitats present and of the palaeoclimate. This is a key remit of the multidisciplinary TW:eed Project (**T**etrapod **W**orld: **e**arly **e**volution and **d**iversification. www.tetrapods.org). At this time Northern Britain lay in equatorial latitudes. The break-up of the "Old Red Sandstone" continent during late Devonian and early Carboniferous time led to the development of sedimentary basins in the Midland Valley of Scotland and Northumberland Basin, alongside "upland" areas approximately coincident with the present day Southern Uplands, the Cheviot Hills and the Lake District-Alston Block.

The tetrapod faunas are hosted by the Tournaisian Ballagan Formation, a thick succession of grey siltstone- and cementstone-dominated facies, interpreted previously as having been deposited on an extensive, largely flat, coastal alluvial plain to marginal marine environment (Anderton, 1985). The abrupt appearance of the grey beds at the base of the formation represents a major change to wetter conditions from the arid or semi-arid fluvial sandstones with calcretes of the underlying Kinnesswood Formation. In the Northumberland Basin this change coincides with basaltic volcanism which marks rapid basinal extension (Chadwick *et al*., 1995). The palaeoenvironments represented by the Ballagan Formation have been investigated through detailed analysis of two sections through the approximately 500 m-thick formation near the England–Scotland border; one is a complete sequence at outcrop and the other the fully cored Norham borehole. Isolated exposures of the formation across this area have also been studied in detail providing snapshots of the range and spatial distribution of depositional environments. A broader perspective of the sedimentary architecture across the basins is gained from less detailed lithological logs of more than 20 boreholes drilled during the period 1965-1986 across the region and archived at the British Geological Survey's National Geological Repository.

The dominant siltstone facies is interbedded with many thin beds of cementstone, units of evaporites and fluvial sandstone bodies. Variations in the proportions of cementstone, evaporites and sandstone can be assessed across the region from the archived borehole logs though this study is the first to recognise the importance of microconglomeratic siltstone and paleosols to the interpretation of this succession. Cementstones constitute a key, but diverse, component of the Ballagan Formation. They occur in beds typically <1 m thick and their frequency of occurrence through the succession varies both laterally and vertically. Though some cementstones represent diagenetically cemented floodplain silts and fine sands, the character of the others indicates formation in lagoons subjected to short-lived marine transgressions, in floodplain lakes with some clastic sediment input, and in saline lakes, some associated with sabkha environments. The importance of supra-tidal sabkha deposits in the succession is only appreciated from the borehole logs. Gypsum and anhydrite beds up to 1 m thick occur in south-east Scotland and in the Northumberland Basin, and accumulated through evaporation from bodies of standing water. Nodular gypsum is abundant across parts of the Midland Valley Basin but is notably absent locally. The proportion of sandstone varies from <10% along the northern margin of the Midland Valley of Scotland to > 40% in south-east Scotland and adjacent parts of the Northumberland Basin. Units of trough cross-bedded, medium and coarse-grained sandstone are fluvial channel sandstone bodies with a north-easterly provenance.

Microconglomeratic siltstone in beds up to 140 cm thick comprises massive or laminated, matrix-supported siltstone with lithic clasts of siltstone and very fine-grained sandstone. Many of these beds overlie paleosols or desiccated horizons and have been pedogenically modified. This facies is interpreted as mass-flow deposits, most likely resulting from seasonal flooding events. The matrix sediment and clasts are sourced from the reworking of overbank sediment. This facies preserves key vertebrate (actinopterygians, rhizodonts, rare lungfish, chondrichthyans and tetrapods), invertebrate and plant fossils.

More than 200 separate paleosols from 0.02 to 1.85 m thick have been identified in the Norham borehole. Evidence of rooting is abundant through all the paleosols, from shallow root mats and thin hair-like root traces to the thicker root traces typical of arborescent lycopods. Most paleosols are entisols or inceptisols, having relatively brief development times. Gleysols contain siderite nodules and some have O horizons containing up to 5% TOC and are inferred to represent marsh or lake margin environments. The vertisols are the thickest paleosols seen and have vertic cracks up to 38 cm deep; these are considered to have formed in forested areas with a diverse plant community. Estimates of mean annual rainfall from paleosol compositions are in the range of 1000-1500 mm per year. High mean annual rainfall and variable soil alkalinities alternating with the presence of deep vertic cracks and deposits of gypsum and anhydrite together suggest a sharply contrasting seasonal climate with repeated cycles of wetting and drying.

No marker horizons have been found to enable detailed stratigraphical correlation throughout the region and the only systematic facies distribution present is that there are generally fewer and thinner cementstones towards the top of the formation, associated with an increase in desiccated horizons and more vertisols, illustrating increasingly drier conditions. Geographically, indications of more marine-like episodes, with wave reworked bars are seen on the northern margin of the Northumberland Basin. The emerging picture is that the low-lying coastal floodplain architecture is complex and dynamic with geographical and temporal interplay of rapidly changing depositional episodes of silt, sand and carbonate, with many periods of pedogenesis and desiccation, suggesting frequent switching from flood-plain to coastal environments. The resulting close juxtaposition of distinct palaeoenvironments and hence of habitats may have been an important factor in the evolution of tetrapods at this time. This study provides a unique insight into an early Carboniferous tropical coastal floodplain and its habitats, and furthers our understanding of the evolution of fluvial seasonal wetland facies and their links to the evolution of life on land.

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Pridolian–Lochkovian macrofaunas from southern Belgium and northern France: de Koninck (1876) revisited

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In southern Belgium and northern France, the essentially siliciclastic rocks unconformably lying on the Caledonian basement were formerly included in the Gedinnian (from Gedinne, a small village of the Namur Province, Belgium). As rightly stressed by Steemans (in Dejonghe *et al*., 2006), the Gedinnian, in its historical type area, mainly corresponds to a lithostratigraphical unit delimitated at its base by a major discordance and its boundaries are strongly diachronous as demonstrated by the miospores (Steemans, 1989). Thus, its use as a regional stage has to be avoided, but it is briefly used here for convenience as a local expression of the Lochkovian *pro parte*. The lower part of the Gedinnian is known for a long time for its diverse invertebrate faunas (*e.g.*, Hébert, 1855; de Koninck, 1876).

Based on Dewalque and Malaise's collections, de Koninck (1876) was the first to illustrate and describe the macrofaunas occurring within the basal "Gedinnian" at Gdoumont on the south-east flank of the Stavelot Massif (Belgium) and at Mondrepuis (northern France) on the southern border of the Dinant Synclinorium. Although these macrofaunas have been revised notably by Leriche (1912), Asselberghs (1930), Boucot (1960), Godefroid (1995) and Godefroid & Cravatte (1999), de Koninck's (1876) material has never been re-illustrated so far. As it has recently been retraced in the historical collections of the Liège University (Dewalque's collection), it is now possible to provide the first photographic illustrations of some type specimens of the species erected by de Koninck (1876), who strongly idealised and embellished the line drawings of his specimens. This discovery is therefore of some interest as is also the case of the recent recovery of almost all the invertebrates (*e.g.*, brachiopods, pelecypods) described by Kayser (1895) from the Pépinster Formation (Eifelian–Givetian). However, the specimens that were part of Malaise's collections have not been found yet in spite of our efforts, but may be housed at the Royal Belgian Institute of Natural Sciences.

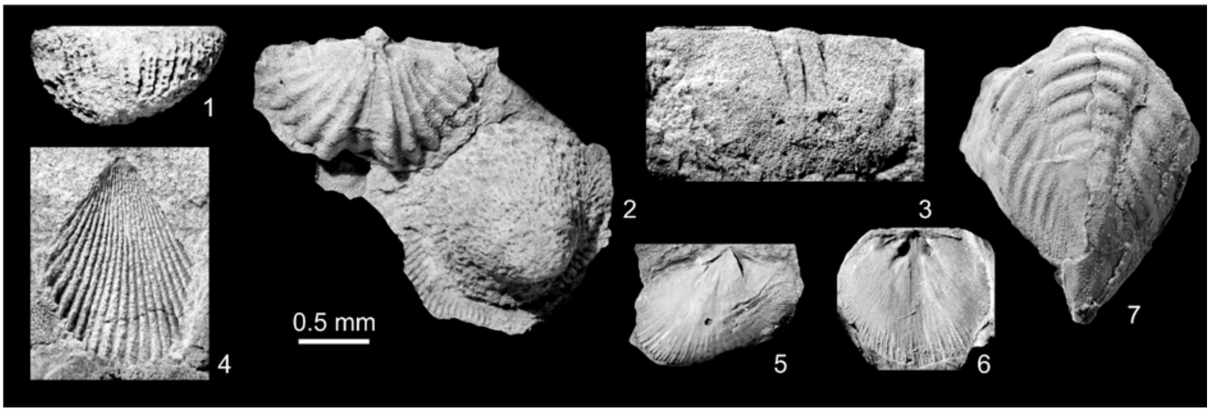

Fig. 1: Some specimens of the Dewalque collection housed at the University of Liège and identified by de Koninck (1876). The specimens no. 1–4 and 5–7 are from the Waismes (Gdoumont) and the Mondrepuis (Mondrepuis) formations, respectively. (1) "*Cyathophyllum binum* Lonsdale" (= de Koninck, 1876: pl. 1, fig. 2). (2) *Quadrifarius dumontianus* (= de Koninck, 1876: pl. 1, fig. 9a-9b) and *Cystiphyllum profundum* (= de Koninck, 1876: pl. 1, fig. 1-1a). (3) *Shaleria rigida* (= de Koninck, 1876: pl. 1, fig. 5?). (4) "*Camarotoechia*" *aequicostata* (= de Koninck, 1876: pl. 1, fig. 7?). (5-6) *Platyorthis verneuili* (de Koninck, 1876). (7) *Digonus roemeri* (= de Koninck, 1876, pl. 1, fig. 15b-15c?).

The material from Gdoumont, which mainly consists of brachiopods, solitary rugose and colonial tabulate corals, has been recovered from the lowermost part of the Waimes (Weismes in German) Formation defined by Vandenven (1991), the age of which is considered as Pridolian at least for the fossiliferous levels (see discussion in Godefroid & Cravatte, 1999). The material only consists of poorly preserved internal moulds and this feature may explain the embellishment of de Koninck's line drawings (*e.g.*, compare the idealized representation of *"Cyatophyllum binum"* with the original specimen (Fig. 1.1)). It includes the following species erected by de Koninck (1876) (their original generic assignment has been modified wherever possible): *"Cystiphyllum" profundum*, "*Chonetes*" *omaliana*, *Shaleria rigida*, "*Camarotoechia" aequicostata*, *Quadrifarius dumontianus*.

Most of the species described and/or reported by de Koninck are from the Mondrepuis Formation, in the eponym locality. In this area, the base of the formation is early Lochkovian in age (Steemans, 1989). The Mondrepuis Formation yields a diverse fauna including notably brachiopods, ostracods, pelecypods, tentaculites and trilobites. The species erected by de Koninck (1876) are the following (see remarks above): *Primitia jonesii*, *Beyrichia richteri*, *Digonus roemeri*, *Platyorthis verneuili*, *Grammysia deornata*, *Avicula subcrenata*, *Pterinea ovalis*, *Tentaculites irregularis*. The specimen illustrated by de Koninck (1876: pl. 1, fig. 1) was selected (but not figured) as the lectotype of *Digonus roemeri* (de Koninck, 1876) by Richter & Richter (1932) (see also Richter & Richter, 1954). Only one specimen identified as such has been traced in the Dewalque collection. Its general outline is in accordance with de Koninck's illustrations but, as it is smaller, it cannot be definitely considered as the specimen figured by de Koninck.

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Diversity of athyridide brachiopods during the Late Devonian–Tournaisian in southern Belgium

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Athyridides (Fig. 1) rank among the most common brachiopods occurring within the Upper Devonian–Tournaisian succession of the Namur–Dinant Basin (southern Belgium), which developed along the southern margin of Laurussia. These spire-bearers (Fig. 1) colonized a wide range of sedimentary environments and display diverse external morphologies (transverse, globose with smooth, ribbed, lamellose or spinous ornamentations, etc.) adapted to different kinds of substrate as well as unusual internal features such as the development of a diplospiralium (see below). Until recently, athyridides from the Namur–Dinant Basin were almost only known by faunal lists devoid of illustration that dated back to Maillieux (1941) and Demanet (1958) but now, our knowledge has progressively increased although the athyridide content from several levels of the considered stratigraphic interval remain obscure.

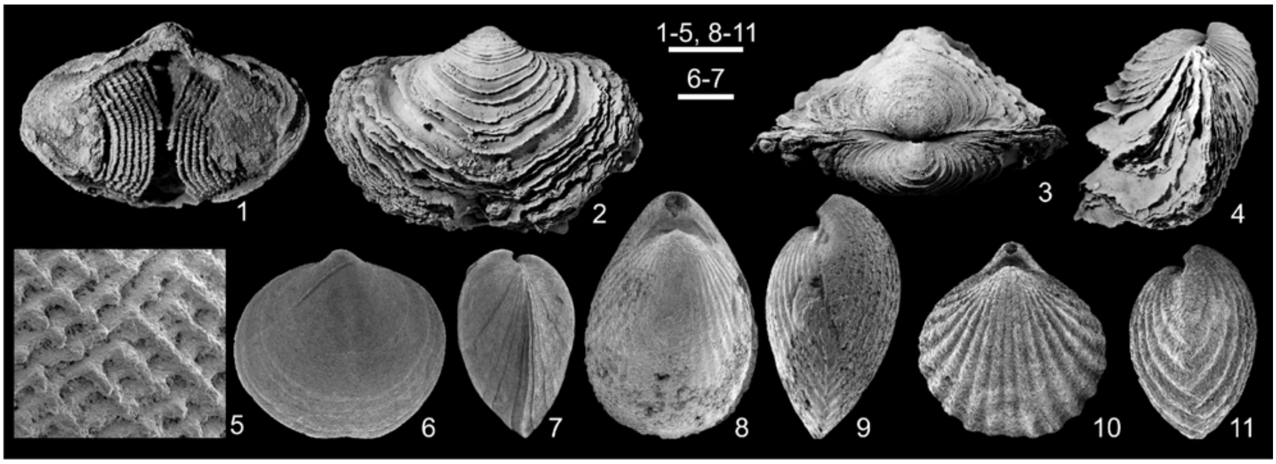

Fig. 1: Tournaisian athyridides from the Tournai Formation (Tournai area). (1-4) *Lamellosathyris lamellosa* (Léveillé); (1) dorsal interior showing the spiral cones laterally directed; (2-4) complete specimen in ventral, posterior and lateral views. (5) *Carteridina? squamigera* (de Koninck), close-up of flat spines. (6-7) *Nucleospira* sp. in ventral and lateral views. (8-9) *Eumetria* sp., juvenile specimen in dorsal and lateral views. (j-k) *Hustedia multiplicata* (de Koninck), complete specimen in dorsal and lateral views. Scale bars: 10 mm (1-4), 0.5 mm (5), 2.5 mm (6-11).

During the Frasnian, the facies succession of the Namur–Dinant Basin reflected a ramp–platform setting with mixed argillaceous–carbonate sedimentation and the development of carbonate build-up levels in its distal part. Besides several unstudied Lower–Middle Frasnian representatives of the family Athyrididae, probably similar to those reported by Brice (1988) in contemporaneous strata of northern France (Boulonnais), the presence of *Anathyris* (Mottequin *et al*., 2013) in the shaly facies of the Lower and Middle Frasnian has to be underlined as it was almost only reported at that time in the East-European Platform, northeastern Russia and southern Siberia (see Modzalevskaya *et al*., 2013) and thus this occurrence constitutes an overlooked step of the Devonian plicathyridine evolution and migration. At least eight athyridide species, belonging to the subfamilies Athyridinae, Cleiothyridininae, Helenathyridinae, and Meristinae, have been identified so far within the interval ranging from the *hassi* to the *linguiformis* zones (Mottequin, 2008a, 2008b). However, recent data related to those inhabiting the mud mounds are still lacking, mainly due to the difficulties of extracting them from massive limestones. The huge development of the Helenathyridinae (mainly *Biernatella* and accessorily *Neptunathyris*; Mottequin 2008a) in the Lower *rhenana* Zone in the distal part of the Namur–Dinant Basin is noteworthy. These small-sized (*ca.* 10 mm or less in width) and smooth athyridides, characterized by a diplospiralium, constitute a large part of the benthos, just before the Lower Kellwasser Event (LKW) (Mottequin & Poty, 2015). Their double-spired spiralia suggests a complex lophophore with reinforced efficiency permitting the animal to live in nutrient-depleted and/or poorly oxygenated environments according to Balínski (1995). *Biernatella* is frequently associated to thin- and smooth-shelled or poorly ornamented rhynchonellides (Lower *rhenana* Zone) and suggest the development of poorly oxygenated environment well before the LKW (Mottequin & Poty, 2015).

The Famennian succession mainly consists of siliciclastics with some limestone occurrences in the mid and uppermost Famennian. The lower Famennian is characterized by the rapid expansion of the cosmopolitan genus *Crinisarina* (Cleiothyridininae) along with rhynchonellides and spiriferides. Until now, only one surviving athyridide species, *Cleiothyridina davidsoni* (Lazarus taxon), is definitely recognized within the lower Famennian (Mottequin 2008b). An unidentified large-sized *Cleiothyridina* species has been recognized in the *crepida* Zone associated to large spiriferides (Cyrtiopsinae) documenting the progressive increase of the size of the spire-bearers which suggests an improvement of the environmental conditions during the lower Famennian. Athyridides from the silty to sandy deposits of middle and upper Famennian age still remain poorly known as is the case for those occurring in the more calcareous mid Famennian Souverain-Pré Formation and its Baelen Member. Dreesen *et al.* (2013) reported rare spire-bearers in the latter (*marginifera* Zone), *i.e.* athyridides and spiriferides. The poor preservation of the uppermost Famennian brachiopods in Belgium does not permit to document in detail their diversity before the Hangenberg Event.

The Tournaisian is dominated by carbonate environments with the occurrence of large-sized Waulsortian mud mounds in the distal part of the ramp that prevailed at that time. Post-Hangenberg athyridide recovery is not yet fully known in southern Belgium, but it is clear that they are more diversified than in the Famennian, although the athyridides slowly declined during the Carboniferous (Curry & Brunton, 2007). The Hastarian–Ivorian Tournai Formation (Tournai area), which consists of argillaceous and siliceous limestones, is characterized by a diverse athyridide assemblage. Representatives of the Cleiothyridininae (*Cleiothyridina*, *Carteridina?*) clearly dominate both in terms of species and number of specimens the other minute to large-sized athyridides (Fig. 1), which include *Lamellosathyris*, *Composita*, *Hustedia*, *Coovenia*, *Nucleospira*, and *Eumetria* (*e.g.*, de Koninck, 1887; Alvarez & Brunton, 2000; Mottequin *et al.*, 2015). These athyridides represent a large part of the brachiopod association including notably spiriferides and productides. The Waulsortian mud mounds yield especially several *Cleiothyridina* species and representatives of the genera *Lamellosathyris* and *Coovenia*.

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Devonian trilobites from The Samnuuruul Formation in the Baitag Bogd area (western Mongolia)

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A biostratigraphic study was performed on calcareous terrigenous sediments of the Samnuuruul Formation within the frame of IGCP 596 & 580 in 2014. The study area is located near Baitag Bogd Range, 110 km southeast of Bulgan soum of the Khovd Province in western Mongolia (Davaa, 1992).

The Samnuuruul Formation, part of Baruunhuurai Terrain, consists of conglomeratic layers alternating with brownish-green, green, dark green, greenish-grey and grey limestones, fine and medium-grained sandstones, siltstones, tuffites and silicites (Kido *et al.*, 2013). During the study, three sections were measured at Buduun Khargait River (N45°17’06” E90°57’31”), Kushuut-Shiveet River (N45°16’18” E90°03’20”), and Shiveet Mountain (N45°05’02” E91°34’13”). In total, 56 samples of trilobite exuvia (commonly disarticulated into cephalon, thorax and pygidium, but also complete specimens) were collected from beds 22, 23, 29, 30, 46 and 50 of unit3 at the Samnuuruul type section and from laterally equivalent intervals. The study resulted in identification of five species belonging to three phacopid genera: *Toxophacops (Zhusilengops) ejinensis* Zhou & Campbell, 1990; *Phacops (Phacops) rana* (Green, 1832); *Toxophacops (Atopophacops) lepida* Zhou & Campbell, 1990 and *Phacops (Phacops) altaicus* (Tschernyschew, 1893)*, Phacops cristata* (Hall, 1861).

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Conodont biostratigraphy, biofacies and apatite isotope records of the late Eifelian Kačák Event in the shallow marine Belarusian Basin

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The Middle Devonian sedimentation patterns in the Belarusian Basin are primarily controlled by the tectonically stable intracratonic setting in the Euramerican continent. The low-relief land areas surrounded a slowly subsiding depression that had only intermittent and restricted connections with an open marine realm. The sedimentary succession, 200–300 m thick, is composed of lagoonal, clayey-dolomitic and partly evaporitic facies in its lower part, and continental variegated clastics with minor carbonates in the upper portion. Sandwiched between both units is the basin-wide Kostyukovichi Horizon, 15–20 m thick on average, showing a characteristic bi-partite division. Its basal unit, usually few metres thick, is composed of bioturbated dolomites with abundant marine fossils (including i.a. conodonts, crinoids, gastropods) intercalated with dolomitic marls and shales. It grades upwards into greenish to variegated shales and siltstones that are generally unfossiliferous and carbonate-poor. The sharp lower boundary of the basal unit, commonly marked by pyritized hardgrounds, clearly records marine incursion into lagoonal shaly-dolomitic, evaporitic environments. The transition from the dolomitic facies to the succeeding siliciclastics reflects gradual shallowing and closing connections with open marine realm, resulting in restricted, probably brackish deposits. The upper boundary of the Kostyukovichi Horizon is sharp, commonly displaying evidence of erosion and emergence. It is overlain by sandy and silty strata of the Polotsk Horizon starting the next depositional cycle.

The present work is based on 18 boreholes with the Kostyukovichi interval, situated mostly in the southern and central parts of the basin. The study included description and sampling of the core material as well as analysis of wireline logs that facilitated correlation of sections across the basin. The conodont study is based on the collection of *ca.* 5,600 conodont elements from 16 boreholes. The conodonts are most abundant in the SW part of the present Devonian subcrop area, *i.e.* in the Pinsk region. Their frequency in the sampled intervals decreases both towards the east and, particularly, northwards. The latter trend is consistent with the sedimentological and palynofacies evidence of weaker open marine influences northwards.

The dominant conodont genus is *Icriodus*, with less frequent *Polygnathus* and only single specimens of *Tortodus*, *Belodella*, *Dvorakia* and *Ozarkodina*. It is noteworthy that nearly 70% of all forms are small immature individuals, mostly icriodids. This suggests a high mortality among juvenile forms probably related to intermittent adverse environmental conditions. *Icriodus* species comprise *I. stelcki*, *I. eriensis*, *I. xenium*, *I. orri* and at least two new taxa. *Polygnathus* is much less diverse, including only *P. parawebbi* and *P. linguiformis*, the latter represented by *P. l. linguiformis*, *P. l. klapperi*, and *P. l.* n. subsp. A *sensu* Uyeno & Bultynck (1993).

According to the recent studies by KN and PB (submitted for a publication) *I. orri* first appeared at the turn of the *kockelianus* and *ensensis* zones and continued into the latter zone. This species, similarly as in the case of *I. stelcki,* has not been found in the Givetian, which constrains the age of the studied strata to the Eifelian Stage. According to Walliser & Bultynck (2011: pl. 3, fig. 9) *Polygnathus linguiformis* n. subsp. A *sensu* Uyeno & Bultynck (1993), found in the basal part of the Kostyukovichi Horizon, first appeared in the *ensensis* Zone (probably near its base, fig. 3). In conclusion, the conodont data evidence that the lower carbonate part the Kostyukovichi Horizon belongs to the *ensensis* Zone. The same age is suggested by the stratigraphic range of the subspecies *P. linguiformis klapperi* whose taxonomic revision is currently underway. Thus, the biostratigraphic data confirm that the Kostyukovichi transgression corresponds to the base of the If eustatic T-R cycle documented from many parts of the world. It is widely accepted that the initial Kačák (=*otomari*) Event is correlated with the If transgression (*e.g.*, Johnson *et al.*, 1996; Walliser, 2000).

The icriodid to polygnathid ratio (I/P) in the conodont collection is 3.4, pointing to a prevalence of the icriodid biofacies. In four sections where a vertical succession of conodont assemblages could have been adequately documented, one may observe a tendency of I/P to increase upwards. This may reflect a shallowing trend seen in the sedimentary succession. The conodont biofacies analysed in the lowermost part of the basal carbonates of the Kostyukovichi Horizon show an irregular distribution lacking any definite basin-scale pattern. The I/P values may be quite variable from 0.6 to 5.3, reflecting the presence of a rare P-I biofacies, the most common I-P, and less common I biofacies. Even closely spaced sections exhibit wide range of the I/P values, in one extreme case even from 1 to 5.3. Such biofacies variability may represent the initial bathymetric or other environmental gradients during the early phases of the Kostyukovichi transgression, related *e.g.* to the differentiated palaeotopography. The latter may had been partly shaped by erosion which preceded the marine incursion.

The Middle Devonian Belorusian Basin was located in the tropical belt of the Southern Hemisphere. In order to constrain seawater temperatures we investigated oxygen isotopic composition of conodonts from the Kostyukovichi strata using secondary ion mass spectrometry (SIMS) technique. The methodology of SIMS for apatite δ^{18}O analyses on single conodonts allows to select an appropriate hyaline and albid crown tissues. The measurement consumes only <100 ng of a conodont element by probing of a very small area (*ca.* 20 µm).

The samples were analysed on SHRIMP IIe/MC ion microprobe in PGI-NRI during two sessions using 15 kV, ~3 nA Cs+ primary ion beam and instrumental configuration and procedures described by Ickert *et al.* (2008). The study included 6 samples from 5 boreholes covering the SW part of the basin. From each sample 5 to 9 conodonts were analysed, and in each element from 2 to 7 measurements were performed. The standard error of any one from 185 single spot accepted analysis was commonly better than 0.2‰ (1δ ± 0.09–0.23‰). The mean δ^{18}O apatite composition of each conodont element was calculated as the unweighted mean from the measurements. The δ^{18}O mean values reported in per mil deviation relative to V-SMOW are in the range from 19.01 ± 0.14‰ to 21.05 ± 0.16‰ with weighted average 20.51± 0.11‰ corresponding to the average temperature of *ca.* 21ºC (calculated using the equations of Lécuyer *et al.* 2013). Taking into consideration also the maximum reached temperature of 25ºC calculated for δ^{18}O= 19.01 ± 0.14‰, they are slightly lower than mean annual sea surface temperatures (22–28°C) of modern tropical to subtropical waters. Moreover, these values generally fall within the range reported for the Eifelian by Joachimski *et al.* (2009) who used the conventional GIRPS method. The average temperature values appear, however, higher by 4–5°C for the Belarusian Basin, if the δ^{18}O values are corrected for a systematic difference between the SIMS and GIRPS techniques (Trotter *et al.*, 2015). No significant palaeotemperature trends have been found both across the basin as well as temporally. Thus the data indicate rather uniform temperature conditions during the Kostyukovichi sedimentation, with seawater temperatures elevated relative to oceanic values in comparable palaeolatitudes. The latter effect may be due to a more equatorial position and/or a restricted nature of the shallow-water intracratonic basin.

The Belarusian Basin seems to represent a particular variant of the Kačák-Event setting in which the most apparent depositional and biotic effects are those directly related to the eustatic If transgression. The low-oxygen conditions, usually regarded as an attribute of the event, are not recorded as black shales which are commonly found elsewhere. This absence is even more striking when the semi-enclosed nature of the basin is considered. The lack of black sediments is most probably due to a shallow-water bathymetry allowing better stirring of water-column by waves and currents, thereby precluding development of a prolonged bottom anoxia. The record of the hypoxic conditions may be, however, more subtle, expressed as pyritization of hardgrounds at the early phase of the Kostyukovichi transgression. Also, the environmental stress suggested by some observations of the biotic content (*e.g.*, high mortality rates of juvenile conodonts or presence of bioturbated beds lacking body fossils) may be partly related to hypoxia.

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Devonian and Carboniferous shallow-water successions from Sonora (NW Mexico) and their importance in global event studies

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Paleozoic sedimentary rocks from NW Mexico were deposited to the south of Laurussia (Laurentia), in the westernmost end of the Rheic Ocean. An almost complete transect of this southern margin is recorded in the State of Sonora (Mexico), where four different groups of facies are present (Stewart & Poole, 2002, and references therein). Shallow-water successions crop out to the northern half of the state and include both cratonic-platform and continental shelf rocks that span discontinuously from the Cambrian to the Permian. Ocean-basin sedimentary rocks appear in central Sonora and to the south, and are known as the Sonora allochthon (Poole *et al*., 2005). The Sonora allochthon is divided into Ordovician to lowermost Mississippian preorogenic strata and Upper Mississippian to middle Permian synorogenic flysch. Poole *et al.* (2005) stated that the Sonoran allochthon was emplaced in central Sonora, overlying the continental-shelf succession, during the late Permian since the youngest flysch is middle Permian in age. This event may have occurred during the westernmost final closure of the Rheic ocean.

Both types of shallow-water deposits crop out north of 28ºN latitude and to the Arizona-Sonora border. The cratonic-platform rocks are located to the NE of the state and the outer carbonate shelf is situated in central and northwestern Sonora.

One of the best outcrops of the Upper Devonian and Carboniferous continental shelf successions is located in Sierra Agua Verde, east-central Sonora (Stewart *et al*., 1999). The Upper Devonian is characterized by an over 420m-thick interval made up of limestones, quarzites and sandstones. The Carboniferous represented by both Mississippian and Pennsylvanian strata and has a total thickness of more than 1400m. Both the Devonian/Carboniferous and mid-Carboniferous boundaries are present, and are characterized by markedly changes in lithology.

Other localities suitable for paleoecological and geochemical analyses are located in the Sierra Martínez (central Sonora). There, Ordovician, Devonian, Carboniferous and Permian deposits had been identified (Poole *et al*., 1995; Stewart & Poole, 2002) but detailed stratigraphic studies lack.

During the last decades, most of the studies published about the Sonoran Paleozoic dealt mainly with the understanding of the geodynamic context, including description of the lithologic successions, consequences of their tectono-sedimentary evolution, and in a final approach, the relation of these successions with the Laurentian craton and their role in the paleogeographic scenario of the southern margin of Laurentia. These works expose the applicability of these successions for paleoecological and paleoclimatic studies based on the analysis of their fauna associations as well as isotopic analysis. Geochemical investigations are of special interest as the effects of anoxic events in Earth's history on shallow-water realms are still poorly documented (*e.g.*, Carmichael *et al*., 2014; Königshof *et al*., 2015). Thus, these studies are of relevant importance during Devonian and Carboniferous periods because of the continuous nature of their deposition in NW Mexico.

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Paleogeographic implications of early Famennian *crepida* Zone conodont faunas, Sonora, NW Mexico

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Faunas of the Early and Middle *crepida* Zones from the Sonora allochthon (NW Mexico) more closely resemble those of Morocco and Europe (Gondwana) than those on the outer shelf in Sonora and in the rest of North America. We studied two conodont samples from different localities within the Sonora allochthon, which is the westward extension of the Ouachita-Marathon orogenic belt of Oklahoma and Texas (Poole *et al.*, 2005, and references therein). Both samples were collected from lime-grainstone turbidites of the siliciclastic Los Pozos Formation. The conodont faunas are dated as Early and Middle *crepida* Zones (early Late Devonian, early Famennian). Both faunas represent the farthest-offshore palmatolepid biofacies. The diagnostic species in these samples is *Palmatolepis crepida* s.s.

We also studied one sample from a bioclastic lime packstone in the upper San Miguel Formation on the Laurentian outer carbonate shelf, north of the allochthon, in west-central Sonora. Its conodont fauna is dated as Middle *crepida* Zone and represents the shallower polygnathid biofacies. The few *Palmatolepis crepida* present in this *Polygnathus*-dominated fauna are a narrow form that differs from that in the allochthon but resembles forms found throughout the rest of North America.

The samples from the Los Pozos Formation are located 10–15 km south of the leading edge of the allochthon, and the San Miguel Formation sample is located 40–50 km north of its leading edge. Thus, the two different collecting areas, one from Gondwana, the other from Laurentia, are now structurally only about 60 km apart.

Most important in distinguishing the two forms of *Palmatolepis crepida* is the shape of typical forms, as illustrated by Ziegler (1962: pl. 6, figs 15–19); these evolved from *Pa. triangularis* by reduction in size and loss of the outer lobe, shortening of platform length, and increased curvature of the carina. Most examples from the western United States (*e.g.*, Sandberg & Ziegler, 1973: pl. 5, figs 9–11) resemble the atypical form illustrated by Ziegler (1962: pl. 6, fig. 12).

Seddon (1970) listed only 4 specimens of reworked *Pa. crepida* from the Llano region in Texas. Although their shape is not known, his other Famennian conodonts are identical to those of the Rheinisches Schiefergebirge of Germany (Variscan orogenic belt). An outstanding example is his typical *Polygnathus styriacus* (Seddon, 1970: pl. 16, figs 13–14). Typical examples of this species are unreported elsewhere in North America.

Within the Sonora allochthon, Early and Middle *crepida* Zone faunas contain *Palmatolepis crepida* s.s., which has a short, round platform, lacks a lobe or has an obsolescent lobe, and possesses a strongly sigmoidal carina. However, the Middle *crepida* Zone fauna on the continental shelf, and Early and Middle *crepida* Zone faunas in the rest of North America (Laurentia) contain a form of *Pa. crepida* that is elongate and has a short lobe and an only slightly sigmoidal carina. This form lies well outside the range of typical *Pa. crepida* s.s. and probably should be considered as a separate subspecies. *Palmatolepis crepida* s.s. has been positively identified in Germany (Ziegler, 1962), Belgium (Sandberg, unpublished data), France (Gilbert Klapper, personal communication), Poland (Szulczewski, 1971), Morocco (Belka & Wendt, 1992), and now on the Sonora allochthon. The absence of *Pa. crepida* s.s. in Laurentia is documented by faunas from Alberta (Johnston & Chatterton, 2001: pl. 13, fig. 12), Ontario (Klapper *et al.*, 2004: table 1, species 57), Nevada (Sandberg, unpublished data), Indiana (Sandberg *et al.*, 1994), and the continental shelf in Sonora.

We conclude on the basis of our conodont study that the Ouachita-Marathon-Sonora and Variscan orogenic belts of northern Gondwana contain rocks that were deposited in a seaway extending from northern South America through northwest Africa to Europe and later were accreted onto the southern continental margin of Laurussia during closure of the Rheic Ocean and the subsequent assembly of Pangea.

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Early Devonian ammonoids from Shakhimardan (South Tien-Shan)

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Lower Emsian (Zlichovian) ammonoids come from a section of neritic deposits on the northwestern slope of Sangibaland Mountain (right bank of the Shakhimardan River, near the village of Dzhidalik, South Fergana, Kyrgyzstan) with a bed-by-bed record of ammonoids, conodonts, dacryoconarids, brachiopods, and corals. The section begins from the tectonic contact of the neritic (Hercynian) limestones of the Sandal Formation with the folded siliciclastics of the Akkul Formation. Ammonoids come from the upper part (Member 4) of the Sandal Formation, sometimes recognized as the Sanguvalyan Beds (Rzhonsnitskaya, 1978, 1982; Bogoslovsky, 1982, 1983).

Pragian-Lower Emsian

(1) Member 1 (0–40 m). Alternation of grey massive and fissured laminated sandstone. The first 10 m contain brachiopods, bryozoans, tabulate corals, conodonts, trilobites; brachiopods (*Karpinskia gigantea*, *Karpinskia* ex gr. *cojugula*, Spiriferida, Atrypida), gastropods (*Platyceras* sp.), dacryoconarids (*Nowakia zlichovensis*, ?*Nowakia* ex gr. *barrandei*).

(2) Member 2 (40–80 m). Massive light grey limestone, dolomitized in places with algae, crinoids, brachiopods, bivalves and corals; brachiopods (Rhynchonellida, *Karpinskia* ex gr. *conjugula*, *K.* ex gr. *fedorovi*, *K. gigantea*, Spiriferida, Atrypida). Level 46 m: brachiopods (*Karpinskia*, *Carinatina*, *Nymphorhynchia*, Spiriferida, *Productella*). Interval 40–80 m is composed of mainly crinoidal-detrital grey limestone with aggregations of crinoid fragments and small algal bioherms (1.5 m across).

(3) Member 3. (80–220 m). Light-grey and bluish-grey compact dolomite, with crinoids, algae, brachiopods, gastropods and corals; brachiopods (*Karpinskia gigantea*, Rhynchonellida, Atrypida, Spiriferida), corals including colonial and solitary rugoses, favositids, and branching tabulate corals.

Lower Emsian (Zlichovian)

Member 4. Interval 220-230 m. Grey and light-grey crinoidal-algal limestone with algal buildups; brachiopods (*Karpinskia*, Rhynchonellida, Atrypida, Spiriferida, Pentamerida). Interval 230-250 m. Algal-crinoid, bryozoan limestone; brachiopods (*Karpinskia, Nymphorhynchia, Eospirifer, Carinatina, Conchidiella, Cymostrophia, Gypidula, Sycorhynchia*, etc.) and fenestellid bryozoans. Level 230: conodonts (*Polygnathus gronbergi, P. inversus*), ammonoids (*Erbenoceras kimi* Bogoslovsky, *Teicherticeras* sp. nov., *Convoluticeras* sp. nov.) Level 240 m: dacryoconarids (*Nowakia barrandei*).

The ammonoid fauna is typical of the upper Zlichovian and is comparable with that of the Zeravshan Range (Bogoslovsky, 1980), Anti-Atlas (Klug, 2001; De Baets *et al.*, 2010), Bohemia (Chlupač, 1976; Chlupač & Turek, 1983) and the Northern Caucasus (Nikolaeva, 2007). The sedimentary environment is interpreted as the close vicinity of a shallow carbonate platform with multiple algal mudmounds. As in other regions, the depositional conditions in the Sangibaland Basin at the end of the Zlichovian became more marine, with an increase in pelagic faunal elements, with ammonoids, conodonts and tentaculites becoming more abundant.

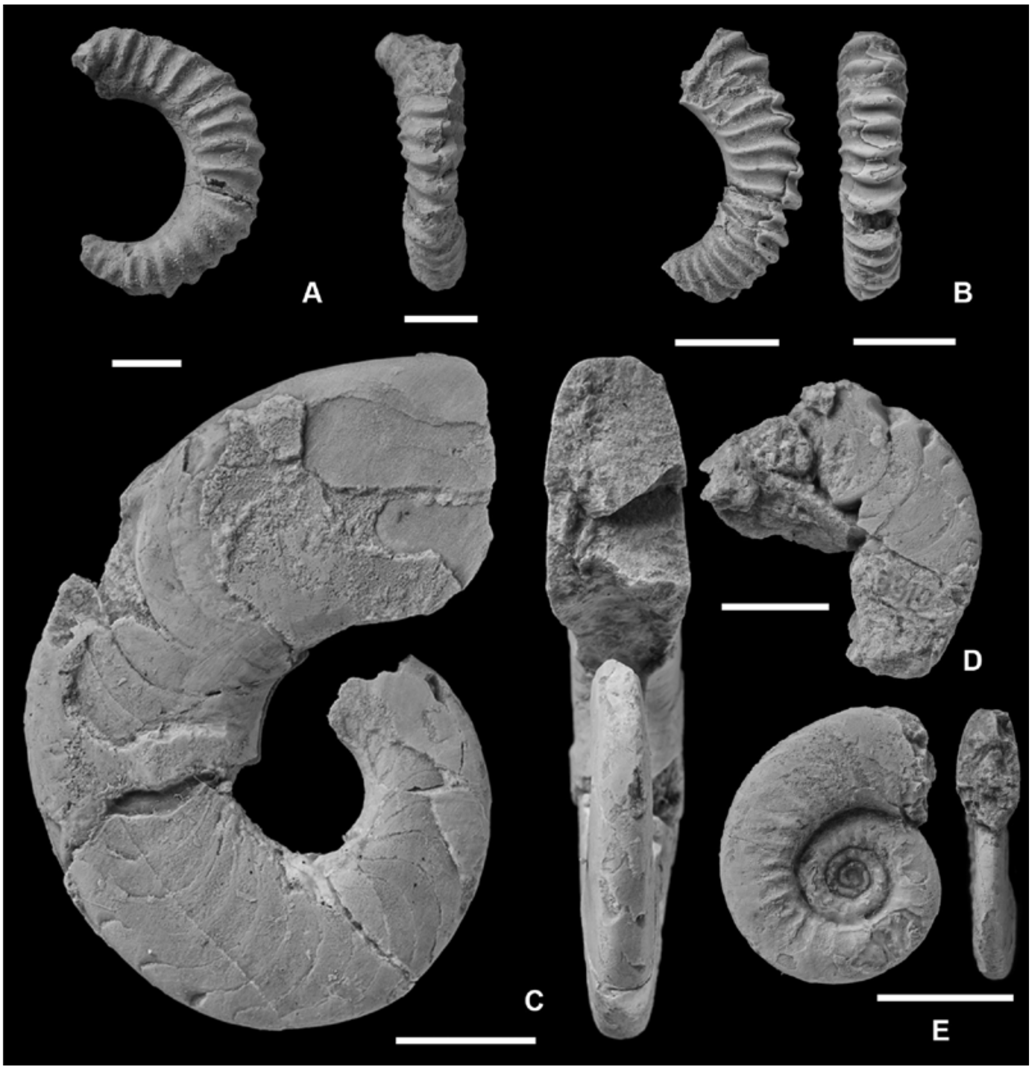

Fig. 1: (A) *Erbenoceras solitarium* Barrande. (B). *Erbenoceras kimi* Bogoslovsky. (C-E) *Teicherticeras* sp. Scale bars: 2 cm.

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What's new with the Famennian vertebrate fauna from Belgium?

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During the 19th and 20th centuries, the vertebrate fauna from the Famennian of Belgium was essentially studied by Lohest (1888) and Leriche (1931). Both authors made a remarkable pioneering work of fossil gathering and description, for various taxa of placoderms, sarcopterygians and acanthodians. Thereafter, a few articles dealing with that topic were published (Lelièvre, 1982; Derycke-Khatir, 1994; Blieck & Lelièvre, 1995; Cloutier & Candilier, 1995; Derycke *et al.*, 1995; Cloutier & Schultze, 1996; Taverne, 1997) until the more extended work of Gaël Clément (MNHN, Paris) in the 2000s on sarcopterygians (Clément, 2002; Clément *et al.*, 2004; Clément & Boisvert, 2006; Clément *et al.*, 2009), placoderms (Janvier & Clément, 2005) and acanthodians (Derycke & Clément, 2013).

This is in the frame of this recent interest for the Famennian of Belgium that a PhD project has been realized from 2011 to 2015 and this presentation summarizes the main results.

The major focus of this PhD was the study of the vertebrate fauna of the tetrapod-bearing locality of Strud (Namur Province), discussed in this volume by Clément *et al.* (2015). The placoderm fauna has been described and includes the arthrodiran placoderms *Phyllolepis undulata* and *Turrisaspis strudensis* (Olive *et al.*, 2015a) as well as the antiarch *Grossilepis rikiki* also present in the Famennian locality of Moresnet (Olive, 2015). Morphological and morphometrical analysises (on the anterior ventrolateral and centronuchal plates) of the genus *Phyllolepis* have been led and indicate that (1) there was only one species of *Phyllolepis* in Belgium, namely *P. undulata*, contrary to Lohest's (1888) and Stensiö's (1939) views, (2) *P. rossimontina* from the Catskill Formation in Pennsylvania, represents a junior synonym of *P. undulata* and (3) the unity of the genus *Phyllolepis* is strongly supported although the characterization of several species within the genus is blurred (Olive *et al.*, 2015a). Moreover, based on morphological and morphometric evidences, the placoderm specimens from Strud are predominantly juveniles. They do not show evidence of size sorting and this locality can therefore be identified as a placoderm nursery – an area nearly exclusively inhabited by juveniles. The Strud depositional environment is a channel within an alluvial plain and the presence of a nursery in such environment could have provided nutrients and protection to the placoderm offspring. This ranks among the earliest evidences for this sort of habitat partitioning in vertebrate history. Placoderm habitat may have been partitioned with adults living more distant from the nursery, migrating to the nursery to spawn or to give birth and then returning downstream from the nursery as part of a seasonal life cycle.

Antiarchs are a major component of the vertebrate fauna from the Devonian of Belgium and they have been the subject of an exhaustive study during this PhD (Olive, 2015). Besides the description of two Givetian *Asterolepis* species from Hingeon (Namur Province) and Mazy (Liège Province), respectively, the material of *Bothriolepis lohesti* from Chèvremont (Liège Province) has been enhanced and the species redescribed in more detail. An undetermined species of *Bothriolepis* has been recorded from the Famennian of Modave (Liège Province). *Remigolepis durnalensis* is described from the Famennian of Spontin near Durnal (Namur Province). Except for the doubtful occurrence of *Remigolepis* sp. in Scotland, this is the first record of this genus in Western Europe. *Grossilepis rikiki* is recorded from the Famennian tetrapod-bearing locality of Strud and from the Famennian of Moresnet (Liège Province). It is the first post-Frasnian occurrence of *Grossilepis* on the central southern coast of the Euramerican continent. This Belgian occurrence may be the result of a late arrival from the Moscow Platform and the Baltic Depression, where the genus is known from Frasnian deposits.

Additionally, a new species of the arthrodiran genus *Groenlandaspis* has been described, *G. potyi* from the upper Famennian of Hun–Annevoie in the Namur Province (Olive *et al.*, 2015b). The remains of *G. potyi* consist of dissociated thoracic armor elements, but the specimen selected as the holotype displays the median dorsal, anterior, and posterior dorsolateral plates in articulation. *Groenlandaspis potyi* constitutes the second occurrence of a *Groenlandaspis* species in continental Europe after the description of *Groenlandaspis thorezi* from the upper Famennian of southern Belgium (Janvier & Clément, 2005). Another probable new species of *Groenlandaspis* is also described, though of unknown locality and horizon; it can, however, be deduced to be from the upper Famennian of Belgium without more precision. Together with the material of groenlandaspidids from the Famennian tetrapod-bearing locality of Strud, this material highlights the richness of Groenlandaspididae diversity in Belgium. The discovery of *Groenlandaspis potyi* in Belgium reinforces the Famennian global distribution of this genus during this period.

A new Famennian locality has been discovered and studied during this PhD (Olive *et al.*, 2015c). The Becco locality (Liège province), belongs to the Theux tectonic window and represents a proximal, probably fluvial, environment corresponding to a channel infill. We present here a preliminary report of the fossil assemblage discovered at the locality. The Becco site has yielded a diverse flora of early seed plants including *Moresnetia zalesskyi*, *Dorinnotheca streeli* and *Condrusia* sp. This assemblage, which is characteristic of the Belgian Famennian, highlights the diversity of early spermatophytes in the country. Becco, has also delivered a rich vertebrate fauna with antiarch, groenlandaspid and phyllolepid placoderms, diplacanthiform acanthodians, as well as actinopterygians and various sarcopterygians. The fossiliferous assemblage of Becco resembles those of several Devonian tetrapod-bearing localities, including that of Strud, and could therefore provide a favorable palaeoecological setting in the search for early tetrapods.

The Famennian Stage in Belgium shows a great potential for the early vertebrate palaeontology. During this PhD, numerous vertebrates have been reported and described, as well as new localities, leading to new palaeogeographical and palaeoecological considerations. The Belgian Famennian has not delivered its entire potential yet and continues to be the object of intensive researches, notably for the onset of the vertebrate terrestrialisation.

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Devonian fossils of the Amazonas and Parnaíba basins, Brazil

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Marine Devonian sequences are well represented in the Amazonas (N. Brazil) and the Parnaíba (N.–NE. Brazil) basins. They provide evidence of widespread marine transgressions across this country, especially during the Pragian–Frasnian interval. The Devonian marine invertebrate fossils of the Amazonas and Parnaíba basins have been the subject of previous taxonomic, stratigraphic, paleobiogeographic, and (more recently) taphonomic studies. However, most of these have focused only on single rock units or individual taxonomic fossil groups (brachiopods, trilobites, bivalves, gastropods, echinoderms, tentaculitids, conulariids, bryozoans, and corals). Very few studies attempted to integrate the available data for the various formations or fossil groups. Nevertheless, a more comprehensive approach is essential to elucidate the paleobiogeographic affinities of the Devonian invertebrate fossils of Brazil. Aiming at this purpose, the present work provides an updated summary of the lithology, paleoenvironment, nomenclature, and age of Devonian rock units where these fossils occur.

The geological reconnaissance of the Amazonas Basin was initiated by Chandles, in 1862, and Agassiz, in 1866, but the first evidence about Devonian marine invertebrate fossils from Brazil was found during the pioneering Morgan expeditions in 1870–71, led by Charles Frederick Hartt, in the Amazonas Basin, and during the Imperial Geological Commission expeditions of 1876–77, directed by Orville Adelbert Derby. Devonian strata of the Parnaíba Basin were first discovered by Small, in 1914, near to the Pimenteira village, in the State of Piauí, but were recognized as Devonian, based on the invertebrate macrofossils, only by Caster, in 1948. Wilhelm Kegel established most of the presently accepted stratigraphic relationships of the different units in the Parnaíba Basin, based mainly on invertebrate fossils collected in the middle part of the 20th century.

The Devonian lithostratigraphic units of the Amazonas Basin comprise (in ascending order) the upper part of the Trombetas Group (Manacapuru and Jatapu formations), the Urupadi Group (Maecuru and Ererê formations) and the Curuá Group (Barreirinha, Curiri, and Oriximiná formations). Marine invertebrate macrofossils occur mainly in the Maecuru and Ererê formations, and are scarcer in the Manacapuru and Barreirinha formations. The Manacapuru Formation has a regressive character with fluviatile, deltaic and low-energy shoreface deposits, indicated by the oolitic ironstones and sandstones with *Skolithos* isp. Chitinozoans and miospores suggest a shallow marine facies of Early Devonian (early Lochkovian) age for virtually all of this unit, with older (early Pridoli, late Silurian) strata – formerly assigned to the basal Manacapuru – now being attributed to the uppermost part of the underlying Pitinga Formation. The Maecuru Formation consists mainly on a sequence of fluvio-deltaic to neritic hummocky cross-stratified fine-grained to conglomeratic sandstones with few siltstone interbeds. It represents a deltaic system progradation interrupted by a fast, short-lived transgression, followed by another deltaic system progradation. On the northern flank of the Amazonas Basin these beds contain the highest diversity shelly faunas of any Brazilian Devonian assemblages. Marine invertebrate macrofossils occur in a shallow marine facies of latest Emsian–early Eifelian age. The Ererê Formation is a section of grey, micaceous siltstones with interbedded bioturbated shales and hummocky cross-stratified fine-grained sandstones between the Maecuru Formation and the Curuá Group (Barreirinha Formation). The Ererê Formation records a larger transgression and deepening in its lower part, and a moderate regression in its upper part. In the outcrop area the Ererê Formation shows deeper environments than the Maecuru Formation, although still under shallow marine conditions. On the west side of the basin, shoreface and delta-front facies developed. Offshore sediments predominated on the east side. The age of the Ererê Formation is latest Eifelian to early Givetian. Marine invertebrate macrofossils of this formation are impoverished, and most of them occur in the lower part of this unit, where palynomorphs suggest latest Eifelian to earliest Givetian age. The highly radioactive black shales of the Barreirinha Formation are related to the widespread Frasnian transgressions coupled with a sustained (Frasnian through early middle Famennian) sea-level highstand, thus recording the deepest water environment in the history of this basin. It represents a sediment-starved anoxic basin, with very condensed sedimentation under distal marine settings. Upwards, regressive depositional settings represent distal marine to progressively shallower marine and prodeltaic environments to the top. Macrofossils are rare, and according to the latest data from the palynomorphs biostratigraphy, the Barreirinha Formation spans in age from early Frasnian through late Famennian.

The Devonian succession in the Parnaíba Basin is represented, in ascending order, by the upper Jaicós, Itaim, Pimenteira, Cabeças, and lowermost Longá formations. During the Devonian, this intracratonic basin had a more restricted access to the open ocean than adjacent contemporary basins; hence, its sediments were deposited under shallow marine conditions. Marine invertebrate macrofossils occur mainly in the Pimenteira Formation (Picos and Passagem members), and are scarcer in the Itaim and Longá formations. The Itaim Formation consists of superposed sigmoidal fine- to coarse- grained sandstone lobes with shale and siltstone interbeds. Few and sparse macrofossils are known, although *Zoophycos* isp. and other ichnofossils are common. This unit is interpreted as a deltaic system entering shallow marine settings. The total age span of the Itaim Formation, as indicated by miospore-based revisions, is latest Emsian–early Eifelian. In the Carolina well (1-CL-1-MA), at the top of this formation, the macrofossil assemblage corroborates the late Early to Middle Devonian age. The lower part (Picos Member) of the Pimenteira Formation consists mainly of interlayered fine-grained hummocky cross-stratified sandstones and bioturbated shales and siltstones with plane-parallel stratification. Individual sandstone bodies commonly amalgamate to form thicker, more tabular complexes of strata. The sandstones are best developed in the older, Middle Devonian part of the formation, but tend to thin out and even disappear in higher sections of Late Devonian age, which become richer in finely-laminated, radioactive dark shales. The upper part (Passagem Member) of the Pimenteira Formation comprises highly micaceous fine-grained sandstones with asymptotic and hummocky cross-stratification, and subordinate climbing-ripple cross-laminated and plane-parallel stratified sandstones and siltstones. The Passagem Member is found only on the eastern outcrop belt of the basin (State of Piauí). According to recent interpretations, the Passagem Member comprises fine-grained distal mouth-bar deposits interbedded with delta-front, hummoky cross-stratified, graded sandstone lobes, collectively representative of a flood-dominated fluvio-deltaic system entering shallow marine settings. The lower part of the Pimenteira Formation marks the first extensive Devonian transgression across the Parnaíba Basin, which started in the late Eifelian and reached its maximum in the earliest Givetian. The Picos Member is envisaged as a transgressive systems tract deposited mostly in shallow marine environment. Deeper marine settings became widespread on the central and western margin of the basin during the Frasnian. In parts of the western flank of the basin the latest Devonian glaciation has removed varied sections of the Pimenteira Formation plus the whole of the ill-developed Cabeças Formation sandstones. Near Colinas do Tocantins village, latest Famennian (Strunian) diamictites assignable to the Cabeças Formation lie directly on the Precambrian basement and are overlain by dark grey to black shales of the basal Longá Formation. The age span of the Pimenteira Formation in the eastern outcrop belt of the Parnaíba Basin (State of Piauí) is assigned as late Eifelian–late early Givetian, based on palynomorphs obtained from shallow core-drills in the region. This corresponds to the lower part of this formation in the deeper central parts of the basin. In the subsurface and southwestern outcrop belt, however, the upper part of the upper Pimenteira Formation is dated as early Frasnian through early Famennian to the early/middle Famennian transition. The Longá Formation is a transgressive marine shaly unit which overlies conformably the Cabeças Formation, recording a sudden drowning of the Cabeças deltaic system. Kegel reported a sparse shelly fauna in the lower part (uppermost Famennian) Longá Formation outcrops at the Barreiras Farm, in Valença do Piauí municipality, composed by shales with interbedded conglomeratic to fine-grained sandstones. Ichnofossils are locally abundant, especially in the intermediate and upper units of the Longá Formation. The total age span of the formation is latest Famennian (Strunian) to early late Tournaisian.

Devonian trilobites of the Amazonas and Parnaíba basins, Brazil

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Devonian trilobites are found in three major Paleozoic intracratonic basins of Brazil (Amazonas, Parnaíba, and Paraná). They are represented by the families Homalonotidae, Dalmanitidae, and Calmoniidae. The distribution of these taxa in the Brazilian territory (Amazonas and Parnaíba basins) is summarized here because of their remarkable scientific and historical importance, and a revised taxonomy and lithostratigraphy of the Devonian (Pragian–Famennian) trilobites from Brazil is presented, based on new research and recent literature. The material studied here is represented by internal and external molds, mostly disarticulated; there are some almost complete specimens, but generally the preservation is not good. Specimens preserved within concretions (especially those from the Parnaíba Basin) are generally better preserved. Open nomenclature has been retained for certain taxa, due to the incompleteness and poor preservation of the specimens on which they are based, especially those from the Amazonas Basin.

In the Amazonas Basin, trilobites are documented only from the Maecuru and Ererê formations. The trilobites of the Maecuru Formation occur in the upper part of the former Lontra Member, which represents a shallow marine facies of Middle Devonian (latest Emsian-early Eifelian) age. Homalonotids are represented by a single taxon, *Digonus derbyi* (Clarke, 1890). Dalmanitids include *Amazonaspis maecurua* (Clarke, 1890), ?*Dalmanites infractus* Clarke, 1890, and Dalmanitidae gen. and sp. indet. Calmoniids are considerably more diverse, with ?*Acastoides menurus* (Clarke, 1890), *Malvinella australis* (Clarke, 1890), ?*Malvinella tumiloba* (Clarke, 1890), "*Palpebrops*" *goeldi* (Katzer, 1903), *Phacopina braziliensis* (Clarke, 1890), *Vogesina gemellus* (Clarke, 1890), plus several gen. indet. species, including *galea* Clarke, 1890, *scirpeus* Clarke, 1890, *macropyge* Clarke, 1890, and *acanthurus* Clarke, 1890. Another trilobite is of uncertain affinity at family level, "*Phacops" pullinus* Clarke, 1890. Trilobites are rare in the Ererê Formation, but are represented by the homalonotid *Burmeisteria oiara* (Hartt & Rathbun, 1875) and the calmoniid *Eldredgeia paituna* (Hartt & Rathbun, 1875).

Regarding the Parnaíba Basin, no trilobite body fossils have been recovered from the Jaicós, Itaim, and Cabeças formations, but trilobite trackways (possible from homalonotids) have been found in the Itaim Formation. Trilobites body fossils occur mainly in the Pimenteira Formation (Picos and Passagem members), and are scarcer in the Longá Formation. Trilobites from the basal part of the Pimenteira Formation (Picos Member) include the homalonotid *Burmeisteria notica* (Clarke, 1913), plus the calmoniids *Eldredgeia* cf. *E. venusta* (Wolfart, 1968), *Metacryphaeus kegeli* Carvalho, Edgecombe & Lieberman (1997), and *Metacryphaeus tuberculatus* (Kozlowski, 1923); registered here for the first time from the Pimenteira Formation. *Burmeisteria notica* is very abundant and well preserved in ironstone concretions, especially near the city of Picos (State of Piauí). More rarely, *Metacryphaeus tuberculatus* and other fossil invertebrates are also found in these concretions. Trilobites from the Passagem Member include a calmoniid, *Metacryphaeus meloi* Carvalho, Edgecombe & Lieberman (1997), and the homalonotid *Burmeisteria notica* (Clarke, 1913). A small trilobite, only known from a single cephalon and pygidium, was collected by Wilhem Kegel from poorly dated basal Longá Formation outcrops at Barreiras Farm (Valença do Piauí area, State of Piauí, eastern Parnaíba Basin), and referred to "*Asteropyge*". It may represent a new form of *Metacryphaeus*, although the presence of a calmoniid within such a young stratigraphic level (Strunian or perhaps even Tournaisian) is exceptional. The fossil may have been reworked from Middle Devonian or older strata. Homalonotids and dalmanitids are relatively cosmopolitan, whereas calmoniids are more endemic and seem to have been restricted to marine cold-waters of the southern hemisphere (Malvinokaffric Realm).

Although the trilobites within the Brazilian intracratonic basins are approximately contemporaneous, they show various patterns of endemism and biogeographical affinities with other Malvinokaffric areas such as Bolivia, South Africa, and the Falkland (Malvinas) Islands. At family level, the trilobite diversity from Brazil is comparatively low, which may indicate biogeographical filtering related to the distance and/or remoteness of the Brazilian basins from more open oceanic waters. The Devonian trilobite assemblages of Brazil share many common features with coeval faunas of other Malvinokaffric areas, including low family-level diversity (in fact even lower in Brazil than elsewhere), a mixture of cosmopolitan and endemic taxa at generic level, and an apparently high endemism at species level.

Orbitally forced sequences and climate reconstruction around the Devonian–Carboniferous boundary, and the Hangenberg Extinction Event

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In Belgium (Namur–Dinant Basin), the late uppermost Famennian ("Strunian") and Tournaisian deposits are controlled by orbitally forced sequences corresponding to precession cycles of short duration (18.6 Ka as average) and eccentricity cycles of longer duration ("third-order" sequences, 2.4 Ma). No other cycles were recognized.

The late "Strunian" precession cycles are typically alternations of shale and limestone. They are well exposed in the Anseremme railway section where at least 25 cycles were recognized in the upper part of the Comblain-au-Pont/Etrœungt Formation. They are included in the transgressive system tract (TST) of the third-order sequence 1 defined by Hance *et al.* (2001, 2002).

The Lower Tournaisian precession cycles vary from alternations of shale and calcareous shale to alternations of calcshale and limestone, and to limestone bed dominated, depending on their position in the third-order sequences. One hundred fifty-five precession cycles were recognized in the Hastarian Substage (Lower Tournaisian), distributing in the uppermost part of the third-order sequence 1, in the sequence 2, and in the TST of the sequence 3.

Nature and evolution of the precession cycles along the eccentricity cycles suggest relatively low eustatic variations but wet–dry climate variations.

In contrast, the lateral and vertical evolution of the eccentricity cycles and their boundaries show that they recorded high-amplitude eustatic variation corresponding to ice age–warm climate alternations.

Two ice ages corresponding to the falling stage system tract (FSST) and to the sequence boundaries are recognized in the Hastarian. The first is stratigraphically situated in the upper part of the MFZ1 foraminifer Zone (FSST of the sequence 1 and sequence 1–sequence 2 boundary), and the second one in the MF3 Zone (FSST of the sequence 2 and sequence 2–3 boundary).

In the Namur–Dinant Basin, the Hangenberg Black Shale is not really marked because its anoxic facies did not spread into the shallow-water environments, or perhaps only as shally intercalations into the cycles, and carbonate facies rich in benthic fossils continued to develop here during its development in other areas. Nevertheless, the following Hangenberg Sandstone, which reflects a strong sea-level drop, is easily recognizable in the Aachen area (Germany), and its lateral variation from sandy limestone to limestone facies is traceable to the Dinant area (Mottequin & Poty, 2014). The levels corresponding to that episode sharply overlie beds rich in "Strunian" brachiopods, rugose corals, stromatoporoids and foraminifera. There is no gap at their base which rests directly on the shales of the last Strunian precession cycle, but they can include some reworked "Strunian" fossils.

Therefore, the extinction event is very sharp and the levels correlated laterally to the Hangenberg Sandstone event do not fit into the succession of the deposits that are controlled by the precession cycles. Moreover, the event does not correspond to a third-order sequence boundary, being included in the upper part of the sequence 1.

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Continental ecosystems at high palaeolatitude before and after the Devonian–Carboniferous boundary: two examples from South Africa and Argentina

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The terrestrialization of living forms is by far one of the most important process that took place during the Palaeozoic. It deeply modified all ecosystems, both marine and continental. Characterized by an unprecedented increase of the biodiversity and of the biomass on emerged lands, it is also marked, at the end of the Devonian period by severe crisis in marine ecosystems as well as by climatic instability. We here report two assemblages situated at both sides of the Devonian–Carboniferous boundary. The first has been collected by R.G. in the Waterloo Farm locality (South Africa) and is latest Famennian in age. The second comes from the Tournaisian part of the Sierra de las Minitas (Argentina). The purpose of this communication is to compare two particularly different environmental settings documenting the changes that occurred globally at the Devonian–Carboniferous boundary.

The Waterloo Farm locality represents a lagoonal system partially separated from the Agulhas Sea by a barrier island complex (Gess & Hiller, 1995). Fine black anaerobic muds deposited in still portions of the lagoon accumulated a huge mixed assemblage representing the life of marine and fresh water influenced parts of the lagoonal system, as well as that of adjacent terrestrial environments. Terrestrial remains largely consist of plant material comprising a minimum of fifteen taxa. These represent most major Late Devonian groups including zosterophyllopsids, trimerophytes, sphenophytes, herbaceous and arborescent lycopdsids, iridopterids and progymnosperms. This locality provides a unique holistic picture of high latitude continental life in Gondwana immediately predating the End Devonian Extinction event.

The here reported Sierra de la Minitas deposits consist in fine to medium grained fossiliferous sandstones deposited in a marine environment (Prestianni *et al.*, 2015). Fossils from this interval include brachiopods, bivalves, crinoids, orthoconic nautiloids, gastropods, scarce fish remains and plants. The plant assemblage reveal a low diversity flora dominated by herbaceous lycopsids but also present traces of ferns and seed plants. Tournaisian Gondwanan plant communities from high latitudes are interpreted as being more complex than previously thought. Their discovery in a sedimentary environment associated with glacigenic deposits, shows that this new record might be linked to the coeval glacial age widely recorded elsewhere in Gondwana.

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Vegetational recovery on an Early Carboniferous coastal plain following the End Devonian Mass Extinction Event

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Following the End Devonian Mass Extinction Event, tetrapods disappeared from the fossil record for a significant time interval (Romer's Gap). However, many new specimens have been discovered within intact ecosystems from a number of Tournaisian localities in the Scottish Borders, UK. These tetrapods, and associated environments, are now being investigated by the NERC funded TW:eed project.

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

After standard palynological processing, abundant miospore assemblages were identified which, as expected, belong to the CM biozone. Samples have been studied at 10 m intervals, and their distribution through the Ballagan Formation is not stable but indicates fluctuations in the diversity of the vegetation. The distribution of megaspores, hand-picked from the >150 µm fraction, shows that they occur in discrete zones. This highlights an episodic return to a lycopod forested landscape. Rare scolecodonts indicate marine flooding events and possibly reworked Devonian miospores suggest erosive periods of basin uplift.

Infaunal molting in Mid Paleozoic trilobites: new insights based on data from South America

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Infaunalism for molting in trilobites has been compellingly supported by a striking three-dimensional molt pattern, which was firstly reported from Late Silurian–Early Devonian phacopids of western Argentina (Rustán *et al*., 2011). The infaunal molt pattern (Fig. 1) is characterized by the thoracopygidium being perfectly articulated, frequently exhibiting dorsal bending; the cephalon separated and located in front or directly above the first thoracic segments, trending to be overturned or perpendicularly oriented, and the hypostome dettached and displaced. Because no other taphonomic agent can be invoked for explaining this distinct spatial arrangement, it has been interpreted as biologically produced during molting, the trilobite being entirely buried in soft sediment.

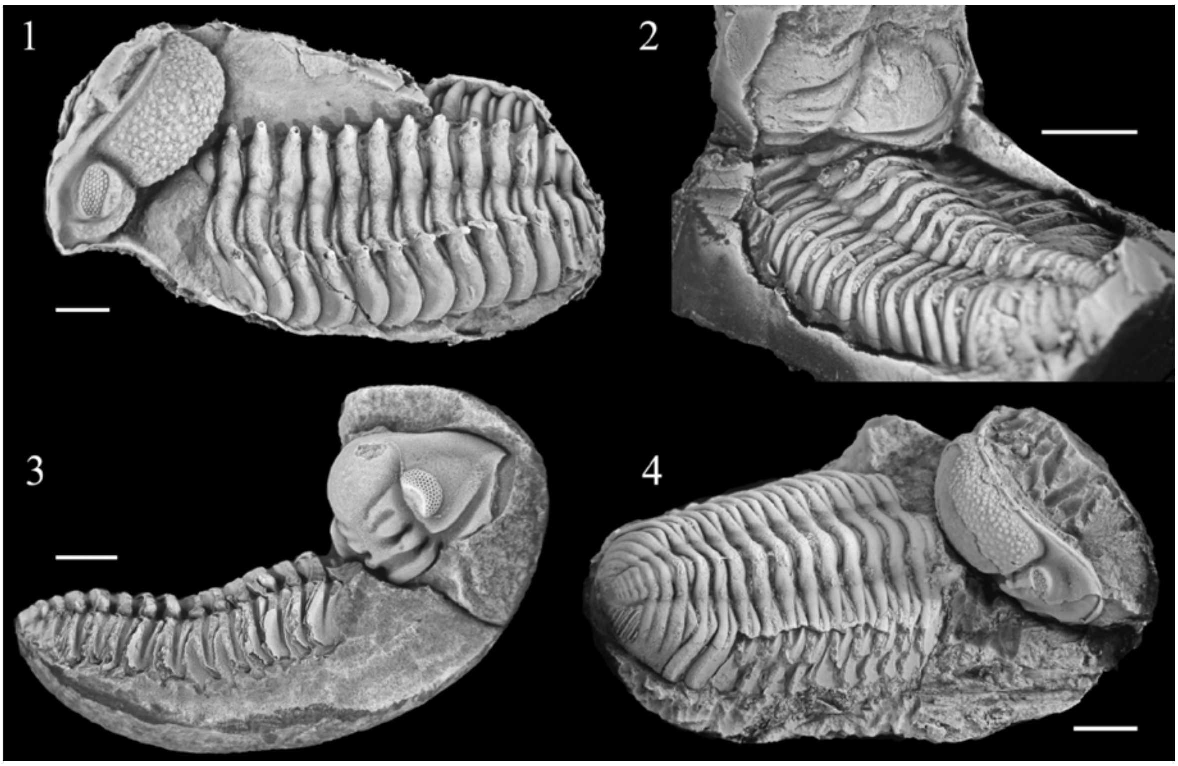

Fig. 1: Trilobites exhibiting the infaunal molt pattern. (1) *Echidnops* n. sp., late Lochkovian of the Talacasto Fm., Argentina (reported as *Paciphacops* n. sp. B by Rustán *et al*., 2011). (2) *Punillaspis argentina*, Middle Devonian of the Chigua Fm., Argentina. (3) *Pennaia verneuili*, Middle Devonian of the Belén Formation, Bolivia. (4) "*Phacops*" *chavelai,* Middle Devonian of the Chigua Fm., Argentina. Scale bar= 1 cm.

Since it is exclusively related to the most vulnerable period of the trilobite adult life (exuviation), this trait is understood as an evolutionary acquisition of a predator-deterrent behavior. Preliminar interpretations (Rustán *et al*., 2011) indicated that this behavior was only present in a putative lineage involving three species of *Paciphacops* from the Argentine Precordillera basin. In addition, an evolutionary trend toward the thickening of the carapace, development of spinosity, and size increase, was preliminary proposed for this *Paciphacops* lineage. Later, however, a thorough taxonomic revision indicated that one of the Argentinian species should be considered as *Echidnops* (Fig 1.1)*,* refusing the idea that the infaunal molt behavior was restricted to a monophyletic *Paciphacops* lineage, endemic from Argentina*.* A revision of the Braniša collection of trilobites, housed at the AMNH, USA (Rustán *et al*., 2012 a, b), allowed the identification of the same molt pattern in several species of the phacopid *Viaphacops* and also in the calmoniid *Pennaia verneuili*, coming mainly from the Middle Devonian of Bolivia. Moreover, a recent revisit of the poorly known Middle Devonian Chigua Formation (Baldis & Longobucco, 1977; Amenábar, 2009), in western Argentine Precordillera, has provided additional specimens of "*Phacops*" *chavelai* along with the calmoniid *Punillaspis argentina*, both of which also exhibit unquestionable infaunal molt patterns (Fig. 1.2 and 4).

Regarding the phylogenetical context, these new evidences definitively confirm that infaunal molting, as an ethological defensive character, appeared more than once in different trilobite families (namely phacopids and calmoniids), thus being clearly polyphyletic. In addition, since Middle Devonian phacopids and calmoniids exhibiting infaunal behavior, lack spinosity and are usually smaller than Lower Devonian representatives, a complex mosaic evolutionary pattern of these traits is suggested, implying that spinosity and size increase would have independently evolved in several different lineages. In accordance with initial interpretations, evidences as a whole reinforce the idea that these trends are in concert with the ecological evolutionary context of the so-called Middle Paleozoic Marine Revolution (Signor & Brett, 1984). This major bioevent is related to the sudden appearance of several groups of durophagous predators which greatly intensified predation pressure in Silurian–Devonian marine ecosystems, triggering defensive evolutionary trends in a number of prey groups. Furthermore, in light of the current larger stock of taxa, embracing a wider stratigraphic and geographic range, causal connections between the burst diversification of predators and evolution of active defensive responses in trilobites are now evident, since they share a common pattern in the fossil record. Mirroring the postulated trend in predation pressure (Nagel-Myers *et al.*, 2009), defensive infaunal molting initiated in the Silurian and rapidly became frequent during the Early Devonian, reaching a maximum during the Middle Devonian, in taxonomic diversity at species, genus and family levels (Fig. 2).

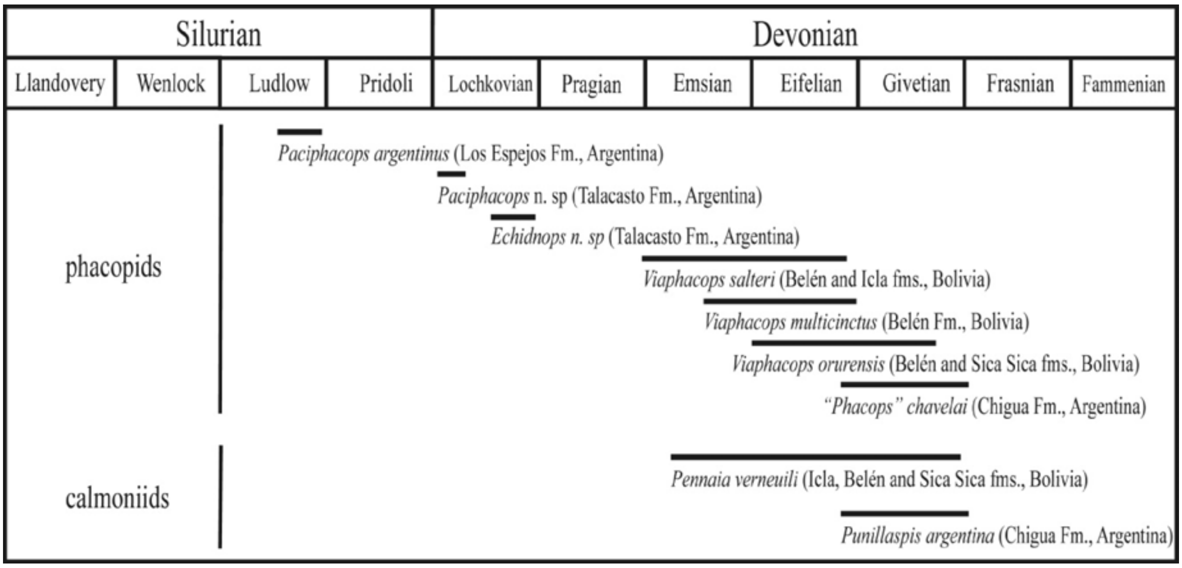

Fig. 2: Record of known trilobites exhibiting the infaunal molt pattern.

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Foraminiferal proliferation in the Alborz basin (Northern Iran): global response to Carboniferous glaciations

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The Lower Carboniferous represents the transition period between the warming conditions of the early Paleozoic and the late Paleozoic cooling ages. This transition period was marked by major changes in tectonic events, global oceanic circulation and biological turnover that influenced sedimentary regimes, bio-provincialism and diversification of various fossil groups such as foraminifera group. The development and biodiversity pattern of the Lower Carboniferous calcareous foraminifers are particularly sensitive to the influence of the glacial–interglacial cyclicity events.

Our study aims to provide insights into climatic variations through a study of the Tournaisian part of the Lower Carboniferous Mobarak Fromation (Tournaisian–Visean) in the Alborz basin. The Mobarak Formation records the development of a storm-sensitive pervasive carbonate factory on the southern Paleo-Tethys passive margin, following the opening of the Paleo-Tethys Ocean into the Alborz basin along the northern margin of Gondwana. Four outcrops in the central Alborz Mountains were selected: the Jaban, Aroo, Shahmirzad and Labnesar sections.

The three foraminiferal assemblages encountered in the Tournaisian interval of the Mobarak Formation are restricted to specific periods within the Ivorian (second half of the Tournaisian). The assemblage with *Granuliferella latispiralis–Latiendothyranopsis* (Jaban, Aroo and Labnesar sections) corresponds to the lower part of the Upper Tournaisian and the lower portion of the Ivorian, MFZ4–MFZ5 (Hance *et al.*, 2006a, 2006b, 2011) and correlates with the Lower Kizelian in the Urals and Upper Cherepetian of the Russian platform (Kulagina *et al.*, 2003, *Palaeospiroplectammina tchernyshinensis* Zone). The second assemblage with *Eotextularia diversa* (Jaban, Aroo, Shahmirzad and Labnesar sections) corresponds to the Cf3 foraminiferal zone of the Franco-Belgian Basin (Conil & Lys, 1977; Conil *et al.*, 1991), upper part of the Ivorian, MFZ6–MFZ7 (Hance *et al.*, 2006a, 2011) and corresponds to *E. diversa* Zone of the Russian Stratigraphic Scale (Kulagina *et al.*, 2003). The third assemblage with *Eoparastaffella ex gr. rotunda* (Jaban and Labnesar sections) corresponds to the uppermost Ivorian (uppermost Tournaisian), MFZ8 (Hance *et al.*, 2006a, 2006b, 2011) and correlates with *E. rotunda* Zone of Russia. The entire Hastarian portion is devoid of well-defined foraminiferal assemblages. The stagnation or even reduction in foraminiferal diversity during the Hastarian was, besides this study, also reported in literature (Bozorgnia, 1973; Ueno *et al.*, 1997; Brenckle *et al.*, 2009). The deterioration of foraminiferal diversity could be linked to a faunal shift from subtropical and temperate taxa to tropic latitudes in response to the glaciations at the Devonian – Carboniferous boundary. This interpretation is corroborated by the simultaneous deposition of lower Tournaisian glaciogenic sediments in South America. The establishment of the *Granuliferella latispiralis – Latiendothyranopsis* assemblage coincides with the first worldwide foraminiferal diversification of the Tournaisian (Kalvoda, 2002). This phase is followed by the lower Hastarian argillaceous interval (MFZ3 and MFZ4), which marks the onset of an Early Tournaisian period of increasing temperatures (Isaacson *et al.*, 2008). The second foraminiferal diversification (*Eotextularia diversa* and *Eoparastafella ex gr. rotunda* assemblages) is congruent with the major foraminiferal shift from Tethyan realms to the higher latitudes in response to the thermal periods. The occurrence of specific foraminiferal taxa in Alborz is tightly governed by transgressions and migration of North Paleo–Tethyan biotic elements. The Tournaisian cyclic patterns of Alborz are very similar to those in the North American and Siberian realms, indicating a shared underlying dependence on large-scale climate evolution. This cyclic pattern correlates directly with the pacing of global eustatic sea level fluctuations caused by climate oscillations, and is in agreement with the 4th order ocean-level fluctuation recognized in oxygen and carbon isotopes curves (Bruckschen & Veizer, 1997).

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The Kellwasser type locality in the Harz Mountains (Germany) revisited – new results after widening of the classical outcrop

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The classical section in the Kellwasser Valley near the Oker Reservoir in the German Harz Mountains is the type locality of the Upper Devonian Kellwasser horizons. The locality, which was already badly preserved shortly after its discovery in the middle of the 19th century (Roemer, 1850), has recently been re-opened and widened (Luppold *et al*., 2010). The newly created section displays cephalopod limestones of upper Frasnian and Famennian age to shales of the Lower Carboniferous ("Kulm-Kieselschiefer"). The Lower and Upper Kellwasser horizons are exposed as are the Lower and Upper *annulata* horizons. Although some parts of the outcrop are highly tectonised (Franzke & Müller, 2012), it is nonetheless possible to reconstruct the sedimentary sequence. The Kellwasser horizons, connected to one of the five most severe mass-extinction events in Earth History (Kellwasser Crisis), can now be studied again in detail. Conodonts sampled by O.H. Walliser (Göttingen) and co-workers in the 1980s as well as new samples were investigated with respect to conodont biostratigraphy and microfacies. The section is very condensed due to sedimentation in a submarine rise setting. The conodonts studied belong to the Upper *rhenana* to Lower *marginifera* zones; conodonts from higher parts of the section have not yet been investigated. Many papers dealt with this classical section, of which only a few shall be mentioned. In an extremely detailed study Beushausen (1900) gave an overview about sections in the Harz Mountains and already pointed out widespread correlation of the Kellwasser horizons. According to the Kellwasser Crisis, the papers by Buggisch (1972), Schindler (1990) and Gereke (2007) shall be addressed among many others. In a comparative study by Gereke & Schindler (2012) correlation from submarine rise settings into basinal facies is demonstrated – including the aspect of "Time-specific facies" (comp. Brett *et al*., 2012). A more detailed overview of the newly exhumed section is given by Gereke *et al.* (2014). The Kellwasser type locality is situated in the European Geopark Harz – Braunschweiger Land – Ostfalen (Schindler & Wilde, 2011) and should be protected as a geosite.

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Cooling or warming in the Pragian? The sedimentary records and petrophysical logs from the key peri-Gondwanan sections

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In many regions, the complex petrophysical characteristics of the biostratigraphically well constrained Early Devonian strata are urgently needed in order to provide the most complete image of the impacts of possible global environmental changes. The principal environmental instabilities in the Early Devonian are well expressed, especially by the obvious differences between the classical megasequences that represent traditional hercynian (Bohemian) stages (Lochkovian, Pragian, Zlichovian, and Dalejan). These stages are characterized by typical marine successions/formations whose boundaries are independent of the official global Devonian subdivision. These may reflect the global or, at least, supra-regional trends in environmental dynamics, and also may partly correspond to the "Time Specific Facies" of Walliser (1984). Especially conspicuous on the global scale are the differences between the Lochkovian and Pragian stages, as they can very distinctively be recognized as turnovers in the marine faunal communities, described from many areas (*e.g.*, Chlupáč *et al.*, 1985; Havlíček & Vaněk, 1998; Koren' *et al.*, 2007); additionally, by a change in the composition of marine sedimentary rocks, a drastic change of environmental proxies (Małkowski *et al.*, 2009), and the extremely high extinction-speciation rates of land plants (Xiong *et al.*, 2013). According to Chlupáč & Kukal (1986, 1988), as well as House (2002), there was a trend toward a gradual increase of water energy and shallowing, culminated close to the base of the Pragian, especially during the Basal Pragian Event. In the type area (Prague Synform, Barrandian area), the boundary event is connected with a positive shift of $\delta^{13}C$ values (Hladíková *et al.*, 1997; Buggisch & Mann, 2004), and with heavily condensed sedimentation around the Lochkovian-Pragian (Lo-Pg) boundary (see Slavík *et al.*, 2012). According to Koptíková *et al.* (2010a, b), the interval close above the boundary is also marked by a change in the delivery of non-carbonate impurities into marine carbonates, with an increased long-distance aeolian input; maybe reflecting a major change of the ocean-atmospheric system. Additionally, the oxidizing conditions spread down the carbonate slope, also occurring with iron in the deepwater carbonate beds of the Pragian; mostly occuring in the oxides and oxyhydroxides rather than pyrrhotite, which is common in the Lochkovian beds. With the exception of coarse bioclastic deposits at the base, the Pragian sedimentary rocks are often characterized by the presence of highly polydisperse and polymodal mixtures of calcisiltitic materials; and instead of cementation, a tendency to early diagenetic compaction and lithification due to re-crystallization predominates. A tendency toward the increased occurrence of nodular limestones is seen, also having violet- and orange-band color hues, but virtually no cherts. It is most likely that a global climate change could have been a crucial factor. Although the rapid and massive change makes the Pragian sedimentary systems so different, an understanding of the parameters and causes is still a challenge.

The methods including magnetic susceptibility measurements (MS), gamma-ray spectrometry (GRS), and alignment of MS logs using the dynamic time warping (DTW) algorithm were applied to the mid-Paleozoic rocks of the Pyrenees and the Prague Synform. The interpretation of petrophysical data from these two key peri-gondwanan regions allows us to determine the essential parts of the Pragian as a still "hot and humid" period, even with the strong differences from the possibly "extremely hot" Lochkovian.

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Romer's Gap: the beginning of the modern fish fauna

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The end-Devonian extinction event marked a profound change in the diversity of fishes. The dominant Devonian taxa, the acanthodians, placoderms and sarcopterygians, were suddenly replaced by minor components of the fauna, the actinopterygians and chondrichthyans (Sallan & Coates, 2010). This replacement began in the early Carboniferous, during Romer's Gap, but the evidence for it has been poor. Until recently, the earliest Carboniferous actinopterygians were represented by the "Foulden fauna" (Sallan & Coates, 2013) a restricted group of small taxa from five lacustrine deposits in Canada, Russia and the UK. Collecting at new sites in Nova Scotia, Canada (Mansky & Lucas, 2013) and the Scottish Borders (Smithson *et al.*, 2012) has uncovered large fusiform and deep-bodied fishes that hint at a previously unrecognised diversity (Fig. 1).

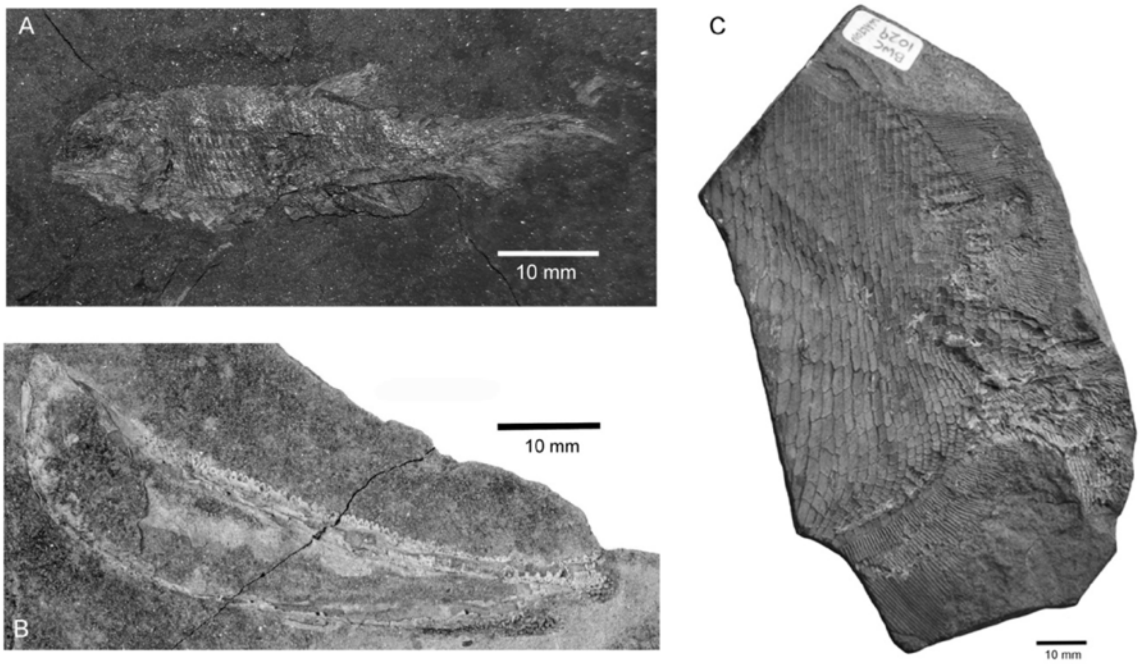

Fig. 1: A. *Aetheretmon valentiacum* a member of the Foulden Fauna from Willie's Hole, Scottish Borders. B. Undescribed actinopterygian mandible from Coquetdale, Northumberland, UK. C. Posterior half of deep-bodied actinopterygian from Walton, Nova Scotia, Canada, figured by Mansky & Lucas (2013).

Similarly, the earliest Carboniferous chondrichthyans were known mainly from localities in China, Russia and North America (Sallan & Coates, 2010). In the UK, the Tournaisian chondrichthyan fauna was represented by a collection of teeth from the Carboniferous Limestone near Bristol and by two teeth from southern Scotland. Collecting at new sites in the Scottish Borders has uncovered an extraordinarily diverse fauna of chondrichthyans (Richards *et al.*, in review). Represented by well-preserved teeth, many of the taxa are new and undescribed. Notably, the plate-like bradyodont teeth have been found in large numbers and exhibit a broad range of shapes and sizes (Fig. 2). They represent fishes that were much larger than their younger relatives from the later Carboniferous.

One group of Devonian fishes that unexpectedly flourished in the early Carboniferous was the Dipnoi (Smithson *et al.*, in review). Previously known from just one species from the River Tweed at Coldstream, seven new taxa have recently been found at Tournaisian sites across Northumberland and southern Scotland (Fig. 3). Like the bradyodont sharks, the Dipnoi were shell crushing predators, and there is growing evidence that immediately after the end-Devonian extinction a durophagous feeding habit was common (Sallan *et al.*, 2011). Romer's Gap has been described as a post-extinction trough for vertebrates (Sallan & Coates, 2010). The recent discoveries in the early Carboniferous of northern Britain and Nova Scotia, suggest that vertebrate diversity was much greater than previously thought.

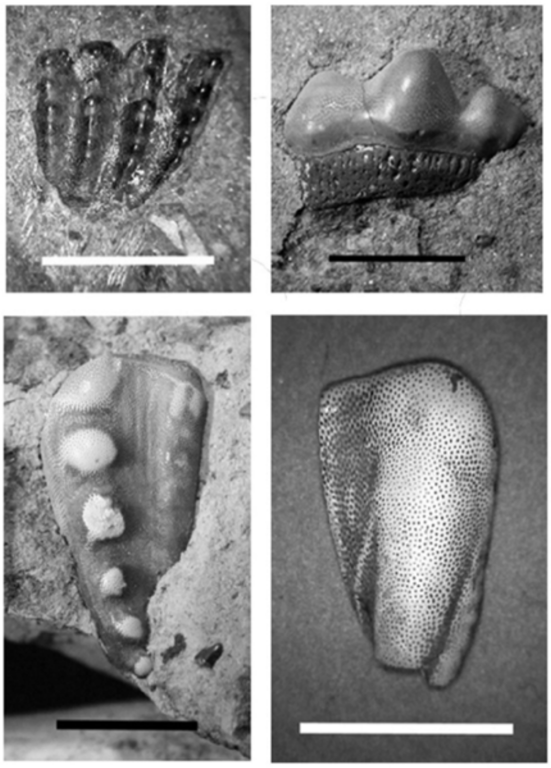

Fig. 2: Examples of bradyodont teeth from Whitrope Burn, Scottish Borders, figured by Richards *et al.*in review. Scale bars: 10 mm.

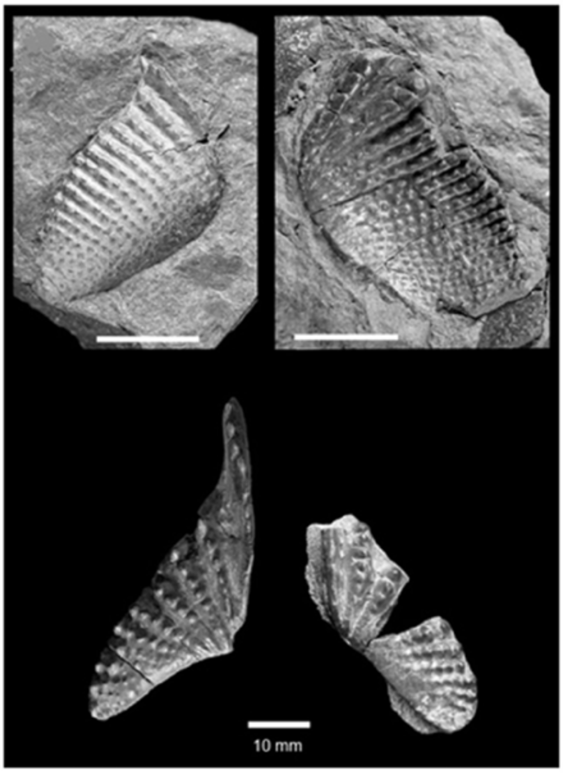

Fig. 3: Examples of lungfish tooth plates from localities along Whiteadder Water and the River Tweed, Scottish Borders and Northumberland, UK, figured by Smithson *et al.*, in review. Scale bars: 10 mm.

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Conodont stratigraphy of Frasnian deposits of the western slope of the Polar Urals

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Frasnian deposits are located 30 km east of Vorkuta City and are exposed along the Malaya Usa River at a distance of 5.6 km from the confluence of the Malaya and Big Usa rivers. Structurally, the area belongs to the Bielsko-Eletskaya structural formational zone on the western slope of the Polar Urals within the Mikhailovsky-Vaygachsky subzone of the Vorkuta-Korotaihinskoy district (State Geological Map, 2005). Upper Devonian deposits of this area have been studied by numerous scientists such as N. N. Jordanskiy, K. G. Voynovskiy-Krieger, G. I. Egorov, V. S. Yenoqyan, G. A. Chernov, M. A. Shishkin and others. Very recently a new paper was published by M. A. Soboleva & D. B. Sobolev (2015).

The investigated Devonian rocks in this area are part of an anticline and belong to deposits of the so-called shervozhskoy suite ($D_{1\text{-}2}$sv) which are overlain by more dolomitic limestones ($D_{2\text{-}3}$di). The complex geological framework is characterized by at least three major faults. Frasnian deposits are mainly composed of limestones. In the lower portion of the sampled section they are often argillaceous and partly siliceous whereas in the upper part of the section they show variable thicknesses, they are often recrystallized and exhibit breccia-like structures. Dolomitic limestones are more common in the upper part than in the lower part of the section. After analyzing the stratigraphic distribution of conodonts the following conodont biozones have been identified: *falsiovalis*, *transitans*, *punctata*, *hassi-jamieae*, *early rhenana*, *late rhenana*. The Standard Conodont Zones by Ziegler & Sandberg (1990) were compared with conodont biozones east of the Russian Platform (Ovnatanova & Kononova, 2008). Based on conodont stratigraphy, the dolomitic limestones are exclusively of Frasnian age.

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Proposed revision of the Famennian (Upper Devonian) standard conodont zonation

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The proposed revision of the Famennian part of the Late Devonian Standard Conodont Zonation of Ziegler & Sandberg (1990) is the result of two main different kind of considerations. The first is philosophical, and consists in refusing: (1) the equivalence between biozones and time, and (2) the presumed phyletic concept on which this zonation was based. The second is practical, and deals with: (1) solving difficulties arose in the recognition of some biozones defined by Last Appearance Datum (LAD), (2) simplifying the zonation eliminating the zonal groups named after only one taxon.

This revision is largely based on the zonation of Ziegler (1962) and the Late Devonian Standard Conodont Zonation of Ziegler & Sandberg (1990) using mostly the same zonal markers, therefore it is perfectly correlatable with them. Modifications have been only made when strictly necessary, as the aim of the proposal is not to destroy what was previously well done, but to improve and simplify the Standard Conodont Zonation, keeping stability over more than 50 years of conodont studies.

The 22 zones constituting the revised zonation are defined by the First Appearance Datum (FAD) of species and subspecies whose stratigraphic ranges are well known, and have wide geographic distribution (Fig. 1), most of which have already been used as markers. Each zone is named after the species or subspecies whose FAD defines the lower boundary. The main changes regard the upper part of the Famennian, and take into account proposals already made by other authors, at least for regional zonation (Corradini, 2008; Kaiser *et al*., 2009; Hartenfels, 2011; Corradini *et al*., submitted).

The stratigraphic distribution of most Famennian conodont taxa has been updated on data available in literature, and unpublished information of the authors.

Ziegler & Sandberg (1990)	THIS PAPER
sulcata	*Pr. kockeli*
Upper *praesulcata*	
Middle *praesulcata*	*Bi. ultimus*
Lower *praesulcata*	
Upper *expansa*	
Middle *expansa*	*Bi. costatus*
	Bi. ac. aculeatus
Lower *expansa*	*Pa. gr. expansa*
Upper *postera*	*Pa. gr. manca*
Lower *postera*	*Pa. p. postera*
Upper *trachytera*	*Ps. granulosus*
Lower *trachytera*	*Pa. r. trachytera*
Uppermost *marginifera*	*A. beulensis*
Upper *marginifera*	*Pa. m. utahensis*
Lower *marginifera*	*Pa. m. marginifera*
Upper *rhomboidea*	*Pa. gr. gracilis*
Lower *rhomboidea*	*Pa. rhomboidea*
Uppermost *crepida*	*Pa. gl. pectinata*
Upper *crepida*	*Pa. gl. prima*
Middle *crepida*	*Pa. termini*
Lower *crepida*	*Pa. crepida*
Upper *triangularis*	*Pa. m. minuta*
Middle *triangularis*	*Pa. del. platys*
Lower *triangularis*	*Pa. triangularis*
	Pa. subperlobata

Fig. 1: Correlation of the Famennian Standard Condonont Zonation of Ziegler & Sandberg (1990, simplified) with the proposed zonation.

The lower boundary of the Famennian is identified as proposed by Klapper (2007), a revision of the current definition of the base of the Famennian is therefore suggested. The definition of the upper boundary (base of the Carboniferous System) is currently under discussion and study.

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Palynology and palaeobotany of the Devonian Samnuuruul Formation, western Mongolia – an update

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The Samnuuruul Formation in western Mongolia is situated in an area that has been subjected to folding, faulting, and extensive fracturing. Comprised of four units, the Formation is dominated by volcanically derived fine grained clastic deposits on a shallow shelf, interspersed with sporadic deposition of limestone in the lower and middle units. The uppermost section of the Samnuuruul Formation (= unit 4) is characterised by a series of coarsening upward sandstones and conglomerates, with interbedded siltstone and shales containing macroscopic plant fossils, perhaps deposited as a series of offshore bars or coastal barrier bars (Kido *et al.*, 2013). This sequence grades upwards into a weathered shale culminating in a series of soil horizons, carbonaceous shales and coal which likely straddle the Devonian/Carboniferous boundary. Within this transition is a 0.5 metre black shale, hypothesised to correlate with the Hangenberg Event (Kido *et al.*, 2013).

The Samnuuruul Formation contains a diverse fauna of bryozoans, foraminifera, bracheopods and cephalopods that indicates a Late Famennian age (Ariunchimeg, 2000), but its palaeobotany or palynology has hitherto not been studied. The Samnuuruul Formation forms part of the Central Asian Orogenic Belt, thus it is surmised that its geographic isolation provided ideal conditions to support ecological refugia – especially in the aftermath of the Frasnian/Famennian event (Kido *et al.*, 2013). The positioning, preservational conditions and fossil contents make this formation of particular interest.

A detailed sampling strategy was conducted, particularly focusing on unit 4, in order to build a refined age profile of the Samnuuruul section. This research is part of an ongoing project, therefore an update on the palynology and palaeobotany of the Samnuuruul Formation will be presented.

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Event-controlled reef drowning and extinction in the Hönne Valley (northern Rhenish Massif, Hagen-Balve reef complex)

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The Givetian–Frasnian of the eastern Rhenish Massif is characterized by numerous small to large-sized reef complexes, which have been the subject of numerous studies on facies, faunas, and palaeoecology. They developed with transgressions in different palaeogeographic positions on the southern inner to external shelf of the Old Red Continent, from nearshore settings and the inner shelf margin to isolated large or small structural highs and volcanic seamounts within the deeper Rhenohercynian Basin. It is long known that many reefs died within the higher Givetian or early in the Frasnian and this has been attributed to local factors whilst the rather sudden extinction of several last reefs has been attributed to the Lower Kellwasser Event (Eder & Franke, 1982). Wilder (1989), however, related it to a "terrestrial-marine teleconnection" caused by the spread of land plants and subsequent increased nutrient delivery into the adjacent shallow sea. Our understanding of regional reef extinctions in the Rhenish Massif is in general still very limited, mostly due to the lack of detailed stratigraphical and microfacies investigations of youngest reef carbonates and overlying post-reefal beds.

Impressively thick (up to 1000 m) reef carbonates of the Hönne Valley (northern Sauerland, eastern end of the Remscheid-Altena Anticline, topographic sheet 4613 Balve) are part of a large reef complex, which extends over 30 km from Hagen in the West to Iserlohn and Hemer and then to Balve in the Southeast. It consists of an initial bank stadium (lower Givetian Schwelm Facies with dominant stromatoporids and tabulate corals) that developed soon into a true bioherm complex (Dorp Facies). Its growth kept up with fast but slightly fluctuating subsidence during the middle Givetian. It is likely that the Hagen-Balve reef belt represents a fringing reef around a synsedimentary high in the core of the Remscheid-Altena Anticline. Reef facies and back-reef cycles of the huge Asbeck Quarry on the eastern side of the Hönne Valley have been studied by Schudack (1993). Marginal slope successions at the southern end, near Balve and close to intercalating basalt volcanoes, were earlier analyzed by Eder (1971). But there are so far no published data on the sudden termination of this massive carbonate platform. Our new data on the final reef phase are based on the study of a drill core (B102, Stichling, 2010) and of an isolated outcrop (Nowak, 2010) in the forest at the Beil/Beul NW of Eisborn, which is a classical site for post-reefal ammonoid stratigraphy. Research was conducted in close co-operation with the Rheinkalk GmbH (Lhoist Group), which operates the Asbeck Quarry and which kindly made the drill core available.

The investigated lower 73 m (Beds -97 to -31) of the core consist of lagoonal limestone dominated variably by the branching stromatoporids *Stachyodes* and *Amphipora*, either in monogeneric or mixed assemblages, and alternating with stromatoporid-poor fine-grained bioclastic limestone. The lack of conodonts is typical for back-reef settings and prevents a precise dating of this succession within the middle Givetian. *Amphipora* and *Stachyodes* indicate shallow, clear and calm water conditions with very mild currents (see Krebs, 1974; Faber, 1980). From *ca.* 51 m (Bed -50) there is a slight decrease in the number of stromatoporids, followed by some poorly fossiliferous brecciated limestone (Beds -44 and -42). *Amphipora* is slowly replaced by *Stachyodes,* which was able to settle in environments with stronger currents. At ca.31 m depth (Bed -30) a change from lagoonal to shallower reef facies is documented by the incoming of dominant laminar and massive stromatoporids, which indicate higher water-energy and relative shallowing. The last *ca.* 4 m of the platform succession (Beds -27 to -25) are represented mostly by brecciated, proximal reef debris limestones (rudstones) with stromatoporids, tabulate (thamnoporid and alveolitid) and solitary rugose corals, and micrite intraclasts. This may indicate reef backstepping during transgression but there is no clear marginal slope facies in the core. Two pulses were interrupted by a unit of calmer deposition (micritic, bioturbated bioclastic limestone with some laminar stromatoporids and alveolitids, Bed -26).

Details of this final phase are exposed in the small outcrop to the SE. It exposes *ca.* 2.8 m of middle-grey, thick-bedded, partly peloidal mudstones to bioclastic wackestones with some tabulate corals, rare colonial Rugosa, very rare stromatoporid fragments, some crinoid debris, ostracods, and some mollusk debris (Beds B1-4). A persisting, restricted polygnathid conodont biofacies, especially the association of *Po. alatus* and *Po.*

paradecorosus, proves that the internal platform drowned suddenly in the latest Givetian (*norrisi* Zone). The first transgressive pulse of the global Frasnes Events enabled the influx of open shelf organisms. The cessation of reef growth led to strongly reduced carbonate accumulation. The highest Givetian (Beds B5-10c) is characterized by unusually dark, organic-rich mudstones/wackestones, partly with some reefal biota (coral-stromatoporid floatstones). This facies is interrupted right at the Middle–Upper Devonian boundary (basal *rotundiloba pristina* or MN 1 Zone) by a lighter limestone with more corals (Beds B11-12a, alveolitid-stromatoporid floatstone).The faunal association and microfacies does not correspond to a cap stadium, known as Iberg Facies from other Rhenohercynian reefs. The term Beul Facies is introduced for drowned platform facies, terminal open marine carbonate bank/biostrome facies without dominant reef caps and their steep relief (dominant coarse debris) or mudmounds (microbialites). Higher in the lower Frasnian, above the exposed cliff, a very fossiliferous, thin biostrome with many colonial Rugosa (*Hexagonaria, Phillipsastrea*), alveolitids, and thamnoporids marks the last reefal stage.

Both in the outcrop and in the core the final reef drowning and extinction must have occurred before the higher Middle Frasnian. Beds above the last reef debris (Bed -24) or outcrop biostrome consist of bioturbated, light-grey nodular limestones that contain *Palmatolepis plana*, indicative of MN Zone 10. In the core, the facies boundary is sharp, with a disconformity. Palaeoenvironmental conditions remained stable subsequently and the pelagic *Palmatolepis* facies continued. Closer to the top (from Bed -20 on), limestones becomes more and more argillaceous and distal. There is no evidence for the Lower Kellwasser beds but this may be due to core loss. The Upper Kellwasser Limestone (Bed -14) is developed as a rather thin, dark-grey, laminated, poorly fossiliferous limestone with a gradual lower contact. It interrupts the light-grey pelagic succession just below the Frasnian–Famennian boundary. Higher in the lower Famennian (*ca.* Middle *crepida* Zone, above the first *Pa. regularis*) laminated black shales re-appear and provide local evidence for the "Nehden Event".

In summary, the new data provide evidence for a stepwise extinction of the Hagen-Balve-Reef in the Hönne area by drowning episodes. However, this was neither related to local factors nor to the much younger Kellwasser Events. The first drowning correlates with the initial Frasnes Event in the latest Givetian and left a biostromal platform and last patch reefs, which produced and shed a much reduced amount of carbonate. The final drowning occurred in the middle Frasnian and may or may not have been induced by global sea-level rise.

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Palynomorphs (miospores, acritarchs, prasinophytes) before and during the Hangenberg crisis

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Above the richly documented palynomorphs (Becker *et al*., 1974) characterizing the lower part of the uppermost Famennian ("Strunian"), one can subdivide the Hangenberg crisis in 3 parts: "a lower crisis interval which started as a prelude with a minor eustatic sea-level fall, followed rather abruptly by pan tropically widespread black shale deposition"; "a middle crisis interval which is characterized by a gradual but major sea-level fall of glacio-eustatic origin"; "an upper crisis which is characterized by post-glacial transgression" (Kaiser *et al*., in press).

The base of the "Strunian", in the reference section of Chanxhe, falls within the higher LL (*lepidophyta–literatus*) Zone, more or less at the morphometric change in *Retispora lepidophyta,* ranging from a majority of large specimens (shale 112 and below) to a majority of small specimens (shale 116 and above) (Maziane *et al*., 2002). The foraminifer *Quasiendothyra kob. kobeitusana* first occurs in limestone 115; the conodont *Bispathodus ultimus* (Upper *expansa* Zone) first occurs in limestone 111. Indeed, a correlation with the Refrath borehole (western Germany, *ca.* 100 km east of Chanxhe) using the morphometric changes in *R. lepidophyta*, shows that the middle *expansa* conodont Zone (and *hemisphaerica–dichotoma* ostracod Zone) corresponds to shales 101 to 112 at Chanxhe (Streel & Hartkopf-Fröder, 2005). The morphometric change of *R. lepidophyta* allows correlations between several sections (outcrops and boreholes) in eastern Belgium (Streel, 1966; Maziane *et al*., 2002). Acritarchs and prasinophytes are particularly abundant in the "Strunian" at Chanxhe. The acritarchs belong to *Micrhystridium, Solisphaeridium, Stellinium* and *Verhyhachium* (Maziane, 1999; Maziane *et al*., 2007). A small percentage of *Maranhites* suggests locally a high sea-level. Higher in the section, acritarchs decrease in abundance and diversity, while miospores abundance is increasing, suggesting a closer shoreline. A lowering of the sea-level is corroborated by the occurrence above bed 123 of shallow water ostracods species belonging to the genera *Platycopina* and *Paraparchiticopina* (Casier *et al*., 2005). Prasinophytes (small *Leiosphaeridia*, small and large *Gorgonisphaeridium*, *Synspheridium, Cymatiosphaera, Pterospermella*) become more and more abundant, suggesting a shift to a lagoonal facies. The first occurrence of the large prasinophyte *Gorgonisphaeridium winslowiae,* above the first level of *Quasiendothyra kobeitusana* (Maziane & Vanguestaine, 1997; Maziane *et al*., 2002) is also a good characteristic of this timespan.

The lower crisis interval starts with the first occurrence of *Indotriradites explanatus* marking the base of the LE (*lepidophyta–explanatus*) Zone. At Chanxhe (shale 146), it corresponds to a major drop in the acritarch diversity and a complete dominance of small *Gorgonisphaeridium* and small *Leiosphaeridia*. These prasinophytes have affinities with cold water and dysoxic-anoxic facies (Tyson, 1995: 301). They are dominant, if not exclusive, until the top of the section (limestone 162) where a fault interrupts the sequence. Intensive work on intercalated shales (bed 156, for instance) showed the presence of *R. lepidophyta* and *I. explanatus* but did not provide other diagnostic miospores. Therefore, several attempts to complete the data until the base of the Hastière Limestone were made with the Royseux section in the Hoyoux valley (Austin *et al*., 1970; Maziane *et al*., 2002), and with the Rivage Pont de Scay section in the Ourthe valley (Sautois, 2007; Prestianni *et al*., in prep.). The LE Zone is confirmed everywhere. The Rivage Pont de Scay section was obviously used by Kumpan *et al.* (2014), although this was not clearly specified. A short positive carbon excursion is showed by these authors in that section and is tentatively correlated with a comparable carbon excursion in the Carnic Alps. It can be correlated with the lower part of the LE Zone in Chanxhe. In the Rhenish Massif, the LE zone is known from the highest part of the early *praesulcata* conodont Zone, in the upper part of the Wocklum Limestone at the Hasselbachtal section (Higgs & Streel, 1984). Ostracod transition between the *hemisphaerica–dichotoma* Zone and the *hemisphaerica–latior* is also firmly correlated with the LE Zone in Hasselbachtal section (Bless & Groos-Uffenorde, 1984). In more offshore localities, the Drewer sandstone, known within the LE Zone between the Wocklum Limestone and the HBS, is in the same stratigraphic position as the short positive carbon excursion in Rivage Pont de Scay and might correspond to a first short-termed glacial advance. The LE zone is followed by the LN (*lepidophyta–nitidus*) Zone which starts with the Hangenberg Black Shales (HBS), on top of the Wocklum limestone (Higgs & Streel, 1994).

The middle crisis interval starts in the Rhenish Massif, above the HBS in the Hangenberg shales (HS) and peaks in the Hangenberg Sandstone (HSS) immediately below the Stockum Limestone. The LN zone in the Rhenish Massif is based on rather poor assemblages with a small number of miospores of limited species diversity. However, in several localities, *Verrucosisporites nitidus* is accompanied by *Vallatisporites vallatus* (Higgs & Streel, 1984). This is consistent with the LVa (*lepidophyta–vallatus*) Zone defined in the Amazon Basin in Brazil by Melo & Loboziak (2003) where LE–LN assemblages have been recognized and renamed Rle–LVa. Diamictites and glacio-marine strata are common in these intervals. However, the Rle is considered possibly representing an impoverished variant (ecofacies?) of the LVa in places where *Verrucosisporites nitidus* and *Vallatisporites vallatus* are absent. Therefore, it is difficult (Streel *et al*., 2013) to accept the conclusion made by Wicander *et al.* (2011) that the diamictite sequence of the Itacua Fm they have studied in Bolivia was a composite representing several deglaciation events starting in the LL through the LE and LN Zones. However, on the evidence provided above in eastern Belgium and western Germany, a glaciation starting in the LE Zone and culminating in the LN Zone, interrupted by the transgressive HBS is well possible. In the Stockum trench II (Higgs *et al*., 1993; Streel, 1999), the more sandy part (HSS), corresponding to the maximum of the regression, contains an atypical LN assemblage of miospores, very rich in *Retusotriletes* ssp. and where *R. lepidophyta* is rare (about 1% but a consistent element). This atypical LN Zone has also been found from the top of the Old Head of Kinsale Fm, in southern Ireland, at the base of the regional Courceyan Stage (Higgs *et al*., 1988) as well as in the Kowala Fm of the Holy Cross Mountains in Poland (Marynowski & Filipiak, 2007). The LE-LN Zones or equivalents are well represented around the world. In north America, for instance, they allowed to date for the first time (Sandberg *et al*., 1972) not only the Bedford Shales in Ohio (see also Molyneux *et al*., 1984), but also the Sappington Shales in Montana (see also Warren *et al*., 2014). Also for the first time, using miospores, the lower part of the continental Pocono Fm in western Pennsylvania was dated as uppermost Famennian (Streel & Traverse, 1978). Laminites intercalated within diamictites (Brezinski *et al*., 2010) in the Spechty Kopf Fm of eastern Pennsylvania carry also well preserved LN assemblages (Richardson *et al*., 2006, Streel *et al*., in prep). Correlation of the LE–LN Zones with equivalent in New York State and Pennsylvania Catskill Fm is still under study (Avkhimovitch *et al*., in prep.), emphasizing the range of changes through time of several new species of *Vallatisporites.* Correlation between Western Europe and the Russian Platform was given by Byvsheva *et al.* (1984), with Poland and Belarus, by Avkhimovitch *et al.* (1993).

The upper crisis interval starts in the Rhenish Massif above the atypical LN Zone where a transgression reflects a post-glacial eustatic rise. The next miospore zone, the VI (*Vallatisporites verrucosus–Retusotriletes incohatus*) Zone is poorly defined, above all by the disappearance of several taxa. Not only *R. lepidophyta* but also *Rugospora flexuosa, Diducites versabilis* and *D. plicabilis. V. verrucosus* is not diagnostic as it first occurs in the LE Zone. The VI Zone is dominated by simple laevigate or microapiculate forms such as *Retusotriletes incohatus* or *Apiculiretusispora coniferus,* known from older zones, but which may comprise here more than 50% of the total spore assemblage. The base of the VI Zone is well displayed, a few cm or dm. below the still official D–C Boundary, in trenches or borehole like the Hasselbachtal borehole (Higgs *et al*., 1993), the Seiler trench (Ziegler & Sandberg, 1984) and the Stockum trench (Alberti *et al*., 1974; Higgs *et al*., 1993). In the last-one, it coincides approximately with the Stockum limestone where the *Protognathodus kockeli* conodont zone is often present.

This limit is consistent with a major change in the terrestrial flora underlined by their deep change in miospores production all around the world.

A new D–C limit. The advocacy of Walliser (1984) for a natural D–C limit at the base of the HBS level is difficult to support from a palynological point of view. For instance in North America, it would return the Bedford and Sappington Shales in the Mississippian. It would also place the Gondwanan glaciation straddling the D–C limit. The contact between the top of the miospore atypical LN Zone (or the LN–VI limit) and the conodont *P. kockeli* is the most suitable candidate to characterise a "near event" limit and then replace the "*sulcata* limit". Renewed trenches like Stockum II might display this contact accurately. By the way, trench protected by a permanent roof is used to protect the stratotype of the Eifelian Stage in Germany. Such new limit would not disturb too much the existing correlation of the D–C Boundary around the world.

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Microfossils across the Daleje Event (Lower Devonian, Emsian) from the Pekárek Mill section (Prague Basin, Czech Republic)

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The Daleje Event was first established as a bioevent (House, 1985); however, this term is mostly used as an equivalent for a distinct transgression that occurred in the middle of Emsian (Chlupáč & Kukal, 1988). In the Prague Basin (Czech Republic), the Daleje Event occurs close to the boundary of Zlíchov and Daleje-Třebotov formations (Ferrová *et al.*, 2012). The older Zlíchov Formation is formed by two lithological units – the Zlíchov Limestone and Chýnice Limestone. The younger Daleje-Třebotov Formation includes three lithological units – Daleje Shale, Třebotov and Suchomasty limestones.

The Pekárek mill section, situated SW from Prague, represents an important outcrop that exposures gradual transition from the Zlíchov Limestone to Daleje Shale. The preliminary biostratigraphical position and summary on macrofaunal composition can be found in Chlupáč *et al.* (1977, 1979) or Chlupáč & Lukeš (1999). More detailed data on palynomorphs, namely spores, from this outcrop were provided by McGregor (1979), who briefly summarised previous data on this stratigraphic level from the Barrandian area. This author also mentioned the presence of other, potentially important, microfossils. However, these fossils have not been studied in detail since then and that was an impulse for the present study that in addition focuses on possible impacts of the Daleje event on fossil faunas.

The Zlíchov Limestone and Zlíchov Lm.-Daleje Shale transition show only few microfacies types; including burrowed, recrystallized wacke- and packstones with varying proportion of calcified radiolarians and dacryoconarid tentaculites, calcified sponge spicules, less abundant trilobites, ostracods and echinoderms. Chondrites burrows occur throughout the section. Higher clayey content in thin sections was recorded from the bed no. 10 onward (*sensu* Chlupáč *et al.*, 1979, *Nowakia barrandei* Zone), with increasing number of dacryoconarid tentaculites and a decreasing number of radiolarians and coinciding with changes in chitinozoan assemblage. Conodonts are very rare in both diversity and abundance in the section, which prevents the correlation of conodont and tentaculite biostratigraphy. Only *Polygnathus perbonus*, *Pandorinellina steinhornensis steinhornensis*, *Belodella* sp. and *Pseudooneotodus beckmanni* have been recorded so far.

Three groups of microfossils were selected for a more thorough qualitative and quantitative study. The first group – prasinophytes, are abundant especially in the Zlíchov Lm.–Daleje shale transition interval and in the lower part of the Daleje Shale. This phenomenon could be associated with change in oceanic circulation resulting from a transgression and eutrophication of the basin (for comparison, see Vodrážková *et al.*, 2013). The second group – chitinozoans, are more abundant in the Zlíchov Limestone, especially in the shale intercalations. Their preservation is, as for other microfossils, moderate to well; unfortunately the specimens are commonly laterally compressed that prevents their determination. The most common genera are *Ancyrochitina*, *Angochitina*, *Ramochitina* and *Bursachitina*. The last studied group are scolecodonts (jaws of polychaete worms). There is only one paper (Šnajdr, 1951) mentioning Devonian scolecodonts from the Prague Basin. Our collection is the biggest from this stratigraphic level and from this region available right now. Unfortunately, the Emsian scolecodonts are almost unstudied globally therefore a comparison with other regions is almost impossible. Our results revealed that the most common families are Paulinitidae and Polychaetaspidae. In other better studied Lower Palaeozoic stratigraphic levels, Paulinitids usually do not represent such a prominent component of the assemblage, except for a peculiar assemblage from the Ponta Grossa Formation, Brazil (Eriksson *et al.*, 2011). A more detailed taxonomical study is in progress right now.

To sum up, the hereby presented collection of microfossils may represent an important piece of puzzle in the palaeogeography of selected fossil groups and also in the reconstruction of the impacts of the Daleje event.

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Achievements in the Pyrenean Lochkovian conodont evolution and biodiversity and its global role in correlations: from Graz 2011 to Brussels 2015, an IGCP-596 ongoing research

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Lochkovian conodont records from five sections allowed Valenzuela-Ríos (2011) to present a first detailed subdivision of middle and upper Lochkovian strata for some sections in the Spanish Central Pyrenees that are the basis for subsequent global correlations. He also presented a tentative subdivision of the lower Lochkovian into three units of local value. These Lochkovian subdivisions were mainly based on the entries of key taxa within known evolutionary histories of either global (middle and upper Lochkovian) or more limited (lower Lochkovian) distribution. Subsequently, he also added information on biodiversity and evolutionary histories of several relevant groups that form the base of the biostratigraphical subdivisions (Valenzuela-Ríos, 2012a, 2012b). Preliminary studies on facies (Valenzuela-Ríos & Liao, 2012) questioned the supposed synchronicity of some “time-specific facies” and reinforced the value of fossils and palaeontological studies for testing age assignations of distant rocks.

Continuous research in the Pyrenees added a new section (Segre 4, Calvo & Valenzuela-Ríos, 2012), complete some gaps in a significant one (Compte-I) and a recent vertical work in the Baen area permitted sampling in levels unreachable until now in two sections and a preliminary correlation between them, increasing considerably the Lochkovian Pyrenean data base net. Recently, road works near the sections Segre 2, exposed a new section of lower Lochkovian strata that will complete the Lochkovian sequence at Segre and will provide with important new data regarding the lower Lochkovian.

Valenzuela-Ríos & Murphy (2013) demonstrated the high similarity of Pyrenean and Nevadan conodont sequences for the middle and upper Lochkovian reinforcing intercontinental correlations and supporting the conodont-based chronostratigraphy for most of the Lochkovian.

Valenzuela-Ríos *et al.* (2014) revisited the Segre sections as a whole and analysed them in a global context. Finaly, Valenzuela-Ríos *et al.* (2015), by studying selected stratigraphical successions and conodont sequences in the Spanish Central Pyrenees and in the Prague Synform established the first detailed correlation for the upper and middle Lochkovian strata and conodont faunas between two north-Perigondwanan terrains (Armorican Terrane Assamblage and Perunica) and proposed a new, more stable, terminology for naming conodont zones.

In brief, the progress during these five years has permitted the establishment of a sound conodont biostratigraphical subdivision in the Pyrenees that can be correlated with sequences in Nevada and Bohemia, and also the Carnic Alps and can serve as basis for further chronostratigraphical subdivision of the Lochkovian Stage. The binomial nomenclature used in naming biostratigraphical units is more precise and enables further incorporation of new data without changing original meaning of former units.

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Microbial activity exemplified by wrinkle structures in the Middle Devonian siliciclastics of the Prague Basin, Czech Republic

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The significant role microbes played in ancient carbonate environments is widely acknowledged. Given the low preservation potential of microbial structures in siliciclastics due to the lack of early diagenetic cementation, it is not surprising that they have not received much attention. Most of the fossil microbial mats (or structures induced by microbial activity) reported from siliciclastic rocks are Proterozoic, Cambrian and Ordovician in age – thus from times with less effective benthic grazing and low or no infaunal activity. Only a few examples of post-Ordovician microbial mats have been recorded from siliciclastics, mostly those occurring in stressed and restricted environments (*e.g.*, Droser & Bottjer, 1986). Here we report for the first time occurrences of microbially induced sedimentary structures (wrinkle structures *sensu* Hagadorn & Bottjer, 1997) from the Middle Devonian (?Givetian) siliciclastic sequences (Roblin Member of the Srbsko Formation) of the Prague Basin, Czech Republic.

Several features of the wrinkle structures preserved in the Roblín Member indicate their biogenic nature: patchy occurrences on the bedding planes, cohesive behaviour (“flowing” microbial mats), dark microlaminae in thin sections formed by mineralized organic material, and a probable cyanobacterial signal recognized through n-alkanes and biomarker analysis.

Sediments of the Roblín Member represent distal, pro-delta turbidites, deposited in a reducing environment characterized by lowered salinity (Kukal & Jäger, 1988; Strnad & Hladil, 2001). The observed wrinkle structures occur almost exclusively in siltstones with sandy admixture, overlain by siltstones with land plant remains. Only rare occurrences of sponges were recorded, preserved as body fossils, providing evidence of quick burial. Hence, specific ecologic and taphonomic conditions prevailed during the sedimentation of the Roblín Member, facilitating microbial mat formation and preservation by the absence of bioturbation (stressed environment for benthic grazers), by suitable facies (heterolithic strata of turbidites), and by quick burial.

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Echinoderm ecosystem rebound and diversification after the Frasnian–Famennian extinction: data from the Central Asian Orogenic belt

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The Frasnian–Famennian (F–F) mass extinction event ranks in the top five in taxonomic and ecological severity and particularly devastated tropical marine ecosystems. Famennian strata in Xinjiang Province, China, contain both the F–F boundary, the Kellwasser and Hangenberg Anoxic Events associated with the F–F and the Devonian–Carboniferous Extinctions respectively, but also a Famennian rebound fauna in a highly fossiliferous shallow marine setting associated with an oceanic island arc complex in the Central Asian Orogenic Belt (CAOB). Although taxonomic and sedimentological details are sparse, a similar rebound fauna has been found in southwestern Mongolia in a different arc complex. Total faunal diversity reported from the Hongguleleng Formation and the "Hebukehe" Formation in Xinjiang is 166 genera and 235 species making it the most diverse Famennian fauna known. Diversity includes 2 genera and species of sponges, 17 genera and 22 species of corals, 1 genus and species of trilobite, 18 genera and 34 species of bryozoans, 48 genera and 57 species of brachiopods, 4 genera and species of cephalopods, 12 genera and 14 species of blastoids, 32 genera and 44 species of crinoids, and 2 genera and 2 species of vertebrates (not including the conodonts). The majority of this faunal diversity is from the Hongguleleng Formation, which is predominantly a shallow marine sequence dating from the latest Frasnian to the middle Famennian (conodont biozones - *linguiformis, triangularis, crepida,* Late *rhomboidea, and marginifera*). The "Hebukehe" Formation ranges in age from middle to late Famennian, is a deeper water sequence with radiolarian cherts with a lower diversity fauna. The "Hebukehe" Formation contains deep-water assemblages of crinoids and blastoids that are taxonomically different from the echinoderm fauna in the Hongguleleng Formation. The Hongguleleng crinoid and blastoid faunas are the most diverse Famennian faunas characterized to date. The rebound from the F–F Extinction Event was more rapid than previously thought. Estimates of recovery time based on sedimentation rates are on the order of 100,000 years. The rebound fauna immediately after the F–F Extinction Event occurred in shallow water and is dominated by crinoids but blastoids are diverse and relatively abundant. Echinoderm communities from later in the Famennian lived in deep water and are associated with maroon and green shales and radiolarian cherts. These faunas are numerically dominated by blastoids. Crinoids are less abundant but contain numerous flexibles. Famennian echinoderms from Xinjiang are morphologically advanced showing many thecal characters rare in Devonian faunas, but common in the Mississippian. The rebound fauna from the F–F extinction was concentrated in NW China particularly for echinoderms and we can conclude that the Age of Crinoids encompassed the Famennian in addition to the stages of the Mississippian. Biogeographic analysis of Famennian bryozoans show a similar pattern of diversification through the Famennian from a Hongguleleng fauna.

Crinoids and blastoids reached an apex in generic richness and abundance during the Mississippian. Explanations include: 1) rising biodiversity of advanced cladids during the transition from the Middle Paleozoic to the Late Paleozoic Crinoid Macroevolutionary Fauna, 2) establishment of widespread carbonate ramps after the demise of Late Devonian reef communities and 3) response to declining predation pressure caused by extinctions of major groups preying on crinoids at the Hangenberg extinction event. Although the causes of the Mississippian crinoid explosion are probably multifaceted, climatic events in the Devonian likely played a major role. Generic richness of echinoderms reached a peak in the Early Devonian reflecting the success of the camerate crinoid-dominated Middle Paleozoic Crinoid Macroevolutionary Fauna during an interval of widespread reefal facies. Throughout most of the Devonian, echinoderm diversity paralleled the reefal diversity. This pattern changed after F–F extinction event. Famennian echinoderm communities were dominated by cladid crinoids and more closely resemble LCPMF rather than MPCMF. The demise of reef communities in the Late Devonian led to the development of widespread carbonate ramps in the Mississippian and for a time the resurgence of the camerate-dominated MPCMF. Significant changes in atmospheric chemistry in the Devonian led to changes in phytoplankton communities which led to significant increases in abundance of suspension-feeding echinoderms beginning in the Late Devonian and accelerating into the

Mississippian. Although much work remains to understand the dynamics of echinoderm community evolution in the Devonian, dramatic climate change had a major impact. Crinoid communities were able to be successful both in the Lower Devonian greenhouse world and in the Mississippian icehouse world because different clades were able to adapt to changing climates and the demise of reef ecosystems and flourish. Whether this success was the result of adaptation to changing sedimentological regime or changing patterns of plankton diversity is unclear at the present time.

Major changes in dominance and diversity of crinoids and blastoids, particularly in North America and Europe, accompanied fundamental shifts in the sedimentation patterns and major reorganizations in the echinoderm communities during the Mississippian. In North America, Kinderhookian (Tournaisian) faunas are known from shallow water carbonates and deeper water facies associated with the Waulsortian buildups. During the Osagean (Late Tournaisian; Early Visean) of North America, blastoids continued to occur in deep water facies, but became very diverse in shallow water facies. Monobathrid camerate crinoid communities reached a zenith on the broad shallow water carbonate platforms such as the Burlington Shelf and correlatives. Blastoids were an integral part of this community and attained their maximum diversity (17 genera) in the Burlington. During the latest Tournaisian and Lower Visean, buildups of the Waulsortian facies were widespread across Europe. Blastoids are commonly found in the flank facies associated with diverse crinoid communities. A major blastoid extinction event occurred in the Early Visean. Both in North America and Western Europe, significant extinctions accompanied the virtual elimination of blastoids from shallow-water habitats. The shift in blastoid habitat preference to deeper water settings lasted only a few million years. By the end of the Visean, blastoids had reinvaded the full spectrum of shallow-water habitats and numerically dominated many echinoderm communities in North America and Europe. The large-scale reorganization of Mississippian echinoderm communities was controlled by changing sedimentological regimes caused by Gondwanan glaciation, the emergence of the Appalachian orogen, and the re-emergence of corals as dominant framework builders in Late Visean reefs.

On the Mid Devonian Hujiersite flora from west Junggar, Xinjiang (China) and its characteristics, age and palaeoenvironment

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The term "Hujiersite flora" derived from the plant assemblage recovered from the Hujiersite Formation, West Junggar, Xinjiang, China and was dated as late Mid Devonian (Givetian) based on dispersed spores. Megaplants in the Hujiersite Flora include lycopsids: *Haskinsia hastata*, *H. sagittata*, *Leclercqia* cf. *complexa*, *L. uncinata*, *Colpodexylon gracilentum*, *Hoxtolgaya robusta* and *Drepanophycus minor*; zosterophylls: *Serrulacaulis spineus* and *Serrulacaulis* cf. *furcatus*; fern-like plants: *Compsocradus givetianus*; progymnosperms: *Aneurophyton doui* and *Tetraxylopteris* sp., and *incertae sedis* plants *Tsaiaconica*, *Taeniocrada* and *Blasaria*. The palynological assemblage in the flora is dominated by a single spore type, *Cymbosporites* cf. *magnificus*, whose relative plants are probably lycopsids, and megaspore *Verrycisporties lui*.

The characteristics of the Hujiersite flora can be summarized as, 1) lycopsids are dominant and probably the main coal-forming plants in the flora; 2) some small and/or herbaceous lycopsids are widespread but at the species level the widespread members are unique and endemic, such as *Haskinsia hastata* ssp. *denticulata*, a probable climber lycopsid *Leclercqia uncinata*, minor-sized lycopsid *Drepanophycus minor* and progymnosperm *Aneurophyton doui*; 3) plants of the order Pseudosporochnales that are common members of the North America Mid Devonian forest are absent; 4) the largest plant in the flora belongs to the tree-like lycopsid, *Hoxtolgaya robusta*, which probably reached the maximum of 4 m in height based on the width of its stem and is shorter than canopy cladoxylopsids (*e.g.*, *Eospermatopteris*) in the Mid Devonian forest of North America.

At least three depositional upward-fining sequences can be recognized in the Hujiersite Formation, consisting of conglomerate, sandstone, siltstone and mudstone in ascending order, and the thin layers of coal occur in bed of siltstone or mudstone. The depositional sequences suggest an alluvial sedimentary facies. The occasional conglomerate layer and lenses of sandstone were deposited in the fluvial environment, probably in the alluvial flat or flood plain. It is suggested that West Junggar was an important land bridge in the global migration of the Devonian plants, including the herbaceous lycopsids, progymnosperms and plants with megaspore *Verrycisporties*.

Integrated stratigraphic analysis of the Middle Devonian (late Givetian) Geneseo Event in the Appalachian and Michigan basins

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The Middle Devonian (late Givetian) Geneseo Event occurs at the *Ozarkodina semialternans–Schmidtognathus hermanni* conodont zonal boundary interval and is the last of at least three events that comprise the Taghanic Crisis; this event is named for paleoceanographic and biotic changes associated with the deposition of the organic-rich Geneseo Shale in the Appalachian Basin (House, 2002; Aboussalam, 2003; Aboussalam & Becker, 2011; Zambito *et al.*, 2012a, 2015). In the northern portion of the Appalachian Basin, the type region for the Taghanic Crisis, the transition from carbonate (Tully Formation) to black shale (Geneseo Formation) deposition is coincident with the loss of most endemic taxa and the onset of faunal cosmopolitanism across North America (Johnson, 1970; Baird & Brett, 2008; Zambito *et al.*, 2012a, 2012b). Here we present an integrated stratigraphic analysis of the Geneseo Event interval from the northern Appalachian Basin (Geneseo Formation) and the central and western portions of the Michigan Basin (Squaw Bay and Milwaukee formations, respectively). These successions are biostratigraphically and chemostratigraphically constrained by new and previously published conodont data and new carbonate carbon isotopic data ($\delta^{13}C_{carbonate}$). We have also used elemental chemostratigraphic data acquired by handheld XRF analysis in each area studied to quantify the degree of dolomitization of the rocks studied (comparison of Ca to Mg), as a proxy for the relative amounts major rock components, including quartz (Si), clay (Al, K), and carbonate (Ca, Mg), and to reconstruct paleoredox conditions using trace element concentrations of Mo, V, U, and other elements.

There is no relationship between degree of dolomitization and $\delta^{13}C_{carbonate}$ values or trends. All successions show a shift to more positive $\delta^{13}C_{carbonate}$ values at the onset of the Geneseo Event; this agrees with observations in other areas of North America (Iowa Basin; Day *et al.*, 2010) as well as Germany and Morocco (Aboussalam, 2003; Zambito *et al.*, 2015). This positive $\delta^{13}C_{carbonate}$ shift is followed by a transition to lighter values, including a distinct offset in trend near the *Schmidtognathus hermanni–Klapperina disparilis* Zonal boundary coincident with abrupt offsets in major rock component elemental proxies which we interpret as evidence for unconformities. The northern Appalachian Basin also possesses overall lower $\delta^{13}C_{carbonate}$ absolute values and a greater magnitude of change through the study interval. All sections show variable paleoredox conditions and trace elemental concentrations suggesting dysoxic conditions associated with the Geneseo Event. Furthermore, at the onset of the Geneseo Event all areas record a transgression based on facies juxtapositions, as well as the incursion of brachiopod taxa associated with the cosmopolitan fauna that characterize this event and its aftermath, such as *Tylothyris*, and *Schizophoria* which are typical of western North America, suggesting that physical biogeographic barriers (Transcontinental Arch) were submerged. This integrated bio-, litho-, and chemostratigraphic approach to identifying and describing the Geneseo Event in eastern North America provides an important baseline dataset for recognizing this event elsewhere and understanding the interactions between organisms and their environment during biotic crises.

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New insights into the trilobite and conodont biostratigraphy of the Middle–Upper Devonian Genesee Group in eastern New York State

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During the Middle Devonian (late Givetian) Global Taghanic Biocrisis, numerous trilobite families underwent extinction including the Homalonotidae (Lerosey-Aubril & Feist, 2012). In northeastern North America, the last occurrence of homalonotid trilobites (*Dipleura dekayi*) has previously been reported in strata deposited during the final stages of the Taghanic Biocrisis (*semialternans* Zone –latest Middle Givetian) including the Tully Formation of the northern Appalachian Basin and the Thunder Bay Formation of the Michigan Basin. Globally observed low-oxygen conditions associated with the Taghanic Biocrisis, represented by the Geneseo and Squaw Bay shales in the Appalachian and Michigan basins, respectively, have been interpreted to be at least in part responsible for the local extinction of the Homalonotidae and other trilobite families. Recent geologic mapping in eastern New York State (northern Appalachian Basin) has documented the occurrence of *Dipleura dekayi* in siliciclastic-dominated, nearshore post-Taghanic (Tully) strata that were deposited below fair-weather wave base. Although these strata have been mapped as Genesee Group, they have yet to be assigned a formation-level designation. An integrated stratigraphic approach, including litho-, sequence-, and conodont biostratigraphy has provided new insight into the stratigraphic succession in the eastern Genesee Group, representing marine shelf through non-marine settings. Lithostratigraphic correlation places the occurrence of *Dipleura dekayi* above eastern New York Tully Formation clastic correlative strata, within the shelf equivalent facies of the basinal Geneseo black shale. Application of a sequence stratigraphic model has enabled the identification of time-rich intervals such as flooding surfaces and sequence boundaries that have yielded conodonts, though disaggregation of these sandstone-dominated and well-cemented (complex carbonate, iron-oxide, phosphatic, organic-rich, and clay mineral cements) samples has been tedious and conodont yields are small. Current conodont biostratigraphic data suggests that *Dipleura dekayi* persisted into at least the latest Middle Devonian (Givetian) *Schmidtognathus hermanni* Zone, based on the co-occurrence of *Polygnathus dubius* and *Icriodus tafilaltensis*, which appear in the *hermanni* Zone (Klapper & Johnson, 1980; Narkiewicz & Bultynck, 2010), and *Polygnathus* cf. *P. ansatus*, which disappears in the same Zone. Furthermore, preliminary lihostratigraphic mapping in other parts of eastern New York suggests that *Dipleura dekayi* may have even survived into the Late Devonian, however, conodont biostratigraphic data is needed to confirm this. Similar to other northern Appalachian Basin taxa that persisted through the Taghanic Biocrisis, *Dipleura dekayi* apparently found intra-basinal refuge in oxygenated, nearshore shelfal settings (Zambito *et al*., 2012).

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Addendum

The Siluro–Devonian successions in the Tassili N'ajjer outcrops (SE Algeria): sedimentology and stratigraphy

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The sedimentary basins of North Africa have accumulated a thick sedimentary succession of Palaeozoic, especially Siluro–Devonian sediments. These successions have been deposited in wide sags and sub-basins in a cratonic setting, along the northwestern passive margin of Gondwana. This sedimentation is mainly controlled by rapid eustatic sea-level variations and by the opening of the proto-Tethyan Ocean during the Early Palaeozoic (Beuf *et al.*, 1971; Boote *et al.*, 1998).

During this Siluro–Devonian Period, a high subsidence occurred, allowing the deposition of a high pile of sediments and organic-rich shales in many places that formed important hydrocarbon reservoirs and source rocks throughout North Africa basins and Middle East (Lüning *et al.*, 2000).

In the prolific Illizi and Berkine basins (Western Ghadames, Algeria), a basin-wide approach is needed, especially with the new "shale gas and shale oil" frontier in the upcoming years, in order to capture regional trends and re-assessment of the Siluro–Devonian successions.

Our project focuses on the Berkine Basin and its margin, which covers nearly 102,000 km^2. This basin includes a thick sedimentary series of 7,000 m corresponding to complex reservoirs but also black shales of the basal Silurian and Frasnian, which are respectively major and secondary source rock systems.

Complete logging of spectacular large-scale and well exposed outcrops of the Siluro–Devonian sediments was carried out at the southern margin (SE, Tassili n'Ajjer) of the Illizi-Berkine basins (Djouder *et al.*, 2012; Djouder *et al.*, 2014). The following analysis incorporates biostratigraphic, ichnological, sedimentological, magnetic susceptibility (MS) and high resolution stratigraphic data. It would allow providing a framework of deposits, ranging from offshore to deltaic deposits for the Silurian and from fluvial to normal-marine depositional conditions for the Devonian.

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Conodonts from the Indert Formation in Shine Jinst area, Southern Mongolia: preliminary results

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Marine Palaeozoic deposits are widespread in South Mongolia. Their biostratigraphy is based mainly on the macrofaunas which are numerous and diverse in some localities. In Mongolia, the use of conodonts for biostratigraphic analyses is very recent (Wang *et al*., 2005).

Upper Devonian and Lower Carboniferous deposits are reported in several areas of Mongolia. During the mapping project "Hailaast uul-50" more than 48 conodont samples were collected from the Indert Formation in the Shine Jinst area (Bayankhongor aimag, Southern Mongolia). According to Aristov & Nyamsuren (1998), the Indert Formation is represented by terrigenous-carbonate sequence and can be subdivided into two parts. The lower part, namely the Heermorit Member, is mainly composed of terrigenous sediments with a single layers of volcanic and carbonate rocks whereas the upper part (Shombon Member) consists of alternating beds of dark-grey, white-grey bedded limestone with biohermal massive limestone at the top. The section, which is located between those described by Aristov & Nyansuren (1998), includes a black shale horizon in its middle part. Conodonts were found from nine dark-grey and grey limestone and three light and grey limestone beds distributed below and above the black shale horizon, respectively. Conodonts from the lowermost part of the section include *Protognathodus* sp., *Polygnathus* sp., *Pseudopolygnathus* aff. *dentilineatus*, and *Polygnathus communis communis*, which is the most common species through all the section. The first representatives of the genus *Siphonodella* are recognized within the bed no. 5 and *Gnathodus* sp. is found below the black shale.

Preliminary identification of conodonts shows that the black shale horizon from the middle part of the section does not correlate with the Hangenberg Event and the Devonian–Carboniferous boundary could be placed somewhere below the bed no. 3. The processing of samples and a detailed taxonomic study on the conodonts are ongoing.

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