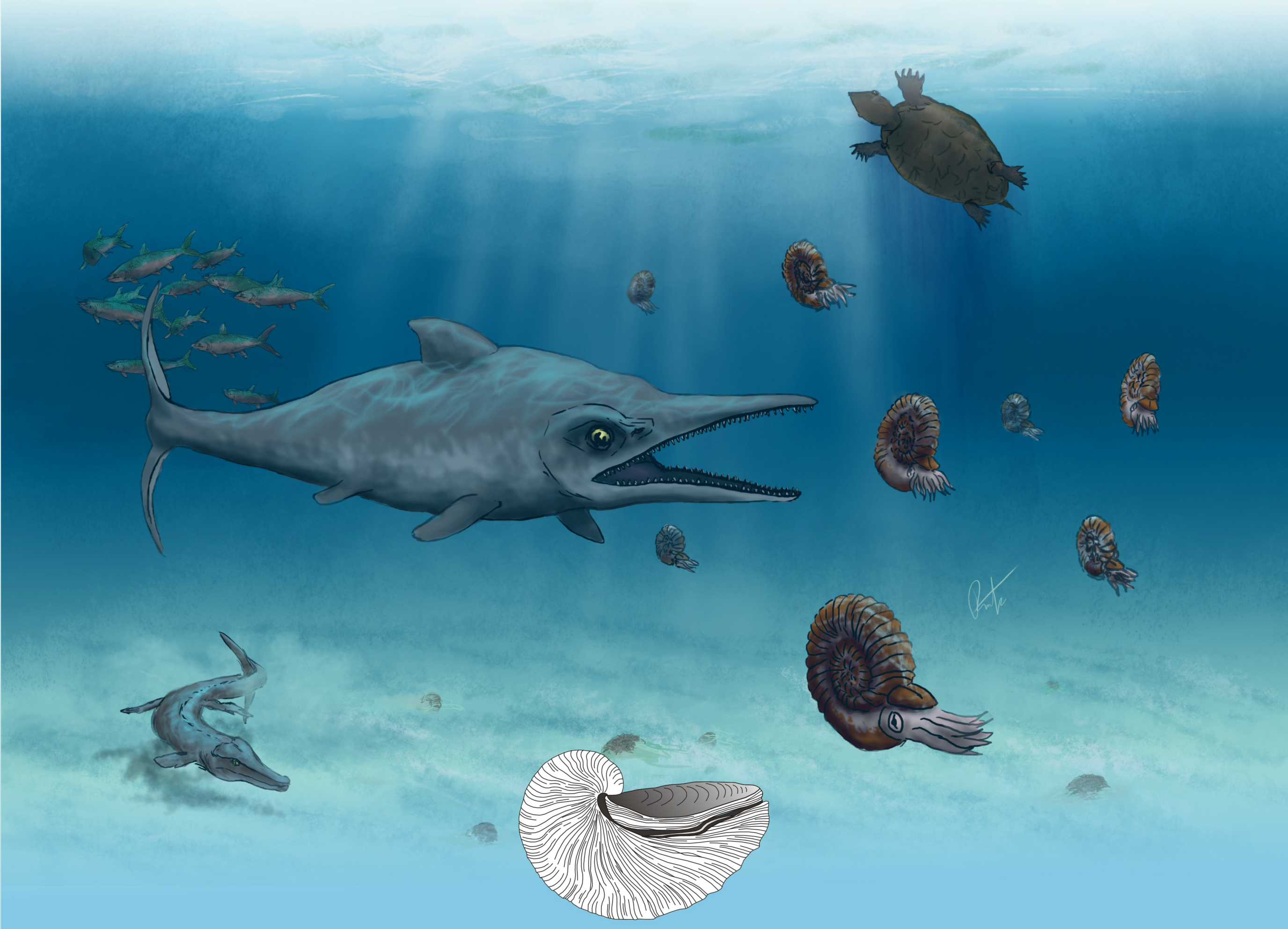
XII[th] Jurassica Conference

Workshop of the ICS Berriasian Group and IGCP 632

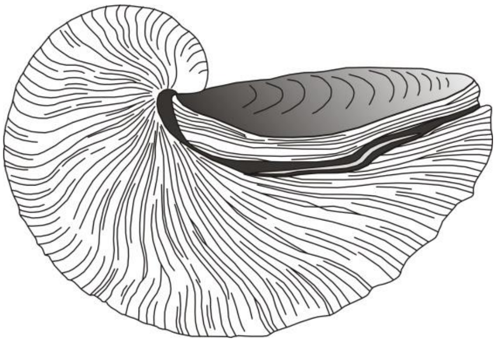
Field Trip Guide and Abstracts Book



Smolenice, Slovakia, April 19–23, 2016

Earth Science Institute, Slovak Academy of Sciences
Bratislava
2016

XIIth Jurassica Conference



Field Trip Guide and Abstracts Book

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Edited by: Jozef Michalík and Kamil Fekete

Earth Science Institute, Slovak Academy of Sciences
Bratislava 2016

Scientific Committee:

Organizing Committee:

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Table of contents

Preface

The Jurassic Period is the most famous Mesozoic time interval, even well known to a wide public. Its immense treasure of fossils, namely ammonites, belemnites, bivalves, brachiopods, corals, dinosaurs (popularized by Spielberg films) and many other groups are serving as the basis for the development of modern concepts of biostratigraphy, chemostratigraphy, palaeoclimatology, palaeoecosystems and Earth systems evolution. Primary criteria for the recognition of chronostratigraphic units and correlations come from a precise ammonite biostratigraphy, supplemented by all other aspects of stratigraphy. On the other hand, only seven of the eleven Jurassic stages have yet fulfilled Global Stratotype Section and Points (GSSP) criteria (Hettangian, Sinemurian, Pliensbachian, Toarcian, Aalenian, Bajocian, Bathonian) sofar. This very special period is typical for its unique global regime with rather stable condition. The strong cyclicity observed in continuous rock sequences can be used for astronomically calibrated timescales, since the periodicity of these rhythms is consistent with orbital forcing due to long Milankovich cycles. Jurassic palaeoclimatic models, quite different from successive Cretaceous ones, can teach us the rules of alternation between glacial (icehouse) and warm (greenhouse) conditions on the Earth.

Eleven JURASSICA brilliant scientific conferences have been organized by Polish colleagues in close cooperation with Slovak and Czech colleagues. Also nine international congresses devoted to the Jurassic system took place in last decades in different countries of the world. They have collected a huge amount of leading knowledge and contributed to scientific research of this time period. However, many aspects concerning fauna, flora, palaeobiogeography and climate remain unrecognized. This was evident in the activities of the renowned IGCP 506 project and, namely in two (7th and 8th) brightest Jurassic Congresses organized under the ICS coverage in Cracow in Poland and in Shehong of Suining (near Chengdu) in China. JURASSICA conferences became an efficient platform to exchange of scientific information from all geoscientific specializations concerned with Jurassic problems and issues.

We decided to join the incorporative effort of the JURASSICA conferences with the workshop of the IGCP 632: **"*Continental Crises of the Jurassic: Major Extinction events and Environmental Changes*"**, specifically focused on the interactions between the major events and climate, and on the correlation between these ancient ecosystems during the Jurassic Period. They both involve wide participation of specialists from all of the world. The second coupling was in attracting of the ICS Berriasian group, which deals with the long- lasting problem of defining of the Jurassic/Cretaceous systems boundary. This question is also essential from point of view of many Jurassic workers. Hopefully, the results of the workshop of this group will crown the Conference.

We hope that this wide coooperation will further evolve to be stronger and complex in the future.

The Scientific Committee of the JURASSICA XII Conference

GUIDE TO THE FIELD TRIP

JURASSIC SEQUENCES OF THE MALÉ KARPATY MTS AREA

XII[th] Jurassica Conference 2016, Smolenice, Slovakia

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Introduction

The field trip represents an introduction to the complex and variegated geological history of a relatively small territory of the Malé Karpaty Mts., composed of units representing various parts of the Western Carpathian sector of the Tethyan Realm. During the field trip, typical Jurassic sequences of two different large-scale units – the Tatric and the Fatric – will be visited.

Tectonic setting of the Western Carpathians (Plašienka)

The Western Carpathians create the northernmost, generally W-E trending arc of the European Alpides, and thus they are linked to the Eastern Alps in the west and to the Eastern Carpathians in the east. The present structural pattern of the Western Carpathians originated from the Late Jurassic–Tertiary subduction-collision orogenic processes in a mobile belt between the stable European Plate and Africa-related, drifting Adriatic (Apulian) continental fragments. Like in other segments of European Alpides, the tectonic evolution of the Western Carpathians is characterized by stacking of pre-Alpine basement-involved thrust sheets and detached sedimentary cover nappes, showing a marked northward migration of pre-orogenic and orogenic processes (e.g., Maheľ, 1986; Plašienka et al., 1997; Froitzheim et al., 2008; Putiš et al., 2009). During final stages of Alpine orogenic processes, the Carpathian collisional system overrode the North European Platform composed of various Cadomian, Caledonian and Hercynian segments amalgamated in pre-Mesozoic times. A large part of the Central and most of the Internal Western Carpathians is covered by remnants of Paleogene sedimentary basins and thick Neogene sedimentary and volcanic rock complexes, which are related to the hinterland Pannonian Basin.

According to the triple general division (Plašienka et al., 1997; Froitzheim et al., 2008), the Western Carpathian orogenic system is composed of the Internal Western Carpathians in the south, the Central Western Carpathians in the middle and the arc of the External Western Carpathians in the North. These three major Western Carpathian sections are separated by narrow zones with extraordinary shortening and intricate structure, partly recording also important along-strike wrench movements in various time periods (Fig. 1).

The Internal Western Carpathians (IWC), or the Pelso Megaunit in other terminology (see e.g. Kovács et al. 2011), are composed of low-grade Paleozoic and low-grade or non-metamorphic Mesozoic complexes showing affinities to the South Alpine (Transdanubian Range) or to the Dinaridic (Bükk Mountains) facies belts. The main tectogenesis of the IWC units took place during the Late Jurassic and Early Cretaceous, showing the southern vergency of principal thrust structures, i.e. opposite to the other Western Carpathian zones.

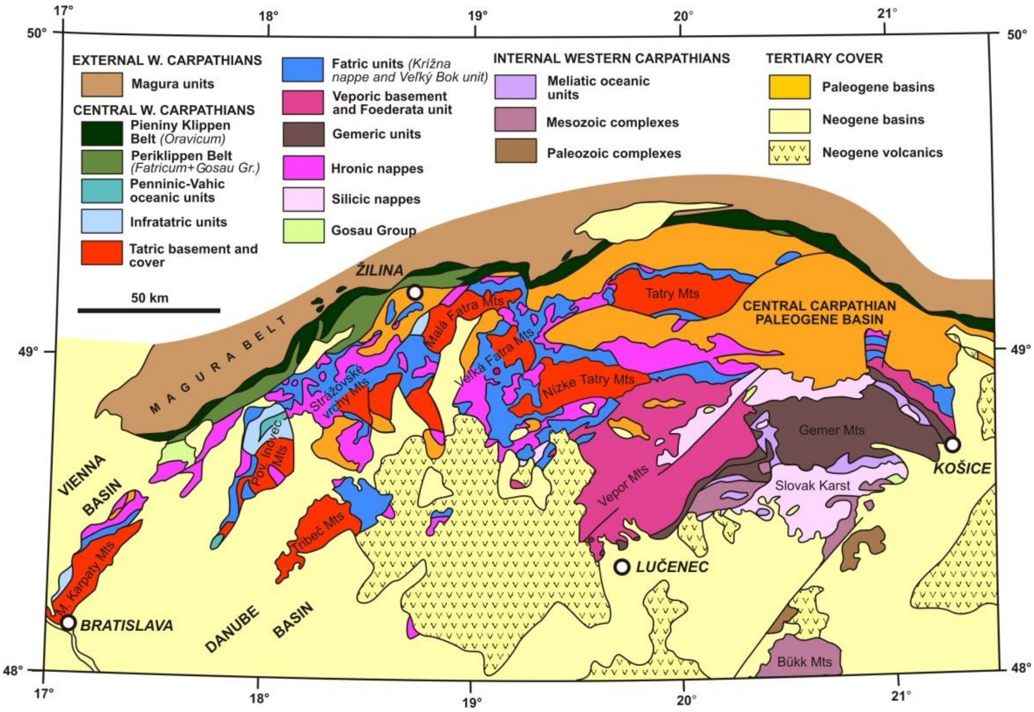

Fig. 1. Simplified tectonic map of the Western Carpathians (after Plašienka, 2012).

The Central Western Carpathians (CWC) are separated from the IWC by a belt of crustal-scale discontinuities (Rába-Hurbanovo-Diósjenő) in the western part, which is covered by thick Cenozoic sedimentary complexes of the Danube and South Slovakian-North Hungarian basins, and by the discontinuous belt of ophiolite- and blueschists-bearing complexes (Meliata Unit in a broader sense) in the area of the Slovak-Aggtelek Karst Mts (figs 1, 2). The CWC represent a pile of Cretaceous thick- and thin-skinned thrust sheets. From bottom to top these are the outermost Tatric basement/cover sheet, overlain by the Fatric and Hronic cover nappe systems, the central Veporic crustal-scale thrust wedge, and the Gemeric basement/cover nappe on top in the SE; the later two are overridden by the Meliatic nappe outliers and the Silica cover nappe system (figs 1, 2). The CWC units correspond to the Austroalpine tectonic system of the Eastern Alps (e.g. Schmid et al., 2008). The Variscan, low- to high-grade basement of the thick-skinned sheets is overlain by the Upper Paleozoic and Mesozoic cover, dominantly composed of Middle Triassic to Lower Cretaceous carbonates. The youngest synorogenic sediments of the outermost Tatric Superunit indicate the termination of the thrusting processes in the CWC area during the late Turonian.

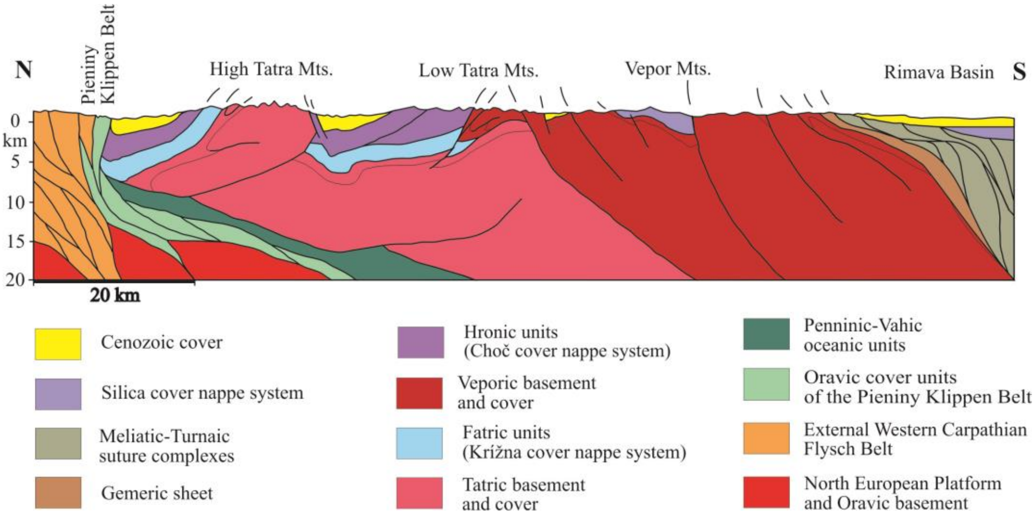

Fig. 2. General tectonic cross-section of the Central Western Carpathians (Plašienka, 2016).

The northern CWC margin is followed by the Pieniny Klippen Belt (PKB), a narrow zone with intricate internal structure that provides a transition from the CWC to the EWC (figs 1, 2). The PKB includes only Jurassic to Palaeogene sediments detached from an unknown, completely subducted substratum. The PKB sedimentary successions exhibit a very variable lithology and complex internal structure. At present, two types of pre-Upper Eocene unit are distinguished within the PKB in a broader sense. The narrow, complex and in places discontinuous northern strip is composed of the PKB units in its strict sense. These were derived from an independent palaeogeographic domain, known as the Pienidic or Pieninic units in the older literature, but renamed as the Oravic domain (Oravicum) by Mahel', 1986. The Oravic domain represents an intra-oceanic ("intra-Penninic"), rifted continental crustal fragment, separated by two branches of the Alpine Atlantic Ocean from the North European Platform to the north and the Austroalpine-Central Carpathian realm to the south. In mid-Cretaceous time, the Oravic domain was partly overridden from the south by the frontal elements of the CWC cover nappes, particularly of supposed Fatric affiliation (Drietoma, Manín, Klape units in the western eastern PKB part; cf. Plašienka, 1995, 2012 and references therein). Emplacement of these cover nappes was followed by development of wedge-top, piggyback synorogenic basins (Gosau Supergroup – cf. Plašienka & Soták, 2015). The frontal Fatric elements incorporated into the PKB structure and their post-nappe sedimentary cover are distinguished as the so-called peri-Klippen zone (Mahel', 1980).

Beyond the PKB, the External Western Carpathians (EWC) are composed of the Flysch Belt and the Carpathian foredeep covering the southern margin of the North European Platform. The Flysch Belt corresponds to an accretionary wedge of the Carpathian Orogen consisting predominantly of Cretaceous–Paleogene deep marine clastics detached from the subducted oceanic basement and intervening continental fragments of the North Penninic (Magura) realm. It includes the inner belt of the Biele Karpaty and the Magura superunits, which are connected to the Rhenodanubian Flysch Belt in the west, but are wedging out towards the Eastern Carpathians. The outer Silesian-Krosno zone is linked with the East Carpathian Moldavides (see e.g. Picha et al,. 2006 and Oszczypko & Oszczypko-Clowes, 2009 for the reviews).

Pre-Alpine basement of the Western Carpathians (Plašienka)

The pre-Alpine crystalline basement of the Western Carpathians, which builds up the Tatric, Veporic and Gemeric thick-skinned thrust sheets, was formed during the Variscan (Hercynian) orogenic cycle. The basement complexes are mainly composed of Lower Paleozoic metapelites, metapsamites, metabasalts and metagabbros, orthogneisses, rarely metacarbonates, which were metamorphosed mainly in the greenschist to amphibolite facies, rarely in granulite and eclogite facies. Metamorphic rocks are intruded by the Late Devonian to Mississippian S- and I-type orogen-related granites, granodiorites and tonalites, seldom dioritic rocks (Petrík et al., 1994; Broska & Uher, 2001; Kohút et al., 2009). Relics of Variscan nappe structures were documented in several parts of the Tatric and Veporic basement (e.g. Putiš, 1992; Bezák et al., 1997; Janák et al., 2001).

The Late Paleozoic post-Variscan period is characterized by development of Pennsylvanian and Permian extensional sedimentary basins filled with mostly continental clastic sediments accompanied by magmatic rocks – basalts and andesites, A-type rhyolites, dacites and small granite bodies (e.g., Vozárová & Vozár, 1988; Uher & Broska, 1996).

Alpine evolution of the Western Carpathians (Plašienka)

The Western Carpathians evolved as a complex collisional orogenic system, related to two suture-like zones that experienced a long-term polystage structural history and extensive shortening, resulting in the superposition and juxtaposition of units derived from sometimes distant palaeogeographical settings (e.g. Plašienka et al., 1997; Putiš et al. 2009). Remnants of ophiolite-bearing mélanges and high-pressure units (Meliata-Bôrka nappes), which are thought to represent Upper Jurassic (Neo-Cimmerian) subduction complexes related to the closure of the Neotethyan oceanic branch, occur in the southern Western Carpathian zones. Northwards, the CWC are composed of a "Palaeo-Alpine" (mid-Cretaceous, before Coniacian) nappe stack of thick- and thin-skinned thrust sheets that represent an eastward continuation of Austroalpine units of the Eastern Alps (e.g. Schmid et al., 2008).

Development of leading structures of the PKB and adjacent zones took place during the Senonian to Eocene, "Meso-Alpine" period. This was related to subduction-collision processes of the South Penninic-Vahic oceanic zone between the Oravic Domain and the northern CWC margin (Plašienka, 2012 and references therein).

The final "Neo-Alpine" stage was governed by complex movements generated by subduction of the Magura Ocean and by formation of its accretionary wedge (Flysch Belt). The Early Miocene oblique "soft" collision of the Western Carpathian orogen with the North European Platform led to a change of movement direction of the overriding plate. It was associated with Miocene opening of the Pannonian Basin system in a back-arc position, extensive calc-alkaline volcanism, and the counter-clockwise rotation of the eastern ALCAPA Domain (cf. Kováč, 2000 and references therein).

The Neo-Alpine phase means the closure of the North-Penninic ocean at the end of Paleogene and beginning of Neogene. accompanied by the counterclockwise rotation, transpression-transtension and uplift of rigid basement blocks, creating the present "core mountains" and intramontane basins inside the Carpathian arc (e.g. Kováč et al., 1997). A large-scale, back-arc type Pannonian Basin developed in the hinterland of a converging system (e.g. Kováč 2000). During Neogene to Pleistocene, intense intermediate-acidic calc-alkaline and basaltic alkaline volcanic-plutonic activity developed inside of the Carpathian arc.

General structure of the Malé Karpaty Mountains (Michalík, Plašienka)

The Malé Karpaty Mts represents an elongated horst structure of the pre-Miocene basement surrounded by large Neogene basins. The horst is separated by SW-NE trending normal and oblique-slip faults from sediments of the Vienna Basin in the NW and the Danube Basin in the SE. As the easternmost segment of the CWC, the Malé Karpaty Mts form an important link between the Eastern Alps and Western Carpathians (Mahel', 1987; Plašienka et al., 1991; Häusler et al., 1993). The substantial part of the Malé Karpaty Mts. is built up by the Tatric basement-cover superunit. Superficial cover nappe systems – Fatric (Krížna) and Hronic (Choč) overlie the Tatric substratum in the northern part of the mountains only (Fig. 3).

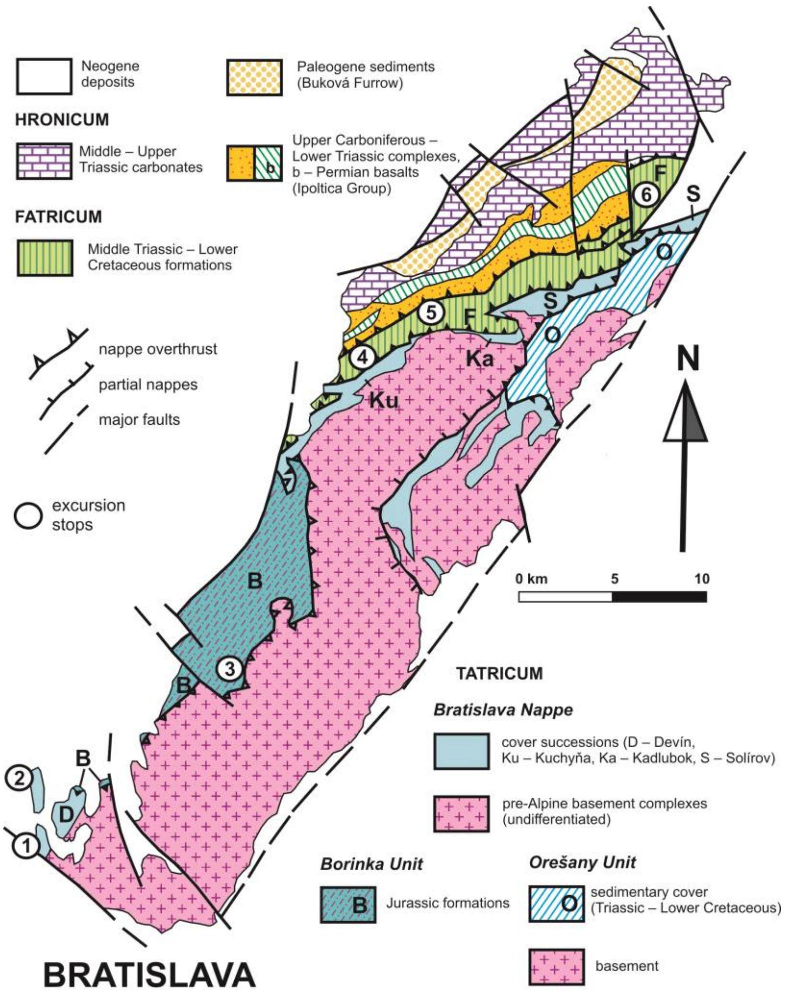

Fig. 3. Simplified tectonic map of the Malé Karpaty Mountains with excursion stop (Plašienka, 2016).

The Tatric units (Plašienka)

Unlike in other "core mountains" of the NW part of the CWC, the Tatricum in the Malé Karpaty Mts is differentiated into several superimposed partial tectonic units. The largest surface part is represented by the Bratislava Nappe, which is a basement-cover thrust sheet overriding the subautochthonous Borinka and Orešany units (Plašienka et al., 1991; Plašienka, 2012; Polák ed., 2012).

The pre-Alpine basement of the Bratislava Nappe consists of two Lower Paleozoic meta-volcano-sedimentary complexes intruded by two different Variscan granitoid massifs. The Pezinok Complex is composed of meta-sediments (phyllites, paragneisses, less migmatites) and amphibolites: it is intruded by S-type granites of the Bratislava Massif. It occupies mainly the southern part of the Mountains. The Pernek Complex, which occurs in a higher Variscan overthrust position, represents a probably Devonian ophiolite-bearing unit composed of low-grade basic meta-volcanites and pelagic meta-sediments (Ivan et al., 2001).

It is associated with shallow intrusion of I-type tonalites of the Modra Massif.

Post-Variscan sedimentary cover of the Bratislava Nappe (Fig. 4) starts with only locally preserved Upper Permian coarse-grained clastics. These are followed by ubiquitous Lower Triassic quartzites and variegated shales overlain by Middle Triassic shallow-marine carbonate complex (Gutenstein Limestone and Ramsau Dolomite). Younger Triassic sediments are not preserved due to deep erosion during Early Jurassic rifting, but occasional clasts of Rhaetian fossiliferous limestones occur in Jurassic breccias. In places, even the Early to Middle Jurassic limestones directly overlay pre-Alpine basement rocks and form Neptunian dykes in them (Fig. 5-Kadlubek; cf. Plašienka 2012 and references therein).

As the result of changeable syn-rift sedimentary conditions, Jurassic strata are partly differing in various parts of the Bratislava Unit. The sedimentation commonly starts with late Lower Jurassic carbonate breccias and massive limestones with brachiopod and belemnite coquinas (Stop No. 1). These are followed by a deepening succession of dark shales, silicified spiculitic spotty marlstones, siliceous limestones, radiolarites, nodular and maiolica-type limestones (Devín, Kuchyňa and Solírov successions – Michalík et al., 1993; Stop No. 2). The Modra Massif is associated with a dissimilar, extremely condensed Kadlubok Succession (Michalík et al., 1994). All successions are terminated by synorogenic coarsening-upward turbiditic deposits of late Albian to early Turonian age, which are overthrust by the Fatric Krížna Nappe.

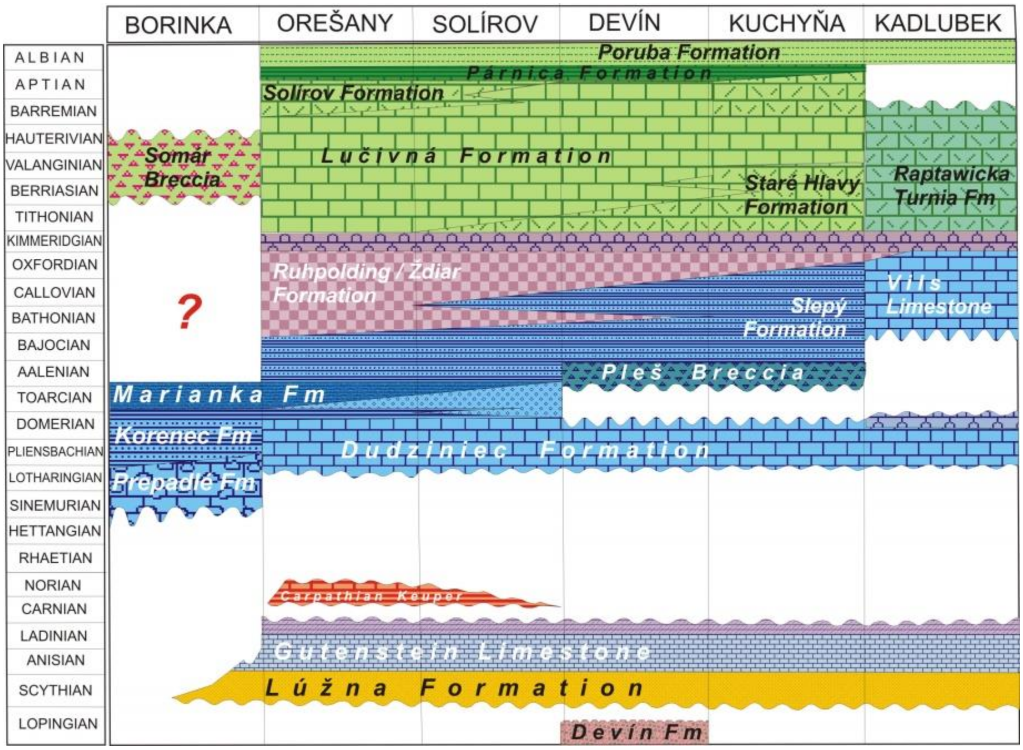

Fig. 4. Schematic lithostratigraphical table showing development of Mesozoic sediments in Tatric units of the Malé Karpaty Mts. (Plašienka, 1989).

The lowermost structural position of the Tatric nappe stack is occupied by the Borinka Unit occurring in a subautochthonous position below frontal parts of the Bratislava Nappe, which is exposed on the NW slopes of the Malé Karpaty (figs 5, 6). It forms the biggest "blue spot" to be seen on general geological maps of the Slovakian Western Carpathians, which suggests a significant amount of Jurassic sediments present there (altogether more than 1 km thick), in contrast to the other parts of the Western Carpathians. In spite of this, most probably only Lower to Middle Jurassic strata are preserved, with an unexposed relationship to underlying complexes. They are composed of syn-rift, coarse-grained polymict breccias, black shales, spiculitic marlstones and turbiditic sandstones.

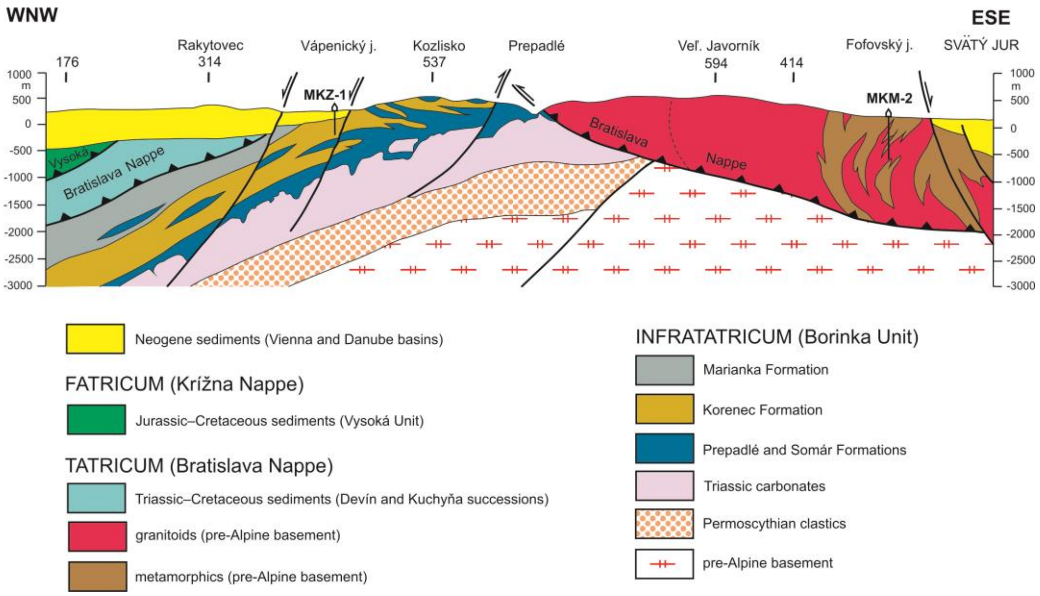

Fig. 5. Geological cross-section of the southern part of the Malé Karpaty Mts (Plašienka, 2016).

The original palaeogeographic settings of the syn-rift Jurassic successions of the Tatricum in the present Malé Karpaty Mts was tentatively reconstructed based on their present structural positions and thrusting direction, sedimentary transport directions and likely position of sources of the coarse-grained terrigenous clastic material (Plašienka et al., 1991; Plašienka, 1995a, b, 2003, 2012). The model outlined in the Fig. 6 assumes development of Jurassic asymmetric halfgrabens flanking the South Penninic (Ligurian-Piemont-Vahic) Ocean.

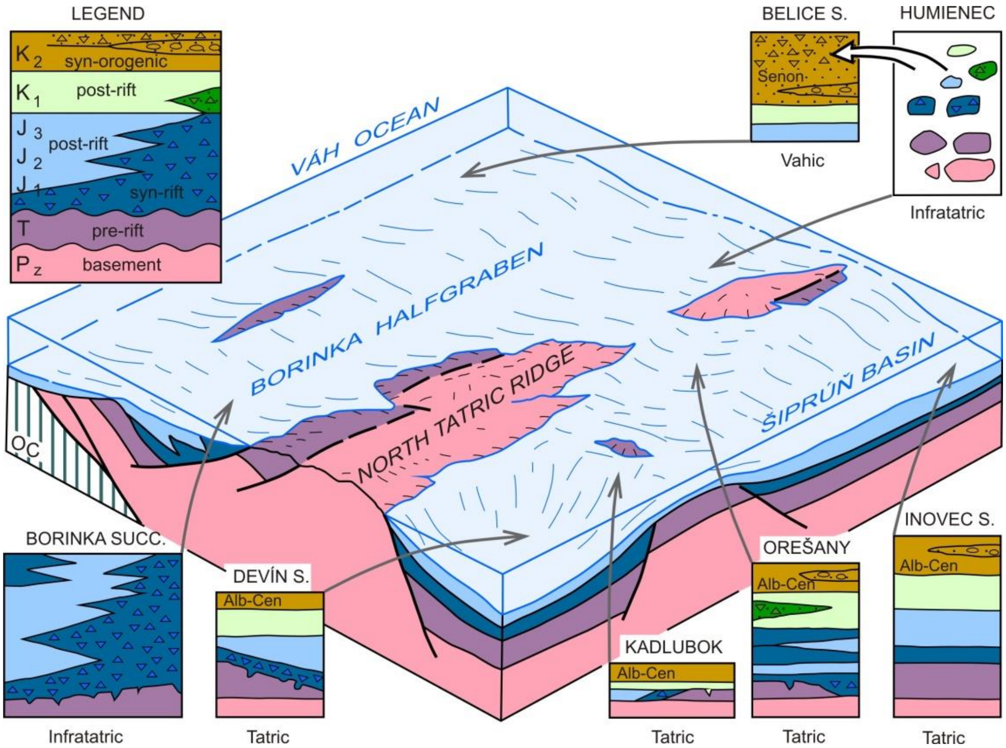

Fig. 6. Blockdiagram illustrating the palaeogeographic relationships of lithostratigraphic successions positioned along the northern Tatric continental margin facing the Váh Ocean to the NW and the Tatric Šiprúň basin to the SE (in present coordinates). Approximately Late Jurassic situation. (Adopted from Plašienka, 2012).

Field trip route

Field stop 1: Devín Castle rock: Mid-Jurassic breccias in the Devín Unit (Michalík)

GEOGRAPHICAL COORDINATES: N 48°10'28.1" E 16°58'37.1"

The frontal part of the Bratislava Nappe is build up of phyllite cover of allochthonous granitoid massif with sporadic dykes of aplites and pegmatites (Fig. 7.; Kováč et al., 1991, Plašienka et al., 1991, Plašienka,1999). Imperfectly exposed Devín Formation outliers cropping out near eastern gate of the Devín castle are the oldest member of the Mesozoic sedimentary cover sequence. They consist of gray-greenish conglomerates and breccias with clasts of granite, vein quartz, phyllite, variegated shales and basic volcanites. Vozárová and Vozár (1988) supposed their Permian age.

Lower Triassic complex, belonging to the Lúžna Formation, build the summit part of the Devínska Kobyla Hill, and the Devín Castle Hill, as well. It is composed of quartzose sandstones with fine-grained to glassy quartz matrix which contains pebbles of white vein quartz, rosa rhyolite and black turmalinic rocks (Mišík and Jablonský, 1978; Mišík, 1986). The well and trench, separating the majestic Devín Citadella from the proper Castle, have been excavated in “Campilian” yellow-gray claystones. Below the bridge, Middle Triassic Ramsau Dolomite crops out in the trench. It is represented by thin layered gray to dark gray crumbling carbonates with smell of bitumen and with inexpressive claey interlayers. The upper part is transformed into monomict dolomite breccia, building eastern slope of the Citadella rock. The Gutenstein Limestone Formation crops out on opposite slopes of the Devínska Kobyla Hill. It is represented by dark bituminous rocks, often with lamination (alternation of thin fine detrital an micritic limestone). Graded fine breccia layers occur frequently. The presence of these rocks in clasts of the Pleš Breccia indicates that the Gutenstein Formation had originally much much greater extent, being considerable eroded during Early Jurassic. This erosion completely removed the Carpathian Keuper complex strata.

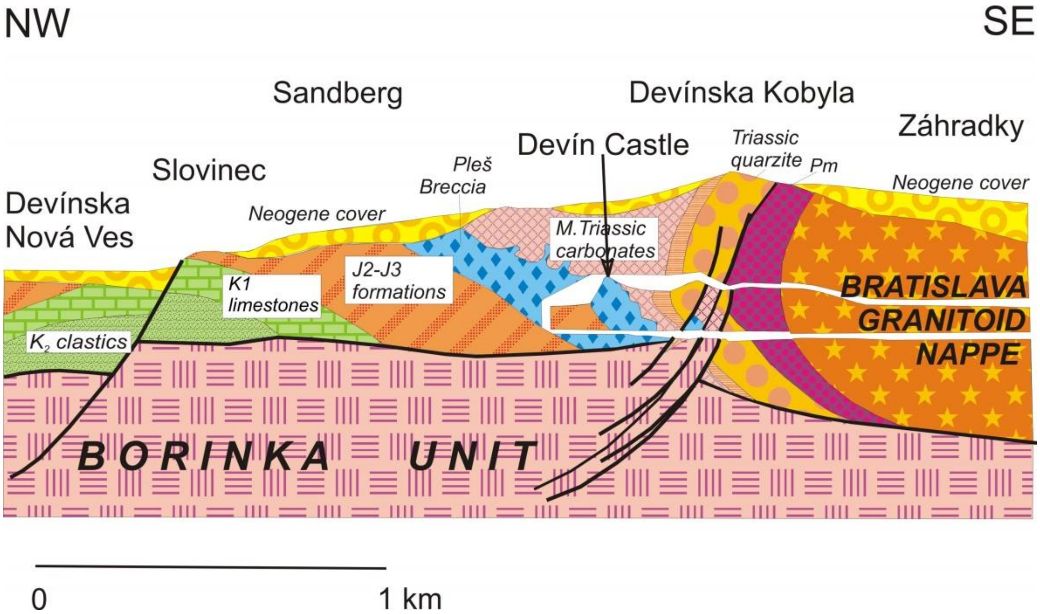

Fig. 7. Schematic geological cross-section (W-E) across the Devínske Karpaty Mts group (Plašienka, 1987; Michalík & Vlčko, 2011).

Dolomite breccia is non-conformably covered by the polymict Pleš Breccia (Michalík, 1984), consisting of clasts of various size (several centimetres to five-six meters). This breccia builts up the most morphologically eminent part of the castle hill, occupied by the Citadella (Baliak et al., 1997; Pipík et al., 2004). Erosional groves up to variously deep neptunian dykes are observable below the breccia base. Individual clasts are formed by gray dolomite, dolomite laminite, dolomitized limestone with pseudomorphoses after gypsum crystals, gray shelly limestone, cherty and phosphatized limestone, sometimes even by speleothemes (Mišík, 1980). Kochanová et al. (1967) described finding of biomicrite clast with remnants of Rhaetian bivalves and foraminifers, Rakús (1996) has found clasts with phosphatized upper Liassic ammonites. Up to now, we failed to duplicate finding of limestone clasts with the Rhaetian fauna, but, instead, we (Michalík et al., 1994) revealed Lower Jurassic brachiopods of the Mediterranean type (Vörös, 1977; 1982) in clasts of dark gray biomicrite from the western rock wall. Michalík (1984) identified the breccia body with the Pleš Breccia of Toarcian age, which originated during Early / Middle Jurassic tensional stress of central Carpathian microplate due to opening of the Penninic Rift.

Macroscopic study of breccia textures indicates that it was generated by complicated, multiplicated process. The Citadella top is dissected by several crevices filled by Miocene sand. The composition, size and reworking of rock clasts in different parts of the breccia body are different. Several clasts were secondarily dolomitized (silicification is less frequent). The matrix between clasts is usually marly, carbonatized, less frequently dolomitized, sometimes consisting of fine debris. In few parts of the breccia (on the Devínska Kobyla Hill slope), fine matrix was “injected” under hydrostatic pressure into internal cavities between clasts. Such process indicates rearranging of material inside more voluminous quickly deposited slumping body. On the other hand, the matrix with laminar structure, or with more-or-less evidently graded little clasts, denoting gradual deposition of fragments and mud mixture from free sedimentary space, is more obvious.

Michalík et al., 1994 described brachiopod findings from four Tatric localities (Pleš, Staré Hlavy and Ostrý vrch in the Kuchyňa Unit and Devín from the Devín Unit) of the Malé Karpaty Mts. Two limestone blocks fallen from western rock wall of the Devín (Citadella) Castle rock consisted of dark brown-gray fine biosparite and contained shell fragments of *Securithyris adnethensis* (Suess) and few specimens of *Linguithyris aspasia* (Meneghini). Presence of these typically “Tethyan” forms (Vörös, 1977, 1982, 1984) in brachiopod fauna of the Pleš Breccia clasts should prove for its Mediterranean character. It is worth of mention that the brachiopod association from the Tatric Kuchyňa Unit in the Malé Karpaty Mts (Michalík et al., 1994) is of the “European” character.

Microscopic study of clasts from the Pleš Breccia Fm under luminiscent microscope indicates multiplicated effect of stress deformation and origin of successive generations of calcite veinlet infillings.

Carbonate clasts with preserved internal structure occur within rocks fragments are formed by oolitic limestones (oosparites), bioclastic limestones (biosparites), pelsparites and limestones with abundant algal nodules. Carbonates are affected by early selective dolomitization (facies selective dolomitization), typical of peritidal and shallow neritic facies zones. The luminiscence of original rock is low, ooid laminae are orange. The matrix between clasts is bright orange red, what indicates raised Sr content.

In marine phreatic environment small cavities formed in original rock were affected by early cementation phase of dolomitization, and subsequently filled by isopachyal cement. Aggregates of cementing newly originating carbonate and veinlets cutting it, are of orange luminiscent colour.

In more advanced stage of dolomitization, cortex growth subsequently combined and closed relict pores. Freatic syntaxial cement brights orange to pale red, zonal banding creating the “dog teeth” pattern indicates mode of growth of rhomboid carbonate crystals into free space in cavities and crevices of the rock.

Clasts of the Pleš Breccia Formation were derived from shallow marine facies zone of the Triassic carbonate platform. Less frequent Rhaetian and Lower Jurassic rocks came from open neritic deposits. Thus, the subsidence in the Devín Unit of the Tatric started in latest Norian being followed by sedimentation of Rhaetian limestones.

The Pleš Breccia body accumulated on a foot of synsedimentary formed fault scarp on the Tatric margin after Toarcian. The destruction of sedimentary sequence in adjacent Tatric zones and forming of depositionary space for accumulation of slope debris was enabled by tensional stress on arising Penninic Rift margin.

Field stop 2: Devínska Nová Ves - Slovinec cliff (Reháková)

GEOGRAPHICAL COORDINATES: N 48°12'05.2"; E 16°58'16.9"

Upper Jurassic and Lower Cretaceous sequence is outcroped in the Slovinec Hill near the Sandberg and Devínska Nová Ves. 37 samples for microfacies analysis and detection of stratigraphicaly important microfossils were taken in meter–intervals from the rock wall.

Sequence 1–37 (Fig. 8) is built of bedded to thin bedded gray to greyish brown mostly micrite locally fine grained cherty limestone. Dark to black grey cherts are concentrated to separate nodules. In beds 8 to 10 slump structures are observed, the cherts are imbricated there. No cherts occur in beds 1–4, 10–13, 21–24. Higher up, the sequence above the bed 34 consists of marly limestones. They locally pass into thin shales penetrated by thin silicite intercalations.

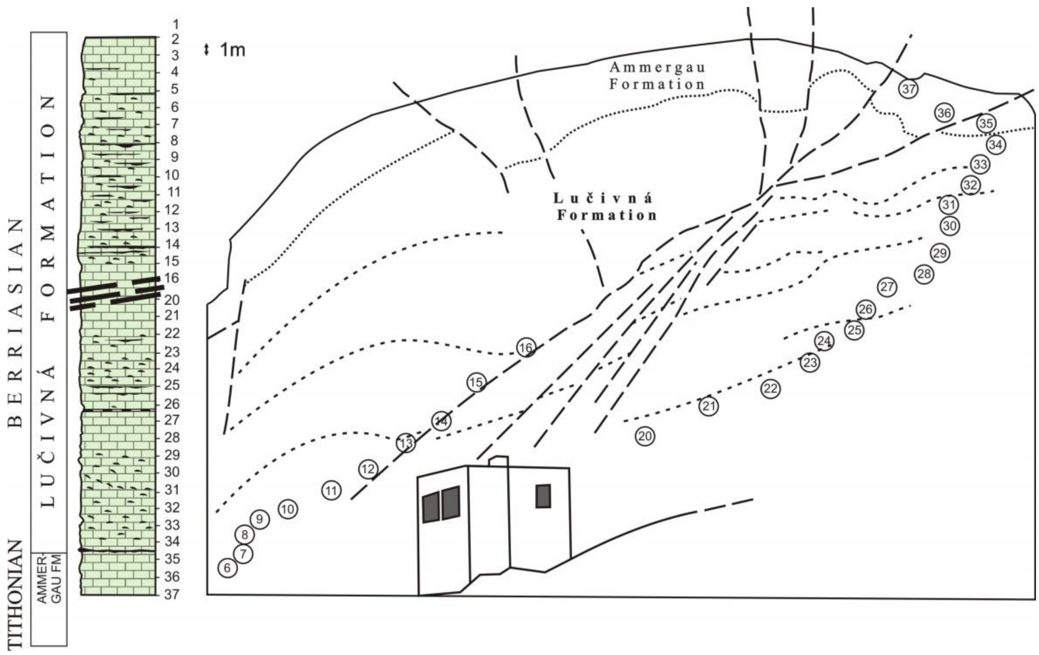

Fig. 8. Schematic illustration of the lithological and tectonic situation in the Slovinec rock cliff near the Devínska Nová Ves (Plašienka et. al, 1989).

The character of limestones are biomicrosparite, locally microsparite (wackestone, mudstone). The rock contains very rare and fragmented calpionellid loricas (often hardly determined due to damage of collars). Among bioclasts, *Calpionella alpina* Lorenz, seldom *Calpionella elliptica* Cadisch, *Crassicollaria parvula* Remane, *Crassicollaria* sp., *Tintinnopsella carpathica* (Murgeanu et Filipescu), microproblematicum *Didemnum carpaticum* Mišík et Borza, spores of *Globochaete alpina* Lombard, calcified radiolarians, fragments of crinoids, ophiuroids, ostracods, bivalves and aptychi were identified. Bioclasts are indistinctly oriented by pressure. Limestones are locally penetrated by abundant fractures filled by calcite; the matrix is silicified in cherty intervals. Epigenetic pyrite is scattered in matrix. Pyrite concentrates in frequent thin stylolites and it locally cuts contours of bioclasts. Very rare silty clastic quartz grains and muscovite leaflets are present too. This part of sequence was correlated with the Oberalm Lst Formation, it Berriasian age is indicated by calpionellid association of the standard Calpionella Zone (the Elliptica Subzone in Reháková and Michalík, 1997a, b).

Late Jurassic to Early Berriasian sequence was identified above the gallery in the western part of the Slovinec Rock. Microfacies study confirmed its overturned position (Plašienka et al., 1989).

Beds 1 to 14 (Fig. 8) consist of gray to greyish brown indistinctly bedded to compact chert limestones passing to the bedded and thin-bedded limestone above bed 5. Limestone is locally replaced by shale alternating by thin marly intercalations. Some beds contain thin laminae of fine detrite. Cherts are dark, forming nodules or stratiform layers.

Limestone structure is mostly microsparite or biomicrosparite (mudstone to wackestone). Recrystallized microfossils are very rare, matrix is localy slightly silicified being penetrated by calcite fractures oriented perpendicularly to metamorphous lamination. *Calpionella alpina*, *Crassicollaria parvula*, *Tintinnopsella carpathica*, *Globochaete alpina*, calcified radiolarians, fragments of crinoids, ophiuroids, ostracods, bivalves and aptychi were identified. The rock contains silty clastic admixure and scattered pyrite; clay minerals are mostly concentrated in stylolites. Limestones are Early Berriasian in age (Calpionella Zone, Alpina Subzone).

Beds 15 to 18 consist of indistinctly nodular gray-grenish limestones (the Tegernsee Lst Formation) passing to grey thin-bedded to shaly limestones and shaly silicites (Ruhpolding Formation). They contain fine scattered detritus, localy concentrated in thin laminae. Mostly microsparitic limestones (wackestone to mudstone) are lacking microfossils. *Globochaete*- *Saccocoma* microfacies was recognized in beds 15 and 16. Spores of *Globochaete alpina*, and *Saccocoma* sp. planktonic crinoids are accompanied by rare aptychi, bivalves, ostracods and very seldom oblique sections resembling calpionellid loricas. Silicified beds contain silicified sponge spicules and radiolarians. Kimeridgian–Tithonian age of this part of sequence is supposed on the base of microfossils mentioned above.

Field stop 3: Borinka Village, Prepadlé Valley, the Borinka Unit (Plašienka)

GEOGRAPHICAL COORDINATES: 48°16'02.1"N 17°07'10.0"E

On the surface, the Borinka Unit is only composed of Jurassic deposits. From the E and SE, it is overthrust by the Tatric Bratislava Nappe, composed of pre-Alpine crystalline basement and Permian–Mesozoic sedimentary cover. In the NW, the Borinka Unit is covered by marginal Miocene deposits of the Vienna Basin. As the lowermost Tatric element of the Carpathians, the Borinka Unit forms a kind of a tectonic window (Figs. 5, 6). Therefore it is sometimes designated as the Infratatricum.

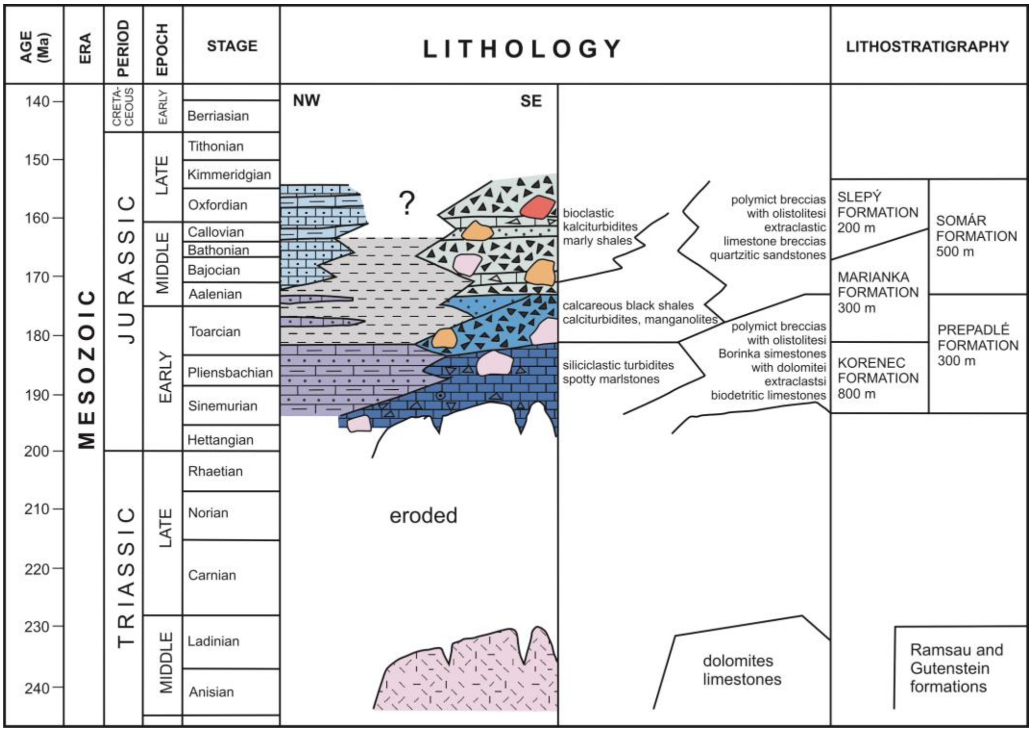

Fig. 9. Lithostratigraphy of the Borinka Succession (according to Polák ed., 2012).

The sedimentary infill of the Jurassic Borinka basin exhibits a noticeably asymmetric arrangement of proximal and distal deposits that are composed mostly of terrigenous clastics (Fig. 9). During the mid-Early Jurassic (Sinemurian – Pliensbachian), massive limestones (Borinka or Ballenstein Limestone Member) with signs of redeposition, olistostromatic bodies of extraclastic carbonate breccias and giant olistoliths of Triassic carbonates (figs. 9, 10, A, B, C, 11), as well as bioclastic limestones and quartzitic sandstones (Prepadlé Formation, at least 300 m thick), were deposited in the SE marginal position (Plašienka, 1987, 2012; Plašienka in Polák ed,. 2012). Simultaneously, the central and NW parts of the basin were filled with mixed carbonate-siliciclastic turbidites and hemipelagic spotted marlstones (Korenec Fm, up to 800 m). The terrigenous input ceased in the axial part of the halfgraben by the late Early Jurassic, when anoxic black shales were laid down (Toarcian–?Bathonian Marianka Fm, more than 300 m; Fig. 10 F). The partly interfingering with the overlying Slepý Fm (Middle – ?Upper Jurassic, more than 200 m) that consists of calciturbidites containing shallow-water biodetritus (Fig. 10 G). Contemporaneously with the Marianka and Slepý fms, huge masses of coarse-grained scarp breccias (Somár Fm, some 500 m) accumulated in the proximal SE part of the basin, just above the Prepadlé Fm (Fig. 10 E). The clastic material of the Somár mixtitic breccias is dominated by basement rocks (Palaeozoic phyllites, amphibolites and granites) with numerous olistoliths of Triassic quartzites and carbonates. The marginal parts of breccia aprons are clast-supported and sometimes totally matrix-free, while more distal, frontal parts of breccia bodies reaching the halfgraben axis are limy mud-supported and occasionally diluted to high-density turbidity currents. These disorganized proximal sediments were deposited as debris avalanches and mass-flows derived from fault-controlled linear sources located to the SE, while the Korenec turbidites were most probably fed by a river that drained a wide dry land (see the model reconstruction in Fig. 11). On contrary, calciturbidites occurring in the Marianka and Slepý fms are almost free of siliciclastic material and were likely derived from the gentler NW counter slope of the basin. Based on these features, the Borinka basin is reconstructed as an elongated tilted halfgraben some 10–15 km wide with a steep, normal-fault escarpment on its SE side. This Early to Middle Jurassic fault separated the basin from a continental ridge (North Tatric ridge – Plašienka, 1995), which was temporarily exposed to subaerial erosion. During Late Cretaceous shortening, the Borinka Unit was overthrust by the Tatric Bratislava basement nappe, thus the source ridge was hidden below and does not crop out at the surface at present. The overthrust plane is accompanied by a ductile shear zone with top-to-the-NW kinematic indicators (Plašienka, 1990; Fig. 10 D, E) and rocks of the Borinka Unit were affected by very a low-grade metamorphic overprint (Plašienka et al., 1993).

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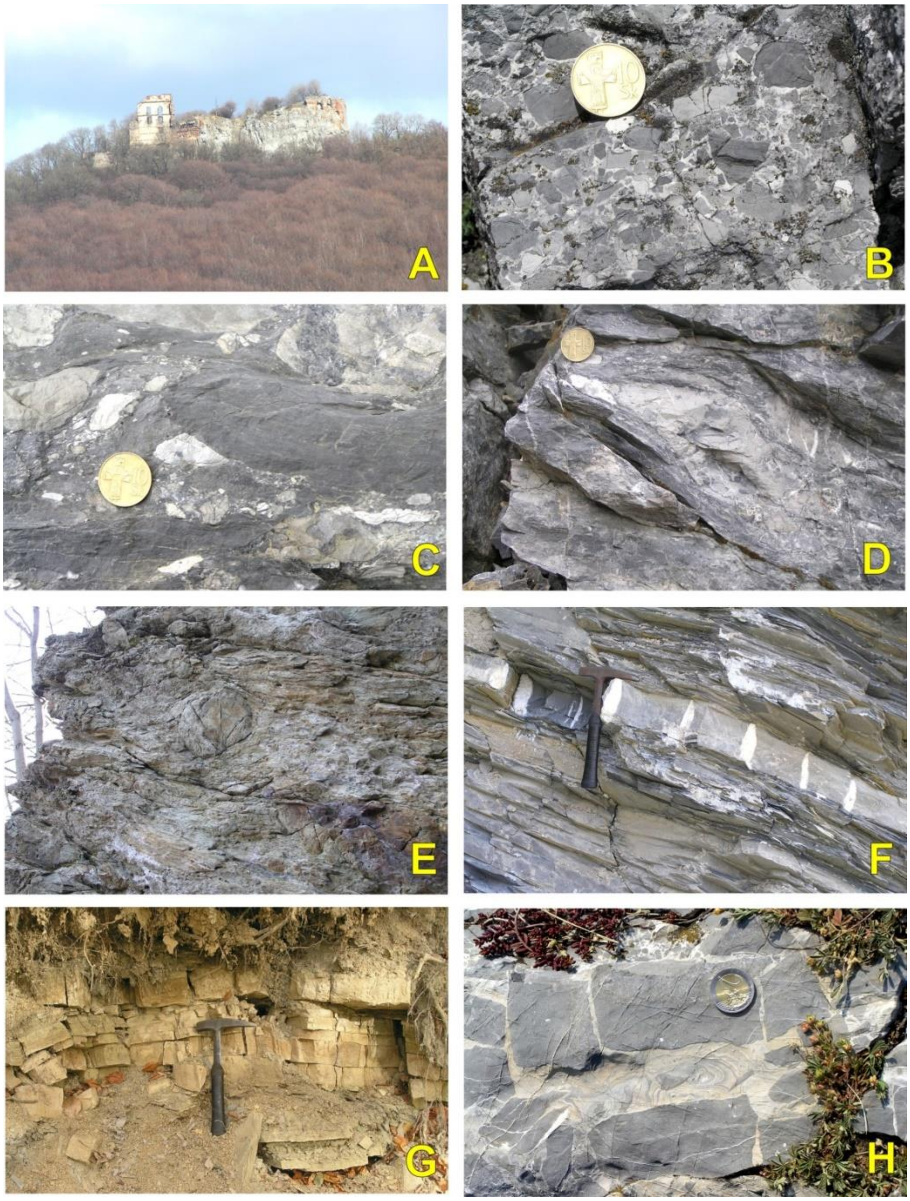


Fig. 10. Phototable of syn-rift sediments of the Borinka (photos A–G) and Devín (photo H) successions (Malé Karpaty Mts): A – megaolistolith of Triassic carbonates with ruins of the Pajštún Castle above the Borinka village; B – Lower Jurassic extraclastic clast-supported carbonate breccias, the host rock of the Pajštún olistolith; C – matrix-supported extraclastic carbonate breccias, Prepadlé Valley near Borinka; D – deformed σ-clast of Triassic dolomite indicating top-to-the-NW thrust direction of the Tatric Bratislava Nappe overriding the Borinka Unit, the same locality as photo C; E – polymictic clast-supported breccias of the Somár Fm (Middle Jurassic of the Borinka Unit), the rounded clast in the centre represents a more resistive amphibolite fragment surrounded by strongly sheared phyllite clastic material forming a "pseudomatrix", the Prepadlé Valley; F – black calcareous shales with a calciturbidite bed, Marianka Fm (Toarcian) of the Borinka Unit, abandoned quarry of roofing slates in the Marianka village; G – calcarenites of the Slepý Fm. (Middle – Upper Jurassic of the Borinka Unit), Turecký vrch military area; H – in situ fragmentation of the Triassic carbonate substratum with fissures injected by Jurassic limy mud, Devín Succession of the Tatric Bratislava Nappe, Devínska Kobyla Hill near Bratislava. Adopted from Plašienka (2012)

By its immense thickness and dominance of unsorted, coarse-grained, deep-marine clastics, the Jurassic Borinka succession has no equivalents in the entire Carpathians. However, its close analogies can be found in cover successions of the Lower Austroalpine nappes of the Eastern Alps, where similar Jurassic scarp breccias are interpreted as derived from marginal normal faults that flanked the opening South Penninic Ocean from the S (see Häusler 1988; Häusler et al., 1993; Plašienka, 1995 and references therein). Such a position fits well also the Carpathian situation, despite no undisputable Penninic oceanic elements are to be found at the surface. The long (some 30 Ma), though episodic activity of the SE marginal fault of the Borinka halfgraben allows for its interpretation as a master break-away fault that separated the lower (SE) and upper (NW) plates of an asymmetric rift zone, which was active until the final break-up of the South Penninic oceanic tract that occurred further to the NW in the late Middle Jurassic (Plašienka, 2003).

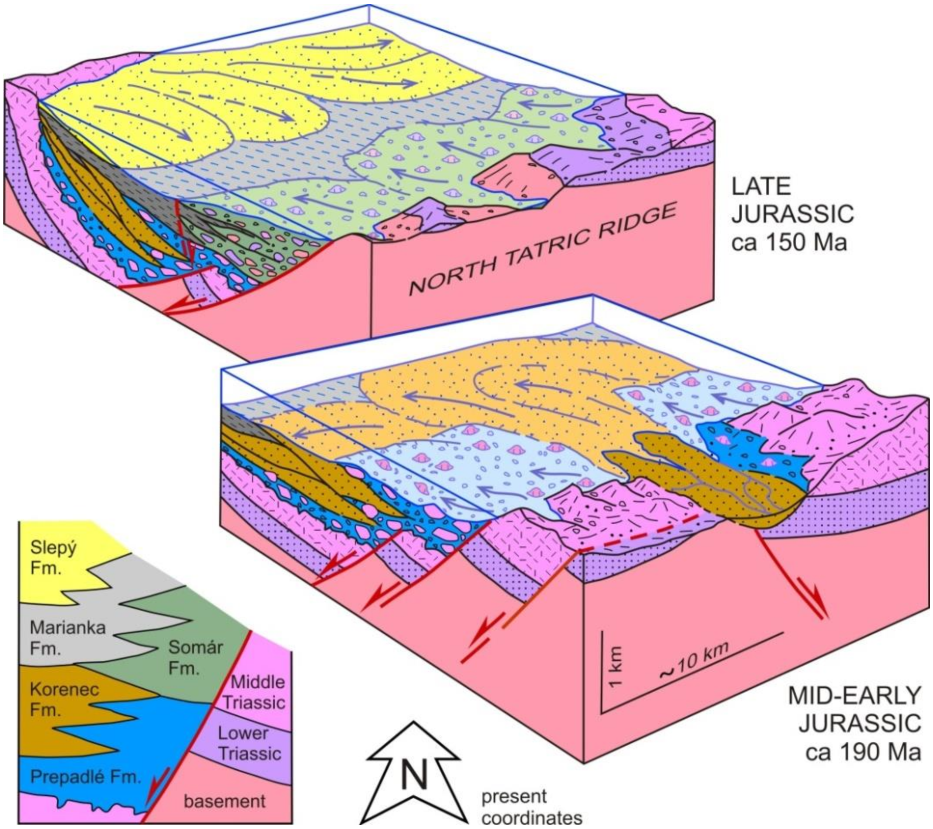


Fig. 11. Model of two evolutionary stages of the Borinka halfgraben. Early Jurassic situation reflects the symmetric rifting mode (the Zliechov Phase), Upper Jurassic halfgraben tilting occurred during asymmetric rifting and breakup of the Vahic oceanic zone to the NW (the Krasín Phase). Adopted from Plašienka (2012).

Structure of the northern part of the Malé Karpaty Mts

The Fatric (Krížna) cover nappe system (Michalík, Plašienka)

The Fatric nappe system is composed of décollement cover nappes originated in areas south of the present Tatricum. By the definition, the Fatricum is composed of both the Vysoká and Krížna partial nappes (Andrusov et al., 1973). However, the structural and facies links between both these units are as close (e.g. Maheľ, 1983), that only the term "Krížna Nappe" (s.l.) is generally used for them. Fatric nappes clearly overlie the Tatric cover and are usually overlain by rocks of the "higher" (generally Hronic) nappes (Michalík et. al, 1999).

However, intrinsic complications arise in the frontal Fatric parts and in the Periklippen area, where the relationships of Fatric units to their substratum cannot be defined in a rigorous way. In the Maheľ's view, the Manín Unit (mainly its pre-Senonian formations) occurring in the Periklippen Belt is also a part of the Krížna nappe system. This conception is followed by few other authors (Michalík & Vašíček, 1980). Plašienka (1995b) extended the Fatricum to include another Periklippen unit - the large Klape unit, with the exception of its Senonian formations. Unlike the Krížna Nappe proper, the Klape and Manín units underwent repeated subsidence, deep-sea sedimentation and strong deformation after their final nappe emplacement.

Facies considerations in the Triassic sediments of the "higher" nappes sometimes inferred a presence of nappes of the "ultra-Hronic" affiliation (the Strážov Nappe in the Strážov Mts, or the Nedze Nappe in the Malé Karpaty Mts). These units would be characterized by involvement of Wetterstein and Dachstein formations as diagnostic Triassic facies and were therefore regarded as the "Gemeric", and later, after both the Silica Nappe and the Silicicum was defined by Kozur & Mock (1973) and Mello (1979), as the "Silicic". However, detailed study of spatial relationships between the reefal, lagoonal, slope and basinal facies of the original carbonate shelf preserved in these nappes revealed close lateral facies and structural links between partial Hronic nappes (Michalík et al., 1993a; Havrila, 1996, Polák et al., 1996). The presence of nappe sheets composed exclusively of reefal facies in the highest structural position can be interpreted not as an indication of an independent higher nappe system only, but simply as partial nappe bodies of the Hronic system, individualized thanks to mechanical competency of massive lagoonal-reef bodies surrounded by basinal, less competent complexes undergoing contraction. Moreover, typical Silica Nappe contains stratigraphic succession terminated by Oxfordian sediments only (Kozur, 1991; Sýkora & Ožvoldová, 1996). On the contrary, the sedimentary record in higher nappes of both the Malé Karpaty and Strážov Mts continued until upper Lower Cretaceous. Therefore, all "higher" nappes in the "core mountains area" are regarded here as constituents of the Hronicum, i.e. the Choč Nappe s.l., which is usually underlain by a thick Upper Paleozoic volcano-sedimentary complex - the Ipoltica Group ("Melaphyre Series"), nowhere present below the Silicic Unit. The latter are spatially restricted to the southern Central West Carpathian zones (the Veporic and the Gemeric domains).

The Krížna nappe group (Maheľ, 1983), redefined as the Fatricum consisting of the Vysoká and Krížna principal nappes by Andrusov et al. (1973), is a tectonic unit representative of the Central Western Carpathians. It overlies various Tatric cover units and it is overlain by another important group of cover nappes - the Choč and higher nappes (the Hronic System).

The Krížna Nappe is a relatively thin (1–3 km), but widespread (more than 12 000 km^2, according to Jacko & Sasvári (1990) overthrust sheet composed of Lower Triassic to mid-Cretaceous sediments of diverse, but mostly carbonate lithologies. They were sheared off their mostly disappeared original basement and tegument along décollement horizons of Scythian and Keuper shales and evaporites to form a far-reaching allochthonous body. The nappe consists of numerous dismembered slices, recumbent folds and imbricates, but large areas with relatively undisturbed stratigraphic successions are present as well.

From the lithostratigraphical point of view, the Krížna Nappe is generally subdivided into the Vysoká and Zliechov-type successions. The Vysoká Succession contains shallow-water Jurassic sediments similar to the Tatric (High Tatra-type successions), while the Zliechov one is a deep-water Jurassic-Cretaceous succession. At the western (Malé Karpaty Mts) and eastern termination of the Central Western Carpathians (the Branisko and the Humenné Mts) the Vysoká type becomes the main constituent of the Fatricum and the Zliechov type gradually wedges out.

There are several crucial problems in the interpretation of the frontal parts of the Krížna Nappe. Some authors (Maheľ, 1978, 1983, 1986 etc; Michalík et al., 1987) consider the important Manín Unit of the Periklippen Belt (the zone between the northern edge of the Tatricum and the Pieniny Klippen Belt itself) as a partial, Vysoká-related unit of the Krížna nappe group because of the resemblance or even correspondence of its Jurassic-Lower Cretaceous sequence to the Vysoká type, while other authors (Andrusov, 1968; Rakús, 1977; Marschalko, 1986; Salaj, 1994, 1995) stressed the continuation of the Middle to Upper Cretaceous succession and they placed the Manín Unit paleogeographically north of the Tatricum. However, in the latter case, the Manín Unit should have juxtaposed the outernmost Tatric, i.e. the Infratatric Zone as it is defined above. Since the Jurassic–Lower Cretaceous strata show considerable differences in the Manín and Infratatric domains, their paleogeographic links are improbable. Consequently, if the Manín unit is a true constituent of the Krížna nappe system, one cannot exclude that also some other Periklippen units, such as the Drietoma, Bošáca, Kostelec, Haligovce and even the Klape Unit, presumably their pre-Upper Turonian formations, also belong to the same nappe system (Plašienka, 1995b).

According to the evolutionary tectonic model of the Krížna Nappe (Plašienka & Prokešová 1996), the principal Zliechov Unit was formed at the expense of a wide basinal area floored by strongly stretched and thinned continental crust. In Mid-Cretaceous times, the Zliechov Basin was progressively shortened through underthrusting of its basement and tegument complexes below the Veporic thrust wedge. The sedimentary fill was detached along the Upper Scythian shale and evaporite complex and formed an initial fold-and-thrust stack prograding outwards. After the complete elimination of the Zliechov Basin substratum, its Tatric and Veporic margins came into collision and the Krížna stack was pushed over the frontal South Tatric ramp, from which the frontal Fatric elements (the Vysoká- and the Manín types), with slope and ridge-related sedimentary successions, were torn off. Finally, in the Late Turonian, Fatric nappe elements gravitationally glided northwards in a diverticulation manner from the South Tatric elevation over the unconstrained basinal northern Tatric areas.

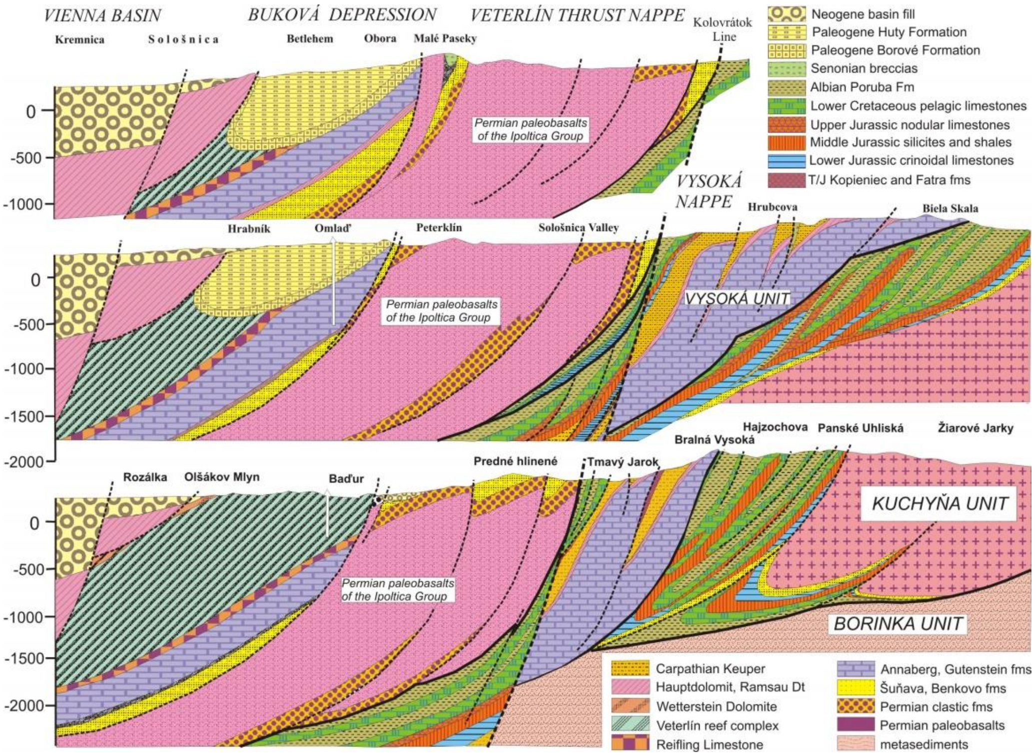


Fig. 12. Geological W-E cross-sections across imbricated nappe structure of the Malé Karpaty Mts in the area between Rohožník and Sološnica. Orig. Michalík.

The Vysoká Nappe in the Malé Karpaty Mts (Michalík).

From the paleogeographical point of view, the Vysoká Nappe (Fig. 7) was derived from the northern marginal parts of the Zliechov Basin in which slope and ridge facies prevailed (Plašienka et al., 1991, Michalík et. al, 1999). The Anisian Vysoká Formation represents 200–250 m thick carbonate ramp sediments of the Gutenstein type. Micritic limestones contain biogene layers with marine benthic fossils and intercalations of tempestites and tsunamites (Michalík et al., 1992a). The upper member of this formation bears marks of hypersaline enviroment, such as dolomitization and pseudomorphs after evaporite minerals. The successive Ramsau Dolomite is about 40–60 m thick. Limestones in the uppermost part of this carbonate complex (Alpine Muschelkalk group) yielded rich Carnian bivalve fauna (Maheľ et al. 1967, Maheľ 1986). They are comparable with the Opponitz Limestone laterally passing into brecciated and cellular dolomites. The Carpathian Keuper complex, although tectonically reduced, attains 200–300 m thickness in several places. Variegated shales contain intercalations of pale gray quartzose sandstones (in the lower member) and gray dolomites (in the uppermost parts).

The Fatra Formation is represented by a sequence of Rhaetian neritic fossiliferous limestones (Michalík, 1974). They are overlain by Hettangian thick shaly sediments (about 100 m) of the Kopienec Formation. Lower Jurassic sandy crinoidal limestones resemble the Trlenská Formation (Bujnovský, et al. 1979) of the Tatricum or the Manín Unit. They yielded a rich collection of silicified fossils (brachiopods, bivalves, foraminifers). Upwards they pass into well bedded cherty crinoidal limestones (the Vývrat Fm), nodular crinoidal limestones and red nodular marlstones (the Prístodolok Fm) and massive crinoidal limestones with ripple- and oblique bedding and with Bathonian fossils (the Vils Fm, Koša, 1998). The crinoidal limestones represent debris aprons along a submarine slope on the basin margin.

Callovian and Upper Jurassic Tegernsee Limestone Fm is intercalated by thin silicite beds with Oxfordian radiolarians. Nodular limestones contain Oxfordian microfossils of the Fibrata Zone (Borza & Michalík, 1988). The topmost part is dated as the Late Tithonian by a rich microplankton association of the Crassicolaria Zone. The Lower Cretaceous sequence consists of the massive Padlá Voda Limestone Fm with limestone breccia intercalations (Nozdrovice Breccia) and of schistose marly limestones of the Hlboč Formation (equivalent of the Kościeliska Fm; Borza & Michalík, 1987, Michalík et al., 1990). Pelagic formations are terminated by the biogenic Bohatá Limestone Fm. The carbonate complex is terminated by the Albian Poruba Formation of pelagic marls (frequently silicified or tectonically reduced).

During the Late Cretaceous–Early Tertiary dextral transpression, mostly Mesozoic Fatric and Hronic nappes complexes in the NW part of the Malé Karpaty Mts (Jurassic - Cretaceous sequences of the Vysoká Nappe in particular) were dissected into numerous duplexes, slices or even "immature" klippen and partly thrust back over the Tatric hinterland (Michalík, 1984; Maheľ, 1987; Plašienka, 1990; Plašienka et al., 1991). The bedding is steeply NW-wards dipping in the eastern parts of the mountains, but the dip decreases eastwards.

The Driny Hill tectonic block near the Smolenice village is separated from the central part of the Malé Karpaty Mts by a N-S fault (Michalík et al., 1992). The surface of this block is morphologically older, distinctly karstified. The only half-blind karstic valley and the only cave accessible for public in the Malé Karpaty Mts are situated right here (Michalík et al., 1992). Relatively good, tectonically less disturbed exposures compared to the eastern part of the mountains enabled detailed lithological and facies studies e.g. in the Hlboč Valley, where almost complete Upper Jurassic–Lower Cretaceous sequence of the Vysoká Nappe is exposed.

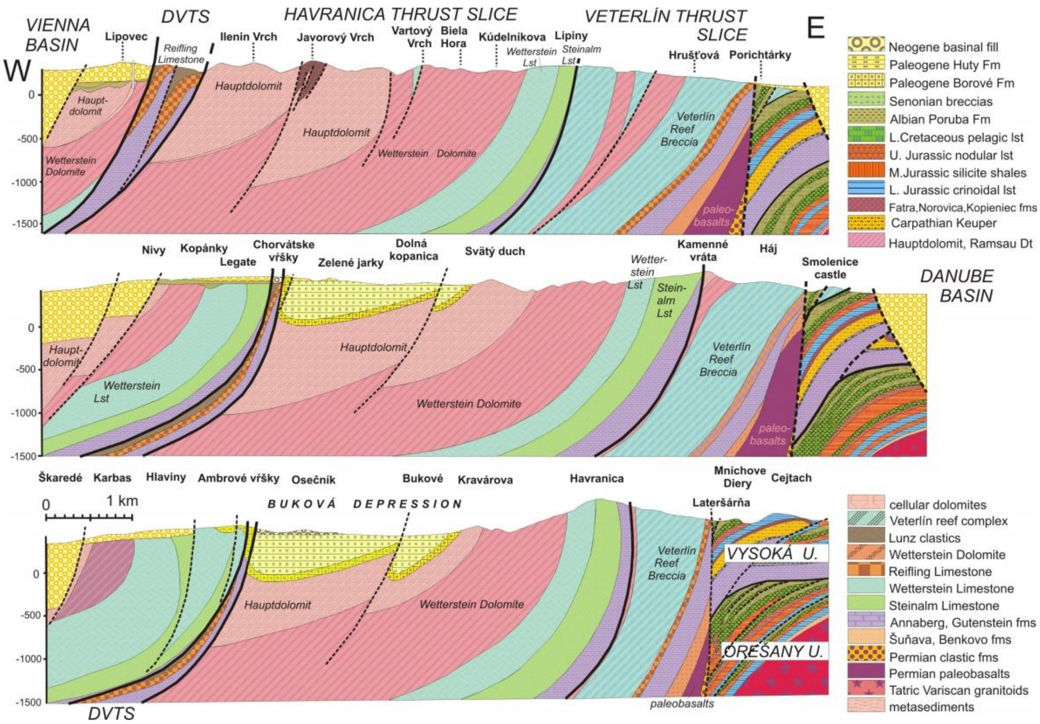


Fig. 13. Geological W-E cross-sections across imbricated nappe structure of the Malé Karpaty Mts in the Biela Hora area between Buková and Smolenice. Orig. Michalík.

The Hronic (Choč) cover nappe system (Michalík. Plašienka)

The pre-progenitor of the term Choč Nappe and/or Hronicum is the "alpinähnliche Fazies" distinguished in the Malé Karpaty Mts by Vetters (1904a, b), who considered it as a particular tectonic unit. The term "Choč Nappe" was used firstly by Lóczy (1917). This term was also accepted by Andrusov, who separated the Strážov Nappe (Andrusov, 1936), originally as the "Strážov - Mojtín Nappe" (Andrusov, 1932) in the Strážov Mts, from the Choč Nappe proper. Therefore, he completized the group of nappes distinguished by him in the Malé Karpaty Mts as the higher and/or highest Subtatric nappes (the Veterník-, Jablonica- and Nedze nappes).

In agreement with Andrusov (l.c.), Hanáček (1954), Mello (1979) and Maheľ (1986, 1987) distinguished two tectonic units in the sequence overlying the Krížna Nappe of the Fatricum. However, both the Choč and Strážov nappes were interpreted very controversially in the Malé Karpaty- Považský Inovec- and in the Strážov Mts. Moreover, many their features are common with tectonic units in NE part of the neighbouring Northern Limestone Alps (Göller Nappe). As in all concepts, the higher subtatric nappes are considered as the highest units in the "core mountains belt", the main contradiction and/or difference being associated with their assignment to a superior unit.

The so called "higher nappes" were explained in the past either as overthrust from the south and understood as higher Subtatric nappes (Andrusov, 1936), and/or as Gemericum nappes (Biely & Fusán, 1967; Andrusov, et al. 1973), and/or Silicicum (Mello, 1979), and/or as a hybrid of the Hronicum and Gemero-Silicicum, and/or as subordinate nappes - slices of the primary Choč Nappe (Maheľ, 1986), and/or as overthrust from the south in one nappe and differentiated by backthrusts into several bodies (Plašienka et al., 1991), or as "original sedimentation areas in the north-western part of the Central Carpathians, and Periklippen Zone" from which these Triassic complexes were squeezed out diapirically on Jurassic and Cretaceous sediments of the same sedimentation area (Salaj, & Began, 1983), and/or as "uneroded and preserved remnants of the Klape Ridge of the Klape Unit in the Periklippen Zone, later thrusted bivergently over younger members of the Klape unit" (Salaj et al., 1987).

Such interpretations set out the geometric position of higher nappes above the Choč Nappe and from the facies point of view, mainly from the lithology of Middle Triassic complexes represented by the Wetterstein Limestone and Dolomite and Schreyeralm Limestone, i.e. facies considered as more southern ones (Andrusov, 1936; Mello, 1979), later from lithology of the Triassic to Cretaceous sequence (Salaj et al., 1987).

Different interpretation of the Hronicum and the affiliation of the Strážov Nappe and/or higher nappes, partly in agreement with the Maheľ´s (1985) view has been presented by Havrila (1996). On the basis of stratigraphical, sedimentological, paleogeographical and structural studies, higher Subtatric nappes were interpreted by these authors as a part of the Hronicum Superunit.

Field stop 4: Kuchyňa, Vývrat Valley below the Prístodolok Hill (Michalík)

GEOGRAPHICAL COORDINATES: N 48°24'55.1"; E 17°11'57.3"

Jurassic sequence forms a tectonically individualized back.thrust slice of the Prístodolok Hill. It starts with shaly Hettangian Kopieniec Formation, which played a crucial role of tectonic lubricant during backthrust mobements. The base of the carbonate sequence consists of the Trlenská Fm - Lower Jurassic limestone intercalated by crinoidal cherty and shelly biosparrudite rich in silicified brachiopod fauna, accompanied by bivalves, belemnites, ammonites and echinoderms. The layers of well bedded cherty limestones with marly intercalations bear current marks on lower bedding planes. A thick rhythmically bedded complex of multi-coloured crinoidal limestones (the Vývrat Formation of Koša, 1998) containing rich Lotharingian–Domerian fauna (described in Buday et al., 1962; Kochanová, 1962; Pevný, 1964) is covered by Toarcian red indistinctly nodular brecciated crinoidal limestones (the Prístodolok Formation). Middle Jurassic strata consist of thick bedded pale crinoidal limestones similar to the Vils Formation. Koša (1998) interpreted the genesis of this crinoidal limestone complex as a huge apron of calcite skeletal material transported from neritic crinoidal meadows down the slope.

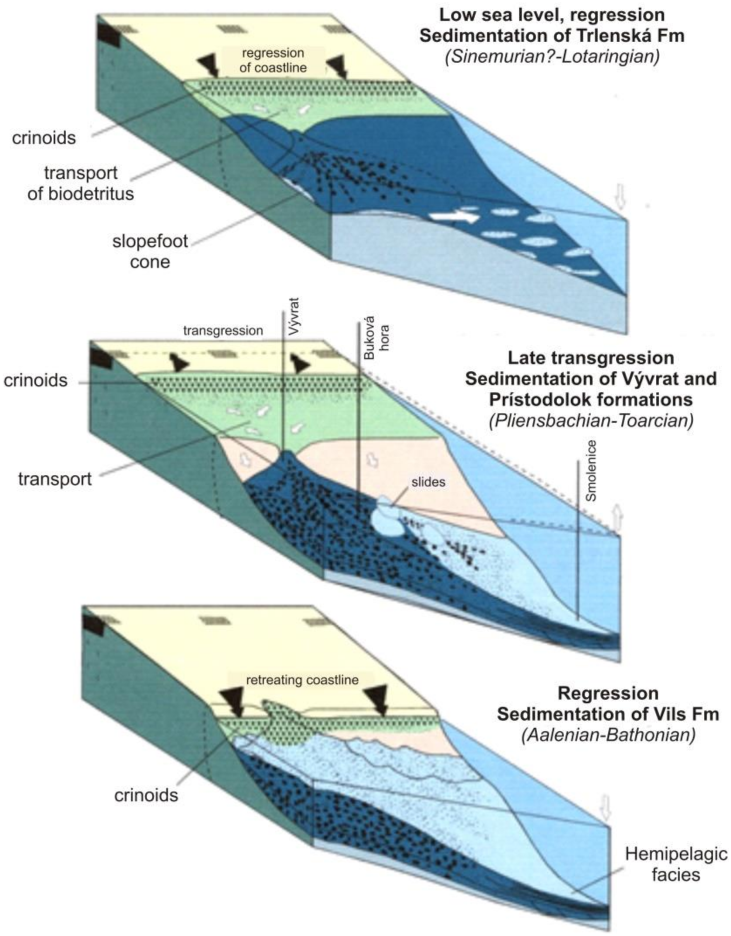


Fig. 14. schematic blockdiagrams showing origin of Lower and Middle Jurassic crinoidal limestone formation in the Fatric basin according to Koša (1998).

Above it, cherty limestones with radiolarites intercalations occur, followed by Bathonian–Callovian red nodular limestones and Oxfordian red silicites (similar to Ruhpolding Fm). Kimmeridgian–Tithonian red nodular limestones crop out on the edge of the Prístodolok Hill above the former Vývrat hunting seat.

Field stop 5: Rohožník, Rohožnícka Valley (Tmavý Jarok) (Michalík)

GEOGRAPHICAL COORDINATES: N 48°25'50.2"; E 17°13'45.0"

Small creek cut small narrows in Upper Jurassic and Lower Cretaceous carbonate sequence of the Vysoká Nappe. 28 meter long section documents steep monoclinal dip studied in detail (Borza and Michalík, 1987; Kováč et al., 1991).

Oxfordian reddish brown and pink nodular cherty limestones (1–8.5) pass upwards into irregulary bedded cherty limestone with radiolarite layer. The nodules consist of microbiosparite with *Colomisphaera fibrata* (Nagy), *Cadosina parvula* (Nagy) and other microfossils.

Nodular limestone sequence attributed to the Czosztyn Fm by Borza and Michalík (l.c.) is formed by pink, red, reddish-brown and pink-grey microsparite. The Kimmeridgian part with abundant *Saccocoma* sp., *Stomiosphaera moluccana* Wanner and other microfossils (9–11.5 m) contains thin crinoidal intercalations. The age of the upper, lithologically similar part (12–14 m) is dated by *Colomisphaera pulla* (Borza), *Carpistomiosphaera tithonica* Nowak, *Chitinoidella* sp, and other microfossils as Early Tithonian.

Gray thick bedded micritic limestones with cherts (14,5–28 m) belong to the Padlá Voda Formation, Microfossils *Calpionella alpina* Lorenz, *Tintinnopsella carpathica* Murgeanu et Filipescu indicate Early Berriasian age. *Calpionellopsis simplex* has been found in the uppermost layer. The Padlá Voda Fm is followed by schistose limestones of the Hlboč Formation.

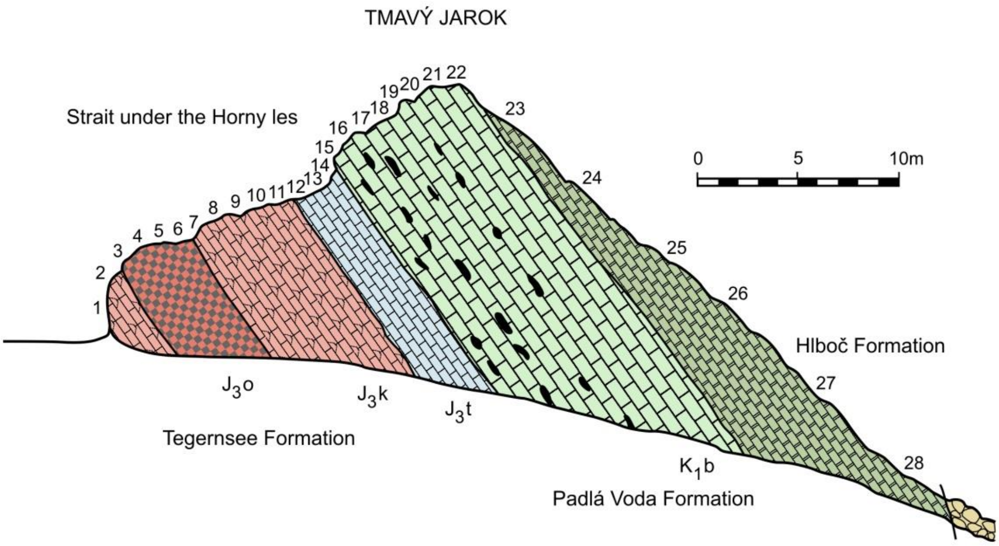


Fig. 15. Schematic cross section of the Upper Jurassic and Lower Cretaceous limestone formations in the Rohožnícka Valley, Tmavý Jarok section (Borza and Michalík, 1988).

Facultative field stop: Mt Roštún (Veľká Vápenná): the Annaberg Limestone with Jurassic clasts in red fissure-fillings (Soták, Michalík)

GEOGRAPHICAL COORDINATES: 48°27'35.5"N, 17°16'25.9"E

Tectonic bodies of the "higher" (Veterlín-, Havranica-, Jablonica- and Nedze-) nappes are build of thick sequences of Triassic carbonates. Rests of Jurassic and younger sediments is preserved only sporadically in clastic formations of the Gosau sedimentary cycle. Their character is important in correlation of these bodies with Carpathian and Alpine sedimentary sequences.

Fissures, cavities and dykes occurring in Middle Triassic carbonates of the Veterlín Nappe are filled by various types of internal paleokarst and calcrete derived sediments, like red-coloured calcisiltites and calcisparites with voids after roots, prismatic aggregates of *Microcodium?*, Fe-oxides, etc. Another Upper Cretaceous and Lower Paleogene fissure fillings are filled up by the Kržľa Breccia - sediments composed of marine carbonate clasts derived from older formations. Clasts of both Upper Jurassic neritic *Clypeina*-limestones and Upper Cretaceous intraclastic and pisolitic limestones in red-coloured intragranular micrite with globotruncanids deserve a special attention. Senonian age of these dykes is proved by planktonic foraminifer species like *Globotruncana linneiana*, *Contusotruncana* sp., *Globotruncana* cf. *falsostuarti*.

Different type of fissure fillings is formed by shallow-water sediments with coralline algae, coated grains and initial ooids, miliolid foraminifers (*Miliola* sp., *Pyrgo* sp.), serpulid worms, thick-walled bivalves and lithoclasts of volcanic rocks (paleobasalts). These limestones also contain large foraminifers of the Miscellaneidae, which allow to determine their Paleocene or Early Eocene age. The Miscellaneidae are represented by species of *Miscellanea miscella* (d´Archiac & Haime), *M. yvettae* (Leppig) and *Miscellanites iranicus* (Rahaghi). Triassic carbonate complex was fractured, karstified and infiltrated by Senonian pelagic sediments and later by Paleocene platform-type sediments.

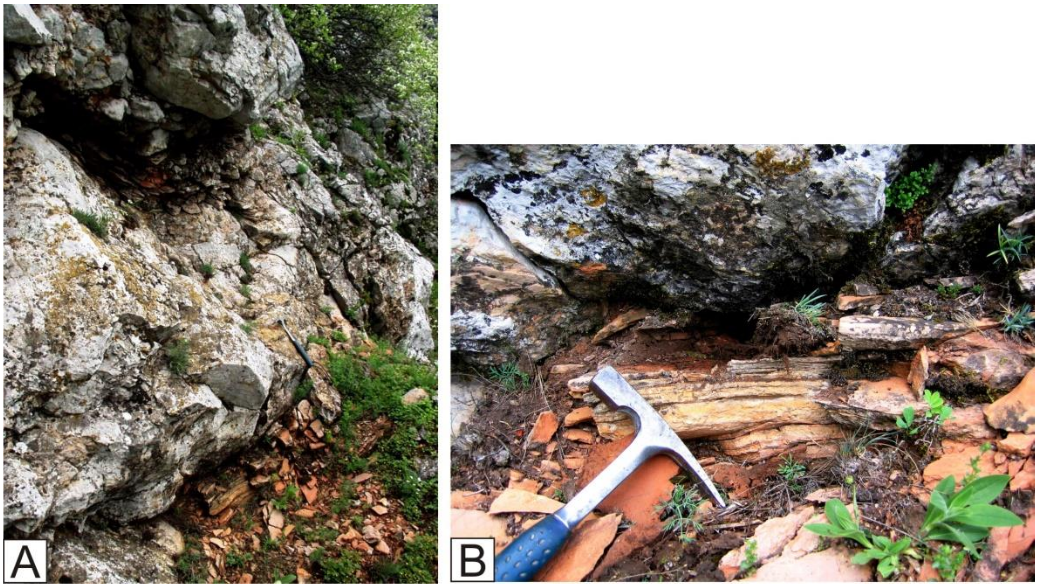


Fig. 16 a,b. Cavities in the Annaberg limestones on top part of the Mt Roštún filled with red Kržla Breccia (Photo Michalík).

Field stop 6: Smolenice, Hlboča Valley (Michalík, Grabowski, Lintnerová)

GEOGRAPHICAL COORDINATES: N 48°30'26.9"; E 17°24'42.8"

The Hlboča section is located in the Vysoká Nappe, in the NE part of the Malé Karpaty Mts, in a half-blind karstic valley (with the only small waterfall in the area called as the Padlá Voda) close to the Smolenice village, ca 50 km to the NNE from Bratislava. The closure of the valley is formed by steep rock walls called as the Mníchove Diery ("Monk´s holes"); they comprise almost complete Upper Jurassic–Lower Cretaceous sequence, dipping monoclinally to the NW (Borza & Michalík 1988).

Tithonian magnetozones, from top of M21n to M20n1n, embracing the Dobeni to the Intermedia subzones, were documented within the uppermost part of the Tegernsee Fm in the Hlboča section. Magnetostratigraphy of the overlying Padlá Voda Fm. is not well constrained due to breccias and stratigraphic gap at the J/K boundary and more intense remagnetization of this formation. Nevertheless, it is assumed that sediments deposited during M19r and large part of M19n magnetochrons were mostly eroded. Above breccia, magnetozones from topmost part of M19n to M17n were described within the Padlá Voda Fm.

Magnetic susceptibility values of Berriasian Padlá Voda Fm is higher than of the Tithonian Tegernsee Fm., which differs from typical magnetic susceptibility trends across J/K boundary in the Tethyan region (Grabowski et al. 2010). Anomalously high magnetic susceptibility of the Padlá Voda Fm. is related to the presence of superparamagnetic magnetite, which occurs commonly in remagnetized carbonates.

Primary C isotopic data were preserved in limestones within the Oxfordian–Kimmeridgian part of Tegernsee Fm. with typically decreasing C-isotope trend. Data from Tithonian part of Tegernsee Formations probably reflect "local" basin processes connected with the breccia formation and/or with possible diagenetic overprint. The C-isotope record of the Berriasian Padlá Voda Fm. is more homogenous (1.4–1.8 ‰ PDB) and assumed as primary. Detailed correlation between isotope and magnetic stratigraphy of the Tithonian–Berriasian interval between Hlboča and Brodno sections is complex also due to J/K stratigraphical gap within the Hlboča section.

Tithonian-Berriasian paleodeclinations reveal counter-clockwise rotation of the Vysoká Unit by amount of ca. 50°. As the Eocene-Miocene paleodeclinations from the cover rocks of the area are comparable, the counter-clockwise rotation must have taken place mostly after Early Miocene (after Karpatian).

The Smolenice Castle

GEOGRAPHICAL COORDINATES: N 48°30'48.5", E 17°25'56.8"

The Smolenice Castle in which the Conference Center of Slovak Academy of Science is situated, has been built on small limestone block of Annaberg and Wetterstein limestones belonging to the Veterlín Nappe thrust slice. This segment is separated from the nappe body by E-W trending Mikuláš Fault zone crossing the Malé Karpaty Mountains.

The Castle was built in the 15th century as a guard castle watching historical Czech Road connecting the Danubian basin with Baltic countries. It was destroyed during Rákóczi's War of Independence and during Napoleonic wars. In 1777, Count János Pálffy from Pezinok inherited Smolenice but did not reside in the castle due to its poor condition and lack of means for rebuilding it. The castle was only rebuilt in the 20th century, by order of Count József Pálffy. The architect Jozef Hubert designed the new castle by using

Kreuzenstein castle near Vienna as a model, and the works were controlled by the architect Paul Reiter from Bavaria. Masters from Italy, Germany, Austria and Hungary, and 60 workmen from Smolenice and nearby villages worked on its construction. The main building made of ferroconcrete has two wings and a central tower.

The castle was damaged in the spring of 1945 during World War II, and in that same year the state became the owner of it. Some reconstructions have been made after 1950, and since June 26, 1953 the castle is in property of the Slovak Academy of Sciences.

Fig. 17. View on the Smolenice castle, the Jurassica 2016 Conference place from the western side (Photo Michalík).

Field stop 7: Chtelnica - Upper Triassic to Lower Jurassic succession of the Považie Nappe with the Sinemurian “konzentratt-Lagerstätte”-type ammonite-rich deposits (Schlögl, Tomašových, Meister, Golej)

GEOGRAPHICAL COORDINATES: 48° 35` 50.40``N 17° 36`19.58``E

This locality is situated on the eastern slope of the Malé Karpaty Mts, approximately 2 km NW from the Chtelnica village (Fig. 18). The succession belongs to the Dechtice Thrust Slice (Fig. 19), which represents a part of the highermost nappes, called the Považie Nappe (Havrila, 2011). It consists of of Triassic, Jurassic and lowermost Cretaceous (Valanginian) sediments.

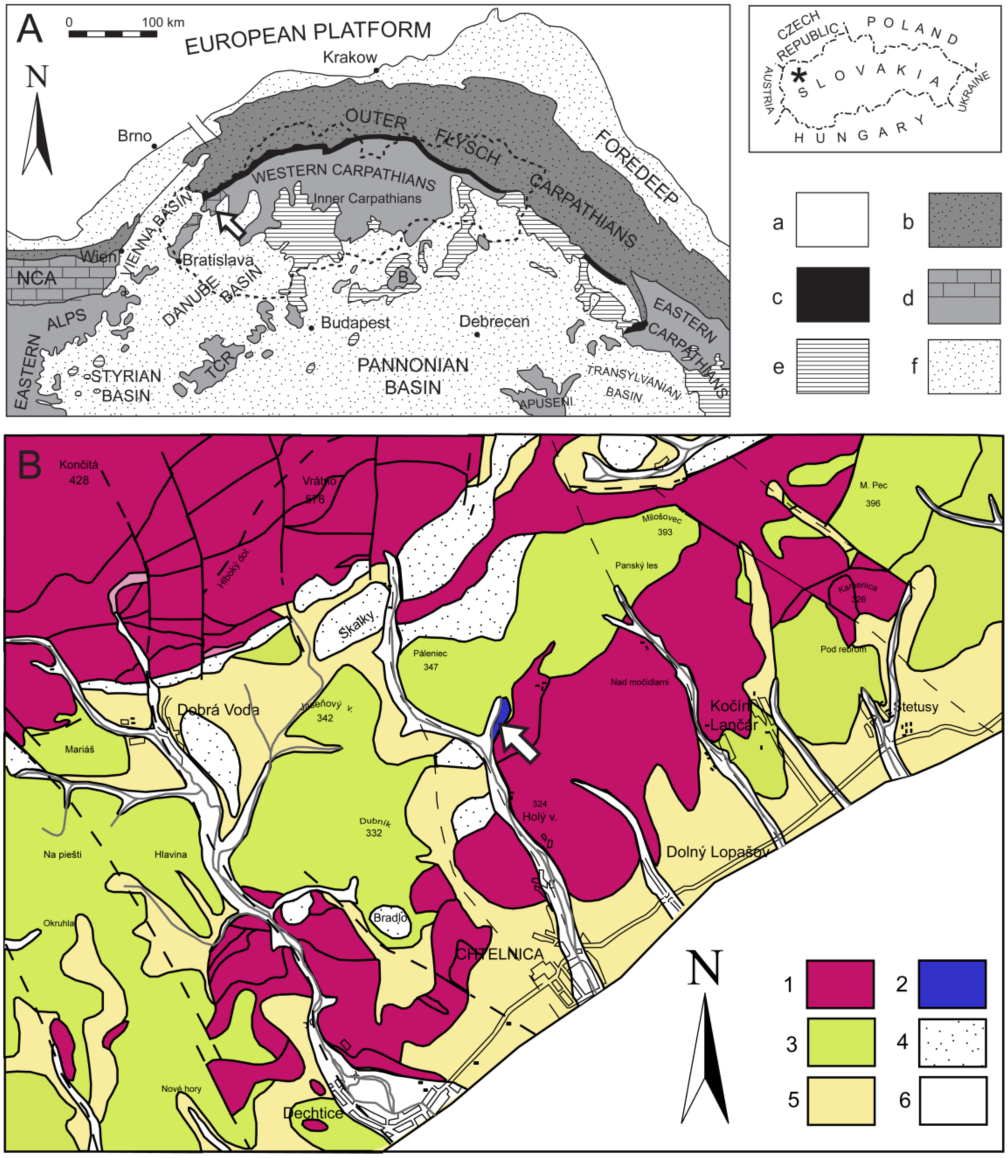


Fig. 18. Geographical and geological setting of the locality. **A.** Geological scheme of Central Europe, with the position of the locality (arrowed). a. European platform, b. Carpathian-Alpine externides, c. Pieniny Klippen Belt, d. Alpian-Carpathian-Dinaride and Pannonian internids, f. Neogene volcanics and sediments. **B.** Geological map of the surroundings of the Chtelnica locality (arrow, after Began et al., 1984). 1-2. Nedze Považie Nappe, 1. Jablonica Group, dolomites, various limestones (Triassic). 2. Hrušové Group, calcareous sandstones, cherty limestones, schists (Lower Jurassic). 3. Bradlo Unit, flysch deposits, calcareous sandstones, limestones, marls (Upper Cretaceous). 4. Siliciclastics (Miocene). 5. Pleistocene to Quaternary.

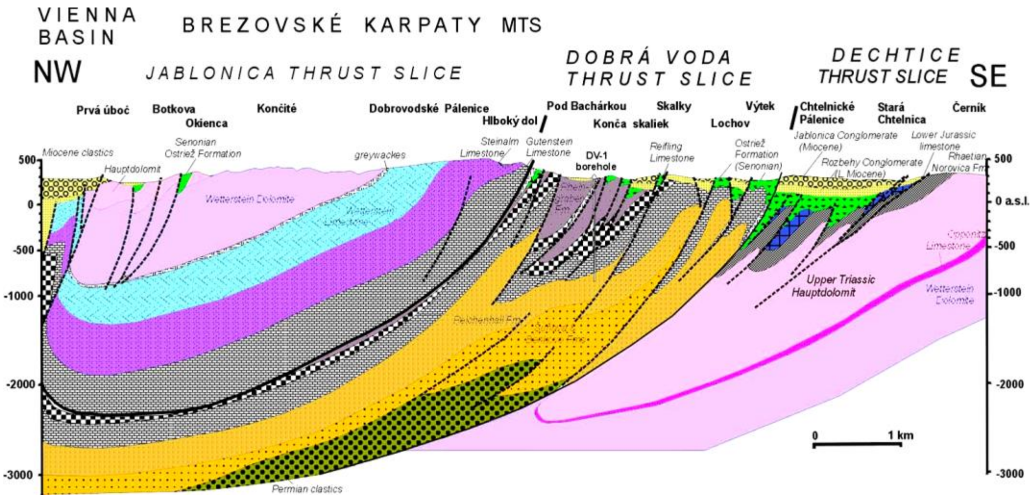


Fig. 19. Geological cross-section of the northern part of the Malé Karpaty Mts across the Dobrá Voda borehole, showing complicated thrust structure of the Brezovské Karpaty mountains group (Michalík et al., 1992).

The facies development of the Jurassic in the Považie Nappe is similar to that of the Upper Austroalpine Tirolicum (Northern Calcareous Alps), and this similarity is also expressed by the names of lithostratigraphical units. The Triassic–Jurassic sedimentary succession can be reconstructed on the basis of several discontinuous sections.

Triassic to Lower Jurassic formations are exposed in the vicinity of the locality (Fig. 18). The main portion is formed by the Hauptdolomit Formation (Carnian–Norian) and the Dachstein Formation (shallow-water limestones derived from tidal flats and restricted lagoons, Norian–Rhaetian). Lower Jurassic sediments lie transgressively on the Dachstein Limestone. The boundary is erosive (with unconformity), accompanied by a stratigraphic hiatus, more or less corresponding to the whole Hettangian. The Lower Sinemurian deposits with ammonites are exposed at two locations separated by ~30 metres (separation of the two outcrops is caused by local tectonic displacements). The first outcrop is in the road-cut on the right side of the road from Chtelnica village to local dam NW of the village. The second outcrop is located on the forested slope above this road. Sedimentary successions of both outcrops show no important differences. The uncovered Sinemurian part of succession is composed of well bedded limestones (Fig. 20), starting with grey crinoidal glauconitic calcarenitic limestones (well sorted crinoidal biosparitic grainstones, beds 1–3) and glauconitic limestones with phosphatised lithoclasts (bed 4 – ammonite shell bed). The beds overlying the ammonite shell bed are greenish sandy limestones and grey crinoidal limestones with undulated bedding planes and green sandy glauconitic intercalations (beds 5–13), and dark-grey sandy crinoidal limestones (beds 14–18). The bed 5 yielded relatively common *Arnioceras* gr. *ceratitoides*. *Arnioceras* gr. *geometricum* was collected from the upper part of the bed 8. The next bed (9) yielded *Paltechioceras* cf. *tardecrescens* (Hauer), suggesting that the bed was deposited during the late Late Sinemurian. Higher, poorly exposed part of the succession is composed of layered pink, brownish to grey bioclastic micritic limestone with Fe/Mn macrooncoids and abundant macrofossils, mainly ammonites (Late Sinemurian), and pink bioclastic limestones with Fe-Mn crusts and Mn concretions (Pliensbachian and/or Toarcian).

The beds 4 and 5 yielded all of the ammonite fauna published by Meister et al.

(2011) and Meister & Schlögl (2013). The bed 4 is the most fossiliferous, encompassing around 90 % of the whole ammonite diversity at the locality. The bed 5 contains mainly larger ammonites (*Lytoceras*, Asteroceratinae and Eoderoceratidae), generally concordantly oriented with the stratification.

Bed 4: In addition to ammonites and nautilids, the macrofauna includes numerous belemnites, bivalves (*Chlamys, Terquemia, Pholadomya, Cardinia, Plagiostoma, Gryphaea*), gastropods, brachiopods (*Zeilleria, Lobothyris, Spiriferina*), serpulids, and vertebrate remains. The bed is rich in glauconite. It is a poorly sorted bioclastic floatstone and packstone, with abundant crinoidal ossicles, benthic foraminifers (*Involutina liassica*, *Involutina turgida*, *Nodosaria* sp., *Trocholina* sp., *Semiinvoluta* sp., often filled with glauconite), fragments of bivalves, brachiopods, ammonites, ostracods, silicisponges, pellets and detritic quartz. The volumetric percentage of bioclasts varies between 35 and 55%. Bioclasts are often phosphatised. Matrix shows traces of bioturbation and is locally Fe-impregnated or phosphatised. Bioclasts and ammonite and bivalve shells are irregularly distributed, poorly sorted and more or less chaotically oriented. Brachiopods do not show encrustation and macroborings and are mostly completely filled by micrite. Terebratulids are predominantly articulated, the proportion of articulation in spiriferinids is moderate. The pectenid bivalves are locally still articulated, thick shelled oysters can be bored and encrusted. Differences in bivalves preservation were probably affected by life habits (infaunal taxa are mostly articulated). Ammonites have preserved septal chambers, with sparitic (small specimens and innermost whorls of large specimens) or micritic (large specimens) infillings. Small- and medium-sized ammonites are often complete, with body chamber and peristome. Some *Arnioceras* still show presence of jaws in the body chamber. Taphonomic preservation varies substantially, bioclasts commonly show a high degree of microbioerosion, and thin micritic/microbial coatings. The shell bed was deposited in a relatively low-energy environment, below the storm wave base (poor sorting, matrix-supported biofabric, and absence of erosive structures). Fe and phosphatic impregnations and crusts as well as presence of glauconite indicate very low net sedimentation or even non-deposition. A rather good preservation of the macrofauna (high percentage of articulated and complete specimens) and variable preservation of bioclasts in thin sections (e.g. crinoidal ossicles range from well-preserved to highly bioeroded and corroded) suggest complex and multi-phase origin of the fossil accumulation:

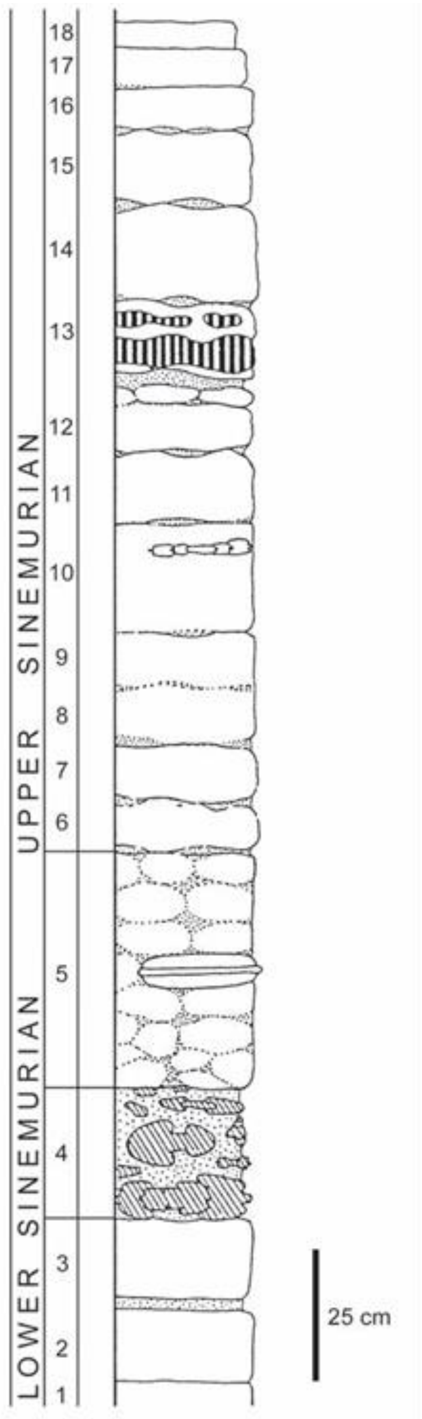
– A. with alternation of periods of increased net sedimentation rate (providing a temporary protection against the shell destruction) and periods of starvation.

– B. in spite of very low net sedimentation, in *situ* carbonate production or some sediment influx caused the creation of the thin sediment cover on the bioclasts, thus securing their protection. Fe-Mn impreg-nations and phosphatization imply early sea floor lithification.

– or C. bioturbation or episodic sediment disturbance leading to local rapid burial. The presence of phosphates is normally interpreted as evidence of high nutrition concentration (e.g. upwellings).

Ammonite fauna of the beds 4 and 5: The extraordinary richness of the collected material (Fig. 21), counting several thousands of specimens brings an exceptional opportunity to study ammonite taxa that are rare in other regions and also numerous new taxa, as well as it provides new phylogenetic and paleogeographical informations (e.g. Fig. 22). The assemblages are well comparable with those of the Apennines, particularly with Monte di Cetona ones and express strong Tethyan paleogeographical affinities, especially when considering Lytoceratoidea and Phylloceratoidea. On the other hand, these two groups do not represent more than 2.5% of the whole fauna. Therefore, although the ammonite association contains numerous Tethyan taxa, these are in strong minority. NW European and/or cosmopolitan taxa prevail, mainly Arietitinae and Agassi-ceratinae.

The condensed bed covers a period from the middle-upper Bucklandi Zone up to the Turneri - *partim* Obtusum Zones. Therefore, most of the fauna belongs to a period that is poorly known in the northern margin of the Tethyan Realm (Austroalpine and Carpathian



units), in contrast to better documented assemblages from the uppermost Hettangian - lowermost Sinemurian or from the Upper Sinemurian.

Ammonite taxa documented from the beds 4 and 5: Phylloceratidae: *Geyeroceras, Calliphylloceras, Partschiceras, Zetoceras*; **Juraphyllitidae:** *Juraphyllites;* **Pleuroacanthitidae:** *Lytotropites, Fucinites, Ectocentrites, Lytoconites;* **Lytoceratidae:** *Lytoceras;* **Schlotheimiidae:** *Angulaticeras (Sulciferites), Angulaticeras (Angulaticeras), Angulaticeras (Boucaulticeras)*; **Arietitidae**: *Coroniceras, C. (Eucoroniceras), Arnioceras, Caenisites, Protocymbites, Agassiceras, Euagassiceras, Asteroceras, Epophioceras;* **Other families: Oxynoticeratidae**, **Cymbitidae, Eoderoceratidae.**

Fig. 20. Lithostratigraphical section through the Chtelnica 1 locality, roadcut (after M. Rakús).

Fig. 21. Surface of ammonite bed with numerous *Arnioceras*, Chtelnica-2 locality (photo by M. Rakús)

Fig. 22. *Angulaticeras (Angulaticeras) spinosus* Meister, Schlögl & Rakús, 2011, intermediate form between *Angulaticeras* and *Phricodoceras* (Dommergues & Meister, 2013).

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CONFERENCE ABSTRACTS

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Lower–Middle Jurassic:

Continental Crises of the Jurassic: Major Extinction Events and Environmental Changes – aims and perspectives of the IGCP 632 Project

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The Jurassic, spanning 201–145 Ma, is a critical interval in the evolution of life on Earth when various tectonic, volcanic, geographic, climatic and biotic events occurred. The break-up of the Pangean supercontinent, which began during the Late Triassic, led to the opening of the North Atlantic, to the northwestward drift of America and the narrowing of the Pacific (e. g., Smith, 1999; Sha, 2002; Sha et al., 2002). This triggered extensive volcanism in the Central Atlantic Province.

The collisions along the Paleo-Pacific margins caused the massive Circum-Pacific (Yanshan) orogeny and volcanic activity (Rowley, 1992; Sha et al., 2006). Although the sea- level was undergoing eustatic oscillations superimposed upon an overall significant sea-level rise from the Hettangian to the Tithonian in Europe and America (Hallam, 2001), great regressions occurred, especially in middle and east Asia, and parts of North America due to regional tectonism (Sha et al., 2006), and major lake systems developed on some continents. The extremely widespread continental flood basalt provinces in both Northern and Southern Hemispheres, such as the CAMP and Karoo–Ferrar (Blackburn et al., 2013; Pálfy & Smith, 2000; Hesslebo et al., 2002), were emplaced. Their atmospheric emissions may have had severe consequences for climates and biotas (Sha et al., 2006). Atmospheric CO_2 concentration was dramatically increased, causing the global warming. Based on plant stomatal data from Sweden, Greenland, and the UK (McElwain et al., 1999; Steinthorsdottir et al., 2011; Steinthorsdottir & Vajda, 2015), for instance, the Triassic–Jurassic CO_2 concentration increase fourfold, from 1200 ppm to 2400 ppm, plausibly leading to greenhouse warming of 3-4°C.

Several extinction events occurred during the Jurassic, starting with the Triassic-Jurassic mass extinction event (c. 200 Mya), followed by the Toarcian anoxic event and the Tithonian extinction event (Hallam & Wignall, 1997). These events were closely related with the fragmentation of Pangea, huge flood basalt, increase in CO_2 and changes in the configuration of the continents.

These extinction events, particularly the marine Triassic-Jurassic and Toarcian extinction events have been widely discussed by numerous authors, although many questions remain to be answered. The terrestrial Jurassic crises were significant and affected huge continental areas and the timing and causes have not yet been clarified. Therefore the new IGCP project 632 *"Continental Crises of the Jurassic: Major extinction events and environmental changes within lacustrine ecosystems*" was launched in 2014 following on the successful IGCP 506 "*Marine and non-marine Jurassic: global correlation and major events*" (2005-2010).

The project is multidisciplinary including paleontology, sedimentology, stratigraphy, geochemistry and geochronology. The main aims are to undertake detailed studies on the patterns and causes of the extinction events as many questions remain to be answered. A crucial task is to identify traces of extinction events in lake ecosystems, particularly correlating between Southern and Northern hemispheres. Another important goal is to clarify the differences between the extinction patterns expressed in the terrestrial and marine realms and answer the questions whether the end-Triassic extinction first occurred on land, in the sea, or simultaneously.

IGCP 632 has already achieved many advances concerning Jurassic continental crises; including correlation through astrochronology, differences in extinction patterns across the end-Triassic event between high and lower latitude continental and marine basins (e.g., Sha et al., 2015) (Fig. 1). Further, studies on ecosystem structure and sedimentary dynamics across Jurassic events have provided new results (e.g., LeTourneau et al., 2015). Other achievements concerning Jurassic ecosystems and events have been collected in the special issue "*Mesozoic ecosystems - Climate and Biota"* to be published in Palaeo3 (Palaeogeography, Palaeoclimatology, Palaeoecology) and the special issue of Palaeoworld, "The Jurassic–Cretaceous Transition", which will be published in 2016.

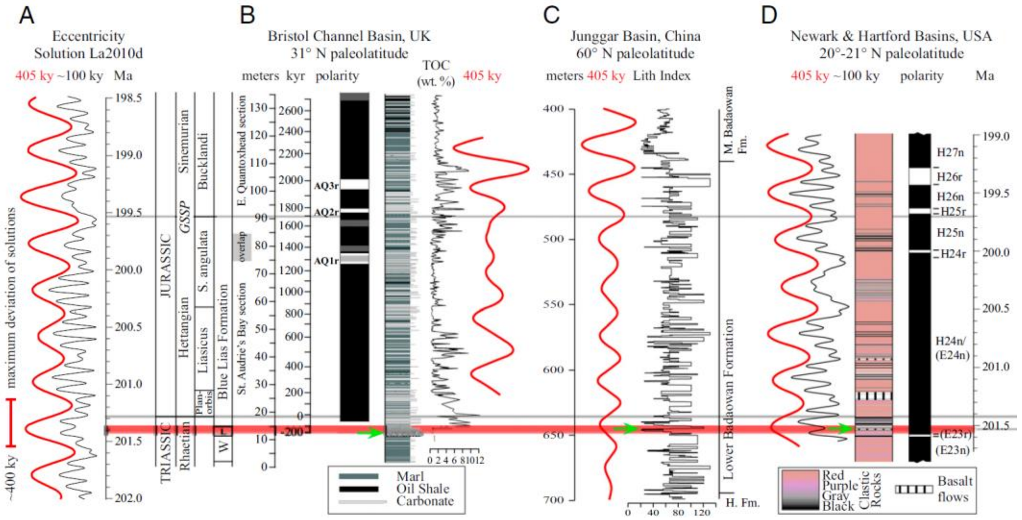

Fig. 1. LITH Index data (C) and correlative sections: (A) Laskar 2010d solution (Laskar et. Al., 2011); (B) Bristol Channel (United Kingdom); (C) Junggar Basin (China); (D) the Newark–Hartford astrochronology and geomagnetic polarity time scale (APTS). The thick red bar indicates the interval of extinctions and uncertainty of correlations between the sections, and the green arrows indicate the last appearance of *Lunatisporites rhaeticus*. A and B are adapted from Ruhl M, et al. (2010) and Hüsing et al. (2014) (potential error added from Laskar et al. (2011)); D is modified from Whiteside et al. (2007) and Kent et al. (2008). Note the difference in phase between the phasing eccentricity cycles in the La2010d solution (selected by Hüsing et al. (2014) for comparison with B) and the geological data that we attribute to chaotic drift; therefore, we have retained the independent times scales for both A and D (after Sha et al., 2015, fig. 2).

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Palaeogeographic changes during the Triassic-Jurassic transition in China

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In general, during the Triassic, the areas north of the Qinling–Kunlun mountain ranges, in northern China, became continental, but the another side of these ranges, in southern China, were still covered by seas. With the fall of global sea level in the Late Triassic, however, the sea started to regress and the retreat was extensive from the late Late Triassic in southern China (Sha, 2013).

Waagenoperna was a genus of epibyssate, marine to brackish-water/lithoral isognomonid bivalves. It has a wide distribution in the areas southwest to the line of Shanghai–Altay Maountain Range, including east, south-central, southwest China and northwest China (Fig. 1), spaning the Triassic–Jurassic boundary and intercalated with the coal-bearing non-marine deposits. However, this bivalve has been generalized Late Permian–Late Triassic age (e.g., Cox, 1969; Hayami, 1975; Gu et al., 1980), causing the palaeogeography of Triassic–Jurassic transition in China to be misunderstood.

As a matter of fact, such bivalve does occur in the Early Jurassic (Kimmeridgian), which has been cofirmed by integrated study including palaeontology and astrochronology (e.g., Deng et al., 2010; Sha et al., 2011, 2012, 2015). On the basis of the recent study on *Waagenoperna* and their geologic and geographic distribution in China, three assemblages were recognized, i.e., Carnian–early Norian *Waagenoperna aviculaeformis–Waagenoperna cf. triangularis* assemblage, Norian–Rhaetian *Waagenoperna lilingensis–Waagenoperna mytiloides* assemblage and Early Jurassic *Waagenoperna lilingensis–Waagenoperna mytiloides–Waagenoperna cf. lilingensis* assemblage.

During Carnian–early Norian, the representatives of *Waagenoperna*, *W. aviculaeformis–W. cf. train-gularis* assemblage, was distributed in east, south-central and southwest China. In Norian–Rhaetian interval, it, represented by *W. lilingensis–W. mytiloides* assemblage, expanded northwestwards and even possibly locally northeastwards, but it was still limited in southern part of China. In Early Jurassic (Kimmeridgian) interval, the assemblage of such bivalve, *W. lilingensis–W. mytiloides–W. cf. lilingensis* assemblage, suddenly colonized the Junggar Basin, northwest corner of China (Fig. 1).

Such temporal and spatial distribution patterns of *Waagenoperna* have clearly indicated that, during Late Triassic–Early Jurassic, there existed big marine embayments along the *Waagenoperna*–bearing deposits in south- and southeastern China (Fig. 1). They opened into or connected with the eastern palaeo-Pacific and possibly connected with each other from time to time, and transgression events frequently happened along the embayments from eastern palaeo-Pacific to northwest China, widely flooded the basins surrounding the embayments. In the Kimmeridgian, the sea invated northwestwards as far as the northwest corner of China, Junggar Basin. It is the long-term existence of Late Triassic–Early Jurassic marine embayments in south- and southeastern China, and the Early Jurassic one in Junggar Basin, and the frequent marine transgressions, and sea flooding along these embayments, ensured a humid climate across all of the areas southwest of and even probably partly northeast to Shanghai–Altay Mountain Range. These transgressions and associated humid climatic conditions helped to create extensive and long-lasting coastal swamps and marsh lands in both paralic and limnic environments. Such environments are very favourable for the colonization of both terrestrial and aquatic plants and animals. New taxa originated in, or migrated into these settings, keeping the creatures thriving. Luxuriant plant and thriving animal growth led to the accumulation of abundant organic matter in these deposits. As a result, a number of Late Triassic–Early Jurassic coal basins and oil fields formed in eastern, southcentral, southwestern and northwestern China, and in the basins along Shanghai–Altay.

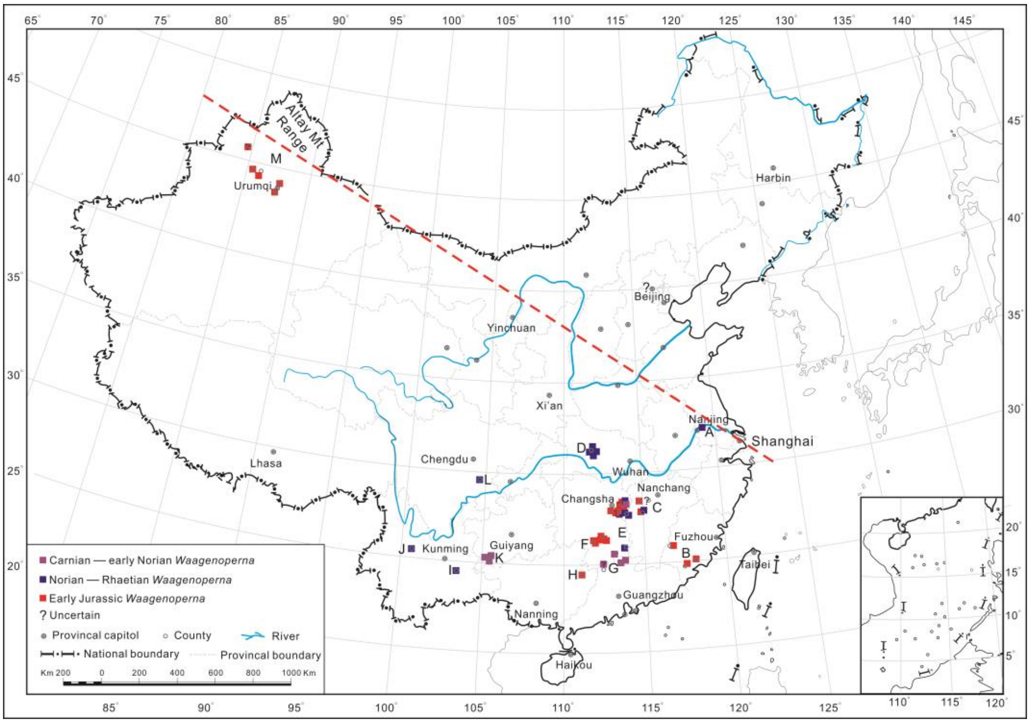

Fig. 1. Sketch showing the historical distribution of Marine–brackish water *Waagenoperna* in China. Almost all the fossil localities yield coal.

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Triassic-Jurassic boundary sections in the Polish Basin – new mineralogical and geochemical data

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Development of the Central Atlantic Magmatic Province (CAMP) and related processes are commonly inferred as a trigger of biogeochemical cycle destabilization, climatic shifts and other global environmental changes at the Triassic-Jurassic boundary. The first part of the palaeoclimatic and palaeoenvironmental research in the Polish Basin was summarised quite recently (Brański, 2014; Pieńkowski et al., 2014) but since that time, the bulk-rock mineralogy, clay mineralogy and geochemistry of the 148 new continental mudrock samples (collected from borehole cores) provided additional information on palaeoclimatic and palaeoenvironmental variations. During the Rhaetian-earliest Hettangian times, non-marine, alluvial-lacustrine sedimentation prevailed in the area of Poland. The most complete Triassic–Jurassic boundary sequences are preserved in the Mid-Polish Trough, where the chemostratigraphic pattern (supported by the palynological and sedimentological data) allowed to correct the position of the of the Triassic-Jurassic boundary.

Changes in detrital clay mineral composition and in the major element con-tents were mostly controlled by palaeoenvironmental factors (especially climate and weathering regime), due to moderate burial and to the fairly closed hydrologic system. After semi-dry climate conditions in the Norian times, smectite predominance in most part of early-middle Rhaetian Wielichowo Beds points to some increase in precipitation and its distinct seasonality. Subsequently, smectite preponderance was replaced by kaolinite and illite domination in the Late Rhaetian-Early Hettangian Zagaje Formation. Kaolinite is a typical product of weathering in a warm (or hot) climate with high precipitation. Moreover, disappearance of calcite, dolomite, hematite, goethite and the presence of siderite (or locally berthierine) points to wet and reducing conditions in the Late Rhaetian-Hettangian times. The chemical and mineralogical composition of the mudrocks has been locally affected by hydraulic sorting and recycling to some extent. However, the imprint of provenance is also observed. For example, the time span of the Rhaetian smectite enrichment is not uniform and suggests the local weathering of mafic rocks that overlaps with the climate record.

It should be noticed that some beds in the Rhaetian (and more rarely in the lower Hettangian) are particularly rich in kaolinite indicating extreme chemical weathering in the aftermath of super-greenhouse events. The weathering indices values are similar to those found in the modern residual sediments from strongly weathered tropical areas. Kaolinite enrichments correspond (at least partly) to negative carbon isotope excursion controlled by isotopically light carbon emission. Nevertheless, kaolinite maxima seem to slightly precede the episodes of sudden methane release. Importantly, abrupt and episodic shifts in the kaolinite-illite ratio point to profound climate destabilisation and a sequence of frequent, catastrophic climatic reversals at the end-Triassic and at Triassic-Jurassic boundary. Most likely, these rapid changes promoted multi-phase extinction. The study was supported by grant financed from resources of the Polish National Science Centre, granted on the basis of decision no. DEC-2012/06/M/ST10/00478.

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Lower Jurassic (Pliensbachian) *Lithiotis*-type bivalve-bearing limestones of the Albanian Alps – sedimentological and palaeoecological preliminary observations

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The Lithiotis-type bivalves (e.g., Lithiotis, Cochlearites, Litioperna, Mytiloperna, Gervileioperna) are Pliensbachian–earliest Toarcian world-wide distributed fossils, which occupied both sides of Pangea in shallow-water shelfs of the south-western Tethys and easternmost part of the Panthalassa Ocean (western margin of Pangea). In Europe they are known from Alpine Spain, Italy, Slovenia, Croatia, Albania, Greece and constitute of the Early Jurassic Alpine-Adriatic-Dinaridic-Hellenidic carbonate platforms with different kind of shallow sea environments, including peritidal to subtidal sedimentation regimes which are typical for Lithiotis-type bivalves. In north-western part of the Albanian Alps (so-called external Albanides, N of Shkodra; see also – Schlagintweit et al., 2006), in three outcrops were studied preliminary Pliensbachian in age Lithiotis-type bivalves-rich limestones: vicinity of Ducaj (middle part of local stream), along mountainous road near Bogë and close to Grabom village along zig-zag-shape road near state boundary with Montenegro (the best, continuous long section approximately up to 200 metres thick sequence). In the last section there are at least five bivalves-rich horizons which are intercalated by grey-dark bluish marly limestones and bioclastic limestones. Some horizons are more softy with marly matrix where bivalve shells are isolated and relatively well preserved, opposite to usual occurrence of such bivalve remains in hard limestones in another Alpine outcrops (Dolomite Mts in Italy, Greece – Peloponnesus, Evia Island etc). Taphonomic and autecological analysis of bivalves-rich horizons based on semi-quantitative observation of orientation of shells and density of their occurrence indicate dominance of parauthochthonous associations (the ratio of horizontal to vertical shells) with a few places with record of shells in life position (dominance of vertical orientation of shells and so-called bouquets).

Some beds full of bivalves have oblique, lens-shape character with sharp boundaries both with under- and overlying beds and maybe correspond to “biostrome” nature in origin. According to first impression of observation of the Albanian Lithiotis-type bivalve-bearing sequences, they have big difference with comparison of Greece occurrences, although these two regions have been very close palaeogeographically. In Greece such accumulations of bivalves are observed in Gavrovo-Tripolitza (=Kruja Zone in Albania), Pelagonian and Parnassos carbonate platforms and usually are intercalated both by oncolitic-rich beds and megalodont-bearing limestones with several storm-origin features of peritidal environments. Sometimes in Albanian case we have also oncolitic limestones but usually they are below and/or above of Lithiotis-bearing part of sections, and are practically without megalodontids. Such preliminary look and comparison between Pliensbachian bivalve-rich sequences of Alpine-Dinaridic-Hellenic realms need more detail investigations both macro- and micropalaeontologicaly.

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Fungal plant decomposition accelerated Early Jurassic climate change

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Toarcian Oceanic Anoxic Event (T-OAE, beginning at 183.22 ±0.26 mya and lasting for some 300 kya, Sell et al., 2014; Boulila et al., 2014), was one of the most violent global warming events (Fig. 1) that occurred in the geologic past, associated with profound disturbances in geochemical, sedimentary, and paleontological records (Suan et al., 2008, 2015). These disturbances are associated with -4 to -8‰ stepped excursions in the carbon-isotope (CIEs) composition of carbonates and organic matter (Kemp et al., 2005, Hesselbo et al. 2007, Hesselbo and Pienkowski 2011), both of marine and continental origin. It is currently believed that this event was triggered by large-scale eruptions, preceded by the sill emplacement and magma outgassing in the Karoo-Ferrar basaltic province (Sell et al, 2014), causing a rapid increase in atmospheric pCO_2 levels and average air temperatures (ca. +5 ^{o}C) (Pálfy and Smith, 2000). This rapid rise in greenhouse gas concentration is further believed to have facilitated the pulsed, astronomically paced releases of methane hydrate along continental margins and induced widespread marine anoxia (Hesselbo and Pienkowski, 2011; Hesselbo et al., 2000) and marine accumulations in oganic matter concentrated mostly in widespread, black bituminous shales (Jenkyns, 1988; Hesselbo et al., 2000, Boulilla et al, 2014), deposited during supergreenhouse event. The Polish marginal-marine strata coeval to the T-OAE carbon rich, marine black shales are represented by poorly consolidated green/grey mudstones, claystones and siltstones with subordinate sandstone intercalations (Ciechocinek Formation), deposited in a large embayment/lagoon fringed by a coastal-deltaic environment (Pieńkowski, 2004) and were studied in detail in four fully-cored borehole profiles. They can confidently be correlated to marine strata by carbon isotope stratigraphy using fossil wood, recording the series of stratigraphically abrupt steps 1 to 5 characteristic of the T-OAE known from marine settings (Hesselbo and Pieńkowski, 2011). However, contrary to the enhanced carbon storage in open marine environment caused by anoxia, the temperature (Dera and Donnadieu, 2012) related decomposition of terrestrial organic matter during the event led to the radical diminishing of terrestrial carbon pool, which is registered in the Polish Basin by very low Total Organic Carbon coupled with oxygenation indices. The Oxygen Index (OI) values reflect decomposition (mineralization) of kerogen and are by an order of magnitude higher within the T-OAE than below and above this interval. Also the kerogen within the T-OAE interval is mostly of type IV highly oxidized/degraded maceral component (inertinite), pointing to high degree of microbial oxygenation/decomposition of terrestrial kerogen. These changes precisely correlate with CIEs. As marine O_2 respiration even in shallow marine basin seems to be of lesser significance (Canfield et al., 1993), the kerogen studied herein must have been oxygenated on land prior to burial and before delivery to the receiving basin, to some extent oxygenation and decomposition could have occurred in the turbulent water column of rivers (Ward et al, 2013). Increasing temperature favoured decomposition (likely fungal) of the most common plant litter – wood, and relative increase in cuticular carbon sequestration at the cost of wood, as it is observed in recent experiments (Feng et al., 2010). This biofeedback released most of the carbon sequestered in the plant litter and soil carbon pool back to the atmosphere, amplyifying greenhouse effect on Earth, which is registered in increasing amplitudes of carbon isotope excursions and abrupt changes in composition of standing vegetation, reflecting climate fluctuations. Anoxic conditions in the basin occurring before the onset of T-OAE could offer an explanation of higher TOC content (McArthur et al, 2008). However, colour and element geochemistry contradict anoxic conditions in the whole Lower Toarcian in Poland - since our record does not indicate any significant enrichment in Mo, we cannot propose any elemental indication for widespread oxygen depletion in the Polish Basin coeval to the Pliensbachian-Toarcian boundary or the well-investigated occurrences of Early Toarcian anoxia, e.g. in the Cleveland or Paris Basins. Our results demonstrate that at a certain temperature threshold the terrestrial carbon sink becomes much less effective, which can amplify climate warming. The Toarcian greenhouse world may serve as an deep geological past analogue for anthropogenically induced climatic changes and can help predicting future climate changes (Davidson and Janssens, 2006).

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Review of the Middle Jurassic crabs (Brachyura) – their stratigraphic and palaeoenvironmental distribution

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The oldest brachyuran crab species is Late Pliensbachian *Eoprosopon klugi* Förster and is known by holotype only. Generally, the Middle Jurassic brachyurans are also extremely rare in the fossil record and are mainly represented by single representatives. Opposite, the Late Jurassic decapods, including crabs which flourished rapidly probably due to the origin of Oxfordian sponge megafacies and Tithonian–Berriasian coral-bearing Ernstbrunn/Štramberk-type carbonates in Europe, are very abundant and documented even by several thousand of specimens. By this reason their systematic position, phylogenetic relationships and palaeoecology is relatively well known and our knowledge on these crustaceans increased rapidly, mainly during the last fifteen years. General shape of carapace and well-developed grooves on them are the most important features of these crustaceans and are useful in classification of forms to genera and species. Our knowledge about distribution and palaeoenvironmental preferences of all known records of the Middle Jurassic crab species, based on single specimens, is very limited. The Middle Jurassic crabs are representatives of two superfamilies and five families: Homolodromioidea (Homolodromiidae: *Homolus*, Goniodromitidae: *Pithonoton*, Prosopidae: *Prosopon*, Tanidromitidae: *Gabriella*, *Tanidromites*) and Glaessneropsoidea (Longodromitidae: *Abyssophthalmus*, *Coelopus*, *Planoprosopon*). Their stratigraphic distribution is indicated by very precisely analysed original data of their occurrences within Bajocian, Bathonian and Callovian strata (Aalenian crabs are unknown) of mentioned genus according to ammonite biozonations (mainly to ammonite subzones, to zones at least) for better understanding of their first step of development and maybe in some future reconstruction of phylogenetic relationships of their roots will be possible. From palaeoenvironmental point of view the Middle Jurassic crabs are mainly connected with shallow marine, high energetic carbonate deposits, dominated by oolitic facies (including ferrugineus-oolitic one), coralliferous reefs, and exceptionally grey/black shales with carbonate concretions which hosted these crabs.

Trace fossil assemblage of Lower Jurassic bioturbated deep water marly limestones of fleckenkalk-fleckenmergel facies in the Central Western Carpathians.

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Specified trace fossil assemblage of Lower Jurassic successions of marly limestones of fleckenkalk-fleckenmergel facies is typical of the Central Western Carpathians. Trace fossils are not such precise stratigraphic or facies marker, but in this case it can be used for suitable ichnological description of so-called “spotted” marlstones of early Jurassic wide-spread fleckenmergel/fleckenkalk facies. The assemblage is consisted of: *Chondrites intricatus*, *Chondrites targionii*, *Palaeophycus*, *Planolites*, *Rhizocorallium*, *Teichichnus*, *Trichichnus* and *Zoophycos.* These trace fossils have wide stratigraphic range and are easily comparable for instance with trace fossils from Lower Cretaceous bioturbated limestones of the Mráznica Formation.

In addition, the lower Jurassic trace fossil assemblages complement the other two the most specific ichnospecies: *Lamellaeichnus* and *Teichichnus* isp. (Šimo and Tomašových 2013). *Lamellaeichnus* can be misinterpreted as *Taenidium* if is sectioned horizontally. Moreover, *Lamellaeichnus* is not confirmed from other stratigraphic ranges of the Central Western Carpathians however a few published trace fossils (e.c. *Virgoglyphus modari*) outside the Carpathian region from Middle Jurassic sediments can be assigned to this ichnogenus (Patel et al. 2014). Problematical form of *Teichichnus* isp. can be also regarded to the typical trace fossils of lower Jurassic spotted limestones of the Western Carpathians.

Palaeoecological conditions of bioturbated substrate can be explained on the trace fossil characters. Frequent trace fossil occurrences of vagile shallow-tier deposit feeders (*Lamellaeichnus*, *Palaeophycus*) implies oxygenated but limited ecological conditions of bottom waters and bottom sediments (hypoxia). Deeper parts of bottom substrate were occupied by sessile producers (*Chondrites*). The deepest levels of bottom substrate with trace fossils reached to redox potential discontinuity on oxic-anoxic boundary (*Trichichnus*). Benthic fauna is presented by sparse occurrence of soft shell macrofauna. Abundant occurrence of large-sized semi-epifaunal foraminifera *Bathysiphon* indicates hypoxia conditions also.

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Toarcian-Aalenian and Bajocian syn-rift events in the Western Carpathians (Pieniny Klippen Belt and Tatra Mountains; Ukraine, Slovakia and Poland)

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The Pieniny Klippen Belt and the Tatra Mountains belong to the Inner Carpathians and their Mesozoic evolution represents a fragment of history of the northernmost part of the Western Tethys, where several tectonic events took place. They resulted in different kind of sedimentary records in the Western Carpathians (Ukrainian and eastern Slovakian parts of the Pieniny Klippen Belt and the Tatra Mountains in Poland, mainly Lower Subtatric – *Krížna* nappe). Such tectonic events are well documented by sedimentological features: synsedimentary breccias, neptunian dykes, hard grounds, ommission surfaces, condensed carbonates etc. The oldest Jurassic rocks of the Pieniny Klippen Belt consists of different type of clastic sediments of wide-spread Alpine *Gresten*-like facies (Early Sinemurian). Overlying beds are represented by spotty limestones and marls of *Fleckenkalk*/ *Fleckenmergel*-type facies of oxygen-depleted environments (Sinemurian-Pliensbachian) (30 m in thickness). Even younger are condensed multicoloured limestones (maximum to 25 cm) which are full of nectonic faunas (e.g., ammonites, belemnites) (uppermost Pliensbachian-Toarcian-Aalenian) with numerous omission surfaces, ferruginous-manganeous crusts, microbial structures – stromatolites and coated grains/nodules (oncoids), and iron-rich ooids in some places. As result of erosion and/or non-deposition they recorded one of such tectono-sedimentary event in this basin which has been connected with Toarcian-Aalenian episode of initial extensional, rift-related movements which disintegrated of the original basin. Just above appear the massive, thick (up to 50 m) Bajocian crinoidal limestones. Episode of condensation could be correlated with uplift effect of tillted blocks originated during first step of rifting process. In the same time in the Tatra Mountains (*Krížna unit)* sedimentation of condensed-type cherry-red limestones full of large ferruginous oncoids and ferruginous-manganese crusts of the Toarcian age which is well dated by ammonites. These limestones are underlain by *Fleckenmergel*/*Fleckenkalk*-type spotty marls and limestones with spiculites whereas the Aalenian deposits are missing (part of the *Krížna unit),* most probable due to rifting and non-deposition effect. In more deeper part of the Tatra basin some calcareous turbidite-type resedimentation occured formed by downslope transport from shallower zones. In the Tatra Mountains, similarly as in the Pieniny Klippen Belt, the big contrast between pelagic sedimentation of *Fleckenkalk*/*Fleckenmergel*-type facies and condensed episode deposits took place and was an effect of isochronous rift-related event, which is known as Devin rifting phase. In both cases submarine swells originated in independent basins, but in the same northernmost part of the western Tethys realm and its passive margin under rift-related control.

However, even younger was Bajocian tectonic event connected with start of sedimentation of crinoidal limestones (mainly in the Pieniny Klippen Belt). Their chronostratigraphical position is well documented in several lithofacies (so-called successions in this basin: Czorsztyn, Niedzica, Czertezik and Branisko) by ammonite faunas which is coming from the lowermost part of these limestones and indicate the presence of an upper part of the Propinquans Zone (Hebridica Subzone), and a lower part of the Humphresianum Zone (mostly the Romani Subzone) of the Lower Bajocian. Underlying deposits of black shales with spherosiderites yielded so far ammonites well documenting the Murchisonae Zone of the Middle Aalenian and the Discites Zone of the lowermost Bajocian. The onset of crinoidal limestone sedimentation appeared thus isochronous in these successions, and it was preceded by a stratigraphical hiatus spanning a marked time-interval of Early Bajocian. The hiatus recognized at the base of the crinoidal limestone complexes covers the time interval of the Laeviuscula Chron and a bulk of the Propinquans Chron of the Early Bajocian and corresponds to the origin and uplift of the Czorsztyn Ridge. The rapid change of sedimentation from dark shales of oxygen-depleted environment to overlying light crinoidal grainstones very well corresponded to syn-rift episode in the Pieniny Klippen Belt basin.

Upper Jurassic:

Marine and terrestrial reptiles from the Upper Jurassic limestones of Owadów-Brzezinki.

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The Owadów-Brzezinki Quarry is one of the most important paleontological sites in Poland. It has yielded exceptionally well-preserved Upper Jurassic (Middle Volgian = Upper Tithonian) fossils of marine and terrestrial biota, including horseshoe crabs and decapod crustaceans, rare ammonites, insects and pterosaurs. The aim of this study is to describes the discovery of new, well preserved marine and terrestrial reptile bones (ichthyosaurs, turtles and crocodylomorphs), which add significantly to our knowledge of these three group. The new genus of Late Jurassic ichthyosaur presented here has some features in common with representatives from the Svalbard archipelago, where turtles and crocodylomorphs are indicative of close relationship with taxa from the Bavarian locality of Solnhofen.

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On the way to a more precise Middle-Late Jurassic radiolarian biostratigraphy a tool for a better palaeogeographic and geodynamic reconstruction of the western Neotethyan realm: key sections in the Northern Calcareous Alps

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Radiolarites in the Northern Calcareous Alps are significant sedimentary rocks and occur widespread in the Jurassic. In the Middle-Late Jurassic the trench-like basin fills (carbonate-clastic radiolaritic flysch) could reach a thickness of about 2000 metres, but radiolarites cover in Callovian-Oxfordian time practically the whole area of the Austroalpine in varying thickness. These radiolarites vary sedimentologically from black, greenish to red ribbon-like radiolarites and greyisch fine-laminated turbiditic variations. They often overly condensed red nodular limestones of the Klaus Formation of slightly different age, in cases dated by ammonoids. Here especially the radiolarite sections with underlying red nodular limestones, dated with ammonoids, play an important role to calibrate the existing radiolarian zonations (mainly based on Baumgartner et al. 1995a, b, Beccaro 2004, 2006). It is very important to note, that the onset of radiolarite deposition is not contemporaneous due to geodynamic reasons and newly formed trench-like basins in front of a propagating nappe front: In the southernmost Northern Calcareous Alps, where the first trench-like basins were formed due to the propagating nappe front, radiolarite deposition started in the Bajocian/Bathonian. The next generation of basins was formed in the Callovian and carry the most important part of the Hallstatt Mélange. More to the north the trench-like basins were formed around the Callovian/Oxfordian boundary (Tauglboden Mélange). The Rofan mélange – the most northernmost known in the Northern Calcareous Alps – starts to form in Late Oxfordian (Gawlick et al. 2009 for a review). On top of the nappe stack a Late Oxfordian/Kimmeridgian to Berriasian carbonate platform pattern evolved (Plassen Carbonate Platform) and limited very often radiolarite deposition in the adjacent basins (Gawlick et al. 2012 for review). Therefore radiolarite deposition in the remaining trench-like basins changed to calcareous radiolarites or cherty limestones partly rich in *Saccocoma*, especially in the Hallstatt Mélange areas. Calcareous turbidites contain very often shallow-water organism (e.g., foraminifera, calcareous algae, incertae sedis). These shallow-water organisms also can be used to calibrate the age range of several radiolarian species, but also the shallow-water organisms of these carbonate platforms can be calibrated with radiolarians, on the way to a better correlation of both shallow- and deep-water sedimentary successions (e.g. Missoni et al. 2001, Auer et al. 2009).

More to the north, radiolarite deposition prevailed until in earliest Tithonian: In that area of the Tauglboden Mélange the transition from radiolarite to more calcareous deposition is late Early Tithonian. North of the Tauglboden Basin again a carbonate platform evolved in the Kimmeridgian and influenced the northernmost Northern Calcareous Alps. In cases carbonate turbidites can reach the distal shelf areas facing the Alpine Atlantic oceanic realm.

Still crucial is in Bathonian to Oxfordian time the calibration of the existing radiolarians zones due to the lack of ammonite bearing sections all over the world (compare Baumgartner at al. 1995b). Therefore the radiolarian biozones have a relatively wide age range and the stratigraphic ranges of different radiolarian species very often lack exact calibration, e.g. with ammonoids.

We present key sections in the central Northern Calcareous Alps, which allow to calibrate the existing radiolarian zonations: The Brielgraben section east of Gosau (middle Callovian), the Klauskogelbach section west of Hallstatt (lower Callovian) and the Fludergraben section north of Altaussee (Oxfordian), all in the Salzkammergut area, and all dated with ammonoids at the top of the underlying red nodular limestones (Klaus Formation). The new radiolarian zonation of the Northern Calcareous Alps will be compared with the radiolarian zonations of e.g. Baumgartner et al. (1995a) or Beccaro (2004, 2006).

A better calibrated radiolarian biostratigraphy is an essential tool for a better reconstruction of the Middle to early Late Jurassic orogenesis related to the closure of the western part of the Neo-Tethys, recently named Neotethyan Belt (Missoni & Gawlick 2011): This Neotethyan Belt belong to the Tethysides, but not to the Cimmerides as commonly wrongly used: The Cimmerides are defined as related to the closure of the Palaeo-Tethys (e.g., Sengör 1985).

A correlation of the different trench-like basins fills, e.g. in the Eastern Alps, the Western Carpathians, units in the Pannonian realm, in the Dinarides, Albanides, and Hellenides is essential for the understanding of this orogenesis, still discussed controversially. The time equivalent trench-like basin formation as well as comparable basin fills advocate for a one Neo-Tethys ocean model. Several back-arc oceanic basins (related to the closure of the Palaeo-Tethys, e.g. Meliata, Maliac, Pindos Ocean) with an independent opening and closing history cannot be confirmed.

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Two types of benthic Middle Jurassic foraminifera from the Vršatec Limestone (Pieniny Klippen Belt, Western Carpathians, Slovakia)

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Paleontological, stratigraphical and sedimentological attributes of three carbonate successions of the Vršatec Limestone (Middle Jurassic, Pieniny Klippen Belt, Western Carpathians) were studied in the context of macro- and microfossil content and comprehensive microfacies observations in order to infer the main parameters of the depositional setting.

Vršatec Limestone represents a unique, several decameters-thick coral reefs that developed on the Czorsztyn pelagic carbonate platform. This reef structure represents the eastern part of the Pieniny Klippen Belt (PKB, Western Carpathians) that was located in the Penninic Ocean. The Vršatec Limestone is formed by coral biohermal framestones, bindstones, and rudstones. In addition to reef constructors, benthic communities are dominated by species-rich bivalve assemblages. Limestones with coral reefs are horizontally replaced by (i) breccias that accumulated at footwall margins of faulted blocks (with clasts formed by biohermal limestones) and by (ii) crinoidal limestones. These biohermal-peribiohermal limestones are overlain by crinoidal-spiculitic limestones.

Mišík (1979) introduced the Vršatec Limestone as a new lithostratigraphic member (biohermal limestones with corals and calcareous sponges) and assumed that it belongs to the Oxfordian stage on the basis of bivalves and corals. He presented lithological and microfacies characteristics of these sediments and determined some foraminifera taxa from the Vršatec Limestone: *Patellina* sp., *Tetrataxis* sp. and so-called "microforaminifers" (all with the Callovian-Oxfordian age).

Mišík & Soták (1998) used the term "microforaminifers" when describing organic-walled relicts of foraminifers from the Vršatec Limestone (Pieniny Klippen Belt, Western Carpathians) and pointed the age as Callovian-Oxfordian. They suggested that these "microforaminifers" represent linings of juvenile parts of foraminiferal test (chitinous membranes) and discussed the typology of foraminiferal linings and their systematic classification. The finding of foraminifera linings is based on the fact that under favorable conditions the foraminifera tests can be naturally stained to a red color by diagenetic impregnations of Fe-oxides and become visible in thins sections. The morphologies of foraminiferal linings allowed Mišík & Soták (1998) to associate these linings with "morphogroups (foraminifers of similar morphotypes) and form genera (foraminifers with incomplete generic identity)". Morphotypes of *textularid, bolivinid* and *buliminid*; *trochamminid, haplophragmoid* and *lituolid*; *involutinid, ammodiscid*; "*dentaliferous*"; *nubeculariid* and uncertain linings were recognized. As regards the possible reasons for the tiny dimensions Mišík & Soták (1998) noted that the main characteristics of the "microforaminifers" include: i) they represent only juvenile part of the foraminiferal test; and/or ii) they represent dwarf forms of adult individuals living under unfavorable conditions.

Morycowa & Olszewska (2013) found abundant foraminifera species of the genera *Rumanolina*, *Paalzowella* and *Troglotella* in the thin sections from the coral-bearing biohermal and peribiohermal limestones from the Vršatec area **(**Pieniny Klippen Belt, Western Carpathians). According to the authors, the stratigraphic distribution of the foraminifera species, the presence of the microfossil *Iberopora* as well as the most coral species indicate the Late Jurassic age for the Vršatec Limestone. However, we disagree with their stratigraphic interpretation of the Vršatec Limestone.

New biostratigraphic results and analysis of the fossilization type of benthic foraminifera have new implications for the age and paleoenvironment l conditions of the area containing the Vršatec Limestone. Assemblages of benthic foraminifera found in the Vršatec Formation are diverse and contain taxa with hyaline wall (*Spirillina, Tethysiella, Paalzowella, Hungarillina, Radiospirillina, Lenticulina* and Nodosariidae), dark microgranular wall (*Troglogtella, Earlandia, Glomospira, Planiiinvoluta*), porcelanous wall (*Nubecularia, Labalina, Ophthalmidium, Cornuspira*), agglutinated wall (*Trochammina, Verneuilinoides, Textularia, Valvulina, Ammobaculites*), and aragonitic wall (*Epistomina* and *Trocholina*). The representatives of benthic foraminifera with porcelaneous wall (*Nubecularia, Labalina, Ophthalmidium, Cornuspira*) are not diagenetically altered and prove the Middle Jurassic age of the Vršatec Limestone. The species *Ophthalmidium obscurum*, *O. terquemi*, *Labalina rawiensis* and *Hungarillina media* appear for the first time during the Bajocian, and the first three species are restricted to the Bajocian-Bathonian. The species *Nubecularia reicheli* is common in the Middle Jurassic, especially during the Bajocian.

We have also found iron-stained benthic foraminifera with very small test sizes and with agglutinated wall (*Trochammina, Verneuilinoides, Textularia, Valvulina, Ammobaculites*), dark microgranular wall (*Glomospira*) and some with hyaline wall (*Spirillina, Tethysiella, Paalzowella, Hungarillina, Radiospirillina, Bullopora, Lenticulina* and Nodosariidae). Such preservation occurs in thin sections with a relatively high recrystallization of micritic matrix. The test cavities are probably stained and/or filled with red-colored to reddish iron oxides or hydrosides that can be delivered from the fungi and iron bacteria (Della Porta et al. 2003). Such conditions might have favoured the iron-bacterial activity as it has been observed in other Paleozoic and Mesozoic red limestones.

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Infrazonal ammonite biostratigraphy of the Upper Kimmeridgian of Polish Lowland (preliminary results) and Late Kimmeridgian events

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Ammonite biostratigraphy

Upper Kimmeridgian deposits are widely distributed in the Polish Lowland, where they are penetrated by numerous deep boreholes, and only in the southern and northern periphery of this region (in the Peri-Carpathian area and northern Pomerania) they lies near to the Earth's surface and accessible through studies of shallow wells and / or quarries. Although general information about Upper Kimmeridgian ammonite distribution of the Polish Lowland has been published in many papers (mainly in the "Profile Głębokich Otworów" series), before the last decades only few ammonites were figured or described (Krantz, 1908; Pachucki, 1965; Malinowska, 1976, 1999, 2001). Detailed information on ammonites distribution accompanied by description and figuration of nearly all ammonoid taxa occurred through boreholes was published recently by Kutek and Zeiss (1997), but their study has been devoted to small area near Tomaszov Mazovecki, and only few ammonites from strata older than Autissiodorensis Zone were recorded. It should be noted, however, that recent advances in study of the Upper Kimmeridgian ammonite succession of the Middle Volga area by the author has revealed possibilities for further subdivision of the Polish uppermost Kimmeridgian, as ammonite succession of the Autissiodorensis Zone of the both these areas are nearly identical.

Detailed study of core stored in the Polish Geological Institute and Warsaw University accompanied by photographying and determination of ammonites as well as by counting of relative abundance of different ammonite taxa provides background for the proposed infrazonal subdivision of Kimmeridgian presented herein (fig. 1).

Mutabilis Zone

There are few ammonites from the Mutabilis Zone s.str. of the studied area were figured till now. For the further subdivision of this zone most important is Kcynia I borehole, which is containing the following succession of faunas: *kappfi* horizon (this immigrational horizon partially is belonging to the Askepta Subzone; it is also recognized in NE Poland by data published in Wierzbowski et al., 2015) with *Amoebites kapffi* (Oppel), *Aulacostephanoides* cf. *desmonotus* (Opp.), *Discosphinctoides* sp. (574,1-580,4 m); *salfeldi* horizon with *Aulacostephanoides* sp., *Glochiceras* sp., *Amoebites salfeldi* (Spath), *Taramelliceras* sp.(568,4-574,1 m); *Sarygulia* cf. *pishmae* (Khud.) (566,1-566,7 m); *Aulacostephanoides circumplicatus* (Quenst.), *A. desmonotus* (Opp.), *Glochiceras* sp. (564,1-566,1 m). Presence of the Lallierianum Subzone is proven for Kcynia IV well, in which *Orthaspidoc-*

eras cf. *lallierianum* (d'Orb.) has been found at 190,75-191,75 m.

Eudoxus Zone

Distribution of aulacostephanid and aspidoceratid macroconchs, which are used for subdivision of the Subboreal Eudoxus Zone (cf. Hantzpergue, 1989) in the Polish Lowland is poorly known due to rarity of these ammonites in cores. Only upper part of the zone (*yo* horizon) could be tentatively recognized by presence of the index species (*Aulacostephanus* cf. *yo* – see Wilczynski, 1962, pl. IV, fig. 1; pl. V; Matyja,Wierzbowski, 1998, pl. IV, fig. 2) as well as assemblage with *Aspidoceras* cf. *quercynum* (Kutek, Zeiss, 1997, pl. 1, fig. 1-2), *Discosphinctoides* ex gr. *roubyanus* (loc.cit., pl. 1, fig. 7-8), and *Sutneria* cf. *eumela* (loc.cit., pl. 1, fig. 3-5), which are typical for the upper Eudoxus Zone of the Russian Platform. However, cardioceratids are locally abundant and permits to recognize here some horizon known from Arctic succession. *Sokolovi* (formerly *kochi*) horizon could be traced by occurrences of the index species *Euprionoceras sokolovi* (Bod.) in the Borów K36 well (596,5 m). Overlying *anglicum* horizon is remarkable of mass occurrences of dwarf cardioceratid ammonites, belonging to *Nannocardioceras anglicum* (Salf.) and closely related species, which are typical for black shale facies. This horizon is recognized at Kcynia I (457,65-490,4 m), Nidzica IG 1 (1087,6-1101,4 m), Borów K36 (435,2-462,8 m) boreholes. Other ammonites, including small-sized *Neochetoceras* and *Aulacostephanus*, are uncommon.

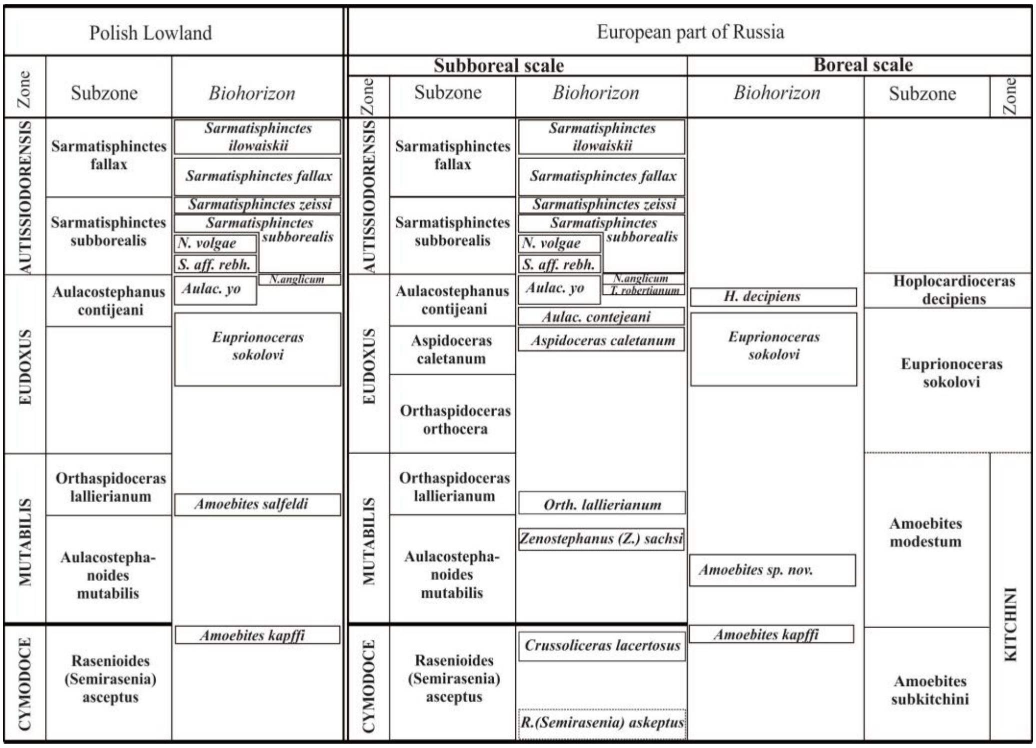

Fig. 1. Infrazonal subdivision of the Upper Kimmeridgian of Polish Lowland and the European Russia by ammonites.

Autissiodorensis Zone

Ammonte faunas of the Autissiodorensis Zone of Polish Lowland are nearly identical to those of the Middle Volga area (Rogov, 2010), and the same succession of biohorizon is recognized in the both studied areas.

Subborealis Subzone

Basal biohorizon of the Autissiodorensis Zone (aff. *rebholzi*) is marked by nearly equal occurrences of ammonites with different biogeographic affinities Биогоризонт perplexa Rogov. Tiny *Sutneria* aff. *rebholzi* Berckh, as well as macroconchs *Schaireria* sp. are very typical for this unit along with *Nannocardioceras krausei* (Salf.), first virgatitids (*Sarmatisphinctes subborealis* (Kutek & Zeiss) and aulacostephanids (*Aulacostephanus volgensis* (Vischn.), *A. (A.) kirghisensis* (d'Orb.), *A. (A.) subundorae* (Pavl.), *A. autissiodorensis* (Cott.)). This horizon is recognized in many wells (Kcynia IG 1, Nidzica IG 1, Płońsk 8, Gostynin IG 4) along with historical occurrences in Northern Poland (Krause, 1908). Overlying *volgae* horizon marked by mass occurrences of the last cardioceratid ammonite ever known, *Nannocardioceras volgae* (Pavl.), while other ammonites (*Sarmatisphinctes subborealis* (Kutek & Zeiss) and *Aulacostephanus* sp.) are rare here. Throughout the Subboreal Realm (including also the Middle Volga and Pechora areas as well England) thickness of this horizon is very small suggesting that duration of the *volgae* hemera was very short comparing with other hemerae of the Late Kimmeridgian. Along with two event horizons mentioned above the single "evolutionary" horizon *subborealis* could be recognized in the lower part of the Subborealis Subzone by occurrence of the earliest *Sarmatisphinctes.* At the upper part of range of this species *Neochetoceras*-rich level is occurred ("Subnudatum level" in Kutek, Zeiss, 1997). Uppermost horizon of the Subborealis zone (*zeissi* horizon) is dominated by the index species and as well as in the Russian Platform it is lacking any ammonites with Submediterranean affinities.

Fallax Subzone

Two biohorizons recognized in this subzone are based on the lineage of the last members of genus *Sarmatisphinctes* (Rogov, 2010). Other ammonites (belonging to the genus *Aulacostephanus*) are rarely occurring in the Fallax Subzone. As well as in the other Subboreal succession there are gradually became more and more rare upwards and totally disappeared in the top of the Autissiodorensis Zone.

Late Kimmeridgian events and ammonoid immigration

Changes in Upper Kimmeridgian ammonite assemblages are very close to those recognized in the central part of the Russian Platform and (at least for the topmost Eudoxus and Autissiodorensis Zone) for England. It should be noted that not only successions of ammonite taxa are very similar in all these Subboreal regions, but even relative abundance of certain ammonite species and genera seems to be very close throughout the realm.

Beginning of the Late Kimmeridgian is marked by mass occurrence of *Amoebites kappfi* (Opp.) in Central and Northern Poland, and at the same level this species has been found in the Middle Volga area. The next interval of strong dominance of Boreal ammonites, which could be connected with cooling event, is recognized at the latest Eudoxus Chron (*anglicum* hemera). Throughout the Subboreal Realm this interval is represented by black shales, which are crowded by dwarfish *Nannocardioceras*. However, lowermost assemblage of the Autissiodorensis Zone is showing quite different ammonite assemblage of the mixing character, in which aspidoceratids are relatively common (above they are disappeared in the Subboreal areas). Above it is again replaced by cardioceratid-dominated assemblage, which is recognized across the huge area. Such strong changes in ammonite association could be caused by climatic oscillations. Above the *volgae* horizon one more remarkable event is traced in the both Polish Lowland and the Volga area ("Subnudatum level" by Kutek and Zeiss, 1997), while above ammonite assemblages of these areas are characterized by differences in distribution of thermophylic ammonites, which are absent in Poland above the *subborealis* horizon but persisted in the Volga area till the end of the Kimmeridgian.

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A Tithonian *Chitinoidella* horizon and "Volgian" and "Portlandian" ammonites in the Owadów-Brzezinki section (central Poland) – a clue for Upper Jurassic interregional correlations

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Youngest Late Jurassic deposits in the epicratonic area of Poland crop out only at Sławno, in the Owadów-Brzezinki quarry near Tomaszów Mazowiecki. These Tithonian deposits are developed as the limestones of the Kcynia Fm., and they succeed the well-known marly deposits of the Pałuki Fm. corresponding to the "Lower" and a lower part of the "Middle Volgian" – well dated by ammonites and described in many papers in the past from the Tomaszów Mazowiecki (Brzostówka) sections (Lewiński, 1923; Kutek, 1994; Kutek and Zeiss, 1974, 1997; and earlier papers cited therein).

The deposits studied (uppermost part of the Pałuki Fm., and the Kcynia Fm.) have yielded abundant ammonites (more than one hundred specimens). A preliminary investigation of the collection shows the presence of two different systematic groups of ammonites: the subfamily Virgatitinae Spath, 1923 and of the subfamily Pavloviinae Spath, 1931. The former is represented by the genus *Zaraiskites* – the species *Z. regularis* Kutek below, and the species *Z. zarajskensis* (Michalski) above, documenting the two succeeding horizons of the Zarajskensis Subzone (upper part of the Scythicus Zone of the "Middle Volgian") – the *regularis* horizon, and the *zarajskensis* horizon (according to the definition of Kutek, 1994). Both these species represent the continuation of the main phyletic "Volgian" lineage, well represented in the underlying Lower and Middle Volgian deposits in Central Poland.

Other ammonites that may possibly be related to the genus *Zaraiskites*, (though they differ in having less regular ornamentation and loosely spaced ribs in the inner whorls) come from the whole stratigraphic interval studied. The oldest forms are similar to "*Zaraiskites*" *pommerania* (Arkell), and these together with younger forms – which generally show a tendency to develop more spaced and irregular ribbing - may be considered as a possible phyletic link between *Zaraiskites* and the genus *Progalbanites* from the English "Portlandian" (cf. Dzik, 1994).

The representatives of Pavloviinae found in a lower and middle parts of the succession studied are macro- and microconchs which may be compared with those of the genus *Virgatopavlovia* as described by Cope (1978) from the Fittoni Zone of the topmost Kimmeridge Clay in southern England. The inner whorls of these macroconchs and the microconchs show the presence of bifurcated ribs resembling very much ornamentation of pavloviids of the *Epipallasiceras* type. Besides, there occur in the collection some specimens which may be compared with other groups, or groups within the genus *Pavlovia*.

The stratigraphical interpretation of the deposits thus indicates that the bulk of them can be correlated with the Zarajskensis Subzone of the upper part of the Scythicus Zone of Russia. It may be suggested, however, that the youngest deposits of the succession may correspond already to the lowermost part of the following "Middle Volgian" zone – the Virgatus Zone – and its lowermost part - the Gerassimovi Subzone (cf. Mitta, 1993) as shown by the occurrence of specimens similar to *Virgatites gerassimovi* Mitta. On the other hand, the lower and middle parts of the deposits studied may be correlated with the Fittoni Zone of the mid Tithonian in England and northern France (top Kimmeridge Clay).

Of special interest for wider correlation is the occurrence of a thin horizon – only a few centimetres in thickness - with common Tethyan chitinoidellids. This horizon is in the middle part of the succession, in the upper part of the Zarajskensis Subzone. It yields numerous specimens of the genera *Borziella*, *Chitinoidella* and *Daciella*, which indicate the presence of the Chitinoidella Zone, a zone widely recognised in Tethys. This zone sits at the top of the Lower Tithonian, spanning the upper part of the ammonite Fallauxi Zone, through the Ponti Zone and into the lowermost part of the Microcanthum Zone (Upper Tithonian).

It should be remembered that the Owadów-Brzezinki quarry represents one of the most important palaeontological sites in the Upper Jurassic of Poland, and it has yielded unusually well-preserved fossils of both marine and terrestrial organisms; and the data provided make possible interpretations of both their stratigraphical and palaeogeographical position (cf. Błażejowski et al., 2014).

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Towards a uniform Oxfordian-Kimmeridgian boundary – current state of knowledge

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The Kimmeridgian Stage although originally named by A. d'Orbigny at the half of XIX century after the Jurassic succession at the village of Kimmeridge on the Dorset Coast, in fact was firstly defined by Salfeld (1913) who recognized the base of the Stage at the base of the Kimmeridge Clays corresponding to a marked change in the ammonite Aulacostephanidae lineage – from the genus *Ringsteadia* to the genus *Pictonia*. Unfortunately, the ammonites of the family Aulacostephanidae are of limited correlation value because of their fairly small palaeogeographic distribution in the so-called Sub-Boreal Province of northern Europe, and moreover, as it has been shown later, the phyletic transition between genera *Ringsteadia* and *Pictonia* at the base of the Kimmeridge Clay in southern England was not continuous because of the stratigraphical gap. Marked differences between the coeval ammonite faunas between the northern and middle-southern Europe resulted moreover in a wrong correlation of the Oxfordian-Kimmeridgian boundary between the particular successions. The difference in position of the Oxfordian/Kimmeridgian boundary is especially pronounced between the Subboreal/Boreal ammonite succession (boundary between the Pseudocordata and Baylei ammonite zones) and the Submediterranean/Mediterranean ammonite successions (boundary between the Planula and Platynota/Silenum ammonite zones). The currently accepted boundary of the stages is placed in a much higher position in the Submediterranenan-Mediterranean areas (about two ammonite zones higher) - which corresponds to about 1.5 Ma, than in the Subboreal standard (Ogg et al., 2012)

The study undertaken in the Flodigarry section at Staffin Bay on the Isle of Skye, Scotland, showed the continuous succession of the Subboreal (Aulacostephanidae) and the Boreal ammonites (Cardioceratidae). The study resulted in recognition of the boundary between the Oxfordian and Kimmeridgian stages at the Pseudocordata/Baylei zonal boundary (Subboreal) which precisely corresponds to the Rosenkrantzi/Bauhini zonal boundary (Boreal). The boundary is marked by the presence of the newly established ammonite horizon (*flodigarriensis* horizon) which may be recognized both by Subboreal ammonites (appearance of the first ammonites of the genera *Pictonia* and *Prorasenia*) as well as the Boreal ones (subgenus *Plasmatites*). Both the section and the horizon have been proposed as the site of the Global Stratotype Section and point (GSSP) for the Oxfordian/Kimmeridgian boundary (Matyja et al., 2006; Wierzbowski et al., 2006).

The correlation of the Flodigarry section with the Submediterranean succession of central Europe was presented on the basis of study of the sections which yielded both the Boreal-Subboreal ammonite faunas and the Submediterranean-Mediterranean ones. These are the sections from central Poland (Polish Jura), but also from southern Germany (Swabian Alb and Franconian Alb) and northern Switzerland (see e.g. Wierzbowski & Matyja, 2014 with earlier papers cited therein, see also Wierzbowski et al., 2016, in press). According to the correlation presented the Oxfordian/Kimmeridgian boundary as defined in the Subboreal/Boreal successions corresponds to the boundary between the Hypselum and Bimammatum zones in the Submediterranean/Mediterranean successions. The latter boundary shows a marked change in ammonite faunas of the family Aspidoceratidae characterized by a general decline of the genera *Euaspidoceras* and *Neaspidoceras*, and a successive appearance of the new genera (*Clambites*, *Aspidoceras*, *Physodoceras*, *Pseudowaagenia*), and thus it may be accepted as a basis for a wider correlations of the Oxfordian/Kimmeridgian boundary in the World.

It should be remembered that the proposed Oxfordian/Kimmeridgian boundary is well characterized by other data – including microfossils (mostly dinoflagellates), and supported by other than palaeontological methods including the palaeomagnetic-sedimentary-tectonic-climatic and geochemical studies. Thus, it is strongly recommended by us (Wierzbowski et al., 2016) the formal recognition of the base of the Kimmeridgian as given above by all the formal stratigraphical associations (International Subcommission on Jurassic Stratigraphy – ISJS and International Commission on Stratigraphy of IUGS).

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Preliminary study and first analytical results of Upper Jurassic black shales from Moscow Region

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The Upper Jurassic dark shaly bituminous clays and black shales (earlier mostly called oil shales) were known in Moscow and its vicinity for a long time since the beginning of the XX century. Despite this, the data of their chemical composition were absent in the literature formerly.

There are two stratigraphic levels of the black shales: the Oxfordian and the Volgian.

The Oxfordian interval (Alternoides zone) can be seen in the riverbed of Moscow river in Kolomenskoye, Saburovo, Kapotnya, but more accessible in the section of Kamennaya Tyazhina (to the south-east from

Moscow). The thickness of the shale bed is 0.1-0.3 m.

The most representative among the Volgian interval (Pseudoscythica Zone) are sections of the southeast of Moscow such as Kolomenskoye, Saburovo, Borisovskie vyselki, Kapotnya, Zyablikovo, Milkovo. The thickness of the shale bed is 0.1-0.2 m (Malenkina, 2014).

We studied and analyzed the Oxfordian and the Lower Volgian shales from of the above sections. All the shales are dark gray to black with very fine horizontal lamination and well expressed platy bedding. Different macrofauna (gastropods, bivalves, ammonites) and biodetritus, sometimes more light small ichnofossils (probably *Chondrites*) are seen on the bedding surfaces of the shales. The irregular thin horizontal microlamination is observed in the thin sections. The lenticular shale fabric expressed by nonuniform distribution of kolloalginit fragments in the form of orange and reddish brown flattened microlenses, plant detritus, clay particles and organic matter are visible. The SEM study of the Oxfordian shales showed the presence of indeterminate radiolarians, some foraminifera shells and nanoplankton: *Watznaueria britannica* (Stradner), *W. fossacincta* (Black), *W. barnesae* (Black), *Zeugrhabdotus erectus* (Deflandre), *Polypodorhabdus escaigii* (Noel), *Biscutum dubium* (Noel), *Stephanolithion bigotii bigotii* (Deflandre), *Cyclagelosphaera margerelii* (Noel) (M.A. Ustinova's definitions). The Lower Volgian shales sporadically contain *Watznaueria sp.*, *W. britannica* (Stradner) и *W. fossacincta* (Black).

The chemical analyses were performed in the Laboratory of physicochemical analysis at the Geological Institute, RAS. Analytical studies of Oxfordian shales (primarily Kamennaya Tyazhina) showed 8.20-10 % of Corg content and from absence to 5 of CO_2, Ni – 151, Mo – 22.9, V – 194 ppm, Fe – 9.92%, S – 4.68%, and some other elements demonstrate elevated concentrations. In general, they are comparable to analogues in the sections of the Kostroma region (Gavrilov et al, 2014).

Analytical studies of Lower Volgian shales (first of all from Kolomenskoye and Kapotnya) showed a variation of Corg content from 11.20 to 20 (pretty close to that of the Panderi Zone shales of the Ivkino from Kostroma region (Gavrilov et al, 2008)). Moreover, the CO_2 content changes from complete absence to 2.8 (whereas all Ivkino shales are more calcareous). Elevated concentrations of Cr (124–229 ppm), Cu (105–229 ppm) and As (45-113 ppm) stand out even in comparison with Ivkino. The remaining elements, although vary quite widely, are in general close to Ivkino section. Generally, there are increased contents, often considerable, such elements as V, P, Ba, Ni, Mo, Fe, Zn, U, Th, Pb, S. Interestingly, that phosphorites lying directly above the studied shales also contain a substantial quantity of Corg (4–5%), (Malenkina, 2014).

Distribution of the black shales is limited more deepwater areas (pre-Jurassic erosion valleys), while in shallow elevated areas there are low-thick condensed sections of the complete absence of shale and almost entirely represented by a phosphate interlayers. Accumulation of the shales was associated with sea level fluctuations.

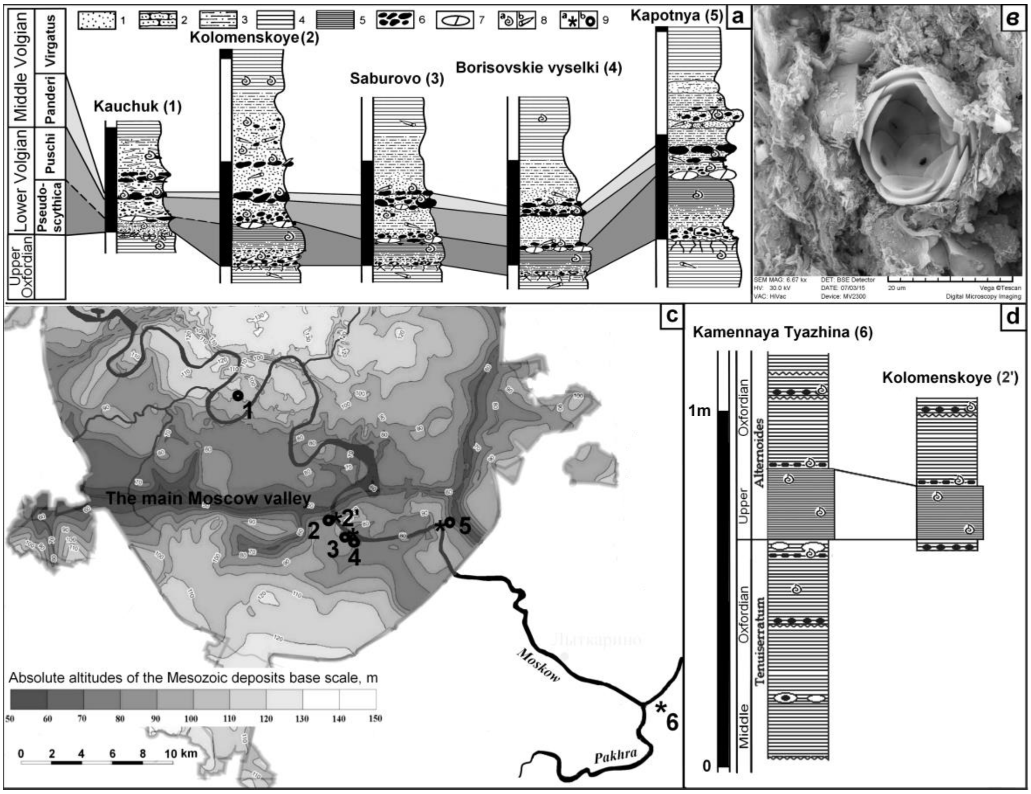

Fig. 1. **a** – Comparison of Lower Volgian sections: 1 - sands, 2 - sandstone, 3 - siltstone, 4 - clay, 5 - shales, 6 - phosphate nodules, 7 - marl concretions, 8 - faunal remains: a-ammonites, b-belemnites, 9 - section points: a-Upper Oxfordian, b-Lower Volgian.
b - *Watznaueria fossacincta* (Black) in the Upper Oxfordian shales from Kolomenskoye.
c – The location map of the studied sections with the relief of the Mesozoic deposits base.
d – Correlation of Upper Oxfordian sections studied.

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Fish-debris tempestites within Volgian-Ryazanian radiolarian lithofacies of Western Siberia

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The multidisciplinary range of work, including the detailed lithofacies analysis, has been recently carried out from central zone of the West Siberian Upper Jurassic – Early Cretaceous paleobasin. Tectonically the studied area is confined to Mesozoic-Cenozoic Frolovskaya depression, which is bordered by Krasnoleninsky (in the west) and Salymsky (in the east) anticlines. The studied stratigraphical interval covers the Abalak (Callovian–Lower Volgian) and Bazhenov (Volgian-Valanginian) Formations, as well as Lower Tutleym Formation, which laterally replaces Bazhenov in the west end of the area. In total, we have documented and sampled the cores of 14 boreholes. The main our objective is to reconstruct sedimentary marine environments and its evolutionary trends during such prolonged (from Volgian to Valanginian) period of organic carbon accumulation. We also sought to compare with the coeval paleobasin of Russian platform, known for its so resembling conditions, periodically occurred and resulted to widespread black shale deposition (Gavrilov et al., 2009; 2014).

Paleogeographically, Frolovskaya depression was belonged to a huge epicontinental marine basin, arisen from global Callovian marine transgression and reached a maximum in the Volgian time (Braduchan et al., 1986, Kontorovich et al., 2013). This maximum has been recorded by formation of significantly widespread Bazhenov horizon. It is built of mainly biogenic (planktonic) material and highly enriched in organic carbon, thus seems to be accumulated under conditions of terrigenous starvation. The paleodepth in the central zone of the Volgian basin is assumed as >400 m(Braduchan et al., 1986, Kontorovich et al., 2013, etc.), but allowed more shallow depth (as 200–400 m) for the studied area (Kontorovich et al., 2013).Bazhenov horizon in the territory ofFrolovskaya depressionis ratheryounger in its age. Stratigraphically it can be subdivided into the Lower (Lower-Middle Volgian) and Upper (Middle Volgian–Valanginian) Members. The Lower Member (15–18 m) is composed of thin bedded and laminated siliceous (radiolarian) rocks with low clay content and moderate (5–7 %) organic carbon. Almost pure chalcedonite, intercalated by radiolarites with traces of reworking, is prevailed near (2–5 m) the top of Lower Member. Finally, it is capped by the distinctly more clayey silicites (2–6 m) abundant in bivalve shells (namely, Inoceramus). Biostratigraphically the “Clayey Unit” corresponds to the uppermost Middle Volgian – Ryazanian. The Upper Bazhenov Memeber (5–12 m), in turn, is formed by laminated marls abundant in calcareous nanoplankton and highly enriched in organic carbon (up to 20 %). Up-section it is gradually followed by terrigenous claystone, and organic carbon is sharply decreased.

Thin (0,5–2,5 cm) beds or lenses of disoderly “dumped” fish bone fragments (0,2–5 mm in size) were found within Bazhenov horizon (fig 1). Commonly such beds are grouped as a series (up to 5–6 cm), silicified or dolomitized, sometimes impregnated in oil-hydrocarbons. In adjacent sediment fish fragments are also present, but rarely scattered and oriented along inherent lamination. According to Zakharov, Saks, 1983; Braduchan et al., 1986, as well as observation of E. Baraboshkin, similar fish-debris ”dumps” were recognized within Bazhenov in adjacent areasand interpreted as a specific coprolites. Our recent observations revealed some typical characteristics of storm stratification in the internal structure of fish-debris beds. The most complete sequence includes following elements (bottom-up, fig 2): 1) erosional basal surface, deformed by numerous indentations resulted from a sticking of fish bone fragments; 2) concentrated fish debris packstone, often normally graded(coarse components pavethe basement); 3) thin laminatedlayer, containing only a few small fragments of fish bones, oriented along the lamination; e) distinct and wavy top surface, probably complicated by ripple or scour pockets.

All listed characteristics indicate scour processes, winnowing and rapid dumping, accompanied by gravity fractionation. We proposed that fish-debris beds were deposited under the storm activity. Small thickness of the beds and concentrationof predominantlyparautochthonous fauna attestthemas distal tempestites, formedunderstorm-induced oscillatory currents according to (Aigner, 1986). The tendency to form storm bed series and very high concentration of fish fragments as compared to adjacent sediment, likely indicating a multi-events and amalgamation a previously accumulated fish deritus material.

The lateral tracing of fish-debris beds enable to recognize up to three distinguished levels thatclosely associate withcoarse-grained and shelly lithofacies within the studied Bazhenov horizon, such as: 1) reworking radiolarites, located in the top of Lower Member; 2) bivalve (Inoceramus) occurrences within ”Clayey Unit”, sandwiched between the Lower and Upper Member; 3) manifest enrichment in siliciclastic silt material that characterized the Low Tutleym Formation in the southwestern part of the studied area, located on the slope ofKrasnoleninsky anticline.

The presence of tempestites enable to assumed a paleodepthofthe Bazhenovbasinas more shallow then 200–400 m, at least by the end of the Lower Memberformation and proposed that since later Middle Volgian the paleobasin became permanently shoaled. It is also possible that the high concentration of biogenic silicaand organic carbon in the Bazhenov lithofacieshave notbeenresultedfrom significantpaleodepthitself, but mainlylong distance to land, caused extremely reduced terrigenous supply and nutrient abundance, lead to high productivity of zooplankton throughout all the period of Bazhenov horizon formation.

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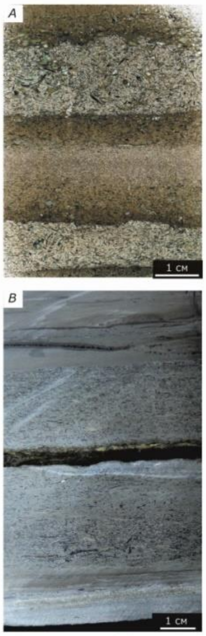

Fig. 1.: Fish debris beds ("dumps") within siliceous (radiolarian) sediment of Lower Menber of Bazhenov horizon: A - Galyanovskaya borehole, B - Yemangalskaya borehole

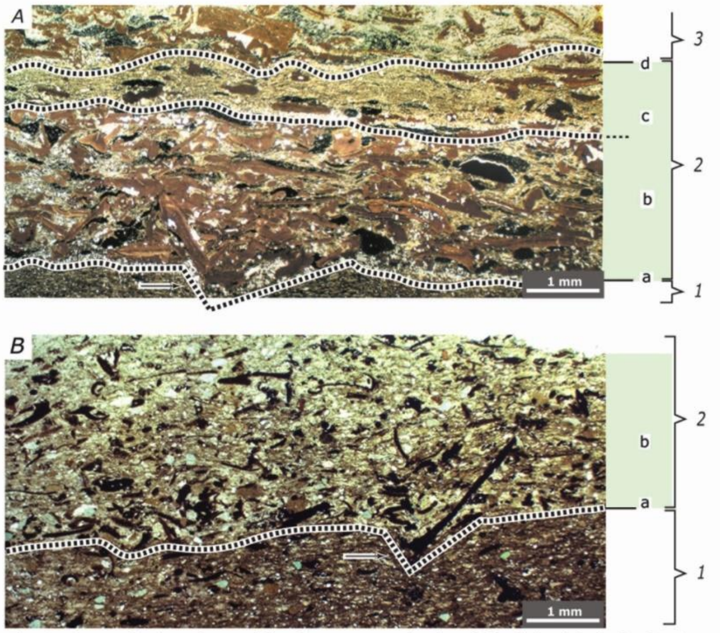

Fig.2. Storm-induced stratification, recognized withinfish debris beds: 1 –siliceous (radiolarian) sediment; 2 – storm beds (tempestites): a – erosional basement, deformed by indentations resulted from a sticking of fish bone fragments; b – concentration of fish debris, normally graded; c – thin laminated layer, containing a few fish fragments, oriented along the lamination d – top surface, probably complicated by ripple or scour pockets. Lower Member of Bazhenov horizon: A – Yemangalskaya borehole, B –Nyzhneyanlotskaya borehole

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Depositional environment of the Sławno Limestone (uppermost Jurassic, central Poland): evidence from microfacies analysis, microfossils and geochemical proxies

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The Owadów-Brzezinki site in central Poland is palaeontologically important because of recent findings of unusually well-preserved marine and terrestrial fossils. The fossils have been predominantly collected from the middle part of the quarry section within the so called Sławno limestones of the Kcynia Formation (beds D13, D11). The findings include rich horseshoe crabs fauna, crustaceans, terrestrial insects and parts of skeletons of sea and terrestrial vertebrates (Kin and Błażejowski, 2012; Kin et al., 2012, 2013; Błażejowski, 2015; Feldmann et al., 2015). According to the stratigraphical study of Kutek (1994) based on ammonite fauna from the nearby Brzostówka section, the Owadów-Brzezinki deposits belong to the Regularis Horizon (an uppermost part of Brzostówka marls of the Pałuki Formation) and Zarajskites Horizon (an exposed part of the Sławno limestones of the Kcynia Formation) of the Zarajskites Subzone of the Scythicus Zone of the Middle Volgian (i.e. the uppermost Lower Tithonian). The collected fossils are, thus, derived from a bit younger sediments than those from the famous Jurassic fossil *Lagerstätten* i.e. Solnhofen and Nusspingen in southern Germany. Although the Owadów-Brzezinki fauna, is seemingly similar to Solnhofen and Nussplingen ones, it grew in different Boreal palaeogeographical settings and was adapted to different palaeoenironment.

The sedimentary succession of the Owadów-Brzezinki quarry is interpreted as a record of the shallowing of the depositional environment, from an offshore to lagoonal-coastal one (Kin et al., 2013). New data based on microfacies analysis, microfossils, oxygen and carbon isotope as well as chemical composition of studied rocks indicate that depositional environments of the older part of the Owadów-Brzezinki section (including Brzostówka marls, and overlying unit I limestones of the Sławno limestones) varied from an offshore or a nearshore one. The water during the formation of this part of the section was well-oxygenated and characterized by a normal-marine chemistry. The carbonates show remarkable rate of the detrital fraction.

Marine regression resulted into the formation of younger parts of the Owadów-Brzezinki section (units II, III, and the lowest part of unit IV of the Sławno limestones, including fossiliferous beds D13, D12) in lagoonal depositional settings at very low rate of detrital grains. The general disappearance of benthic foraminifera (with some episodes of their re-appearance), high-amplitude variations in oxygen and carbon isotope values of the rocks, high and variable P/Al, U/Th, Ni/Co, Mo/Al and Mn/Al ratios (Fig. 1), and the occurrences of pseudomorphs after evaporate crystals (probably gypsum) indicate variations in seawater salinities (from hypersaline to brackish) and the oxygenation level of benthic waters, which resulted in the variations of benthic fauna assemblage (from marine to brackish faunas) or the total lack of benthic fauna at some intervals. Environmental conditions of the restricted lagoon varied in a short-term scales resulting in life blooms and extinctions under sudden appearances of dysoxic/anoxic conditions, which have probably allowed the preservation of a diversified faunistic fauna and soft tissues of organisms at certain horizons. The dysoxic/anoxic episodes probably occurred during the deposition of fauna-rich beds (D12, D13) and the younger rocks of the unit III. The youngest limestones of the Owadów-Brzezinki quarry (unit IV) were deposited during the re-appearance of waters of normal marine chemistry in the intertidal-subtidal zone.

The depositional history of the Owadów-Brzezinki site is non-typical, compared to other famous fossil *Lagerstätten*, and is characterized by short-term fluctuations in the oxygenation level of bottom waters and their salinities.

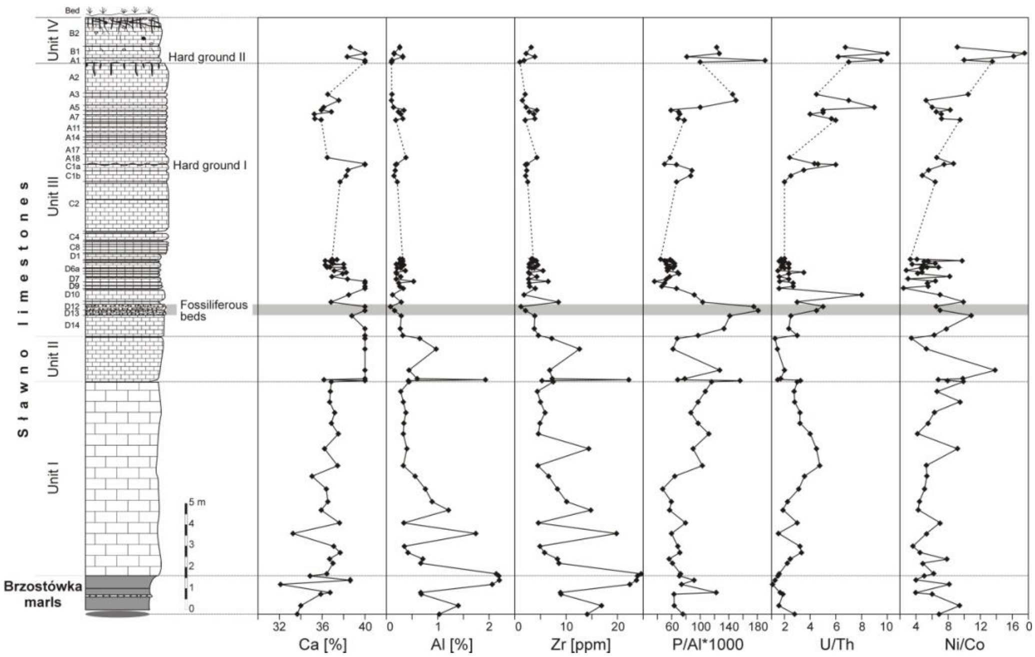

Fig. 1. Lithology, Ca, Al, Zr concentrations, and P/Al, U/Th, Ni/Co ratios of bulk carbonates from the Owadów-Brzezinki section. Note the decreasing rate of detrital material towards the top of the section and high and variable U/Th and Ni/Co ratios of the upper part of the section, which points to the episodes of water dysoxia/anoxia.

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The first findings of the bivalve genus *Aulacomyella* in the Upper Jurassic deposits of the Krížna Nappe and the Pieniny Klippen Belt (Western Carpathians)

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Although upper Jurassic bivalves are common in the deposits of the Western Carpathians region and were collected for many years, in the last decade interesting hitherto unknown genus was discovered. The valves of the "paper pecten" *Aulacomyella similis* (Fig. 1.1-1.3, 1.5) were collected on the locality Stankowa skala (Polish part of the Pieniny Klippen Belt) and in the vicinity of Čierna Lehota village (Krížna Nappe, Strážovské vrchy Mts.). On both localities interesting sedimentological signs were recognized. In the first one, valves of *Aulacomyella* occur in Early Kimmeridgian (Strombecki-Divisum zones) deposits with volcanic material and in the second one, the thin fossiliferous horizon (with ammonite *Cymaceras (Cymaceras) guembeli*, Early Kimmeridgian), is developed within huge packet of limestones without macrofossils. The accompanied bivalve fauna is very scarce. Only "*Placunopsis*" *tatrica*, *Liostrea* sp. and *Camptonectes (Camptochlamys)-Eopecten*? sp. (Fig. 1.4) were recognized. In Germany, horizons with *Aulacomyella similis* are known from 19-th. century as "Monotisbank" and are lower Kimmeridgian in age (Shick 2003) or from laminated plattenkalk (early Late Kimmeridgian) (Fürsich et al, 2007). Worldwide this genus was found in deposits from ?Callovian/Oxfordian to Early Tithonian age and is considered to be stratigraphically important for the Kimmeridgian and Early Tithonian (Kelly and Doyle, 1991). Concerning the mode of life, this genus lived under disoxic conditions and if lived as epibenthic recliner or pseudoplanctonic is still unclear (Fürsich et al, 2007; Kelly and Doyle, 1991).

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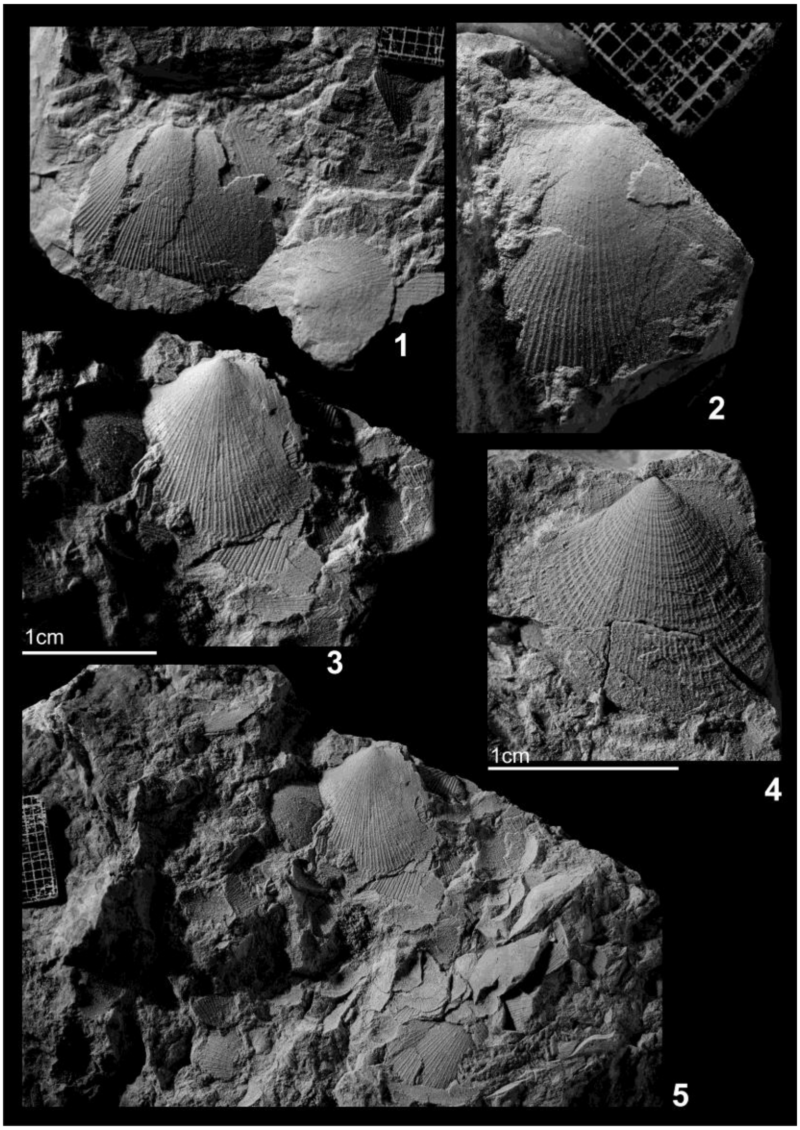

Fig. 1: 1-3, 5. *Aulacomyella similis* (Münster 1833). 1,2. Čierna Lehota village, Strážovské vrchy Mts., Slovakia. Early Kimmeridgian. 3,5. Stankowa skala, Poland. Pieniny Klippen Belt. Early Kimmeridgian; 4. *Camptonectes (Camptochlamys)-Eopecten*? sp. Čierna Lehota village, Strážovské vrchy Mts., Slovakia. Early Kimmeridgian.

Tithonian/Berriasian bryozoan-stromatoporid biota of the Štramberk Limestone (Outer Carpathians, Czech Republic)

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Late Jurassic bryozoans are connected with the apparent period of decline, which is still considered as an artefact caused by the incompleteness of the fossil record until their sustained radiation commenced in the Early Createaceous.

The newly-described Tithonian/early Berriasian bryozoan fauna of the cyclostome cerioporinids from the Štramberg Limestone is dominated volumetrically by nodular, hemispherical mostly multilamellar colonies comprising the stenolaemates of Cerioporina von Hagenow.

Taxonomically, this fauna is represented by the colonies belonging to suborder Cerioporina von Hagenow of the Heteroporidae Waters (*Heteropora* Blanvillae), Ceriopridae Reuss (*Ceriopora* Goldfuss and *Defranciopora* Hamm), as well as Cavidae d'Orbigny represented by *Ceriocava* d'Orbigny and the *incertae sedis* of *Reptomulticava* d'Orbigny. The most characteristic feature of the studied assemblage is the presence of massive, multilamellar, hemispherical colonies, ranging from a few mm up to 3 cm in diameter, accompanied predominantly by benthic faunas of corals, bivalves, gastropods, echinoids and stromatoporoids. The analysis of the stromatoporoid assemblage reveals the presence of a few taxa which commonly exhibit a typical spherical/hemispherical and mashroom-shaped morphology such as: multilamellar *Calciagglutispongia*, spheroidal *Dehornella* with characteristic astrorhizae, branching colonies of *Cladocoropsis* and *Cylicopsis* occurring in tturbidite slope facies as well as *Neuropora* – chaeatetid sponge - ubiquitous element in various facies of the coral-reefs and lagoons. The most diverse? Late Tithonian stromatoporoid-bryozoan association occurs in the marly to silty sediments in the fossiliferous horizon where most of the fauna is represented by reworked fossils of unstable substratum, below fair-weather wave base, rarely? affected by storm events, but mostly tranquil. The Jurassic stromatoporoids, if occur, are clearly related either to the coral reef facies or inner ramp/lagoonal facies.

Stromatoporoids associated with the encrusters (bryozoans and sponges) in the Štramberg Limestone facies are strong competitors and are particularly important as palaeoecological indicators. They indicate a shallow water environment of the Štramberg Limestone biota. Stromatoporoids, lived in a mildy mesotrophic to strongly oligotrophic carbonate environment preferred by the high-energy reefs. The palaeogeographical position of the Štramberg Limestone situated northwards of the isolated Intra-Tethys setting shows the prevailed occurrence of stromatoporoids developed under the influence of the oligotrophic waters.

Cyclostome cerioporinids, (Heteroporidae, Cavidae and Cerioporidae), have been present since the mid-Jurassic (Aalenian), with more abundant *Reptomulticava* and *Defranciopora* during the Cretaceous (Valanginian-Hauterivian), described from Jura, E Paris Basin and NW Germany. The regression and climatic cooling in the late Valanginian (*Trinodosum* Zone) was connected with the disappearance of this fauna and its renewal during the transgression in the early Hauterivian. Both massive colonies favoured high energy environments with a rocky or coarse sandy bottom in the shallow and warm waters.

Berriasian-Valanginian boundary in the Crimean Mountains

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At present, stratigraphic ranges of some late Berriasian ammonite genera and species are defined not very precisely because of three reasons. First, complete Berriasian–Valanginian sections are absent in many regions, second, the same taxa are controversially identified, and third, they are inadequately studied. Accordingly, position of the Berriasian–Valanginian boundary in the Mediterranean is disputable. Hoedemaeker (1982) who studied complete Berriasian–Valanginian sections in Spain distinguished above the upper Berriasian Picteti Subzone an interval, characteristic of which are representatives of genera *Tirnovella* (*T. alpillensis* included), *Kilianella, Sarasinella, Neocomites*, and *Olcostephanus.* This interval termed the Tirnovella alpillensis Subzone was included into the Thurmanniceras (Kilianella) retrocostatum Zone of the lower Valanginian and supplemented by remark that *alpillensis* forms with abundance maximum in synonymous subzone commenced their evolution in the Picteti Subzone of the upper Berriasian. Later on, Company (1987) established presence of *T. alpillensis* in the Otopeta Zone and occurrence of *F. boissieri* in the lower part of the Valanginian Pertransiens Zone in Spain. In preliminary ammonoid zonation suggested for the Mediterranean region (Hoedemaeker, Bulot, 1990), there was an interval of "unnamed association" above the Picteti Subzone, which was included into the Boissieri Zone and corresponded to the Alpillensis Subzone in the earlier ammonoid zonation suggested by Hoedemaeker (1982). Expecting a more complete investigation and description of fauna, experts on the problem recommended including this interval into the Berriasian. Later on, it was decided to consider the interval as the upper Tirnovella alpillensis Subzone of the Boissieri Zone (Hoedemaeker et al., 1993). Despite the opposition of Hoedemaeker, that decision was authorized in resolutions of the International Ammonite Working Group (Rawson et al., 1999; Hoedemaeker, Rawson, 2000). New information about distribution of *T. alpillensis* and *F. boissieri* in Mediterranean sections appeared in recent years. In Morocco, *alpillensis* forms have been detected in the Otopeta Zone (Aguado et al., 2000), while *boissieri* specimen was described from the Otopeta Subzone ranked accordingly as the upper Subzone of the Boissieri Zone (Wippich, 2003). In the mentioned region, *F. boissieri* is found in association with *Subthurmannia latecostata, T. alpillensis*, and *Thurmanniceras thurmanni.* At the Stramberk locality (Czechia), species *Subthurmannia* cf. *boissieri* is associated with Valanginian ammonites *Thurmanniceras pertransiens, T. thurmanni, K. roubaudiana*, and *K. clavicostata*, which are characteristic of the Pertransiens Zone (Houša, Vašiček, 2004). As is noted in the cited work, however, the species in question is confined in the Stramberk locality to the base of lower Valanginian deposits above deeply eroded Berriasian sediments (a greater part of the Boissieri Zone is missing), and shells of this taxon are redeposited most likely. Taking all this into consideration by positioning the Berriasian–Valanginian boundary in Mediterranean region, the "Kilian Group" decided to transfer the Otopeta Zone into the Berriasian and ranked it as upper subzone of the Boissieri Zone (Hoedemaeker et al., 2003). This decision is consistent with recommendation of the Brussels Symposium (Bulot, 1996) to define the Berriasian–Valanginian boundary at the first occurrence level of *Calpionellites darderi* at base of Zone E. More exactly, this level corresponds to the appearance datum of the typical Valanginian species *T. pertransiens.*

Valanginian ammonites are scarce in the Crimean Mountains, and it is difficult to establish here the relevant zonation (Zones of the Cretaceous..., 1989). None of the sections with the Berriasian–Valanginian transition proved by paleontological materials is known here. The Valanginian sediments transgressively overlap as a rule either the Berriasian and Upper Jurassic deposits, or the Tavricheskaya Group. In the Varnautskaya and Baidarskaya depressions of the southwestern Crimea, the deeply eroded Tithonian and Berriasian deposits are overlain by clays containing ammonites *N. neocomiensis*, *K. roubaudiana*, and *T. thurmanni* of the lower Valanginian (Eristavi, 1957; Lysenko, 1964). The only place, where E.Yu. Baraboshkin established based on ammonites the lower Valanginian Pertransiens Zone (Atlas of the Cretaceous…, 1997; Arkadiev et al., 2002), is section of the Bel'bek Valley in the southwestern Crimea. Even here, nevertheless, the Berriasian–Valanginian boundary cannot be defined precisely, because the Euthymiceras–Neocosmoceras Beds correlated with the Boissieri Zone and beds with ammonites of the Pertransiens Zone are separated by carbonate and quartz conglomerate strata barren of ammonites and conventionally attributed to the Berriasian. Deposits with ammonites of the Otopeta Zone are established in the Kacha and Bodrak river basins of the southwestern Crimea (Baraboshkin and Mikhailova, 2000), where they discordantly overlie the Tavricheskaya Group, and concrete position of the Berriasian–Valanginian boundary is problematic here as well. In the Crimean Mountains, species *T. alpillensis* and *F. boissieri* have not been found as yet in association with ammonites of the lower Valanginian Otopeta or Pertransiens Zones (Baraboshkin, Mikhailova, 2000), and it would be motiveless therefore to support or disprove reasonably the resolutions of the "Kilian Group".

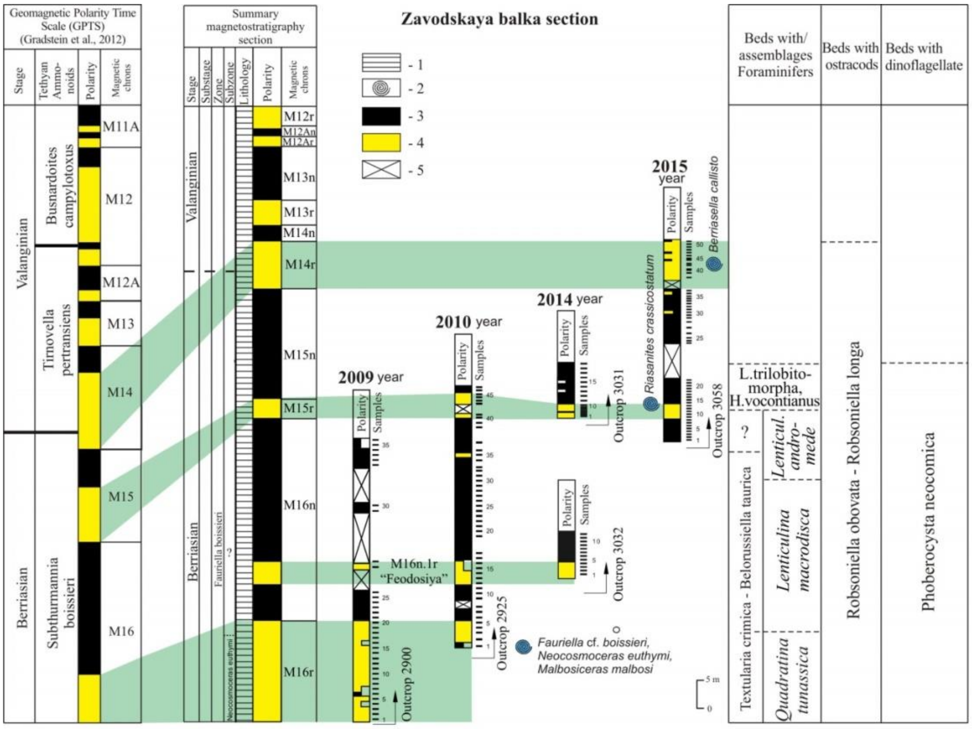

Fig. . Composite section of Berriasian - Valanginian of Zavodskaya balka (1 - clays; 2 - ammonites; 3- normal, 4 - reverse; 5 - missing data.)

In 2009-2015 years the authors studied the Upper Berriasian "Zavodskaya Balka" section (Feodosiya, Crimea) (fig. 1) (Arkadiev et al., 2010, 2015; Guzhikov, Bagaeva, Arkadiev, 2014). Among results of these studies, there was a discovery of ammonites *Neo-*

cosmoceras euthymi, *Fauriella* cf. *boissieri*, *Malbosiceras malbosi* in the upper part of the succession. This assemblage is characteristic for Neocosmoceras euthymi Subzone of the Mountaineous Crimea (Arkadiev et al., 2012) corresponding to standard Tethyan Malbosiceras paramimounum Subzone of the Boissieri Zone (Reboulet, 2014). Ammonites classified as *Riasanites crassicostatum* were discovered in 2014 in the upper part of the section, 40 m above the *Neocosmoceras euthymi* finds. In 2015, ammonites *Berriasella callisto* were founded above *Riasanites crassicostatum* finds. In this way, based on ammonites first substantiated the presence of a single sequence all previously proposed for the Crimean Mountains Upper Berriasian biostratons, including Crassicostatum Subzone and Beds with Jabronella cf. paquieri and Berriasella callisto (Arkadiev et al., 2012). Species *Berriasella callisto* may indicate the presence of Otopeta Subzone, because in Spain sections it known from this stratigraphic interval (Tavera, 1985). By biostratigraphic correlation, based on foraminifers, ostracods and dinocysts, the studied section is an age analogue to upper Berriasian — lower Valanginian of standard Tethyan scale. The palaeomagnetic column presents an alternating polarity. The magnetic chrons analogous to the M15 and M14 are identified in it. By magnetostratigraphic correlation, the studied section there is an age analogue of the Berriasian—Valnginian boundary (Otopeta Subzone and Pertransiens Zone). The existence of the M16n.lr subchron ("Feodosiya") is confirmed.

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3-D geological model of Jurassic deposits from the Lublin Basin, E Poland

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The 3D geological model of Jurassic deposits from the Lublin Basin is a part of the 3-D model of the region comprising the geological profile from Ediakarian to Quaternary. The model has been recently constructed in the Polish Geological Institute – NRI as a part of the program of sedimentary basins modeling by a team consisting of regional geologists, geophysicists and experts in modeling. Mapped regional structure covers the area of 260x80 km located between Warsaw and Polish-Ukrainian border, along NW–SE-trending margin of the East European Craton. Within the basin, the Paleozoic beds with coalbearing Carboniferous and older formations containing hydrocarbons and unconventional prospects are covered unconformably by Permo-Mesozoic and younger rocks. Vertical extent of the regional model is set from topographic surface to -6000 m ssl and at the bottom includes some Proterozoic crystalline formations of the craton. The project focuses on internal consistency of the models in different scales – from basin (small) scaleto field-scale (large-scale). The models, nested in the common structural framework, are being built with regional geological knowledge, ensuring smooth transition in the 3D model resolution and amount of geological detail.

Modeled Jurassic strata reaches 700 m of thickness in the western part of area. Overmost of the area, they overlie the Palaeozoic (Carboniferous, Devonian) and are covered by the Upper Cretaceous.The first stage of the modelling process was a data integration and an update of the database with geological information derived from boreholes and geophysical interpretation. Structural modelling of top and base of Jurassic was based on 2D seismic interpretation and data from 420 wells. Internal stratification of the units was modeled with borehole data only. In order to make the detailed Jurassic model, data inspection and verification was done for selected 163 wells, of which 155 included Jurassic deposits. The parameters that were used to build the model comprised stratigraphy, well picks of layers, lithology and depositional environment interpretation. For most well profiles we used chronostratigraphic record from the Boreholes section of the Central Geological Database (http://otworywiertnicze.pgi.gov.pl/). Borehole data and geophysical logs permitted to correlate tops and bases of Lower, Middle and Upper Jurassic deposits. Additionally, formal lithostratigraphic units (Formations) of Lower and Upper Jurassic were distinguished. In 56 boreholes, units from CBDG database were used and in 99 boreholes, formations were identified on the basis of geophysical logs and description of the cores contained in archival record. Also, thickness of individual lithological types – based on data from geophysical log interpretation and core descriptions and cutting samples from all 155 boreholes – were included in the model. Joint analysisof all available literature data and own research and observations permitted to interpret depositional environments and connect them to litho- and chronostratigraphic units in individual wells. Data relating to porosity and permeability of Jurassic deposits, derived from the analysis of core and geophysical logs, were also included in the model database.

Structural arrangement of the Lublin basin has been analyzed on about 1000 2-D seismic lines, where selected seismic horizons have been traced in the entire depth of the model. For Jurassic the depth and geometry of the top and base as well as the presence and shape of faults displacements were interpreted from the seismic. Thus, top and bottom of Jurassic as well as internal horizons were characterized in much greater detail than would be possible with borehole data alone.

Final model was based on the geological conceptual outlines of the Lublin Basin, well data, well logs and seismic data interpretations, calibrated to model resolution and spatial extension and corrected for known depositional features, hiatuses etc. It shows spatial distribution of the chrono- and lithostratigraphic units, depositional environments, lithofacies and petrophysical parameters. Lithofacies model of the Upper Jurassic was built in three steps from the most general to the most detailed. First, the lithostratigraphy was modeled in chronostratigraphic framework. The chronostratigraphic domain was discretized in the gird of 250x250 m horizontal dimension. Vertically the grid is discretized accordingly to total unit thickness and generally grid layers do not exceed 10 m. The resulting grid was used to model depositional environments and finally lithofacies were modeled. The model can be used to predict and communicate the lithology and other attributes of sedimentary rocks at any point or at any line section. It may help to observe changes of structural and thickness trends of formations and to determine the anticipated depositional environments and petrophysical properties in the profile of the Jurassic. Detailed structural characteristics of the layers in the entire model above and below Jurassic show trends of subsidence, what allows identifying zones with possible synsedimentary active faults. The model was created as a future multidimensional platform for common research and studies related to sedimentary rocks attributes and petrophysical properties. Its generalized image will be presented in the web application available to public and detailed version will be available on demand with dedicated 3D viewer application.

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Revealing what has been overlooked - petroleum potential of the Jurassic deposits in Central Poland.

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The Southern Permian Basin covers a large geographic area of northern Europe including the UK, Denmark, Netherlands, Germany and Poland. For many operators it has been a heartland for hydrocarbon production from the Rotliegend sandstones and overlying Zechstein carbonates. However, in this mature petroleum basin many exploration opportunities still remain within the Mesozoic succession. Jurassic strata containing both, excellent source and reservoir rocks, are of the main interest.

The Jurassic petroleum system is very well recognized in Germany and Netherlands. Most of the oil found in Mesozoic reservoirs was generated from the Lower Jurassic (Toarcian) Posidonia Shale Formation, which is best developed in Netherlands, Germany and Poland (Ciechcinek Formation equivalent). Additional source rocks of great significance can be found in the Middle and Upper Jurassic deposits, with the Upper Kimmeridgian/Tithonian Clay Formation (Pałuki Formation equivalent) being one of the most important. Reservoir horizons are present in clastic units of the Lower and Middle Jurassic as well as carbonates of the Upper Jurassic strata. Abundant Jurassic oil and gas accumulations in Germany and Netherlands are connected with salt tectonics, that contributed strongly to trap formation. Furthermore salt structures frequently provide extra seal for oil and gas reservoirs (Lott et al., 2010).

In the Polish part of the Southern Permian Basin the exploration for hydrocarbons in the Jurassic section (thickness: 900–2035m) has until now been neglected. Although well recognized by numerous deep wells, Jurassic deposits were never the main target for hydrocarbon exploration. Moreover, they were considered as having poor petroleum potential. The revision of an archive well data supported by a set of brand new geological and geochemical analyses, revealing numerous oil and gas shows in the Jurassic layers, as well as good reservoir and source rock properties of Jurassic horizons, indicate that the petroleum potential of Jurassic deposits could have been underestimated (Grotek, 2008; 2012 a and b).

The Lower Jurassic succession is usually developed as alternating sandstones, siltstones and claystones deposited in fluvial, deltaic to shallow shelf and lagoonal environment (Feldmann-Olszewska, 1997a). Measured porosities of the Lower Jurassic sandstones in the revised wells range from 5 to 15%. Permeabilities are up to 70mD, with the most frequent values not exceeding 10mD.

The Middle Jurassic deposits consist of alternating sandstones, siltstones and claystones deposited in a siliciclastic shelf environment (Feldmann-Olszewska, 1997b). Porosity values of reservoir horizons range from 3–15%. Permeabilities are up to 78mD.

The Upper Jurassic strata are dominated by limestones and marls deposited in a broad carbonate shelf environment (Lott et al., 2010). The topmost part of Upper Jurassic consists of alternating siltstones, shales, marls and marly shales. Porosities of carbonate reservoirs are up to 27%, with permeabilities ranging from 0.1 to 10mD (25mD maximum).

The geochemical studies on the quality of source rocks in the Jurassic section of Central Poland indicate at least two intervals with a significant potential for hydrocarbon generation. The lower one composed of the Middle Jurassic (Aalenian, Bajocian and Bathonian) claystones, mudstones and shale and the upper one composed of the Upper Jurassic (Upper Kimeridgian/Tithonian – Pałuki Formation) marly shale.

The Middle Jurassic source interval reflects increased values of the total organic carbon content (TOC) within the few hundred metres thick interval. Large part of the section (Bajocian and Bathonian) shows TOC in the range between 1.5 and 3% and the type-III kerogen as a dominant organic matter. However, the lowermost 50–60 metres (Aalenian) is organically much richer, with TOC up to 13%. The measured thermal maturity indicates the oil window with vitrinite reflectance values up to 1.1% (Grotek, 2008; 2012 a and b).

The marly shale of Pałuki Formation has very good and excellent generative potential, revealing the TOC values of around 3% on average, with some peaks reaching even 11%. The organic matter is composed mainly of the type-II kerogen. All analysed samples reflect the thermal maturity at the level of early oil window (0.55–0.65% Ro). Thickness of the net pay zone within the Pałuki Formation is estimated at 70–150 m.

This needs to be emphasized that all analysed wells were drilled on the structural heights surrounding the significantly deeper (500 m) part of the regional syncline. Hence, the considered source intervals likely reached much higher level of maturation in that deeper section. Thermal maturity modelling suggests that both the Middle Jurassic and the Upper Jurassic source rocks entered the gas window (1.3–1.4%Ro) and oil window (0.9–1.1% Ro), respectively. The effective oil generation could have occurred at the depth of 3000 m, while generation of dry gas started around 500 m deeper.

Considering the presented results, the quality of analysed source rocks is clearly enough to generate and expel hydrocarbons. Despite the lack of conventional discoveries, there is a quite high potential for exploration of unconventional petroleum systems (shale gas and shale oil). Moreover, oil and gas accumulations in traps related to salt domes still cannot be excluded.

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Posters:

J/K boundary interval in Siberia: Litho-, bio-, magneto-, and chemostratigraphy

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To find the optimum solution concerning the Berriasian GSSP, it would be good way to define the most preferable level or, at least, interval for determination of the GSSP in each region where the J/K boundary deposits have been recorded.

The J/K boundary beds are observed in a huge territory of Siberia; they are dominated by terrigenous rocks of marine and continental geneses, which are of very different lithologic compositions and belong to the upper part of the regional Bazhenovo Horizon. With any of the accepted markers which are under examination of Berriasian Working Group, the J/K boundary in Siberian sections will be within the Bazhenovo Horizon.

The J/K boundary interval in Siberian sections is now well described by a system of parallel (independent) zonal scales based on different fossil groups (ammonites, belemnites, bivalves, microfauna, and microphytofossils). However, there are no biostratigraphic markers here which permit a direct correlation between Boreal and Tethyan sections. If the Berriasian GSSP will be determined in Mediterranean sections, the identification of this level in Siberian sections will be possible only based on a combination of data obtained by palaeontological and nonpalaeontological methods of stratigraphy (bio-, chemo-, magnetostratigraphy). Unlike the Tithonian–Berriasian boundary, only the Volgian–Ryazanian boundary in Boreal sections has reliable bioevent markers. In Siberia it was assigned to the base of the *Chetaites sibiricus* or *Praetollia maynci* ammonite zones.

The J/K boundary traditionally defined at the base of the Jacobi Zone is positioned in Siberia above or below or at the point of connection with the base of the *Craspedites taimyrensis* ammonite Zone according to magnetostratigraphic data (Houša et al., 2007; Bragin et al., 2013) and the most recent models of correlation between Siberian and Western Mediterranean sections (Rogov et al., 2015; Schnabl et al., 2015; Shurygin & Dzyuba, 2015). The so-called traditional basal Berriasian interval (between the bases of the Jacobi and Grandis subzones) corresponds in Siberia to the interval including the relevant magnetostratigraphic units, and the base of the *Arctoteuthis tehamaensis* belemnite Zone (Fig. 1). Additionally, a positive $\delta^{13}C$ excursion was identified here in the marine carbonate (belemnites) carbon records from the beds corresponding to the upper part of the basal Berriasian interval (Dzyuba et al., 2013). This excursion is comparable to analogous excursions detected in Europe, and we consider it an important marker for interregional correlation of the J/K boundary deposits. The composite Tethyan $\delta^{13}C$ curve that is based on bulk carbonate analyses is relatively smooth as the result of the mixing of different biogenic components, which may also be of different age (the averaging effect).

The best integrated stratigraphic study of the J/K boundary interval in Siberia was performed for the Nordvik section located in northern East Siberia (see Rogov et al. in the present Abstract Volume). In Western Siberia, the most stratigraphically-complete section spanning the both Tithonian–Berriasian and Volgian–Ryazanian boundaries is located in the foothills of the Northern Urals on the Maurynya River. Ammonite-based and belemnite-based biostratigraphy, and high-resolution C- and O-isotope stratigraphy have been clarified for the Maurynya section (Dzyuba et al., 2013). Additionally, the first Sr isotope data from this section were recently reported (Izokh et al., 2015).

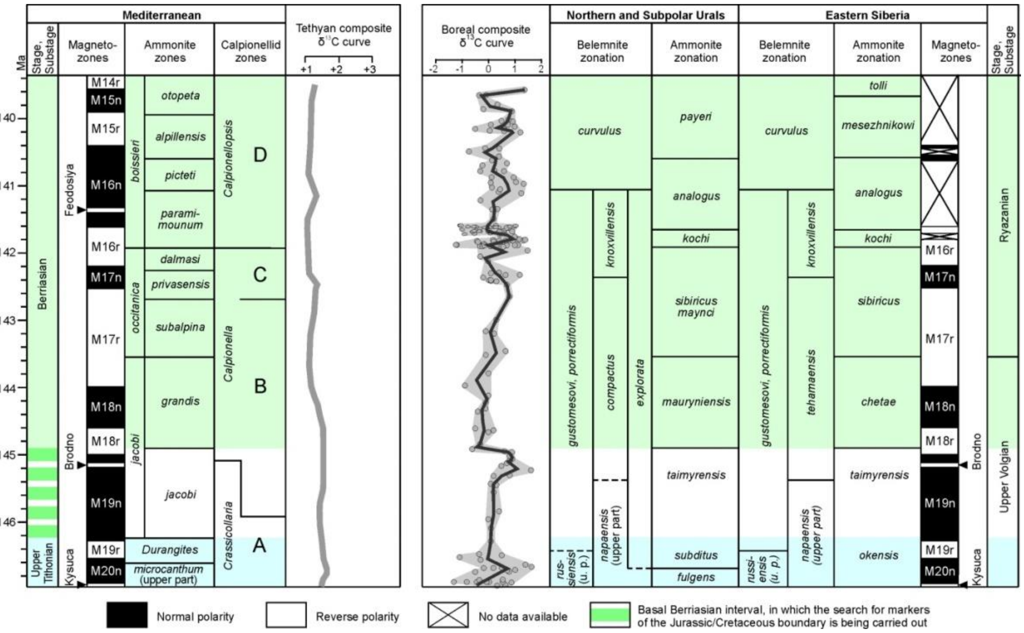

Fig. 1. Boreal (Siberian) bio-, magneto- and chemostratigraphy, compared with the Tethyan (Mediterranean) successions (after Dzyuba et al., 2013 and Shurygin & Dzyuba, 2015).

If a set of parallel biostratigraphic scales is applied with regard to palaeomagnetic and isotopic events, this can ensure quite a narrow uncertainty interval for the position of the J/K boundary in Siberian sections (Shurygin & Dzyuba, 2015). The least interval of the uncertainty of the position of this boundary in Siberian sections will be ensured by the selection of one of two markers: biostratigraphic (base of the Grandis Subzone) or magnetostratigraphic (base of the M18r magnetozone). This is a contribution to the IGCP608 and programs 30 and 43 of the Presidium of the RAS.

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Lithology and microfacies of the Jurassic–Lower Cretaceous Nižná Limestone Fm in the Krásna Hôrka Quarry (PKB)

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The Pieniny Klippen Belt is a tectonic melange representing the boundary between the Outer and Central Western Carpathians. Within this melange, Jurassic and Cretaceous sedimentary rocks from deep-water (Kysuca Basin) to shallow-water environments (Czorsztyn Unit) occur. The Nižná Unit was originally distinguished by Scheibner (1967) as being a particular subunit of the Kysuca Unit of the Pieniny Klippen Belt. The Jurassic/Lower Cretaceous development of both units is approximately the same, consisting of Callovian-Oxfordian radiolarites (Czajakowa Radiolarite Formation), Kimmeridgian red nodular limestones (Czorsztyn Limestone Formation) and Tithonian-Lower Cretaceous white Calpionella and Nannoconus limestones with cherts (Pieniny Limestone Formation), (Józsa & Aubrecht, 2008). Instead of dark grey marls of the Koňhora Fm which are typical for the Kysuca Unit, organodetritic limestones termed as the Nižná Limestone Fm (Scheibner 1967) are present in the Nižná Unit. This Urgonian-like limestone was originally mapped as Middle Jurassic crinoidal limestone (Andrusov, 1931).

According to the planktonic foraminiferal assemblages, the age of the Nižná Limestone Fm is mostly Aptian (Scheibner, 1967; Mišík, 1990). Repeated submersion of the Nižná Unit occurred in this time, as in the Czorsztyn Unit. The processes that led to the emergence of the Nižná Unit had most likely already commenced in the Hauterivian, as shown by some occurrences of coarse-grained turbidites and mass-flow deposits in Hauterivian marls of the Kysuca Unit. These data imply that the Nižná Unit can be placed in the Kysuca sedimentary area on the northern side of the Kysuca Trough, closer to the Czorsztyn Swell (Józsa & Aubrecht, 2008). Klippens with thick-bedded, light grey to reddish, fine- to coarse-grained organodetritic limestone of the Nižná Limestone Fm can be traced in the Orava territory between the Sedliacka Dubová village and the town of Tvrdošín.

Microfacies of the Nižná Limestone Fm in the Krásna Hôrka Quarry (Fig. 1) is represented mainly by biodetritic, relatively coarse-grained, poorly sorted packstone, grainstone to rudstone. Boundstones with silicified corals were also found. The bioclasts are commonly rounded, micritized or silicified and consist of echinoderm particles (crinoid ossicles, echinoid spines, fragments of bryozoans, bivalve (mostly oysters and rudists), gastropod, brachiopod shells and rare fragments of dasycladaceans and coralline algae. *Cyclagelosphaera. brezae, Rucinolithus wisei, Cyclagelosphaera deflandrei* and *Watznauria barnease* are most common in calcareous nannoplankton assemblage. Foraminifers are also present, mainly as bad preserved fragments of orbitolinid foraminifers (*Orbitolina sp.*), to a more extent there are miliolids, lagenids, textularids (*Sabaudia minuta* (Hofker) and agglutinated biserial forms. Rarely also planktonic forms. The grainstone varieties also contain fragments of calcareous sponges and oncoids. The bioclasts are often partly silicified.

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Fig. 1. Photo of the quarry near Krásna Hôrka village exposing the Jurassic and Lower Cretaceous sediments of the Nižná Unit.

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Detection of chrome spinels of harzburgitic provenance in the Kimmeridgian of the central Northern Calcareous evidenced Late Jurassic erosion of an obducted Neotethyan ophiolites in the southern Eastern Alps

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The causes for the Middle to Late Jurassic tectonic processes in the Northern Calcareous Alps are still controversially discussed (see Gawlick et al. 2009 for a review). There are several contrasting models for these processes, formerly invented as "Jurassic gravitational tectonics".

Whereas in the Dinarides or the Western Carpathians Jurassic ophiolite obduction and a Jurassic mountain building process with nappe thrusting is widely accepted equivalent processes are still questioned for the Eastern Alps. For the Northern Calcareous Alps an Early Cretaceous nappe thrusting process is widely favoured instead of a Jurassic one, obviously all other Jurassic features are nearly identical in the Northern Calcareous Alps, the Western Carpathians or the Dinarides. In contrast, the Jurassic basin evolution processes as best documented in the Northern Calcareous Alps were in recent times adopted to explain the Jurassic tectonic processes in the Carpathians and Dinarides. Whereas in the Western Carpathians Neotethys oceanic material is incorporated in the mélanges and in the Dinarides huge ophiolite nappes are preserved above the Jurassic basin fills and mélanges, Jurassic ophiolites or ophiolitic remains are not clearly documented in the Northern Calcareous Alps.

Here we present chrome spinel analyses of ophiolitic detritic material from Kimmeridgian allodapic limestones in the central Northern Calcareous Alps. The geochemical composition points to a harzburgite provenance as known from the Jurassic suprasubduction ophiolites well known from the Dinarides/Albanides. These data clearly evidence Late Jurassic erosion of obducted ophiolites before their final sealing by the Late Jurassic – earliest Cretaceous carbonate platform pattern.

The new data of detrital chrome spinel grains in the western central Northern Calcareous Alps result in the following conclusions (Gawlick et al. 2015):

1. Erosion of the obducted ophiolite stack started in the Kimmeridgian and not in the Early Cretaceous as previously assumed (Faupl & Pober 1991). This clearly indicates that the first thrusting event related to ophiolite obduction (upper plate) in the Northern Calcareous Alps is of Jurassic age. Additionally, in a Jurassic strike-slip tectonic environment redeposition of eroded oceanic crust cannot be expected (Frank & Schlager 2006).
2. Geochemical composition of the detrital chrome spinels points to a harzburgite provenance. The (Jurassic SSZ) ophiolites occur in a higher nappe position as the (mainly) lherzolitic (Triassic) ophiolites, as proven in the ophiolite nappe stack e.g. in Albania (Mirdita ophiolites).
3. The southern Northern Calcareous Alps underwent the same Jurassic to Early Cretaceous geodynamic history as the Western Carpathians, the Dinarides, and the Albanides/Hellenides with Middle to early Late Jurassic ophiolite obduction and the onset of erosion of the ophiolitic nappe pile in the Kimmeridgian (compare Gawlick et al. 2008, Missoni & Gawlick 2011). A Kimmeridgian to earliest Cretaceous carbonate platform evolved on top of the nappe stack including the obducted ophiolites (Schlagintweit et al. 2008). Erosion of the obducted ophiolite nappe stack started in the Kimmeridgian and lasted until the late Early Cretaceous (Aptian) (Krische et al. 2014), but interrupted by the (Late) Kimmeridgian to earliest Cretaceous platform evolution, which protected the ophiolite nappe stack against erosion during that time span (Gawlick et al. 2009). In the Early Cretaceous also this platform was widespread eroded and can only be reconstructed by pebble analysis from mass flows in the Lower-Upper Cretaceous sedimentary successions.

The Northern Calcareous Alps are therefore part of the mountain building process in the northwestern Tethyan realm. As this orogen resulted from the closure of the western part of the Neotethys Ocean, but this orogenesis do not belong to the Cimmerides (as defined as a result of the closure of the Palaeo-Tethys: e.g. Sengör 2005). Therefore Missoni & Gawlick (2011) invented the term Neotethyan Belt as part of the Tethysides for this orogen.

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Tithonian–Berriasian magnetostratigraphy in the Northern Calcareous Alps (Leube quarry, Northern Calcareous Alps, Austria) – first results

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Unlike the Western Carpathians, Tithonian and Berriasian magnetic stratigraphy has been never applied so far in the Northern Calcareous Alps. All formerly investigated sections are localized in the Tirolic units and they reveal multiphase, syntectonic remagnetization (Pueyo et al., 2007). The only locality investigated outside the Tirolic Unit is the Nutzhof section in the Gresten Klippen Belt, near Wien, where J/K boundary was magnetostratigraphically documented (Lukeneder et al. 2010).

We present the first magnetostratigraphic and magnetic susceptibility results from the Tithonian – Berriasian succession of the Leube section (central Northern Calcareous Alps, Austria). The Leube section (Tirolicum) is very well accessible and outcropped in an active quarry. It comprises succession of the Tithonian to Valanginian hemipelagic limestones and marls of 340 m thickness. Its age was estimated on the basis of calpionellids and ammonites from the Upper Tithonian (Crassicollaria intermedia Subzone) to lowermost Valanginian (boundary between Calpionellopsis and Calpionellites Zones) (Krische et al., 2013; Bujtor et al., 2013). The succession contains in several levels mass-flow deposits, especially frequent in the Upper Tithonian with decreasing intensity up to the the Tithonian/Berriasian boundary interval (Oberalm Formation + Barmstein Limestone). The upper part of the Oberalm Formation is represented by well bedded greenish marly limestones interbedded with marls. The Schrambach Formation starts in the upper part of the Lower Berriasian with marls intercalated with cherty limestones and – scarce – polymictic turbidites. A peculiar lithological feature is the presence of red carbonate beds in the upper part of the Lower Berriasian (Gutratberg beds), between Remaniella and Elliptica Subzones (Krische et al., 2013). Important to note is the decrease in the sedimentation rate and the change to more condensed sedimentation. This can be also documented by a negative isotope excursion.

Pilot paleomagnetic investigations revealed that the rocks, although partially remagnetized, retained their primary magnetization and are suitable for a magnetostratigraphic study. Clockwise rotation of the paleomagnetic vector is observed, which confirms the previously estimated trend of Mesozoic paleodeclinations (e.g. Mauritsch and Márton, 1995). The project is performed within Austrian – Polish bilateral cooperation for the years 2015 – 2017. Future investigations will be focused on integration of bio-, magnetostratigraphy, magnetic susceptibility and chemostratigraphy in order to evaluate timing of important paleoenvironmental events (tectonic and climatic vs. eurybathic changes).

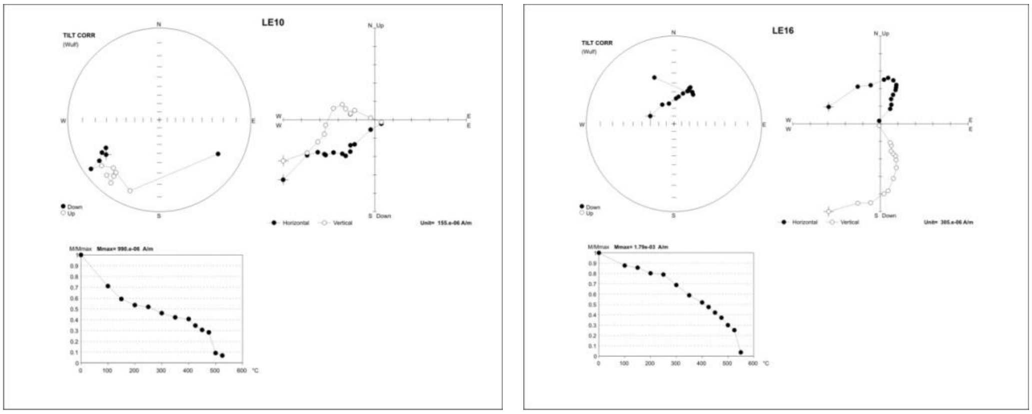

Fig. 1.: Thermal demagnetization of typical specimens of reversed polarity (upper diagram) and normal lower diagram. Upper left: stereographic projection of demagnetization path (after bedding correction); upper right: orthogonal projection of demagnetization path (after bedding correction); lower left: natural remanent magnetization (NRM) decay curve during thermal treatment.

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Unconformity between the Triassic and the Jurassic in the High-Tatric Unit, Tatra Mountains.

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The Triassic/Jurassic boundary interval and the Jurassic were periods of intense palaeogeographical changes in the Alpine-Carpathians domain. As a result of rifting processes and opening of new ocean basins, a prevailing extensive tectonic regime led to disintegration of Triassic carbonate platforms occupying the northern part of the Western Tethys (Michalík and Kováč, 1982). The tectonic activity contributed to form isolated fault-bounded blocks, leading to a horst-graben morphology (Plašienka, 2012). Drowned carbonate platforms were formed on subsiding areas, on which the shallow-water sediments were replaced by pelagic deposits. Isolated platforms were formed on elevated blocks, on which shallow-water sedimentation continued. In many places of the Alpine-Carpathians domain, the sedimentary record of the stratigraphic interval related with the disintegration of Triassic platforms is incomplete and contains a number of stratigraphic gaps.

The Tatra Mountains are the northernmost of the so-called core-mountains of the Central Western Carpathians. The sedimentary cover of a Variscan crystalline massif consists of Permo-Mesozoic rocks, which are exposed in two successions − Sub-Tatric and High-Tatric, differing in completeness and facial development (Lefeld, et al., 1985). The High-Tatric succession is composed of three major tectonic units: Kominy Tylkowe, Czerwone Wierchy and Giewont (Kotański, 1961). The deposits of the Kominy Tylkowe (autochthonous) unit rest directly on the crystalline basement or form the so-called paraautochthonous folds, however, palaeogeographically representing the same region. The Czerwone Wierchy and Giewont (allochthonous) units have been detached from the basement and overthrusted northwards over the Kominy Tylkowe Unit to form High-Tatric nappes. In the High Tatric succession, a number of stratigraphical gaps occur at the Triassic/Jurassic boundary interval and within the Jurassic, which are expressed as unconformity surfaces. In various parts of the area the Triassic is directly overlain by the Dudziniec Formation (Sinemurian-Bajocian – sandy-crinoidal deposits), the Smolegowa Formation (Bajocian − white crinoidal limestones), the Krupianka Formation (Bathonian – red crinoidal limestones, nodular limestones and ferruginous limestones) or the Raptawicka Turnia Formation (Callovian-Hauterivian – wavy bedded, nodular and massive limestones). Moreover, the Bajocian and Bathonian sediments are limited to isolated, lenticular bodies or even just to infillings of neptunian dykes penetrating the Triassic (Łuczyński, 2001; 2002).

Based on the analysis of spatial relations between particular Jurassic formations and of the stratigraphic gaps between them, four main unconformities have been distinguished. In stratigraphic order these are: base of the Dudziniec Formation (erosional unconformity), base of the Smolegowa Formation (penacordance or paraconformity), base of the Krupianka Formation (erosional unconformity) and base of the Raptawicka Turnia Formation (drowning unconformity).

The unconformity at the base of the Dudziniec Formation occurs only in the Kominy Tylkowe unit, to which the Dudziniec Formation is limited. The contact between the Triassic and the Lower Jurassic is uneven and has a clearly erosional character. This unconformity is a result of two main processes: (i) emersion and erosion of the whole High-Tatric Unit in the Late Triassic and (ii) abrasion during the Liassic transgression, which took place only in the Kominy Tylkowe area. The unconformity at the base of the Smolegowa Formation occurs in all the High-Tatric units and generally has an erosional character. In scale of particular exposures, the Triassic/Jurassic contact runs parallel to the bedding in the Triassic. In the Giewont Unit, in places in which the Triassic/Jurassic boundary can be traced along continuous transects on longer distances, the Bajocian rests westwards on consecutively older Triassic strata. This indicates a penacordant contact. The Smolegowa Formation is usually limited to lenticular bodies of limited lateral extend or just to infillings of neptunian dykes, however in some places its thickness reaches up to 20 m. This thickness diversity is a result of syndepositional faulting, which took place in the Bajocian and led to an increase of accommodation space in some areas. The unconformity at the base of the Krupianka Formation shows a great spatial variability. In particular outcrops the Bathonian rests on the Anisian, the Aalenian or the Bajocian. The occurrence of the Bathonian is limited to isolated, lenticular bodies with maximum thickness reaching 5 m in the autochthonous unit. In some areas the Bathonian deposits can be found only in neptunian dykes penetrating the Triassic. Erosional discontinuity surfaces, commonly underlined by ferruginous coats, occur also within the Krupianka Formation. This suggests that the unconformity at the base of the Krupianka Formation formed as a result of several episodes of erosion, emersion and non-deposition. The unconformity at the base of the Raptawicka Turnia Formation also has a generally erosional character. In most areas, the stratigraphic gap at the base of the Raptawicka Turnia Formation embraces the Bajocian/Callovian or the Bathonian/Callovian interval, however in some places (especially in the Czerwone Wierchy Unit), the gap is larger and the Callovian rests directly on the Triassic. The onset of sedimentation of the Raptawicka Turnia Formation deposits marks an abrupt transition from shallow-water settings into deep-water pelagic environments This indicates that the unconformity at the base of the Raptawicka Turnia Formation is a drowning unconformity, and formed due to the drowning of a carbonate platform that took place after sedimentation of the Krupianka Formation deposits .

The present complex architecture of the contact between the Triassic and the Jurassic in the High Tatric Unit is an effect of overprinting of several distinct processes including tectonic activity, non-deposition and erosion. A detailed analysis of the nature of the described unconformities, and of the geometry and spatial distribution of the overlying and underlying strata allows to present a reconstruction of the development of the High-Tatric Unit at the Triassic/Jurassic boundary interval.

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Organic carbon-rich shales within coarse-grained lithofacies of Jurassic–Cretaceous transition at the Russian Platform

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Organic carbon-rich shale, intercalating with sandy sediment are uncommon and can not be explained by traditional models, based on anoxia appearance. In the Central Russia very thin but extremely carbon-rich shale horizons are present within shallow-water coarse-grain Middle Volgian – Ryazanian sequence (6-7 m). This transitional Jurassic–Cretaceous interval is quite representative in Mar'evka and Kashpir sections, located in Ul'anovsk and Samara regions (Rogov et al., 2015).

In both sections the sequence is built of fine-grained sandstone lithofacies, commonly muddy and containing glauconite or siliceous sponge spicules. The dominance of the components is observed at the certain intervals, so glauconitic sandstone composes Middle Volgian Virgatus and Nikitini Zones, while spiculites and gaize-like glauconite-quartzose sandstone, cemented with chalcedony or calcite, are common within Upper Volgian and Ryazanian intervals. Lamination is not well preserved in the sandstone due to bioturbation, but incomplete mixing of constituents, observed in thin sections, apparently point to it. Numerous levels of reworked phosphorites, belemnites or shells condensation are the typical for the sequence. The deposition of upper Middle Volgian – Ryazanian lithofacies took place in the nearshore shelf environments, below fair-weather wave base, but storm currents were the important processes. The low thickness of stratigraphical units (from 0,3-0,5 to 1,5-2 м for the one Zone), combined with almost complete ammonite record, indicates a strong stratigraphical and sedimentological condensation, caused by general siliciclastic starvation and partial removing of sediment during a hydrodynamic events.

Two distinct black shale horizons were found within the sequence. The lower one is about 2-5 cm in thickness, located in glauconitic sandstone of Mar'evka section and corresponded to Nikitini Zone. The thicker black shale horizon (10-12 cm), enriched in silica components (spicules and, probably, radiolarians) is lying within gaize-like sandstone at the base of Ryazanyan interval, detected in Kashpir section. Previously it has been suggested as of fresh-water origin (Braduchan et al., 1989), however, occurrence of ammonites (but quite rare) clearly point to marine environments.

Both shale horizons have sharp bases, and its tops are deeply truncated by Planolites burrows, filled by sandy material. Such characteristics are indicative for breaks in sedimentation with a possible removal of sediment. This is consistent with limited lateral extension of studied black shale horizons and its pinching at relatively close distance. However, the presence of similar sandstone above and below of the black shales, as well as a distinct contamination of shale tops by scattered sandy material, suggest that a nearshore deposition of coarse-grained material continued to be a background.

Rock-Eval parameters of black shale are quite similar and show a low maturity and high source potential (Tab. 1).

In terms of sequence stratigraphy, the models of transgressive black shale (BT) and black shale at the maximum flooding (MT) are commonly involved (Wignall, 1991; Wignall and Newton, 2001, Tyson, 2005, etc.). Testifying them for the coarse-grained sequence of Jurassic–Cretaceous transition, its limited applicability can be concluded. The improved transgressive model, exclusively proposed for nearshore black shale varieties (TN), based on case study of Kimmeridgian-Tithonian sandy sequence in Buolonnais, northern France (Wignall, Newton, 2001) seems to be more appropriate.

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Sample	S1	S2	Tmax	HI	OI	TOC
Black shale of Nikitini Zone in Mar'evka – lower	4.01	184.33	402	444	58	41.53
–upper	1.38	78.74	406	399	56	19.72
Black shale at the base of Ryazanian interval in Kashpir section – lower	1.66	46.7	421	278	132	16.81
–upper	0.86	14.39	422	163	159	8.8

Tab. 1. Rock-Eval parameters of black shale.

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Time averaging of Holocene cephalopod assemblages in condensed sediments and implications for the fossil record

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Shells of chambered cephalopods tend to be prone to significant postmortem transport and biostratigraphic condensation. However, direct estimates of spatial and temporal resolution of death and fossil cephalopod assemblages are absent. We show that amino acid racemization they are time-averaged at centennial scales in bathyal environments characterized by extremely reduced sedimentation rates off New Caledonia. The few shells that are thousands of years old are represented by highly degraded relicts. Therefore, although temporal resolution of nautiloid assemblages is too coarse for fine-scale paleoecological analyses, it is sufficiently high relative to the time scale of cephalopod evolutionary turnover. Dead shells occur in sediments at water depths (300 to 400 m) that are close to where living *N. macromphalus* are most common. Therefore, dead shells of this species accumulate with a relatively high bathymetric fidelity. The mixture of extant calcitic foraminifers and foraminifers that went extinct during the Pleistocene suggests that foraminifers in oozes found within several *Nautilus* shells are biostratigraphically time-averaged. We suggest that in the absence of early seafloor cementation, disintegration rates of aragonitic cephalopods in oozes are relatively high and do not allow formation of biostratigraphically-condensed assemblages, in contrast to significantly condensed assemblages with calcitic foraminifers.

Bio- and magnetostratigraphy of the Upper Tithonian-Lower Berriasian in southern Ukraine

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The lowest Cretaceous on the south coast of Ukraine has been known since the first ammonite studies of Retowski (1893). Since 2000, our study has focussed on SE Crimea, with investigation of magnetostratigraphy, ammonites, calpionellids, forams and nannofossils. Between Theodosia (Feodosiya) and the headland of Ili Burnu ("Cape St Ilya") there are extensive exposures in lower Berriasian strata. Above the two meters thick breccia that was formerly recognised by soviet geologists as the base of the Berriasian (Druschits, 1975), there are almost 90 metres of mudstones and microbreccia (with minor micrites), the Dvuyakornaya Formation (Permyakov et al., 1984). The so-called "Theodosia marls" come above and we have renamed them as the Mayak Formation. These micrites and marls are in part inaccessible and have an estimated thickness of around 80m. These two formations, cropping out between the eastern end of the Dvuyakornaya Bay and the town of Theodosia, yielded ammonites (Glushkov, 1997; Kvantaliani, 1999; see Arkadiev et al., 2012 for references) correlatable with western European finds (Le Hégarat, 1971). Despite the very great thickness of the Theodosia sequence, we conclude (from earlier accounts and our own collecting) that only two ammonite faunas are present-faunas assigned to the subzones of *Berriasella jacobi* (but see Frau et al., in press) and of *Pseudosubplanites grandis*. There are long intervals with no ammonites, but there are a few representatives that can tentatively be assigned to a Jacobi Subzone assemblage close above the large breccia (Arkadiev et al., 2012) and then in the lower Mayak Fm, where a richer fauna is dominated by *Delphinella* species (Jacobi Subzone) with *Berriasella*, and, finally, in the upper Mayak Fm a distinct assemblage is dominated by large *Pseudosubplanites* species (*B. grandis, B. berriasensis* etc). Unfortunately, we have been unable to achieve our aim of recognising the standard calpionellid biozonation in these sections, because of problems of preservation and reworking. However, first appearances of calcareous nannofossils can be related to magnetozones, which have been identified as a result of detailed palaeomagnetic studies (Fig. 1).

More than 280 orientated samples from dark and medium-grey mudstones, breccias, micritic limestone, and clayey micrites and marl (with an average sampling interval of about 30 cm) were subjected to the standard palaeomagnetic experimentation. Multicomponent analysis of thermal and alternating field demagnetization data reveals that the natural remanent magnetization of the samples is composed of two or three components. The most stable high-temperature component in the temperature range from 300°C to 520°C (580°C) and high coercivity component in alternating field demagnetization above 30-35 mT are towards the end point in orthogonal projections for most of the specimens (characteristic component ChRM). This component is best highlighted by the results of thermal demagnetization of mudstone, but also determined by the demagnetization of limestones and marls. In different parts of sequence, ChRM is characterized by normal or reversed polarity, which was allocated to lithologically different sediments. Experiments on magnetic mineralogy have identified magnetite (partially oxidized to maghemite) as the main carrier of ChRM. There are other weighty arguments in favour of the primary magnetization of the ChRM component. The recent suggestion of pervasive remagnetization of sedimentary rocks in Crimea and the Western Pontides during the Early Cretaceous (Çinku et al., 2013) does not apply to our study area in eastern Crimea.

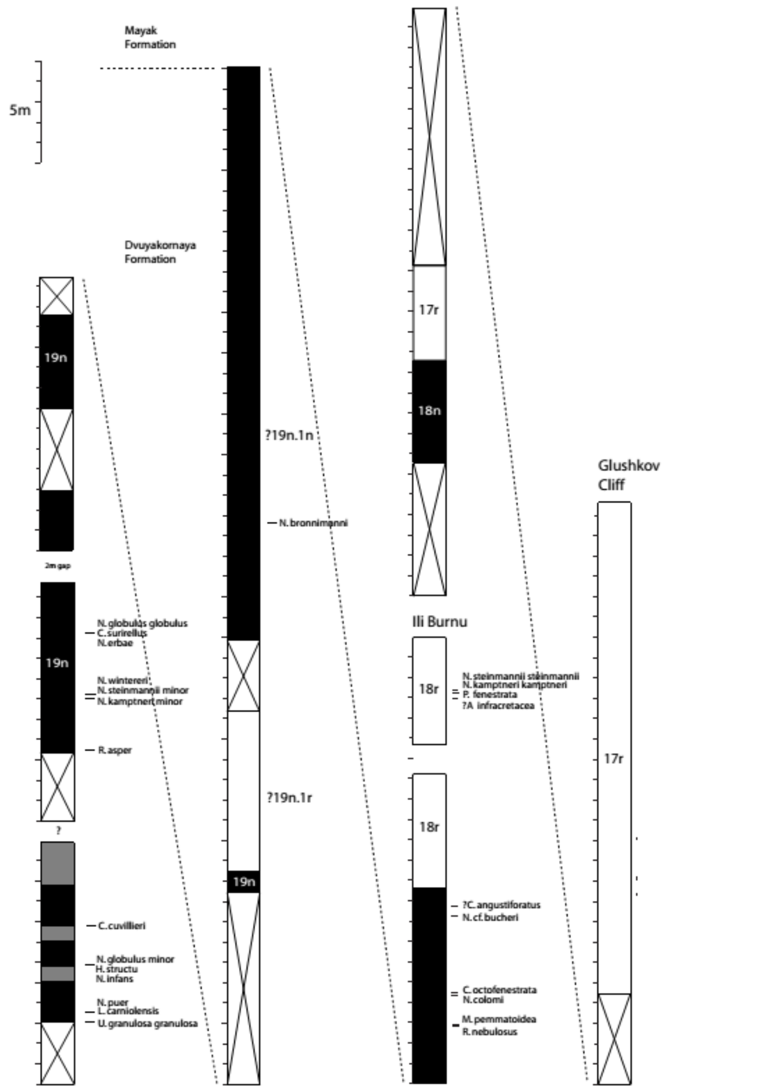

Fig. 1. The magnetozones of normal (black block) and reversed (white block) polarities related to calcareous nannofossils for Dvuyakornaya Formation and Mayak Formation. Unsampled parts are given by crossed blocks.

For the purpose of classification of magnetozones, we follow the procedure described by Man (2008). A short description of this procedure with respect to magnetostratigraphy is given by Pruner et al. (2010). As the stratigraphic position of the section was inferred from palaeontology, the polarity zones detected could be identified against the Geomagnetic Polarity Time Scale.

In the studied interval we identify magnetozones M19n, M18r, M18n and M17r. This interpretation is constrained by recent work inland at the Zavodskaya Balka (Arkad'ev et al., 2015) which identifies M16r in the Occitanica Zone to the Boissieri Zone. In addition to biostratigraphic controls of ammonites (no lower than the Jacobi Subzone and no higher than Grandis Subzone), preliminary studies have identified useful nannofossil species (Figure) which in western European sections (Casellato, 2010: Wimbledon et al., 2013) have their first appearance in M19n (e.g. *N. steinmannii minor*, *N. kamptneri minor*, *C*, *cuvillieri*, *C. surirellus*, *N. wintereri*).

The first occurrence of *N. steinmannii steinmannii* and *N. kemptneri kamptneri* is recorded in a reversal that we interpret as M18r. Our interpretations of the magnetostratigraphy differ somewhat from those of Guzhikov et al. (2012).

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WORKSHOP OF THE ICS BERRIASIAN GROUP

(JURASSIC/CRETACEOUS BOUNDARY)

JKB workshop-stratotypes:

New Bio- and Magnetostratigraphic Data at the Jurassic-Cretaceous Boundary of the Chigan Cape (Vladivostok Region, Russia)

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We have studied the well-known Chigan section (Chigan Cape, Podiapolsky Town region, coordinates 42°57'37.8"N, 123°17'47.0"E) previously referred to Berriasella jacobi ammonite zone (Konovalov, Konovalova, 1997; Sey, Kalacheva, 1999) based on ammonite findings: *Pseudosubplanites* cf. *grandis*, *P.* aff. *combesi*, *Berriasella* ex gr. *jacobi*, *Dalmasiceras*, and others. Some geologists [5] supposed that the section contains Jurassic–Cretaceous (J/K) boundary interval. Stratigraphic description of the section was accomplished by macrofauna searching and samples collecting for the paleomagnetic and micropaleontological analysis. Outcrops consist of gray poorly sorted muddy sandstones (fig. 1).

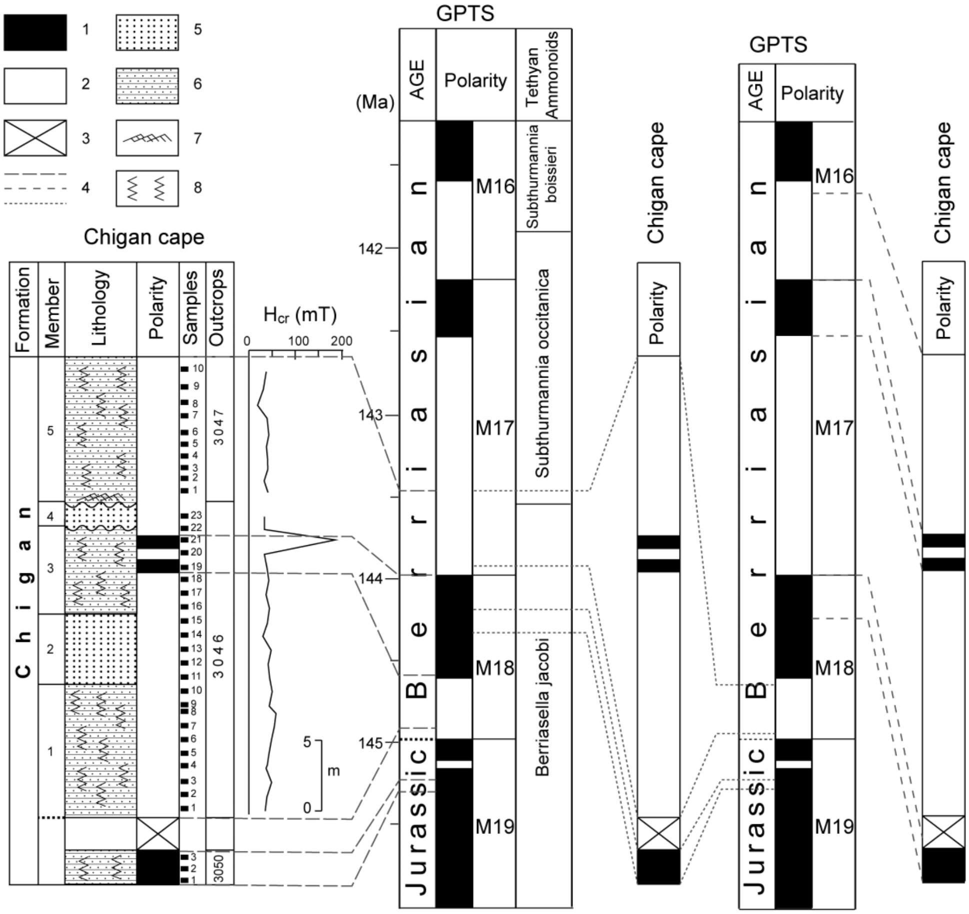

Fig. 1. Different variants of paleomagnetic correlations of the Chigan cape section with the Geomagnetic Polarity Time Scale (GPTS) (Gradstein et al., 2012). Legend: polarity: 1 – normal, 2 – reverse, 3 – no data; 4 – correlation lines of different possible correlations; lithology: 5 – sandstones, 6 – muddy sandstones, 7 – cross-bedding, 8 – bioturbation.

Most of sandstones are intensively burrowed by *Schaubcylindrichnus coronus* Frey et Howard, 1981, as a dominate ichnogenus, and also contain *Teichichnus* isp., *Thalassinoides* isp., *Ophiomorpha irregulaire* Frey, Howard et Pryor, 1978, *Phycosiphon incertum* Fischer-Ooster, 1858, *Rhizocorallium commune* Schmid, 1876, *Asterichnus lawrencensis* Bandel, 1967, *Bichordites monastiriensis* Plaziat et Mahmoudi, 1988, *Neonereites uniserialis* Seilacher, 1960, *N. biserialis* Seilacher, 1960 and some non-identified taxa (Baraboshkin, Baraboshkin, 2015). The ichnoassemblage and lithology are typical for the lower shoreface zone. A specific 1.5-m level of middle-upper shoreface massive sandstones (member 4) was recognized in the middle part of the section. It is limited by the erosional surfaces at the base and at the top. The upper surface is a transgressive surface, which is overlaid by 10-cm cross-bedded sandstone, replaced laterally by bioclastic rudstones. The visible thickness of the section is 33 m. These layers crop out in steep cliffs at a distance of 500 meters. Its bedding is nearly horizontal and they are crossed by a number of Late Cretaceous gabbro dikes. For the comparison we have studied section 3050 to the south (~1.1 km), which continues the Chigan Formation (Sey, Kalacheva, 1999) and has the same stratigraphic age (Konovalov, Konovalova, 1997).

Macrofauna. In the rockfall at the base of the section we found the remains of ammonites: an imprint of *Pseudosubplanites* cf. *combesi* Le Hégarat (fig.2) and living chamber fragment of *Pseudosubplanites* sp. In addition, in the collection of I.V. Konovalova (1993), courtesy of the "Primorgeologiya" Company, we have determined *Berriasella* cf. *jacobi* Mazenot (fig. 3) and *Pseudosubplanites* sp., also found in the debris at the base of the same sections. All these findings characterize the Lower Berriasian Jacobi Zone. It should be noted that *P.* cf. *combesi* differs from other *Pseudosubplanites* by evolute shell and prevalence of bifurcate ribs. It is also very similar to some Upper Tithonian forms (*Oloriziceras* type).

Fig. 2. *Pseudosubplanites* cf. *combesi* Le Hégarat. Collected by V.P. Nechaev, 2014.

Fig. 3. Cast of *Berriasella* cf. *jacobi* Mazenot. Collection of I.V.Konovalova, 1993, sample 15-1547. Scale bar is 1 cm.

Palynology. The plant detritus, poor preserved gymnosperms pollen and spores, rare indeterminate proximochorate – proximate cysts and dinocysts *Sirmiodinium grossii* Alberti, *Systematophora areolata* Klement and *Tubotuberella rhombiformis* Vozzhen. were found in only one sample (3046/3) of 14. This assemblage ranges from Oxfordian to Early Valanginian.

Foraminifers. It was studied 11 powders and 3 thin sections for definition of microfossils. Thin sections (№№3046-3, 3a, 10) contain hardly distinguishable cross-sections of *Reophax, Bulbobaculites, Ammobaculites, Kutsevella, Flabellammina, Triplasia*?, *Gaudryina*?, *Trochammina.* The assemblage of agglutinated foraminifers was found in the outcrops 3046, 3047, 3050. It consists of primitive (~ 30%) *Reophax* (40%), Haplophragmiidae (50%), *Trochammina* (10%) and rare species Ataxophragmiidae (3%). The comparison of the assemblages with *Gaudryina* ex gr. *gerkei, Kutsevella labythnangensis, K. praegoodlandensis* from Chigan Cape with foraminifera zones (f-zones) and beds of Spitsbergen, Pechora Basin, Siberia is difficult, because they were formed under different conditions. Chigan assemblages are closer to the shallow-water assemblages of the north Western Siberia. In Bolshekhetsky area the assemblage with *Evolutinella* spp., *Gaudryina* cf. *gerkei* was found together with ammonites of the *Taimyrensis* Zone. It has 16 species common in f-assemblage of Chigan Cape. The assemblage with *Gaudryina gerkei, Trochammina rosaceaformis*, which was found together with *Buchia* cf. *volgensis* (Lahusen) has 13 identical species (Naydenov et al., 2013). A similar pattern is observed in the Chigan Formation sandstones with *Gaudryina* ex gr. *gerkei, Kutsevella labythnangensis, K. praegoodlandensis.* The section 3050 contains “Volga-type” *Trochammina* and *Evolutinella*, but the section 3046 contains "the Neocomian type" *Gaudryina* ex gr. *gerkei* and a lot of *Trochammina*.

Magnetostratigraphy. Samples from 34 stratigraphic levels were studied in the sections 3046, 3047 and from three stratigraphic levels – in section 3050 (Fig. 1). The sandstones have magnetic susceptibility (*K*) 6-$12*10^{-5}$ SI units and **NRM** $0.02\text{-}2.15*10^{-3}$ A/m

(The gabbro have *K*=60-140*10^{-5} SI units, **NRM** = 100-1000*10^{-3}A/m). Magnetite or related titanomagnetite are the principal magnetic minerals in the sandstones and gabbro. The hematite was found at the only level (sample 3046/21 near the base of member 4) (Fig. 1). Usually such levels are related to hiatuses and active oxidation of magnetite grains. Thermomagnetic and alternating field cleaning showed reproducible results, which substantially increase the reliability of paleomagnetic measurements relative to the results based only on one of magnetic cleaning procedures. The gabbro samples have one component of the **NRM** – **ChRM** (*D*=293^o, *I*=84^o). The mean paleomagnetic direction in sandstones: *D*=247^o, *I*=(-84^o).

The paleomagnetic column of sections 3046-3047 consists of the reverse polarity zone (R). Two narrow intervals of normal polarity (N) were recorded in the middle part of the R-zone (Fig. 1). The baked contact test is positive (the sandstones from unbaked zone have a reverse magnetization; the baked zone and the gabbro have normal **NRM**). Normal polarity fixes in the outcrop 3050 (Fig. 1). These facts demonstrate the ancient nature of the magnetization. The test of reversal is negative, but this fact does not reject the hypothesis of the ancient nature of the **NRM**, because gabbro is tens of millions years younger than the sandstone, and outcrops 3050 and 3046-3047 are located in different the tectonic blocks.

Discussion. Ammonite findings correspond to the well-known data (Konovalov, Konovalova, 1997; Sey, Kalacheva, 1999) on presence of the Jacobi Zone in this section. If the previous ammonite findings from the uppermost Chigan Formation characterized Jacobi zone, therefore the R-magnetozone can be analogue either polarity Chron M18r, or M17r. This R-zone may be equivalent to the M18 + M17r, because small N-polarity interval (samples 3046/19-21) corresponds to the break in sedimentation and a significant part of M18n could not preserve in the section (Fig. 1).

The main result of this study is the possibility of obtaining of paleomagnetic and micropaleontologic data together with the ammonite findings, which gives a hope for the determination of the J/K boundary in the Chigan Formation in future.

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The Nordvik section – Boreal auxiliary section for the base of the Berriasian and candidate section for the SSSP of the Ryazanian Stage

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1. Nordvik as auxiliary section for the base of the Berriasian in the Boreal Realm

Strong faunal provincialism across the Jurassic-Cretaceous boundary leads to existence of numerous zonal scales, which sometimes cannot be applied for nearby regions, and to long-term usage of separate stages for Panboreal Superrealm (Volgian and Ryazanian) and Tethys-Pantalassa Superrealm (Tithonian and Berriasian). As the Berriasian Stage is now considered as internationally accepted for Geologic Time Scale, search for auxiliary sections providing high-resolution stratigraphic records across the J/K boundary became especially important irrespective to boundary level (which is now a matter of discussion). Among the Boreal sections, the Nordvik outcrops are without any doubts the most studied (Zakharov et al., 2014). Volgian and Ryazanian deposits are well-characterised here by many fossil groups, providing possibilities for establishing of independent zonal scales based on ammonites, belemnites, bivalves, forams and dinoflagellate cysts (Nikitenko et al., 2008, 2013; Zakharov et al., 2014). This is the single Boreal section providing full palaeomagnetic succession across the J/K boundary (Houša et al., 2007; Bragin et al., 2013). Recent advances in studying of carbon and oxygen stable isotope values of belemnite rostra, which are abundant throughout the section, providing outstanding stable isotope curve (Zak et al., 2011; Dzyuba et al., 2013). Although direct correlation of the Nordvik succession with those of the Tethys is possible only by means of palaeomagnetics, some belemnites, ammonites and bivalves permits to recognize inter-regional correlational levels between this section and Californian succession (cf. Zakharov, 1981; Dzyuba, 2012; Bragin et al., 2013; Shurygin, Dzyuba, 2015).

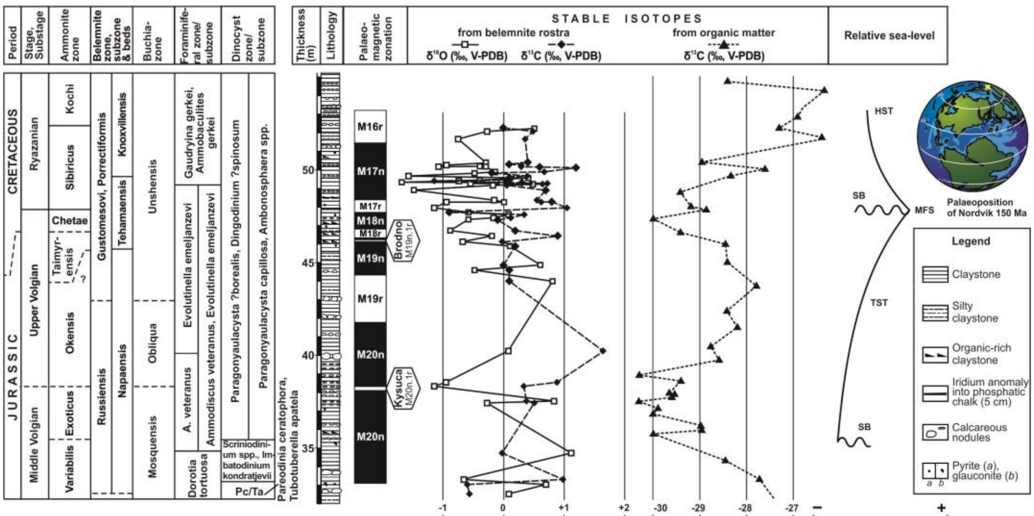

Fig. 1. Integrate stratigraphy of the J/K boundary beds of the Nordvik section, Northern Siberia

2. Nordvik as SSSP candidate section for the Ryazanian Stage

In spite of some recent progress in the Boreal-Tethyan correlation across the J/K boundary, both the Tithonian and Berriasian stages cannot be properly used in the Panboreal Superrealm, and substage boundaries cannot be traced from Tethyan to Boreal regions. Thus, for the Boreal areas, separate Volgian and Ryazanian stages are used. In the type area of the Ryazanian stage, the Russian Platform, this stage is represented by highly condensed sandy members containing numerous concretions and pebbles and usually attains 0,5-3 m in thickness. Identification of the faunal succession here is a difficult task because even in closely located sections some lens-like units could be missing or replaced by other lenses. Nevertheless, the Ryazanian in the type areas (Russian Platform, Ryazan area) spans nearly the same time interval as “Boreal Berriasian” or Ryazanian as it used in Arctic, i.e. from the base of the Sibiricus (Maynci) Zone to the top of the Tolli Zone. It should be noted that the Volgian/Ryazanian boundary as defined herein is located significantly above the discussed boundary markers for the Berriasian Stage.

We are propose to proceed usage of the Volgian and Ryazanian stages for the Panboreal superrealm, as they are well-known to the both exploration geologists and researchers in these territories. Being studied in much precision and compared with other Boreal sites of this age, the Nordvik section seems to be the best candidate for the Secondary Stratotype Section & Point (SSSP, Cope, 1996) of the Ryazanian Stage. Its lower boundary in this section could be chosen at the base of the thin phosphatised limestone (Member 9), containing ammonite genus Praetollia, which appearance along with appearance of Chetaites sibiricus can be used as primary boundary marker.

2.1. Characteristics of the Volgian-Ryazanian transitional beds of the Nordvik section

Uppermost Middle Volgian to Lower Valanginian deposits of this section (Paksa Fm) are composed from black shales, which are gradually coarsening upwards and changing to clayey silts without sedimentary breaks. Full succession of zones by ammonites, bivalves, forams and dinocysts is represented here (Fig. 1).

2.2. Biostratigraphy

Volgian–Ryazanian transitional beds of the Nordvik section are characterised by relatively diverse and abundant micro- and macrofossils providing high-resolution biostratigraphic subdivision. These zones are generally of good correlational potential across the Panboreal Superrealm (Fig. 1).

2.3. Magnetostratigraphy

Magnetostratigraphic study of the Nordvik section permits the recognition of the full succession of magnetozones spanning from the M20n to M16r (Houša et al., 2007; Bragin et al., 2013). It should be noted, however, that Upper Volgian succession is poor in ammonites (Rogov et al., 2015), and thus position of the J/K boundary defined by palaeomagnetic remains unclear in terms of ammonite zones.

2.4. Chemostratigraphy

Oxygen stable isotope values derived from belemnite rostra are showing gradual warming trend across the Volgian–Ryazanian transition, while $\delta^{13}C$ values are showing short positive excursion near to the top of the Volgian (Dzyuba et al., 2013; Zakharov et al., 2014). Basal bed of the Ryazanian is also characterised by iridium anomaly (Zakharov et al., 1993), which could be coeval with iridium anomaly discovered in the Barents Sea shelf and Svalbard (Dypvik et al., 2010).

2.5. Sedimentology

Black shales of the Volgian-Ryazanian transition were deposited in the central part of the Yenisei-Khatanga strait with an estimated depth ca. 150-200 m (Zakharov et al., 2013).

Conclusions

1. The Nordvik section could be chosen as auxiliary section for the lower boundary of the Cretaceous Stage in the Panboreal Superrealm.

2. SSSP of the Ryazanian stage is proposed at the base of the member 9 of the Nordvik section. This section, containing full succession of zones based on different groups of micro- and macrofossils, can be also con-

sidered as parastratotype of the Ryazanian Stage.

3. Key event for the base of the Ryazanian is FAD of the ammonite genus Praetollia, which is coincides with FAD of Chetaites sibiricus.

4. High-resolution magnetostratigraphic succession recognised in the Nordvik section provides direct correlation of this section with Tethyan succession.

5. Carbon stable isotope values derived from belemnite rostra as well as iridium anomaly could provide additional boundary markers.

The Nordvik section is the most studied Boreal section of the Jurassic-Cretaceous transitional beds and it meets all requirements applied for boundary stratotypes.

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New palaeomagnetic interpretations near the Jurassic-Cretaceous boundary in the Nordvik Peninsula

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We examine and discuss recently published magnetostratigraphic data from the Nordvik section (north Siberia) around the Jurassic-Cretaceous boundary, and its calibration with biostratigraphy. Specifically, we discuss the original interpretation by Houša et al. (2007), new interpretations by Bragin et al. (2013), and the commentary on that work by Guzhikov (2013). The discussion is followed by our new interpretation of these data (review paper by Schnabl et al. 2015). We consider some of the limitations of the Nordvik section, and conclude that the base of M18r, because it is in a condensed part of the sequence, makes a poor contender for precise long-range correlation.

The magnetozone M17r found by Bragin et al. 2013 is an important discovery. However, the density of the sampling was not enough for a correct interpretation. Combination of data acquired from Houša et al. 2007 and Bragin et al. 2013 enables a new magnetostratigraphic interpretation (fig 1.). The new interpretation proves that the minimal sedimentation rate was 0.16 m/Ma and not 2 m/Ma as presumed Houša et al. 2007. The maximum sedimentation rate was 12 m/Ma. It is necessary to agree with the opinion of Guzhikov (2013), that more J/K boundary interval sections in boreal regions are needed.

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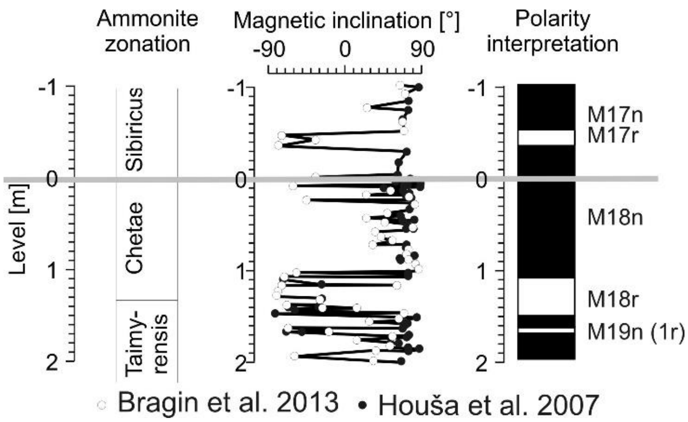

Fig. 1. The new interpretation of the magnetostratigraphy at Nordvik Peninsula.

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Kashpir section (Volga River, Russia), the proposed auxiliary section for the J/K interval in Subboreal Realm

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Kashpir reference section is located to the south of Syzran' town near Kashpir Village, on the right bank of Volga River (N 53º01′56″, E 48º27′05″), where Middle Volgian – Hauterivian deposits are exposed (Fig. 1). Kashpir is one of historical sections of the Volgian Stage, which was reported in numerous publications and was proposed as the stratotype of Kashpurian Stage by I.G. Sasonova and N.T. Sasonov. The Jurassic – Cretaceous transition interval of the section has been re-described recently (Rogov et al., 2015) and characterised by ammonites (Rogov et al., 2015; Baraboshkin et al., 2015), belemnites and Buchias (Dzyuba, Urman, Shurygin, 2015), palynomorphs (Harding et al., 2011; Pestchevitskaya, Lebedeva, Ryabokon, 2011), ostracods (Kolpenskaya, 1995), stable isotopes (Gröcke et al., 2003, the Ryazanian only), palaeomagnetic and mineralogical data (Baraboshkin et al., 2015; Ruffell et al., 2002). Therefore, Kashpir section is one of the most well-studied sections in Subboreal Realm. Even if it is highly condensed, it contains a number of potential direct markers (ammonites, belemnites, buchiids and dinocysts; palaeomagnetic reversal and stable isotope data), which could be used for interregional correlation of J/K boundary interval (Figs. 1, 2). Unfortunately only stable isotopes and palaeomagnetic reversals one may use for the direct Boreal–Tethyan correlation of the both Tithonian/Volgian and Berriasian / Ryazanian. It needs additional study. Nevertheless, Kashpir section could be proposed as auxiliary section in Subboreal Realm to the GSSP, which hopefully will be chosen in the future.

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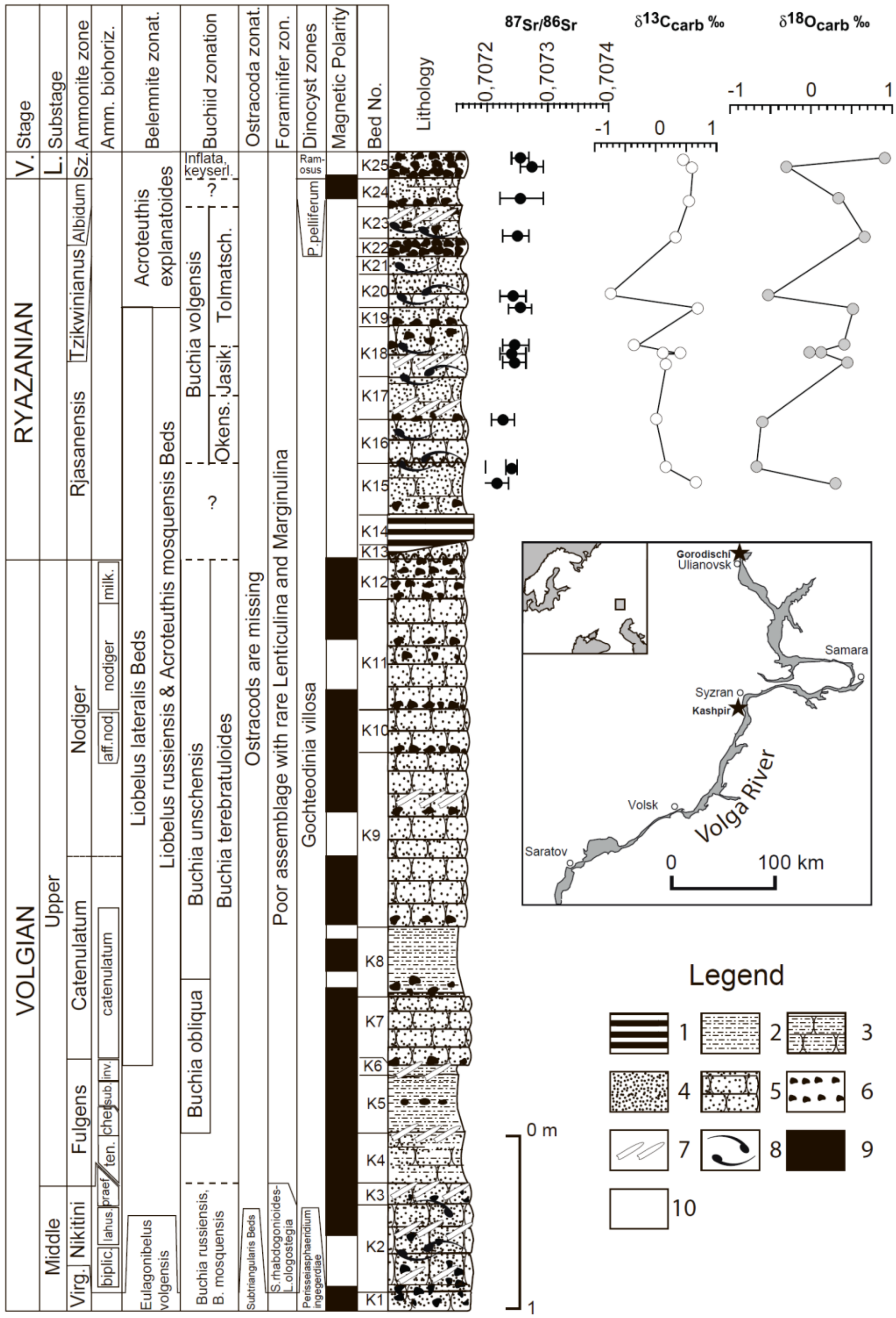

Fig. 1. Composite stratigraphy of Kashpir section (Based on Yakovleva, 1985; Kolpenskaya, 1995; Gröcke et al., 2003; Harding et al., 2011; Baraboshkin et al., 2015; Dzyuba, Urman, Shurygin, 2015; Rogov et al., 2015). The map demonstrates the location of Kashpir and Gorodishchi sections. Legend: 1 – oil shales; siltstones: 2 – poorly cemented; 3 – Ca-cemented; sandstones: 4

– poorly cemented; 5 - Ca-cemented; 6 – phosphorite pebbles and nodules; 7 – belemnite horizons; 8 – shell (mainly Buchia) debris; geomagnetic polarity: 9 – normal; 10 – reversal.

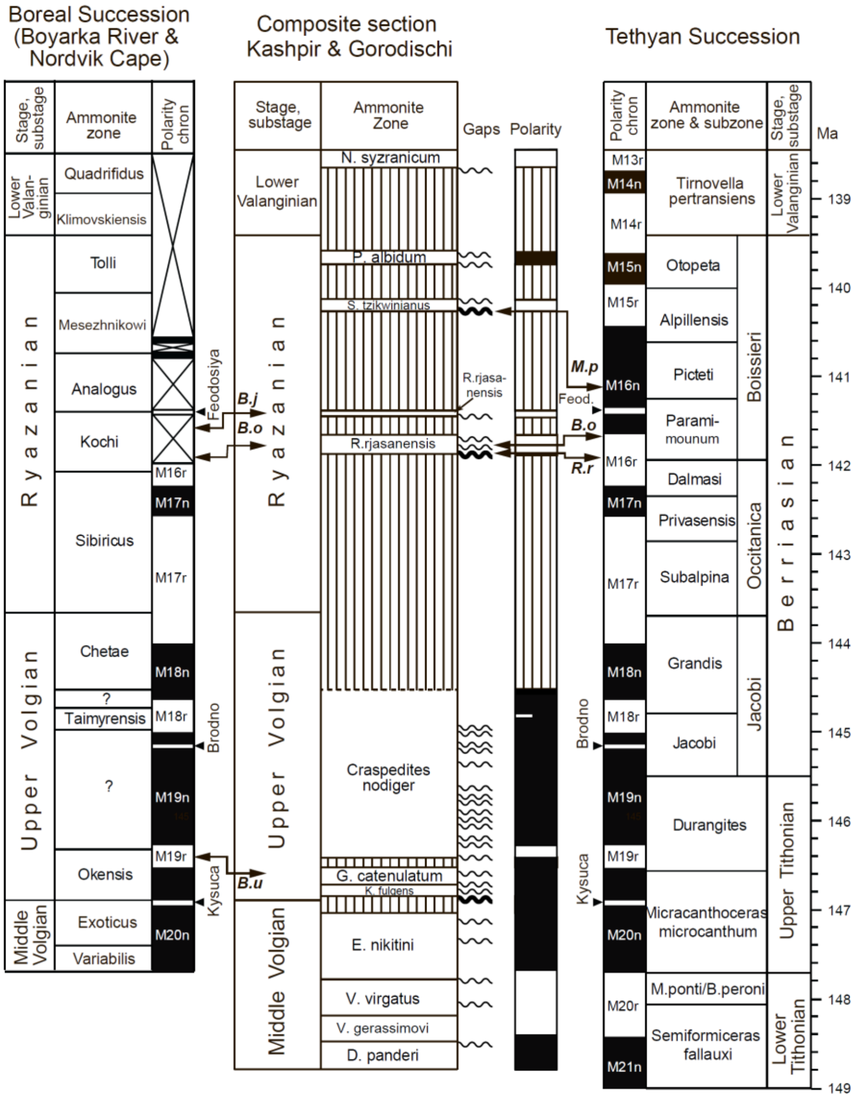

Fig. 2. Magnetostratigraphic correlation of the Jurassic-Cretaceous boundary composite succession of the Middle Volga region with other regions (after Baraboshkin et al., 2015, with changes; Rogov, Alifirov, Igolnikov, 2015). Thick wavy lines – discontinuites, recognized by (Harding et al., 2011); vertical lines - discontinuites. FADs of some Boreal / Tethyan markers: *M.p – Meiourogonyaulax pertusa* (Pestchevitskaya, Lebedeva, Ryabokon, 2011); *R.r – Riasanites rjasanensis; Buchia: B.j – B. jasikovi; B.o – B. okensis; B.u – B. unschensis*. The legend and the position of Gorodishchi section see at Fig. 1.

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Complex stratigraphy, lithology and magnetic proxies of the J/K boundary interval in the Pieniny Klippen Belt (Western Carpathians, Slovakia)

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The most complete and well preserved Jurassic /Cretaceous sequences occur in the Pieniny Klippen Belt (Outer Carpathians) and in the Krížna Unit of the Central Carpathians. Plankton (calpionellid-, calcareous dinocyst- and nannoplankton) and O and C isotope fluctuations were studied in three selected (Brodno, Strapková and Hlboča) J/K boundary key sections. Nannofossil assemblages of Tithonian Rosso Ammonitico are dominated by *Conusphaera*. The *Polycostella* abundance increased during start of the calpionellid Chitinoidella Zone and decreased towards the Crassicollaria Zone. *Helenea chiastia* accompanied by first small nannoconids appeared during latest Early Tithonian. Cadosinid cysts abundance in the Semiradiata Zone indicates surface water warming.

The start of Late Tithonian Crassicollaria Zone is correlable with the reverse magnetic Kysuca (M20n.1r) Subzone. Small nannoconids, *Hexalithus noeliae* and *Litraphidites carniolensis* appeared within the Microstaurus chiastius Zone. Stable isotopes ($\delta^{18}O$, $\delta^{13}C$) and low C_{org} indicate colder period, disturbed by warmer latest Tithonian episode.

The J/K boundary is defined by morphological change of *Calpionella alpina* tests. The standard Calpionella Zone base is located below the reverse magnetic Brodno (M19n.1r) Subzone in the Brodno section, and/or in half of the M19 Zone in the Strapková and Hlboča sections. Poorly diversified nannofossils (*Watznaueria*, *Cyclagelosphaera*, *Conusphaera*, *Poly-costella)* are relatively abundant. Boundary interval is designated by the *Nannoconus wintereri* FO together with small nannoconids at the base, and the *Nannoconus steinmanni minor* FO at the top. Temperature increase indicated by oxygen isotopes followed Late Tithonian cooling. Nannoconids bloomed due to temperature/salinity changes associated with earliest Berriasian warm water influx. Correlation of calcareous microplankton and of C and O stable isotope and $TOC/CaCO_3$ data distribution was used in the characterization of the J/K boundary interval. The $\delta^{13}C$ values ranging from 1.1 to 1.4 ‰ (PDB) in limestone with minimum of residual C_{org} indicate balanced C regime in sea water column during the boundary interval (Michalík et al., 2009). Small $\delta^{18}O$ changes (from -1.5 to -2.5 ‰ PDB) are correlable with radiolarians concentrations in cycles reflecting fluctuation of basinal currents activity. The more negative $\delta^{18}O$ excursion near the J/K boundary could indicate temperature rise and salinity changes reflected by calcareous microorganism production.

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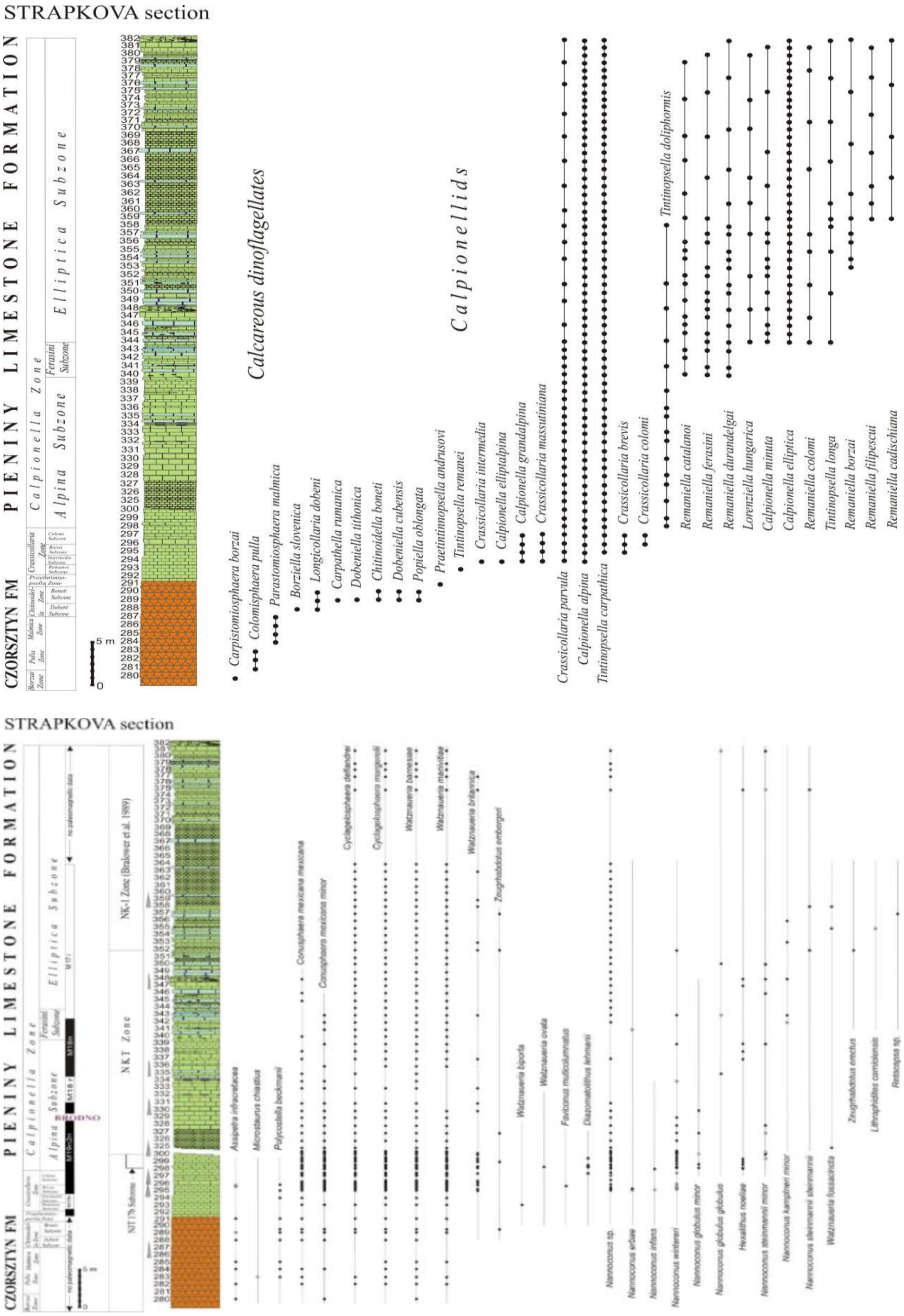

Fig. 1.: Composition and distribution of micro- and nannoplankton in the J/K boundary beds, Strapkova section.

Tithonian to Early Berriasian ammonites from the Štramberk Limestone of the Kotouč Quarry near Štramberk (Outer Western Carpathians)

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Since the beginning of historical collections, the Štramberk Limestone has been famous for the abundance of fossils. Ammonites represent a significant part of them. Fossils are deposited in many museums, above all in the Moravian-Silesian Region (Czech Republic), in Vienna (Austria) and in Munich (Germany). Old faunistic collections miss detailed localization.

Recently, we, together with friendly local collectors of fossils, have been focused on the collection of ammonites in the active Kotouč Quarry, in its part designated as Homole Block (Fig. 1). In the quarry, ammonites occur in the limestones comparatively sporadically and accidentally. The larger part of our collection of early Berriasian ammonites and the small part of Tithonian ammonites have already been published (Vašíček et al. 2013; Vašíček & Skupien 2013, 2014).

The stratigraphically oldest finding is a single incomplete specimen of *Franconites* cf. *fascipartitus* (Zeiss). It comes from Level 9 (Locality 1 in Fig. 1) and represents, according to data in the literature, *Neochetoceras mucronatum* Zone (lower part of early Tithonian, Ti1a). Another early Tithonian finding is that of *Sublithacoceras* cf. *fringilla* Zeiss, from Level 9 as well (Locality 2), lower part of early Tithonian (*Franconites vimineus* Zone or Subzone in the upper part of the *Semiformiceras darwini* Zone, Ti1a). Important findings of Early Tithonian ammonites come from the middle part of Level 6 (Locality 3 in Fig. 1). They belong to *Lemencia ciliata* (Schneid) and *Richterella richteri* (Oppel). According to data in the literature, both species come from the lower part of the *Semiformiceras fallauxi* Zone (higher early Tithonian, Ti1b).

The most important our locality of Tithonian ammonites is a place of so-called white layers (Locality 4 in Fig. 1) on Level 8. The layer provided a number of extraordinarily favourably preserved fossils of many groups of invertebrates, and also several shells of ammonites of rather small size but of zonal importance. Determined ammonite species do not correspond to a single horizon of the same age. Two juvenile shells of *Simoceras admirandum* (Zittel) are the stratigraphically oldest. This species is a guide species for the uppermost part of the *Semiformiceras fallauxi* Zone (higher part of early Tithonian, Ti1b). Together with them, other two stratigraphically important species were found, namely *Micracanthoceras microcanthum* (Oppel) and *Oloriziceras magnum* (Tavera). These species occurres in the *Simplisphinctes* Subzone (basal part of late Tithonian) defined by Tavera (1985) in Zeiss (2003) as the lower subzone for *Micracanthoceras microcanthum* Zone (Ti2a). *Simplisphinctes* Subzone is the range zone for the genus *Simplisphinctes*. (It has the other statute as the other Tithonian zones.) Bulot et al. (2014) use for *Simplisphinctes* Subzone only “lower part of *Micracanthoceras microcanthum* Zone”. Smooth shells of stratigraphically unimportant *Haploceras elimatum* (Oppel) occur rather frequently together with them.

The imperfectly preserved specimen of *Ernstbrunnia* cf. *densecostata* (Tavera) from another place (Locality 5) of so-called “soft layers” on the exit road from Level 5 to Level 4 should also represent the basal part of upper Tithonian. Typical representatives of the species occur in the basal part of late Tithonian in the *Micracanthoceras microcanthum* Zone (Ti2a).

A large-sized, stratigraphically important specimen is represented by the finding of *Paraulacosphinctes senex* (Oppel) in the uppermost part of the road from Level 8 to Level 9 (Locality 6). The mentioned species in the Štramberk Limestone is accompanied, according to historical findings, by *Paraulocosphinctes transitorius* (Oppel). Yet we have not succeeded in finding the last-mentioned species in Kotouč. According to the finding of *P. senex*, it can be however concluded that the ammonite *Paraulocosphinctes transitorius* Subzone (higher part of late Tithonian, Ti2b) in the concept of Zeiss (2003) is unambiguously verified here.

At the west edge of Level 5 (Locality 7), an ammonite-bearing layer with several less perfectly preserved ammonites appeared. Here, the finding of the recently determined species *Boughdiriella chouetensis* Frau et al. is of high stratigraphic importance. One of accompanying fragments was determined as *Paraulacosphinctes* cf. *senoides* Tavera. The former species occurs in the *Protacanthodiscus andreaei* Zone (uppermost part of late Tithonian according to Frau et al., 2015, Ti2c).

As far as the places of occurrence of early Berriasian ammonites are concerned, the stratigraphically older part is represented by the exit road from Level 4 to Level 3 (Locality 8). In the findings, *Berriasella jacobi* Mazenot and *Tirnovella allobrogensis* (Mazenot) dominate. Sporadically *Spiticeras blancheti* Djanélidzé, *Berriasella oppeli* (Kilian), *Delphinella consanguinea* (Retowski) and *Malbosiceras* cf. *asper* (Mazenot) occur. The ammonite assemblage belongs to the lower part of the *Berriasella jacobi* Zone (Be1a).

It is two places of occurrence of ammonites on Level 5 that are remarkable. In Locality 9, where we could document in more detail almost a 13 m thick section, several fragments of not too well preserved ammonites were found. The most significant of them are *Delphinella* cf. *janus* (Retkovski) and *Riasanella* cf. *rausingi* (Mitta). With them, two imperfectly preserved impressions of *B. jacobi* were found.

East of the studied section in Locality 10, more impressions and ammonites of various sizes and poor quality, usually corroded are there on bedding planes. Large-sized specimens of *Pseudosubplanites grandis* (Matenot) dominate among them. Together with them, rare *Berriasella jacobi* and *Tirnovella allobrogensis* occur. By analogy with the early Berriasian in Crimea (e.g. Arkadiev & Bogdanova, 2012), it is the case of higher part of the *Berriasella jacobi* Zone (Be1b).

The last place with lower Berriasian ammonites is there on Level 6 (Locality 11). The ammonite assemblage contains, in addition to more frequent *Ps. grandis*, also *Berriasella oppeli*, *Tirnovella allobrogensis* and *Delphinella* sp. According to the ammonite association as well as stratification, it can be expected that the layer is the equivalent of Locality 10 (Be1b).

From the localization and stratigraphic position of the ammonites occurrence places in the Kotouč Quarry (Fig. 2) and from measurement of layers, a comparatively chaotic placement of ammonite-bearing places follows. In the Kotouč Quarry the Štramberk Limestone do not create a continuous section.

The determined assemblage of ammonites, coming from exactly localized places on mining levels in the Homole Block in the Kotouč Quarry, documents an evidenced total stratigraphic range from the higher part of early Tithonian to the basal part of Berriasian inclusive. Moreover, neither a continuous sequence of strata nor section in the Štramberk Limestone derived on the basis of calpionellids in thin sections and according to the measurement of strata by Houša (1983) has been proved. In several places with measurable stratification, we have not succeeded unambiguously even either in proving or disproving of the overturned or normal position of strata. In addition, it is necessary to state that the directions of dips of strata given by Houša applied to the whole of the Homole Block are comparatively close to our measurements in lower Berriasian limestones in the section on Level 5 (205/75) and on Level 6 (210/65). Generally it holds however true that the lower Berriasian occurs merely in an area that is close, from the point of view of both direction and distance, to the Mendocino Fault. Southwest of the mentioned fault, only places with Tithonian ammonites of various stratigraphic levels occur in the quarry.

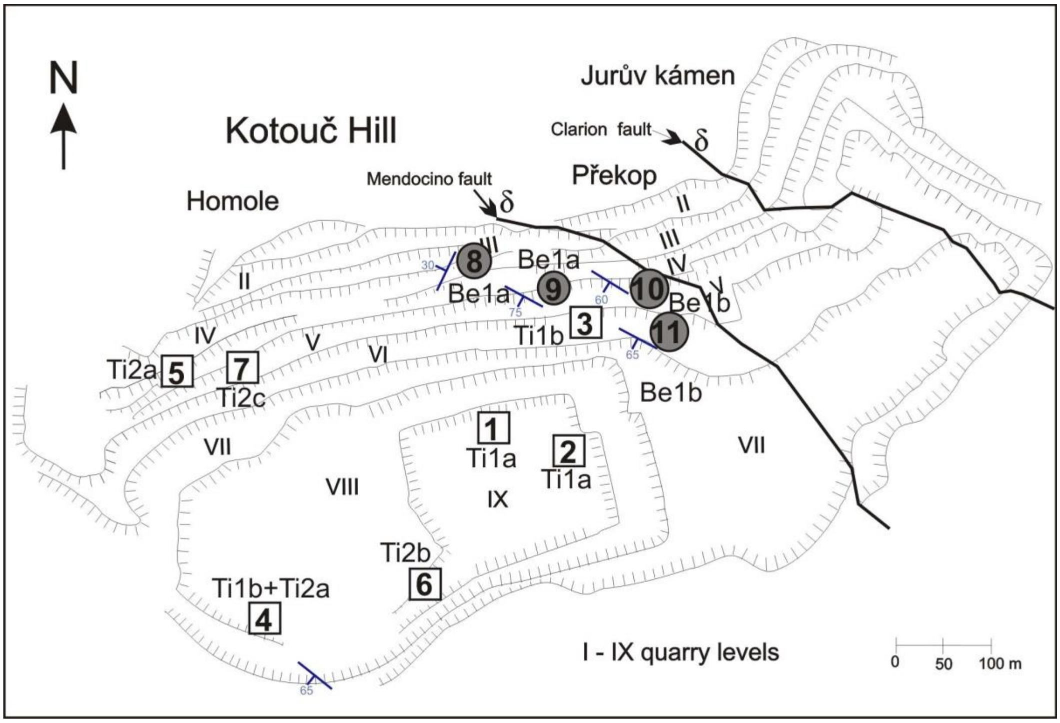

Fig. 1. Location and age of the discoveries of the Tithonian (marked with the square) and Berriasian (marked with the circle) ammonites at the Kotouč Quarry. For symbols Ti and Be see text.

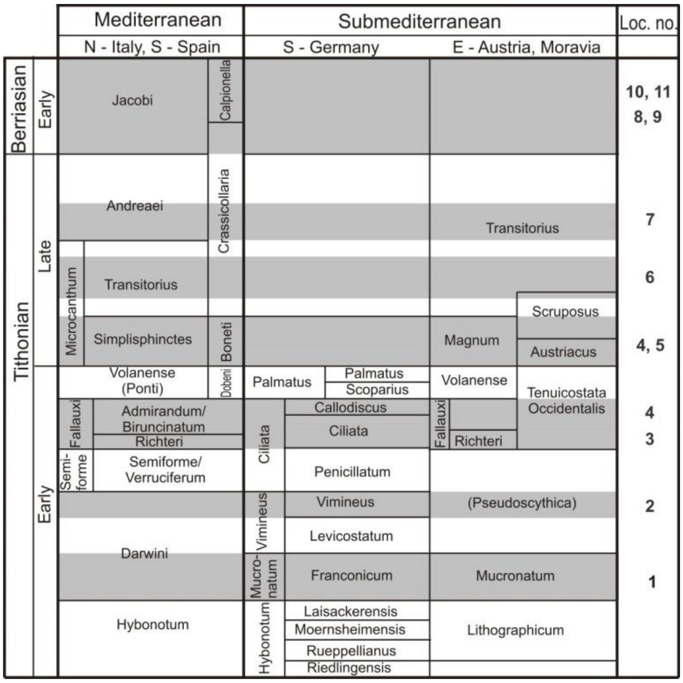

Fig. 2. Ammonite zones of the Tithonian and lowermost Berriasian with marking (in grey straps) of the stratigraphic position of ammonite findings. Numbers on the right side refer to the order of locations under study. Zonations after Zeiss (2003), Bulot et al. (2014), Reboulet et al. (2014).

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Calcareous nannofossils of the Jurassic/Cretaceous boundary strata in the Puerto Escaño section (southern Spain) - biostratigraphy and palaeoecology

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We obtained material from the Puerto Escaño section (southern Spain) to study the Jurassic/Cretaceous (J/K) boundary interval. The same samples had already been processed for magnetostratigraphic studies and biostratigraphic zonation based on calpionellids and ammonites (Pruner et al. 2010), but not for calcareous nannofossils.

The aim of this study was to process the samples using micropalaeontological analysis and to compare and calibrate results for calcareous nannofossils with existing magnetostratigraphic and other biostratigraphic data.

The calcareous nannofossil assemblage was dominated by the genera *Watznaueria*, *Cyclagelosphaera*, *Nannoconus*, *Conusphaera* and *Polycostella*. Several nannofossil bioevents were recorded on the basis of the distribution of stratigraphically important taxa, including zonal and subzonal markers. Based on the lowest occurrences (LO) of *M. chiastius*, *N. globulus minor*, *N. wintereri*, *N. steinmanii minor*, *N. steinmannii steinmannii*, *N. kamptneri minor* and *N. kampteri kamptneri*, two nannofossil subzones (NJT 15b, NJT 17a) and two nannofossil zones (NJT 16, NK-1) were recognised. New palaeoecological data are introduced, based on geochemical analysis and macrofauna occurrences.

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JKB final discussion:

Synthesis of calcareous nannofossil events across the Jurassic/Cretaceous boundary: implications for the definition of the Berriasian base.

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Calcareous nannofossils are a powerful biostratigraphic tool for dating and for interregional correlations of Jurassic to Recent marine sequences. The latest Jurassic was a crucial time interval for calcareous nannoplankton as a major speciation episode took place with the appearance and rapid evolution of several new genera and species. In particular, the calcareous nannofloras dramatically change across the Jurassic/Cretaceous (J/K) boundary interval, as the highly calcified nannoconids appeared and progressively dominated the assemblages at low latitudes (Bralower et al. 1989, Erba 2006, Casellato 2010). The high number of biohorizons (mainly appearances) provides the opportunity to achieve high-resolution biostratigraphic data and amplify the possibility of dating and correlating at regional to supraregional level.

In this study we present new data and critically revised published nannofossil biostratigraphies for the Tithonian-Berriasian interval. We aim at evaluating the reproducibility and variability of individual biohorizons, in order to discriminate among primary and secondary ones. We estimated the age of biohorizons relative to magnetostratigraphy in the CM20-CM17 interval, and also relative to calpionellid and ammonite zonations. We contribute to the Berriasian Working Group (WG) efforts concerning the improvement of a self-reinforcing integrated stratigraphic matrix across the J/K boundary interval (Wimbledon et al. 2011), a scheme that will be the basis for the choice of the GSSP representing the base of the Cretaceous System.

We collected a database comprising sites from different paleogeographic settings and latitudes (Europe, north America, Tibet, Argentina and Atlantic Ocean). We critically evaluated nannofossil preservation and abundance, and the taxonomic concepts adopted by different nannofossilists. The calibration against magnetostratigraphy was privileged for the evaluation of the reproducibility of single nannofossil biohorizons and their time variability.

Calcareous nannofossil biohorizons are distinguished in primary and secondary based on their reproducibility at least at regional scale and relativley continuous stratigraphic range. The primary biohorizons that characterize the J/K boundary interval are first occurrences (FO) of some *Nannoconus* species: the FO of *N. globulus minor* correlates with the topmost part of CM20N; the FO of *N. wintereri* correlates with the middle part of CM19N; the FO of *N. steinmannii minor* correlates with the uppermost part of CM19N-lowermost part of CM18R; the FO of *N. steinmannii steinmannii* falls within the lowermost part of CM17R. Secondary biohorizons are FOs of *Rhagodiscus asper* in the middle part of CM19R, *Cretarhabdus surirellus* correlating with the lowermost part of CM19N, *Cruciellipsis cuvillieri* and *Hexalithus strictu* within the middle part of CM19N, *N. kamptneri minor* correlating with the lowermost part of CM18R, *N. kamptneri kamptneri* within the lowermost part of CM17R.

The appearances of new taxa are also accompanied by abundance fluctuations of rock-forming nannofossil genera (i.e. *Conusphaera, Nannoconus, Polycostella, Watznaueria*), resulting in marked nannofacies changes. Five ”nannofacies” were distinguished in the CM20-CM18 interval in the Tethys and Atlantic Oceans (Casellato & Erba, *in prep.*). Such assemblage changes are proposed as additional stratigraphic characterization: in particular, the nannofacies across the J/K boundary interval is dominated by nannoconids.

Based on new data and literature survey, we propose the FO of *N. steinmannii minor* as the most robust and globally recognized event in the J/K boundary interval: this event has been used as a zonal biohorizon in all available nannofossil biozonations of the past four decades. We underline that the FO of *N. steinmannii minor* largely correlates with the basal portion of CM18R.

Relative to calpionellid Zonation the FOs of *N. globulus globulus*, *H. strictu*, *N. wintereri* and *C. cuvillieri* approximate the base of the *Calpionella* (B) Zone in the middle part of CM19N, while the FOs of *N. steinmannii minor* and *N. kamptneri minor* fall within the upper part of this zone. Concerning the ammonite zonation, the FOs of *N. steinmannii minor* and *N. kamptneri minor* approximate the middle part of the *jacobi-grandis* Zone (Wimbledon et al. 2011) or the uppermost *jacobi* Subzone (Schnabl et at. 2015).

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Magnetic susceptibility as a stratigraphical marker at the Jurassic/Cretaceous boundary: does it work?

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Magnetic susceptibility (MS) in pelagic and hemipelagic carbonates of the Late Tithonian – Berriasian age is usually confined to lithogenic influx into a basin (Grabowski et al., 2013). So, it should be treated rather as lithologic or chemostratigraphic proxy and not as a global stratigraphical marker (like e.g. geomagnetic reversals). However, increasing amount of integrated bio-, magnetostratigraphically controlled MS data from the Upper Tithonian and Berriasian sections from the Tethyan realm reveal that MS variations might be applied as a local to regional stratigraphic marker. It is well known that the Berriasian MS curve in the Western Carpathians reveals a characteristic U shape (Grabowski et al. 2013). The MS highs are observed in the upper Tithonian and lowermost Berriasian (between magnetozones M20n and lower part of M19n) and in the Upper Berriasian (in magnetozone M16n). Profound MS low related to increased carbonate productivity is observed in the upper part of the Lower Berriasian and lowermost Upper Berriasian (magnetozones M17r to M16r). The presence of these long term trends is confirmed in the sections of Pieniny Klippen Belt (PKB, Kysuca – Pieniny basin), Tatra Mts (Fatric units), Hungary (both Tisia unit and Bakony Belt) and the Western Balkan in Bulgaria. They result from a superposition of tectonic/climatic and possibly also eustatic (eurybatic) factors and their synchronism is now intensively tested (Grabowski & Sobień 2015).

However, it appears that also minor MS variations might give some clues for high resolution stratigraphic correlations in the Pieniny and Fatric basins. There is a well known contradiction between situation of the Jurassic/Cretaceous (J/K) boundary in the Brodno section of the PKB. The boundary is located either in the middle part of magnetozone M19n2n (Houša et al. 1999) or at the bottom of M18r (Michalik et al. 2009) according to different definition criteria od boundary between the Crassicollaria and Calpionella Zones. Correlation of multiple sections from the Pieniny Klippen Belt (Brodno, Strapkova), Fatric units (Pośrednie III, Filipka Valley) and Eastern Alps (Nutzhof) clearly demonstrates that MS variations within magnetozone M19n are apparently synchronous. The J/K boundary defined as the Colomi/Alpina Subzonal boundary falls in different parts of M19n and does not conform to the MS trends. Alternatively, the J/K boundary based upon the Intermedia/Alpina Subzonal boundary, falls always in the pre-Brodno part of M19n (M19n2n) and agrees very well with minor ups and downs of the MS curve. It is disputable, whether such detailed MS correlation might be extended also beyond the Pieniny – Fatric domain, However it seems, that rather this definition (Intermedia/Alpina) of the J/K boundary might have a bigger potential as a synchronous stratigraphic marker. MS variations might be helpful in detailed positioning of the boundary within the magnetozone M19n2n.

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Palaeomagnetic and high-resolution magnetostratigraphic investigations across the J/K boundary strata: the role in palaeogeography

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The reliability of the interpretation of tectonic rotations can be enhanced by systematic palaeomagnetic and magnetostratographic investigations. The principal aim of detailed magnetostratigraphic and micropalaeontological investigation of the Jurassic/Cretaceous (J/K) boundary is to precisely determine the boundaries of magnetozones and narrow reverse subzones, as well as to find global correlation across the J/K boundary (Fig. 1). Previously, the high-resolution magnetostratigraphy of the Tithonian-Berriasian boundary strata was investigated at Brodno near Žilina, Western Carpathians (WCA). For the first time, two reverse subzones were detected within magnetozones M20n and M19n and both can be correlated with analogous subzones in the M-sequence of marine anomalies (Houša et al. 1999). Palaeomagnetic directions from this locality indicate large (110^{o}) counter-clockwise rotation and clear difference in the values of palaoedirections (20^{o}) between Late Tithonian and Early Berriasian. The interpretation of data inferred from a relatively small area of the WCA was, furthermore, preceded by statistical and global-tectonic processing of palaeomagnetic data from the broader region comprising Permian to Neogene rocks of the Alpine–Carpathian–Pannonian Zone (ACPZ). This procedure involving more than 300 palaeomagnetic pole positions permitted the calculation of the reference palaeogeographic coordinates and the determination of palaeogeographic affinities of the individual blocks. The processing of palaeomagnetic data resulted in the construction of synoptic maps showing the orientations of palaeomeridians and palaeogeographic latitudes computed from statistically derived mean pole positions from the Northern Apennines to the Outer WCA and the Inner WCA. Palaeogeographic affinity to the African Plate was found for the Northern Apennines, Southern Alps, Istria and the Transdanubian Mountains, as indicated by the rotation and absolute values of palaeolatitudes. Orientations of palaeomeridians for the individual areas of the ACPZ indicated a predominance of counter-clockwise palaeotectonic rotations. Anomalous clockwise rotations were evidenced only for the NE Alps (documented for the Jurassic and Cretaceous only) and the Outer Eastern Carpathians (documented for the Jurassic and – with less probability – also for the Cretaceous). Tectonic rotations resulted in a scatter of palaeomagnetic pole positions. A specific distribution of palaeomagnetic pole positions for rocks of the same age motivated a formulation of a theoretical model simulating palaeotectonic rotation of rocks assemblages about vertical axis (Krs et al. 1992). Counter-clockwise rotations prevail throughout the WCA from the Permian to the Early to Middle Eocene rocks. Up to 110° rotation occurred in the Permian rocks and the flysch formation shows a counter-clockwise rotation of about 60°. The most prominent palaeolatitudinal drift dates to the Permian and Triassic, and a similar drift was also documented for the

Permo-Triassic rocks of the European lithospheric plate. Rotations of individual blocks induce large scatters of palaeomagnetic pole positions even though they may affect only small units. In contrast, changes in pole positions due to drift of larger units are generally smaller although the transitions involved are appreciable.

The new project: *"Integrated multi-proxy study of the Jurassic-Cretaceous boundary in marine sequences: contribution to global boundary definition"* **(**GAP 210/16/09979) combines biostratigraphy and magnetostratigraphy with sedimentology and geochemistry to generate high-resolution stratigraphic framework supporting the J-K boundary definition and the GSSP selection respectively. We expect to sample in detail the following localities: Štramberk, Kurovice (Czech Republic), Durlston Bay (Dorset, England), St Bertrand's Spring and Le Chouet (France). The data will be correlated with well-recognized deep-water sections (Brodno) as well as shallow water sections (Le Chouet, Tatric succession) with poorly developed chronostratigraphy. The project will be realized in a broad international cooperation. The results will be presented and discussed mainly during meetings of the Berriasian Working Group (BWG). Cooperation has been approved by: Prof. William Wimbledon (England) the chairman of the BWG.

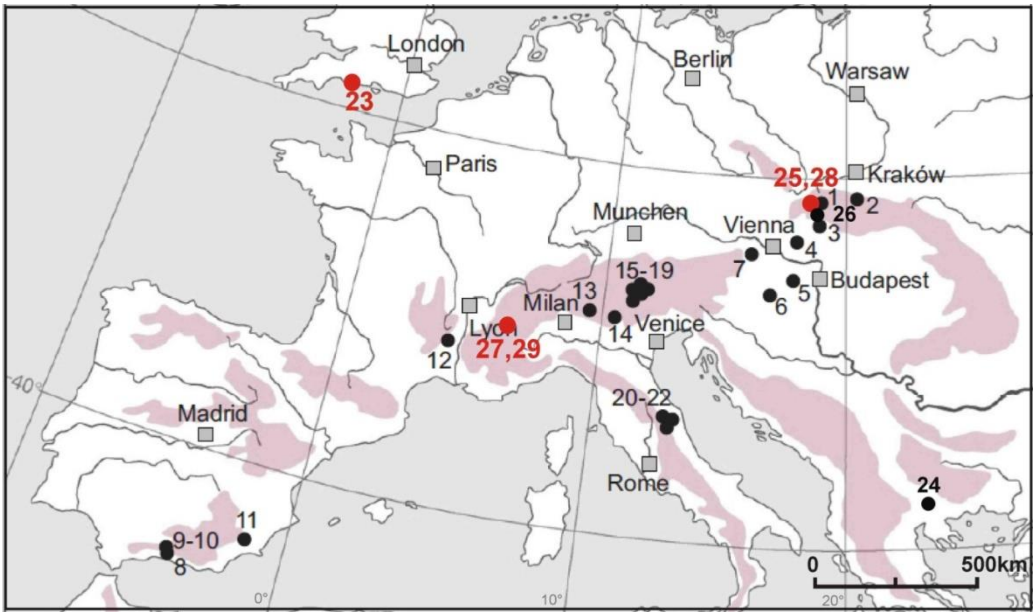

Fig. 1. Location of magnetostratigraphically studied J/K boundary sections in Europe (sections selected for study are in red): 1. Brodno; 2. Western Tatra; 3. Strážovce; 4. Hlboča; 5. Lókút; 6. Sümeg; 7. Nutzhof; 8. Sierra Gorda; 9. Carcabuey; 10. Puerto Escano; 11. Rio Argos; 12. Berrias; 13. Torre de Busi; 14. Cole di Vignola; 15-19. Foza, Frisoni, Xausa, Bombatierle, Mezzosilva; 20.-22. Bosso, Arcevia, Fonte Giordano; 23. Durlstone Bay; 24. Barlya; 25. Štramberk; 26. Strapkova; 27. Le Chouet; 28. Kurovice; 29. St Bertrand's Spring.

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Calpionellids in the Upper Jurassic/Lower Cretaceous pelagic carbonate sediments of the Western Carpatians – tool for their stratigraphy and paleoenvironmental interpretation

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Calpionellids as the important constituent of (sub)tropical Tethyan calcareous microplankton play a key role in the biostratigraphy of Upper Jurassic/Lower Cretaceous pelagic and hemipelagic carbonate sediments in the Mediterranean area (Michalík, 1995). High-resolution quantitative analysis of calpionellid associations boundary in selected West Carpathian JKB sections (Brodno, Rochovica, Strapkova, Samášky, Hlboča, Strážovce, Zliechov, Butkov, Podbranč, Hrušové), indicates major variations in relative abundance of species composition, species variability and diversity and also in structural composition of their loricas. In West Carpathian sequences studied, the mass abundance of these microfossils has been closely connected predominantly with shallow intrashelf basins and elevated ridges. These environments were characterized by a permanent current regime positively influencing the nutrient input. High nutrient potential (in accordance to the composition) activated the explosion waves in evolution of specific planktonic associations and also selected forms. Such relatively dense environment invoked feedback pressure on the planktonic organisms. It seems that small usually less calcite calpionellid forms coincided with environments better supplied by nutrients and they occured with higher fertility-related nannofossils. On the other hand, larger elongated calpionelid forms with composed collars (creating usually diversified associations) indicate tendency to food specialization. Diversified calpionelid associations were linked with blooms of highly calcified K-selected coccoliths/nannoliths. It is worth mentioned, that the abundance and size of calpionellid loricas also decrease towards to open marine environments.

Successive calpionellid events are recognizable in the whole Mediterranean Realm which allowed to create widely accepted alpionellid zonal scheme (Lakova, Petrova 2013) composed of seven caplionellid zones (Chitinoidella, Praetintinnopsella, Crassicollaria, Calpionella, Calpionellopsis, Calpionellites and Tintinnopsella).

The J/K boundary interval can be characterized by several calpionellid events – the onset, diversification, and extinction of chitinoidellids (Latest Early Tithonian); the onset, burst of diversification, and extinction of crassicollarians (Late Tithonian); and the onset of the monospecific *Calpionella alpina* association close to the J/K boundary (Michalík et al. 2009) The J/K boundary in the best preserved West Carpathian sections (Brodno, Strapkova, Hlboč, Strážovce), is traced between the Crassicollaria and Calpionella zones. This limit is defined by the morphological change of *Calpionella alpina* loricas dominated by small globular tests at the beginning of the Calpionella Zone (its Alpina Subzone). Event of monospecific *C. alpina* association which was confirmed by now in all studied sections along the Tethyan area (Michalík and Reháková, 2011), was interpreted by Reháková (2000) as reflection of environmental instability related to eustatic lowering of the sea level (sensu (Haq et al. 1987). On the other hand, calpionellid radiation and diversification events were identified during transgressive and highstand intervals. Changes in morphological parameters of *Calpionella alpina* loricas along the J/K boundary interval were statisticaly analysed and proved (Kowal-Kasprzyk, 2014).

During calpionellid evolution the lorica composition changed several times, probably in connection with changes in sea-water temperature and chemistry. Two distinct overturn events (change of microgranular lorica into the hyaline one) recorded in the Latest Early Tithonian and during the Middle Aptian were synchroneous with investigated peaks in nannoplankton abundance. Microgranular calpionellids were replaced by hyaline forms. The increase of water temperature (result of enhanced volcanic activity ?) and contemporaneous climate change could influence the depletion of microgranullar forms or could lead to cessation of their loricas production. The rests of ?cysts/bags visible localy in microgranular loricas could be signalize the stress in environmental conditions. On the other hand, the increase of water temperature and high concentration of $CaCO_3$ influenced the flourishing of nannoplankton. Ciliate protozoans feeding on calcareous phytoplankton started to agglutinate their loricas with the rests of nannofossils. It seems that the nannoplankton diversity influenced strictly calpionellid diversification. Thus radiation and diversification of hyaline calpionellids coincided with diversification of calcareous nannoplankton. Intervals in which small hyaline calpionellid forms were dominated coincided with the abundance radiations of nannoconids.

Salinity variations or volcanic episods producing rich content of metal could have been responsible for thinning and deformation of calpionellid loricas (salinity/metal-induced malformations) observed on crassicollarian loricas during the Late Tithonian and some of tintinnopsellid loricas documented during the Latest Berriasian and Valanginian. Valanginian episode of greenhouse climate associated with increased evolutionary rates in competetive planktonic communities (planktonic foraminifera, radiolarians) could led to calpionellid crisis and to their total decimation.

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Review of the Upper Volgian ammonite biostratigraphy of Arctic

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Although the lower boundary of the Berriasian Stage and thus the Cretaceous System still not defined by accepted GSSP, recent advances in Boreal-Tethyan correlation of the J/K boundary beds has shown that nearly all discussed GSSP levels falls within the Boreal Upper Volgian Substage (cf. Wimbledon et al., 2011; Bragin et al., 2013; Shurygin, Dzyuba, 2015). Thus improving of the both high-resolution stratigraphy and interregional correlation of the Upper Volgian has a special significance for tracing the lower boundary of the Cretaceous System in high latitudes of the Northern Hemisphere.

Upper Volgian in the type area of the Volgian Stage, the Russian Platform, is now well-subdivided by ammonites, which permits to recognize succession of 4 zones and 11 biohorizons (Rogov, 2014). However, this succession is based mainly on eudemic ammonites belonging to taxa which are rarely occurs outside this region (i.e. *Kachpurites, Garniericeras* and *Craspedites* (*Trautscholdiceras*). In spite of some minor differences between local Late Volgian ammonite faunas outside the Russian Platform the single zonal scale, which was at first created based on sections of the rivers Kheta and Boyarka (Khatanga depression), can be accepted for nearly all Arctic areas (Rogov, Zakharov, 2009).

Here generalized succession of zones, subzones and biohorizons of the Upper Volgian of Arctic is provided (fig. 1).

Craspedites okensis Zone.

Base of this zone and the Upper Volgian Substage is marked by FAD of *Craspedites (Craspedites)* belonging to the *C. (C.) okensis* group. Since the pioneering works on the Upper Volgian of Siberia this zone is subdivided on two subzones (Okensis below and Originalis above), the latter is recognized by co-occurrences of *Craspedites (C.)* ex gr. *okensis* and *C. (Taimyroceras)* spp. From the other hand, in the both Boreal and Subboreal areas the lineage *Craspedites (C.) praeokensis* Rogov, MS – *C. (C.) okensis* can be traced, but relation between these horizons and the former subzones within the Okensis Zone remains unclear. Recent field works held at the Kheta river (2015) has revealed that upper part of the Okensis Zone is dominated by eudemic species *Khetoceras margaritae* (*margaritae* horizon), which co-occurred with *C. (C.) okensis*, while in situ records of *C. (Taimyroceras)* in the Okensis Zone were not found. Rare *Praechetaites* were also reported from the Okensis Zone of the Kheta river by Shulgina (1967). In the Nordvik section as well as in Spitsbergen and Western Siberia *C.* (*Taimyroceras*) ex gr. *originalis* occurred with *C. (C.) okensis*. As follow from distribution of *Craspedites (C.) praeokensis* Rogov, MS and *C. (C.) okensis* in the Russian Platform, the Okensis zone is corresponding to the Fulgens and Catenulatum zones of the type area of the Volgian Stage.

Craspedites taimyrensis Zone.

Lower boundary of the Taimyrensis Zone is defined by disappearance of the *Craspedites (Craspedites)*, and assemblage of this zone is consists from *C. (Taimyroceras)*, which are represented by the index species and few still undescribed species. Unfortunately in the type section of this zone at the Kheta river Upper Volgian deposits are now hardly accessible because they are covered by numerous glacial boulders, and in situ ammonite occurrences here are relatively uncommon. At least two ammonite assemblages could be tentatively recognized here, the lower which consists from typical *C. (T.) taimyrensis* and *C. (T.) discoides* Rogov MS (in cannon-ball-like concretions) and upper with crushed *C. (T.)* ex gr. *taimyrensis* (in giant carbonate concretions). Assemblage with *C. (T.) discoides*

Rogov MS has also been found in Spitsbergen and the Nordvik section, while typical *C. (T.) taimyrensis* are known also from Western Siberia and Subpolar Urals. Age of the *C. (T.) canadensis* in the Ellesmere Island (Arctic Canada) is also corresponding to the Taimyrensis Zone. Variability and dimorphism of *C. (T.) canadensis* are very close to those of the *C. (T.) taimyrensis*. Stratigraphic range of the Taimyrensis Zone is nearly coincides with those of the Nodiger Zone of the Russian Platform.

NW Europe	E. Greenland, Norwegian Sea shelf	Spitsbergen		Franz-Josef Land	Russian Platform			Western Siberia	Northern Siberia			NE Russia	Arctic Canada
Zone	Zone	Zone/Subz.	*Biohor.*	Zone	Zone	Subzone	*Biohorizon*		Zone	Subzone	*Biohor.*		Zone
Volgidiscus lamplughi	**Chetaites chetae**	?		**Chetaites chetae**		**Volgidiscus singularis**	***Volgidiscus singularis***	**Chetaites chetae**		**Chetaites chetae**		**Chetaites chetae**	?
Subcraspedites preplicomphalus (*pars*)	?	**Craspedites (Taimyroceras) taimyrensis**		?		**Craspedites (Trautscholdiceras) nodiger**	***C. (T.) milkovensis*** ***C. (T.) nodiger*** ***C. (T.) transitionis***	**Craspedites (Taimyroceras) taimyrensis**		**Craspedites (Taimyroceras) taimyrensis**		?	**Craspedites (Taimyroceras) taimyrensis**
	Beds with Subcraspedites sowerbyi	**Craspedites okensis**: **Originalis**	***Craspedites okensis***			**Garniericeras catenulatum**	***Garn. catenulatum*** ***Garn. internicarinatum***	**Garniericeras catenulatum**	**OKENSIS**	**Craspedites (Taimyroceras) originalis**	***Khet. marg.***		***Beds with Subcraspedites*** **spp.**
					FULGENS	**Kachpurites subfulgens**	***Kachpurites involutus*** ***Kachpurites subfulgens*** ***K.cheremkh.***	**Kachpurites fulgens**		**Craspedites (Craspedites) okensis**			
		Okensis	***Craspedites praeokensis***			**Kachpurites fulgens**	***K.tenuicost.*** ***K.evolutus*** ***Crasp. praeok.***				***Crasp. praeok.***		

Fig. 1. Panboreal correlation of the Upper Volgian Substage by ammonites.

Chetaites chetae Zone.

Lower boundary of this zone should be defined by FAD of the ammonites genus *Chetaites*, while *C. (T.)* ex gr. *taimyrensis* occurred in the Taimyrensis, Chetae and Sibiricus zones, while their rare occurrences are known also from the Kochi zone. Uncommon *Praechetaites* were also found loose from this zone. Very important is record of *Volgidiscus* in the type section of the Chetae Zone (Kheta river). This section is hardly accessible now, while its description (cf. Golbert et al., 1981) providing more or less enough information about ammonites and other important fossils occurred here. This zone could be easily traced in other Boreal regions by occurrence of the index-species, which is easily distinguished from other coeval ammonites. *Chetaites chetae* / cf. *chetae* occurred in the topmost part of the Volgian Stage in Nordvik, recently they were discovered in the Franz-Josef land. In the Western Siberia *Chetaites* occurred together with *Craspedites (Taimyroceras)* and first *Shulginites*, while in the shallow-water deposits of Subpolar Urals topmost Volgian is characterized by *Shulginites* and *Subcraspedites* (Maurynia) or by *Chetaites chetae* and *Praechetaites* (Yanu-Mania). Differences between ammonite assemblages from the uppermost Volgian of the different sections of Subpolar Urals could be caused by their possible different age (in terms of ammonites biohorizons) rather than by facial differences, because similar assemblages were reported also from deep-water black shales of the central part of the Western Siberia. *Chetaites chetae* are also known from East Greenland, where they occurred at the topmost part of the Volgian (Surlyk et al., 1973). *Chetaites* ex gr. *chetae* is also occurred in uppermost Volgian of NE Russia. Presence of *Volgidiscus* and early *Shulginites* in the Chetae Zone provides its correlation with Singularis Zone of the Russian Platform and Lamplughi Zone of NW Europe.

It should be noted that all zonal boundaries of the Arctic Upper Volgian ammonite zones has significant correlational potential across the Panboreal Superrealm, although their possible infrazonal subdivision still remains tentative.

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Resolving the positioning of the Tithonian/Berriasian stage boundary and the base of the Cretaceous System.

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Since the setting up of a new ICS Berriasian Working Group in July 2007, there has been a new phase of activity on refining Tithonian and Berriasian correlations, directed towards addressing the outstanding issue of the choice of a Jurassic/Cretaceous boundary (Wimbledon et al 2011). The definition of a putative J/K boundary level in Tethys is less of a problem nowadays, but long-range correlation to other areas is difficult. Both austral and boreal regions were isolated and far from Tethys, and had, in diversity terms, more impoverished biotas; also, extensive areas of the world were then land, with non-marine sedimentation and biotas. Therefore, there has always been much effort by many colleagues put into trying to improve correlation between marine to non-marine areas and from the core area of oceanic Tethys to isolated seas, seaways and landlocked basins towards the two poles.

A decision was made early by the new Berriasian WG to dispense with previous diversions and pre-occupations, and to direct all energies towards factual matters that would promote a decision on selecting a primary marker for the base of the Berriasian. Therefore, the WG has concentrated on the detailed documentation of known key sections and seeking out new useful localities, giving special attention to integrating data from as many fossil groups as possible, preferably calibrated with magnetostratigraphy (Grabowski 2011). Numerous sites, from California and Mexico to Tibet and the Russian Far East, have been studied and assessed. Our first decision as a

WG was to examine prospective levels for a J/K boundary starting with the base of the Jacobi Subzone, then working upwards to further prospects if this was not satisfactory: so that the Alpina Subzone base, base of M18r, base of Pseudosubplanites grandis Subzone could all be considered in turn, if necessary.

Past decisions dictate that a Tithonian/Berriasian boundary and a GSSP should be defined in marine sequences in Tethys. Tethys was the largest geographical entity at that time, and thus many sites in western Tethys have received special attention in the last five years. As agreed at our first meetings, work has concentrated on calibration of markers in an attempt to construct a useful matrix that will constrain a boundary level as near to the base of the Berriasella jacobi Subzone as possible, i.e. at the base of or within magnetozone M19n. Unlike some upper Cretaceous stages, where one fossil taxon is the only tool used for definition of a GSSP, in the Tithonian/Berriasian boundary interval in Tethys several groups may be present and complement one another, so that calpionellids, calcareous nannofossils, radiolarians, forams and ammonites may contribute to give an integrated matrix. Authors have attempted definition of the boundary level using, particularly, calpionellids, ammonites, nannofossils and, notably, magnetostratigraphy. Unlike some other Cretaceous stages, there is no marked chemostratigraphic event in the latest Tithonian and Berriasian that we can use to help fix a boundary.

Prior to 2007, J/K correlation had already shifted away from a concentration on ammonites. This was because widespread endemism in ammonites had repeatedly been recognised as an obstacle to correlation, even in western Tethys. There has been recent WG activity in southern France (Le Chouet, Font de St Bertrand, Beaume, Charens etc) and this has, amongst other things, highlighted the absence of *Berriasella jacobi* in the lower part of its nominal subzone (Frau et al. in press), and the predominance of *Delphinella*, and a similar situation has been found at Theodosia (Ukraine). Similarly, the difficulty of separating "Jacobi Subzone" and "Grandis Subzone" faunas has been recognised at several sites. Thus the Jacobi Zone, chosen by the WG for the focus of its first studies, has been downgraded as a possible GSSP level, and the definition and usefulness of the Grandis Subzone's base has been brought into question. Further, the lack of biotic markers bracketing the base of M18r has confirmed its unsuitability as a primary marker.

In recent times, calpionellids have been seen as the most useful fossil group by numerous authors, and the turnover from *Crassicollaria* species to small orbicular *Calpionella alpina, Crassicollaria parvula and Tintinopsella carpathica* has been documented consistently as a widespread marker in the middle part of M19n.2n. At the Berriasian WG's meeting in Warsaw this was the preferred marker for definition of the base of the stage (Wimbledon). This level lies in middle of M19n, and the interval traditionally labelled as the "Berriasella jacobi Subzone" and it is constrained also by the FADS of species of nannofossil (*Cruciellipsis cuvillieri, Nannoconus wintereri, Hexalithus geometricus* and *Nannoconus globulus globulus*). Anomalies in the first appearances of some nannofossil species in M19n in Tethys are still a matter for further study (Svobodova and Kostak in press). It is important to note that the core area for successful correlations in Tethys has expanded due to recent studies: with the application of the "western Tethyan" calpionellid scheme (Michalik & Rehákova 2011; Michalík et al. 2009) to Mexico (Lopez et al. 2011), Kurdistan and Iran, the finding of lower Berriasian nannofossil markers identified in North Africa, Yemen, Iraq and the Andes, and magnetostratigraphy around the J/K boundary extended to California and North Africa for the first time.

Work still must focus on finding proxies for these key marker species in the boreal and austral regions (Riccardi 2015) and in non-marine areas, and on the careful application of magnetostratigraphy where it is likely to be productive. The non-marine of northern China finally has provided evidence for locating the J/K boundary level, well below the famous Jehol units, in the Tuchengxi Formation (Li and Matsuoka 2015). Some useful proxies close to the *C. alpina* level have been identified in Siberia, and this, plus the revision of the magnetostratography, is an improvement with a key part of the boreal (Bragin et al 2013; Dzyuba 2012; Schnabl et al 2015). One of the biggest challenges for Tethyan correlation remains the marine areas southern Tibet. Recent work presenting radiometric dates alongside contradictory/incompatible ammonite and nannofossil results (Liu et al. 2013) is in need of urgent revision. First decisions by the Berriasian Working Group on the primary marker for the Tithonian/Berriasian boundary and a contender GSSP are expected in 2016.

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