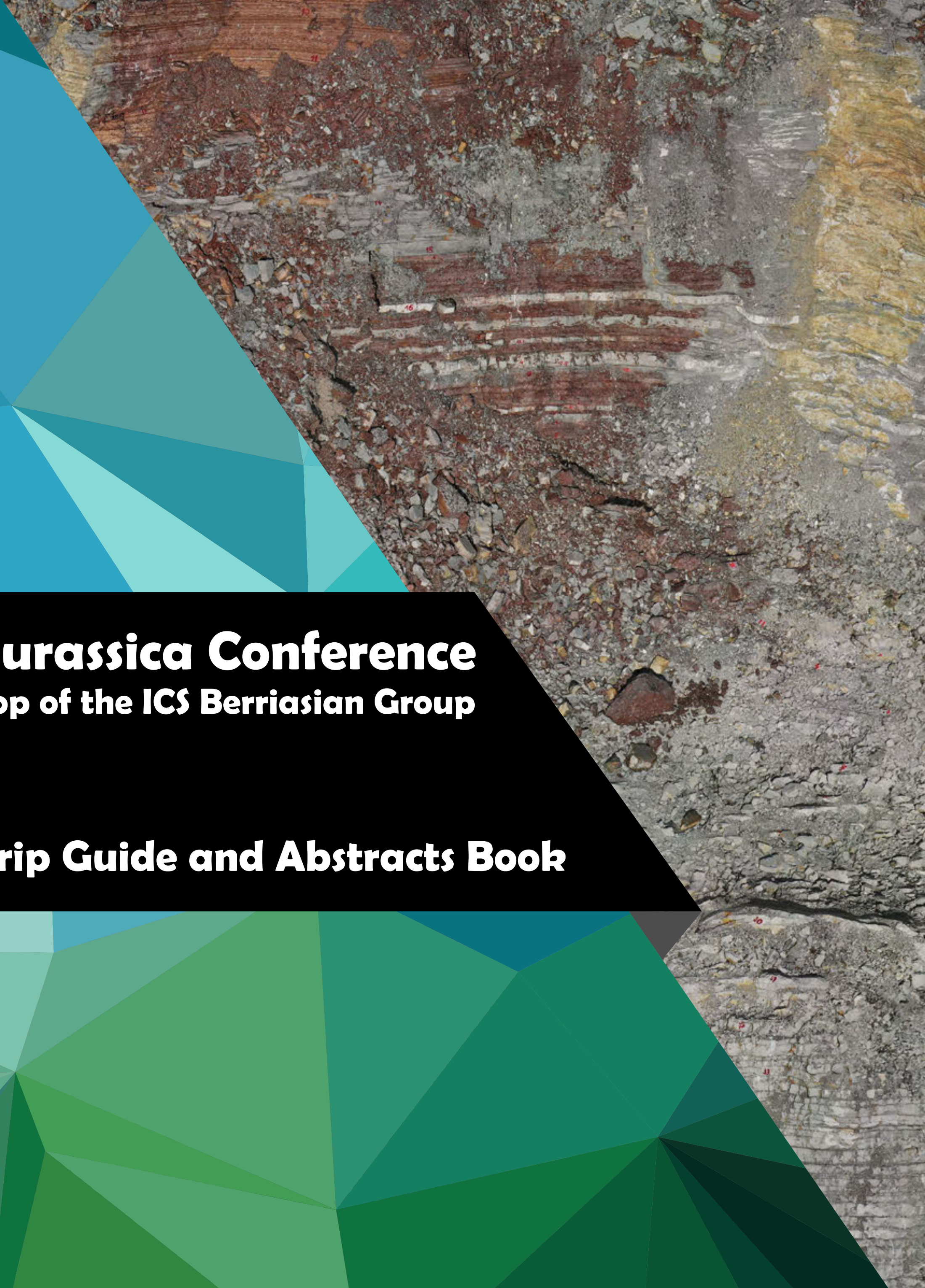

XIVth Jurassica Conference

Workshop of the ICS Berriasian Group

Field Trip Guide and Abstracts Book

EARTH SCIENCE INSTITUTE, SLOVAK ACADEMY OF SCIENCES
BRATISLAVA, 2019

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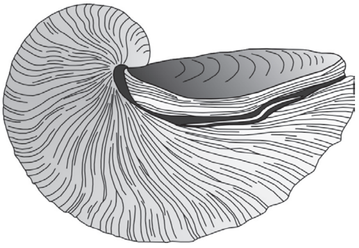

June 10–14, 2019
Bratislava, Slovakia

Edited by:
Kamil Fekete, Jozef Michalík and Daniela Reháková

Earth Science Institute, Slovak Academy of Sciences
& Faculty of Natural Sciences, Comenius University

Bratislava, 2019

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POLSKIE TOWARZYSTWO GEOLOGICZNE
SOCIETAS GEOLOGORUM POLONIAE
1921

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The manuscripts in this abstract book have been subjected to the review. Comments of the reviewers which helped to clarify some aspects of the original manuscripts are greatly appreciated.

This monograph is released as a result of **APVV-14-0118** Project ‘Regional stratotypes for genetic, earthtime and paleoenvironmental properties of the Western Carpathian sedimentary basins’. Financial support of this project from Slovak Research and Development Agency (APVV) and also from the Slovak Commission for United Nations Educational, Scientific and Cultural Organization is gratefully acknowledged.

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Slovenskej komisie
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Volume is dedicated to oustanding work of
Andrzej Wierzbowski in Jurassic biostratigraphy

Andrzej Wierzbowski

60 years of scientific research in Jurassic geology

Prof. A. Wierzbowski was born on September 1, 1938 in Warsaw. He graduated in 1961 at the Faculty of Geology, University of Warsaw. In 1961 he joined the Department of Geological Sciences, Polish Academy of Sciences, where he started postgraduate studies of Jurassic ammonites under the supervision of a famous geologist and paleontologist – Prof. E. Passendorfer. He obtained a Ph.D. degree in 1965 after presentation of a thesis entitled: "Upper Oxfordian and Lower Kimmeridgian of the Wieluń Upland (in Polish)". Since that time he has been engaged in stratigraphical studies of the Upper Jurassic sediments. Till today he is faithful to this topic.

In 1967 Prof. A. Wierzbowski began work at the Faculty of Geology, University of Warsaw, initially at the Department of General Geology, then, after re-organization of the Faculty, at the Department of Dynamic Geology. In the years 1971–1973 he participated in geological studies in Cuba, where he began to prepare a Doctor of Science thesis entitled "Oxfordian ammonites of Pinar del Rio Province (western Cuba): their revision and stratigraphical significance". He obtained a D.Sc. degree in 1977, which was given by the Scientific Council of the Faculty of Geology. His D.Sc. thesis was later awarded by the Ministry of Higher Education and Technics. He was employed at the Faculty of Geology, University of Warsaw as an associate professor starting from 1983, and attained a full professorship in 1995. After he retired from the Faculty of Geology, from 2011 to 2016, he worked in the Museum of the Polish Geological Institute – National Research Institute. In 2014 he was awarded a medal "Rewarded for Polish Geology" by the Ministry of the Environment.

Prof. A Wierzbowski's scientific activity is mainly focused on the stratigraphy of the Jurassic, as well as on the sedimentology, paleogeography and microfacies of this system. He primarily deals with ammonite paleontology, paleoecology and biostratigraphy. For many years he has been conducting studies of the Jurassic rocks in the Polish Jura Chain (especially in the Wieluń Upland), in the border of the Holy Cross Mountains, in the Pieniny Klippen Belt, the Kujawy area, and the Peri-Baltic Syneclise in Poland. He was also engaged in studies of the Jurassic deposits of Cuba (1971–1973), Spitsbergen (1979), Barents and Norwegian seas (1985–1992), Scotland (2001–2003), Slovakia (since 1997), Ukraine (2001–2004), and Russia (2007–2012). His principal achievements in the area of ammonite biostratigraphy include:

(1) Documentation of the paleogeographical differentiation of global ammonite faunas based on the comparison of coeval Oxfordian ammonites from Europe and Cuba.

(2) Determination of the detailed biostratigraphy of the Toarcian–Kimmeridgian succession of Spitsbergen.

(3) Determination of the detailed biostratigraphy of Jurassic and lowermost Cretaceous deposits from wells drilled on the shelves of the Barents and Norwegian seas (in cooperation with Norwegian IKU).

(4) Documentation of the biostratigraphy, lithology and facies changes of the Oxfordian and the Lower Kimmeridgian in the Polish Jura Chain and adjacent areas.

(5) Presentation of a proposal of the Global Boundary Stratotype Section and Point (GSSP) for the Oxfordian–Kimmeridgian boundary in the Flodigarry section in Isle of Skye (Scotland) and its correlation with auxiliary sections in the Subboreal Province (Russia) and the Submediterranean Province (Poland and Spain).

(6) Studies of the Tithonian ammonites of the Rogoźnik Coquina Member in the Pieniny Klippen Belt (awarded by a Science Secretary of the Polish Academy of Sciences), and the Tithonian ammonites from the Tomaszów Syncline, Holy Cross Mts.

(7) Documentation of the biostratigraphy and correlation between various Jurassic rocks of the Czorsztyn, Niedzica and Czertezik successions of the Pieniny Klippen Belt.

(8) Biostratigraphical and lithological investigations of the Upper Jurassic of the Wapienno and the Bielawy sections in the Kujawy area of Poland.

(9) Determination of the biostratigraphy of the Middle Jurassic Ore-bearing Częstochowa Clay Formation,

(10) Paleontological studies of the factors determining ontogenetic development of ammonite shells.

Prof. A. Wierzbowski is a co-author or principal author of about 160 publications devoted to the Jurassic rocks and their biostratigraphy, which have been published both in international and Polish journals, as well as of about 120 short comments, reviews and summaries. In addition, he has participated in many geological conferences, including all the Jurassic congresses, where he has given several tens of lectures. He was the chairman of the 7th International Congress on the Jurassic System in Kraków in 2006. He also took part in many grant projects funded by Polish and International Organizations.

Prof. A. Wierzbowski, for many years, has conducted tutorials and has given lectures for students of the Faculty of Geology, the Faculty of Geography and Regional Studies, as well as for students of the Inter-Faculty Studies in Environmental Protection of the University of Warsaw. He has given lectures on general or dynamic geology and paleoecology, conducted tutorials and seminars on the same subject and conducted geological trips for students – to the coast of the Baltic Sea and to the Holy Cross Mountains in Central Poland. He was a supervisor of 40 M.Sc. theses and 5 Ph.D. theses. In addition, he has contributed to popularization of geological knowledge by taking part in radio broadcasts, an UNI-KIDS project, and cyclic broadcasts of the Polish ("Such a landscape"), and of the Polish and Slovak televisions ("Through the Carpathians"); for this he was awarded by the Ministry of Education a Medal of National Education.

Prof. A. Wierzbowski acted as a head of the Institute of Basic Geology of the Faculty of Geology (1981–1984), a vice-dean of the Faculty of Geology (1984–1987), a deputy of the Inter-Faculty Studies in Environmental

Protection (1993–1996), a head of the Department of Dynamic Geology of the Faculty of Geology, University of Warsaw (till 2009). He was also a member of the scientific councils of the Institute of Paleobiology, Polish Academy of Science, of the Inter-Faculty Studies in Environmental Protection, University of Warsaw, of the Committee of Geological Sciences, Polish Academy of Sciences, of the Faculty of Geology, University of Warsaw, and of the Polish Geological Institute – National Research Institute. Till now he acts as an editor-in-chief of the Volumina Jurassica journal, which is edited by the Polish Geological Institute – National Research Institute and the Faculty of Geology, University of Warsaw, and supported by the International Subcommission on Jurassic Stratigraphy (ISJS) of the International Union of Geological Sciences (IUGS). In addition, he is a convenor of the Kimmeridgian Working Group of the International Subcommission on Jurassic Stratigraphy of the International Commission on Stratigraphy and works actively on the Global Boundary Stratotype Section and Point (GSSP) proposal of the Oxfordian–Kimmeridgian boundary. He was also a founding member of the Polish Working Group of the Jurassic System, an initiator of "Jurassica" conferences and actively takes part in work of the society of Jurassic geologists. In addition, he has been participating in the sharing and planning of a lot of geotouristic projects in the area of the Polish Jura Chain as well as in the Opoczno and the Łuków counties in Poland. He has also arranged geological exhibitions including ones for a Museum of the Pieniny National Park in Krościenko nad Dunajcem in Poland.

Dear Father, on my behalf and on behalf of your colleagues and friends I wish you a lot of other work successes and many joy and happy moments in the circle of your loving family.

Hubert Wierzbowski

XIVth Jurassica Conference
& Workshop of the ICS Berriasian Working Group

FIELD TRIP GUIDE

Macrofossils from the Snežnica section (coll. Juraj Danko)

Preface

Immense treasure of fossils, namely ammonites, belemnites, bivalves, brachiopods, corals, dinosaurs makes of the Jurassic Period the most famous Mesozoic time interval, well known even to a wide public. Representatives of many fossil groups are serving as the basis for the development of modern concepts of biostratigraphy, chemostratigraphy, paleoclimatology, paleoecosystems 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 the Global Stratotype Section and Points (GSSP) criteria (Hettangian, Sinemurian, Pliensbachian, Toarcian, Aalenian, Bajocian, and Bathonian) so far. This very special period is typical of its unique global regime with rather equalized condition. Expressive 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 paleoclimatic models, quite different from successive Cretaceous ones, can teach us the rules of alternation between glacial (icehouse) and warm (greenhouse) conditions on the Earth.

Long series of JURASSICA scientific conferences have been organized by Polish, Slovak and Czech colleagues in close mutual cooperation. Also ten international Jurassic congresses devoted to the Jurassic system took place in last decades in different countries of the world (the eleventh's one is planned to be held in Budapest, 2022). They have collected a huge amount of leading knowledge and contributed to the scientific research of this period. However, many aspects concerning fauna, flora, paleobiogeography and climate remain unrecognized. JURASSICA conferences became an efficient platform to exchange of scientific information from all geoscientific specializations concerned with Jurassic problems and issues.

After 12th successful joint meeting in Smolenice 2016, we decided to join the incorporative effort of the JURASSICA Conference with the Workshop of the ICS Berriasian group, which deals with the long-lasting problem of defining the Jurassic and 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 cooperation will further evolve to be stronger and more complex in the future.

The organizing committee

A short introduction to the West Carpathian geology

Dušan PLAŠIENKA

Tectonic setting of the Western Carpathians

The Western Carpathians form 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 the 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 sedimentary Paleogene and thick Neogene sedimentary basinal infillings 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 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.

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 the ophiolite- and blueschists-bearing complexes (the 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

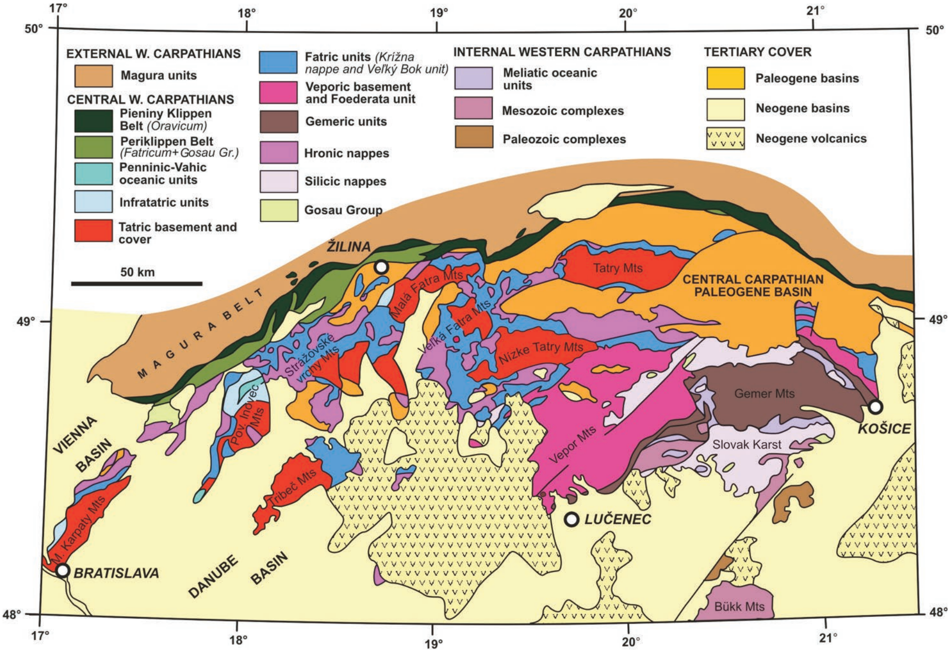


Fig. 1. Simplified tectonic map of the Western Carpathians (Plašienka 2012, adapted).

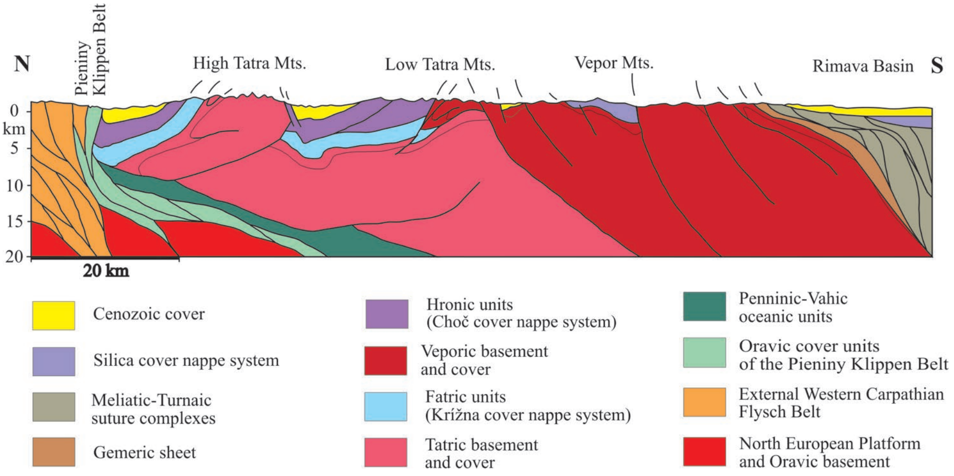


Fig. 2. General tectonic cross-section of the Central Western Carpathians.

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 latter 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.

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 Paleogene sediments detached from an unknown, completely subducted basement. 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 paleogeographic domain, known as the Pienidic or Pieninic units in an older literature, but renamed as the Oravic domain (Oravicum) by Maheľ (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 (Maheľ 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 the accretionary wedge of the Carpathians Orogen consisting predominantly of the 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).

The Pre-Alpine basement of the Western Carpathians

The oldest rock complexes of the Western Carpathians are built up by fragments of the Hercynian (Variscan) Orogeny which are recently incorporated into the Alpine nappe system. The pre-Alpine crystalline basement of Slovakia mainly consist of Upper Proterozoic (?) to Lower Paleozoic metapelites, metapsammites, metabasaltic and metagabbro rocks, orthogneisses, rarely metacarbonates, metamorphosed mainly in greenschist to amphibolite facies, rarely granulite and eclogite facies. The basement units were intruded by the Hercynian (Devonian to Mississippian) S- and I-type orogen-related granites, granodiorites and tonalites, rarely dioritic rocks (Petrík et al. 1995; Broska & Uher 2001; Kohút et al. 2008). The crystalline basement was developed between Laurasia and fragments of Gondwana during the Hercynian orogeny, mainly in the Devonian–Mississippian periods. (Fig. 3.) Relics of pre-Alpine nappe structures were documented in several parts of the Tatric and Veporic basement sheets (e.g. Putiš 1992; Bezák et al. 1997; Janák et al. 2001).

The post-Hercynian Permian stage is characterized by extensive volcanic and plutonic activity producing basalts, andesites, A-type rhyolites, dacites and granites, and by subsidence of extensional sedimentary basins filled up by clastic sediments (e.g. Vozárová & Vozár 1988; Uher & Broska 1996)

Alpine evolution of the Western Carpathians

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 paleogeographic settings (e.g. Plašienka et al., 1997; Putiš et al. 2009; Fig. 4). 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 the "Paleo-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 formation of its accretionary wedge (the "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, being associated with the 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; Fig.5).

The closure of the North-Penninic Ocean during the end of Paleogene and beginning of Neogene has been accompanied by 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 the 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.

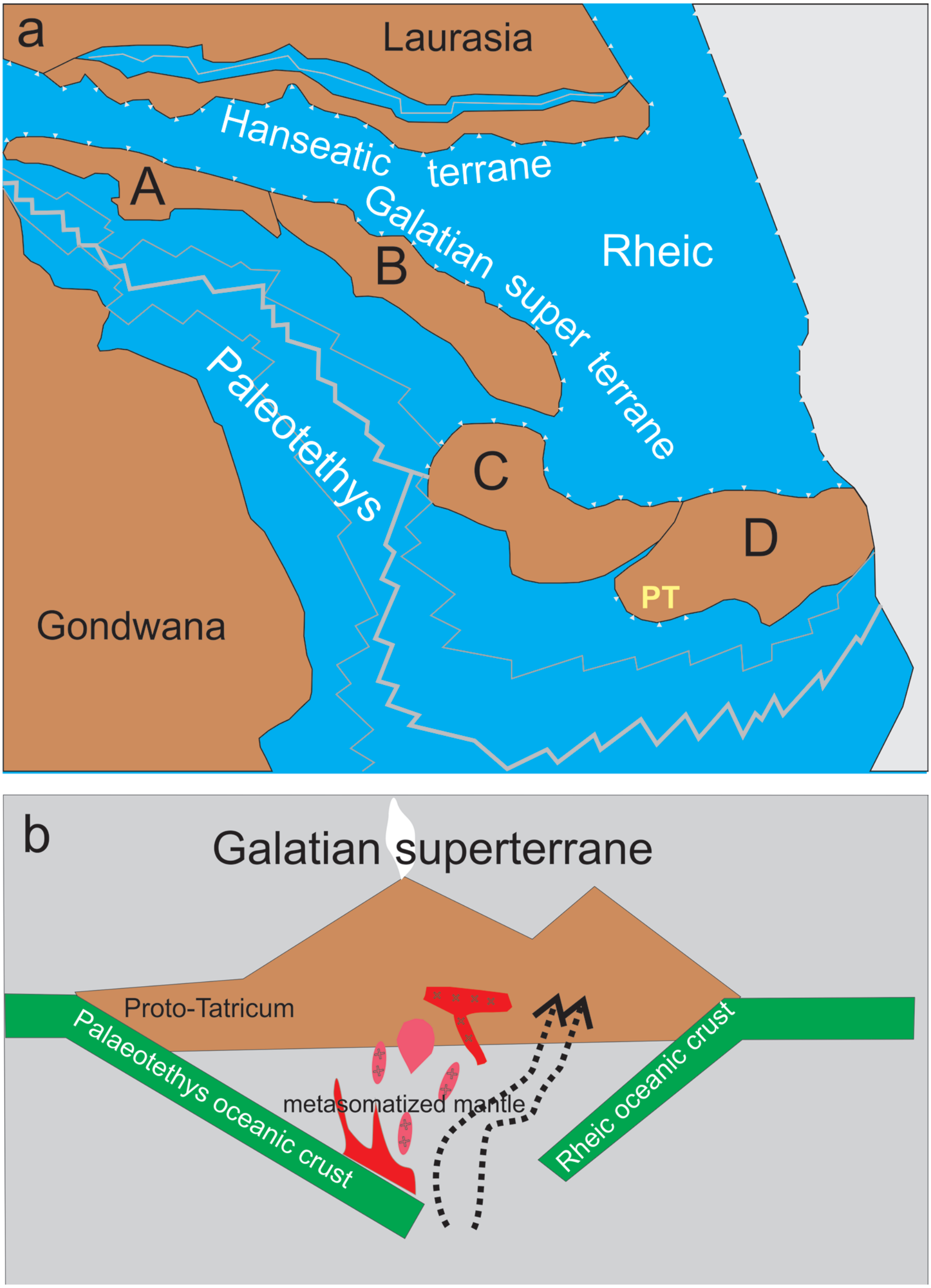


Fig. 3. Post-Variscan paleogeographic situation of the Mediterranean area with the position of future West Carpathian units (Broska et al. 2013): a – Reconstruction of Variscan domains according to Stampfli et al. (2011) (slightly modified) and proposed position of Proto-Tatric area; Explanation: A – The Meguma teranne, B – The Armorica terrane, C – The Ibero-Ligerian terrane, and D – The intra-Alpine terrane; and b – The Paleotethys ocean subducts from the south initiating the I-type magmatism in Proto-Tatric realm.

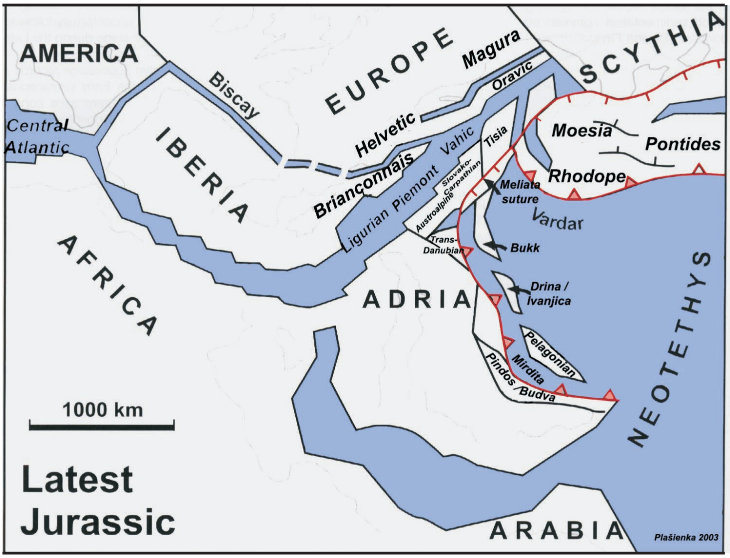


Fig. 4. Paleoalpine paleogeographic situation of the Mediterranean Tethys area with the position of future West Carpathian units (Plašienka 2003).

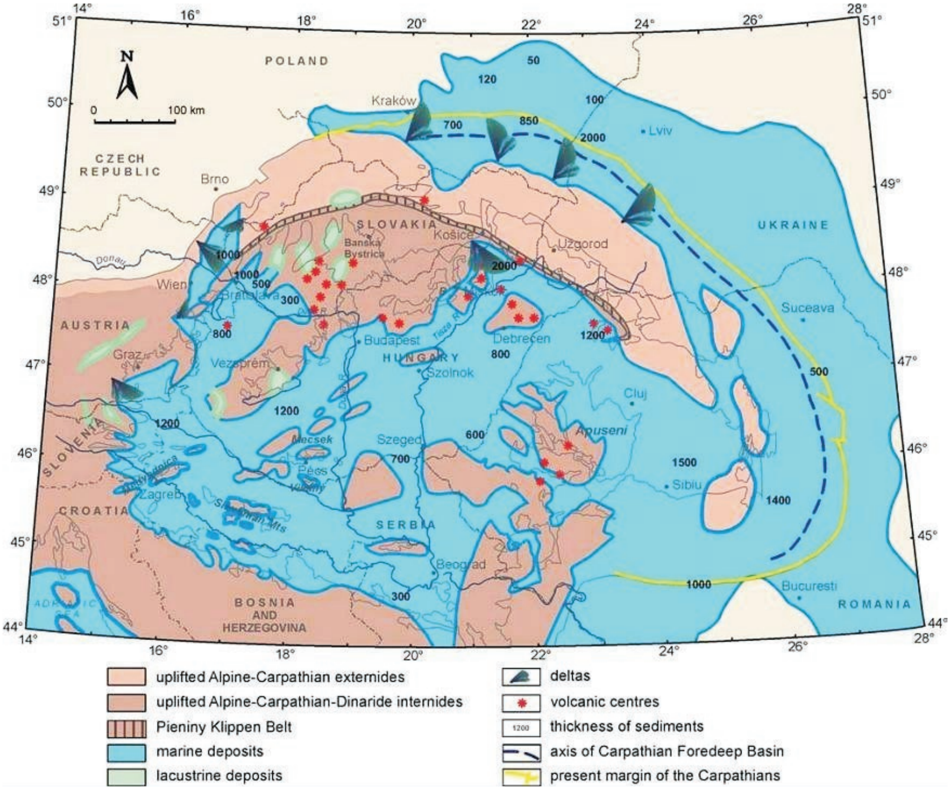


Fig. 5. Neoalpine paleogeographic situation of the Mediterranean Tethys area with the position of future West Carpathian units (Kováč et al. 2007).

The structure of the Pieniny Klippen Belt

Dušan PLAŠIENKA

Introduction

The tectonic contact of two principal superunits of the Western Carpathians (the Outer and Central Carpathians) is rimmed by the Pieniny Klippen Belt – a characteristic element of their mountains structure (Fig. 6). This unit, originally forming the rim of the European shelf, is typical of tensional basins-and-ridges development since Early Jurassic until Paleogene, not interrupted by Paleoalpine tectonic movements, when superficial nappe structure of Central Carpathians has originated. Its typical klippen style contrasts with the slight diagenetic transformation of rock sequences. On the other hand, rocks of Central Carpathian sequences are usually much more affected both by diagenesis and tectonic stress. This fact favorizes the complex study of Jurassic and Cretaceous sedimentary sections in the Pieniny Klippen Belt. Since Early Bajocian (Ivanova et al. 2019), they have been formed in two parallel shallow, but considerably subsiding marine basins separated by the Czorsztyn Ridge. Our Strapkova and Brodno sections formed in more distal areas of the basin, in neighbourhood of the Penninic rift system, which has been gradually invaded by the Mid Atlantic – Penninic

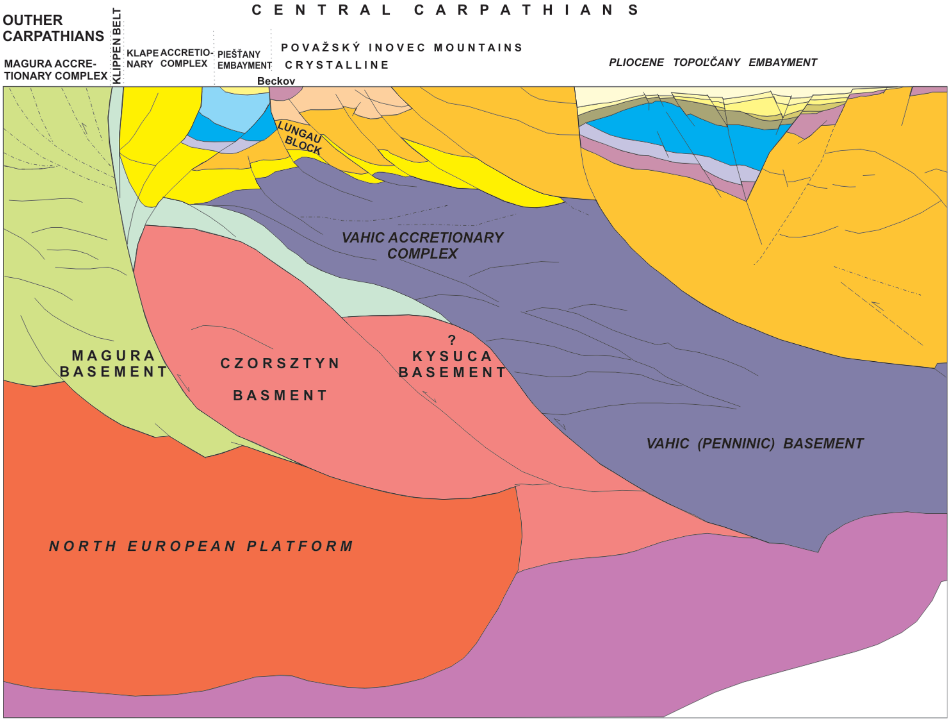


Fig. 6. An interpretation of deep seismic profile through the West Carpathian margin from the Tatric to the the Bohemian Massif (Plašienka et al. 1991).

Ocean arm during Jurassic and Cretaceous (Michalík 1994; Plašienka 2003).

In the Western Slovakia, the Pieniny Klippen Belt (PKB) is morphostructurally divided into four sectors: Podbranč-Trenčín, Púchov, Varín and Orava, which differ in their inner structure and in presence of the individual units. The geological and tectonic division of the PKB is however more complex. Numerous units, developments, lithostratigraphic and tectonic units have been distinguished during long-term investigations (e.g. Birkenmajer 1977; Mišík et al. 1996).

The Púchov part of the PKB, between the Vlára river valley and town of Bytča in NW Slovakia, is a SW–NE trending, some 45 km long and up to 20 km wide zone of extremely intricate structure. It involves all types of units known in the PKB – the Oravic superunit, as well as the "non-Oravic" units of the Central Carpathian affiliation (Fig. 7).

The Oravic (or "Pienidic" in older literature) Superunit includes typical Klippen of the ridge-derived Czorsztyn Succession (including the largest klippe of this succession in the entire PKB – the Vršatec Klippen), basinal Kysuca and Pieniny Successions (the first one corresponding to the Branisko Succession in Poland) several types of "transitional" successions as the Pruské Succession (similar to the Niedzica Succession from the Polish part of the PKB – cf. Aubrecht & Ožvoldová 1994), The Czertezik Succession (Wierzbowski et al. 2004), the Orava Succession (Schlögl et al. 2000), the Nižná Succession (Józsa & Aubrecht 2008), the Mariková Succession, or the Streženice Succession (Began & Borza 1963). A special Fodorka Succession (Salaj 1987) was described from the Horné Sŕnie area – it is a succession deposited presumably north of the Czorsztyn Ridge, i.e. it would correspond to the Grajcarek Succession of

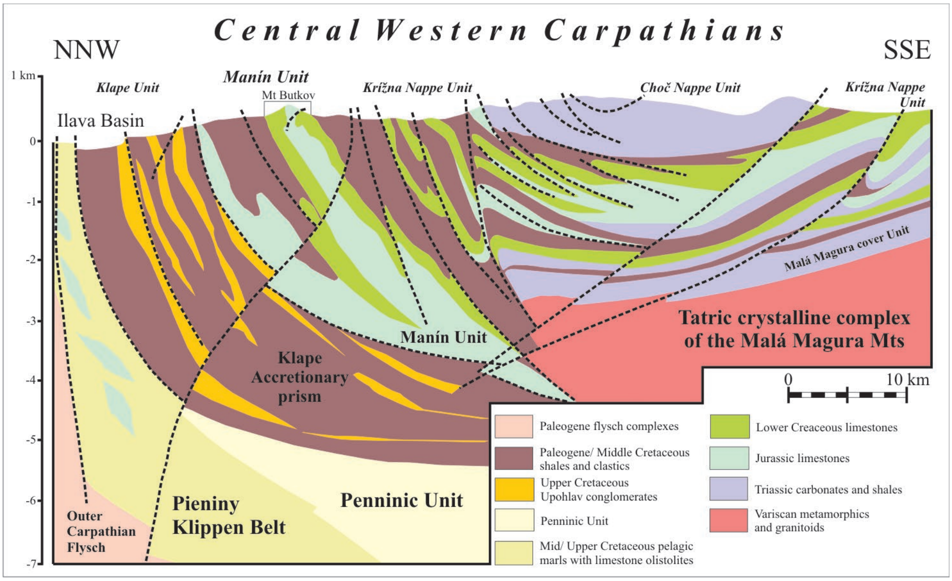


Fig. 7. Generalized cross-section through margin of the central Western Carpathians in contact with the Pieniny Klippen Belt, Middle Váh Valley segment (Žítt & Michalík 1988).

the Magura Superunit in the Polish PKB part. Klippen of the Oravic Superunit occur along the northwestern margin of the PKB, forming a narrow (a few km) "Klippen Belt *sensu stricto*". The much broader southeastern part is mostly built by the "non-Oravic" units, with occasional tectonic windows of Oravic units and the Senonian – Paleogene overstepping cover (Gosau Supergroup). This zone was designated as the "Peri-klippen Zone" by Maheľ (1980).

Three large units compose the "non-Oravic" Peri-klippen zone. The Drietoma Unit, embracing Upper Triassic–Cenomanian, dominantly basinal succession of likely Fatric (Krížna–Zliechov Succession) provenance, overrides the Oravic units. It forms synclinal tectonic outliers in the Vršatec area, but dominates towards the SW in the Trenčín sector of the PKB. The youngest member of the Drietoma Unit is the mid-Cretaceous (Albian–Cenomanian) synorogenic flysch with „exotic" conglomerates. This provides a link to the huge Klape Unit, which prevails in the Púchov Peri-klippen Zone. The Klape Unit is composed of some thousand metres thick mid-Cretaceous wildflysch complex (the Klape Flysch) with big olistolites of Triassic and Jurassic carbonates (e.g. the spectacular Klape Klippe). In the Považská Bystrica area (around the Nosice dam), the belt of the Klape Unit is up to 15 km wide, composed of four to five juxtaposed subunits divided by antiformal strips of the Kysuca Unit and/or synforms of overstepping Gosau sediments (Fig. 1). These Klape subunits are considered to represent strike-slip duplexes, accumulation of which caused exceptional broadening of the PKB in the Púchov sector.

The SE-most component of the Peri-klippen Belt is the Manín Unit, which is occurring on the left side of the Váh River, in the NW part of the Strážovské vrchy Mts (Fig. 7). Its Lower Jurassic–Cenomanian sequence (including the characteristic Urgon-type platform limestones) closely relates to the Vysoká-type ridge successions of the Fatric Superunit (e.g. the Belá Unit in the Strážovské vrchy Mts). However, many authors prefer the Tatric affiliation of the Manín Unit. The Manín Unit is dominated by mid-Cretaceous hemipelagic and flysch formations, older stiff limestones build several large "Klippen", which are in fact brachyanticlines (Butkov, Podhorie, Manín Narrows, Drieňovka). Senonian sediments within both the Klape and the Manín units were either considered to represent their integral continuous sequences (Salaj 1990), separated by a stratigraphic hiatus in places (Marschalko & Kysela 1980), or tectonic windows of the underlying Kysuca Unit (the Podháj Succession; Rakús & Hók 2005). However, we favour the variant in which the Senonian sediments in the Klape and Manín Zone represent a post-nappe, Gosau-type cover. The mid-Cretaceous flysch of the Manín Unit is from the SE overridden by the frontal Fatric elements with basinal Zliechov Succession (typical Krížna Nappe). Nevertheless, there occurs also a strip of another puzzling element – the Kostolec Unit. Presently, the blocky Kostolec Klippen of shallow-water Jurassic limestones embedded in the mid-Cretaceous flysch are regarded as olistolites of an unknown provenance (Rakús & Hók 2005).

Overthrust of Oravic units over various Upper Cretaceous–Eocene flysch formations of the Magura and/or Biele Karpaty superunits can be documented along the NW margin of the Púchov sector of the PKB (Mt Vršatec, Maríková). However, this early thrust-related structure was strongly overprinted by the Tertiary transpression; consequently all units are forming a broad positive flower structure. Oravic units along the NW margin are mostly steeply SE dipping, while the Peri-klippen Belt is affected by large-scale upright folding (Fig. 8). Local axial plane cleavage is developed in the fold hinges. Macrofold axes strike parallel, or slightly oblique to the belt boundaries. They are seldom horizontal, but rather plunging in both directions, thus forming brachyclines (Fig. 8). Numerous post-folding faults – slickensides are generally steep to vertical, with gently plunging striae pointing to an oblique- or strike-slip, dominantly dextral movement. In the NE tip of the Púchov sector, near the town of Bytča, the PKB is rapidly narrowing, almost disappearing, due to dextral offset along the W–E trending dextral fault named the Bytča fault zone. The next Varín sector of the PKB is W–E trending and located within the southern limb of the structural flower, therefore it is strongly affected by backthrusting (Marko et al. 2005).

Summing up, the Púchov sector of the PKB is the widest one (if considered together with the Peri-klippen Zone), embracing numerous units, both Oravic and "non-Oravic". The latter most probably represent the frontal elements of the Central Carpathian Fatric cover nappe system incorporated into the PKB structure. Exceptional breadth

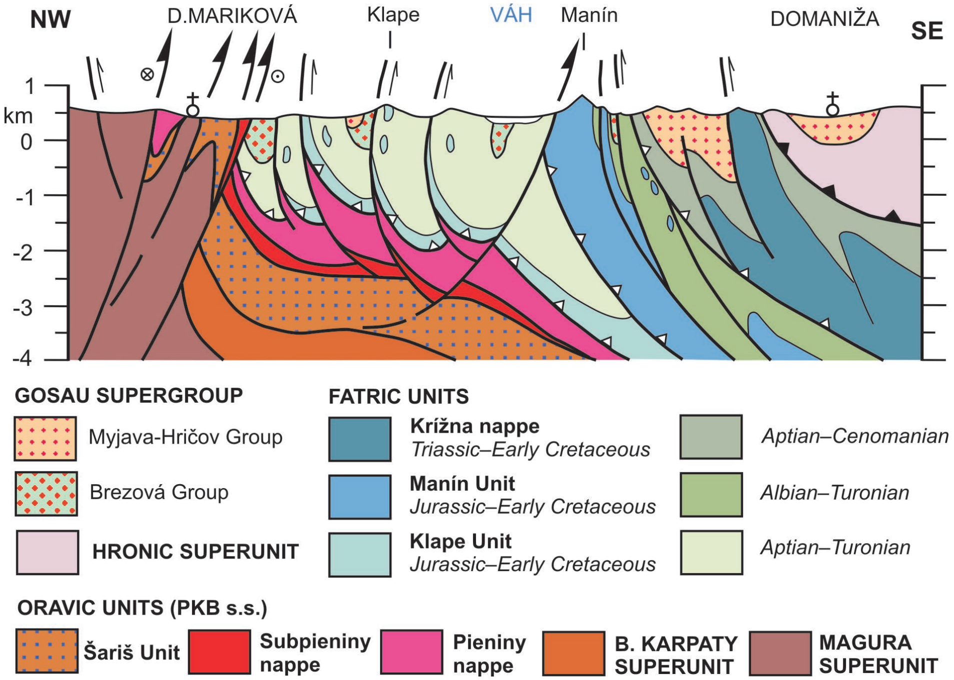


Fig. 8. Character of structure of the western part of the Pieniny Klippen Belt (Plašienka & Soták 2015).

of the Púchov sector is caused by accumulation of several strike-slip duplexes of the Klape Unit. The structural relationships indicate first downward (NW-ward) propagated, piggy-back mode of thrusting during the Late Cretaceous–Early Tertiary, followed by large-scale upright folding passing into dextral wrenching during the Oligocene–Lower Miocene, which incorporates also the Eggenburgian (Burdigalian) sediments. The Middle –Late Miocene period is characterized by sinistral transtension along the Mur–Mürz–Leitha–Dobrá Voda–Považie–Žilina wrench corridor, and opening of small Ilava Basin filled with Pliocene–Quaternary fluvial sediments.

Short outline of the Pieniny Klippen Belt evolution

Based on the existing data mostly from western Slovakia, the following principal evolutionary tectonic stages can be reconstructed in the units participating on the structure of the Pieniny Klippen Belt and adjacent zones (Plašienka 2003, 2008) (Figs. 9a, b);

- Triassic – little known carbonate ramp in the Oravic Domain;
- Lower Jurassic to Aalenian – wide symmetric rifting, tectonic subsidence with mostly anoxic sedimentation in halfgrabens;
- Bajocian – origin of the Czorsztyn Ridge due to thermal uplift above a lithospheric-scale north-dipping detachment fault accompanying the strongly asymmetric rifting phase;
- Bathonian – continental breakup on the inner side of the Czorsztyn Ridge, opening of the South Penninic–Vahic oceanic tract with the Kysuca–Pieniny Basin being located on its northern (in present coordinates) flanks;
- Callovian to Tithonian – overall thermal subsidence in entire Oravic domain;
- Berriasian to Valanginian – renewed asymmetric rifting, repeated thermal uplift of the Czorsztyn Ridge, south-dipping detachment fault on the northern side of the Czorsztyn Ridge;
- Hauterivian to Barremian – breakup of the North Penninic–Magura Ocean north of the Czorsztyn Ridge;
- Late Early Cretaceous to Late Cretaceous – thermal subsidence, the Czorsztyn Ridge became a pelagic swell;
- Late Turonian – nappe emplacement of frontal diverticules of the Fatric (Krížna) nappe system of the Central Western Carpathians (Drietoma, Klape, Manín units) onto the southern flanks of the Vahic oceanic crust;
- Coniacian to Santonian – commencement of subduction of the Vahic oceanic lithosphere below the Central Western Carpathians, the Krížna elements deformed in a position of a “false” accretionary complex, resedimentation of Albian exotic conglomerate material from the Klape Unit into flysch deposits of the Oravic Kysuca–Pieniny Unit;
- Campanian to Maastrichtian – gradual closing of the Vahic Ocean, partial positive inversion of the Magura Basin;
- Maastrichtian to Paleocene – final closure (still incomplete) of the Vahic Basin with numerous narrow remnant and piggy-back flysch basins, collision of the accretionary complex with the Czorsztyn Ridge, detachment and thrusting of inner Oravic units along horizons of Liassic black shales and formation of an incipient foreland fold-

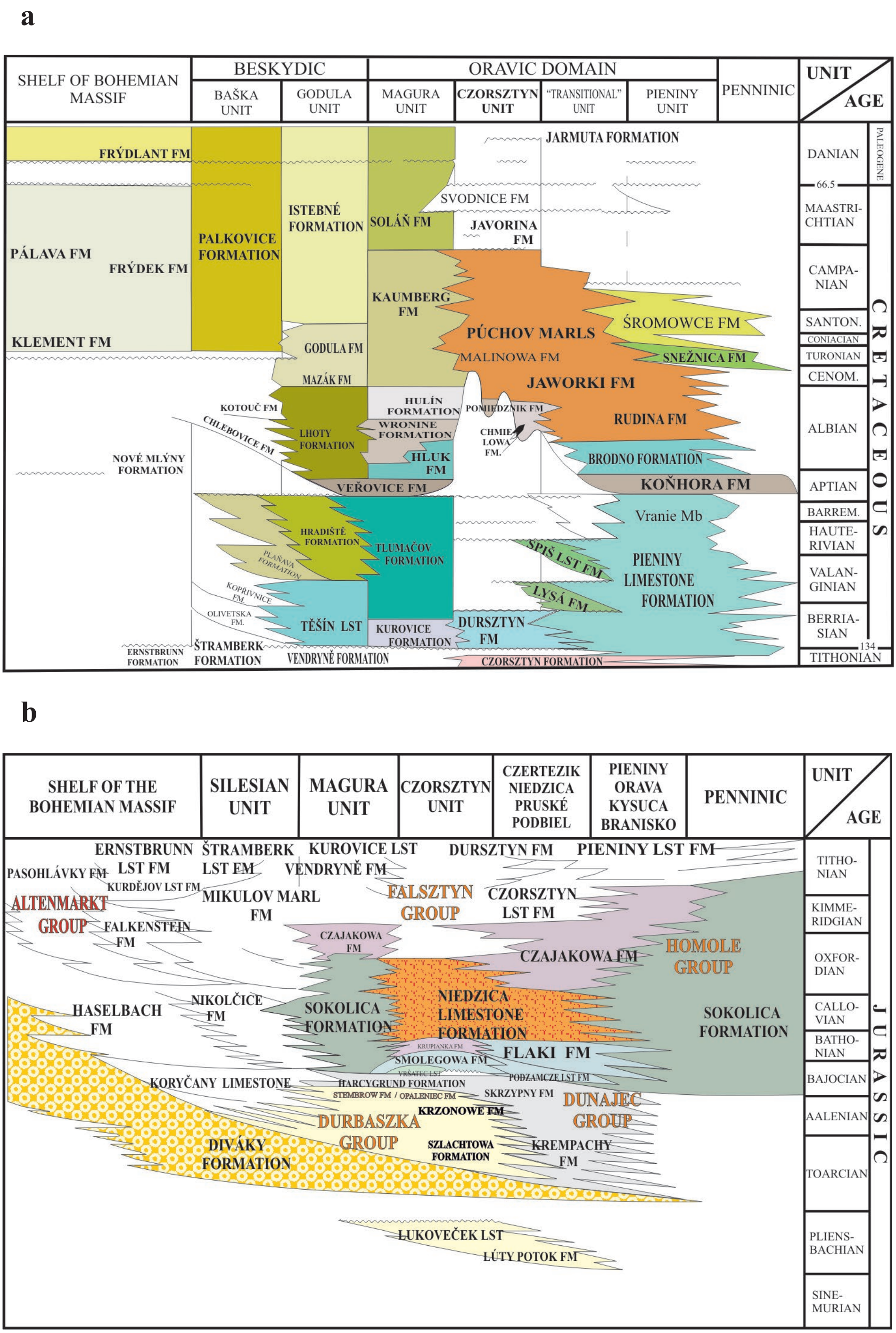


Fig. 9. Lithostratigraphy of Cretaceous (a) and Jurassic (b) formations in the Outer Carpathian units (Michalík according to Řehánek 1978; Skupien et al. 2009; etc., adapted).

and-thrust belt of detached and piggyback units and synorogenic Gosau sediments;

- Eocene – beginning of subduction of the Magura Ocean, detachment of the Czorsztyn unit from its basement that was underthrust beneath the CWC, its duplexing, recumbent folding and thrusting on the southern Magura elements;
- Middle Eocene to Oligocene – extension and subsidence on the inner side of the PKB, formation of the Paleogene Central Carpathian (Podhale) Basin in a fore-arc position;
- Early Miocene – closure of the Magura Ocean, dextral transpression and oroclinal bending in the Pieniny Klippen Belt due to counterclockwise rotation of the Central Western Carpathian block, development of a positive flower structure – the flower is usually centred by a narrow, generally vertical zone of the PKB s.s., in which strike-slipping prevailed that has lead to the formation of the typical "klippen" (block-in-matrix) tectonic style caused by pervasive brittle faulting;
- Middle to Late Miocene – sinistral transtension along the western, SW–NE trending sector of the Pieniny Klippen Belt; the NW–SE trending eastern Slovakian sector underwent only dextral wrenching – first transpression during the Early–Middle Miocene, then transtension pursued by general extension during Late Miocene and Pliocene (opening of the Transcarpathian Basin); the eastern PKB is followed by the so-called Pieniny andesite line (PAL) that extents from the Polish Pieniny Mts (Mt Wżar) to the eastern Slovakian–Ukrainian chain of the Sarmatian–Pannonian subduction-related stratovolcanoes.

Problem of the so-called "Peri-klippen units"

The Klape Unit is considered either as a part of the Vahic accretionary complex (Maheľ 1981), marginal wildflysch complex of a laterally moving plate margin (Marschalko 1986), or as a diverticulation Fatric nappe (Krížna Unit) of the Central West Carpathians (Plašienka 1995). The Vahicum is a zone with Jurassic oceanic crust, analogous to the South Penninic zones of the Eastern Alps. The Klape Unit consists of thick Middle and Upper Cretaceous, mostly flysch complexes with exotic conglomerates (the Upohlav Conglomerate) and klippen (olistoliths in this case) of Triassic and Jurassic carbonates. The flysch complexes are separated by a sequence of shallow-water oyster-bearing sandstones of Cenomanian age (the Orlové Fm). Conglomerates contain an extraordinary variety of sedimentary and magmatic pebbles derived from the Central Carpathians (e.g. Mišík & Sýkora 1981), their sources were often placed in the completely disappeared "Ultrapieninic Cordillera", later renamed as the exotic "Andrusov Ridge" (Birkenmajer 1988). The Klape Klippe is built of shalow-water Jurassic limestones. The unit is exposed in the Púchov and Varín sectors of the PKB (Rakús & Marschalko 1997).

Pre-Turonian members of the Drietoma Unit could originally represent parts of the Fatricum. The Drietoma Unit outrops in the Podbranč–Trenčín sector of the PKB contain also Upper Triassic rocks, the Carpathian Keuper and Kössen beds, which are not typical of the Pieniny Klippen Belt. Overlying strata, such as thick Lower Jurassic Kopienec and Allgäu Fms, Upper Jurassic radiolarites and nodular limestones, as well as Lower Cretaceous cherty and biodetritic limestones are akin to the Fatric Zliechov Unit. Terrigenous turbiditic sequence, resembling the Klape or Poruba flysch complexes represents the youngest, Albian–Cenomanian part of the Drietoma sequence (Began 1969).

The lithostratigraphy of Pieniny Klippen Belt units and Peri-klippen units

Ján SCHLÖGL and Roman AUBRECHT

The sedimentary history of Pieniny Klippen Basin can be divided in three stages, with (1)? Hettangian–Aalenian mostly oxygen-depleted dark terrigenous deposits within an undifferentiated epicontinental sedimentary basin, (2) Bajocian to Lower Cretaceous crinoidal, reefal, Ammonitico Rosso, siliceous (cherty limestones and radiolarites) and "biancone or maiolica-like" deposits sedimented in the platform-through system, and (3) synorogenic Late Cretaceous marly and flysch deposits (Fig. 10).

The swell (Czorsztyn) Unit

The Czorsztyn Unit represents sedimentary succession, with Lower Jurassic–Aalenian part sedimented in the relatively shallow epicontinental conditions, and Bajocian–Lower Jurassic deposited in the shallow parts of the former pelagic carbonate platform (PCP) called Czorsztyn Swell. Late Cretaceous is represented by marly and flysch deposits. The Middle–Upper Jurassic sedimentary history was accompanied by numerous synsedimentary

Fig. 10. Start of the Czorsztyn swell sequence: crinoidal limestone of the Smolegowa Fm. Slávnické Podhorie–Skalica (photo by J. Michalík).

tectonic features; such as neptunian dykes and scarp-breccias.

The only possible Triassic deposits of the Czorsztyn Unit are dolomites preserved in the small klippe Michalova Hora near Dolná Maríková, but their attribution to this unit is disputable, mainly due to different Upper Jurassic development of the here-preserved succession. Similarly, the stratigraphical and paleogeographical position of the quartzites occurring near the Mariková klippen remains unclear, although their assignement to the Upper Triassic Keuper facies seem to be most probable.

Lower Jurassic deposits are preserved at a few localities only, mainly in the Slovak and Ukrainian parts of the Pieniny Klippen Belt. Upper Sinemurian Fleckenmergel–Fleckenkalk deposits with *Echioceras raricostatum* were documented behind the Vršatec Klippen. Lower Sinemurian dark organodetritic limestones and Upper Sinemurian/Pliensbachian Fleckenmergel–Fleckenkalk facies were described from Dolný Mlyn near Stará Turá (W Slovakia), Beňatina (E Slovakia) and Priborzhavskoje and Velyky Kamenets (Ukraine) (Hlôška 1992; Schlögl et al. 2004).

Middle and Upper Jurassic deposits display some important sedimentary turnovers (Fig. 5). Uppermost Liassic to Lower Bajocian grey spotted marly limestones, marlstones and black shales (Krempachy Marl Fm and Skrzypny Shale Fm) were “suddenly” replaced by white and red crinoidal limestones during the late Lower and Upper Bajocian (Smolegowa and Krupianka Lst Fms; Fig. 10), which probably mirrors both the sea level drop and the local extensional tectonics, associated with the tilting of the crustal blocks. The crinoidal limestones contain more or less rich clastic admixture, derived from the still emerged parts of the Czorsztyn Swell. In addition to quartz grains, maily dolomite clasts prevail, indicating that the Triassic rocks were present in the source area. The extension and the platform breakdown were accompanied by the deposition of the syntectonic scarp-breccias on the toes of the rising blocks. This facies is restricted to the West Slovak part of the PKB only, called the Krasin Breccia (Aubrecht & Szulc 2006), and probably also Vršatec peri-biohermal breccia (Ivanova et al. 2019). The latter represents the facies derived from the coral–calcareous sponges biohermal limestones (the Vršatec Lst). The age of this unique facies was recently estimated as Early Bajocian (Schlögl et al. 2006) and not Oxfordian as it was thought before (Mišík 1979).

Later sedimentary turnover during the latest Bajocian and Bathonian was probably related to a global sea-level rise and/or breakup unconformity at the beginning of thermal subsidence period (Plašienka 2003). The platform and slope deposition was replaced by pelagic deposition of Ammonitico Rosso or by red non-nodular micritic limestones (the Czorsztyn Lst Fm, the Bohunice Fm; Fig. 11). Their sedimentation, although interrupted by the Late Bathonian to the Early Oxfordian sedimentary break, continued until the Early Tithonian. This long-lasting hiatus was probably controlled by both, eustasy and rapid paleogeographic rearrangement of the host basins, as indicated by recently acquired paleomagnetic data from various sections from Slovakia, Poland and Ukraine (Lewandowski et al. 2005, 2006). The contemporaneous deposits are almost completely missing, and can be traced only by detailed observations of

Fig. 11. Start of the Ammonitico Rosso sedimentation in the Údol section (photo by R. Aubrecht).

neptunian dyke infillings, extensively developed especially in the Púchov segment of the PKB (Vršatec, Štepnická skala, Vieska–Bezdedov). Evolution to the overlying Dursztyn Lst Fm is gradual; the formation shows a large facies variability from micritic and sparitic coquinas (Rogoza Coquina and Rogoznik Coquina) to micritic, more or less bioclastic limestones (Korowa Lst and Sobotka Lst) of the Tithonian age. They were followed by bioclastic Lysa Lst Fm of the Berriasian and Valanginian age and by crinoidal Spisz Lst Fm of the Hauterivian age. The carbonate sedimentation was interrupted by the period of emersion, with sedimentary break covering the Barremian–Aptian. At least local subaerial exposition was documented by paleo-karst surfaces (Aubrecht et al. 2006). Albian and Cenomanian red marly limestones and marlstones and cherts (the Chmiełowa and the Pomiędznik Fms) overlie directly the paleokarst surface.

Basinal (Kysuca and Pieniny) units (Fig. 9a,b)

Deposits of the deepest central parts of the Pieniny Klippen Basin south of the Czorsztyn Swell are represented by the Lower Jurassic to Upper Cretaceous pelagic and flysch formations of the Kysuca–Pieniny Unit (the Branisko Unit was distinguished as an equivalent of the Kysuca Unit in Poland – Birkenmajer 1977).

Although the Lower Jurassic part of the succession was documented at numerous sections, their assignment to this unit is not always clear, due to prevalent disconnection of the Lower Jurassic strata from the Middle Jurassic strata. Continuous sections are very rare. Another reason is that some rock bodies belonging to different klippen units, such as Orava or Drietoma units were formerly erroneously included into the Kysuca–Pieniny Unit.

The Early Jurassic age of the Zázrivá Beds was rejected recently, due to the new biostratigraphic data suggesting their Aalenian age (Aubrecht et al. 2004). Therefore, the oldest known Lower Jurassic deposits are sandstones, arkoses and quartzites of the Sinemurian age (the Gresten Fm, Orava, Ukraine), overlain by Fleckenmergel–Fleckenkalk deposits of the Pliensbachian to Early Bajocian age (Krempachy Marl Fm, Skrzypny and Harcygrund Shale Fms). The time of deposition of dark shales with abundant thin-shelled bivalves *Bositra* (Harcygrund Shale Fm, former *Posidonia* Beds) in the Kysuca-Pieniny Basin is represented in the Czorsztyn Unit by hiatus, separating the oxygen-depleted dark deposits and platform slope biodetritic deposits. While the Sinemurian–Lower Bajocian sedimentation indicates still undifferentiated depositional basin, the next sedimentary history already points to dissection of the Pieniny Klippen Basin into elevations (Czorsztyn Swell) and troughs (Kysuca–Pieniny Basin).

Deposition of the Bajocian deep-water cherty limestones and spongiolites (the Podzamcze Lst Fm) are laterally replaced by cherty crinoidal limestones. In the Kysuca-Pieniny Basin these crinoidal limestones are represented by distal turbidites only (the Flaki Lst Fm). Siliceous deposition related to rise of the CCD level in the whole Tethys is represented by black, red and green radiolarites stratigraphically ranging since the Callovian until the Kimmeridgian or Early Tithonian (the Sokolica Radiolarite Fm and the Czajakowa Radiolarite Fm). Similar deep-water deposits are widespread in the basinal successions of the whole Western Carpathians. During the Kimmeridgian, the sedimentation of radiolarites still continued in the Pieniny Unit, but it was replaced by red nodular limestone in the Kysuca Unit (the Czorsztyn Lst Fm). The following depositional stage is uniformly represented by grey micritic limestones of the “biancône” or the “maiolica” type, locally with cherts, with the stratigraphic range from the Tithonian to the Barremian (the Pieniny Lst Fm).

This Pieniny Fm composed of *Calpionella* or calcareous nannoplankton-bearing facies is overlain by Barremian to Aptian dark shales (the Koňhora Fm, Michalík et al. 2008). Albian to Lower Cenomanian of the Kysuca Unit is represented by bluish to greenish marls with limestone beds (the Rudina Fm), followed by red marls and marlstones of the Middle and Upper Cenomanian age (the Lalinok Fm); the end of marly sedimentation is represented by red marls with thin sandstone intercalations of the Lower and Middle Turonian age (the Púchov Fm). The start of turbiditic deposition in the Turonian (the Snežnica Fm) marks the change of the sedimentation. These sandstone turbidites are followed by psammitic to psefitic deposits of the Coniacian and Santonian age (the Śromowce Fm), which are analogous to the Upohlav Conglomerate of the Klape Unit, suggesting the tectonic approximation of these units. The upper limit of the overlying Campanian red marls represents a sedimentation break, caused by orogenic phase related to collision of the Inner and Central Carpathians and the Oravic Block. The southernmost Kysuca-Pieniny Unit was the first one affected by this orogenic movements. Sandstones, breccias (the Jarmuta Beds) and limestones with *Orbitolina* are deposited on folded pre-Maastrichtian strata.

Tithonian/Berriasian sections in the Pieniny Klippen Belt

Jozef MICHALÍK

One of major points of the GSSP Programme is the collection of data from complete sections, which could serve as candidate stratotypes of stage boundaries. A net of regional stratotypes can provide continuous record of both sedimentation and biotic events across the Jurassic/Cretaceous boundary, as well as a precise evaluation of all proxies necessary for exact drawing of the boundary location. In the Western Carpathians, the Brodno section (Michalík et al. 1990, 2009; Houša et al. 1996) has been selected and proposed as the regional stratotype of the J/K boundary. Due to some lacks in stratigraphic record preserved in its sequence (missing of index ammonites, somewhat reduced thickness, etc.), complementary J/K boundary sections have been studied in recent time in the area of Central Carpathians in the Strážovce section (Borza 1984; Michalík et al. 1990); the Hlboča section (Grabowski et al. 2010a) and Pośrednie sections in the Tatra Mts (Grabowski & Pszczółkowski 2006; Grabowski et al. 2013).

Up to the present, remarkable advances in calpionellid and nannoplankton biostratigraphy across the J/K boundary interval have been made in Tethyan Jurassic/Cretaceous boundary (JKB) sections (Lukeneder et al. 2010, 2016; Wimbledon et al. 2013; Svobodová & Košťák 2016). Opening of the Tethyan/Panthalassa passage between Gondwana and North America enabled phyletic evolution of small planktonic protozoans and autotrophic algae in renewed circum-equatorial oceanic current. This evolution included number of bioevents useful for global correlation of pelagic carbonate sequences. Despite of certain global similarity, these events were different in details due to specific paleoenvironmental changes (Michalík & Reháková 2011). The boundary level should be situated within a bundle of events allowing good correlations in the case of absence of the primary ammonite marker.

On the other hand, warming in combination with eustatic oscillations could result in a diversity changes of the fauna in the Panboreal Realm (Wimbledon et al. 2013; Zakharov et al. 2014). During prominent sea-level rise, connection of Boreal sea with the Panthalassa Ocean, indicated by Middle Volgian ammonites with Pacific affinity, opened. Disturbance of the marine ecosystem indicated by green algae blooms correlates with negative excursion of C_{org} isotope near the Volgian/Ryazanian boundary. Due to different history and divergent evolution of Boreal and Tethyan bioprovinces, their stratigraphic correlation is difficult: the only connecting link seems to be the magnetostratigraphy (Houša et al. 2007; Grabowski 2011).

During the Berriasian, sedimentation in subsiding West Carpathian basins has been characterized by an acceleration in the “planktonic rain“ of organic matter and calcareous microskeletons. This change, which was detectable in the majority of Western Carpathian successions also produced pelagic sediments of the “Maiolica“ type (the Pieniny Limestone Formation). Our field trip will demonstrate the JKB sequence in three rock sections of the pelagic limestones of the Pieniny Klippen Belt in the Váh River Valley.

1st Stop – Brodno section

Jozef MICHALÍK, Daniela REHÁKOVÁ, Otília LINTNEROVÁ,
Eva HALÁSOVÁ and Jacek GRABOWSKI

Location

The Brodno section is situated in an abandoned quarry on the eastern side of the narrow straits of the Kysuca River Valley north to the town of Žilina (49°16’03.2”N, 18°45’12.7”E), known as the „Kysuca Gate“ (Michalík et. al. 2009; Fig. 12). It yields a record of hemipelagic marine sedimentation in a marginal zone (the Pieniny Klippen Belt) of the Outer Western Carpathians. The lithology, fossil record (including ammonites and aptychi) and stratigraphy were studied by Andrusov (1938, 1950, 1959), Scheibner (1961, 1962, 1967), Borza (1969), Scheibner & Scheibnerová (1969), and Samuel et al. (1988). A more detailed description of the Upper Jurassic and Lower Cretaceous litho- and biostratigraphy was provided by Michalík et al. (1990), Reháková & Michalík (1992), and Vašíček et al. (1992). Houša et al. (1996) introduced the magnetostratigraphy of the Jurassic/Cretaceous boundary beds correlated with the microbiostratigraphic data.

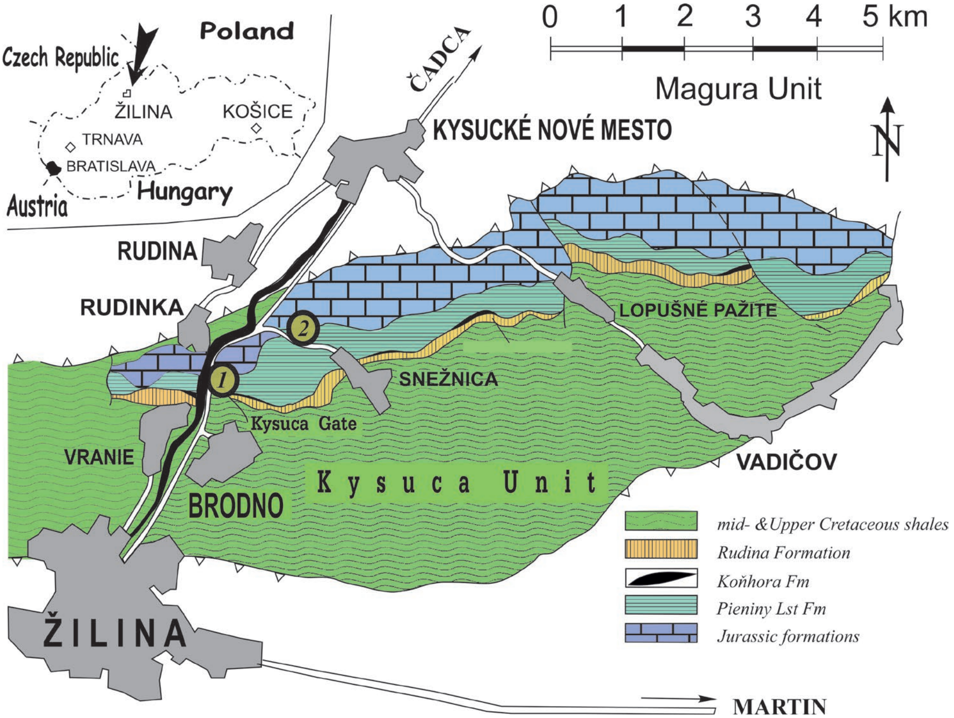


Fig. 12. Localization of the Brodno and Snežnica sections (circles) in the Kysuca Gate, north of the Žilina city (J. Michalík).

The results of an integrated biostratigraphic study using three microplankton groups (calpionellids, calcareous dinoflagellates and nannofossils), as well as stable isotope data ($\delta^{18}O$, $\delta^{13}C$) in the Brodno section have been discussed by Michalík et al. (2009). This section was proposed as the West Carpathian regional J/K boundary stratotype. Although the Brodno section lacks ammonite record, it has been presented as a potential candidate considering its continuously well exposed and biostratigraphically properly documented succession, at least for the West Carpathian region. The distribution of the stratigraphically important planktonic organisms revealed several coeval calpionellid and nannofossil bioevents recorded in the pelagic carbonate sequence of the Jurassic/Cretaceous boundary age. The stable isotope data underline environmental changes during the interval studied.

Sedimentology and microfacies

The succession starts with red nodular marly limestones of the "Ammonitico Rosso" lithofacies, known as the Czorsztyn Limestone Formation (Birkenmajer 1977; Fig. 13). As in many other Tethyan areas, the Late Jurassic sedimentation rate in the Pieniny Klippen Basin has been low as it received only a limited terrigenous clastic input. In an analysis of the periodicity of the Milankovitch frequency bands in the Spanish Rio Argos section, Hoedemaeker & Lereveld

Fig. 13. Brodno Quarry on the foot of the Brodnianka Hill – general view on the West Carpathian JKB regional stratotype. The sequence is overturned, the left upper side of the rock wall consists of the Czorsztyn Limestone Formation, and the right side is formed by the Pieniny Limestone Formation. Left top corner: a detailed view of the Jurassic/Cretaceous boundary interval with the Brodno Sub-magnetochron (photo by J. Madarás and J. Michalík).

(1995) situated sequence boundaries on the base of marly interbeds. Similarly, according to Schlager (2005), siliciclastics may be found in all system tracts, as they are a common constituent of basinal lowstand fans ("reciprocal sedimentation"). To the contrary, Michalík (2007) argued that the character of lowstand deposits strongly depends on the lithological composition of the shore that area emerged. As the Lower Cretaceous lowstand sequences in the West Carpathian area were mostly supplied by carbonate platform-derived calcitic debris, they were formed by fine-detrital (the grain size depends on the proximity/distality trends) limestone beds.

Sedimentary environment and sequential architecture

According to an analysis of the microfacies distribution (see Michalík 2007), several cyclical repetitions of the microfacies parameters were recognized in part of the sequence appearing on the left side of the quarry wall (Figs. 12, 13). These cycles are 0.5 to 1.6 m thick. Considering an average sedimentary rate of 2 mm/ka, which results from microbiostratigraphical analysis of the formation, their duration should be roughly equal to 400 kilo-years (800 or 2,400 ka, respectively). As phenomena proving the condensation and amalgamation of cycles are generally common in this facies, these oscillations evidently had a character of Milankovich long eccentricity cycles. The architecture of these cycles seems to be controlled by eustatic sea level changes. The sequence is arranged into inexpressive low frequency (40 ka, i.e., obliquity) cycles expressed by an alternation of limestone layers and more marly insertions. The origin of these cycles has probably been ruled by climatic (humidity driven) oscillations. The biostratigraphic boundaries are usually not identical with the sequence ones, the former running usually within the highstand part of the underlying cycle (Fig. 14).

1. The lowermost cycle (beds L51 to L58) consists of pale greenish to rose-coloured limestones (*Saccocoma* to *Globochaete* wackestones) with microfossils (*Cadosina parvula*, *Stomiosphaera moluccana*, *Cadosina semiradiata semiradiata*, *Colomisphaera pulla*, and *Carpistomiosphaera tithonica* documenting **Early Tithonian Pulla** and **Tithonica zones.** The last, thickest and most micrite layer (L58) represents the highstand conditions close to the end of the M22 normal paleomagnetic chrone.
2. The second cycle of thin-bedded nodular to brecciated pale greenish limestones (wackestone to packstone) with red cherts and marly interlaminae (L59 to L67 beds) is terminated by thicker L68 layer forming the highstand part. *Saccocoma* Agassiz and *Globochaete alpina* Lombard predominate over crinoid ossicles, bivalve and aptychi fragments, ostracod shells, foraminifer tests, calcified radiolarians, and dinoflagellates (*Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca* and *Parastomiosphaera malmica*) of the **Early Tithonian Malmica Zone** association.

The calcareous nannofossil assemblage from the interval L52 to L68 is dominated by *Conusphaera mexicana mexicana*, *Conusphaera mexicana minor*, *Cyclagelosphaera margerelii*, *Cyclagelosphaera deflandrei*, *Watznaueria barnesae*, and *Watznaueria manivitae*. The absence of the nannolith *Polycostella beckmannii* in

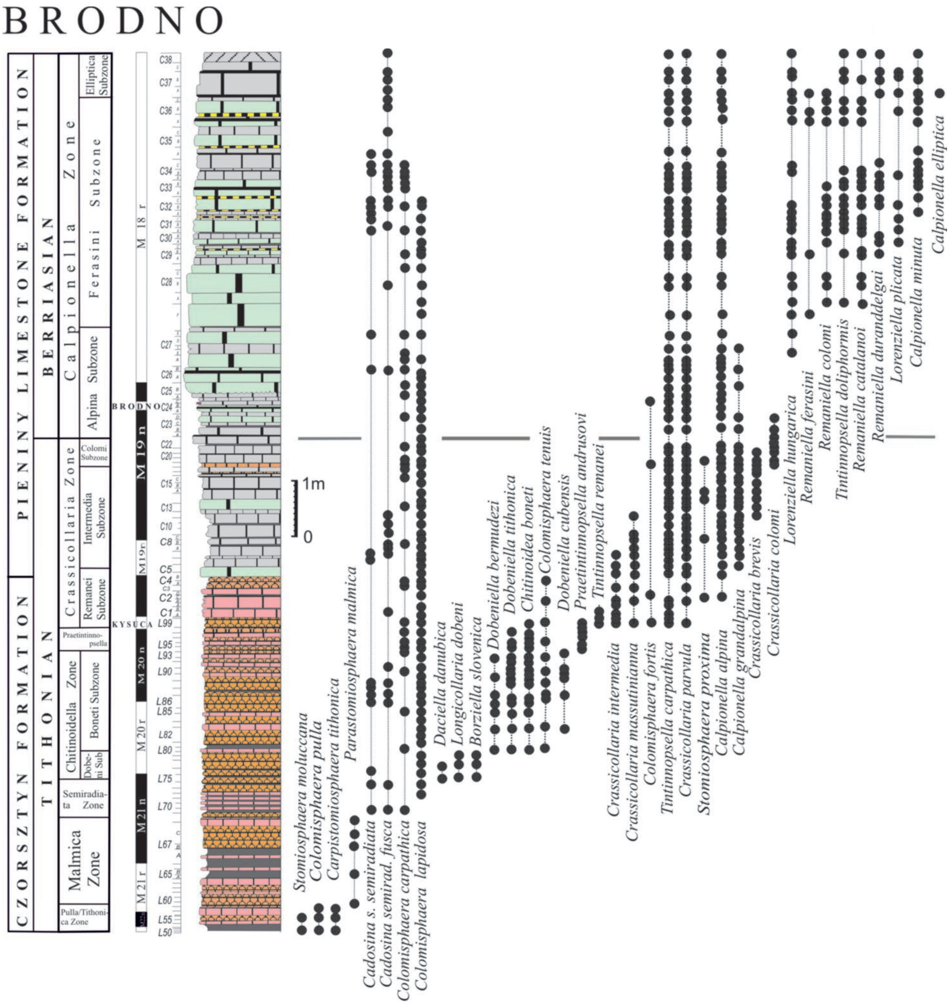


Fig. 14. Lithological log of the Brodno J/K sequence studied, distribution of calpionellids and calcareous dinoflagellates, calpionellid and cyst zonations.

the association permits parallelization with the **Early Tithonian Hexapodorhabdus cuvillieri (NJ 20-A) Subzone** of the Conusphaera mexicana mexicana Zone.

3. The lower part (beds L69 to L74) of the higher, third cycle (the upper part of the normal M21 magnetozone), consists of a radiolarian–globochaetid wackestone and packstone. Acme accumulation of thick-walled *Cadosina semiradiata semiradiata* (L69) and *Cadosina semiradiata fusca* (the **Semiradiata Acme Zone**) accompanied by abundant *Conusphaera* could be a proxy of increasing sea surface temperature conditions.

The middle part (beds L75 to L79) of the cycle is formed by rose-grey biomicrite of the radiolarian–*Saccocoma–Globochaete* microfacies (packstone, wackestone). Calcareous dinoflagellate cysts (*Parastomiosphaera malmica*, *Schizosphaerella minutissima*, *Colomisphaera carpathica*, *Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca*) and early calpionellid forms with microgranular lorica (*Longicollaria dobeni*, *Borziella slovenica* and *Daciella danubica*) indicate the **Dobeni Subzone** of the latest Early Tithonian Chitinoidella Zone (the lowermost part of the reversed M20 magnetozone).

The upper part (L80 to L89) of the cycle consists of marly nodular to brecciated limestones with marly interlaminae. Calcareous dinoflagellates are represented by *Schizosphaerella minutissima*, *Colomisphaera carpathica*, *Colomisphaera nagyi*, *Colomisphaera tenuis*, and *Cadosina semiradiata semiradiata*. The occurrence of *Chitinoidella boneti*, *Borziella slovenica*, *Dobeniella tithonica*, *Dobeniella cubensis*, and *Dobeniella bermudezi* characterizes the **Boneti Subzone of the Chitinoidella Zone**.

Calcareous nannofossils obtained from L69 up to L96 were assigned to the **Polycostella beckmannii Subzone (NJ 20-B)** within the range of the Middle Tithonian; magnetochrone M21n to M20n. The assemblages of the lower part of this interval are dominated by *Conusphaera mexicana mexicana*, accompanied by *Conusphaera mexicana minor*, *Watznaueria barnesae,* and *Watznaueria manivitae*. The nannolitic form of *Polycostella beckmannii* are abundant in the interval L77 to L83. *Discorhabdus ignotus* and *Zeugrhabdothus erectus* occur less frequently.

4. The fourth cycle (L90 to L98) is represented by a complex of pale bedded indistinctly nodular biomicrite limestones. Wackestones of radiolarian –*Saccocoma*–*Globochaete*, and locally silicified *Saccocoma*–radiolarian biomicrites contain *Colomisphaera tenuis*, *Schizosphaerella minutissima*, and *Colomisphaera carpathica*. *Chitinoidella boneti*, *Dobeniella tithonica*, *Dobeniella bermudezi* and transitional early hyaline *Praetintinnopsella andrusovi* characterize the uppermost Boneti Subzone (Chitinnoidella Zone) and the passage into the **Late Tithonian Praetintinnopsella Zone**.

5. The fifth cycle starts with the L99 layer (**paleomagnetic Kysuca Subzone**) below well-bedded pale rose-grey "Maiolica" limestones of the Pieniny Limestone Formation. Each limestone layer (4 to 20 cm thick) is separated by thin (2 to 40 mm) marly interlaminae. If the sedimentary rate is assumed to attain 2.9 mm/ka, each bed represents a time interval of 40 ka climatically driven obliquity cycle. Then, the eccentricity cycle comprises 60 to 232 cm in thickness. Biomicrite wackestone with *Crassicollaria*–*Globochaete*–radiolarian microfacies contains *Crassicollaria intermedia*, which predominate over *Crassicollaria massutiniana*, *Crassicollaria parvula*, *Calpionela alpina*, *Calpionella grandalpina, Tintinnopsella remanei,* and *Tintinnopsella carpathica*. The association of calcareous dinoflagellates is composed of *Schizosphaerella minutissima*, *Colomisphaera carpathica*, *Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca*, and *Stomiosphaerina proxima*. The calpionellid index association indicates the **Late Tithonian Remanei Subzone of the Crassicollaria Zone**.

Samples L98 to C26 were attributed to the **Microstaurus chiastius Zone NJK**. The FO of *Helenea chiastia* and *Hexalithus noeliae* indicates the Late Tithonian Hexalithus noeliae Subzone (NJK-A). Watznaueriaceae coccoliths (*Watznaueria barnesae, Watznaueria manivitae*) fluctuate in a range of 25 to 80 %, *Cyclagelosphaera margerelii* in

3–20 %. *Discorhabdus ignotus* and *Zeugrhabdothus erectus* is abundant (up to 10 %) in the C1B bed. The LO of *Polycostella beckmannii* observed in the C4A sample indicates Late Tithonian age.

6. The sixth cycle (C14–C16) is built up of well bedded pale Maiolica limestones (biomicrite *Crassicollaria –Globochaete* and radiolarian–*Crassicollaria* wackstone) with thin (up to 2 cm) marly interbeds. Small *Crassicollaria brevis* dominates over *Calpionella grandalpina*, *Calpionella alpina*, *Crassicollaria parvula* and *Tintinnopsella carpathica.* Their association with calcareous dinoflagellates of *Schizosphaerella minutissima*, *Colomisphaera carpathica,* and *Stomiosphaerina proxima* characterize the **Intermedia Subzone of the Late Tithonian Crassicollaria Zone**. Here, the FO of *Nannoconus infans* (C13) and with the FO *Nannoconus wintereri* (C17) has been recorded. Both forms, which flourished under warmer and possibly more nutrient-depleted surface waters, indicate the **Late Tithonian NJK-b to NJK-c subzones**.

7. Bedded pale grey biomicrite wackestone to packstone (C17–C22) with thin (up to 2 cm) marly interbeds consists of crassicollarian–globochaete and radiolarian–globochaete–crassicollarian microfacies. Common *Globochaete* with *Crassicollaria parvula* and *Calpionella grandalpina* predominate over *Crassicollaria colomi*. *Calpionella alpina*, *Tintinnopsella carpathica*, and *Tintinnopsella doliphormis* are frequent. Dinoflagellates contains *Schizosphaerella minutissima*, *Colomisphaera carpathica*, *Colomisphaera fortis*, and *Stomiosphaerina proxima*. The presence of *Crassicollaria colomi* indicates the **Colomi Subzone of the Crassicollaria Zone**. Sole *Cruciellipsis cuvillieri* was found in C20, close to the FO of *Nannoconus wintereri.*

8. The calpionellid–globochaete microfacies in a well bedded pale gray biomicritic wackestone with thin (up to 1 cm) marly insertions (C23A–C25 A) is dominated by small spherical *Calpionella alpina*. *Crassicollaria parvula*, *Crassicollaria colomi* along with *Calpionella grandalpina* and *Tintinnopsella carpathica* are less frequent. The base of the Alpina Subzone of the Calpionella Standard Zone was identified in the C24A Bed. The **Brodno Magneto-Subchron** was located in the layer C24B.

9. Well bedded pale biomicritic wackestones with Calpionella–Globochaete and Calpionella–radiolarians microfacies (C25B-27E). *Globochaete alpina* dominates over *Crassicollaria parvula*, *Tintinnopsella carpathica*, *Cadosina semiradiata fusca*, *Cadosina semiradiata semiradiata*. The microbreccia layers contain small limestone clasts with Tithonian microfossils.

10. A complex with anomalously thick (20–48 cm) layers of biomicritic Calpionella wackestone (C28A–C29A) is terminated by submarine slump. Small sphaerical *Calpionella alpina* still dominates. The FO of *Nannoconus steinmanni minor*, the increase in abundance and diversity of nannoconids in C28 enabled drawing the base of **NJK-D Nannoconus steinmanni subsp. minor Subzone**, which is correlated with the earliest Berriasian. The start of nannoconid bloom is indicated by the FO of *Nannoconus steinmanni minor***,** *Nannoconus globulus minor*, and *Nannoconus kamptneri minor* accompanied by *Conusphaera mexicana mexicana*, *Cyclagelosphaera deflandrei*, *Cyclagelosphaera margerelii*, *Diazomatholithus lehmannii*, *Discorhabdus ignotus*, *Watznaueria*

barnesae, *Watznaueria britannica*, *Watznaueria manivitae*, and *Zeugrhabdotus embergeri.*

11. The radiolarians in thick-bedded cherty limestones with radiolarian–Calpionella microfacies (C29B–C38) are dispersed in the wackestone, but also concentrated in six 4–6 cm thick radiolarite layers. The first occurrence of *Remaniella ferasini* (Catalano) in the overlying thick bedded cherty "Maiolica" limestones indicates the base of the **Ferasini Subzone of the standard Calpionella Zone**.

Carbonate and C_{org} contents

Organic matter contents in Lower Tithonian 1st to 5th cycles (0.15 to 0.25 %) are gradually decreasing upwards in each cycle. This fluctuation could be related with changing humidity, which is also supported by rapid lithofacies fluctuations (Fig. 7). The most impressive peak was observed at the beginning of the cycle 4 (L93; Fig.6). The lowest values were attained just below the J/K boundary, in upper parts of the cycles 5 to 8 (on the base of the Pieniny Limestone Formation). On the other hand, the calcium carbonate content is gradually increasing (from 85 to 97 %) with small minimum in cycle 6 on the base of the Pieniny Lst Formation (Fig.15). Carbonate content increase fits well with the onset of nannoconids.

Stable carbon and oxygen isotopes

The C and O isotopes ratios could have been influenced by burial history of sediment due to recrystallization of primary carbonate minerals, to cementation and temperature increase with burial depth, and to other processes. Fine grained limestone composed mainly of calcitic micro and nannoplankton tests could retain its primary character. The fossils could have been broken and disturbed, partially dissolved and re-crystallized in micro scale, but the carbonate composition still indicates low diagenetic overprint and its composition can be regarded as more-or-less primary. Carbon isotope curves from bulk carbonate samples of the J/K boundary sequences worldwide show smooth trends resulting from equilibrated rate of bio-productivity and organic matter burial (Weissert & Mohr 1986; Weissert & Channel 1989; Weissert & Lini 1991; Gröcke et al. 2003; Tremolada et al. 2006). In the Brodno sequence, the average value of $\delta^{13}C$ (L90–C27: 1.45 ‰) ranges between 1.3 and 1.5 ‰ (PDB) (Fig.15).

The lowermost cycle (up to L58) as a part of the Czorsztyn Limestone Formation (the Ammonitico Rosso facies) contains slightly raised $\delta^{13}C$ values (1.46–1.73 ‰). In the second, third and fourth cycle, $\delta^{13}C$ values gradually decrease to the lowest value in L98 (1.28 ‰). The only small positive excursion occurs in L79 (1.51 ‰) sample, corresponding to the *Polycostella* peak. Rhythmic fluctuations during gradual rise of the average $\delta^{13}C$ values in 4th to 6th cycle (start of the Maiolica facies at the base of the Pieniny Limestone Formation) probable reflect rhythmic character of the rock sequence due to sea-level oscillations (Figs. 14, 15). Much wider range of $\delta^{13}C$ values (1.55–1.33) is recorded from 7th cycle (immediately below the J/K boundary level) with a decrease in their average. The $\delta^{13}C$ values in cycles above the J/K boundary are increasing, again.

The authentic character of the $\delta^{13}C$ record of our samples is underlined by relative high and conservative $\delta^{18}O$

values (−2.29 to −0.88). The fractionation of oxygen isotopes is more sensitive to temperature and salinity variations in the marine water. The $\delta^{18}O$ values in carbonate rock could reflect these environmental proxies recorded by micro- and nannofossils (Price et al. 1998; Gröcke et al. 2003; Hay et al. 2006; Tremolada et al. 2006).

The mathematic average of the $\delta^{18}O$ value in the Brodno section attains −1.62 ‰. $\delta^{18}O$ values less than the average (from −1.85 to −2.29 ‰) in the 2nd cycle could reflect relative warmer episode during Early Tithonian with temperature changes in range of 2–3 °C. Positive excursions in cycles 3 and 4 (approximately −1.5 ‰) indicate a progressive fall of temperature (nearly 2–3 °C), which is more or less correlatable with the *Polycostella* flowering. Higher positive $\delta^{18}O$ excursion (C3 bed) potentially indicates other change than a temperature fall only. This positive $\delta^{18}O$ event was accompanied not only by earlier diminishing of *Polycostella*, but also by drift of abundance of *Watznaueria and Cyclagelosphaera* which could indicate changes of water composition, e.g. salinity or eutrophication. Around the J/K boundary (cycles 6, 7 and 8), the more negative $\delta^{18}O$ values (−1.5 to −2.6 ‰) indicated a temperature increase. This is also indicated by rich *Nannoconus* occurrence that pleads in favour of the end of the cold period. Stable isotope analyses also proved a modest cooling of the earliest Berriasian surface waters.

The data obtained indicate a sea water temperature in a range between 15.5–21.3 °C, when we used $\delta^{18}O_w$ – 1.0 ‰ VSMOW, deemed appropriate for the ice-free world of post-Jurassic time (Gröcke et al. 2003). These values fit the Kimmeridgian–Tithonian 14–21°C temperature interval calculated by Gröcke et al. (l.c.), Price et al. (1997, 2000) for northern Tethys. However, this relative large (5–6 °C) temperature fluctuation seems to be unrealistic. A part of this apparent temperature fall could be attributed to the effect of surface-water salinity decrease (see also Tremolada et al. 2006, etc.). The $\delta^{18}O$ indicates that uppermost Tithonian deposits were formed during relative cold period (18.5 °C in average) temporally interrupted by warm episodes but overall rather arid than humid (Fig. 15). This is documented also by monotonous $\delta^{13}C$ content and low contents of organic carbon. Short term fluctuation of $\delta^{18}O$ values indicated temperature-, salinity changes and invasion of warm water (or stagnancy of cold water input) into the basin around the J/K boundary interval: this is documented by blooms and definitive expansion of nannoconids, accompanied by depletion of calpionellid association.

Stable isotopes ($\delta^{18}O$, $\delta^{13}C$) analyses indicated relative cold period occasionally disturbed by warm episodes during uppermost Tithonian. This is documented also by low contents of organic carbon. Near the J/K boundary the oxygen isotope values indicated temperature and salinity changes probably influenced by an invasion of warm water (or stagnancy of cold water input) into the basin resulting in nannoconid bloom episodes. Late Tithonian cooling was followed by temperature increase during very end of Tithonian and at the beginning of the Berriasian.

Magnetostratigraphy and correlation with the Global Polarity Time Scale (GPTS)

According to Houša et al. (1999), the base of the standard Crassicollaria

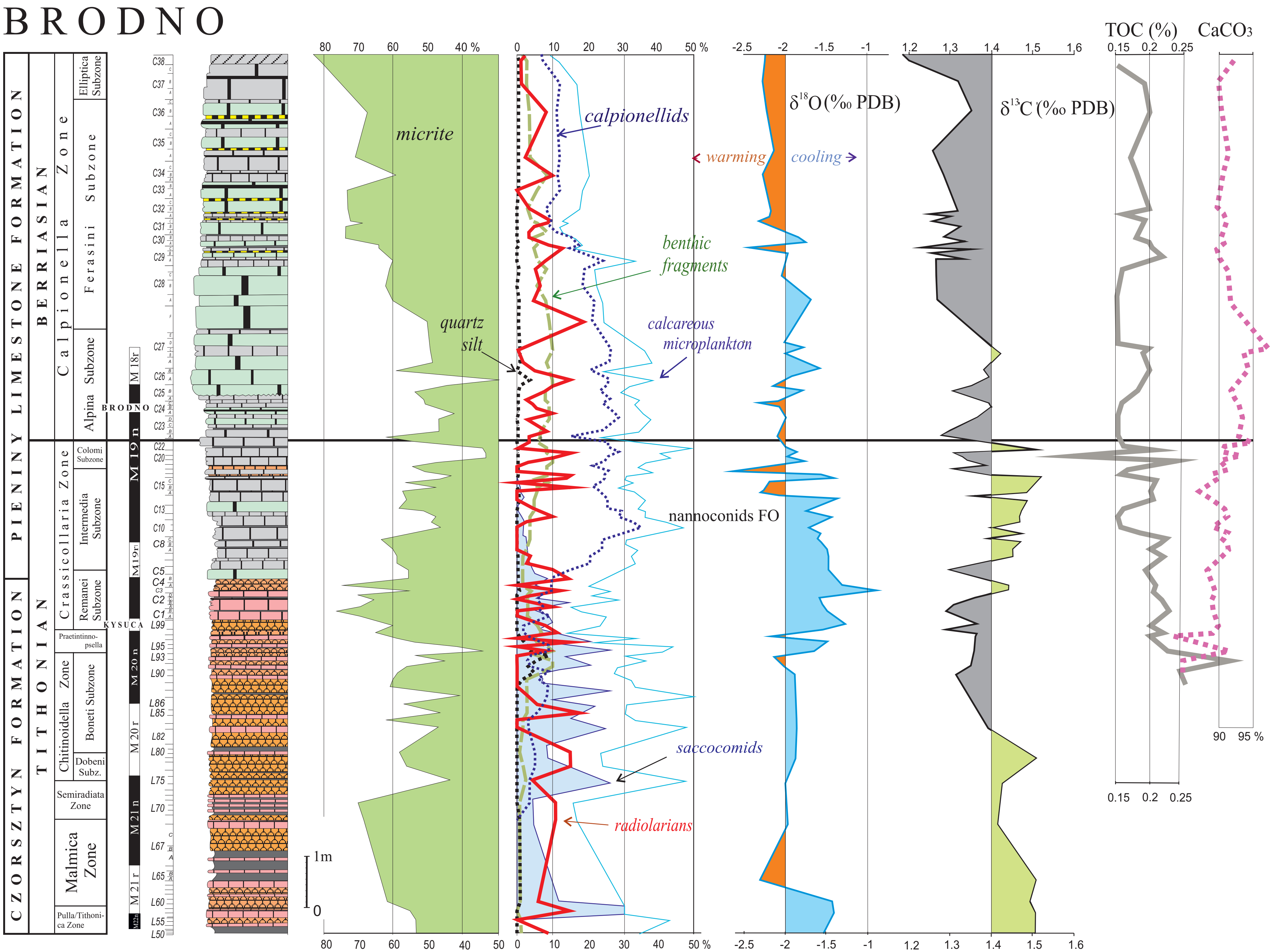
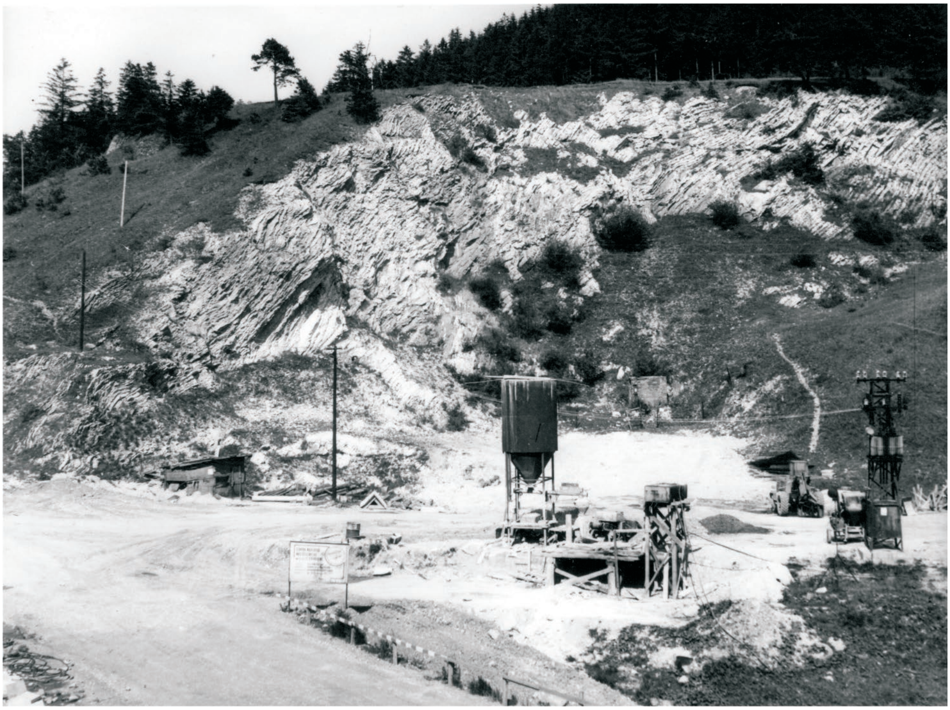


Fig. 15. Lithological column of the Brodno sequence studied, magnetostratigraphy, quantitative representation of allochems in microfacies; chemo- and isotope stratigraphy.

Zone in the Brodno section lies approximately in the middle of the M20n Magnetozone. The base of the standard Calpionella Zone, i.e. the Jurassic/Cretaceous boundary lies in the middle part of the M19n Magnetochron (his solution 2), between C15A and C15B beds. These authors correlated their Brodno section data with sections in northern Italy (Foza), central Italy (Val Bosso), and Spain (Rio Argos). Pszczółkowski et al. (2005) identified the NJK-c Subzone with the Late Tithonian Nannoconus wintereri Subzone. Grabowski & Pszczółkowski (2006) located the Jurassic/Cretaceous boundary (between the A and B calpionellid biozones of Remane 1971; Remane et al. 1986) within the M19n Magnetochron, below the Brodno (M19n-1r) Subchron.

Ogg & Lowrie (1986) put the J/K boundary on the base of the Grandis/Occitanica Zone (~top of the Jacobi Zone = the base of Tirnoviella subalpina Zone, correlated with the base of M18r Magnetochron.

The interval immediately above the base of the Beriasella privasensis Zone (=M18n/M17r; Lowrie & Channel 1983; Márton 1986) is typical of a drowning event (Gawlick & Schlagintweit 2006), with synsedimentary slumpings (Hoedemaeker & Leereveld 1995), kaolinite- (Schyder et al. 2005), phosphate- (Houša et al. 1996), or iridium enrichment (Zakharov et al. 1996), or even with Mjølnir- (Dypvik et al. 2006), Shatsky Rise- and Morokweng impact craters (Koberl et al. 1997; Mahoney et al. 2005; Tremolada et al. 2006).



Historical photo of the Brodno Quarry from the sixties. Archive of Dimitry Andrusov.

2nd stop – Snežnica section

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Lilian ŠVÁBENICKÁ and Kamil FEKETE

Location and geological setting

Another important section encovering the JKB sequence in the western sector of the Pieniny Klippen Belt is named as the Snežnica section. The section is exposed by hundred meters tall wall of a freshly abandoned quarry (49°16´14.35 N, 18°46´31.18 E) in a steep SE slope of the Snežnica hill (Figs. 12, 16).

It is located on the left side above the local road to the Snežnica village. From the whole sequence outcropping in the quarry, we selected interval belonging to the Late Jurassic–Early Cretaceous, which was further documented in detail and studied for their bio- and chemostratigraphy. Totally 117 samples have been selected for thin-sections which were used for microfacies analyses and for documentation of succession of stratigraphically important calcareous microfossils – calpionellids and calcareous dinoflagellates. Calcareous nannofossils have been studied from several pilot samples so far only.

Microfacies, calpionellid and calcareous dinocyst zonation

Microfacies were interpreted according to Dunham's (1962). Standard microfacies types (SMFs) and facies zones (FZs) as proposed Wilson (1975) and modified by Flügel (2004) were determined. Standard SMF2, SMF3 and SMF4 microfacies were recognized. They characterize basin – slope environment of deposition (FZ 3–4). Calpionellid zonation of Reháková & Michalík (1997) and calcareous dinoflagellate zonation sensu Reháková (2000) were applied. Limestone sequence studied in the Snežnica section is dated by a succession of calcareous dinoflagellates as the Late Oxfordian (Parvula Zone) to Early Tithonian Malmica Zone and continuously, on the base of calpionellid succession as late Early Tithonian (Chitinoidella Zone, Dobeni Subzone) to late Early Berriasian (standard Calpionella Zone, Elliptica Subzone; Fig. 17).

Czajakowa Formation (Birkenmajer 1977)

Late Oxfordian Parvula Zone (sensu Reháková 2000); Sn-0; 1.1; 2; and 2.1 samples

Grey, laminated siliceous limestones of *Bositra* microfacies, *Bositra*-radiolaria–spiculite and spiculite microfacies (packstone, passing locally to wackestone; SMF 2) contain small fragments of thin *Bositra* shells (showing transport), aptychi, crinoid columnalia fragments, silicified sponge spicules, and rare *Cadosina parvula, Colomisphaera lapidosa*, *Colomisphaera carpathica* cysts. Radiolarian tests filled by microgranular SiO_2 contain neomorphic calcite crystals. Matrix is locally impregnated by Fe-hydroxide and in some cases penetrated by thin calcite filled veins and fractures.

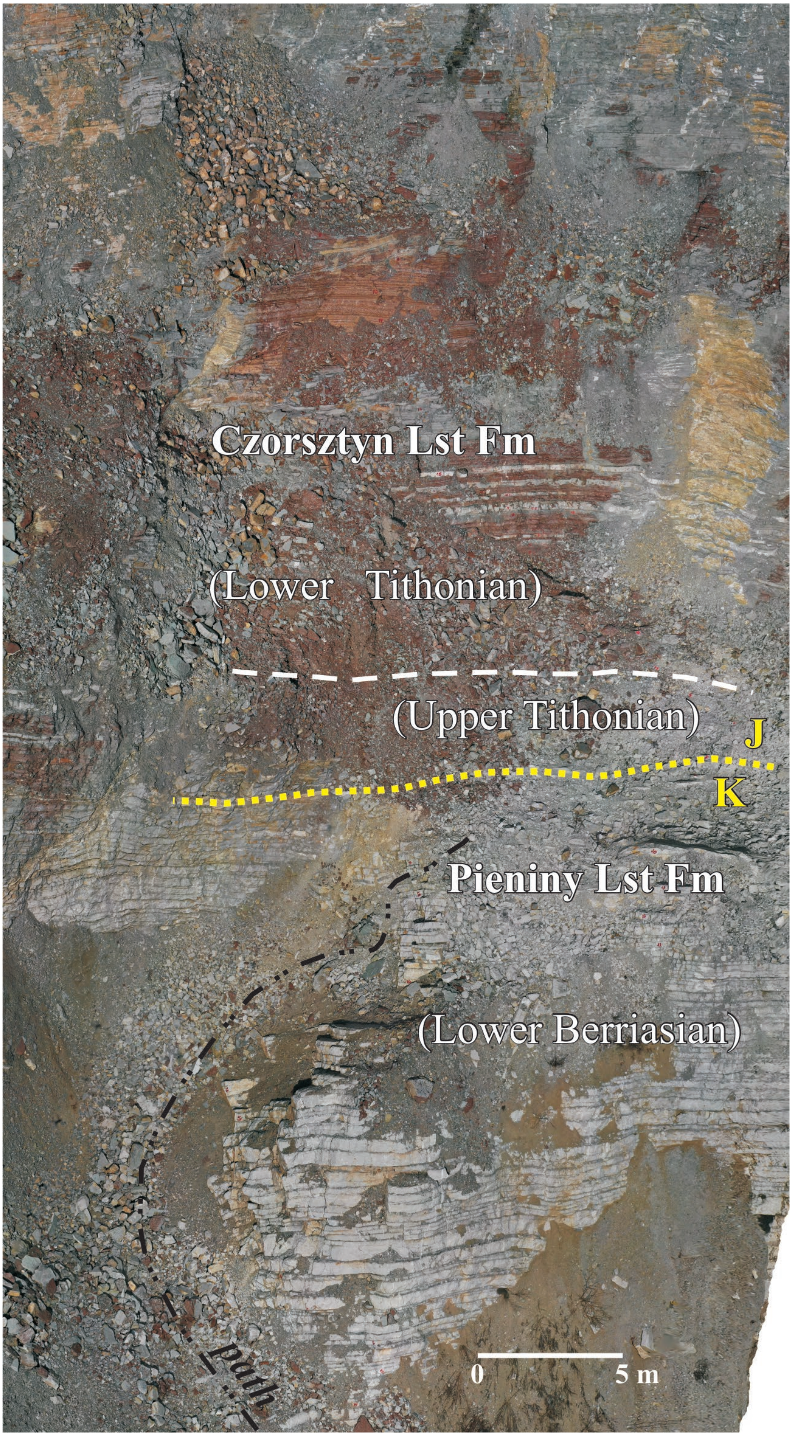

Fig. 16. Aerial view of the Snežnica section using DJI drone (photo by M. Marciš and K. Fekete).

Late Oxfordian Fibrata Zone (sensu Reháková 2000); Sn-2.2 and Sn-3.1 samples

Grey-brown laminated detrital siliceous limestones in *Bositra*-spiculite and *Bositra* microfacies (packstone; SMF 2) with accumulations of pyrite on the surface and with chert nodules. Locally graded and sorted *Bositra* filaments are dominating over radiolarians, sponge spicules, rare crinoids, aptychi and cysts of *Cadosina parvula, Colomisphaera fibrata* and *Colomisphaera minutissima*.

Early Kimmeridgian Parvula Acme Zone (sensu Reháková 2000); Sn-3.2 sample

Brown laminated and bioturbated biomicrite limestone (wackestone; SMF2-3) contains small fragments of *Bositra* filaments, crinoid columnalia and aptychi, common cysts of *Cadosina parvula* and less frequent *Colomisphaera minutissima*. Slightly recrystallized matrix contains pyrite nests.

Kimmeridgian Moluccana Zone (Nowak 1976); Sn-3.3 sample

Pinkish-grey, fine-grained limestone beds are separated by thin clay laminae. They contain belemnites and abundant pyrite. Biomicrite (wackestone, SMF 2-3) is bioturbated, it contains laminae rich in resedimented bioclasts (abundant *Cadosina parvula*). The microfossils are represented by small fragments of *Bositra* filaments, crinoids (also planktonic *Saccocoma* sp.), aptychi and cysts of *Stomiosphaera moluccana, Colomisphaera minutissima*. Matrix is slightly recrystallized being locally enriched in pyrite.

Czorsztyn Limestone Formation (Mojsisovics 1867)

Late Kimmeridgian Borzai Zone (Nowak 1976); Sn-4; 4.1; 4.2; 5; and 5.2 samples

Reddish brown and brown nodular limestone is composed of biomicrite of *Saccocoma*-radiolarian or *Saccocoma* microfacies (packstone; SMF 2), and laminated biomicrite of *Saccocoma–Globochaete* microfacies (packstone or wackestone; SMF2-3; Fig. 18). Planktonic crinoids *Saccocoma* sp. dominate over *Globochaete alpina* spores, fragments of aptychi, filaments, ostracods, foraminifera with calcitic tests, crinoid ossicles and columnalia, cysts of *Carpistomiosphaera borzai*, *Colomisphaera lapidosa*, *Colomisphaera carpathica, Colomisphaera cieszynica, Colomisphaera minutissima*, *Commitosphaera czestochowiensis, Stomiosphaera moluccana*, *Stomiosphaera sp., Cadosina parvula.* Some of bioclasts are bearing marks of microborings, some of them being pyritized or silicified. Few samples contain fine siliciclastic admixture (quartz grains and muscovite). The matrix is sometimes affected by slight dolomitization; stylolites and fractures are frequently impregnated by Fe hydroxides. Slightly recrystallized matrix contains scattered pyrite cubes (locally forming nests). On the base of *Saccocoma* elements analysed, it seems that Early Tithonian S-3: Sacoccoma Zone sensu Benzaggagh et al. (2015) starts here little bit earlier.

Early Tithonian Pulla Zone (Reháková 2000); Sn-6; 6.5; 7; 8; 9.5; and Sn-10 samples

In the upper part of thin bedded reddish brown and brown nodular or pseudo-nodular limestones (locally

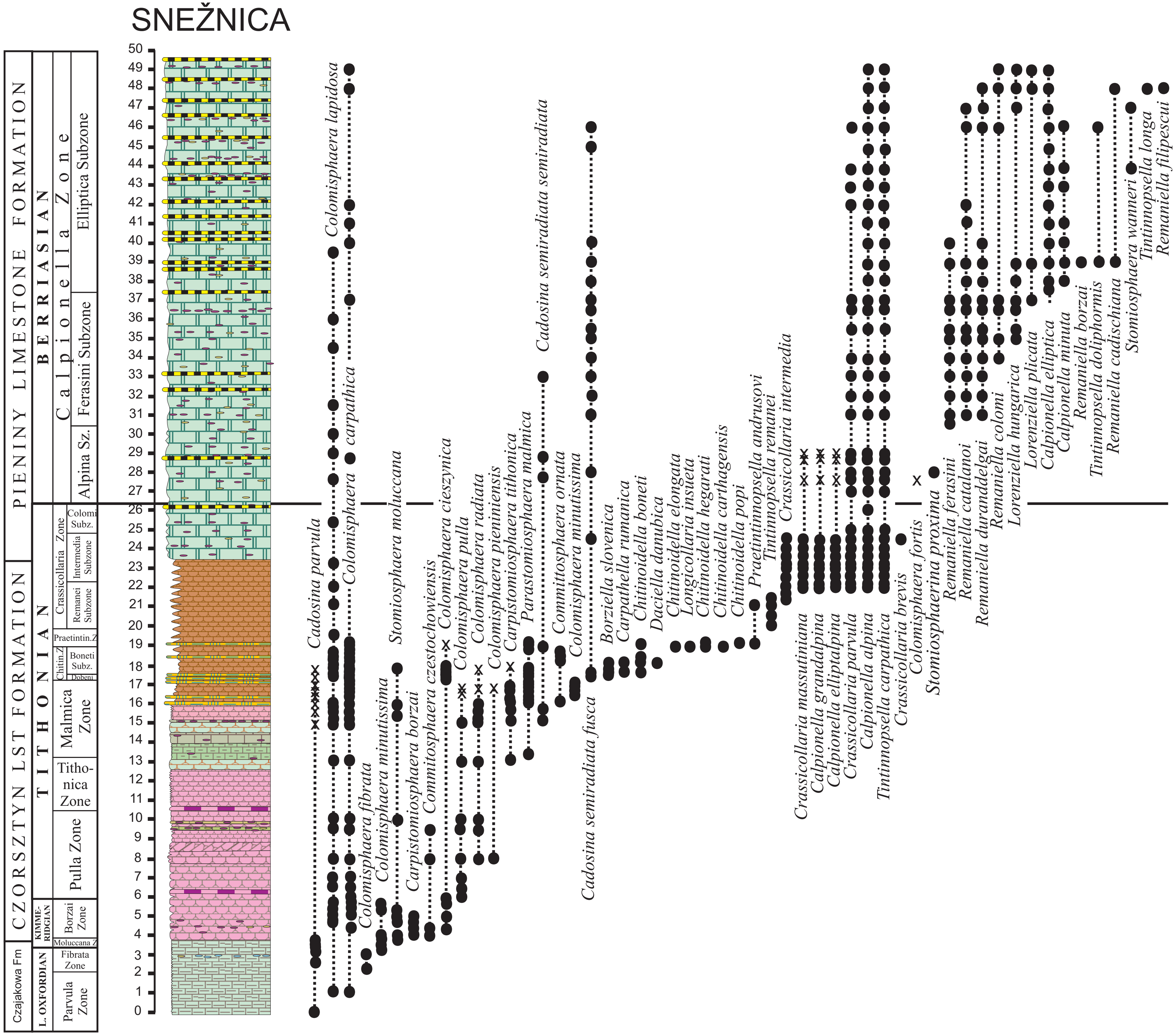

Fig. 17. Lithological log of the Snežnica J/K sequence studied, distribution of calpionellids and calcareous dinoflagellates, calpionellid and cyst zonations.

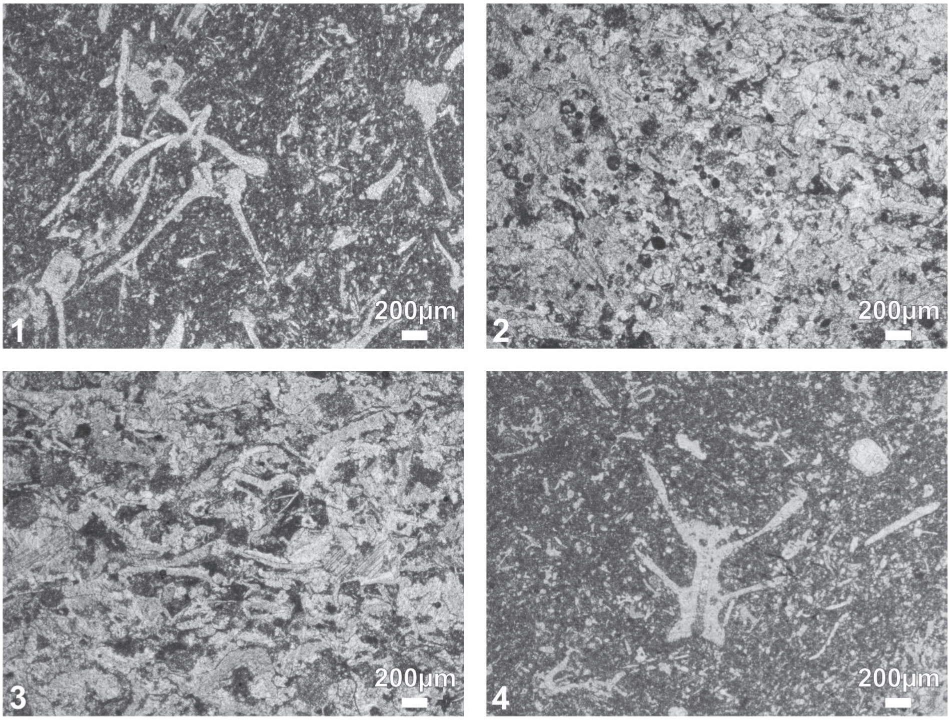

Fig. 18. Late Jurassic microfacies in the Snežnica section: 1. *Saccocoma–Globochaete* wackestone to packstone. Sample Sn 15; 2. Pelbioclastic *Saccocoma* packstone. Sample Sn 16.3; 3. *Saccocoma* packstone. Sample Sn 17.3; 4. *Saccocoma–Globochaete* wackestone. Samples Sn 19.2

with greenish nodules) slightly laminated siliceous limestones with stratiform cherts occur. Laminated locally bioturbated biomicrite packstone of *Globochaete–Saccocoma* microfacies rich in belemnites locally passes to wackestone or wackestone (SMF 2-3). *Saccocoma* sp. and *Globochaete alpina* prevail among bioclasts being accompanied by less frequent filaments, ostracods, bivalves, foraminifera (*Lenticulina* sp., *Spirilina* sp.), crinoids (*Pentacrinus* sp.), aptychi, calcified radiolarians and cysts of *Colomisphaera pulla, Colomisphaera lapidosa, Colomisphaera cieszynica, Colomisphaera carpathica, Colomisphaera radiata, Colomisphaera pieniniensis, Committosphaera czestochowiensis*. Bioclasts are locally phosphatized; some of them are silicified. Bioclasts in bed Sn7 are chaotically arranged. Pyrite is scattered in matrix which is slightly recrystallized and rich in stylolites which are impregnated by Fe- hydroxides. Some of samples contain fine siliclastic admixture (quartz grains and muscovite).

Early Tithonian Tithonica Zone (sensu Lakova et al. 1999); Sn-11; 12; and Sn-13 samples

Greenish-grey fine-grain limestones with cherty layers, thin bedded grey laminated limestones, reddish brown nodular and pseudo nodular limestones with chert nodules and ammonite molds.

They are biomicrite locally laminated packstone or wackestone of *Saccocoma–Globochaete* microfacies (SMF 2–3). Packstone locally pass to wackestone with chaotically arranged bioclasts. Besides dominating *Saccocoma* sp. and *Globochaeta alpina,* the rock contains crinoid columnalia, foraminifera, *Spirilina* sp., aptychi, calcified radiolarians (locally filled by chalcedony), sponge spicules, cysts of *Colomisphaera tithonica, Colomisphaera pulla, Colomisphaera lapidosa, Colomisphaera carpathica, Colomisphaera radiata, Cadosina semiradiata semiradiata, Cadosina parvula, Stomiosphaera moluccana* (Fig. 19). Some of bioclasts are phosphatized or silicified. Matrix of packstone with rich stylolites and scattered pyrite is slightly recrystallized.

Early Tithonian Malmica Zone (sensu Nowak 1968); Sn-13.3; 14.3;

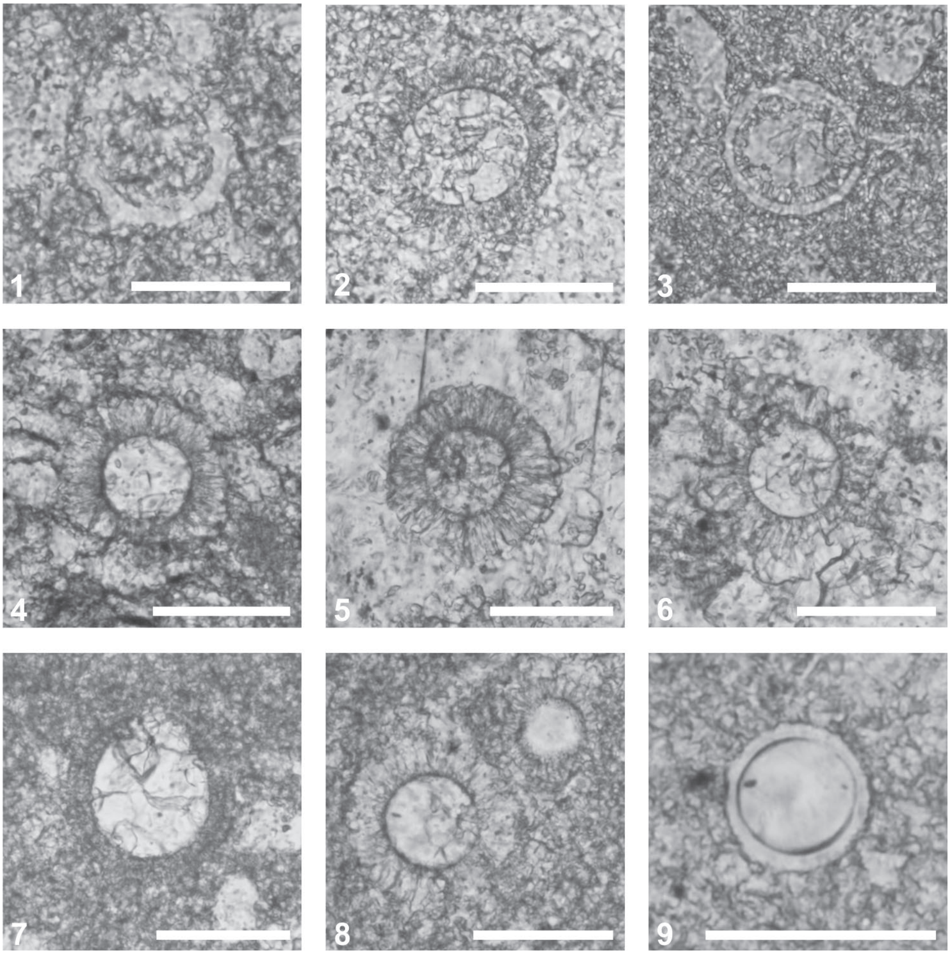

Fig. 19. Early Tithonian dinoflagellate cysts from the Snežnica section: 1. *Stomiosphaera moluccana* Wanner, Sn 10; 2. *Carpistomiosphaera tithonica* Nowak, Sn 15; 3. *Parastomiosphaera malmica* (Borza), Sn 13.3; 4. *Colomisphaera carpathica* (Borza), Sn 15.4; 5. *Colomisphaera cieszynica* Nowak, Sn 17.3; 6. *Committosphaera ornata* (Nowak), Sn 18.1; *Cadosina semiradiata semiradiata* (Wanner), Sn 20.5; 8. *Colomisphaera carpathica* (Borza) and *Colomisphaera lapidosa* (Vogler), Sn 28.9, 9. *Cadosina semiradiata fusca* (Wanner), Sn 43.5. Scale bar is 50 µm.

15; 15.1; 15.2; 15.3; 15.4; 16; 16.1; 16.2; 16.3; 16,4; 17; 17.1; and Sn-17.2 samples

Reddish brown and brown nodular and pseudo-nodular limestones with local thin clayey intercalations, light grey fine-grained (allodapic) limestones with brown cherts.

Pelbiomicrite, bioturbated packstone and chiefly wackestone of *Globochaete–Saccocoma* microfacies or packstone of *Saccocoma* microfacies were determined. They represent SMF 2 and SMF 4. *Saccocoma* sp. and *Globochaete alpina* spores are still dominating, being accompanied by fragments of ostracods, bivalves, foraminifera, aptychi, echinoids, cysts of frequent *Parastomiosphaera malmica* (Fig. 19), rare *Colomisphaera carpathica*, *Colomisphaera minutissima, Colomisphaera lapidosa*, *Colomisphaera pieniniensis, Colomisphaera pulla*, *Committosphaera ornata, Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca*, *Cadosina parvula*, *Carpistomiosphaera tithonica*, *Colomisphaera radiata*, *Stomiosphaera moluccana, Stomiosphaera* sp. In several layers (Sn 14.3, 16.1 and Sn 17), bioclasts are arranged chaotically. Matrix and bioclasts are locally silicified. On the base of analysed *Saccocoma* elements, this interval could be correlatable with the Saccocoma S4 Zone (Benzaggagh et al. 2015) or with the Darwini – Semiforme ammonite Zone.

Early Tithonian Chitinoidella Zone, Dobeni Subzone (*sensu* Grandesso 1977 and Borza 1984); Sn-17.3; 17.4; and Sn-17.5 samples

Pale green fine-grained limestones: pelbiomicrite, laminated (locally with graded allochems) packstone of *Saccocoma*, *Globochaete–Saccocoma*, and *Saccocoma*–crinoidal microfacies – SMF-2, 3, 4 with chert nodules. *Saccocoma* sp. is dominating over *Globochaete alpina*, crinoid columnalia and rare foraminifera, aptychi, bivalve fragments, microgranular calpionelids, *Borziella slovenica*, cysts of *Colomisphaera carpathica, Colomisphaera cieszynica* and *Parastomiosphaera malmica* prevail over redeposited *Carpistomiosphaera tithonica, Cadosina parvula* and *Colomisphaera radiata* cysts.

Late Tithonian Chitinoidella Zone, Boneti Subzone (*sensu* Grandesso 1977 and Borza 1984); Sn 17,6; 18; 18.1; 18.2; 18.3; and Sn-18.9 samples

Reddish brown- and brown nodular limestones with thin marly layers, pale grey to green fine-grained (allodapic) limestones is built of slightly bioturbated, locally laminated biomicrite with graded bioclasts: packstone, wackestone, locally passing to packstone or *Globochaete–Saccocoma*/pelbiomicrite wackestone with synsedimentary erosion-supported intraclasts and extraclasts – SMF 2, 3, 4. *Globochaete alpina* and *Saccocoma* sp. are dominating over crinoids, bivalves, ostracods, aptychi, juvenile ammonites, calcified radiolarians, sponge spicules, crinoids, foraminifera tests, *Colomisphaera carpathica, Colomisphaera lapidosa, Colomisphaera cieszynica, Parastomiosphaera malmica, Stomiosphaera moluccana, Colomisphaera radiata, Committosphaera ornata, Committosphaera czestochowiensis*, *Cadosina semiradiata semiradiata, Cadosina semiradiata fusca* cysts, microgranular loricae of *Borziella slovenica, Carpathella rumanica, Chitinoidella boneti, Daciella danubica, Longicollaria insueta, Chitinoidella elongata, Chitinoidella hegarati, Chitinoidella* *carthagensis*, *Popiella oblongata* (Fig. 20). Some of bioclasts are phosphatized. Fractures in matrix and stylolites are filled by calcite impregnated by Fe–hydroxide.

Late Tithonian Praetintinnopsella Zone (Grandesso 1977); Sn-19; 19.1; 19.2; 19.5; and Sn-19.8 samples

Reddish brown- and brown nodular limestone (locally with greenish grey nodules) with beds of fine-grained allodapic limestone. Biomicrite, bioturbated *Saccocoma*–radiolarian–*Globochaete* wackestone with nests composed of the *Saccocoma* packstone or biomicrite wackestone, *Globochaete*–*Saccocoma* packstone, pelbiomicrite *Globochaete–Saccocoma* crinoidal packstone, *Globochaete*–radiolarian wackestone belonging to SMF 3, 4 contain frequent *Globochaete alpina*, *Saccocoma* sp., locally also abundant calcified radiolarians, sponge spicules, rare ostracods, bivalves, aptychi *Laevaptychus* sp., crinoids, foraminifera test fragments (*Spirilina* sp., *Lenticulina* sp.), cysts of *Colomisphaera lapidosa*, *Colomisphaera cieszynica, Colomisphaera carpathica*, *Colomisphaera sp.*, *Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca*, *Parastomiosphaera malmica*, loricae of *Praetintinnopsella andrusovi*, *Chitinoidella boneti*, *Chitinoidella hegarati*, *Chitinoidella popi*. Some bioclasts are silicified. Packstone is locally rich in clayey admixture and stylolites.

Late Tithonian Crassicollaria Zone, Remanei Subzone (Remane et al. 1986); Sn-20; 21.4; 21.5; 21.8; and Sn-22 samples

Reddish brown- and brown nodular limestones. Biomicrite wackestone or packstone of *Saccocoma–Globochaete* and radiolarian–*Saccocoma–Globochaete* microfacies locally with synsedimentary erosion-supported intraclasts were identified as belonging to SMF 3.

Globochaete alpina, *Saccocoma* sp. and calcified radiolarians dominate over fragments of ostracods, bivalves, aptychi, juvenile ammonites, crinoids, foraminifera, cysts of *Colomisphaera lapidosa*, *Colomisphaera carpathica* and over rare first fully hyaline loricae of *Tintinnopsella remanei*, *Calpionella alpina*, *Crassicollaria intermedia* and last *Praetintinnopsella andrusovi*. The matrix is slightly recrystallized.

Pieniny Limestone Formation (Birkenmajer 1977)

Late Tithonian Crassicollaria Zone, Intermedia Subzone (Remane et al. 1986); Sn-22.5; 23; 23.1; 23.5; 23.8; 24; and Sn-24.5 samples

Reddish brown- and brown nodular and thin-bedded Maiolica-type limestones. Biomicrite and bioturbated wackestone of *Calpionella*–*Globochaete* microfacies – SMF 3 (Fig. 21).

Planktonic crinoids *Saccocoma* sp. rapidly decrease in abundance. Bioclasts belong to *Globochaete alpina*, calcified radiolarians, fragments of bivalves, ostracods, aptychi, juvenile ammonites, foraminifera (*Spirillina* sp., *Lenticulina* sp.), fragments of agglutinated foraminifera (*Protomarsonella* sp.), cysts of *Colomisphaera lapidosa*, frequent loricae of *Crassicollaria intermedia*, *Crassicollaria massutiniana*, *Crassicollaria parvula*, *Calpionella alpina*, *Calpionella grandalpina*, *Calpionella elliptalpina*, rare *Tintinnopsella carpathica*. Matrix is locally penetrated by calcite-filled fractures and veins. Pyrite forms nest accumulations.

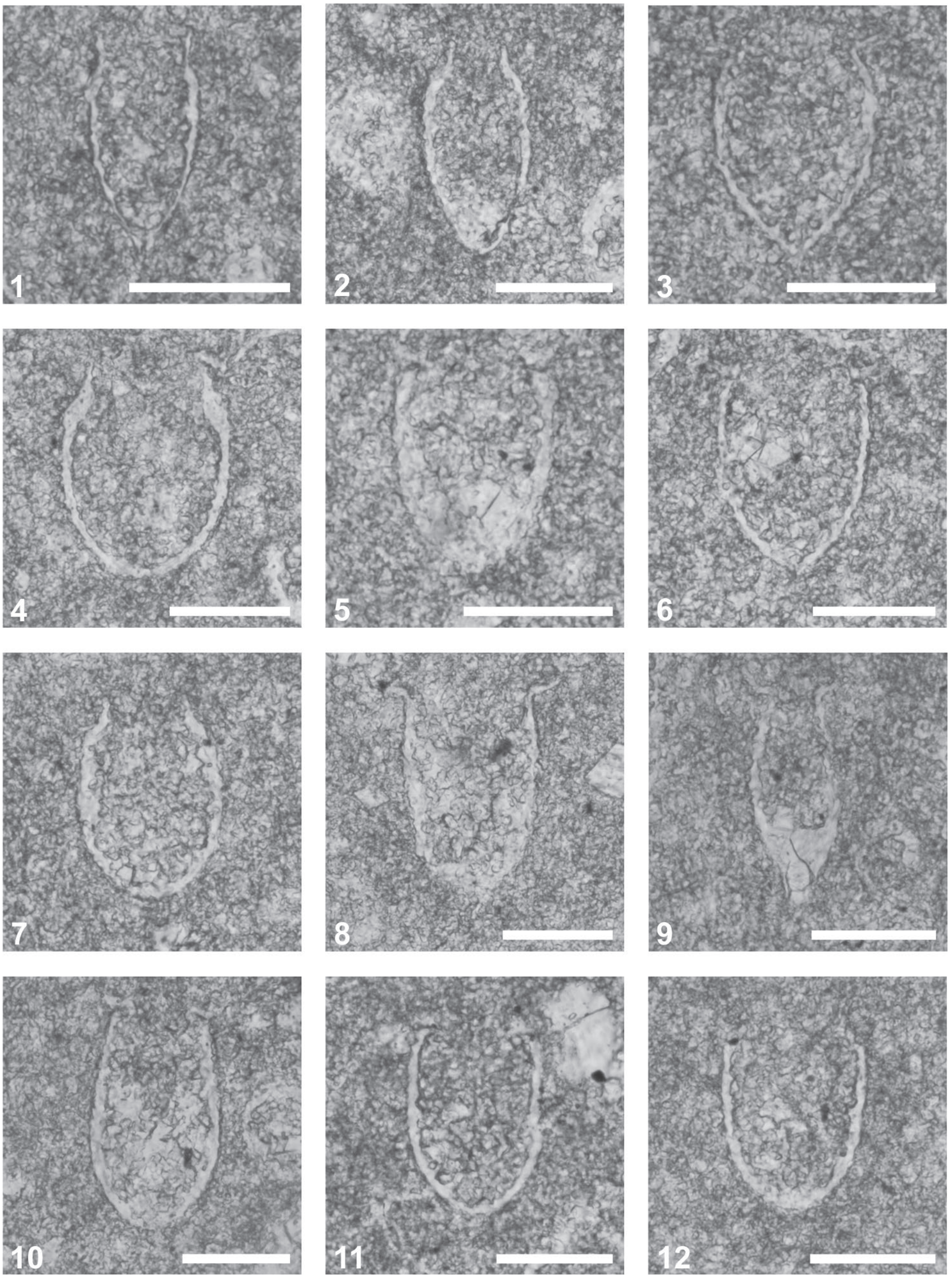

Fig. 20. Late Tithonian–Early Berriasian calpionellids from the Snežnica section: 1. *Crassicollaria parvula* Remane, Sn 25; 2. *Crassicollaria colomi* Doben, Sn 36.5; 3. *Tintinopsella doliphormis* (Colom) Sn 31.5; 4. *Calpionella alpina* Lorenz, Sn 35.5; 5. *Remaniella ferasini* (Catalano), Sn 33; 6. *Remaniella colomi* Pop, Sn 35; 7. *Calpionella elliptica* Cadish, Sn 44.5; 8. *Tintinopsella longa* (Colom), Sn 44.5; 9. *Tintinopsella subacuta* (Colom), Sn 45.5; 10. *Remaniella cadischiana* (Colom), Sn 39; 11. *Remaniella borzai* Pop, Sn 39.5; 12. *Remaniella duranddelgai* Pop, Sn 39.5. Scale bar is 50 µm.

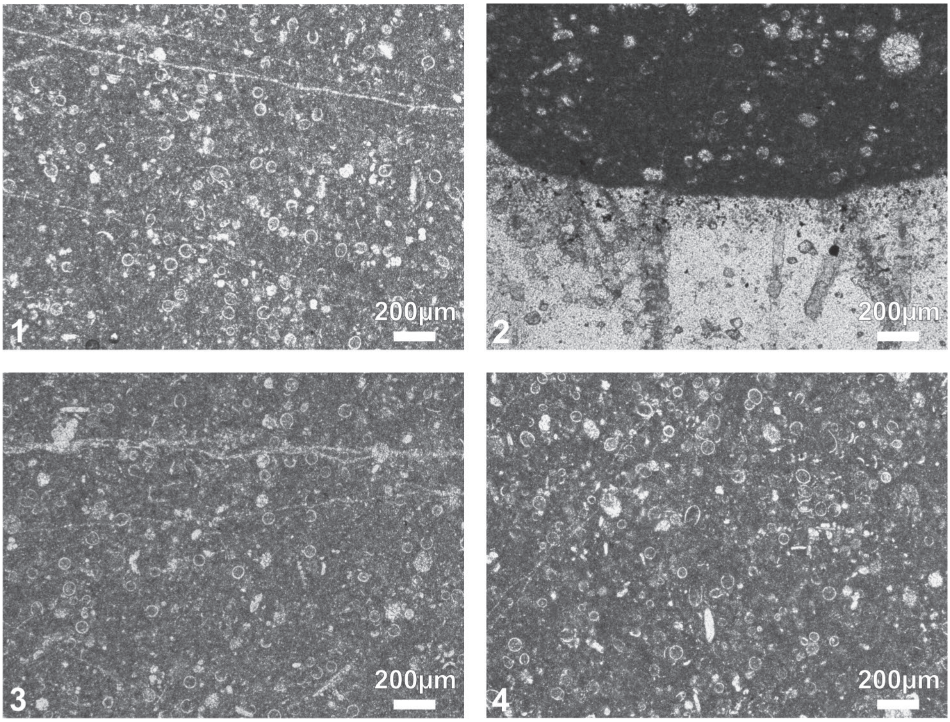

Fig. 21. Late Jurassic–Early Cretaceous microfacies in the Snežnica section: 1. *Calpionella–Globochaete* wackestone of the Colomi Subzone, Crassicollaria Zone, Sample Sn 24; 2. Chert layer in radiolarian–*Calpionella* wackestone – the onset of Alpina Subzone, Calpionella Zone; J/K boundary interval. Sample Sn 26.3; 3. *Calpionella-Globochaete* wackestone – the onset of Alpina Subzone, Calpionella Zone; J/K boundary interval. Sample Sn 26.3; 4. *Calpionella-Globochaete* wackestone of the Remaniella Subzone, Calpionella Zone. Sample Sn 36.5

Late Tithonian Crassicollaria Zone, Colomi Subzone (Pop 1994); Sn 25; 25.4; 25.8; and Sn-26 samples

Thin bedded Maiolica limestone with dark-grey chert nodules. Biomicrite wackestone of *Calpionella–Globochaete* microfacies – SMF 3.

Bioclasts belong to *Globochaete alpina* spores, loricae of *Crassicollaria parvula* dominating over *Crassicollaria massutiniana*, *Calpionella grandalpina*, *Calpionella alpina* and *Tintinnopsella carpathica*, *Cadosina semiradiata semiradiata* cysts, fragments of ostracods, crinoid columnalia, aptychi, foraminifera (*Lenticulina* sp., *Spirillina* sp.). Some of bioclasts are impregnated by pyrite, some of them are phosphatized. *Crassicollaria colomi* was not observed, the Zone was determined on the base of rapid decrease of large *Calpionella* species and by C*rassicollaria parvula* predomination.

Early Berriasian Calpionella Zone, Alpina Subzone (*sensu* Pop 1974; Remane et al. 1986) – followed by Reháková & Michalík 1997; Lakova et al. 1999; Boughdiri et al. 2006; Andreini et al. 2007; Michalík & Reháková 2011; Lakova & Petrova 2013; López-Martínez et al. 2013, 2015; Guzhikov et al. 2012; Grabowski et al. 2010a,b; Wimbledon et al. 2013, Grabowski et al. 2014; Hoedemaeker et al. 2016; Michalík et al. 2016; Svobodová

& Košťák 2016; Lakova et al. 2017; Wibmledon et al. 2017; Elbra et al. 2018a,b; Kowal-Kasprzyk & Reháková 2019, Svobodová et al. (2019); Grabowski et al. (in press) – **Sn – 26,3; 27; 27.6; 28; 28.3; 28.9; 29; 29.8; and Sn-30 samples.**

Pale, regularly thin bedded Maiolica type limestone with dark-grey chert nodules. Biomicrite wackestones of *Calpionella–Globochaete*–radiolarian microfacies – SMF 3 ,4 (Figs. 21, 22). Small spherical forms of *Calpionella alpina* dominated over rare *Crassicollaria parvula* and *Tintinnopsella carpathica*. There are also common calcified radiolarians, *Globochaete alpina* spores, rare cysts of *Colomisphaera lapidosa*, *Stomiosphaerina proxima*, aptychi fragments, bivalves, ostracods, crinoids, ophiurids, foraminifera and sponge spicules. Some beds contain increasing amount of resedimented bioclasts, calpionellids like *Calpionella grandalpina*, *Calpionella elliptalpina*, *Crassicollaria massutiniana*, cysts *Cadosina semiradiata semiradiata*, *Cadosina semiradiata fusca*, *Colomisphaera fortis* and *Saccocoma* sp. Deformations of calpionelid loricae have been observed. Matrix is locally penetrated by frequent fractures and veins filled by calcite.

Early Berriasian Calpionella Zone, Ferasini Subzone (Pop 1994);

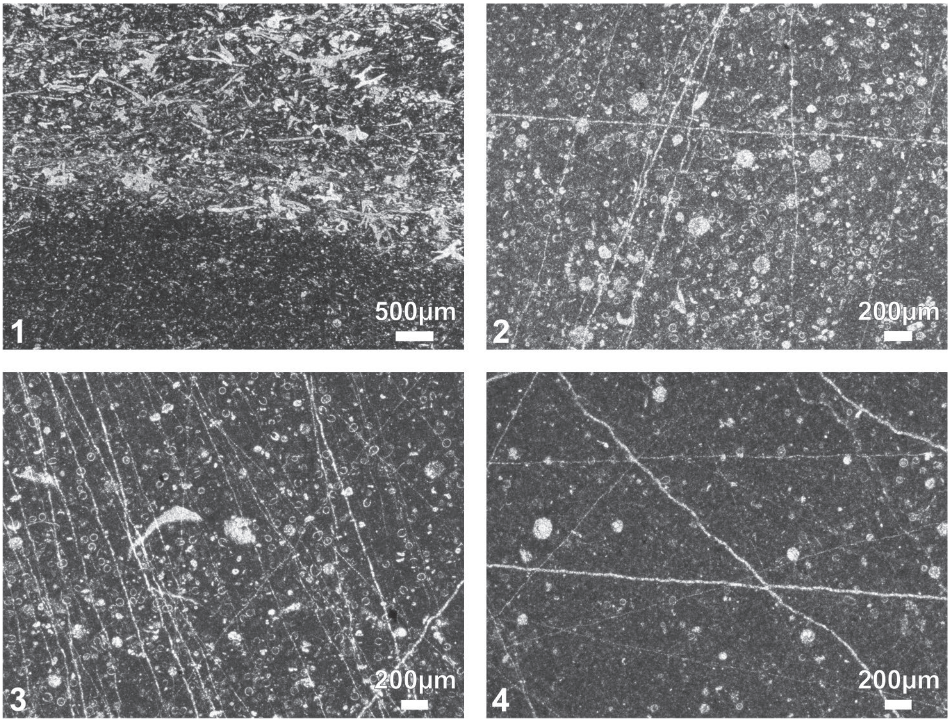

Fig. 22. Late Jurassic–Early Cretaceous microfacies in the Snežnica section: 1. Laminated *Saccocoma–Globochaete* wackestone to packstone with rare calcified radiolarians. Sample Sn 14, 2. Radiolarian–*Calpionella* wackestone of the Alpina Subzone, Calpionella Zone. Sample Sn 28; 3. Radiolarian–*Calpionella* wackestone of the Alpina Subzone, Calpionella Zone. Sample Sn 29; 4. *Calpionella*–radiolarian wackestone of the Elliptica Subzone, Calpionella Zone. Sample Sn 44

Sn-30,5; 31; 31.5; 32; 32.5; 33; 33.5; 34; 34.5; 35; 35.5; 36; 36.5; 36.5; and Sn-37 samples

Pale, regularly thin bedded Maiolica type limestone with dark-grey chert nodules and stratiform chert layers. Biomicrite wackestone of *Calpionella*–*Globochaete*–radiolarian microfacies and bioturbated wackestone *Calpionella*–radiolarian microfacies – SMF 3.

Calpionella alpina together with *Globochaete alpina* and calcified radiolarians dominated. They are accompanied by fragments of bivalves, crinoids, ophiurioids, aptychi, foraminifera, calpionellids – *Remaniella ferasini*, *Remaniella catalanoi*, *Remaniella duranddelgai*, *Remaniella colomi, Lorenziella hungarica*, *Lorenziella plicata*, *Crassicollaria parvula, Tintinnopsella carpathica* (Fig. 23), cysts of *Colomisphaera lapidosa, Stomiosphaerina proxima, Cadosina semiradiata fusca*, *Cadosina semiradiata semiradiata.* At the base of the Zone in sample Sn-30.5, few Tithonian calpionellid species and few of *Saccocoma* sp. fragments were documented. At the end of this Subzone, morphologically variegated *Calpionella* species (*Calpionella* sp.) appear. Matrix is penetrated by frequent thin fractures filled by calcite.

Middle Berriasian Calpionella Zone, Elliptica Subzone (Pop 1974); samples Sn 37.5; 38; 38.5; 39; 39.5; 40; 40.5; 41; 41.5; 42; 42.5; 43; 43.5; 44; 44.5; 45; 45.5; 46; 46.5; 47; 47.5; 48; 48.5; 49; 49.5

Pale, regularly thin bedded majolica type limestone with dark-grey chert nodules and stratiform chert layers. Biomicrite wackestone of *Calpionella*–radiolarian microfacies – SMF 3. Calpionellids and calcified radiolarians prevail in the microfacies. *Calpionella alpina*, *Calpionella elliptica*, *Calpionella minuta*, *Calpionella* sp., *Crassicollaria parvula*, *Tintinnopsella carpathica*, *Tintinnopsella doliphormis*, *Lorenziella hungarica*, *Lorenziella plicata, Remaniella ferasini*, *Remaniella catalanoi*, *Remaniella duranddelgai*, *Remaniella colomi*, *Remaniella cadischiana, Remaniella borzai, Remaniella filipescui*, cysts of *Colomisphaera lapidosa*, *Colomisphaera carpathica, Stomiosphaera moluccana*, *Stomiosphaera wanneri*, *Stomiosphaera* sp., *Cadosina semiradiata fusca*, calcite walled foraminifera – *Spirillina* sp., *Lenticulina* sp., *Nodosaria* sp., *Patelina subcretacea*, fragments of agglutinated foraminifera, infrequent fragments of bivalves, echinoids, crinoids, aptychi, ostracods, and ophiuroids were determined. Up to Sn-40 sample, *Calpionella* species slowly decreases in abundance. Some of loricae are deformed. Matrix is penetrated by net of fractures filled by calcite, larger accumulations of pyrite were also observed; in some cases pyrite impregnated bioclasts.

Calcareous nannofossils and nannofossil zonation

The abundance and mode of preservation of nannofossils are highly dependent on lithology. Nodular limestones of the Ammonitico Rosso facies composing the Czorsztyn Limestone Formation yielded poor and fragmented nannofossils with relative high species diversity. Similarly, biomicritic limestones of the Pieniny Limestone Formation contain extremely poor nannofossils, as well. Watznaueriaceae are quantitatively dominating and nannoconids are found on rare occasions. In both formations, nannofossils are strongly affected by dissolution.

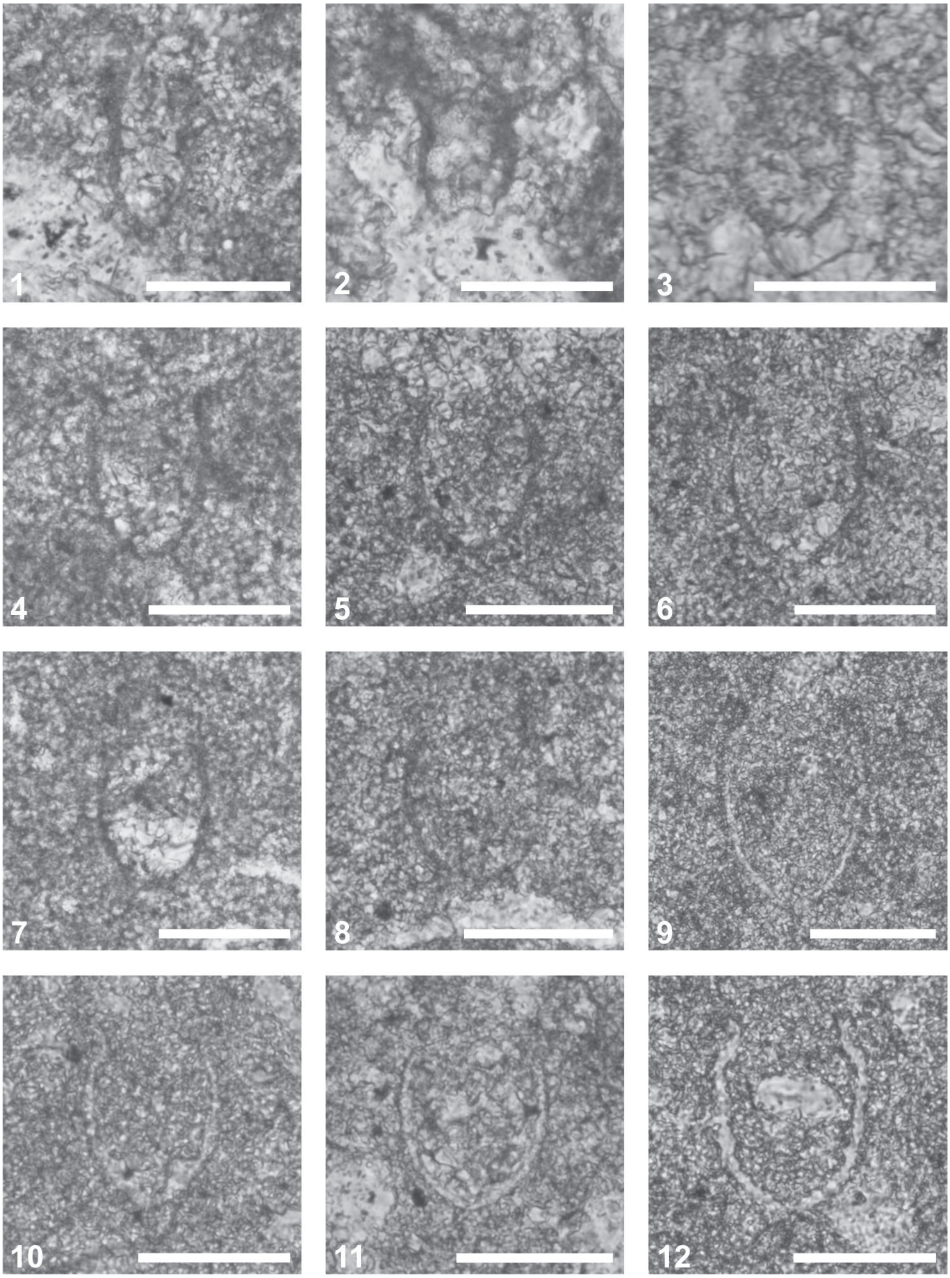

Fig. 23. Uppermost Early to Late Tithonian chitinoidellids and calpionellids from the Snežnica section: 1. *Longicollaria dobeni* (Borza), Sn 18; 2. *Borziella slovenica* (Borza), Sn 18.1; 3. *Dobeniella cubensis* (Furrazola-Bermúdez), Sn 18.1; 4. *Chitinoidella boneti* Doben, Sn 20.5; 5. *Chitinoidella hegarati* Sallouhi, Boughdiri and Cordey, Sn 21; 6. *Chitinoidella popi* Sallouhi, Boughdiri and Cordey, Sn 21; 7–8. *Longicollaria insueta* Řehánek, Sn 20.5; 9–10. *Praetintinnopsella andrusovi* Borza, Sn 21; Sn 21.4; 11. *Tintinnopsella remanei* Borza, Sn 21.4; 12. *Crassicollaria* aff. *intermedia* (Durand-Delga), Sn 21.4. Scale bar is 50 µm.

Therefore, their composition cannot be regarded as representative of any original calcareous nannofloral spectra.

The preliminary results show that the first occurrence (FO) of *Faviconus multicolumnatus*, indicating Kimmeridgian NJT14 Zone (Casellato 2010) was recorded in 4.9 m. Problematic fragment of ?*Conusphaera mexicana minor*, Tithonian NJT15a Zone has been found in 11.1 m. These indexes are followed by FOs of *Polycostella beckmannii*, NJT15b Zone in 13.1 m, *Nannoconus globulus minor* in top 24.3 m and *Nannoconus wintereri*, NJT17b Zone in top 25.9 m. However, poor preservation of nannofossils in overlying strata prevents obtaining of further reliable biostratigraphical data.

Radiolarians and radiolarian zonation

We tried to isolate radiolarians from all samples in which radiolarians were detected in thin sections. Out of 13 samples, three were productive. The samples were first treated with 10 % acetic acid. Sample 28.9 revealed a poorly preserved radiolarian fauna, the residues of the other samples yielded rare sponge spicules and some of them also undeterminable structureless spheres, probably belonging to radiolarians. All samples were then processed with diluted 5 % hydrofluoric acid. Moderately well-preserved radiolarians were obtained from samples 14.00 and 44.50, whereas sample 28.9 and all other samples were devoid of determinable radiolarians. After each treatment we examined the etched rock fragments under a binocular microscope to check the occurrence of radiolarians. All radiolarians appearing in relief on the rock surface were found in limestone; no radiolarians could be extracted from chert nodules. The species inventory of the productive samples is listed in the Table 1 and illustrated in Figures 24–27.

Sample 14.00. A 7 cm thick bed of light gray laminated limestone with a 3–4 cm thick layer of gray vitreous chert in the middle part. Radiolarians are moderately well-preserved; nassellarians are much more abundant than spumellarians (Fig. 24). The assemblage contains several species characteristically appearing in the Tithonian, such as *Eucyrtidiellum pyramis* (Aita), *Cinguloturris cylindra* Kemkin and Rudenko, *Crococapsa accincta* (Steiger), *Crococapsa pseudouterculus* (Aita), *Doliocapsa doliolum* (Aita), *Parapodocapsa amphitreptera* (Foreman) and *Pseudodictyomitra carpatica* (Lozyniak) (Aita & Okada 1986; Steiger 1992; Goričan 1994; Hori 1999). *Archaeodictyomitra apiarium* (Rüst) shows a wide intraspecific variability in this assemblage. In some specimens the intersegmental constrictions are well expressed (Fig. 24: 32–34) similarly to those of the ancestor species *Archaeodictyomitra minoensis* (Mizutani). In other specimens, the constrictions are much weaker (Fig. 24: 36). The broad age assignment to the Tithonian is evident even from genera alone – *Neorelumbra* first appears in the Early Tithonian and *Protunuma* last appears in the Late Tithonian (O’Dogherty et al. 2009).

Sample 28.90. White micrite with large irregularly shaped nodules of gray replacement chert. Radiolarians are rare and heavily corroded (Fig. 25). Only a few species could be determined with certainty and the diversity is reduced due to the poor preservation. The stratigraphically important species are *Hsuum raricostatum* Jud, *Parapodocapsa furcata* Steiger and *Praeparvicingula cosmoconica* (Foreman)

Table 1: Occurrence of radiolarian species in the studied samples. The second column gives the zonal ranges of the species according to Baumgartner et al. (1995a). The zonal assignment according to Baumgartner et al. (1995a) and Matsuoka (1995) is shown in the bottom rows.

Radiolarian taxa Samples	**UAZ95**	**14.00**	**28.90**	**44.50**
Angulobracchia heteroporata Steiger				X
Angulobracchia mediopulvilla Steiger				X
Angulobracchia? *portmanni* Baumgartner	13–22			X
Arcanicapsa spp.			X	X
Archaeodictyomitra apiarium (Rüst)	8–22	X	X	X
Archaeospongoprunum patricki Jud	13–22			X
Cinguloturris cylindra Kemkin and Rudenko	12–17	X		
Crococapsa accincta (Steiger)		X		
Crococapsa pseudouterculus (Aita)		X	X	
Cryptamphorella dumitricai Schaaf		X		X
Deviatus diamphidius (Foreman)	8–14			X
Dicerosaturnalis gratiosus Dumitrica and Hungerbühler				X
Dicerosaturnalis trizonalis (Rüst)		X	X	X
Doliocapsa doliolum (Aita)		X		
Emiluvia chica Foreman	3–18	X		X
Eucyrtidiellum pyramis (Aita)	12–13	X		
Halesium palmatum Dumitrica				X
Hemicryptocapsa capita Tan	17–18		X	
Hemicryptocapsa carpathica (Dumitrica)	7–11			X
Hiscocapsa? *altiforamina* (Tumanda)	18–21			aff.
Hiscocapsa kaminogoensis (Aita)		cf.	cf.	
Hsuum raricostatum Jud	13–15		X	X
Mirifusus dianae (Karrer) s.l.	7–20			X
Neorelumbra buwaydahensis Kiessling		cf.		
Neorelumbra tippitae Kiessling		cf.		cf.
Obesacapsula cetia (Foreman)	10–17			X
Obesacapsula rusconensis Baumgartner	13–19		cf.	X
Obesacapsula verbana (Parona)	11–20		cf.	X
Pantanellium berriasianum Baumgartner	13–15	X		
Pantanellium squinaboli (Tan)	11–22	X	X	X
Parapodocapsa amphitreptera (Foreman)	9–18	X		
Parapodocapsa furcata Steiger	13–16		X	X
Praeparvicingula cosmoconica (Foreman)	13–22		X	X
Protunuma japonicus Matsuoka and Yao	7–12	cf.		
Pseudocrucella? *elisabethae* (Rüst)	13–22			X
Pseudodictyomitra carpatica (Lozyniak)	11–21	X		X
Pseudoeucyrtis? *fusus* Jud	13–17			X
Pseudoxitus gifuensis (Mizutani)	11–16		X	
Spinosicapsa aff. *coronata* Steiger *sensu* Baumgartner et al. (1995b)	11–20	X		X
Spinosicapsa milloti (Schaaf)	13–19			X
Spinosicapsa triacantha (Fischli)				X
Svinitzium depressum (Baumgartner)	13–18		cf.	cf.
Tethysetta boesii (Parona)	9–22	X		X
Thanarla patricki (Kocher)		X		
Triactoma kellumi Pessagno and Yang		X		
Tritrabs ewingi (Pessagno)	4–22			X
Xitus robustus Wu			X	
Zhamoidellum sp. A *sensu* Goričan (1994)		X	cf.	
AU Zones of Baumgartner et al. (1995a)		**12–13**	**13–15**	
Zones according to Matsuoka (1995)		***Pseudodictyomitra carpatica* Zone**		

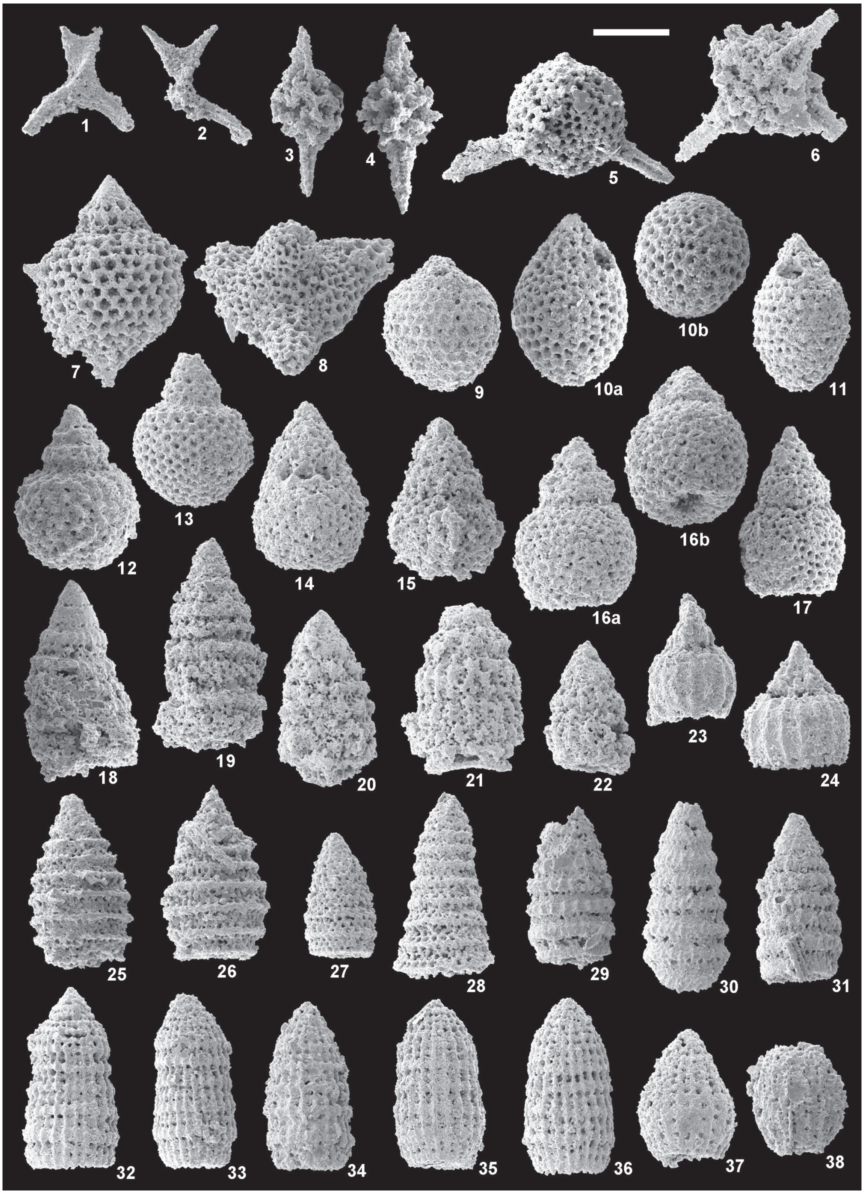

Fig. 24. Radiolarians from the Snežnica section, Sn-14: 1, 2. *Dicerosaturnalis trizonalis* (Rüst); 3. *Pantanellium squinaboli* (Tan); 4. *Pantanellium berriasianum* Baumgartner; 5. *Triactoma kellumi* Pessagno and Yang; 6. *Emiluvia chica* Foreman; 7. *Spinosicapsa* aff. *coronata* Steiger; 8. *Parapodocapsa amphitreptera* (Foreman); 9. Cryptamphorella *dumitricai* Schaaf; 10a–b, 11. *Zhamoidellum* sp. A; 10a–b: lateral and antapical view of the same specimen; 12, 13. *Crococapsa pseudouterculus* (Aita); 14. *Crococapsa accincta* (Steiger); 15. *Hiscocapsa* cf. *kaminogoensis* (Aita); 16a–b, 17. *Doliocapsa doliolum* (Aita); 16a–b: lateral and antapical view of the same specimen.; 18. *Cinguloturris cylindra* Kemkin and Rudenko; 19. *Cinguloturris* sp.; 20. *Xitus* sp.; 21. *Neorelumbra* cf. *buwaydahensis* Kiessling; 22. *Neorelumbra* cf. *tippitae* Kiessling; 23, 24. *Eucyrtidiellum pyramis* (Aita); 25, 26. *Tethysetta boesii* (Parona); 27, 28. *Praeparvicingula* spp.; 29. *Pseudodictyomitra carpatica* (Lozyniak); 30, 31. *Pseudodictyomitra* spp.; 32–36. *Archaeodictyomitra apiarium* (Rüst); 37. *Thanarla patricki* (Kocher); 38. *Protunuma* cf. *japonicus* Matsuoka and Yao. Magnification: Fig. 5; 125x (scale bar 120 μm); Figs. 1–4, 6–8, 18–22, 25–29, 31–36, 38: 150x (scale bar 100 μm); Figs. 9–17, 23–24, 30, 37: 200x (scale bar 75 μm).

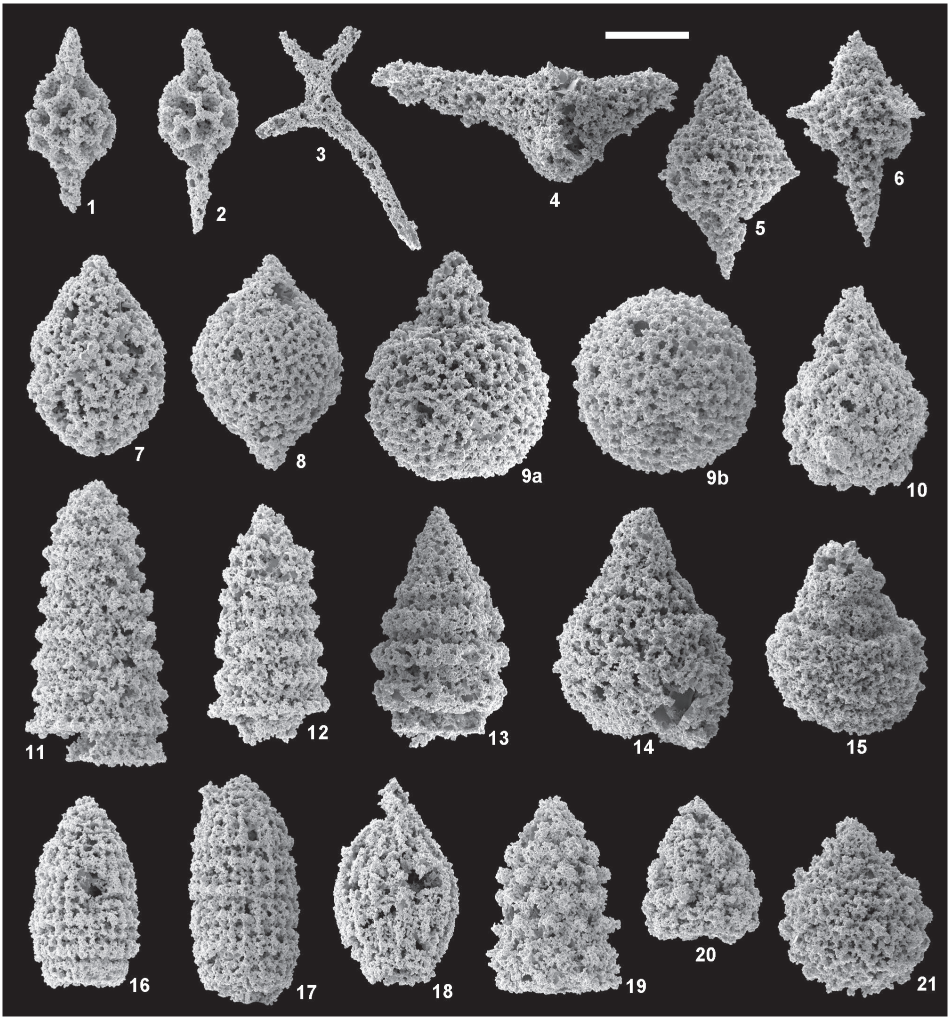

Fig. 25. Radiolarians from the Snežnica section, Sn-28.9: 1, 2. *Pantanellium squinaboli* (Tan); 3. *Dicerosaturnalis trizonalis* (Rüst); 4. *Parapodocapsa furcata* Steiger; 5, 6. *Spinosicapsa* spp.; 7. *Zhamoidellum* sp.; 8. *Hemicryptocapsa capita* Tan; 9a–b. *Crococapsa pseudouterculus* (Aita); lateral and antapical view of the same specimen; 10. *Hiscocapsa* cf. *kaminogoensis* (Aita); 11, 12. *Praeparvicingula cosmoconica* (Foreman); 13. *Svinitzium* cf. *depressum* (Baumgartner); 14. *Obesacapsula* cf. *verbana* (Parona); 15. *Obesacapsula* cf. *rusconensis* Baumgartner; 16, 17. *Archaeodictyomitra apiarium* (Rüst); 18. *Hsuum raricostatum* Jud; 19. *Xitus robustus* Wu; 20. *Pseudoxitus gifuensis* (Mizutani); 21. *Arcanicapsa* sp.Magnification: Fig. 15: 100x (scale bar 150 µm); Figs. 1–6,11–12, 14, 16–21: 150x (scale bar 100 µm); Figs. 7–10, 13: 200x (scale bar 75 µm).

that all first appear in the latest Tithonian (UA Zone 13 of Baumgartner et al. 1995a).

Sample 44.50. A 2.5 cm thick layer of dark gray replacement chert with gray micrite at margins. Radiolarians are moderately well-preserved (Figs. 26–27); spumellarians are more abundant and diverse than in the other samples. Large nassellarians such as *Obesacapsula* and *Mirifusus* are common. Pyritized specimens were also very rarely found; most of them belong to cryptocephalic nassellarians.

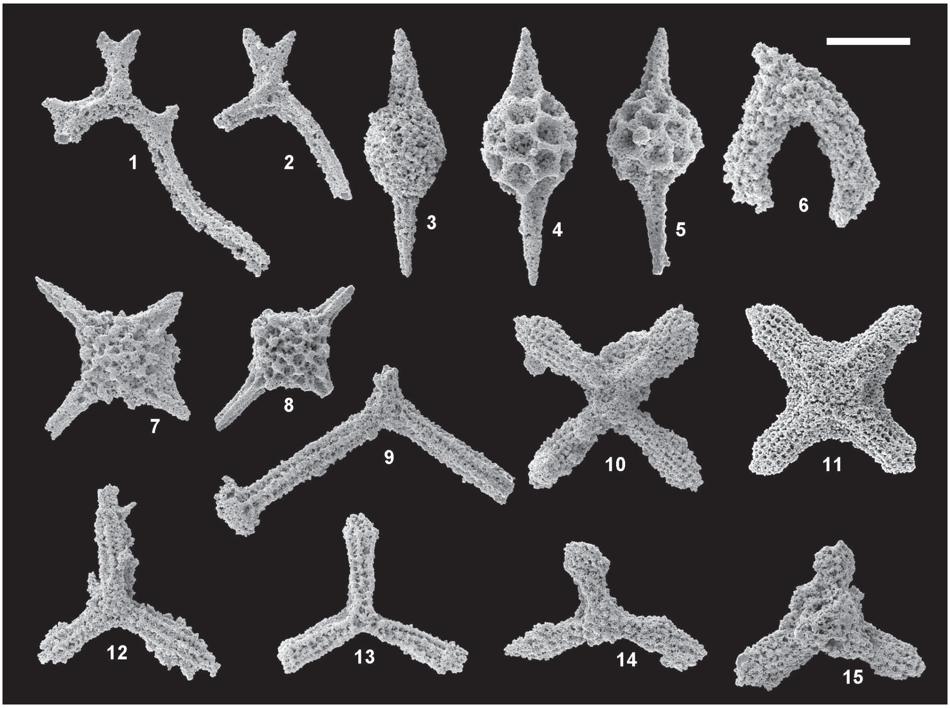

Fig. 26. Spumellarian radiolarians from the Snežnica section, Sn-44.5: 1. *Dicerosaturnalis gratiosus* Dumitrica and Hungerbühler; 2. *Dicerosaturnalis trizonalis* (Rüst); 3. *Archaeospongoprunum patricki* Jud; 4, 5. *Pantanellium squinaboli* (Tan); 6. *Deviatus diamphidius* (Foreman); 7, 8. *Emiluvia chica* Foreman; 9. *Tritrabs ewingi* (Pessagno); 10, 11. *Pseudocrucella*? *elisabethae* (Rüst); 12. *Halesium palmatum* Dumitrica; 13. *Angulobracchia heteroporata* Steiger; 14. *Angulobracchia*? *portmanni* Baumgartner; 15. *Angulobracchia mediopulvilla* Steiger. Magnification: Figs. 7–15: 100x (scale bar 150 µm); Figs. 1–6: 150x (scale bar 100 µm).

In addition to *Hsuum raricostatum* Jud, *Parapodocapsa furcata* Steiger and *Praeparvicingula cosmoconica* (Foreman) present in sample 28.90 below, other species first appearing in the latest Tithonian UA Zone 13 of Baumgartner et al. (1995a) occur. These species are *Angulobracchia*? *portmanni* Baumgartner, *Pseudocrucella*? *elisabethae* (Rüst), *Pseudoeucyrtis*? *fusus* Jud and *Spinosicapsa milloti* (Schaaf) (Table 1)

According to the zonation of Baumgartner et al. (1995a), the sample 14.00 is assigned to the UA Zones 12–13 as suggested by *Cinguloturris cylindra* Kemkin and Rudenko and *Eucyrtidiellum pyramis* (Aita) (Table 1). Samples 28.90 and 44.50 are assigned to the UA Zones 13–15 based on *Hsuum raricostatum* Jud and species mentioned above with FADs in the UA Zone 13. *Hemicryptocapsa carpathica* (Dumitrica), occurring in sample 44.50 was, in the zonation of Baumgartner et al. (1995a) restricted to the Jurassic (see Table 1) but it was later found also in the Berriasian (Matsuoka 1998). According to the zonation established by Matsuoka (1995), all three samples belong to the rather long Pseudodictyomitra carpatica Zone. This zonal assignment is suggested by the presence of *Pseudodictyomitra carpatica* (Lozyniak) (Table 1) and the lack of *Cecrops septemporatus* (Parona),

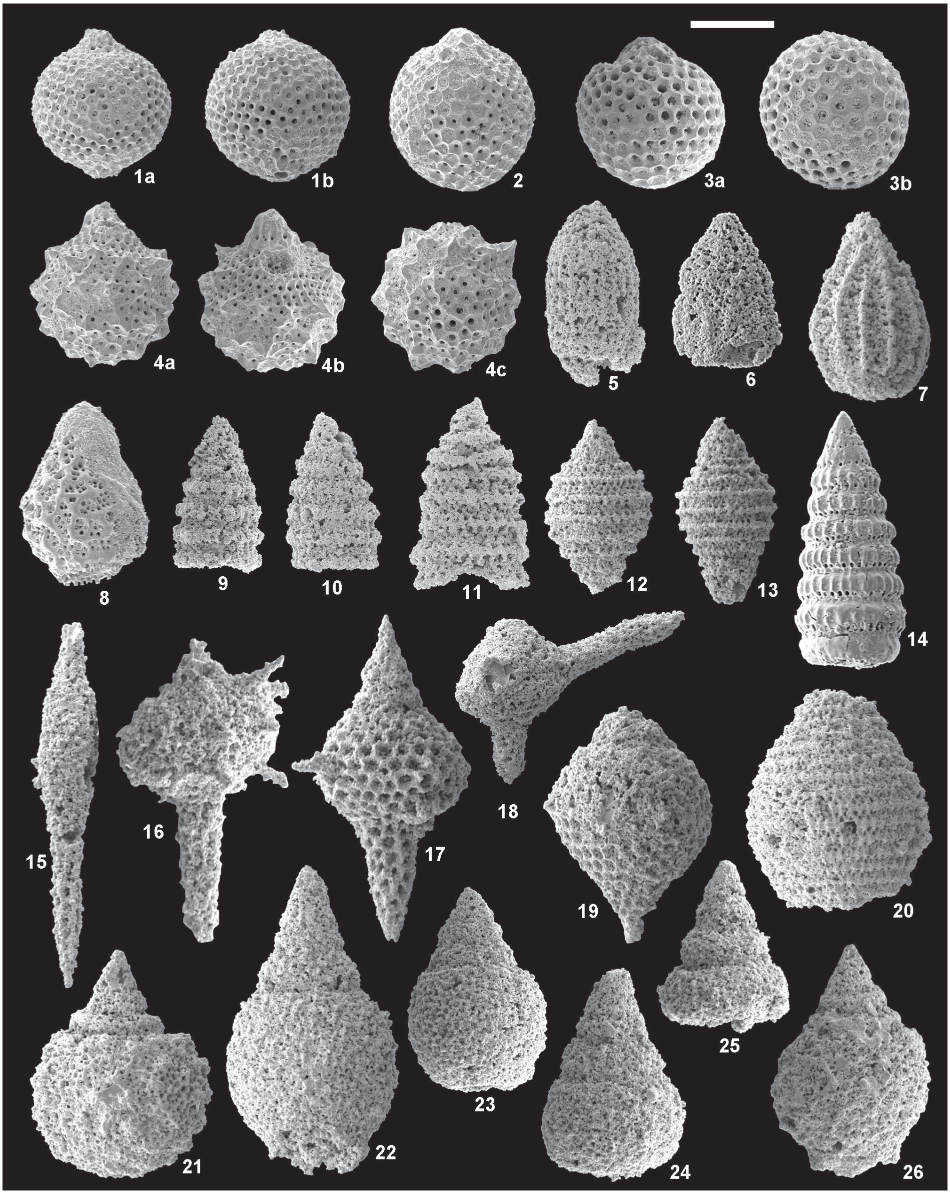

Fig. 27. Nassellarian radiolarians from the Snežnicasection sample Sn-44.5. 1a–b. *Hemicryptocapsa carpathica* (Dumitrica); 2, 3a–b. *Cryptamphorella dumitricai* Schaaf; 3a–b: lateral and antapical view of the same specimen; 4a–c. *Arcanicapsa* sp. Lateral (a), apical (b) and antapical view (c) of the same specimen; 5. *Archaeodictyomitra apiarium* (Rüst); 6. *Neorelumbra* cf. *tippitae* Kiessling; 7. *Hsuum raricostatum* Jud; 8. *Hiscocapsa*? aff. *altiforamina* (Tumanda); 9, 10. *Svinitzium* cf. *depressum* (Baumgartner); 11. *Praeparvicingula cosmoconica* (Foreman); 12, 13. *Tethysetta boesii* (Parona); 14. *Pseudodictyomitra carpatica* (Lozyniak); 15. *Pseudoeucyrtis*? *fusus* Jud; 16. *Spinosicapsa milloti* (Schaaf); 17. *Spinosicapsa triacantha* (Fischli); 18. *Parapodocapsa furcata* Steiger; 19. *Spinosicapsa* aff. *coronata* Steiger *sensu* Baumgartner et al. (1995b); 20. *Mirifusus dianae* (Karrer) s.l.; 21. *Obesacapsula cetia* (Foreman); 22–25. *Obesacapsula verbana* (Parona); 26. *Obesacapsula rusconensis* Baumgartner. Magnification: Figs. 12–13, 19–26: 100x (scale bar 150 µm); Figs. 5–7,9–11, 14, 15–18: 150x (scale bar 100 µm); Figs. 2–4, 8, 14: 200x (scale bar 75 µm); Figs 1a–b: 250x (scale bar 60 µm). Specimens in figs. 1–4, 8 and 14 are pyritized.

the evolutionary FAD of which defines the top of this zone. Here we note that radiolarian zonations available are rather rough across the Jurassic–Cretaceous boundary. A group of radiolarian researchers is currently working intensely on refining the precision of radiolarian dating in the Tithonian–Berriasian interval. Two objectives are followed – to include a great number of species in the future range chart (e.g. O'Dogherty et al. 2018) and to carry out high resolution sampling in key J–K boundary sections (e.g. Matsuoka et al. 2018).

Stable carbon and oxygen isotopes

Sequences of the Rosso Ammonitico and Maiolica facies are characterised with a "long term" carbon isotope trend without any CIE (carbon isotope excursions, see Michalík et al. 2009, 2016; Michalík & Reháková 2011). Values of the $\delta^{13}C$ in the micrite matrix gradually decreased from values about +3 ‰ in Late Oxfordian to values around +1 ‰ in Late Tithonian and this relatively stable values persisted during the whole Berriasian. In the Snežnica section (Fig. 28), $\delta^{13}C$ data ranged between +1.013 to +2.040 ‰ (VPDB) confirming the $\delta^{13}C$ trend indicating decelerated sea water C-cycling (Weissert & Chanell 1989; Price et al. 2000); they were documented in majority of sections on the Tethyan margin. Increase of the sea water temperature (approximately 2–4 °C) has been suggested on the base of the $\delta^{18}O$ trend in the J/K boundary interval in the Brodno and Strapkova sections (Michalík et al. 2009, 2016). However, these results from micrite matrix should be interpreted with a caution. Pelagic carbonate sediment largely derived from skeletons of planktonic organisms (i.e. nannofossils, calpionellids, etc.) and its original $\delta^{18}O$ content could be influenced by local conditions, especially by rate of precipitation and evaporitization of surface waters in the Early Berriasian arid climate. Wider range (in span −6 to +1 ‰) and frequent changes of $\delta^{18}O$ values in the rock record seems to be the result of both sea-water salinity variations and short time sedimentary cycles during J/K boundary. The decrease of the $\delta^{18}O$ values from the Intermedia /Colomi boundary interval to the base of the Alpina Subzone indicates a warming trend. Large positive shifts of $\delta^{18}O$ values could reflect evaporation-related early diagenetic changes and short time eustatic fluctuations. Few short and one longer progressive increase of $\delta^{18}O$ values visible in the Alpina and Ferasini subzones may represent a slight cooling trend. Shifts of $\delta^{18}O$ composition could be also influenced by meteoric water in groundwater release from aquifers to basins during eustatic sea level drop (Price et al. 2000; Haq 2014). The $\delta^{18}O$ distribution in the sections suggested that large lateral variation of water salinity/composition could be expected.

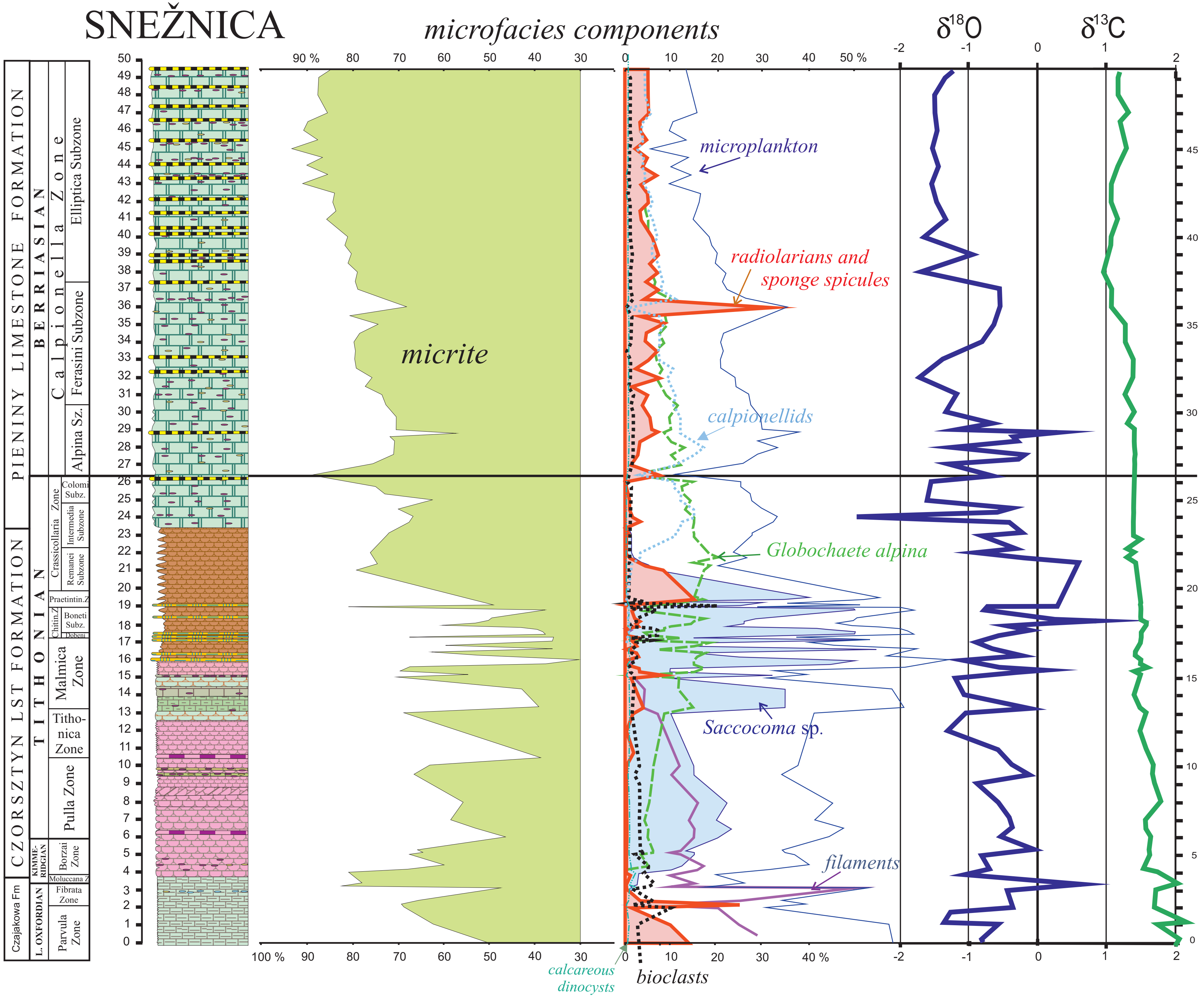

Fig. 28. Lithological column of the Snežnica sequence, quantitative representation of allochems in microfacies; calpionellid and cyst zonations and chemostratigraphy.

3rd Stop – Strapkova section

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Location

An important section encovering the JKB sequence in the western sector of the Pieniny Klippen Belt in the Outer Western Carpathians, Slovakia is named as the Strapkova section (Michalík et al. 2016). The Strapkova section (49°04'09.34"N, 18°10'00.85"E; 589 m a.s.l.) is exposed on a steep SE slope of the Strapkova hill below the Mount Vršatec (Biele Karpaty Mountains, Fig. 29). It is located below local road to the Červený Kameň approx. 1250 m NE from the Vršatecké Podhradie village, westwards of the Middle Váh Valley.

Geological setting

Hemipelagic succession of the Strapkova section (attributed to the Orava Unit by Haško 1978; and Schlögl et al. 2000) starts with spotted limestones. A rich ammonite fauna indicates Late Sinemurian Raricostatum Subzone of the homonymous zone. The Kozinec Formation composed of

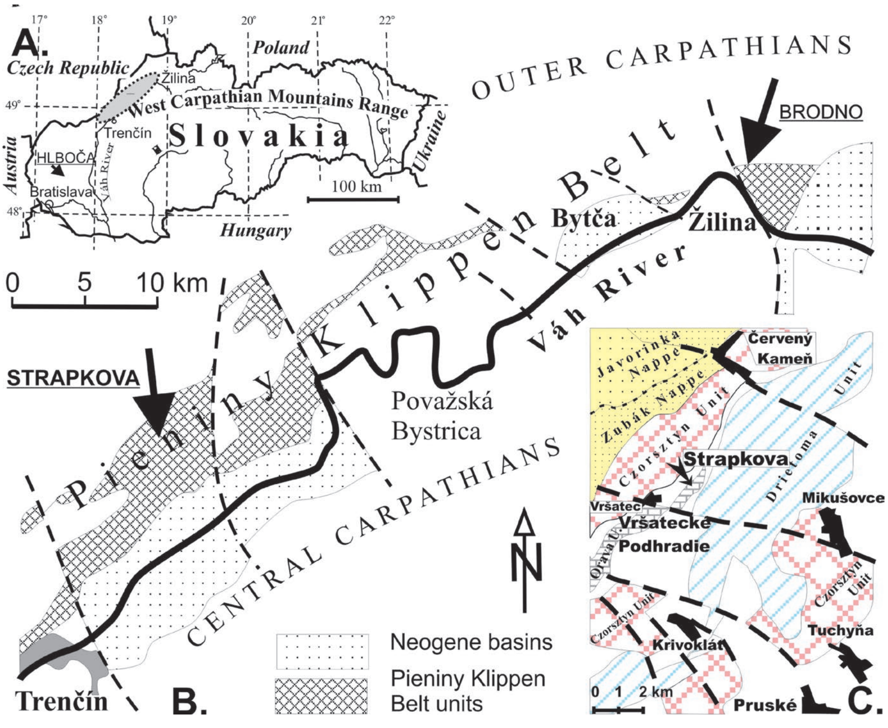

Fig. 29. Situation sketch of the Strapkova area below Mt Vršatec in Middle Váh Valley (arrow indicates the Strapkova section).

red pseudonodular limestones alternating with greenish-grey marly limestones contains ammonites of an interval from the latest Sinemurian Macdonelli Subzone of the Raricostatum Zone to the Early Pliensbachian Davoei Zone. Grey-greenish finely bedded limestones and yellow-grey marly shales contain abundant ammonites of the Pliensbachian and Toarcian Margaritatus and Spinatum zones. Red nodular limestones following upwards are considered as Toarcian in age, despite of the poor preservation of the ammonite fauna.

Well bedded cherty spiculitic limestones of the Podzamcze Limestone Formation contain sole beds of crinoidal packstones being capped by a 1 m thick interval of red nodular limestone (Fig. 30). Czajakowa Radiolarite Formation is built of red radiolarites (1 m thick) with Middle Oxfordian radiolarians, thick (1.5 m) layer of pink limestone rich in belemnite rostra and "upper" red and green radiolarites with Kimmeridgian *Saccocoma* packstones in its upper part. Radiolarites pass gradually to thin bedded red cherty and nodular limestones intercalated by red marlstones. The marlstones are followed by the Czorsztyn and the Pieniny limestone formations, which formed the subject of our study. A well preserved Upper Tithonian–Lower Berriasian Strapkova sequence of hemipelagic limestones completes knowledge on the Jurassic/Cretaceous boundary in the Western Carpathians (Michalík et al. 2016).

Lithology and microfacies of the Strapkova section

The **Czorsztyn Limestone Formation** (ca. 11 m thick, samples 280 to 291, Fig. 31) is represented by red nodular limestones of the Rosso Ammonitico facies. Due to corrosion and solution, ammonites are very poorly preserved. Limestone layers contain elongated to stratiform nodules of brown red cherts. The formation includes *Saccocoma*–filamentous wackestones to packstones, *Saccocoma–Globochaete*–filamentous packstones, *Saccocoma*–radiolaria–*Globochaete* packstones, *Saccocoma–Globochaete*–radiolaria packstones, *Saccocoma–Globochaete* wackestones to packstones and radiolarian wackestones. Radiolarians and spicules are partially or totally calcified. Since the Late Tithonian, saccocomas have been gradually replaced by *Globochaete alpina* spores in the role of dominating microfossils. Red nodular limestone of the Rosso Ammonitico facies (Czorsztyn Limestone Formation) is dated as Kimmeridgian to the Tithonian.

Following biostratigraphical units can be recognized in the bed succession observed (beds 280–365, Fig.31):

Borzai Zone (sample 280) – packstones to wackestones of *Saccocoma*-filamentous microfacies with *Carpistomiosphaera borzai, Colomisphaera lapidosa*: Late Kimmeridgian.

Pulla Zone (samples 281–283) – packstones to wackestones of the *Saccocoma–Globochaete* microfacies with *Colomisphaera pulla, Colomisphaera carpathica*: Early Tithonian.

Malmica Zone (samples 284 to 287) – wackestones of the *Saccocoma–Globochaete* and *Saccocoma*–radiolarian–*Globochaete* microfacies containing *Parastomiosphaera malmica, Carpistomiosphaera tithonica:* Early Tithonian.

Chitinoidella Zone, Dobeni Subzone (samples 288 to 289) – *Saccocoma–Globochaete*–radiolaria packstones contain rare *Longicollaria dobeni,*

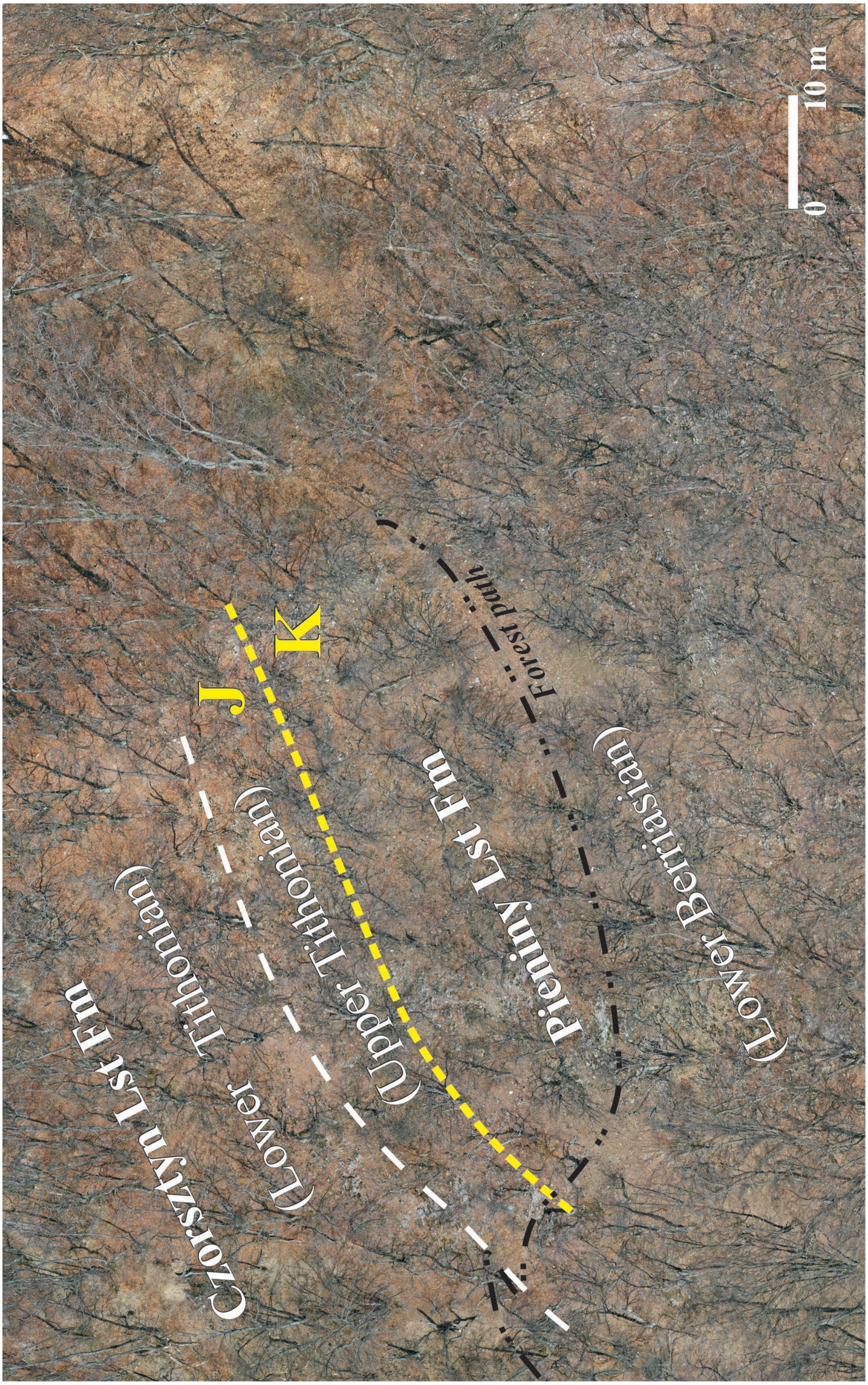

Fig. 30. Aerial view of the Strapkova section using DJI drone (photo by M. Marciš and K. Fekete).

Carpathella rumanica, Borziella slovenica, Dobeniella tithonica, Colomisphaera carpathica and *Colomisphaera tenuis:* latest Early Tithonian**.**

Chitinoidella Zone, Boneti Subzone (samples 289.4–290) – *Saccocoma–Globochaete*–radiolaria packstones and *Saccocoma–Globochaete* wackestones to packstones with *Chitinoidella boneti*, *Chitin. elongata*, *Longicollaria dobeni*, *Dobeniella cubensis*, *Popiella oblongata, Colomisphaera carpathica*, *Colom. lapidosa*, *Colom. tenuis* and *Colom. fortis:* Late Tithonian.

Praetintinnopsella Zone (sample 291) – radiolaria wackestones contain rare chitinoidellids, cysts of *Colomisphaera carpathica* but also the first hyaline calpionellid form represented by *Praetintinnopsella andrusovi:* Late Tithonian.

The **Pieniny Limestone Formation –** After a thin transitional interval (earliest Late Tithonian Praetintinopsella Zone), the sequence continues by Maiolica facies of the Pieniny Limestone Formation (Late Tithonian to Late Berriasian). Our study has been focused on the lower part of the Pieniny Formation, ca. 40 m thick (from the Late Tithonian Crassicollaria remanei Subzone to Middle Berriasian Calpionella elliptica Subzone). Successive occurence of biostratigraphically important calpionellids and calcareous dinoflagellates is shown in the Fig. 31.

The Pieniny Limestone Formation is formed by pale grey to white biomicritic limestones variable in bed thickness. Radiolaria–*Globochaete*–calpionellids, radiolarian–calpionellid–*Globochaete*, *Globochaete–Calpionella* and calpionellid–*Globochaete*–nannofossil microfacies were identified. The composition of abundant bioclasts in micrite matrix varies between wackestone to packstone. The rock contains numerous calpionellids, foraminifera, *Involutina* sp. *Lenticulina* sp., benthic and planktonic crinoid segments (*Saccocoma* sp.), echinoids, ophiuroids, bivalves, juvenile ammonites, aptychi, ostracods, sponge spicules, problematicum *Didemnoides moreti* and *Didemnum carpaticum.* Saccocomids disappeared; crassicollarian loricas are currently deformed.

Some layers contain laminae rich in bioclasts and extraclasts derived from the Crassicollaria Zone. Small bioclasts are sometimes affected by silicification, or phosphatized; some radiolarian tests are impregnated by pyrite. Local silty quartz grains (quartz and muscovite in samples 340 to 359) and scattered (also framboidal) pyrite occur in the matrix. Layers affected by synsedimentary slumps and containing sedimentary breccia were observed between 300–325, and 347–346.

Crassicollaria Zone, Remanei Subzone (sample 293) – radiolarian wackestone with very seldom sections of microgranular chtitinoidellids contains *Tintinopsella remanei*, *Calpionella alpina, Crassicollaria intermedia,* and cysts of *Colomisphaera carpathica*: Late Tithonian.

Crassicollaria Zone, Intermedia Subzone (294 to 294.6) – *Calpionella–Globochaete* wackestones to packstones with *Crassicollaria intermedia*, *Crass. parvula*, *Crass. massutiniana*, *Calpionella alpina*, *Calp. grandalpina*, *Calp. elliptalpina*, *Tintinnopsella carpathica,* and cysts of *Colomisphaera lapidosa, Colom. carpathica*, *Stomiosphaerina proxima*, *Cadosina semiradiata semiradiata,* and *Cadosina* sp.: Late Tithonian.

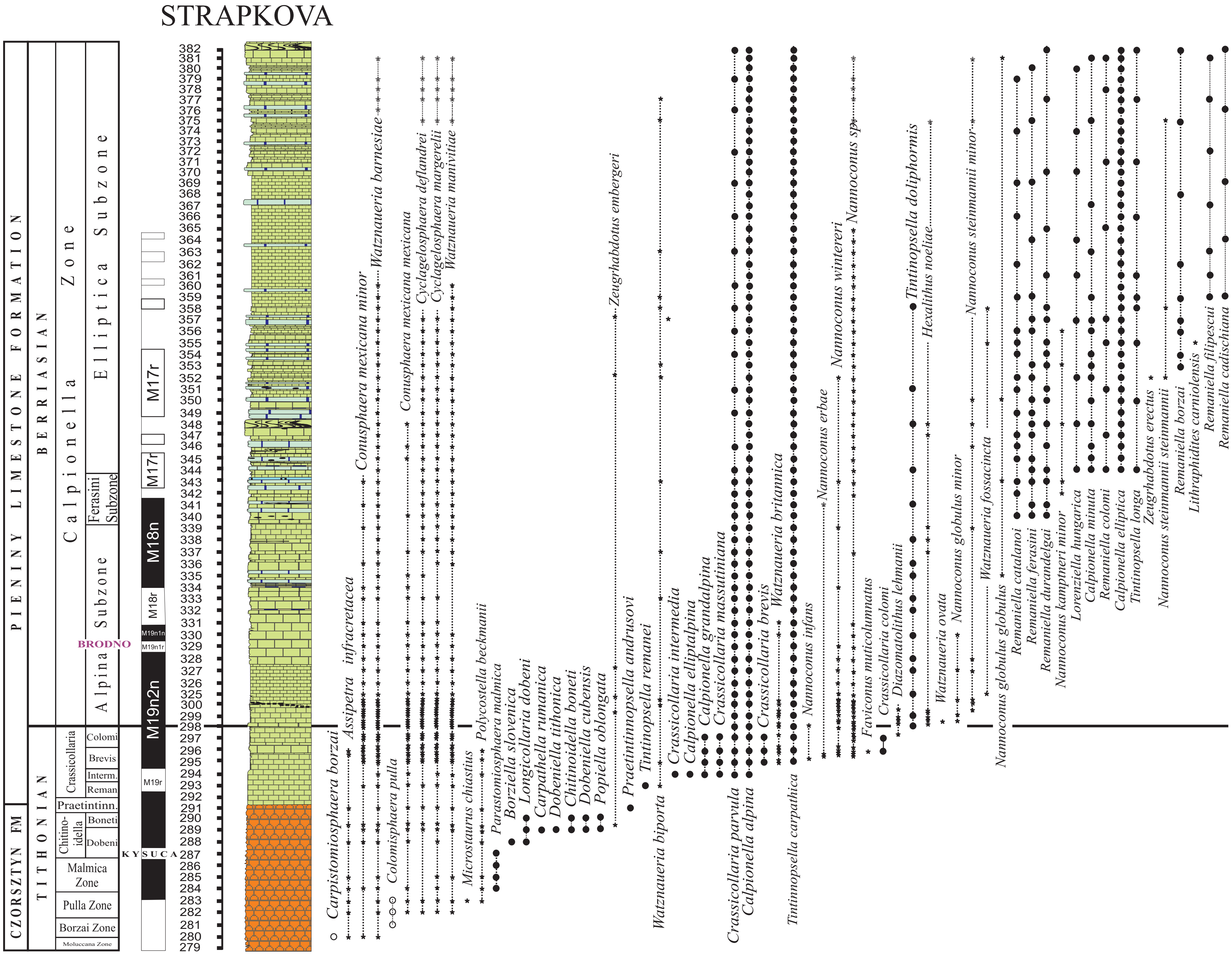

Fig. 31. Lithological log of the Strapkova J/K sequence studied, distribution of nannofossils, calpionellids, calcareous dinoflagellates, and calpionellid and cyst zonations.

Crassicollaria Zone, Brevis Subzone (294.7 to 296.2) – radiolarian–*Calpionella–Globochaete*, *Calpionella–Globochaete*, *Globochaete–Calpionella*, laminated and/or bioturbated wackestones contain *Crassicollaria brevis*, *Crassicollaria parvula*, *Calpionella alpina*; *Crassicollaria massutiniana*, *Calpionella grandalpina, Tintinnopsella carpathica*, cysts of *Colomisphaera lapidosa, Colomisphaera carpathica*, *Stomiosphaerina proxima*, *Cadosina semiradiata semiradiata* and *Cadosina semiradiata fusca* are less abundant if compared with the Intermedia Subzone: Late Tithonian.

Crassicollaria Zone, Colomi Subzone (296.3 to 297) – *Crassicollaria colomi* FO was identified in slightly bioturbated biomicrite with Calpionella–*Globochaete*, radiolarian–*Calpionella*, radiolarian–*Calpionella–Globochaete* and radiolarian microfacies. *Crassicollaria parvula* dominates over *Crass. colomi*, *Crass. brevis*, *Crass. massutiniana,* and *Calpionella alpina*, which prevails over *Calpionella grandalpina* and *Tintinnopsella carpathica*. *Colomisphaera lapidosa, Colom. carpathica*, *Stomiosphaerina proxima*, *Cadosina semiradiata semiradiata*, *Cados. semiradiata fusca* cysts were also identified: Late Tithonian.

Calpionella Zone, Alpina Subzone (298–339) – biomicrite wackestone composed of radiolarian, radiolarian–calpionellid and calpionellid microfacies. The sample 298 shows transition from the microfacies rich in *Crassicollaria parvula* to microfacies in which sphaerical forms of *Calpionella alpina* dominate indicating the J/K boundary interval according to Remane´s et al. (1986) definition. Four crassicollarian abundance events influenced by synsedimentary erosion were documented (298.1–298.4). Since the sample 298.6, *Calpionella–Globochaete* wackestones prevail, radiolarians are abundant (in 299, 332 and 338). Dominating *Calpionella alpina* with rare *Crassicollaria parvula* and *Tintinnopsella carpathica* with *Tint. doliphormis* create a typical Alpina Subzone calpionellid association. Calpionellids are accompanied by rare to seldom cysts of *Colomisphaera carpathica*, *Col. cieszynica*, *Col. lapidosa*, *Col.* cf. *fortis*, *Col.* sp., *Stomiosphaerina proxima* and *Cadosina semiradiata semiradiata,* microproblematica of *Gemeridella minuta* and *Didemnum carpaticum:* Early Berriasian.

Calpionella Zone, Ferasini Subzone (340–343) – biomicrites, localy slightly bioturbated with calpionellid–*Globochaete*, calpionellid–*Globochaete*–radiolarian and radiolarian wackestones. In calpionellid association *Calpionella alpina* dominated over not frequent *Remaniella ferasini, R. catalanoi, R. durandelgai, R. borzai, Tintinopsella carpathica, Crassicollaria parvula*. Dinoflagellate cyst association consists of *Colomisphaera lapidosa*, *Col. carpathica, Stomiosphaerina proxima, Cadosina semiradiata fusca* and *Cad. semiradiata semiradiata*: Early Berriasian.

Calpionella Zone, Elliptica Subzone (344–359) – biomicrites, localy bioturbated wackestones with radiolarian–*Calpionella–Globochaete* and *Calpionella–Globochaete* microfacies contain *Calpionella alpina, Calp. elliptica, Calp. minuta, Tintinopsella carpathica*, *Tint. longa*, *Lorenziella hungarica*, *Remaniella catalanoi, Rem. ferasini, Rem. durandelgai*, *Rem. borzai, Rem. colomi*, *Rem. filipescui*, *Rem. cadischiana*. Cysts are represented by *Colomisphaera lapidosa*, *Colom. carpathica, Cadosina semiradiata semiradiata* and *Cad. semiradiata fusca:* late Early Berriasian.

Calcareous nannofossils and nannofossil zonation

In the samples studied, calcareous nannofossils are rather rare and their preservation ranges from moderate (only in a few samples) to extremely poor, heavily etched by dissolution. In total, 29 calcareous nannofossils taxa were indentified. A comparable diversity has been observed in the Barlya section (Lakova et al. 1999) and in the Nutzhof (Reháková et al. 2009). A slightly lower diversity has been reported in the Brodno (Michalík et al. 2009) and the Hrušové sections Ondrejíčková et al. 1993), conversely higher diversity and abundance also have been observed e.g. in the Puerto Escaño (Svobodová & Košťák 2016) or Torre de Busi and Foza sections (Casellato 2010). Successive distribution of nannofossils along the lithological column is shown in the Fig. 31. *Watznaueria* (more than 55 %), *Cyclagelosphaera* (nearly 20 %), *Conusphaera* (14 %), and *Nannoconus* (7 %) are the most abundant components of the assemblage (Fig. 31). The occurrence of these most abundant genera is in accordance with previous studies of calcareous nannofossils of the JKB interval (e.g. Michalík et al. 2009; Reháková et al. 2009; Lukeneder et al. 2010; Wimbledon et al. 2013). Nannoliths represented by *Polycostella beckmannii*, *Hexalithus noeliae* and *Assipetra infracretacea* are less present. The species indicative of eutrophic environments such as *Zeugrhabdotus erectus* and *Diazomatholithus lehmannii* occur only sporadically. Despite the poor preservation, several biostratigraphically important species have been recorded: *Nannoconus wintereri*, *N. steinmannii minor*, *N. kamptneri minor*, *N. steinmannii steinmannii*.

The abundance of calcareous nannofossils in the sequence is generally low. On average throughout the section, about 50 specimens per sample were observed (one specimen per six fields of view of the microscope). Due to the low abundance and prevailing bad preservation of calcareous nannofossils, only several biostratigraphic events have been defined. The first occurence (FO) of *N. wintereri* was recorded in the bed 298.1, close to the expected JKB interval based on calpionellids (this study, see above). This bioevent represents the base of the NJT 17b Subzone, which Casellato (2010) considered to cover the JKB interval. The FO of *N. steinmannii minor* was recorded in bed 300.0 in middle part of the M19n magnetozone. Casellato (2010) indicates it as the base of the NKT Zone. *N. kamptneri minor* occurs sporadically from bed 343 upwards. The FO of *N. steinmannii steinmannii*, i.e. the base of the NK-1 Zone (*sensu* Bralower et al., 1989) was recorded in bed 352, in lower part of the Elliptica Subzone. *N. kamptneri kamptneri* was not found in the samples studied.

Nannofossil distribution documents Tithonian NJT 17b Subzone to Early Berriasian NKT and NK-1 nannofossil zones (*sensu* Casellato 2010 and Bralower et al. 1989).

Carbonate and C_{org} contents

The $CaCO_3$ content in the uppermost part of the Czorsztyn Fm is relatively high. In basal part of the Pieniny Fm (from the beds 291 to 300) it decreases below 80 % (Fig. 32). The decrease is in accordance with microfossil analysis which pointed to raised silica bioproduction. The $CaCO_3$ content reaches up to 90 % in the Pieniny Fm again (325–360), where nannoconid and calcareous microplankton remnants became abundant (Tremolada et al. 2006; Michalík et al. 2009; Grabowski et al. 2013).

However, locally (the bed 334), the $CaCO_3$ content decreased below 50 %. Microfacies study have suggested that the main source of silica in the whole sequence came from radiolarians and only a very low amount came from detrital minerals (quartz, clays, accessories). Silica (opal–chalcedony) of radiolarian tests has been dissolved, replaced by calcite and concentrated in cherts.

TOC content is low (0.08–0.31 %) in all samples. The C_{org} contents slightly increased (more than 0.1 %) in the top

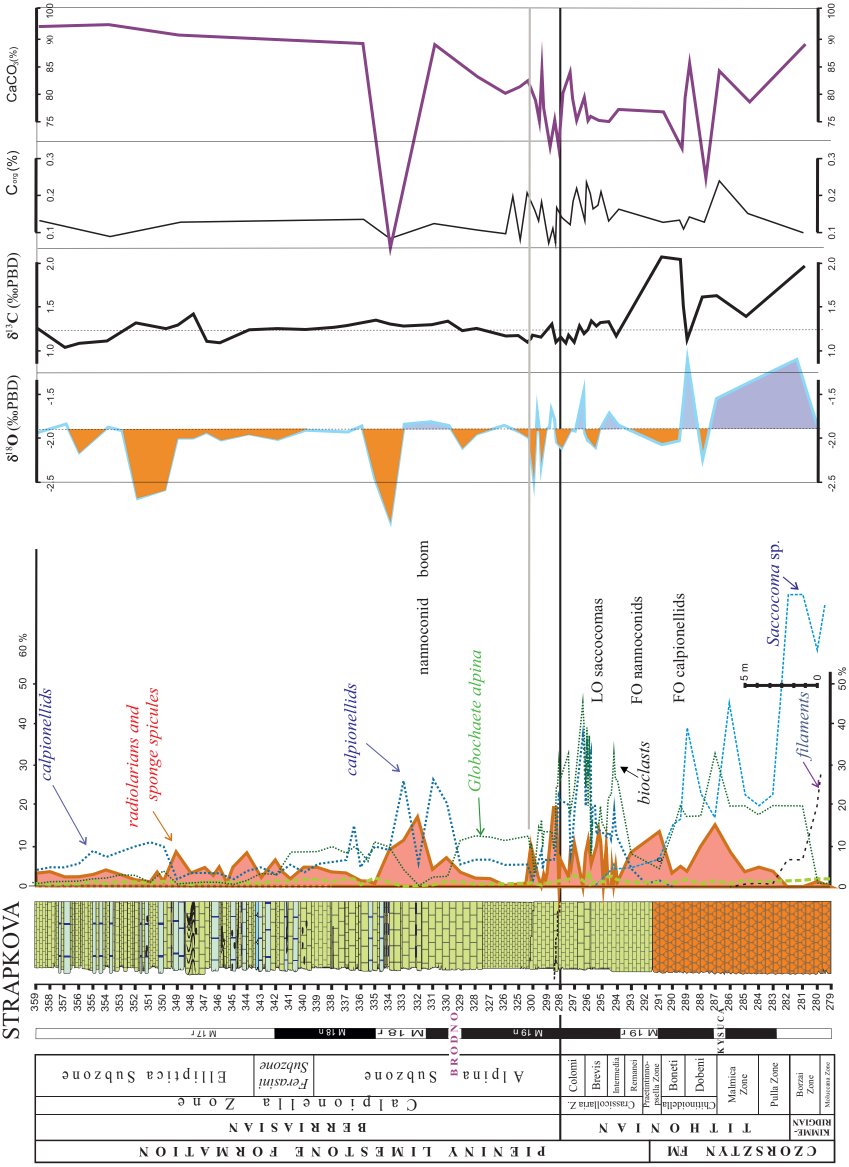

Fig. 32. Correlation of lithostratigraphy, quantitative representation of allochems in microfacies, and chemostratigraphy of the Strapkova section sequence.

of the Czorsztyn Fm and at the base of the Pieniny Fm, where $CaCO_3$ content decreased. Similarly, in beds 350 and 353, slight TOC accumulation could resulted from selective sorption of (dissolved) C_{org} by fine grains with more active surface, but probable also from raised fossil production.

Stable carbon and oxygen isotopes

Both C and O isotopes of bull rock samples change in relative narrow intervals ($\delta^{13}C$ in range of +1.09 to +1.96 ‰ VPDB, $\delta^{18}O$ −2.93 to −1.20 ‰ VPDB) in the section studied.

Late Tithonian $\delta^{13}C$ data (+1.96 to +1.46 ‰ VPDB) are aranged in slightly decreasing trend (Fig.32). Next, higher up section (beds 188–300) values achieving range +1.14 to +1.38 ‰ (in average +1.24 ‰ VPDB) show a new (balanced) isotope C composition of marine water during sedimentation of the Pieniny Fm. High resolution carbon isotope record resembles typical (stable or smooth) trend worldwide documented in the J/K boundary sequence (Weissert & Mohr 1986; Weissert & Channel 1989; Weissert & Lini 1991; Gröcke et al. 2003; Tremolada et al. 2006). The same $\delta^{13}C$ values between 1.3 and 1.5 ‰ (VPDB) have been presented in the Brodno (+1.3 to +1.6 ‰), Hlboča (+1.0 to +1.5 ‰), or Strážovce (+1.0 to +1.3 ‰) sections (Michalík et al. 1995, 2009). At the Nutzhof section (Lukeneder et al. 2010) which is located in an equivalent position on the north Tethyan margin, bulk carbon isotope values lie between +0.49 and +2.10 ‰.

The span of $\delta^{18}O$ data is not larger than 2 ‰ following slight but continual negative trend since Late Titonian to Early Berriasian. Typically, $\delta^{18}O$ data "peak" more between individual beds and could be diagenetically shifted more than $\delta^{13}C$. In the basal part of the Pieniny Fm (beds 292–300.6) $\delta^{18}O$ data shifted from −1.48 to −2.48 ‰. $\delta^{18}O$ values in higher part of the section (325–360) reach −1.84 to −2.93 ‰. Take to account all data presented above, we assume that $\delta^{18}O$ followed relative differences in water temperature during sedimentation.

Magnetic susceptibility

Moderately good correlation of MS with IRM (Grabowski in Michalík et al. 2016) indicates a significant contribution of ferromagnetic minerals to the MS. Although a long term decrease of the IRM_{1T} is observed as in the case of the MS, both curves are not identical which indicates that contribution of paramagnetic minerals to MS cannot be neglected.

Magnetic susceptibility reveals a long term decreasing trend. Its values are relatively high in lower half of the section, between 8–16×10^{-9} m^3/kg in the Tithonian and lowermost Berriasian (the Alpina Subzone, up to sample 338). Large MS variations are also observed in that part of the section. The MS decreases by 50 % throughout the Tithonian, up to the JKB. Then it fluctuates between 4 and 10×10^{-9} m^3/kg in the lower part of the Alpina Subzone, in M19n and M18r magnetozones. Significant increase up to 12×10^{-9} m^3/kg is observed in upper part of the Alpina Subzone, in the bottom part of the M18n magnetozone. Then MS again decreases throughout the M18n magnetozone to 4×10^{-9} m^3/kg. Within the Ferasini and Elliptica Subzones, MS values gently fall from 4 to 3×10^{-9} m^3/kg, with only two minor positive excursions in the M17r magnetozone.

Rock magnetism and demagnetization

Samples were moderately to weakly magnetic with NRM intensities in the lower part of the section (up to sample 335 including Tithonian and lower part of the Berriasian) mostly between 1 and 5×10^{-4} A/m. Sample 296.5 revealed the highest NRM intensity around 9.5×10^{-4} A/m. Higher up, in the upper part of the Lower Berriasian, the NRM values fluctuated around 1×10^{-4} A/m.

Low coercivity minerals dominate within the section which is manifested by negative values of S-ratio, mostly between −0.9 and −0.7. Three samples (ST 333, 337.5 and 356.5) reveal slightly higher values of S-ratio: between −0.5 and −0.3. A single sample ST 296.5 reveals extremely high value of S-ratio: 0.54. The sample 296.5 contains also unusually large amount of ferromagnetic minerals which is manifested by very high intensity of the IRM_{1T}. The sample 296.5 might be distinguished also by relatively high unblocking temperatures (up to 620 °C) and slightly different direction of C component (see below). Results of Lowrie's (1990) analyses confirm that medium and high coercivity minerals dominate in this sample. The maximum unblocking temperature of 640 °C unambiguously indicates to presence of hematite. Samples with moderately negative values of S-ratio (between −0.3 and −0.7) reveal presence of magnetite which is a dominant magnetic carrier. Its presence is documented by maximum unblocking temperature of 520–560 °C in the 0.1T curve. However, the contribution of hematite is still significant as can be seen on the 1T curve. Samples with low negative values of S-ratio contain almost exclusively magnetite. From the vertical log of S-ratio (Grabowski in Michalík et al. 2016) it follows, that the contribution of hematite is slightly more distinct in the lower half of the section.

During thermal demagnetization, three characteristic NRM components were revealed. The least stable A component is unblocked between 20 and 150–200 °C. An intermediate B component is demagnetized in the temperature range 200–420 °C. Finally, a double polarity C component might be identified between 420 and 480–520 °C. Unfortunately, abrupt MS rise is observed during thermal treatment between 400 and 450 °C and sometimes the C component cannot be demagnetized to the origin.

Age of magnetization components and paleotectonic implications

The **A component**_clusters match better in the present day coordinates. Its direction in geographic coordinates is close to the present day normal polarity geomagnetic field direction in the area of investigation. Therefore, it is interpreted as recent viscous remanent magnetization of no geological importance. The mixed polarity **C component** is interpreted as the primary one. After bedding correction, the normal (Cn) and reversed (Cr) directions cluster in the NW and SE quadrant, respectively, of stereonet with moderate inclination. Its primary nature is also supported by the fact that polarity changes of the C component correlate well with the Global Polarity Time Scale (see below). The clustering of the C component does not improve after tectonic correction as might be expected in the case of primary component. The McFadden & McElhinny's (1990) reversal test gives negative results (critical angle 14.5°, $\gamma_c = 30.6°$). It might be explained either by contamination of the intermediate B component or incomplete demagnetization of the samples containing hematite. The **B component** must be regarded as secondary magnetization, as it always reveals a normal polarity. Significant spread of both B and C components might result from overlapping of unblocking temperature spectra and from incomplete demagnetization of hematite. Position of the B component is usually close to Cn primary component. Therefore, the B component most probably represents pre-folding or early synfolding remagnetization of normal polarity. It might be acquired during the maximum burial or early phase of Late Cretaceous folding and thrusting, alike abundant secondary magnetizations documented in the Central Western Carpathians (Grabowski 2005; Grabowski et al. 2009).

In the pre-folding coordinates, the declination of C component reveals a moderate 46° counter-clockwise (CCW) rotation from the present-day north. However, clustering of the C component is too weak for significant paleotectonic application (the value of precision parameter k >10 is required; see Van der Voo 1993). Having applied some selection (rejecting specimens deviating from the main cluster), the amount of the CCW rotation slightly decreases to 35°. Clustering of the C component (both normal and reversed populations) improves after tectonic correction, although the precision parameter k is still slightly below 10 and the reversal test is still negative. Declination of the C component is concordant with the general CCW of the study area. A counter-clockwise rotation of 47° (±18°) was reported (Márton et al. 2013) from the Upper Cretaceous pelagic marls in the PKB in the neighboring locality of Vršatec.

Paleoinclination of the Strapkova section (41°), corresponding to paleolatitude 24°N ±5° is slightly shallower than Tithonian – Berriasian paleoinclinations from the PKB and Central Carpathian reference sections (Márton et al. 2015) which results from incomplete cleaning of the primary C component.

Magnetostratigraphy and correlation with the Global Polarity Time Scale (GPTS)

According to the polarity of the C component, four normal (N1–N4) and four reversed polarity intervals (R1–R4) were documented. Samples 292 and 292.5 revealed normal polarity of C component (N1 interval). The subsequent four samples between 293 and 294.5 were of reversed polarity (R1 interval). The long normal polarity (N2) interval was indicated between 295 and 328.5. It is followed by quick polarity changes manifested by R2 (329 and 329.5) and N3 (330) intervals. The sample 330.5 was of undefined polarity. Three distinct polarity intervals were distinguished in upper part of the section: reversed R3 interval (samples 331.5–334), normal N4 interval (334.5–341.5) and reversed R4 (343–363.9) interval.

The N1 interval is interpreted as the topmost part of the M20n magnetozone (between Tithonian Praetintinopsella Zone and the bottom of the Remanei Subzone). R1 interval is correlated with the M19r magnetozone. It covers the Remanei and Intermedia subzones. Long normal N2 interval must be interpreted as the M19n2n. The boundary between Crassicollaria and Calpionella zones is usually situated within this magnetozone (for review, see Ogg et al. 1991; Grabowski 2011; Satolli et al.

2015). Short R2 and N3 intervals, in lower part of the Alpina Subzone, are respectively correlated with the M19n1r (“Brodno”) and M19n1n magnetosubzones. R3 interval is interpreted as the M18r magnetozone. This magnetozone is situated entirely within the Alpina Subzone (Houša et al. 2004; Grabowski & Pszczółkowski 2006; Pruner et al. 2010). Next normal N4 interval is paralleled with the M18n. The boundary between the Alpina and Ferasini subzones falls in upper part of this magnetozone. It is concordant with the FAD of *Remaniella ferasini* which is observed usually in the M18n magnetozone (Ogg et al. 1991; Houša et al. 2004). A long reversed R4 interval in upper part of the section is interpreted as the M17r. It starts in middle part of the Ferasini Subzone and continues into the Elliptica Subzone. It is concordant with abundant data from Italian sections (Ogg et al. 1991) and from the Pośrednie sections (Grabowski & Pszczółkowski 2006), where the FO of *Calpionella elliptica* is observed also in the M17r magnetozone. The FO of *Remaniella cadischiana* is noted in the bed 359. As this taxon appears usually in upper part of the M17r (Grabowski & Pszczółkowski 2006; Grabowski et al. 2010a,b), it seems that the top of the section is quite to the M17r/M17n magnetozones boundary.

Paleoenvironment and sequential architecture

Wackestones and packstones of the Pieniny Limestone Formation are formed mostly of tests of planktonic microorganisms, while mudstone micrites and biomicrites are composed of nannoplankton remnants and unidentified calcite test fragments. Although differences in both the rock composition and granulometry of the “biancone” facies are not expressive, eight 7–16 m thick cycles are recognizable in the sequence studied. Each of them starts with packstone beds containing infrequent remnants of benthic organisms, abundant (sometimes redeposited) tests of calpionellids, occasional small (eolian) grains of quartz and mica leaflets. These beds are comparable with lowstand part of the cycle. Upwards, the following part is typified by increased content of calcareous dinocysts and calpionellid tests. The highest part is richer in chert and frequently includes laminar concentrations of (mostly calcified) radiolarian tests. These cycles respond to eustatic cycles Ti3–Ti6 and Be1–Be4 (Haq 2014).

Generally, the distribution of calpionellids shows several abundance peaks. The first one is in the Late Tithonian, the second one – in upper part of the Alpina Subzone, and third one – below the onset of the Ferasini Subzone. Calpionellid and radiolarian abundance curves alternate in discrete peaks: each decrease of calcareous plankton is associated with an increase of remnants of silica-secreting organisms (Reháková & Michalík 1994; Michalík et al. 2009, 2016).

Radiolarians occur in fine silicified laminae in samples 315.15; 333; 339, 351.1; 381.9; 385.8; 388.25; 388.6; 393.2; 394.3; 395.15 interpreted as contourites (Schlögl et al. 2000). Their presence represent a special feature of the Strapkova sequence. The abundance of radiolarian tests is the highest in each fifth lamina 1.9 to 2.2 mm thick with slightly erosive base. Similar limestone layers with radiolarian laminae occur in the Brodno section (bed C 42; Michalík et al. 2009), or in the Rochovica section (in the latter case, they occur in much younger, Valanginian to Aptian strata; Michalík et al. 2008).

The layer below the radiolarian laminite is bioturbated (Michalík et al. 2016). Traces of *Chondrites*, *Palaeophycus*, *Planolites*, *Thalassinoides*, and *Trichichnus* have been identified in cross-section perpendicular to the bedding plane. Primary sedimentary features (cross-bedding stratification, lamination) were mostly destroyed by bioturbation. The largest burrows (*Thalassinoides*) are on average 5–9 mm in diameters, *Planolites* and *Palaeophycus* burrows attain diameter of 2 to 3 mm. *Planolites* and *Thalassinoides* burrows are penetrated by *Chondrites* (with diameter of 0.4 to 0.6 mm). Simple vertical pyritized burrows of *Trichichnus* are of 0.2 mm diameter. Framboidal pyrite clusters accumulated in places with bioturbation structures. Size of burrows, different ethological character (domichnia, fodinichnia, chemichnia) and trophic levels of these traces indicate that the bottom has been well supported with nutrients and oxygen and inhabited by burrowers at different depth.

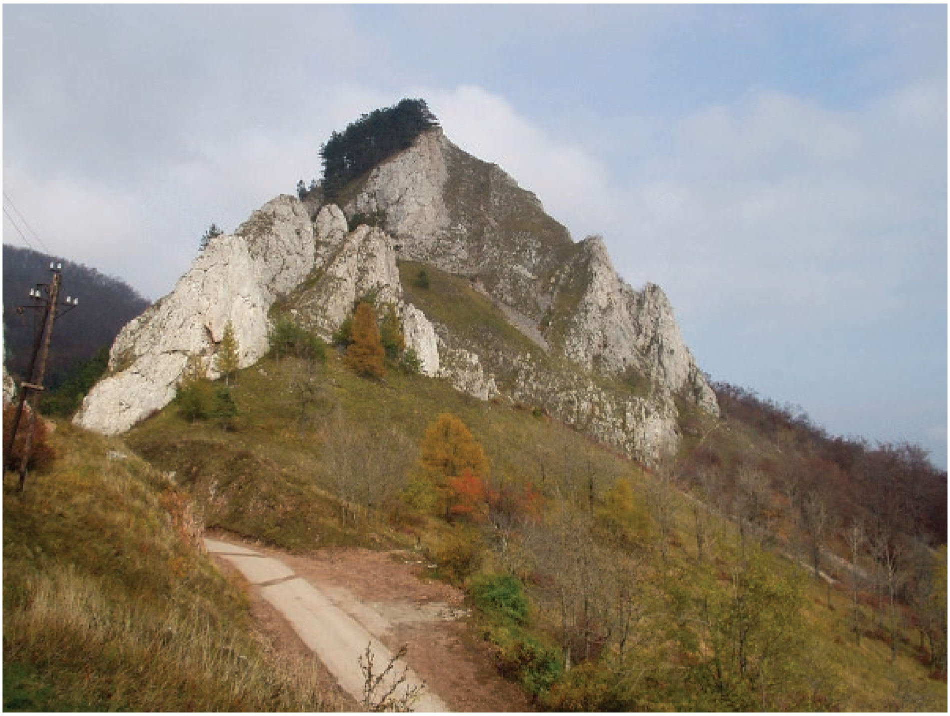

Fig. 33. Morphology of the Pieniny Klippen Belt: Mt Duchny above Vršatské Podhradie village.

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Appendix: List of microfossils

Calpionellids

Borziella slovenica (Borza, 1969)
Calpionella alpina Lorenz,1902
Calpionella elliptalpina Nagy, 1986
Calpionella elliptica Cadisch 1932
Calpionella grandalpina Nagy, 1986
Calpionella minuta Houša,1990
Carpathella rumanica Pop, 1998
Crassicollaria brevis Remane, 1962
Crassicollaria colomi Doben, 1963
Crassicollaria intermedia (Durand-Delga, 1957)
Crassicollaria massutiniana (Colom, 1948)
Crassicollaria parvula Remane, 1962
Daciella danubica Pop, 1998
Dobeniella bermudezi (Furrazola –Bermudez 1965)
Dobeniella cubensis (Furrazola –Bermudez 1965)
Dobeniella tithonica (Borza, 1969)
Chitinoidella boneti Doben, 1963
Chitinoidella elongata Pop 1997
Chitinoidella hegarati Sallouhi, Boughdiri and Cordey, 2011
Chitinoidella popi Sallouhi, Boughdiri and Cordey, 2011
Chitinoidella cartagensis Sallouhi, Boughdiri and Cordey, 2011
Longicollaria dobeni (Borza, 1966)
Longicollaria insueta (Řehánek,1986)
Lorenziella hungarica Knauer and Nagy, 1964
Lorenziella plicata Remane, 1968
Popiella oblongata Reháková, 2000
Praetintinnopsella andrusovi Borza, 1969
Remaniella catalanoi Pop, 1996
Remaniella colomi Pop, 1996
Remaniella cadischiana (Colom, 1948)
Remaniella filipescui Pop, 1994
Remaniella duranddelgai Pop,1996
Remaniella borzai Pop, 1994
Remaniella ferasini (Catalano, 1965)
Tintinnopsella carpathica (Murgeanu and Filipescu, 1933)
Tintinnopsella doliphormis (Colom, 1939)
Tintinnopsella remanei Borza, 1969
Tintinnopsella longa (Colom, 1939)

Calcareous dinoglagellates

Carpistomiosphaera borzai (Nagy, 1966)
Carpistomiosphaera tithonica Nowak, 1968
Colomisphaera cieszynica Nowak, 1968
Colomisphaera fibrata (Nagy, 1966)
Colomisphaera nagyi (Nagy, 1966)
Colomisphaera pieniniensis (Borza, 1969)
Colomisphaera pulla (Borza, 1964)
Colomisphaera radiata (Vogler, 1941)
Colomisphaera tenuis (Nagy, 1966)
Colomisphaera fortis Řehánek, 1992
Colomisphaera lapidosa (Colom, 1935)
Colomisphaera carpathica (Borza, 1964)
Parastomiosphaera malmica (Borza, 1964)
Schizosphaerella punctata Deflandre & Dangeard 1938
Stomiosphaera moluccana Wanner, 1940
Stomiosphaerina proxima Řehánek, 1987
Cadosina semiradiata fusca (Wanner,1940)
Cadosina semiradiata semiradiata (Wanner,1940)

Another microfossils

Gemeridella minuta Borza et Mišík 1975
Didemnoides moreti (Durand-Delga 1957)
Didemnum carpaticum Borza et Mišík 1975
Globochaeta alpina Lombard 1945

Calcareous nannofossils

Assipetra infracretacea (Thierstein, 1973) Roth, 1973
Conusphaera mexicana (Trejo, 1969) subsp. *mexicana* Bralower in Bralower et al. 1989
Conusphaera mexicana (Trejo, 1969) subsp. *minor* (Bown et Cooper, 1989), Bralower in Bralower et al. 1989
Cyclagelosphaera deflandrei (Manivit, 1966) Roth, 1973
Cyclagelosphaera margerelii Noël, 1965
Cruciellipsis cuvillieri (Manivit, 1966) Thierstein, 1973

Diazomatolithus lehmanii Noël, 1965
Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Faviconus multicolumnatus Bralower in Bralower et al. 1989
Hexalithus noeliae (Noël, 1956) Loeblich et Tappan, 1966
Lithraphidites carniolensis Deflandre, 1963
Microstaurus chiastius (Worsley, 1971) Bralower et al., 1989
Nannoconus sp. Kamptner, 1931
Nanoconus erbae Casellato, 2010
Nannoconus globulus (Brönnimann, 1955) subsp. *globulus* Bralower in Bralower et al. 1989
Nannoconus globulus (Brönnimann, 1955) subsp. *minor* Bralower in Bralower et al. 1989
Nannoconus infans Bralower in Bralower et al. 1989
Nannoconus kamptneri (Brönnimann, 1955) subsp. *minor* Bralower in Bralower et al. 1989
Nannoconus kamptneri subsp. *kamptneri* Brönnimann, 1955
Nannoconus steinmannii (Kamptner, 1931) subsp. *minor* Deres et Achéritéguy, 1980
Nannoconus steinmannii (Kamptner, 1931) subsp. *steinmannii* Deres et Achéritéguy, 1980
Nannoconus wintereri Bralower et Thierstein in Bralower et al. 1989
Polycostella beckmannii Thierstein, 1971
Retacapsa sp. Black, 1971
Watznaueria barnesiae (Black in Black et Barnes, 1959) Perch-Nielsen, 1968
Watznaueria biporta Bukry, 1969
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964
Watznaureia fossacincta (Black, 1971a) Bown in Bown et Cooper 1989
Watznaueria manivitiae (Bukry, 1973) Moshkovitz et Ehrlich, 1987
Watznaueria ovata Bukry, 1969
Zeugrhabdotus embergeri (Noël, 1958) Perch-Nielsen, 1984
Zeugrhabdotus erectus (Deflandre in Deflandre et Fert, 1954) Reinhardt, 1965

Radiolarians

Angulobracchia heteroporata Steiger, 1992
Angulobracchia? *portmanni* Baumgartner, 1984
Angulobracchia mediopulvilla Steiger
Arcanicapsa sp.Takemura, 1986
Archaeodictyomitra apiarium (Rüst, 1885)
Archaeospongoprunum patricki Jud, 1994
Cinguloturris cylindra Kemkin and Rudenko, 1993
Cinguloturris sp. Dumitrica and Mello, 1982
Crococapsa accincta (Steiger)
Crococapsa pseudouterculus (Aita)
Cryptamphorella dumitricai Schaaf, 1981
Deviatus diamphidius (Foreman, 1973)
Dicerosaturnalis trizonalis (Rüst)
Dicerosaturnalis gratiosus Dumitrica and Hungerbühler
Doliocapsa doliolum (Aita)
Emiluvia chica Foreman, 1973
Eucyrtidiellum pyramis (Aita, 1986)
Halesium palmatum Dumitrica
Hemicryptocapsa capita Tan, 1927
Hemicryptocapsa carpathica (Dumitrica)
Hiscocapsa cf. *kaminogoensis* (Aita)
Hiscocapsa? aff. *altiforamina* (Tumanda)
Hsuum raricostatum Jud
Mirifusus dianae (Karrer, 1867)
Neorelumbra cf. *buwaydahensis* Kiessling, 1995
Neorelumbra cf. *tippitae* Kiessling, 1995
Obesacapsula cetia (Foreman, 1973)
Obesacapsula verbana (Parona, 1890)
Obesacapsula cf. *verbana* (Parona, 1890)
Obesacapsula rusconensis Baumgartner, 1984
Obesacapsula cf. *rusconensis* Baumgartner, 1984
Pantanellium squinaboli (Tan, 1927)
Pantanellium berriasianum Baumgartner, 1984
Parapodocapsa amphitreptera (Foreman)
Parapodocapsa furcata Steiger, 1992
Praeparvicingula spp. Pessagno, Blome and Hull, 1993
Praeparvicingula cosmoconica (Foreman)
Protunuma cf. *japonicus* Matsuoka and

Yao, 1985
Pseudocrucella? *elisabethae* (Rüst)
Pseudoeucyrtis? *fusus* Jud
Pseudodictyomitra carpatica (Lozyniak, 1969)
Pseudodictyomitra spp. Pessagno, 1977
Pseudoxitus gifuensis (Mizutani)
Spinosicapsa aff. *coronata* Steiger
Spinosicapsa milloti (Schaaf)
Spinosicapsa triacantha (Fischli)
Spinosicapsa spp. Ožvoldová, 1975
Svinitzium cf. *depressum* (Baumgartner)
Tethysetta boesii (Parona, 1890)
Thanarla patricki (Kocher)
Triactoma kellumi Pessagno and Yang, 1989
Tritrabs ewingi (Pessagno, 1977)

Trace fossils
Chondrites
Palaeophycus
Planolites
Thalassinoides
Trichichnus
Thalassinoides

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CONFERENCE ABSTRACTS

Floristical changes in the Jurassic depositional successions, borehole Cianowice 2, southern Poland

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The borehole Cianowice 2 (located in the vicinity of the Krzeszowice Graben and Kraków–Lubliniec Fault Zone, about 20 km NW from Cracow) is one of the places where the existing Jurassic floral remains have not yet been investigated. Fragments of drill core containing plant remains come from the siliciclastic sedimentary rock interval between 265.5 and 244.5 m, containing 5 depositional successions representing different sedimentary environments (Pieńkowski 2014): up to 262.4 m occurs succession 1, representing alluvial fans with 3 cycles separated by erosional unconformities; succession 2 between 255.5 and 262.4 m, with 5 cycles representing meandering/anastomosing rivers with channel fill, floodplain, levee and crevasse splay deposits; succession 3 between 255.5–249 m, representing lacustrine and backswamp deposits; succession 4 between 249–245.1 m, representing meandering/anastomosing river system (channel fill/point bar-distributary channel, floodplain deposits); succession 5 between 245.1–244.0 m, representing channel fill deposits. The overlying part of Jurassic section (234.5–244.5 m) is represented by carbonate marine sediments, representing the Callovian transgression, followed by Oxfordian interbiohermal facies (Korzkiew Basin). These packages are dated by ammonite *Kosmoceras* ex gr. *pollux*, as the Middle Callovian (ammonite zone Coronatum and subzone Grossouvrei). The Jurassic marine sedimentation ended in early Kimmeridgian (Matyja & Ziółkowski 2014).

The stratigraphical position of the siliciclastic part of Cianowice 2 section is a subject of debate, as no leading fossils have been found before. The age was tentatively interpreted as ?Early Jurassic (Pieńkowski 2014), Middle Jurassic (Bathonian–Callovian, Matyja & Ziółkowski 2014) or both (Pieńkowski 2014).

Macro- and microfloral remains have been studied in purpose of reconstruction of the plant community from Cianowice and its paleoecology. Plant macroremains are preserved in 27 core samples from 14 levels, and 98 determinable small leaf fragments have been found, representing 20 taxa.

The most numerous and diverse are bennettitaleans, (10 species, and 51 plant fragments) and ginkgophytes (3 taxa and 19 fragments). Conifers (3 taxa and 14 fragments) and are less diverse, but frequent. Seed ferns, cycads and ferns are less common or sporadic.

The plant composition somewhat changes between the successions, being the most diverse in the succession 2 (flood plain). Some taxa are specific for only one depositional succession, some are present in two or three of them. The sporomorphs assemblage from 13 levels, belonging to the same successions as macrofloral remains, differ significantly in terms of parent plants. In all the successions, sporomorph spectra are dominated by fern-derived taxa, while in macrofloral assemblages ferns are very rare, represented just by 2 fragments.

The hypothetical environment is proposed as a hill slope falling into the river valley or lake. Since floral remains were evidently transported, they were most probably washed down along the slope and accumulated in the valley. Some pollen could be transported by the wind over longer distances.

The general taxa composition of macroflora is similar to the European Middle Jurassic floras. Among 20 plant species identified from Cianowice, eight species were up to now reported exclusively from the Middle Jurassic. Three species are known from the Early–Middle Jurassic, two species range from the Middle Jurassic to Early Cretaceous and one taxon ranges from the Upper Triassic to the Early Cretaceous. Only one species was reported as the Upper Triassic taxon and its occurrence in Cianowice extends the maximum age range from the Upper Triassic to the Middle Jurassic.

Also, some species are common between Cianowice and nearly situated Middle Jurassic localities in Grojec and Zabierzów, described by Reymanówna (1963). These finds suggest the Middle Jurassic age of Cianowice deposits.

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Kimmeridgian ammonite assemblage from Zengővárkony, Mecsek Mts, Tisza Megaunit, South Hungary

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Kimmeridgian strata and their ammonites of the Mecsek Mts are reported first by Böckh (1880) but remained unpublished; only faunal lists are announced (Vadász 1935, Főzy 1993). The Upper Jurassic at Zengővárkony (eastern Mecsek Mts.) is represented by continuous sedimentation from the Oxfordian till the Tithonian with the total thickness of 20 metres; however the Oxfordian and Kimmeridgian are thin, representing only 4 metres (Nagy 1963). New collection from the condensed (3 m thick) ammonitico rosso type reddish, nodular limestone sequence at the abandoned quarries of Zengővárkony, eastern Mecsek Mts, (South Hungary) provided a rich, but poorly preserved, fragmentary and transported ammonite fauna of 120 specimens, representing some ammonite zones of the Kimmeridgian. The fauna has a Mediterranean character, however Phyllo- and Lytoceratids represent less than 10 % of the total collected specimens. The fauna is dominated by the Taramelliceratidae and Aspidoceratidae (60 % of the total collected individuals), and some taxa are firstly reported from the Mecsek Mts. Beside the worn ammonite internal moulds some badly preserved aptychii and belemnite rostra occur. Preliminary faunal list: *Phylloceras consanguineum, Holcophylloceras polyolcum, Lytoceras sutile, Taramelliceras* sp., *Taramelliceras (Taramelliceras) costatum, T. (T.) pugile, T. (T.) trachynotum, Streblites* sp., *Aspidoceras acanthicum, A. binodum, A. caletanum, A. longispinum, A. uninodosum, Pseudowaagenia acanthomphala, Hybonoticeras pressulum, H.* sp. aff. *haynaldi, Physodoceras* sp. aff. *wolfi*, *Orthaspidoceras* sp. aff. *ziegleri, Nebrodites* sp., *Praesimoceras* sp, *?Mesosimoceras* sp. The only one collected *Aspidoceras caletanum* may refer to the faunal connection towards the ammonite faunas of the Submediterranean Province along the northern Tethyan margin.

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Berriasian fauna and ammonite biostratigraphy of the Leube quarry (Salzburg, Austria), Northern Calcareous Alps and its paleobiogeographical significance

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Berriasian ammonites from the Leube quarry (St. Leonhard near Salzburg, Austria, Northern Calcareous Alps) are first reported by Fugger (1907), however not much taxonomical work published on these ammonites. Bujtor et al. (2013) reported a rich but poorly preserved Late Berriasian ammonite fauna from the quarry, which indicates the Upper Berriasian Subthurmannia boissieri Zone. Bujtor et al. (2013) also reported a ?*Djurjuriceras* sp. indicating the Upper Tithonian but no ammonites reported yet from the 150 m thick interval in between. Field work in the quarry in September, 2018 provided some faunal elements (ammonites, aptychii, belemnites, brachiopods, and ichnofossils) from the Lower/Middle Berriasian strata of the Oberalm Formation, which is the first record of the Early–Middle Berriasian fossils from the quarry. Detailed description of the lithostratigraphy and formation is after Gawlick et al. (2009). These ammonites may refer to the Berriasella jacobi and/or Subthurmannia occitanica Zones. Preliminary faunal list: *Malbosiceras* sp. aff. *malbosi* (Pictet, 1867) FO in the upper part of Jacobi Zone; LO in lower part of Boissieri Zone. *Lytoceras* sp., *Punctaptychus* cf. *punctatus* (Voltz, 1837) FO in Upper Tithonian; LO in Middle Berriasian; and ?*Pseudobelus* sp. These fossils indicate the Lower–Middle Berriasian, and provide an evidence for the continuous sedimentation from the Upper Tithonian to the Upper Berriasian sequence of the Leube quarry and fits well into the biostratigraphical scheme reported before. Beside these nektonic elements a poorly preserved brachiopod is found. The *Pygope catulloi* (Pictet, 1867) is the first record from the quarry, however it is known from the NCA. Aptychii and *Pygope catulloi* are shelly specimens; however ammonites are internal moulds, which indicate that the water depth was below the ACL but above the CCL. Both ammonites and the brachiopod are crushed and/or flattened, which indicates fast sedimentation that did not let the the conchs to be filled up with sediments. A rich ichnofauna is also present with frequent and big sized *Zoophycos* sp. specimens occurred in the quarry walls. These faunal elements of the Early–Middle Berriasian reflect the Mediterranean character of the Northern Calcareous Alps and support the results of Bujtor et al. (2013) on the biogeographical affinities of Late Berriasian ammonite assemblage from the same locality.

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Early Jurassic radiolarians from Mount Rettenstein, Northern Calcareous Alps, Austria

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Mount Rettenstein is located at the southern rim of the Northern Calcareous Alps and belongs to the Upper Tirolic units. The mountain yields a complete stratigraphic succession of Lower to Upper Jurassic sediments (Rettenstein succession *sensu stricto*) that tectonically overlie the Middle Jurassic Hallstatt Mélange. The most complete section of the Rettenstein succession is exposed in the Weitenhausgraben cirque, on the southern slope of the mountain.

The Rettenstein succession (Fig. 1A) starts with an up to 100-m-thick grey marly limestone of Hettangian? to Pliensbachian age (Tollmann 1960). Tollmann (1960) assigned the grey marly limestone to an age from the Lias α–β at the base to the Lias γ at the top. However, the age assignment is based on fragmented ammonites, which were mostly collected from the scree and could usually not be identified with certainty. The grey marly limestone is overlain by condensed red marly limestone yielding a rich ammonite fauna of Early Pliensbachian to Early Toarcian age (Fig. 1B; Meister & Böhm 1993). Middle Jurassic red calcareous marls with *Bositra* and *Protoglobigerina* follow above a hiatus. These marls are erosionally truncated by the Rettenstein Debris Flow. Middle to Upper Jurassic Ruhpolding Radiolarite group follows above. The top of Mount Rettenstein is built of the several hundred meters thick Upper Jurassic Plassen Formation (Auer et al. 2009).

The grey marly limestone of the Rettenstein succession provided one of the best preserved Early Jurassic (Pliensbachian) radiolarian faunas known from the western Tethyan realm. Six samples from three localities on Mount Rettenstein have been studied for radiolarian taxonomy and biostratigraphy. Five samples were taken from two separate sections in the Weitenhausgraben cirque and one from the western flank of the mountain. In total, we identified 71 species, belonging to 45 genera; four species will be described as new. The oldest samples are assigned to the lowermost Pliensbachian *Canutus tipperi – Katroma clara* radiolarian Zone of Carter et al. (2010). The assemblages in the upper part of the sampled unit indicate an interval from the *Zartus mostleri – Pseudoristola megaglobosa* Zone to the *Eucyrtidiellum nagaiae–Praeparvicingula tlellensis* Zone that covers the rest of the Pliensbachian (Fig. 1B). Based on previous ammonite data, indicating that the lithological boundary with the overlying red marly limestone lies in the Ibex Ammonite Zone (Meister & Böhm 1993), we narrowed the age of the radiolarian samples to the early Early Pliensbachian (Fig. 1B).

In the Northern Calcareous Alps, comparable assemblages were found in the Dürrnberg Formation, which characterizes the open-marine Hallstatt facies zone but is known only from blocks in the Jurassic Hallstatt Mélange. Previously published radiolarian data are re-evaluated and the originally proposed age assignments revised. At two localities, the published Hettangian–Sinemurian age (Gawlick et al. 2001) is emended to the early Early Pliensbachian that is in accordance with the age of radiolarians from Mount Rettenstein. A rich radiolarian assemblage from another locality in the Dürrnberg Formation was previously assigned to the late Early Pliensbachian (O'Dogherty & Gawlick 2008; Carter et al. 2010) and is somewhat younger than the assemblages studied herein.

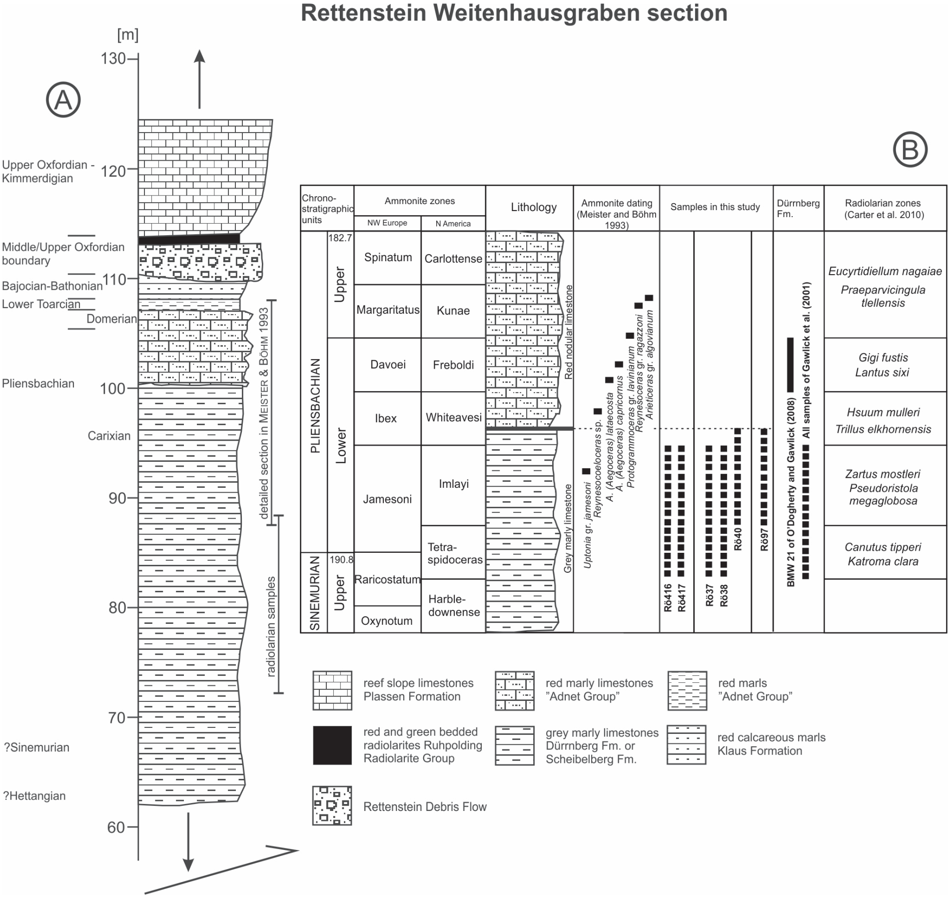

Fig. 1. A: Stratigraphy and lithology of the Mount Rettenstein succession *sensu stricto*. **B:** Combined radiolarian and ammonite dating of Lower Jurassic deposits on Mount Rettenstein. The upper age limit of the grey marly limestone is constrained with ammonites, determined in the overlying red nodular limestone. Radiolarian dating of samples from the Dürrnberg Formation is shown for comparison.

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The Pieniny Klippen Belt and Periklippen Zone in the Podbranč-Myjava segment: tectonic relation, microfacial differences and correlations

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This study is focused on the westernmost occurrence of the Pieniny Klippen Belt (PKB) and Periklippen Zone (PKZ) between village Podbranč and Myjava town. Near Podbranč, the PKB emerges from the substratum of the Neogene Vienna Basin and then spreads for some 600 km further eastward as a narrow, extremely complicated zone that separates the Cretaceous basement cover nappe stack of the External Western Carpathians. During detailed geological mapping we distinguished the Oravic units – Sub-Pieniny and Pieniny units. The last-mentioned unit occur along the northern PKB margin, where they are strongly affected by backthrusting and destral transpression. The wider southern area is built by a different nappe unit, which is correlated with the Drietoma Unit of probably Fatric affiliation – interpreted as a part of the PKZ.

The Pieniny Unit represent the Kysuca succession, laterally replaced by the Czertezic succession east and westwards. It includes Low. Jurassic spotty marlstones with filament microfacies (posidonia beds). They are overlapped by Mid. Jurassic siliceous limestones and radiolarites. The sequence and by maiolica-type cherty limestones passing to the Low. Cretaceous grey, marly and bioturbated limestones. The Czorsztyn succession include Mid. Jurassic sandy crinoidal limestones of enkrinite microfacies. Similarly, as the Niedzica succession, which include strongly deformed red crinoidal limestones what reflected the anastomosic stylolitic contact between the echinoderm’s fragments.

A fairly different unit is exposed in the south. It includes Upp. Triassic organodetritic limestones composed by huge portion of bivalves (*Rheativicula contorta*), lumachelas and aptychus. The Low. Jurassic strata include spotted silicified marlstones of the „Fleckenmergel“ facies and spotted marlstones with silicispongea microfacies. In places, these are intercalated by a several meters thick, boudinaged layer of reddish, allodapic organodetritic sandy limestones. The badly exposed and poorly defined Mid.-Upp. Jurassic sequence consists of relatively thin silicified limestones and marlstones, followed by well bedded, spotted mudstone with phantoms of calpionelids. Despite some differences, we correlate this unit with the Drietoma and/or Klape Unit of the PKZ. This interpretation is corroborated by the presence of probably Senonian Gosau-type conglomerates (Rašov Fm), which fill in synclinal structures in this unit, similarly as in the Klape and Drietoma units in the Middle Váh Valley.

Magnetic susceptibility and stable isotope ($\delta^{18}O$) record of shallower and deeper water Jurassic–Cretaceous paleoenvironments in the Outer Western Carpathians, Czech Republic

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Stable isotopes are frequently used as indicators of paleoenvironmental changes. Likewise, the magnetic susceptibility is often used as a paleoclimatic proxy. To describe paleoenvironmental setting and -changes as well as test possible cyclicity in the sedimentary record at different paleobathymetric conditions over Jurassic–Cretaceous transition within the NW margin of Tethysian realm, an extensive magnetic and stable isotope study was carried out in two Outer Flysch Carpathian localities from Czech Republic (Štramberk and Kurovice).

Štramberk A and B sections represent platform slope deposit – reef talus (Vaňková et al. submitted) and were deposited on the Baška–Inwałd Ridge at the northern margin of the Silesian Basin (Golonka 2011). Kurovice section was deposited in the Magura Basin and represents deeper water environment (slope below the aragonite CCD; Košťák et al. 2018 and references therein). Magnetic susceptibilities reveal only very minor variations in Štramberk sections. Low $\delta^{13}C_{carb}$ values, suggesting limited bioproductivity and reflecting primary global signal of the C-cycle in the Early Berriasian, as well as limited climatic oscillations in $\delta^{18}O$ were observed. Kurovice section displays larger fluctuations in magnetic susceptibilities. Significant climatic trends are recorded in the uppermost Jurassic–Lower Cretaceous of Kurovice based on the $\delta^{18}O$ data. A rapid warming shift is seen within the Jurassic terminal part – i.e. the Colomi Sbz. In the upper part of this zone, slightly below the J–K boundary, the opposite cooling trend started. It has a continual and long termed character up to the Elliptica Sbz. Correlation (Fig. 1) shows that magnetic susceptibility correlates mostly positively with the $\delta^{18}O$ trend within both localities. Since no significant magneto–mineralogical differences were observed in either locality (Elbra et al. 2018; Vaňková et al. submitted), the susceptibility record most likely supports the $\delta^{18}O$ paleoclimate interpretation. This is very important observation as both localities represent a different character of the environment – i.e. pelagic sedimentation influenced by frequent slumps on the slope (Kurovice) and shallow-water, peri-reef organodetritic sedimentation at Štramberk.

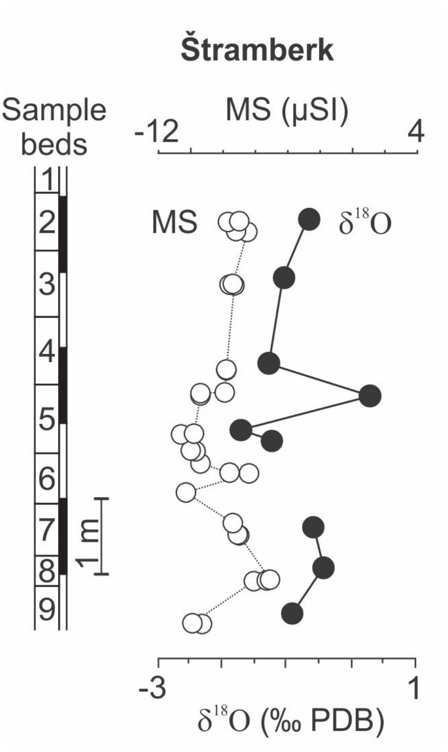

Fig. 1. Magnetic susceptibility (MS) and δ^{18}O of uppermost part of Štramberk section (modified after Vaňková et al, submitted).

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Biostratigraphy and microfacies of the Jurassic–Lower Cretaceous sequence in the Haligovce Klippe (Pieniny Klippen Belt)

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In the Haligovce Klippe (Pieniny Klippen Belt), north of the Haligovce village, a sequence of the Middle Triassic–Cretaceous beds were exposed. The corresponding sequence (49°22’52.5”N, 20°27’48.5”E) starts with Middle Jurassic (Nemčok et al. 1990) grey to dark grey thick bedded crinoidal limestones with cherts. According to microstructure, they represent crinoidal biomicrosparite/biomicrite (crinoidal wackestone/packstone). Limestones are affected by intense silicification. Fragments of echinoderms, bryozoans, brachiopods, bivalves and small benthic foraminifers are present.

The crinoidal limestones passes upwards into grey to greenish, massive (locally bedded: 5–20 cm) „biancone” limestones with cherts and rare layers of marly shales. According to microstructure, they represent biomicrite/biomicrosparite (wackestone/locally packstone), biomicrite (wackestone) with rare clasts of crinoidal limestones, respectivelly intrabiopelmicrite/ locally intrabiopelmicrosparite (wackestone/packstone). Mainly calpionellid biomicrite, rarely radiolarian-calpionellid biomicrite (calpionellid wackestone) microfacies can be observed. In the lower part of the limestones, association of *Calpionella alpina* Lorenz, rare *C. minuta* Houša, *Remaniella cadischiana* (Colom), *R. catalanoi* Pop, *R. colomi* Pop, *R. ferasini* (Catalano) and *Tintinnopsella carpathica* (Murgeanu et Filipescu) from the Calpionella Zone (middle Berriasian) occur. *Calpionella elliptica* Cadisch with rare *Tintinnopsella carpathica* and *T. subacuta* (Colom) appear in the upper beds. This ssociation is followed by *Calpionella alpina*, *Remaniella cadischiana*, *R. colomi, R. filipescui* Pop, *Calpionellopsis oblonga* (Cadisch), *Cs. simplex* (Colom), *Lorenziella hungarica* Knauer et Nagy, *Tintinnopsella carpathica*, *T. longa* (Colom) and *T. subacuta* representing Calpionellopsis Zone, Oblonga Subzone in the upper part of the limestones. Redeposited *Crassicollaria massutiniana* (Colom) from the Late Tithonian Crassicollaria Zone is documented within this calpionellid association. Calcareous nannofossils *Nannoconus steinmannii minor* (Kamptner, 1931) Deres and Achéritéguy, 1980, *N. steinmannii steinmannii* Kamptner, 1931, *N. kamptneri minor* (Brönnimann, 1955) Bralower *in* Bralower et al. 1989, *N. kamptneri kamptneri* Brönnimann, 1955, *N. globulus globulus* Brönnimann, 1955, *Micrantolithus hochschulzii* (Reinhardt, 1966) Thierstein, 1971, *Watznaueria* sp., *Cyclagelosphaera* sp. and *Zeugrhabdotus* sp. also occur. Other fossil remains are represented by *Globochaete alpina* Lombard, *Ostracoda* div. sp., filaments, small benthic foraminifers, fragments of aptychi, radiolarians, sponge spicules, rare calcareous dinocysts, nannoconids, *Didemnoides moreti* (Durand Delga) and prisms of *Inoceramus* sp.

“Biancone” limestones passes upwards into grey to dark grey, thick bedded organodetrital limestones with cherts. According to microstructure, they represent intrabiopelmicrite/intrabiopelmicrosparite (packstone/wackestone), locally intrabiopelsparite (grainstone). In the lower part of the limestones, planktonic foraminifers *Praehedbergella luterbacheri* (Longoria) and *Praehed. praetrocoidea* (Kretchmar et Gorbatchik) from the Luterbacheri Zone can be observed. In the upper part of the limestones, *Globigerinelloides* sp., *Gl. ferreeolensis* (Moullade) and *Hedbergella trocoidea* (Gandolfi) from the Ferreolensis Zone, followed by *Gl. barri* (Bolli, Loeblich and Tappan) representing Barri Zone can be identified. Associaton of planktonic foraminifers indicates Aptian (Gargas) age sensu Moullade et al. 2005, possibly younger Algerianus and Trocoidea zones bounded by the occurrence of these species. The sequence passes upwards into light grey massive organodetrital limestones of the Nižná Limestone Formation. They are characterized by intrabiosparite (grainstone), locally biomicrosparite/biointramicrosparite (wackestone) microstructure. Common well-rounded obitolinids, e.g. *Mesorbitolina* cf. *parva* (Douglass) indicating Late Aptian age occur in association with bivalves, partially rudist shell fragments, small benthic foraminifers *Mesoendothyra* aff. *complanata* Hottinger, echinoderms, bryozoans, calcareous algae and recrystallized biodetritus.

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The problem of occurrence of the Aalenian in central Poland as based on revision of the ammonite fauna and dinoflagellate cysts: preliminary data

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The lower Middle Jurassic of central Poland records the onset of major transgression, which established marine environments over the Polish Basin for the majority of the Jurassic. The basal marine sequence of the thickness of ca. 260 m can be divided into sandstone-dominated, lower complex and dark shales, siltstones and mudstones of the upper complex. Based on agglutinated foraminifera and superposition with overlying strata, the lower complex was attributed to the lower Aalenian (Dayczak-Calikowska & Moryc 1988; Feldman-Olszewska 1997). The stratigraphic attribution of the upper complex to the Upper Aalenian–Lower Bajocian interval was inferred from the ammonite fauna and foraminifera recovered from several cores drilled into Justynów Anticline (Dayczak-Calikowska 1976). This fauna and embedding rock samples, stored in the Geological Museum of the Polish Geological Institute – National Research Institute in Warsaw, has been recently taken for analyses, in order to calibrate the Middle Jurassic dinoflagellate succession of the Polish Basin against the standard ammonite zones.

The ammonites in the studied Gałkówek H1, H2, H7, H8, H10, H11, H12 cores (Justynów Anticline, Łódź area) are representatives of the family Sonninidae, especially of the genera *Nannina-Dorsetensia*. This assemblage is indicative of the lowermost part of the Humphriesianum Zone (upper part of the Lower Bajocian) – i.e. the Romani Subzone, and possibly the directly underlying part of the topmost part of the Propinquans Zone. All these ammonites were referred previously to as *Leioceras, Costileioceras* and *Ludwigia* typical of the Aalenian, but these determinations have appeared erroneous.

Four rock splinters were picked from the cores at the levels with diagnostic ammonites and processed palynologically. The examined palynofacies are dominated by woody particles, the marine palynomorph fraction is very sparse and poorly preserved. The samples studied yielded similar Dinoflagellate cyst assemblages composed of: *Nannoceratopsis* sp., *Batiacasphaera* sp., *Kallosphaeridium* sp., *Pareodinia* cf. *ceratophora*, *Dissiliodinium* sp., *Wanaea* sp., *Durotrigia* sp., *Durotrigia* cf. *daveyi*, ?*Korystocysta* sp. These taxa, except the last one, are typical constituents of the Lower Bajocian assemblages in northwestern Europe, whereas the range base of *Wanaea* sp. was reported at the base of the Humphriesianum Zone (Feist-Burkhardt & Götz 2016).

The results of preliminary, combined ammonite-palynological study of the Gałkówek cores from central Poland challenged the notion of the Aalenian age of the marine Middle Jurassic basal shaly complex and allowed to ascribe at least its upper portion to the uppermost Lower Bajocian. The occurrence of the Aalenian strata in these cores and elsewhere in the Polish Lowland remains to be an open problem and needs further validation.

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Tracing a legend: the “lost” ammonite collection of Jenő Noszky, Jr.

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Jenő Noszky, Jr. (1909–1970) was a geologist of the Hungarian Geological Institute, who dedicated decades to the study of the Mesozoic of the Bakony Mountain (Transdanubian Range, Hungary). He did geological mapping and during his fieldwork he collected thousands of fossils, especially Jurassic ammonites. He explored all of the important Mesozoic fossil sites of the Bakony. As a matter of fact, he was a passionate fossils hunter.

Noszky carried out large collection campaigns in the Bakony Mountains, but published very little on his fossils. At the same time, on the bases of the fossil content of the often condensed successions of the Bakony Mountains, Noszky was able to distinguish different Jurassic stages, which was an important step in his times towards the better understanding of the Mesozoic stratigraphy.

Most of his publications on the Jurassic of the Bakony are short notes only – reports on his successive field seasons. He published brief faunal lists only, mentioning some of the important taxa, but he never described, or illustrated his fossils. His main publication on Jurassic stratigraphy and fossils was published after his death as a part of the 1: 200 000 geological map explanatory of the Bakony Mountains (Noszky 1972).

One of his main collecting sites was Páskom Hill, near Borzavár, in the northern part of the Bakony Mountains, where he gathered the Upper Jurassic ammonites from an artificial trench. His Páskom Hill fossils were legendary: according to the stories his ammonites were preserved with shell, and in some cases even the original ?colored pattern of the shell was preserved. It was known, that many of his ammonites belonged to Aspidoceratidae – the favorite group of cephalopods of Noszky.

After the death of Noszky his collection fell into oblivion, and apparently was lost. But finally many of his fossils – if not all –, were rediscovered in repositories of the Hungarian Geological and Geophysical Institute and thus became available for study.

After revisiting the site and the fossils, it become clear that the Páskom Hill section represents an extremely thin and condensed succession, and the fauna is very rich and well preserved. Albeit many of the ammonites are preserved with shell, the original color (pattern) was not recognized. But some of the ammonites, especially aspidoceratids possess unique traces of epizoans. Among these traces the following types can be distinguished: (1) microborings of algae and/or bryozoans; (2) grazing traces of molluscan radula (*Radulichnus*); (3) home scars left behind possibly by patellid gastropods (limpets); (4) regular echinoid grazing traces (*Gnathichnus*); (5) elongated pits of acrothoracia balanids. Latter represent a new type of commensalism between the ammonites and the boring balanids, which was never documented before.

Re-excavating the Páskom Hill site it becomes obvious that the rock succession is condensed and thin, probably less than 2 meters. The ammonite fauna suggests that it represents different stratigraphic horizons, such as Platynota, Strombecki, Divisum and Beckeri Zones. It may represent the lowermost Tithonian as well.

Aspidoceratids and ammonites related to the genus *Nebrodites* are very common.

The presence of *Sutneria* is unique, since these small sized forms were never reported from the Bakony until now. Some ammonites may represent new species for the science. The first Páskom Hill ammonites were figured by Főzy (2017) but the entire fauna is still under revision.

Within a few hundred meters south-east of Páskom Hill, the Szilas Ravine outcrop yielded a different and thicker succession where Kimmeridgian is poorly documented but the Tithonian is more complete (Főzy 1990). This suggests that late Jurassic sedimentation was episodic, and strongly controlled by the uneven bottom topography.

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The first direct evidence of the Jurassic ophiolitic obduction in the Eastern Alps (Austria): mass input of detritic Cr-spinels in Kimmeridgian sediments of the central Northern Calcareous Alps

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In the Kimmeridgian allodapic limestones near the Mt. Dietrichshorn in the central Northern Calcareous Alps (Hallstatt Mélange area of the Saalach zone), rich ophiolitic detritus in form of chrome-spinels was recorded. The Kimmeridgian age of the limestones is proven by the occurrence of the benthic foraminifera *Protopeneroplis striata* and *Labyrinthina mirabilis*, the dasycladalean algae *Salpingoporella pygmea*, and the alga incertae sedis *Pseudolithocodium carpathicum*. From the geochemical composition the analysed spinels have a dominance of Al-chromites (Fe^{3+}–Cr^{3+}–Al^{3+} diagram). In the $Mg/(Mg+Fe^{2+})$ vs. $Cr/(Cr+Al)$ diagram they can be classified as type II ophiolites and in the TiO_2 vs. Al_2O_3 diagram they plot into the SSZ peridotite field. This points to a harzburgite provenance of the analysed spinels as known from the Jurassic suprasubduction ophiolites well preserved in the Dinarides/Albanides. These data point to the Late Jurassic erosion of obducted ophiolites before their final sealing by the Late Jurassic–earliest Cretaceous carbonate platform pattern.

The causes for the Middle to Late Jurassic tectonic processes in the Northern Calcareous Alps are still controversially discussed. There are several contrasting models for these processes, formerly designated "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 still widely favoured instead of a Jurassic one, obviously all other tectonostratigraphic Jurassic features are nearly identical in the Northern Calcareous Alps, the Western Carpathians and the Dinarides, especially the formation of the Middle and Late Jurassic sedimentary Mélanges (Hallstatt Mélange in general). In contrast, the Jurassic basin evolutionary 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, because they are eroded in the area of the today´s southern rim of the Northern Calcareous Alps.

To conclude: The Eastern Alps, Western Carpathians, Southern Alps, units in the Pannonian realm and the Dinarides/Albanides/Hellenides were all affected more or less contemporaneously by Middle-Late Jurassic ophiolite obduction and belong therefore to the same paleogeographic domain, i.e. the northwestern and western shelf of the Neotethys ocean. The existence of several independent oceanic domains between microcontinents cannot be confirmed. The proof for eroded obducted ophiolites in the Late Jurassic by our analyses complete the picture of a northeast-southwest-southeast striking orogen (from Tisza in the northeast to the Dinarides to the west and the Hellenides in the southeast) in Late Jurassic times, the Neotethyan Belt.

Sedimentary mélanges in the Alps–Carpathians–Pannonian realm–Dinarides/Albanides/Hellenides: paleogeographic and geodynamic consequences based on matrix ages and pebble provenance

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The Middle-Late Jurassic mountains building process in the Western Tethyan realm was triggered by west- to northwestward-directed ophiolite obduction onto the wider Adriatic shelf (western/northwestern margin of the Neo-Tethys). This Adriatic shelf was the former Middle Triassic to Middle Jurassic passive continental margin of the Neo-Tethys Ocean, which started to open in the Middle Triassic (Pelsonian/Illyrian-boundary) and to close its western parts from the Early/Middle Jurassic-boundary onwards with the onset of east-dipping intra-oceanic subduction. Ongoing contraction led to ophiolite obduction onto the former continental margin since the Bajocian. Trench-like deep-water basins formed in sequence with the northwest-/westward propagating nappe fronts, which served as source areas of the basin fills concomitantly within the evolving thin-skinned orogen in a lower plate situation. Deposition in the basins was characterized by coarsening-upward cycles, i.e. sedimentary mélanges as synorogenic sediments, in cases tectonically overprinted.

The sedimentary and tectonic features of these mélanges demonstrate clearly their original depositional settings in trench-like basins in front of a propagating nappe stack formed in the footwall in the course of ophiolite obduction. The former western/northwestern Neo-Tethys continental margin attain a lower plate position in relation to the obducted ophiolites from Bajocian time onwards: the oceanic realm and the most distal parts of the former passive margin were incorporated into the nappe stacking. The ophiolitic and Meliata mélanges were formed as most oceanward preserved relics of trench-like basins in front of the propagating ophiolitic nappe stack, often with incorporated components from the continental slope (Meliata facies zone). In the course of ongoing ophiolite obduction, thrusting progressed to the outer shelf region (Hallstatt Limestone facies zone). In Bathonian to Early Oxfordian times the Hallstatt nappes with the Hallstatt mélanges were established, expressed by the formation of the up to 900 m thick basin fills comprising its material mainly from the outer shelf region. In Callovian to Middle Oxfordian times the nappe stack reached the former carbonate platform influenced outer shelf region. Newly formed basins received material from the outer shelf region, occasionally mixed with material from the approaching ophiolite nappes. Ongoing shortening led to the formation of the proximal Hallstatt nappes with concomitant mobilization of Hallstatt mélanges with components originated from a reef influenced to reefal provenance region. The basins characterized by redeposits from the lagoonal outer shelf region of the Late Triassic passive margin platform arrangement were formed around the Middle/Late Jurassic-boundary. Persistent tectonic convergence caused the partial detachment and northwest- to west-directed transport of the older basin groups and nappes originally formed in a more oceanward position onto the foreland.

Around the Oxfordian/Kimmeridgian boundary a shallow-water carbonate platform pattern established in a period of decreased tectonic activity. These platforms were formed on top of the obducted ophiolites or on top of the different nappe fronts of the newly formed nappe stack. The Kimmeridgian to Early Tithonian time was characterized by platform progradation over the adjacent deep-water basins containing the sedimentary mélanges. From the late Early Tithonian the imbricate wedge started uplifting, resulting in the successive collapse, unroofing and erosion of parts of the Kimmeridgian-Tithonian carbonate platforms. Several mélanges and ophiolite bodies glided northwest- to westward along low-angle planes in latest Jurassic to Early Cretaceous time. This Middle-Late Jurassic orogen was named Neotethyan Belt and ranged from Tisza/Western Carpathians in the northeast to the Hellenides in the south.

Analyses of ancient Neo-Tethys mélanges along the Eastern Mediterranean mountain ranges allow both, a facies reconstruction of the outer western passive margin of the Neo-Tethys and conclusions on the processes and timing of Jurassic orogenesis. Comparison of mélanges identical in age and component spectrum in different mountain belts figured out one Neo-Tethys Ocean in the Western Tethyan realm, instead of multi-ocean and multi-continent scenarios. The evolution of several independent Triassic-Jurassic oceans is unlikely considering the fact that re-sedimentation into newly formed trench-like basins in front of a west- to northwestward propagating nappe stack including ophiolite obduction is nearly contemporaneous along the Neotethyan Belt. The Middle to Late Jurassic basin evolutions with their sedimentary cycles and component spectra are comparable everywhere. In all places ophiolitic, Meliata and Hallstatt mélanges and the ophiolites are far-travelled fragments of the Neo-Tethys Ocean and its western/northwestern outer shelf, brought into their present position by west-/northwest-ward far-distance thrusting. More details in Gawlick & Missoni (2019).

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Plant remains from fossil faeces (coprolites) of a large predator from the Early Jurassic of Poland (Sołtyków)

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Studied material comes from the abandoned clay-pit at Sołtyków near Odrowąż, situated c. 25 km north of Kielce in the Mesozoic margin of the Holy Cross Mountains (Central Poland). The Early Jurassic (Hettangian) age of sediments is confirmed by megaspores (Marcinkiewicz 1960), microspores (Ziaja 2006) and sequence stratigraphy (Pieńkowski 2004). According to Pieńkowski (2004), exposed succession represents the lower and middle part of the Zagaje Formation, composed of sandstones, siltstones, claystones, siderite-bearing deposits with coal and organic-rich mudstone intercalations. Sedimentary succession in Sołtyków is interpreted as alluvial plain deposits, with river channel, levee, crevasse splay and overbank fluvial plain/lacustrine sediments.

Macrofloral remains are represented by 492 suitable for study specimens, consisting mainly of leaves, shoots, rhizomes and fructifications (Barbacka et al. 2010). Almost all major plant groups are present, including lycophytes, sphenophytes, pteridophytes, pteridosperms, bennettites, cycads, ginkgophytes and conifers. Most common taxa are conifer *Hirmeriella muensteri* (Schenk) Jung. Microflora consists of sixty-three taxa of pollen grains and spores (Ziaja 2006). Most frequent taxon is *Classopollis torosus*, produced by the *Hirmeriella muensteri*. Majority of the plant groups of the microflora have corresponding taxa in the macroflora.

Apart from macro- and microflora, tetrapod track assemblage was described from this locality (Gierliński et al. 2004, Niedźwiedzki 2011). Footprints belonging to different tetrapod groups, such as sauropodomorphs, ornithischians, theropods, therapsids, early mammals, lepidosaurs, pterosaurs and early crocodylomorphs were found. Besides tetrapod tracks, numerous invertebrate trace fossils were described (Pieńkowski & Niedźwiedzki 2009, Pieńkowski & Uchman 2009).

The matter of this study are plant remains obtained from coprolites collected from Sołtyków locality and identified as produced by a large predator dinosaur. The material was dissolved using buffered formic acid (3–5 %) and acetic acid (2–3 %) and then extracted plant fragments were treated with Schulze's reagent. Eight distinct types of cuticles were found, mainly belonging to pteridosperms and ginkgophytes. Less common types can be attributed to conifers and cycads. Apart from cuticle fragments, small charcoal and seed fragments were present. Almost none of cuticles obtained from coprolites can be connected to macroremains known from Odrowąż so far. It provides new data for reconstruction of the Early Jurassic ecosystems of southern Poland.

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Upper Berriasian chemostratigraphy in the Barlya section (western Balkan, Bulgaria): implications for detrital input, paleoproductivity and paleoclimatic changes

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The Barlya section, situated in the Western Balkan (Bulgaria), contains a complete sedimentary succession from the Callovian to the Hauterivian (Lakova et al. 2007). Around the Lower/Upper Berriasian boundary, calpionellid limestones of the Glozhene Fm pass into hemipelagic marls and marly limestones of the Salash Fm. A 39 m thick studied interval, calibrated with biostratigraphy and magnetic stratigraphy, ranges from the upper part of polarity chron M17r (upper part of the Lower Berriasian) to the polarity chron M14r (lowermost Valanginian) (Grabowski et al. 2016).

A long term increase of lithogenic input is observed in the interval studied. The siliciclastics are represented by phyllosilicates (mica, chlorite and kaolinite), quartz and feldspars. The amount of K-feldspar and quartz/phyllosilicate ratio decrease throughout the Upper Berriasian. The relative amount of kaolinite (kaolinite/(mica+chlorite) ratio) decreases which indicates that the terrigenous flux was not solely related to humidity changes but rather controlled by sea-level variations as well as an uplift and erosion of the NeoTethyan Collisional Belt, south of the West Balkan basin. The provenance indicators (La/Sc and Cr_{detr}/Th) suggest that increasing erosion of felsic rocks occurred in the latest Berriasian, while the admixture of minerals from mafic source might be expected in the Lower Berriasian.

The bulk values of redox proxies through the section suggest that the sediments were formed in oxic conditions, approaching the oxic/dysoxic interface in the lower Berriasian and upper part of the Upper Berriasian. It is supported by a similar shape of U/Th and Ni/Co curves, as well as the values of Ce anomaly (Ce/Ce*). A slight Mo enrichment in is only observed in the Lower Berriasian.

Carbon isotope curve correlates very well with the reference Upper Berriasian $\delta^{13}C$ data from the Vocontian Basin (Emmanuel & Renard 1993) indicating similar second order variations, with decrease in $\delta^{13}C$ values from 1.4 to 0.9 ‰ throughout the polarity chron M16n (Grabowski et al. 2016). The carbon isotopic ratio is inversely correlated with organic paleoproductivity proxies expressed by calculated P_{org}, Zn_{org} and Cd_{org} deposition rates. A profound minimum of $\delta^{13}C$ in polarity chron M16n correspond to the regressive and high organic productivity interval from the Upper Berriasian (Oblonga Subzone).

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Magnetostratigraphy and lithogenic input around the Jurassic/Cretaceous-boundary: new data from a thick Late Tithonian to Berriasian deep-water carbonate succession in the Northern Calcareous Alps

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The Leube quarry near Salzburg in the central Northern Calcareous Alps exposes a thick succession of late Jurassic to early Cretaceous sedimentary rocks which are part of the Lower Tirolic Unit. The Alpine Haselgebirge (Permian) Mélange (Late Jurassic) is followed by a mass flow, which marks here the start of the about 150 m thick Late Tithonian to Middle Berriasian Oberalm Formation. The succession is not much disturbed by tectonic faults and offers therefore possibilities for multiproxy-studies (e.g. Krische et al. 2018). More detailed data from the section encompassing the Jurassic/Cretaceous (J/K) boundary (Krische et al. 2013) are presented here. Samples were taken for thin sections (biostratigraphy, microfacies), magnetic susceptibility and magnetostratigraphy. Gamma ray spectrometric (GRS) measurements were performed. Geochemical analyses, isotope stratigraphy and clay mineral analyses are in progress.

The profile starts about 50 m above Alpine Haselgebirge with thick mass flow up to 10 m in thickness, common resediment layers of the Plassen Carbonate Platform to the south are intercalated in Calpionella-bearing wackestones with chert nodules and layers in specific levels as well as mm- to cm-thick layers of greenish claystones to marls. The limestone succession show a fining-upward trend and the mass flows are getting less thick and more fine-grained during the latest Tithonian to earliest Berriasian. Sedimentation is mainly controlled by the shedding of the carbonate platform to the south. Therefore, the amount of $CaCO_3$ and the thickness of the different stratigraphic intervals in section depends on the carbonate production of the adjacent platform and not by planktonic carbonate productivity. During sea-level highstand phases resediments and carbonate mud were exported into the basin while during the timespan regression-transgression condensed deep-water Radiolaria–Calpionella–wackestones were deposited. A stratigraphical gap or extreme condensation occurs at the J/K boundary. The upper part of the Crassicollaria Zone is not detected yet in respect to not enough dense sampling. Just below the J/K boundary a spectacular shallowing upward trend is observed which might reflect the late highstand and fast progradation of the platform. Magnetostratigraphic record proves that the section seems not complete. Some gaps or condensation horizons should be expected also in the Berriasian part. The sections terminate in the Calpionella Elliptica Subzone (upper part of the Lower Berriasian) in the reversed polarity interval which might be interpreted as magnetozone M17r.

Small scaled fluctuations in the siliciclastic input in the Tithonian and in Berriasian, based on magnetic susceptibility measurements (MS) and elements with strong to very strong correlation with Al. The K and Th-curves correlates well with the MS, but not the mineralogy of the intercalated clayey layers, which consist practically exclusively of illite, as known from other sections of the Oberalm Formation elsewhere. The amount of K and Th shows a well-defined increasing trend throughout the Berriasian – between the Alpina and Elliptica Subzones, with maximum at the top of the section. The absolute minimum of terrigenous input matches exactly the shallowing upward interval just below the J/K boundary.Our data can be very well correlated with the Tithonian – Berriasian sea-level fluctuations (Haq 2017).

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New Upper Kimmeridgian–Tithonian section in the Lower Sub-Tatric (Krížna) succession in the Lejowa Valley (Western Tatra): integrated stratigraphy and impications for lithogenic input

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A pelagic Kimmeridgian–Tithonian section in the Lejowa valley, ca. 47 m thick, comprises the uppermost part of radiolarian limestones (Czajakowa Radiolarite Formation), red platy and nodular limestones of Ammonitico Rosso type (Czorsztyn Limestone Formation) and grey marly limestones of the Jasenina Formation. Integrated dating of the Lejowa section (in progress) is based on calcareous dinocysts, calpionellids and magnetic stratigraphy. The interval studied spreads throughout the calcareous dinocyst zones, from the Moluccana Zone (Upper Kimmeridgian) to the Semiradiata Zone (Lower Tithonian) and calpionellid zones Chitinoidella boneti Subzone almost to the Jurassic/Cretaceous boundary (Cr. colomi Subzone). According to preliminary magnetostratigraphic interpretation it corresponds to polarity zones from M24r to the lower part of M19n. The Kimmeridgian/Tithonian boundary (Borzai/Pulla zonal boundary) falls in the lower part of the Czorsztyn Limestone Formation.

Carbon isotope curve reveals a fast decrease from 2.5 ‰ in the Upper Kimmeridgian to 1–1.5 ‰ in the Lower Tithonian and then variations between 0.8 and 1.3 ‰ in the Upper Tithonian. The trend agrees very well with published data from the Lower Sub-Tatric and High-Tatric successions (Jach et al. 2014; Pszczółkowski et al. 2016). Magnetic susceptibility (MS) correlates positively with lithogenic geochemical proxies (Al, Ti and others) in the Jasenina Fm but not in the Czajakowa and Czorsztyn Fms. This might indicate that red coloured pigment which affects the MS is related to hematite of authigenic origin. Large and abrupt increase of terrigenous input, from 1 to 5 % of Al, is observed in the uppermost part of the polarity zone M20r (Semiradiata Zone, Jasenina Fm). Then the Al content decreases stepwise to ca. 2 % in the Intermedia and Colomi subzones (M19n2n). Sediments are generally well oxidized, however a long term decrease of Th/U ratio is observed from 7–8 in the uppermost Kimmeridgian/lowermost Tithonian to 4–5 in the upper Tithonian. Comparing to the Lókút section (Transdanubian Mts, Grabowski et al. 2017) the section in Lejowa Valley is much more affected by terrigenous input – the maximum Al content in the Lower Tithonian in Lókút is less than 0.5 %. It suggested that, in the Krížna Basin, the terrigenous input was controlled mostly by progradation and proximity of the NeoTethyan Collisonal Belt (e.g. Gawlick & Missoni 2019) while in the Transdanubian unit, the decreasing detrital trend was related to increasing carbonate productivity and most probably climate aridization (Grabowski et al. 2017).

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Carbonate platforms of the Tethys Ocean at the Jurassic–Cretaceous transition: case studies

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The recently held JK2018 – International Meeting around the Jurassic–Cretaceous Boundary (the edited abstract volume of which was edited by Granier 2019a) provided an opportunity to reopen the debate on the only system boundary of the Phanerozoic that, according to Ogg & Hinnov (2012), does not have an accepted global definition. Problems apparently appeared shortly after the Oppel's (1865) publication entitled "Die Tithonische Etage", followed by the death of the author in December of that same year. The redefinition of the Tithonian (originally comprising the Berriasian) and Neocomian (originally starting with Valanginian pyriteous ammonites) stages, the introduction of the Berriasian, Infravalanginian and Valanginian (sub-) stages, the persistent use of the Purbeckian either as a stage or as a facies, erroneous correlations of shallow-water facies with basinal series, and last but not least nationalistic views led to a confusion that still persists today.

The area where part of the drama unfolded is the Jura Mountains, which were then located on the northern margin of the Central Tethys. Rare records of ammonites and calpionellids, coupled to a sequence stratigraphic approach, led a group of authors (Charollais et al. 2008; Strasser et al. 2016) to propose a refined stratigraphic scheme for this shallow-water domain. It corrects past mistakes and can be extended beyond the Central Tethys to distant shallow-water areas of Eastern and Western Tethys (Granier 2019b). The "Purbeckian regression" was once regarded as the changeover period between the Jurassic and the Cretaceous. In the Jura Moutains, the "Purbeck facies" of the Goldberg Formation (Charollais et al. 2008: Fig. 2; Granier 2019b: Fig. 2), which is (?) latest Tithonian to early Berriasian in age, is characterized among other features by occurrences of charophyte stems and gyronites. However, charophyte remains are still present in the overlying Berriasian Pierre-Châtel and Vions formations. In addition, sequence stratigraphy establishes that the regression is actually represented by a period of increasing subaerial erosion and non-deposition that affected the Vions Formation as well as the lower and middle Chambotte Formation. It reached its peak at the end of the Berriasian, just before the Valanginian transgression took place.

On the basis of the rich and diverse assemblages of benthic foraminifera and "calcareous" green algae known from the Jura Mountains, Granier (2019b) identified 5 dual biozones, i.e., 3 to 4 zones and 1 to 2 subzones for the Tithonian–lower Valanginian interval:

- the *Anchispirocyclina lusitanica* zone for the Tithonian-lower Berriasian (encompassing the stage boundary);
- the *Protopeneroplis ultragranulata* subzone for the upper Tithonian–lower Berriasian;
- the *Rajkaella minima* zone for the middle Berriasian;
- the *Falsolikanella campanensis* zone for the upper Berriasian [a *Falsolikanella campanensis* subzone for the upper Berriasian, as part of a *Rajkaella minima* zone for the middle–upper Berriasian];
- the *Pseudocyclammina lituus* zone for the lower Valanginian pro parte.

As demonstrated earlier (Granier 2019b), "This scheme can be more or less successfully applied in the shallow-water settings of the eastern and western Tethys domains". As a matter of fact, the most correlatable events are related to biological crises and renewals associated with the lower/middle Berriasian and the Berriasian/Valanginian boundaries. That is not the case for the Tithonian/Berriasian boundary. Evidence is obtained from both published (Granier 2019b) and unpublished data, including two case studies from SE Spain (Sierra Mariola) and W Senegal (N'Diass 1) which will be presented during the meeting.

In conclusion, the poor correlativity of the Tithonian/Berriasian boundary, in addition to its lack of stability over the last decades, pleads the putting forward of the Berriasian/Valanginian boundary instead as the best alternative for the Jurassic/Cretaceous system boundary.

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Lower Cretaceous bryozoans of the northern Tethyan carbonate platform (Alpstein area, northeastern Switzerland)

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During the Early Cretaceous, major paleoceanographic changes are mirrored in the northern Tethyan carbonate platform by changes in the carbonate factory and by platform drowning. The central European portion of the platform is presently locked up in the Helvetic realm, which extends from southeastern Germany and western Austria through Switzerland to eastern France (Föllmi et al. 2006). Lower Cretaceous is the period in which bryozoans are still considered as an artefact caused by the incompleteness of the fossil record until their sustained radiation commenced in the Late Cretaceous. The cyclostomes form a well-diversified and distinctive fauna in the early Cretaceous until the significant radiation of cheilostomes started(?) in the Late Albian–Early Cenomanian. The newly described bryozoan fauna from the Alpstein area in the northern Alpine Helvetic thrust and fold belt (see Hara & Furrer 2018) ranges from the Middle–Upper Berriasian Öhrli Formation to the Upper Barremian/Lower Aptian Schrattenkalk Formation. The scarce bryozoan fauna of the Middle–Late Berriasian is characterized by the presence of the thick, branched colonies of *Multizonopora* d'Orbigny, 1853. The rich Early Valanginian fauna from the sandy facies of the *Pygurus* Member (Betlis Formation) is characterized mainly by the presence of large branched colonies and spherical multilamellar sturdy colonies. This assemblage is represented by a few genera belonging to a few families such as <u>Cavidae</u>, <u>Cytitidae</u>, <u>Cerioporidae</u>, <u>Tretocycloeciidae</u> and <u>*incertae sedis*</u> represented by the following genera *Chartecytis* Canu and Bassler, 1926, *Multizonopora* d'Orbigny, 1853, *Diplocava* Canu and Bassler, 1926, *Tretocycloecia* Canu, 1919 and *Reptomulticava* d'Orbigny, 1854. The Altmann Member of the Tierwis Formation with latest Hauterivian-Early Barremian age is mainly characterized by two taxa: *Reptomulticava* d'Orbigny and *Defranciopora* Hamm (<u>Cerioporidae</u>), both building strong multilamellar colonies, however, branched colonies of *Chartecytis* also occur. The youngest assemblage of the studied Alpstein material belongs to the Schrattenkalk Formation (Late Barremian–Early Aptian) with only one taxon of *Reptomulticava*. *Reptomulticava* shows a distinct internal layering, with up to a dozen layers, which vary in width and length and are arranged parallel or transversal to each other, what may be connected with the hydrodynamics of the environment (Fig. 1).

The new bryozoan fauna from the northern Tethyan carbonate platform in the Alpstein area (northeastern Switzerland) should be compared with the similar fauna from the Helvetic realm of southeastern Germany (Hillmer 1975), western Austria, and also with the bryozoans from the northern Tethyan margin in the southern part of the Jura mountains of western Switzerland (canton Vaud; see Canu & Bassler 1926) and eastern France (Walter 1989, 1991). The bryozoans from the Alpstein belong to four distinctive assemblages, which are mostly differentiated in their biodiversity. Two assemblages, the Middle–Late Berriasian and Late Barremian–Early Aptian ones, are only represented by a few individuals (*Multizonopora* and *Reptomulticava*). The other two – Early Valanginian is the richest in taxa, similarly as the Latest Hauterivian–Early Barremian assemblage. The Alpstein assemblages include mostly free-walled taxa, which show strong branched or spherical colonies, that may prefer shallow-water conditions, moderate to strong hydrodynamics and warm to temperate climate. The two rich assemblages from the Pygurus Member (Early Valanginian) and Altmann Member (Latest Hauterivian–Early Barremian) correlate with episodes of drowning or platform demise (Föllmi et al. 2006).

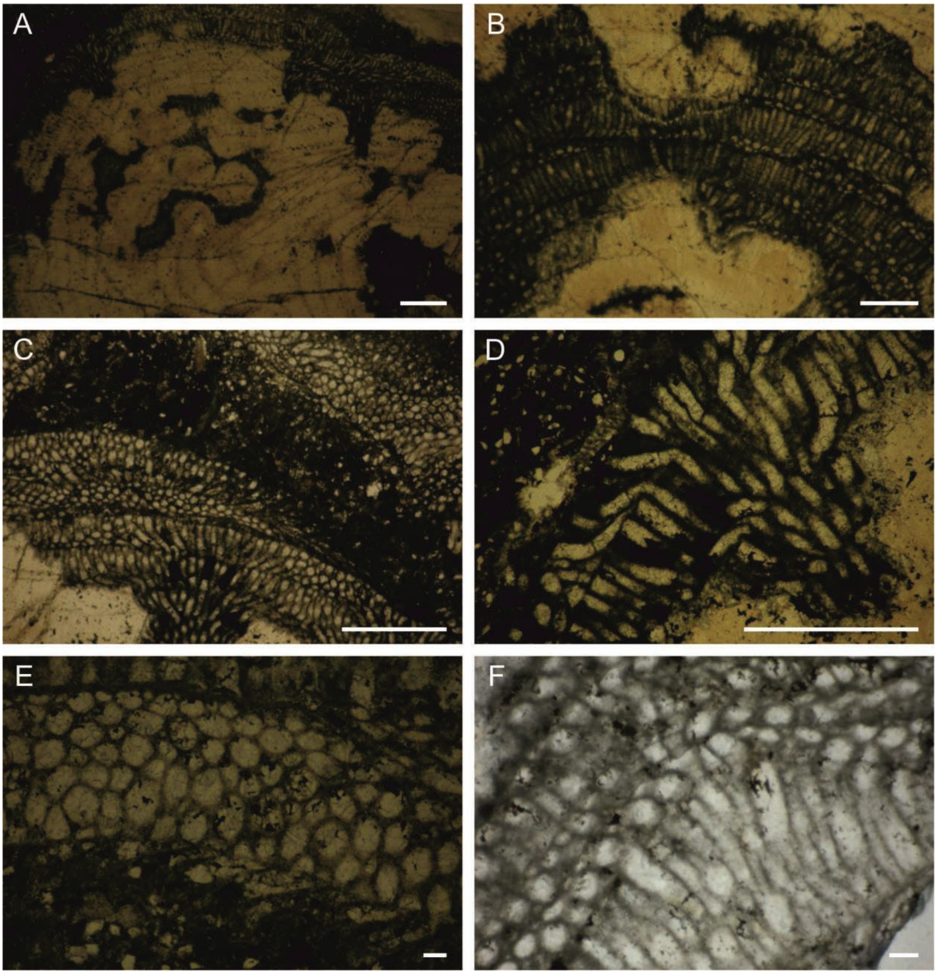

Fig. 1. A–F: *Reptomulticava* sp. thin-sections through the colonies, where the multilamellar structure is seem, A. scale bar 0.1 mm; B. 0.15 mm; C. 0.025 mm, D. 0.1 mm; E. 0.2 mm, F. 0.1mm. Altmann Member (Tierwis Formation), Latest Hauterivian - Early Barremian, Alpstein area, NE Switzerland.

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Biostratigraphy, lithostratigraphy and chemostratigraphy of Late Jurassic and Early Cretaceous pelagic facies between Czorsztyn, Zamkowa Góra and Červený Kláštor (Pieniny Klippen Belt)

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Late Jurassic and Early Cretaceous deposits of Pieniny Klippen Belt (PKB) have been formed in sedimentary basin which was a part of Alpine Tethys. Stratigraphy of proximal, shallow facies is based on ammonite and brachiopod fossils. In case of distal, hemipelagic and pelagic facies, formed below ACD and near CCD level, major stratigraphic zonation has been established for *Chitinoidellidae*, *Calpionellidae* microfossils and calcareous dinoflagellate cysts (Grün & Blau 1997; Reháková 2000). Moreover, for the last 20 years stratigraphic techniques based on stable carbon isotopes have been used successfully and gained recognition as an accurate and complementary stratigraphic method.

Biostratigraphic and chemostratigraphic studies have been conducted on 8 geological sections of Branisko and Pieniny succession of PKB, situated in Pieniny Mountains between Czorsztyn, Zamkowa Góra and Červený Kláštor. Micropaleontological analysis of thin sections provided chitinoidellid, calpionellid and calcareous dinoflagellate cyst zonation. Stable carbon and oxygen isotope analyses have been conducted on selected and prepared samples. Chemostratigraphic analysis have been conducted with use of portable XRF device Bruker S1 Titan 600, with elemental range from Mg to U.

Field-work provided lithostratigraphic assignments for each of studied sections. Czajakowa Radiolarite Formation (CRF) has been identified in 4 geological sections. Micropaleontological studies did not provide diagnostic calcareous dinoflagellate taxa thus the only premise regarding age of these strata were the age of deposits overlaying CRF and literature based biostratigraphic data (Bąk et al. 2018). In consequence stratigraphic range of CRF has been set on Oxfordian–Early Kimmeridgian. Czorsztyn Limestone Formation (CLF) of *Ammonitico Rosso* facies has been distinguished in 3 studied sections. Micropaleontological studies provided calcareous dinoflagellate and chitinoidellid zonation which gave an opportunity to establish stratigraphic range of CLF from Early Kimmeridgian to Middle Tithonian. Pieniny Limestone Formation (PLF) of *Maiolica* facies has been identified in 7 geological sections. In 2 sections PLF overlays CRF and in case of 3 studied sections overlays CLF. Changes in CLF and PLF facies distribution observed over the top of CRF is most probably a consequence of variability of basin basement. CRF–CLF–PLF sedimentary sequences most likely represent shallower zones of pelagic part of the PKB basin and CRF-PLF sequences correspond to deeper part of the basin. Micropaleontological studies of PLF thin sections provided chitinoidellid, calpionellid and calcareous dinoflagellate cyst zonation which showed clearly diachronous character of PLF sedimentation in the Upper Jurassic. According to these studies, the beginning of sedimentation of PLF in deepest parts of the basin corresponds to the Early Kimmeridgian and in the shallower zones to the Middle Tithonian. The age of youngest PLF strata in studied sections is uncertain due to insufficient quantity of index microfossils observed in thin sections and relatively poor resolution of biostratigraphic zonation starting from

Late Valanginian. However, in most geological sections, calpionellid microfossils pointed out presence of Early Valanginian Calpionellites and Tintinnopsella zones *sensu* Grün & Blau 1997. Kapuśnica Formation has been distinguished in one geological section and did not deliver index microfossils thus its age has been set on the basis of lithostratigraphy on Aptian–Albian (Birkenmajer 1977).

Stable carbon isotope analysis provided isotope stratigraphic data for 6 geological sections. Carbon isotope curves established for Upper Jurassic samples shows typical for this period negative isotope trend and in case of Early Cretaceous samples also characteristic stagnant isotope trend.

Correlation of lithostratigraphy with XRF geochemical data reveals that each of distinguished lithostratigraphic unit may be characterized by a specific geochemical fingerprint. Geochemical analysis of elemental composition provides strong premises for Kimmeridgian and Lower Tithonian silicification of the sediment in near CCD depths and volcanic activity in Early Berriasian (Oszczypko et al. 2012).

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The J/K-boundary section in the Leube quarry (Northern Calcareous Alps): sedimentology, stratigraphy, microfacies combined with geochemical proxies

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"For the last twenty years, building on a considerable and growing body of literature, calpionellids have been seen by numerous authors as the most useful fossil group that could provide a J/K marker. Further, the turnover from Crassicollaria and large Calpionella to small orbicular Calpionella alpina (…) has been documented repeatedly as the most consistent and widespread marker in the middle of magnetic subzone M19n.2. …" (Wimbledon 2017)

A J/K boundary section is exposed in the Lower Tirolic Units of the Northern Calcareous Alps in the Leube quarry near Salzburg (Austria). The Permian Alpine Haselgebirge Mélange is in this location part of a middle to late Jurassic section and followed by a mass flow, which marks here the start of the Oberalm Formation. The Upper Tithonian Oberalm Formation is dated by the first occurrence of *Calpionella alpina* (Lorenz), *Crassicollaria massutiniana* (Colom) and *Crassicollaria intermedia* (Durand-Delga). The end of the Oberalm Formation coincides with the drowning of the Plassen Carbonate Platform around the middle/late Berriasian-boundary (Gawlick & Schlagintweit 2006). The existing profile of the quarry (Krische et al. 2013) shows a sequence of the Oberalm Formation with a thickness of 150 m. The J/K boundary section is not disturbed by tectonic faults and therefore the morphospecies change of *Calpionella alpina* should be a good marker to fix the J/K boundary. The samples for thin sections, magnetostratigraphy, geochemical analyses and XRD of the clay layers were taken around the J/K boundary. The former boundary was estimated near a negative $^{18}O/^{16}O$ isotope excursion (Maier 2014) and the occurrence of last mass flow in the Oberalm Formation.

The researched profile starts about 50 m above the Alpine Haselgebirge mélange with big mass flows up to 10 m thickness, resediments of the Plassen Carbonate Platform and *Calpionella*-bearing micrites. These *Calpionella*-bearing micrites, wackestones and packstones are the most common sedimentary rocks in the lower part of the profile. The limestones from the middle of the profile upwards contain chert nodules and -layers. One layer with shallow-water debris from the lagoonal area show a remarkable difference in the geochemical composition. The mass flows and resediments from the Plassen Carbonate Platform, now reaching the Lower Berriasian, consists of angular Haselgebirge mélange clasts, benthic foraminifera, dasycladacean algae (i.e., *Clypeina sulcata,* Alth) and reefal components.

Two thicker clay layers can be found in the profile. They mainly consist of Illite like the Haselgebirge clasts.

The general trend in the profile lead to the result, that the limestone succession show a fining-upward trend and the mass flows are getting less in thickness and more fine-grained during the latest Tithonian. The late platform evolution (Gawlick & Missoni 2011) shows a backstepping of the reef and listric faults in its frontal area. This backstepping is mirrored by the fining-upward trend. The continuous filling of the Tauglboden-Roßfeld foreland basin ended in the Aptian.

Calpionella alpina can be found in the whole profile. The morphospecies change is located below the clay layers and last mass-flow deposit. Upsection, the occurrence of *Callpionella elliptica* proves the lower Berriasian above the remarkable change in morphospecies.

At the J/K boundary (based on Calpionellid biostratigraphy) is no remarkable change in the geochemical composition, the isotope curve, lithology or microfacies. The measured fluctuations in the siliciclastic input on base of magnetic susceptibility measurements (see Grabowski et al., this volume) and the layers with shallow-water components have to be interpreted in the light of the Late Tithonian–Early Berriasian basin-platform pattern along the Neotethyan belt. Platforms shielded at that time the hinterland to the south and eroded siliciclastics were deposited in the orogen-nearer Sillenkopf Basin. Since the late Middle Berriasian the drowning of the Plassen Carbonate Platform give way for those erosional products also to the north as visible also in the younger parts of the Leube quarry succession. To solve these newly arised questions around the J/K boundary further detailed studies are needed.

The results of the magnetostratigraphy are published in an additional work by Grabowski, Gawlick, Hirschhuber 2019.

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New taxa from the Upper Jurassic of the Hády hill at Brno (Czech Republic)

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New Upper Jurassic (Oxfordian) fossils from Hády quarry in Brno (Czech Republic, Moravia) were recently mentioned by Hykš (2018). In this abandoned quarry, autochthonous Jurassic limestones lay horizontally on folded Devonian strata. Both Jurassic stratigraphic members (detritic and cherty limestones *sensu* Bubík & Baldík 2011) yield abundant, but often poorly-preserved fossils. The studied material, acquired mainly from private collections of local fossil collectors, comprised hundreds of fossils in 11 taxa: Porifera, Serpulidae, Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Belemnitida, Echinoidea, Holothuroidea, Chondrichthyes and Plesiosauria. Most of the invertebrate fauna agree with taxa collected and described by Kuboš (1982) and Kočí (2002). The most common fossils were terebratulid brachiopods (*Moeschia*, *Galliennithyris sensu* Kuboš 1982), accompanied by less common rhynchonellid brachiopod (*Septaliphoria*) finds. Terebratulid brachiopod *Dictyothyris kurri*, best known from the Middle and Upper Oxfordian of Western Europe, was documented for the first time from Czech Republic. Relatively common were ammonites (especially perisphinctid faunas representing Tethyan Realm and cardioceratid faunas from Boreal Realm). Of all ammonite taxa we highlight the presence of stratigraphically important *Cardioceras* (*Subvertebriceras) densiplicatum*, whose occurrence is characteristic for the lowermost Middle Oxfordian (Boreal stratigraphic subzones *Vertebrale* and *Maltonense*) and which, eventually, becomes rare through the upper Middle Oxfordian (subzone *Tenuiserratum*). Further new taxa from Czech Jurassic include spines of sea urchin *Rhabdocidaris* cf. *copeoides* and holothurian sclerites of *Stueria* cf. *malmensis* and *Theelia* sp.

Because the only study focused on vertebrate fossils from Hády was a preliminary report of shark and marine reptile teeth (Gregorová 2013), we payed close attention on shark teeth taxonomy, which are relatively common, but whose assignment to *Sphenodus longidens*, after almost 90 years (Oppenheimer 1932), remained uncertain. In studied material, two relatively high, isolated teeth of *S. longidens*, were recognised (height 37 and 27 mm). Lower teeth of similar shape were assigned to *Sphenodus* sp. Vertebrate fossils also include four multi-cusped teeth of *Notidanoides muensteri*, a cushion-shaped *Asteracanthus* sp. tooth, an isolated placoid scale *Sphenodus* aff. *macer* and tooth of marine reptile Plesiosauria indet. None of herein mentioned species were reported from locality Hády before (except *S. longidens*).

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New microfossil data for Tithonian–Valanginian interval of Puerta Curaco section, Neuquén basin (Argentina)

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The Early Tithonian–Early Valanginian of the Neuquén Basin, Argentina, is mainly represented by distal marine facies known as Vaca Muerta Formation. This unit has received worldwide attention during the last decade, since the Vaca Muerta Formation is considered as a world-class unconventional oil and gas play, as well as its abundant fossil content and temporal continuity along several hundred meters of section that comprise the Jurassic–Cretaceous boundary. Although considerable work has been done regarding paleontological, sedimentological and stratigraphical aspects, so far there is there is still no full agreement in the biostratigraphic correlations between the Andes and the Tethys.

The Puerta Curaco section is a well-exposed stratigraphically continuous basinal section of the Tithonian–Valanginian, located 30 km eastern of the Chos Malal town in the northern part of the Neuquén Embayment. It is located within the thin-skinned Chos Malal fold-and-thrust-belt, which forms part of the Cordillera Principal in the Andes. The Vaca Muerta Formation is formed by a 407 m thick marlstone/limestone rhythmic succession and comprises the Early Tithonian–Early Valanginian *Virgatosphinctes andesensis* to *Neocomites wichmanni* Andean ammonite Zones (Kietzmann et al. 2016).

The Vaca Muerta Formation in Puerta Curaco area has been interpreted as a shallowing upward carbonate ramp system, characterized by basinal to outer ramp deposits, where 5 composite depositional sequences and 15 high-ordered depositional sequences has been recognized and correlated along several stratigraphic section in the Neuquén basin (Kietzmann et al. 2016). In the section all the Andean ammonite zones were identified and a detailed magnetostratigraphy is being developed, as well as obtaining absolute ages (Kohan Martinez et al. in preparation).

Detailed micropaleontological studies of Vaca Muerta Formation (Early Tithonian–Early Valanginian) in the southern Mendoza Neuquén Basin (Puerta Curaco section) demonstrates similarity to the micropaleontological content of outcrops already examined by the same basin: Arroyo Loncoche, Río Seco del Altar and Tres Esquinas sections (Ivanova & Kietzmann 2017; Kietzmann 2017). They are all characterized by a relatively rich micropaleontological assemblage of calcareous dinoflagellate cysts, as well as levels with poor preserved chitinoidellids/calpionellids and benthic foraminifera.

In the Early Tithonian–Early Valanginian interval the dinocysts zones previously proposed for the Tethyan realm and confirmed in the Vaca Muerta Formation (Arroyo Loncoche, Río Seco del Altar and Tres Esquinas sections) were also established in the outcrop of Puarta Curaco: *Carpistomiosphaera tithonica, Parastomiosphaera malmica,* *Colomisphaera tenuis, Colomisphaera fortis, Stomiosphaerina proxima, Stomiosphaera wanneri, Colomisphaera conferta* and *Carpistomiosphaera valanginiana*. The distribution of calpionellid species allows recognizing three of the calpionellid standard zones: *Chitinoidella, Crassicollaria* and *Calpionella* Zones.

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A preliminary study of Toarcian deposits of the Križna Unit (Tatra Mts) which possibly correspond to the Oceanic Anoxic Event

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Spotted limestone and marls of the Križna unit from the High Tatra Mts have been studied since the beginning of the 20th century. The basic stratigraphical zonation of the strata is presented by Kuźniar (1908) and Siemiradzki (1923). This study was continued by Iwanow (1972, 1985), who created a detailed chronostratigraphical scheme. The biostratigraphical dating of the deposits to the Upper Sinemurian–Lower Bathonian, based on ammonite fauna, is given by A. Wierzbowski (see Iwańczuk et al. 2013). Among the ammonite fauna collected since the beginning of the 20th century in the Tatra Mts. there was, however, no species characteristic of the Lower Toarcian. In the Świniarski gully (Kopy Sołtysie) during field work in 2018 black limestones and shales containing Lower Toarcian ammonites were found. Ammonites are generally poorly preserved and flattened – nevertheless the genera *Harpoceras* and *Hildaites* have been recognized which generally indicate the presence of the Serpentinum Zone of the Lower Toarcian.

The occurrence of a negative carbon isotope excursion is diagnostic of the Early Toarcian Oceanic Anoxic Event (TOAE) worldwide as well as of the Tethyan sections. Measured bulk carbonate $\delta^{13}C$ values in the investigated interval oscillate between 0 and 1.5 ‰ VPDB, and there are no clear positive and negative excursions. These results, along with ammonite fauna typical for the uppermost part of the Serpentinum Zone, indicate that the studied strata could be assigned to the upper part of Falciferum Subzone of the Serpentinum Zone of the Lower Toarcian.

Besides low carbonate $\delta^{13}C$ values, the presence of the manganese ore-bearing beds is reported from the Lower Toarcian strata of the Western Tatra Mts.. Similar phenomena including manganese mineralization or an increase in manganese contents in the interval corresponding to the TOAE are observed in various Tethyan sections. The hydrothermal activity of sea floor was likely responsible for the delivery of Mn to the sedimentary basins, so elevated Mn concentrations are indicative of TOAE deposits or the deposits of similar age from the Western Tethys . In the Świniarski gully the elevated Mn content is observed in a narrow interval of the lowermost part of the Lower Toarcian deposits, which are outcropped nowadays. This may by an indicator of the proximity to the TOAE.

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The Paleocene and Eocene boundary in China

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The Paleocene/Eocene (P/E) boundary period is the most significant climatic transition during the Cenozoic, when the PETM (Paleocene Eocene Thermal Maximum) caused rapid warming and severe fluctuation of the earth system, especially in marine settings. The P/E boundary strata in China mainly outcrop in southern Tibet and SW Tarim Basin as parts of the Cenozoic Tethyan sea.

In the southern Tibet, the P/E boundary strata outcrop within the limestone of Zongpu Formaiton as part of the tethyan Himalyan deposit dominated by a carbonate ramp depositional environment. A larger benthic foraminiferal turnover was identified across the P/E boundary from the Miscellaneae–Daviesina assemblage to an Orbitolitese–Alveolina assemblage within the Zongpu Formation. The P/E boundary is between the SBZ 4 and SBZ 5, where it is marked by the extinction of Miscellanea miscella and the first appearance of Alveolina ellipsodalis and a large number of Orbitolites. Chemostratigraphically, the $\delta^{13}C$ values from the study section also show excursions in the transitional strata corresponding to the faunal changes.

The SW Tarim Basin in Xinjiang represents a distal branch of the NE Tethys, Paleocene to Eocene strata outcrops there as the Qimugen Formation and provided optimal section for investigating the P/E boun–dary transient. The Qimugen Formation is characterized by gray-greenish silty mudstone of the lower unit and brownish red gypsiferous mudstone of the upper unit. By detail field-based lithological records and the planktonic and benthic foraminiferal assemblage analysis, the P/E boundary was redefined within the black mudstone bed within the lower unit of the Qimugen Formation. The planktonic containing succession of Qimugen Formation can be subdivided into four biozones, characteristic datums including Globanomalina pseudomenardii, Globanomalina luxorensis and Pseudohastigerina wilcoxensis. Planktonic foraminiferal turnover is marked by the cool water subbotinids give way to warm water muricate taxa, co-varying with the gradual disappearance of benthic foraminifera. The foraminiferal assemblages together with other microfossils obtained in the study section suggest a shallow marine environment with connections to the adjacent Tethyan ocean during the Paleocene to Eocene transient in the SW Tarim Basin, with warming surface water and transgressions.

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Chemo-, bio- and magnetostratigraphy of the Jurassic–Cretaceous boundary in the Snežnica (Outer Western Carpathians, Slovakia)

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The Snežnica, 50 m long, section is situated in Pieniny Klippen Belt (PKB, Outer Western Carpathians, Northwest Slovakia) and is composed of Mesozoic hemipelagic limestones. The lithology is gradually changing from ammonitico rosso in Jurassic part into maiolica in the Creaceous. Fresh, non-weathered, rocks are exposed in the studied section in a newly abandoned quarry.

Ongoing pilot research of local stratigraphy and paleoenvironment is based on paleomagnetic and micropaleontological (Calpionellid, Calcareous Dynocyst and Calcareous Nannofossil stratigraphy) methods.

According to pilot samples the section covers calcareous dinocyst zones from Late Oxfordian (Fibrata) to Early Tithonian age (Malmica), followed by succession of calpionellid zones from Chitinoidella Zone (Dobeni Subzone – late Early Tithonian) to Calpionella Zone (Elliptica subzone – late Early Berriasian).

Calcareous nannofossils have been studied from only few pilot samples. Both Czorsztyn and Pieniny limestone formations provided poorly preserved assemblages in which Watznaueriaceae quantitatively dominate and nannoconids are rarely found. For the time being, the study shows that *Favioconus multicolumnatus*, NJT14 Zone (Kimmeridgian; Casellato 2010) was recorded in 4.9 m, *Polycostella beckmannii*, NJT15b Zone (Tithonian) in 13.1 m and *Nannoconus wintereri*, NJT17b Zone (the uppermost Tithonian) in 25.9 m.

Natural remanent magnetization (NRM) values are higher in Kimmeridgian and Tithonian – parts of the section (up to 27.74 mA/m) and very low in Berriasian (0.096 mA/m). Magnetic susceptibility (MS) values show similar trend like NRM values as well as the MS values from other Tethyan sections (Grabowski 2011). Berriasian – part of the section indicates slightly negative or close to zero MS whereas Tithonian and older part of the section indicates higher MS values (Fig. 1). Thermal demagnetization was used for identification of primary component of magnetization.

Several authors have assigned mercury (Hg) enrichments in sedimentary rocks to volcanism adjacent to stratigraphy boundaries (Sial et al. 2016). Tracing the Hg content has potential to be a new testing tool of global volcanic activity (especially of large igneous provinces (LIPs)) close to J–K boundary. It may also associate (in case of Snežnica section) with volcanism in Velykyi Kamianets.

Submarine LIPs (from Tithonian to Berriasian age) are known from Pacific Ocean (Sager et al. 2016). Content of Hg was acquired on 60 pilot samples from Snežnica and show low (between 1–95 ng/g) Hg concentrations.

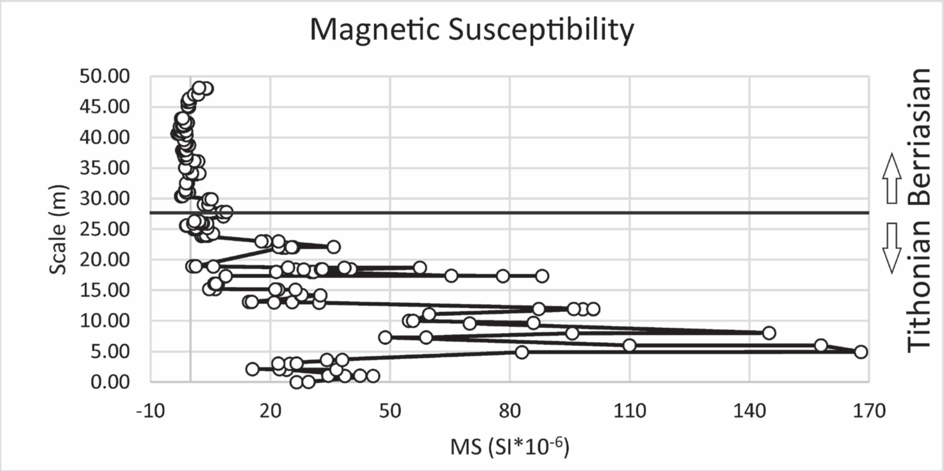

Fig. 1. The MS values from pilot sampling across the Snežnica section.

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Bajocian and Tithonian/Berriasian tectonic reorganizations in the northernmost part of the Western Tethys (Pieniny Klippen Basin case study) – paleoenvironmental and paleoceanographic repercussions

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In the northernmost part of the Western Tethys several tectonic events took place, which resulted in different kinds of sedimentary records in the Western Carpathians during Mesozoic time evolution. Good evidences of such events occur in the Pieniny Klippen Belt (PKB), very well documented by distinctive drastic change of facies, synsedimentary breccias, neptunian dykes, hard grounds, omission surfaces, condensed carbonates etc.

One of the most important geotectonic elements of the Pieniny Basin within Western Carpathians basins was the Czorsztyn Ridge (Swell), which originated during the Middle Jurassic (Early Bajocian) time. Paleogeographically it has been the main object which separated, between the Middle Jurassic to the Late Cretaceous times, two large Carpathians basins, the Magura Basin on NW side and the Pieniny Basin on SE side. The rapid change of sedimentation from dark shales of oxygen-depleted environments (*Fleckenkalk*/*Fleckenmergel*-type – Aalenian to earliest Bajocian) to overlying light crinoidal grainstones (Early/Late Bajocian transition) reflects so-called Krasín tectonic phase (according to Plašienka, 2018 with literature therein) of the Bajocian tectonic activity within Pieniny Basin very well, which corresponds with others Middle Jurassic Western Tethyan geodynamic reorganizations (e.g., Csontos & Vörös 2004; Golonka et al. 2006). The onset of the crinoidal sedimentation, perfectly dated biostratigraphically by ammonites (late Hebridica Subchron of the Propinquans Chrone of late Early Bajocian) was preceded by a marked stratigraphical hiatus, which covers the time interval of the Laeviuscula (may be even Discites) Chron and a bulk of the Propinquans Chron of the Early Bajocian (Krobicki & Wierzbowski 2004). This hiatus corresponds to the origin and uplift of the Czorsztyn Ridge and duration of this event can be calculated as ±2.0 Myr maximum (Krobicki 2018).

The next significant tectonic event within Pieniny Basin took place close to the Tithonian/Berriasian transition (J/K boundary) and is marked by the earliest Cretaceous (Berriasian – Calpionellopsis Chrone) synsedimentary breccia (so-called Walentowa Breccia Member – after Birkenmajer 1977) which is very widely distributed (from Polish sections up to Ukrainian part of the PKB). Sedimentation of this breccia coincides very well with uplift movements (Walentowa Phase – after Plašienka 2018) of the whole Czorsztyn Ridge (marked also significantly by change of brachiopod assemblages in this time as shallowing-upward event – Krobicki 1996) and perfectly manifested tectonically controlled origin of submarine scarps/cliffs and origin of synsedimentary tilted blocks and troughs.

Additionally, during these two tectonic events a special sedimentary condensation episodes originated (omission surfaces with ferruginous-manganese crusts, phosphatic concretions pavements and/or large phosphatic oncoids), the most probably as effect of change of oceanic circulation just after tectonic uplift, which induced very active upwelling currents along submarine part of the Czorsztyn Ridge (Golonka & Krobicki 2001).

Significantly, that during tectonic Neo-Cimmerian reorganization, in the Ukrainian part of the PKB (so-called Kamyanyi Potik Unit in Rakhiv vicinity and the Chyvchynian Mountains) huge volcano-sedimentary complex occur and is represented by: basalts (basaltic pillow lavas including), volcanic breccias of debris-flows (with blocks of the limestones and basalts) within volcanic/tuffitic matrix, peperites and coarse/fine-grained calcareous pyroclastic turbidites („pyroclastic flysch" as pyroclastic density currents – PDS in recent literature) (Hnylko et al. 2015). These associations were formed during the earliest Cretaceous times as calpionellid data indicate (Berriasian – Calpionellopsis Chrone).

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Early Jurassic (Pliensbachian) mangrove-type environments in the Albanian Alps

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In the Albanian Alps (so-called external Albanides, N of Shkodra) near state boundary with Montenegro, the continuous section with the Late Triassic–Early Jurassic carbonate deposits sequence is crop out (about 300 m in thickness). The Late Triassic rocks are represented by medium and thick-bedded dolomites intercalated by thin-bedded limestones of shallow-water Lofer-type facies. Still younger, the Early Jurassic part of section is represented by extremally shallow-water limestones and marly limestones (fenestrate limestones and/or tempestites) with several episodes of emersions with calcretes and fossil karst phenomena. *Lithiotis*-type huge bivalves, are concentrated in upper part of this Early Jurassic rocks (Pliensbachian in age). These bivalves (*Lithiotis*, *Cochlearites*, *Lithioperna*, *Mytiloperna*, *Gervileioperna*), which dominated within "*Lithiotis*" facies, are most significant representatives of buildup-maker of shallow marine/lagoonal bivalve mounds (reefs) in numerous places around the Pangaea during Pliensbachian–Early Toarcian time. They are worldwide distributed fossils, which occupied shallow-water shelfs of the south-western Tethys and easternmost part of the Panthalassa Ocean. 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. 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. Bivalve-rich limetsones /marls are intercalated by oolitic/oncolitic leyers which indicate shallow-water environments (subtidal?) with high-energy regimes. On the other hand, this sequence comprises several coal-bearing intercalations between intertidal carbonate rocks of full–marine–lagoonal–land transitional lithofacies. Alteration of ingressions caused in the coastal area floods resulting in flora devastation and dryness of different degree, sometimes effecting in swamp formation. There were several coastal cycles, and aired roots confirm occurrence of mangrove paleoenvironments. Some leaf remains have been collected: one of them from the genus *Pachypteris* (seed fern), the second, *Brachyphyllum* (conifer). Particular species of both genera were supposed to be adapted to salty substrate and/or salty mist. Based on their gross morphology and cuticular structure as well as on depositional environments in which usually reminded, they were interpreted as growing in coastal habitats which here could be confirmed by root systems. Generally, the localities with *in situ* fossil record of ancient mangroves are extremely rare due to their sporadic distribution over the world and very low fossilization potential in such high hydrodynamic shallow-marine environments. In our section several tempestite horizons occur just above of root-bearing deposits and indicate catastrophic events which “killed” mangrove-type plants which occupied near-shore environments.

A profile of the Callovian–Berriasian pelagic carbonates in the West Balkan Mts from the Serbian/Bulgarian border to the Iskar River Valley

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The pelagic carbonate sediments of Callovian to Berriasian age in the West Balkan Mts appear as largely cropping out “trinity” of the Yavorets (massive micritic limestones), Gintsi (pale-rose nodular limestones), and Glozhene (intraclastic and micritic platy limestones) formations. One group of sections located close to the Serbian/Bulgarian border includes the Rosomač in the eastern Serbia, and Barlya, Gintsi 1 and Ginsi 2 sections in the western Bulgaria. Another group involves the sections of Sarbenitsa, Bov, and Yavorets, located to the east on both sides of the Iskar River Valley. The three pelagic carbonate formations represent distinct sedimentary cycle of long duration and slow rate of sedimentation which has as lower and upper boundaries stratigraphic unconformities.

A calcareous dinocyst zonation in the section of Barlya consisting of the *C. fibrata*, *C. parvula*, *St. moluccana*, *C. borzai*, *C. tithonica*, *P. malmica*, *C. tenuis*, *C. fortis*, and *St. proxima* zones (Lakova et al. 2007) gave ground for assignment of the Yavorets Formation to the Oxfordian and lower Kimmeridgian, the Gintsi Formation – to the mid Kimmeridgian to lower Tithonian, and the base of the Glozhene Formation – to the lower Tithonian. Calpionellid zonation in the sections of Barlya and Gintsi (Lakova & Petrova 2013) includes the *Chitinodella* Zone with its lower *Dobeni* subzone (top lower Tithonian) in the top Gintsi Formation, *Boneti* Subzone, *Praetintinnopsella*, and *Crassicollaria* zones (upper Tithonian) in lower half of the Glozhene Formation, and *Calpionella* Zone with its *Alpina* and *Remaniella* subzones (lower Berriasian) in the upper part of the Glozhene Formation.

The successive *Bossitra* filamentous, *Globuligerina* – Radiolarian, *Saccocoma*, *Globochaete*, and calpionellid microfacies have been identified in the Callovian to Berriasian pelagic succession from the base up-section in Barlya (Lakova et al. 2007). These microfacies are highly correlatable with those described in the section of Veliky Kamenets in the Carpathians (Reháková et al. 2011).

The Tithonian and Berriasian of the Rosomač section has shown presence of transported platform microfossil within the pelagic limestones, thus suggesting a more proximal position in the basin compared to the Barlya section (Petrova et al. 2012).

The pelagic carbonate sedimentary cycle is covered by the hemipelagic limestone–marlstone alternation of the Salash Formaion of late Berriasian age (*Calpionellopsis* Zone). In the sections of Gintsi 1 Gintsi 2, the base of the Salash Formation is related to a stratigraphic hiatus spanning the mid-Berriasian *Simplex* Subzone and to a slight angular unconformity (Lakova & Petrova 2013), whereas in the section of Barlya this unconformity is quite hidden manifested only in the too short M17r magnetic subchron (Grabowski, unpublished data).

To the east, the section of Yavorets (Petrova et al. 2019, this volume) seemed to be rather similar to the Barlya section. The sections of Sarbenitsa and Bov (Petrova

2011) revealed the presence of terrigenous sediments such as sandstones and siltstones at the base of an atypical Salash Formation. The timing of terrigenous sedimentation was proved as mid-late Berriasian (*Simplex* Subzone of the *Calpionellopsis* Zone).

The Callovian–Berriasian pelagic carbonates were deposited in a basin which proximal part was to the west, around the Serbian/ Bulgarian border, and continued distally to the east (e.g., Yavorets area), where the terrigenous input after the end of this sedimentary cycle might suggest a close proximity of a turbiditic basin. Throughout the area, the end of pelagic carbonate deposition is somewhat coeval (*Simplex* Subzone in the mid Berriasian) and is normally followed by limestone–finely terrigenous accumulation of another cycle (the Salash Formation) characrerized by increasing of both the fine terrigenous input and rate of sedimentation.

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Progress on the non-marine Jurassic/Cretaceous boundary in northern China

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In China the well developed Jurassic and Cretaceous strata are mainly of non-marine origin (Xi et al. 2019). The previous definition of a non-marine Jurassic/Cretaceous (J/K) boundary in northeastern China was mainly based on the age assignment of the well-known non-marine Jehol Biota of eastern Asia. Although the *Eosestheria–Ephemeropsis–Lycoptera* bearing strata in China, Mongolia and Transbaikalia of Russia were originally assigned to Early Cretaceous in 1920s. The whole Jehol Group of western Liaoning of northeastern China, which contains the Jehol Biota in the lower and the Fuxin Biota in the upper, was revised to the Middle–Late Jurassic since early 1960s. This age revision was further supported by the recoveries of an alleged Bathonian (Middle Jurassic) *Arctocephalites* ammonite fauna and a Late Jurassic *Buchia* fauna from eastern Heilongjiang Province in middle 1980s. Since early 1990s, through the revisions of the above mentioned marine faunas of eastern Heilongjiang to Early Cretaceous (Sha 1992; Futakami et al. 1995), the Jehol Biota was re-assigned back to the Early Cretaceous by some authors. At the same time the recoveries of feathered dinosaurs, early birds, mammals and angiosperms from the Yixian and Jiufotang formations stimulated the interests to carry out the precise radiometric dating for the Jehol Group and its underlying strata in western Liaoning and northern Hebei. The new radiometric dating indicates that the non-marine J/K boundary in northern China would be delineated within the contemporaneous Houcheng (in northern Hebei) and Tuchengzi (in western Liaoning) formations, which are stratigraphically much lower than the Jehol Group of western Liaoning.

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Isotope (δ^{13}C, δ^{18}O) proxies for interpretation of sedimentation, climate and plankton evolution on the J/K boundary

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The J/K boundary has been well documented in the Brodno, Strapková and Snežnica sections situated in the Pieniny Klippen Belt (Slovakia). The more-or less continuous sequences of the Ammonitico Rosso and Maiolica facies are characterised with a “long term” carbon isotope trend without any CIE (carbon isotope excursions, see Michalík et al. 2009, 2016; Michalík & Reháková 2011). δ^{13}C values of the micrite matrix gradually decreased from values about +3 ‰ in Late Oxfordian to values around +1 ‰ in Late Tithonian and this relatively stable values prolonged over the whole Berriasian. In the Snežnica section, δ^{13}C data ranged between +1.013 to +2.040 ‰ (VPDB) confirming the δ^{13}C trend indicating decelerated sea water C-cycling (Weissert & Chanell 1989; Price et al. 2016) and documented in majority of sections of the Tethyan margin. Increase of the sea water temperature (approximately 2–4 °C) has been suggested on the base of the δ^{18}O trend in the J/K boundary interval in the Brodno and Strapkova sections (Michalík et al. 2009, 2016). However, these results from micrite matrix should be interpreted with a caution. Pelagic carbonate sediment largely derived from skeletons of planktonic organisms (e. i. nannofossils, calpionellids, etc.) and its original δ^{18}O content could be influenced by local conditions, especially by rate of precipitation and evaporitization of surface waters under Early Berriasian arid climate. Wider range (in span −6 to +1 ‰) and frequent changes of δ^{18}O values in the rock record seems to be the result of both sea-water salinity variations and short time sedimentary cycles during J/K boundary. The decrease of the δ^{18}O values from the Intermedia/Colomi boundary interval to the base of the Alpina Subzone indicates a warming trend. Large positive shifts of δ^{18}O values could reflect evaporation-related early diagenetic changes and short time eustatic fluctuations. Few short and one longer progressive increase of δ^{18}O values visible in the Alpina and Ferasini subzones may represent a slight cooling trend. Shifts of δ^{18}O composition could be also influenced by meteoric water in groundwater release from aquifers to basins during eustatic sea level drop (Price et al. 2016; Haq 2014). The δ^{18}O distribution in the sections suggested that large lateral variation of water salinity/composition could be expected.

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Magneto- and biostratigraphy of the Jurassic–Cretaceous transition in the Transdanubian Range (Hungary)

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A magneto- and biostratigraphic study of the Tithonian and Berriasian pelagic limestones has been performed in the Hárskút and Lókút sections (Transdanubian Range, Hungary). The sections are situated in different sedimentary zones of the Transdanubian Range unit and reveal clearly distinct lithologic record. Combination of the magneto- and biostratigraphic (calpionellids, nannofossils, ammonites) methods allowed their precise correlation. Stable carbon isotope ($\delta^{13}C$) data is under investigation.

Recently excavated Lower Berriasian interval of the Lókút section (see Grabowski et al. 2010), with c.a. 8 meters of monotonous Maiolica-type limestones with cherts, starts at the top of the Grabowski et al. section, in the *Calpionella alpina* Subzone (top of the M19n magnetozone). Magnetostratigraphic research revealed few inversions of the magnetic polarity, interpreted here as a record from the top of M19n up to the M17n magnetozone, the latter within the *Calpionella elliptica* Subzone.

The Hárskút section, composed of two outcrops referred in the literature as the HK-12 and HK-12/a sections (see e.g. Főzy et al. 2010), revealed c.a. 16 m of the Lower Tithonian–Lower Valanginian succession. The rock record starts with the Ammonitico Rosso-type limestone, most probably in the M22n magnetozone (Lower Tithonian). Numerous magnetic polarity inversions, including the sequence of excursions within the lowermost part of M22n magnetozone (see Ogg et al. 2016) have been found. The succession becomes less nodular (to pelitic) upwards and continues up to the M14r magnetozone (Lower Valanginian). Calibration of magnetic stratigraphy with the biostratigraphic scheme and the Geologic Time Scale was performed based on abundant ammonite data; micro- and nannofossil stratigraphy is in progress.

Thermal demagnetization was applied as the most efficient in isolating the paleomagnetic components. Although the sections were partially remagnetized, specimens retained a primary magnetization of mixed polarity (see Fig. 1). Both, the primary magnetization and the normal polarity Cretaceous overprint reveal ca. 60–80 degrees counterclockwise rotation, in accordance with the previous paleomagnetic studies in the Transdanubian Range (see e.g. Márton & Márton 1981). Diversity in the magnetic mineralogy between studied sections has been observed – Hárskút section is characterized by a contribution of hematite whilst in Lókút magnetite is the only magnetic carrier (see also Fig. 1).

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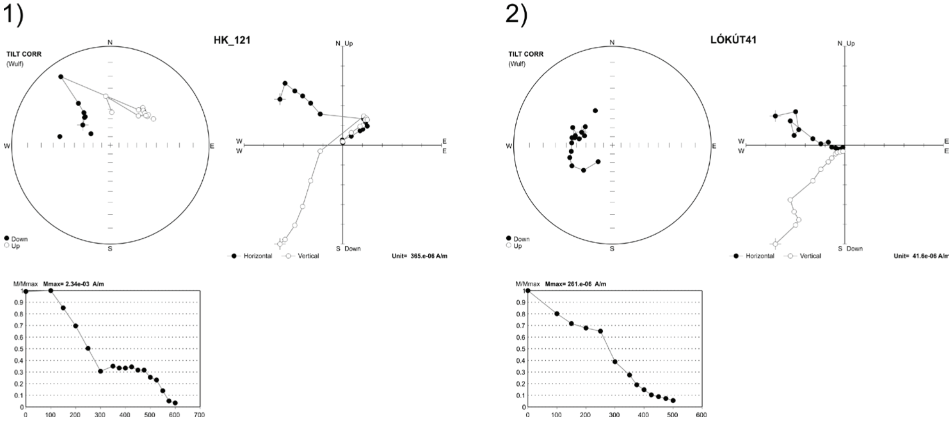

Fig. 1. Thermal demagnetization of typical specimens from studied area. 1) Reversed polarity sample from Hárskút section (left diagram) and 2) normal polarity sample from the Lókút section (right diagram). Upper left: stereographic projection of demagnetization path (after tilt correction); upper right: orthogonal projection of demagnetization path (after tilt correction); lower left: natural remanent magnetization (NRM) decay curve during thermal treatment. Hárskút NRM decay curve indicates hematite as a magnetic carrier (unblocking temperatures 600 ˚C and more), in turn Lókút NRM decay curve points to magnetite as a magnetic carrier (unblocking temperatures around 500 ˚C).

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Neptunian dykes and other symptoms of syndepositional tectonic activity in the High-Tatric Lower Jurassic, Tatra Mountains, Poland

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Best described and well known Jurassic neptunian dykes of the High-Tatric series (Tatricum) in the Tatra Mountains are those filled with the Bajocian and Bathonian sediments and penetrating the Triassic of the allochthonous Czerwone Wierchy and Giewont units (Łuczyński 2001). In these units various Middle Jurassic formations (Smolegowa Fm Krupianka Fm and Raptawicka Turnia Fm) discordantly rest with a significant stratigraphic gap on the Middle Triassic substrate (Łuczyński 2002; Jezierska & Łuczyński 2016). In contrast to that, in the paraautochthonous Kominy Tylkowe Unit, the sedimentation across the Triassic/Jurassic boundary is generally continuous, and the Lower Jurassic is represented by the Dudziniec Formation, which is developed in a wide range of sandy-carbonate facies (Jezierska et al. 2016). Recently, neptunian dykes that penetrate several horizons of this formation have been described from the Kościeliska Valley (Łuczyński & Jezierska 2018).

The Sinemurian to Aalenian Dudziniec Formation is represented by mixed carbonate-clastic deposits, ranging from sandstones to crinoidal limestones. The sedimentary development and facies distribution was governed mainly by synsedimentary tectonic activity and by distance from alimentation areas. The sandy facies represent periods of block-faulting and tectonic instability, while the carbonate crinoidal facies correspond to episodes of deposition in relatively stable conditions. The Kościeliska Valley region, in which the described neptunian dykes occur, is located in the eastern part of the autochthonous unit representing a shallower and a more proximal part of the basin than the areas located further west. Seven main lithofacies (lithological varieties) have been distinguished in the studied sections, based on such attributes as: lithology, microfacies, colour, occurrence of sedimentary structures, composition, and the size and sorting degree of extraclasts and intraclasts. Microfacies determinations were done according to a combination of different classifications applied to mixed carbonate-clastic rocks (Jezierska & al. 2016).

The neptunian dykes are hosted by pink/grey/white hybridic limestones (sparry-hybridic arenites) and by pink/purple sandy-conglomeratic limestones (silicidoloclastic-bioclastic wackestones) occurring in the lower parts of the exposed sections (Łuczyński & Jezierska 2016). The summarized thickness of the two facies is around 12 m, with dykes evenly distributed and not following any particular horizons. No dykes have been found higher in the sections, and no internal discontinuity surface within the Dudziniec Formation, from which the dykes would penetrate downwards, has been identified. Based on their distribution, and relation to the hosting rocks, the dykes are most probably of Sinemurian to Pliensbachian age.

Neptunian dykes penetrating the Dudziniec Formation are filled with various types of deposits: variously coloured pelitic limestones (calcilutites) and fine calcarenites, and red ferruginous calcareous sandstones (hybridic arenites). The dykes show a whole array of irregular shapes, and in several places the host-rock is so densely cut by a network of cross-cutting dykes filled with various sediments that it has an appearance of an internal breccia. In many cases different types of infillings co-occur in particular systems of interconnected dykes. The development of the fissures took place in multiple stages and the infilling deposits came from multiple sources. The sandy varieties came directly from the host rocks or from loose sediments present on the sea bottom at the time of fracturing. The fine carbonate internal deposits most probably came from the neighbouring uplifted and corroded carbonate massifs. Products of weathering, both in dissolved form and as small particles, were washed into the sedimentary basin of the autochthonous unit, and redeposited within the dykes.

The described neptunian dykes are yet another indication that the sedimentary development of the Lower Jurassic sandy-carbonate facies in the autochthonous unit of the Tatra Mountains was strongly influenced by synsedimentary tectonic activity, such as block-faulting. The distribution of Jurassic neptunian dykes in the High-Tatric succession is limited neither to the foldic and parautochthonous units nor to the Triassic as the host rocks. The relatively rare occurrence of dykes in the Dudziniec Formation of the "autochthonous" unit is probably caused by different mechanical properties of the poorly bedded coarse-grained sandy crinoidal rocks as compared to the well-bedded Triassic limestones and dolomites.

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Excellently-preserved earliest Cretaceous radiolarian fossils from the Marian Trench and their application to outreach activities: Calendar and playing cards

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A calendar (Fig. 1) and a set of playing cards using scanning electron microscope images of radiolarian skeletons are prepared for enhancing a degree of social recognition of radiolarians. The radiolarian fossils come from a single rock sample of earliest Cretaceous (Berriasian) tuffaceous clyey radiolarite collected during a dive of the submersible „Shinkai 6500" along the outer slope of the Mariana Trench (Ogawa et al. 1994). The sample contains more than 400 radiolarian species belonging to the gernera *Alievium, Archaeodictyomitra, Cinguloturris, Complexapora, Crococapsa, Doliocapsa, Emiluvia, Eucyrtidiellum, Hemicryptocapsa, Hsuum, Loopus, Mirifusus, Mesovallupus, Neorelumbra, Pantanellium, Protovallupus, Protunuma, Pseudodictyomitra, Ristola, Spinosicapsa, Tethysetta, Thanarla, Valupus, Xitus* and *Zhamoidellum* (Matsuoka 1998). Candidates of marker taxa defining the Jurassic–Cretaceous boundary can be found in the fauna.

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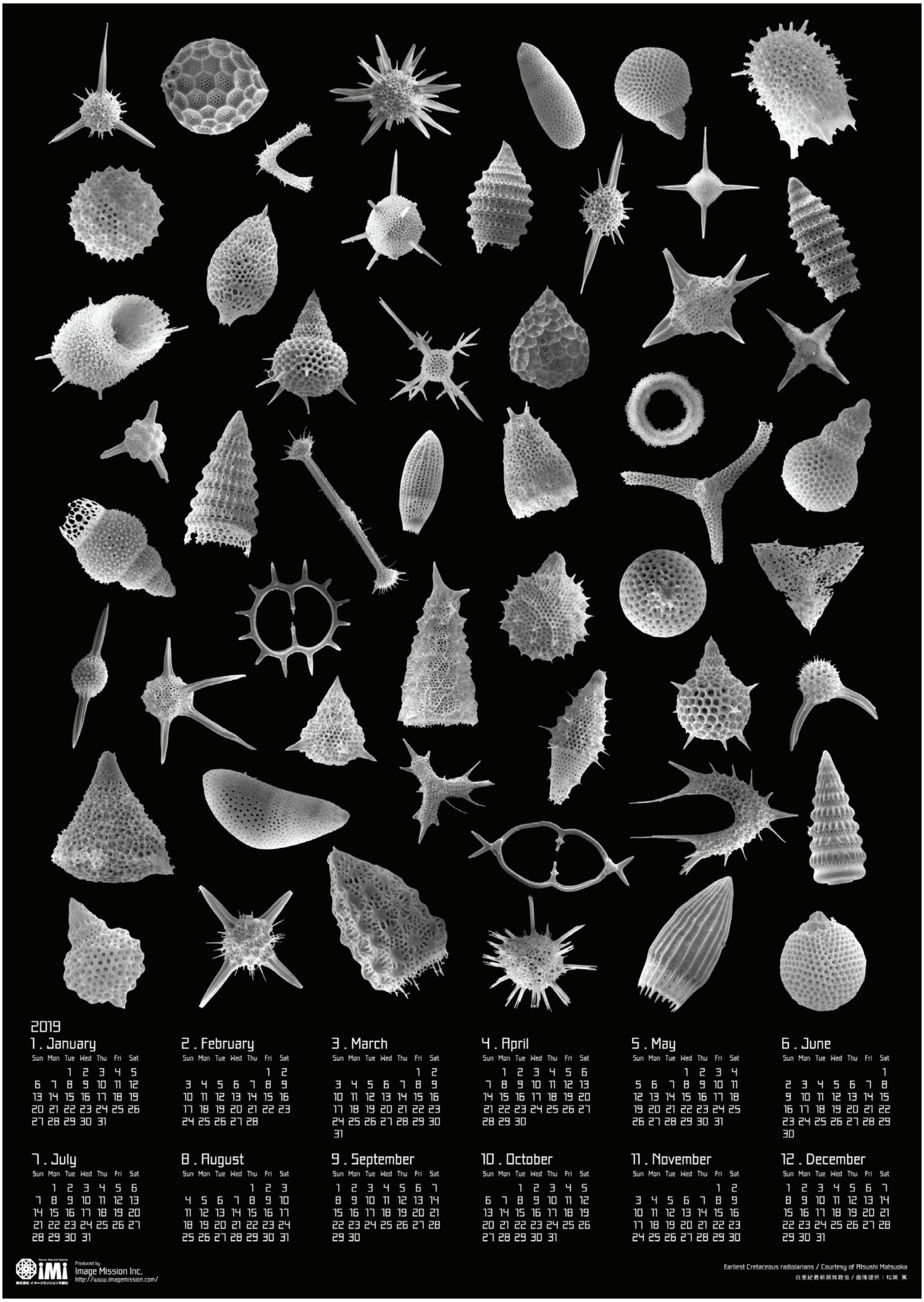

2019

1. January

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

2. February

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28		

3. March

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

4. April

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
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14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

5. May

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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19	20	21	22	23	24	25
26	27	28	29	30	31	

6. June

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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9	10	11	12	13	14	15
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23	24	25	26	27	28	29
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7. July

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
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21	22	23	24	25	26	27
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8. August

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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18	19	20	21	22	23	24
25	26	27	28	29	30	31

9. September

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

10. October

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
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20	21	22	23	24	25	26
27	28	29	30	31		

11. November

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

12. December

Sun	Mon	Tue	Wed	Thu	Fri	Sat
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8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

Fig. 1. Calendar of 2019 using scanning electron microscope images of earliest Cretaceous (Berriasian) radiolarian fossils from the Mariana Trench.

Radiolarian phylogeny around the Jurassic–Cretaceous boundary and radiolarian biostratigraphy in the Bosso Valley section, central Italy

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Radiolarians are good candidates for defining the Jurassic–Cretaceous boundary (JKB) because they are wide spread and can be found in both shallow and deep sedimentary facies worldwide. Radiolarian-bearing pelagic sequences across the JKB have been reported in ODP/IODP sites in the western Pacific and land sections in Japan, the Philippines, southern Tibet, Iran, Oman and others. Evolutionary lineages of several radiolarian taxa across the JKB are reviewed and suitable bioevents, which are approximate to the JKB, are presented. These lineages include the radiolarian genera: *Alievium, Archaeodictyomitra, Cinguloturris, Complexapora, Crococapsa, Doliocapsa, Emiluvia, Eucyrtidiellum, Hemicryptocapsa, Hsuum, Loopus, Mirifusus, Mesovallupus, Neorelumbra, Pantanellium, Protovallupus, Protunuma, Pseudodictyomitra, Ristola, Spinosicapsa, Tethysetta, Thanarla, Vallupus, Xitus* and *Zhamoidellum*. Among them the *Loopus–Pseudodictyomitra* lineage, *Protovallupus–Mesovallupus–Vallupus* lineage, *Eucyrtidiellum* lineage, *Cingulotturis* lineage and *Complexapora* lineage are promising phylogenies for defining the JKB.

As discussed by Goričan et al. (2018), the evolutionary first appearance datums (FADs) within firmly recognized lineages are extremely valuable. The *Loopus–Pseudodictyomitra* lineage is more advantageous than the *Protovallupus–Mesovallupus–Vallupus* lineage because the former has a much wider paleobiogeographic distribution than the latter. Applying to the so far established radiolarian zones, the JKB lies within the Unitary Association Zone 13 of Baumgartner et al. (1995) and within the *Pseudodictyomitra carpatica* Zone of Matsuoka (1995). The base of the *Pseudodictyomitra carpatica* Zone is defined by the evolutionary FAD of *Pseudodictyomitra carpatica*. Detailed morphological analysis of *Loopus* and *Pseudodictyomitra* species is presented and the relationship between the JKB and speciation within the lineage is discussed.

The Bosso Valley section in Umbria–Marche, central Italy, is one of potential candidates for GSSP of the JKB. The Maiolica

Formation, which crosses the JKB, is characterized by whitish, beige to gray colored, well-bedded micritic limestones with abundant black to gray chert layers and nodules. Calpionellid stratigraphy and magnetostratigraphy have been studied sufficiently in the section (Housa et al. 2004). The base of the *Calpionella alpina* Subzone, i.e. the calpionellid-based JKB, is placed between Beds 77 and 78 (Housa et al. 2004). We are carrying out detailed field observations and careful sample collections in a 5 m interval across the JKB. Acid-etched examination of rock samples revealed that well-preserved radiolarians are recognized inside the lime part near the chert layers or nodules. The results of our radiolarian biostratigraphic study in the Bosso Valley section are presented.

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Record of the Toarcian Oceanic Anoxic Event in a hemipelagic carbonate system: a study from a new section in the Western Carpathians

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The Toarcian Oceanic Anoxic Event (T-OAE or Jenkyns event) was one of the most severe environmental perturbations of the Mesozoic Era coupled with second order mass extinction, anoxia, carbon cycle perturbation and marine calcification crisis. However, the impact of these phenomena, especially the calcification crisis is still poorly understood. In the NW Tethyan pelagic carbonate shelf, the scarcity of suitable sections to study has hindered reconstruction of regional and global changes. Here we report new geochemical and paleontological data from Skladana Skala, a section in the Western Carpathians in central Slovakia, composed of thick series of carbonate rich sediments, marls and marly limestones ($CaCO_3$ from 40 to 80 %) covering the Upper Pliensbachian–Lower Toarcian, where 60 cm thick pyritic black shale intercalation represents the T-OAE. Carbon isotope records ($\delta^{13}C_{carb}$ and $\delta^{13}C_{TOC}$) are indicating a short negative excursion at the Pliensbachian–Toarcian transition and above a broad positive excursion in the Lower Toarcian interrupted by a sharp negative excursion recorded only in the $\delta^{13}C_{TOC}$ with very low values (~31 ‰), restricted to the black shale unit. At this black shale level TOC reaches 2–3 % (compared to a background of ~0,3 % TOC) and $CaCO_3$ content decreases significantly to 3–7 %. Ammonite biostratigraphy indicates the presence of Serpentinum Zone, the Exaratum Subzone for the black shale unit and the Falciferum Subzone above. Calcareous nannofossils are almost completely absent in the Upper Pliensbachian and lowermost Toarcian at Skladana Skala, but higher up, above the T-OAE they appear with fairly high diversity, allowing to identify the boundary between NJT6 and NJT7 nannozones. The last occurrence of *M. jansae* (11.70 m) matches with the end of the carbon isotope event (CIE) corresponding to the T-OAE, as observed in other Tethyan areas. Above the T-OAE interval, nannofossils assemblage documents the recovery of environmental conditions (from 12.30 m) and they appear to be primary carbonate producers as suggested by the matching pattern of calcium carbonate content and the number of individuals. Trace fossil assemblages are indicating significant changes in oxygen availability on the seafloor. A trend towards oxygen depletion above the Pliensbachian–Toarcian transition can be assumed, with a total absence of bioturbation in the black shale unit. Above the T-OAE trace fossil diversity becomes fluctuating and still indicating low oxygen levels. Results suggest that carbonate systems suffered a significant setback during the T-OAE in the Western Carpathians which might reflect a more widespread crisis that affected the hemipelagic-pelagic carbonate systems in the NW Tethyan shelf. Although direct evidence is still lacking, we speculate that a combination of effects of global warming, ocean anoxia and acidification explain the observed phenomena.

Stratigraphy of Middle Jurassic to basal Cretaceous foraminiferal facies reflecting hyposaline and hypoxic waters on the mid-Norwegian shelf

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On the mid-Norwegian shelf the Bajocian to Ryazanian Melke and Spekk formations contain a continuous foraminiferal succession consisting almost entirely of agglutinated taxa. These are analysed in sample material mainly from the commercial well 6610/7-1 drilled in the Helgeland Basin on inner part of the shelf. The foraminiferal assemblages are applied to development of a zonal scheme and environmental assessments based on species diversities, morphogroup distribution and faunal similarities combined with sedimentary proxies as TOC, gamma activity and calcium carbonate content.

In Mesozoic times the mid-Norwegian shelf formed the eastern part of a narrow sedimentation area subsiding along faults between Norway and Greenland. The sedimentary succession deposited on the shelf from Lower Jurassic to lowermost Cretaceous reveals an upward increasing marine influence from fluvial, through marginal marine to offshore shelf facies with oxygen depletion in the final stage. The seaway that developed during this process connected the Boreal Ocean with the Tethys.

The changing foraminiferal succession of well 6610/7-1 allows distinguishing of 7 interval zones (5 in Melke and 2 in Spekk formation) with age assessments, in ascending order: *Recurvoides* aff. *pachyspirus* Zone, Bajocian; *Riyadhella sibirica* Zone, Bajocian-Bathonian; *Riyadhella shapkinaensis* Zone, Bathonian; *Recurvoides scherkalyensis* Zone, Callovian-Early Oxfordian; *Glomospirella otorica* Zone, Kimmeridgian; *Recurvoides praeobskiensis* Zone, Volgian; *Trochammina* aff. *annae* Zone, Volgian-Ryazanian.

Quantitative comparison of the mid-Norway foraminiferal faunas with those of the Boreal Realm, particularly Western Siberia, Spitsbergen, and the Canadian Arctic Archipelago reveals close similarities. Typical features of these faunas are the entirely or dominantly agglutinated composition, low species diversity and taxonomic endemity, which are explained by calcium carbonate depletion, reduced salinity and tendency to hypoxia. High degree of similarity with the mid-Norway assemblages indicates impact of Boreal conditions on the mid-Norway shelf through the open seaway between Greenland and Norway.

The low diversity virtually agglutinated nature of the Melke Formation faunas reflects the effects of restricting factors (Fig.1). Through the main body of the formation (2609–2336 m), morphogroup analysis demonstrates that the surficial and infaunal groups occur in almost equal quantities suggesting that the redox boundary was located below the sediment-water interface implying that the bottom waters were oxygenated, as also suggested by the low gamma activity. Hyposaline conditions are assumed as the main restricting factor which is in accordance with extremely low carbonate content. In addition, the boreal impact might have amplified these local developments. In the upper part of the Melke Formation (2330–2318 m) reduced infaunal and expanded surficial morphogroups signal increasing hypoxia.

The organic-rich black shales of the Spekk Formation with high gamma readings contain extremely low diversity agglutinated assemblages. The surficial morphogroup composed almost entirely of small-sized *Trochammina* is heavily dominant, indicating that the redox boundary coincided with the sediment-water interface overlain by hypoxic water. This required a thermohaline-stratified water column created by supposed freshwater influx from western sources and accentuated by boreal impact.

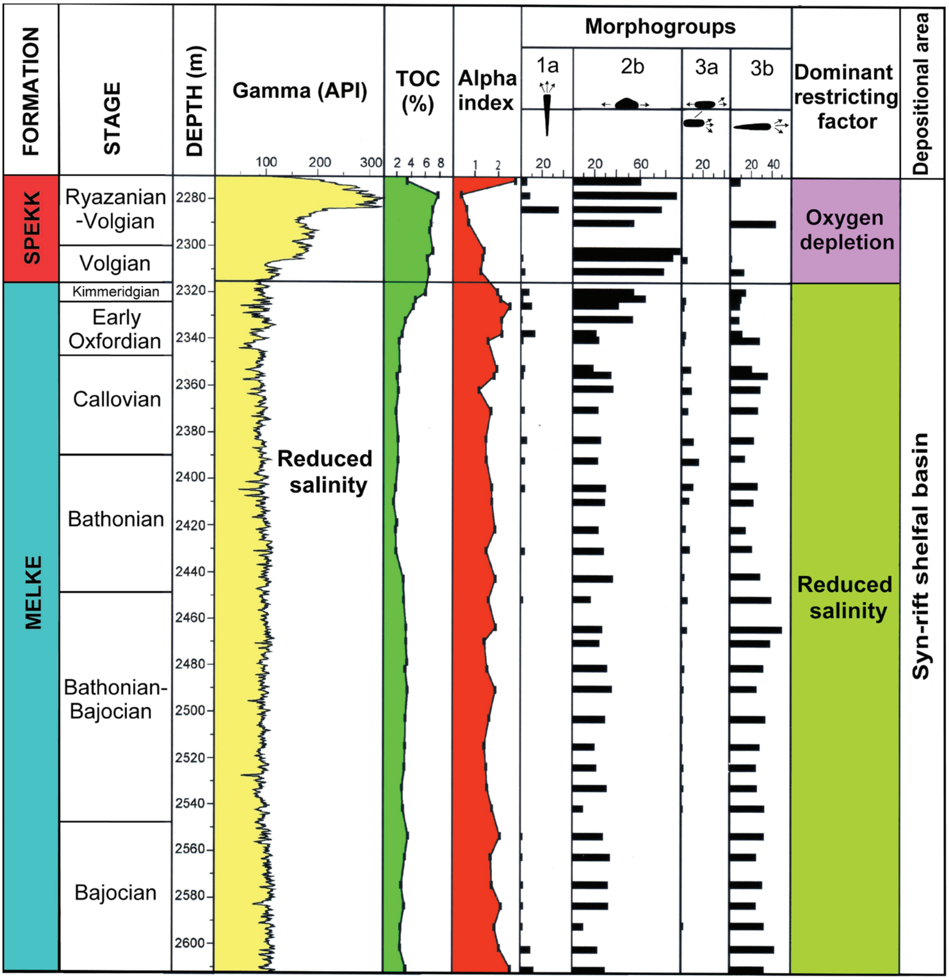

Fig. 1. Summary graph comparing lithological and foraminiferal proxies to reflect environmental conditions from Bajocian to Ryazanian, well 6610/7-1 on the mid-Norwegian shelf.

A relationship between carbon-isotopes and soil carbon – a tool for temperature estimates in the Rhaetian and Early Jurassic

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Decreasing carbon isotope ratios in Earth's surface carbon reservoirs testify to a radical reduction of the terrestrial carbon pool as a response to climate warming, in contrast to enhanced carbon storage caused by nutrient supply and eutrophication in coeval open marine environments. Temperature estimates in deep geological past are often controversial, they are almost entirely based on $\delta^{18}O$ analyses in calcium carbonate (mostly fossils). Here we show carbon isotope and organic matter (Total Organic Carbon – TOC) response to climatic changes and inferred paleotemperature estimates from the fully cored Kaszewy 1 borehole located in central Poland, which yielded 980 m of continuous core, of which 112 m belongs to the Rhaetian and 782 m to the Lower Jurassic. New carbon-isotope data obtained from homogenous organic material (separated wood – $\delta^{13}C_{wood}$) allowed chemostratigraphical correlation with the biostratigraphically constrained Mochras profile (UK), supported by sequence stratigraphic correlation and biostratigraphical proxies. Continental Total Organic Carbon (TOC_{cont}) concentrations in the Polish succession are strongly positively correlated with $\delta^{13}C_{wood}$ values (r=0,6 – expotential correlation in statistically significant number of 225 samples). In contrast, 23 samples containing significant amounts of marine kerogen show a weak negative correlation (r=−0,2) and were not taken into further consideration. Changes to the terrestrial carbon reservoir and TOC_{cont} content during the Rhaetian–Early Jurassic times are hypothetically related to temperature changes and enhanced decomposition of terrestrial carbon pool during hotter periods, caused by microorganisms (mainly fungi). Given the $\delta^{13}C_{wood}$ /TOC_{cont} function and assuming that higher content of light ^{12}C isotope reflected additional CO_2 in the latest Triassic/Early Jurassic atmosphere and higher temperature, an approximate estimation of the annual mean air temperature changes for c. 40°N paleolatitude, spanning over 25 Mya of the latest Triassic–Early Jurassic time, is attempted. Approximate absolute temperature scale of the carbon isotope values/continental TOC content plot of the Kaszewy profile was calibrated based on the stratigraphically well constrained paleotemperature proxy of oxygen isotope values from benthic invertebrate fossils in marine deposits in UK and Portugal (corrected for air temperature by adding 5 degrees). Accuracy of these estimations depend on the position of a given sample against the trend line. Weaker correlation in Rhaetian deposits is explained by local environmental factor (TOC concentration dependent on a more localized fluvial plain settings), while mostly deltaic–coastal deposits contain more representative, averaged material delivered from a large catchment area. Approximate average air temperature through the Rhaetian and Early Jurassic ranged from some 19 °C to 30 °C. The observed trend of interpreted temperature changes is generally in concordance with pCO_2 trends calculated from stomatal index.

Paleomagnetism and integrated stratigraphy of the Jurassic–Cretaceous transition in the Kurovice and Štramberk sections, Outer Western Carpathians, Czech Republic: contribution to paleogeographic evolution

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The definition of Jurassic–Cretaceous (J–K) boundary is still not fully established and it is the last system boundary without a GSSP. Conclusions on the calibration of calpionellids, magnetostratigraphy, ammonites and nannofossils define a base of the Berriasian stage using *C. alpina* within the magnetic subchron M19n.2n (Wimbledon 2014). Recently, we were able to compare magnetostratigraphy of several studied sections and demonstrated that the J–K sections in the sub-Boreal Realm can be correlated with the Tethyan ones. Currently, we finished detailed study of the localities Štramberk and Kurovice (Czech Republic; Elbra et al. 2018; Vaňková et al. submitted).

The Kotouč Quarry near Štramberk, known from the 19th century as an important paleontological site, was considered to be one of the potential J–K transition sections. Rock magnetic measurements indicate the presence of magnetite (carrier of characteristic remanent magnetization – ChRM) and goethite. Magnetozones M18r (section A and lower part of section B) and M18n (top half of section B) were found. The overall paleolatitude suggests 33°N (± 3 deg) position.

Kurovice J–K section comprises of Kurovice limestones and overlying Tlumačov marlstones in medium to thick beds. Rock magnetic results suggest presence of magnetite (carrier of ChRM), goethite and/or hematite. The section spans from chron M21r to M17r. The magnetostratigraphy was supported by calpionellid and nannofossil distribution (Fig. 1). Increased abundance of sphaerical species of *Calpionella alpina* Lorenz was observed along the J–K boundary interval in the magnetosubzone M19n.2n. Slighty below this bioevent, the first occurrence of calcareous nannofossil species *Nannoconus wintereri* was recorded. The value of the virtual geomagnetic pole calculated for tilt corrected data is Plat=13.2°N, Plon=7.4°W (Elbra et al. 2018). This primary Tithonian/Berriasian mean paleomagnetic direction is counter-clockwise rotated, compared to the expected European reference directions, by about 150° and is in agreement with that obtained from the Brodno section (Houša et al. 1999). Conversely, clockwise rotation was recorded from the Tatra Mountains in Poland (Grabowski et al. 2010). The rotations were interpreted as the result of tectonic NW movement of the Western Carpathians from the domain of the Alpine collision. A specific distribution of paleomagnetic pole positions for rocks of the same age motivated a formulation of a theoretical model simulating paleotectonic rotation of rock assemblages about vertical axis. The direction of Kurovice section indicates paleolatitude of ca. 24°N (± 4 deg).

Paleolatitude for both sections is in good agreement with data given by other authors for nearby localities.

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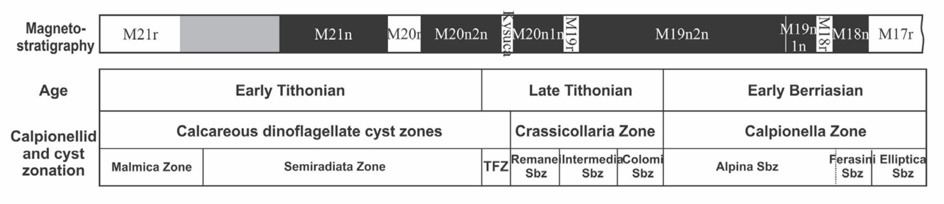

Fig. 1. The magnetostratigraphy, calpionellid and nannofossil distribution of Kurovice section (modified after Svobodová et al. 2019).

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Calpionela alpina Event on the J/K boundary

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Genus *Calpionella* reveals a large diversity of the sizes and proportions of lorica, which can be documented through time, as well as in co-occurring assemblages. Changes in morphological parameters of *Calpionella*loricae at the J/K boundary – previously declared by Nowak (1971), Borza (1984), Remane (1986) and later verified numerically by Lakova (1994) – were observed by all specialists studied the calpionellid succession in this time interval (see Kowal-Kasprzyk & Reháková 2019).

A detailed biometric study of the calpionellid assemblages of samples from the Polish Outer Carpathians, Brodno (Slovakia), Le Chouet (France), section Z at Río Argos (Spain), and Strapkova (Slovakia) were recently prepared (Kowal-Kasprzyk & Reháková 2019).

In the mid late Tithonian – Intermedia and Brevis subzones of the Crassicollaria Zone – the morphology of *Calpionella* was strongly diversified: small spherical (typical *C. alpina*), large (*C. grandalpina*) and elliptical (*C. elliptalpina*) loricae can be observed. It is an interval of the largest diversification of *Calpionella*. Their sizes vary between 40–50 µm and 100 µm, means/medians are diversified in individual assemblages (65–80 µm) and mean ellipticities are larger than 1.

In the latest Tithonian – the Colomi Subzone of the Crassicollaria Zone – a trend of diminishing lorica size is noted. It seems that discussed change in calpionellid size and morphology is rather gradual than rapid.

The J/K boundary interval is characterized by a distinct unification of *Calpionella* morphology, including the domination of small and medium-sized spherical forms. Sizes are relatively uniform in all of the studied assemblages (means/medians 60–65 µm with relatively small standard deviations), and mean ellipticities are slightly lower than 1.

The obtained results can provide statistical support for the current definition of the J/K *Calpionella alpina* Event. It is characterized by a decline of large *Calpionella* specimens (*C. grandalpina* Nagy), the disappearance of elliptical *Calpionella* specimens (*C. elliptalpina* Nagy), the last occurrence of *Crassicollaria brevis* Remane and *Crassicollaria massutiniana* (Colom), and increase in the relative abundance of small spherical forms of *Calpionella alpina* (see Kowal-Kasprzyk & Reháková 2019).

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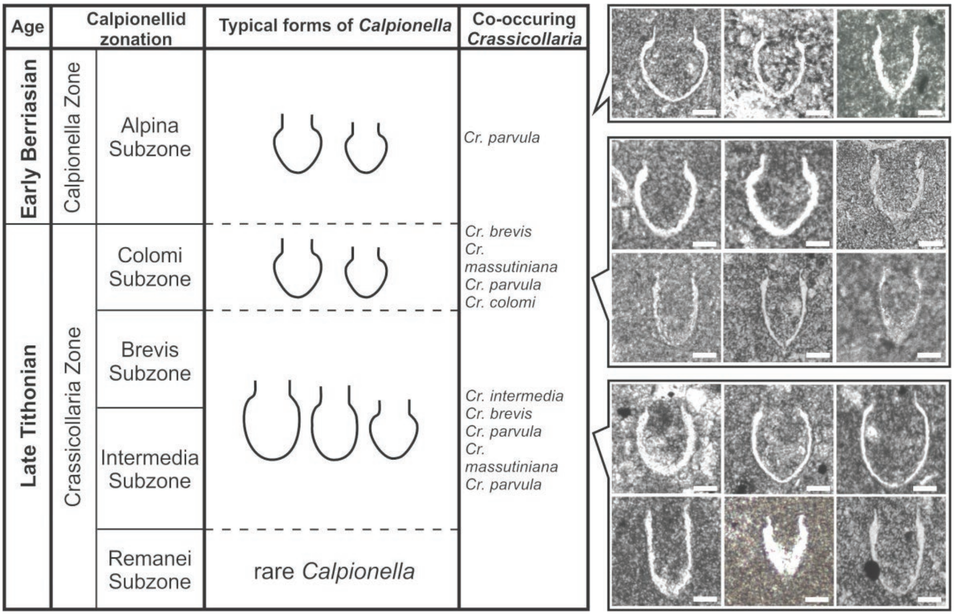

Fig. 1. Typical forms of *Calpionella*and typical calpionellid assemblages in the Crassicollaria Zone and the J/K boundary.

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Jurassic Sedimentary Evolution of the Alpine-Dinaric Transition Zone: a time for an overview?

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The Alpine-Dinaric transition zone is marked by three large-scale Mesozoic paleogeographic units that were established in the Upper Triassic, after the main rifting of the Neotethys. On the south, the Dinaric (Friuli, Adriatic) Carbonate Platform (DCP) lies entirely within the Dinarides. Towards the north it passes into approximately E–W extending (present-day coordinates) Slovenian Basin (SB) that is situated mostly within lowermost Southalpine nappes, but occurs also within Dinarides. On the north, Julian Carbonate Platform (JCP) composes the major rock-mass of the eastern Southern Alps. Limited outcrops of two deep-marine units of not entirely resolved paleogeographic positions, Bovec (BoB) and Bled (BlB) basins, are structurally emplaced within JCP successions. SB wedges out towards west, whereas towards east all units are covered by Paratethys sediments. In last two decades the extensive research was done in Jurassic successions of these units, which enriched insight into sedimentary evolution of the region.

The crisis of the Triassic/Jurassic boundary is manifested on the JCP margin, where barrier reefs are replaced by ooidal shoals. The general opening of sedimentary environments is recorded also in inner parts of both platforms (please note that DCP margin is not preserved). In the SB this is reflected in alternation in composition from bioclastic to ooidal calciturbidites, but limestone breccias and evidences of synsedimentary slumping, faulting and block tilting indicate that environmental crisis was accompanied with pulse of accelerated subsidence. Relatively uniform conditions are observed until Pliensbachian. Namely, during this period ooids are shed to the SB almost exclusively from the north-lying JCP, which could be attributed to wind-driven, shallow-water currents on both platforms.

Main Jurassic change occurs towards the late Pliensbachian, when new extensional pulse disintegrates JCP. Particularly at the platform margin neptunian dykes are formed and ooidal limestone is replaced by bioclastic deep-shelf limestone. Upwards, the major drowning unconformity occurs and it is often characterized by Fe-Mn crusts. It is further overlain by Toarcian marl-rich sediments. The deepest drowned part of the JCP turns into BoB. In the central, less subsided part of the JCP, this interval is marked by a prominent gap. In the SB, the initial deepening of the JCP is reflected in a change in composition of calciturbidites from ooidal to crinoidal/lithoclastic. The overlying Toarcian marls vary greatly in thickness therefore indicating differentiated block-subsidence of the basinal floor. In the BlB that was deep-marine already since the Triassic, extension is documented in large synsedimentary slump. These events are less expressed on the DCP, where during the Toarcian transgression some deep-marine limestones were deposited, but shallow-water conditions were soon re-established.

In the Bajocian the central JCP turns into pelagic plateau known as Julian High that is almost until the end of Jurassic characterized by ammonitico rosso facies. Simultaneously, the SB successions changes from high-siliceous limestone to radiolarian chert. In the southern part of the SB as well as in the BoB pelagites alternate with oolitic calciturbidites that are shed from the DCP, the latter being dominated by wide ooidal shoals during the entire Middle Jurassic. Detailed studies of the southernmost SB margin, however, show that the DCP-SB transitional zone experiences another (Bajocian–Bathonian) tectonic pulse. It results in prominent collapses and south-ward retreat of the DCP margin. These collapses produce limestone megabreccias composed of Upper Triassic, Lower and early Middle Jurassic platform-margin and slope lithoclasts.

The Upper Jurassic of the DCP margin is marked by a short (early Oxfordian) deepening followed by establishment of wide barrier reef. During this period north-lying basins are starved from resediments and pelagites prevail. The mid-Kimmeridgian emergence of the DCP diminishes the reef and massive limestone is replaced by bedded end-Jurassic ooidal limestone, often accompanied with micritic limestones with algae. This change is documented in the reoccurrence of sporadic calciturbidites in the southern part of the SB. In all paleogeographic units of the eastern Southern Alps a rapid change to calpionellid-bearing Biancone limestone is dated to the Late Tithonian. This characteristic facies indicates uniform sedimentary conditions and generally levelled paleotopography across the entire region.

Ammonite biostratigraphy of the Upper Pliensbachian and Toarcian of the new TOAE section Skladaná skala from Central Carpathians

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The Skladaná skala section (Fatric Unit) in the Malá Fatra Mountains is a single section in the Central Western Carpathians where the Toarcian Oceanic anoxic event is preserved. All other sections tend to be condensed and do not preserve any organic-rich sediments of the Early Toarcian age. The section consists of relatively deep-water marls and limestones of the Allgäu Formation, deposited during the Sinemurian–Toarcian in a subbasin of the Zliechov Basin. This subbasin passed in the southern direction into a structural elevation with the deposition of oncoidal, crinoidal and nodular limestones (Mišík & Rakús 1964). The lithostratigraphical succession and ammonites at Skladaná skala were described by Rakús (1964, 1984), dividing the succession into 3 units. The lower unit (Unit 1) formed by marly limestones contains the Late Sinemurian ammonites (*Echioceras raricostatum, Paltechioceras nodotianum* and *Oxynoticeras oxynotum*). The middle unit (Unit 2) formed by alternation of marly limestones and marlstones contains Late Pliensbachian ammonites (*Amaltheus stokesi* and *Pleuroceras spinatum*). The upper unit (Unit 3) is characterized by prevalence of marlstones and marls with Lower and Middle Toarcian ammonites – *Dactylioceras (Orthodactylites)* cf. *semicelatum, D. athleticum, Harpoceras* ex.gr. *falciferum* and *Hildoceras* ex. gr. *bifrons*. However, the high-resolution subdivision of the succession into stratigraphic zones remained unknown and the zone boundaries were not identified, and the stratigraphic, sedimentological, and geochemical nature of the Pliensbachian–Toarcian deposition is not possible without such stratigraphic framework.

In our study, we measured and sampled bed by bed three subsections, arranged from the west towards the east (SS1–SS3). Trace fossils in the SS2 section were analyzed by Šimo & Tomašových (2013). The succession is affected by several vertical faults that do not allow simple horizontal correlation among the subsections. In the upper part of the succession (upper part of Unit 2 and the Unit 3 of Rakús), macrofauna is essentially represented by cephalopods (both ammonites and belemnites). However, with the exception of some specific layers, their abundance is low. The benthic shelly groups are almost missing. Ammonites are mostly fragmented in limestones, better preservation is linked to the small-scale transition between limestones and marls in some beds.

The upper part of the marly limestone–marlstone alternation belongs to the Late Pliensbachian late Margaritatus Zone and the Spinatum Zone (SS2 and lower part of SS1). This stratigraphic interval is at least 18 m-thick, with very numerous *Amaltheus* sp. and rare *Leptaleoceras* sp. in SS2 pointing to the late Margaritatus Zone (Gibbosus Sz.); and scarce and fragmented *Pleuroceras* and rare *Emaciaticeras* in the beds 4–28 in SS1 section indicating very late Spinatum Zone. The Tenuicostatum Zone of the Early Toarcian is not yet verified by ammonites. However, it is situated between the last occurrence of the late Pliensbachian ammonites of the upper part (although not terminal part) of the Spinatum Zone (bed 28 of SS1 section) and the first ammonites of the Exaratum Subzone of the Serpentinum Zone (bed 64 in SS2 section). One meter thick interval above the bed 64 is characterized by the highest abundances of ammonites, with *Harpoceras* gr. *serpentinum, H. exaratum, H. elegans* and *Dactylioceras* gr. *semiannulatum*, indicating the middle–upper parts of the Exaratum Subzone. The marls above this interval are almost devoid of macrofauna up to the Bed 72 that is rich in highly fragmented ammonites, mostly belonging to *Harpoceras* gr. *falciferum* and scarce *Hildaites* sp., indicating Falciferum Subzone of the Serpentinum Zone. Beds 81 and 83 contain small fragments of *Hildaites*, indicating the same subzone. First *Dactylioceras* gr. *commune* of the Bifrons Zone of the Middle Toarcian was found ~370 cm above the bed 85. Although the distribution of ammonites is limited to few layers only, they are mainly composed of stratigraphically diagnostic taxa and they generate a solid biostratigraphical framework for the sedimentological and geochemical studies across the Toarcian Oceanic Anoxic Event in the Central Western Carpathians.

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Integrated bio-stratigraphic and magnetostratigraphic correlation of the Jurassic–Cretaceous boundary in non-marine sequences in Liaoning (China)

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We initiated a joint study of Jurassic–Cretaceous (J/K) boundary sections in Western Liaoning. Western Liaoning is known for its Lower Cretaceous continental units (and fossils) including Tuchengzi Formation. These layers contain volcanic material that is actively used for radiometric dating. Paleomagnetic and magnetostratigraphic research clarifies the interpretation of the time interval at the J/K boundary. We show that the sedimentation in Liaoning was so rapid that individual studied sites contain only one magnetozone and this is an advantage for magnetostratigraphy when use as an aid for J/K boundary determination. Specifically, we found that both Dabanyngzi and Huangtuliang are stratigraphic units of normal polarity, while Xingjiagou displays reverse polarity. The individual profiles are to be stratigraphically linked. The interconnection between several stratigraphy profiles was studied using a photogrametry survey from the drone. Additionally, we identified fossils of the clam shrimps (Branchiopoda) and ostracods (Ostracoda) and combined them with magnetostratigraphy. This allowed linking sites in Liaoning site with the Swanage site in Southern England.

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Magdalenian stone tools artifacts made of Jurassic chert

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The outcrops of Olomučany chert are located 5–10 km N/NE of Brno in relics of Jurassic sediments in SSE part of Olomučany village. The layered cherts are embedded in up to 50 m thick Callovian to Kimmeridgian limestones (Kalášek 1963). The chert is macroscopically grey to greyish black and microscopically formed by microfossils and opaque matter, probably also of organic origin. Parts of this matter are coloured rusty-brown due to the presence of secondary iron oxides. The microfossils comprise mainly of sponge spicules and bryozoans. Preferential orientation of what are replaced clasts of the original rock is sometimes visible at low magnification (Přichystal 2013).

The siliceous matter is mostly formed by chalcedony, crystals of macroquartz are scarce. Chalcedony forms both the cryptocrystalline matrix and bigger spherulites, most likely replaced microfossils, which may reach up to 0.2 mm in diameter. In this way the Olomučany chert is coarser-grained than most erratic flints encountered in Silesian and north-Moravian territory (Přichystal 2013). Rather exceptional are grains of green glauconite. There are traces of tectonic disturbance of the cherts in the form of healed fissures which may have acted as planes of weakness when the chert was flint-knapped. However, a heat-treatment of Olomučany chert has potential to improve the flaking properties.

Heat-treatment of cherts and flints improves their flaking quality and edge sharpness and was practiced by prehistoric people throughout the world. In Europe, its oldest evidence comes from the Solutrean (around 24000–17000 uncal BP) of France and Iberian Peninsula. There followed a gap of more than 6000 years before it was used in the Mesolithic (from 9 500 uncal BP). Our research aims to identify the same technique in the Magdalenian (15000–11500 uncal BP) of Moravia (Czech Republic) where local Jurassic cherts (Olomučany type) were used. We used a combination of three methods, the Fourier-transform infra-red spectroscopy (FTIR), mass magnetic susceptibility (MSmass) and measurement of isothermal remanent magnetism (IRM). Whereas FTIR is certainly suitable to identify heat-treated cherts, it is less reliable when temperatures of <300 °C were used. Temperatures around 250 °C, however, are probably sufficient to improve flaking qualities of fine-grained SiO_2 materials (Crabtree & Butler 1964; Schmidt et al. 2012).The results of our research indicate that Magdalenian artefacts made of Jurassic cherts and previously identified as heated by visual observation are identifiable through the combination of MSmass and IRM as their overall magnetism drops, probably due to the oxidation of trace magnetite in the analysed cherts and neo-formed goethite or haematite. Heating of the samples above 500°C result in newly formed magnetite and rise in magnetisation. The heating over 300°C was probably unintentional, because the mechanical properties of Olomučany chert rapidly worsen above 350 °C. Magnetic methods are thus recommended to be applied in combination with FTIR for identification of intentional and unintentional past heat-treatment of cherts.

The samples 3851-54, 3852-54 and 3955-54 contain two IRM component. The first component with B/2 (after Kruiver et al. 2001) between 31 and 51 and relative amount between 47 and 81 % reflects the impact of magnetite. The second IRM component with B/2 between 1413 and 2089 and relative amount between 18 and 53 % reflects the impact of iron oxides with higher coercivity such as goethtite. The equivalent laboratory-heated rock samples measurements for comparison are in progress. Above proposed magnetic studies performed on the artifacts are therefore useful and independent tool to understand the technique of heat treatment of the rock before flaking.

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Aquatic insects are not capable returning to land

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Among insects, 236 families in 18 of 44 orders independently invaded water. We report living amphibiotic cockroaches from tropical streams of UNESCO BR Sumaco, Ecuador. We also described the first fossil aquatic roach larvae (6 spp.; n = 44, 1, 1, 1, 1, 1) from the most diverse tropical Mesozoic sediments (Middle Jurassic Bakhar Fm in Mongolia, Kimmeridgian Karabastau Fm in Kazakhstan; Aptian Crato Fm in Brazil), and the Barremian Lebanese and Cenomanian Myanmar ambers. Tropic-limited occurrences are trophic- (biomass/litter-fall), structural- (diversity) and also abiotic-factor-dependent (high temperatures). Diverse Paleozoic aquatic eoblattids were (re)described from the lower Permian sediments of Elmo, U.S.A. and Chekarda, Russia. They competed with true cockroaches to reach water prior to the Mesozoic (Fig. 1). Due to different evolutionary rates or periodical changes in water characteristics, non-adapted terrestrial insects repeatedly invaded the aquatic realm with well adapted hydrobionts. Obscurely, most aquatic lineages still survive. In contrast with Crustacea, aquatic-terrestrial reversal is absent. A single principal lineage, namely of moths, ancestral to butterflies (origination of modern insects from ephemerans and dragonflies is questioned), possibly evolved from insects with aquatic immature stages, and none from aquatic adults. The rest of the orders are terrestrial-derived. The proposed reason for the lack of land return is the character of numerous aquatic adaptations related to reductions, which are unlikely to be resuppressed. The aquatic insect family/terrestrial insect family ratio over time reveals a sharp rise from the Late Carboniferous to Late Triassic followed by still lasting stability. Diversification of aquatic insects seems consistent with a 62.05±0.02 Ma periodicity.

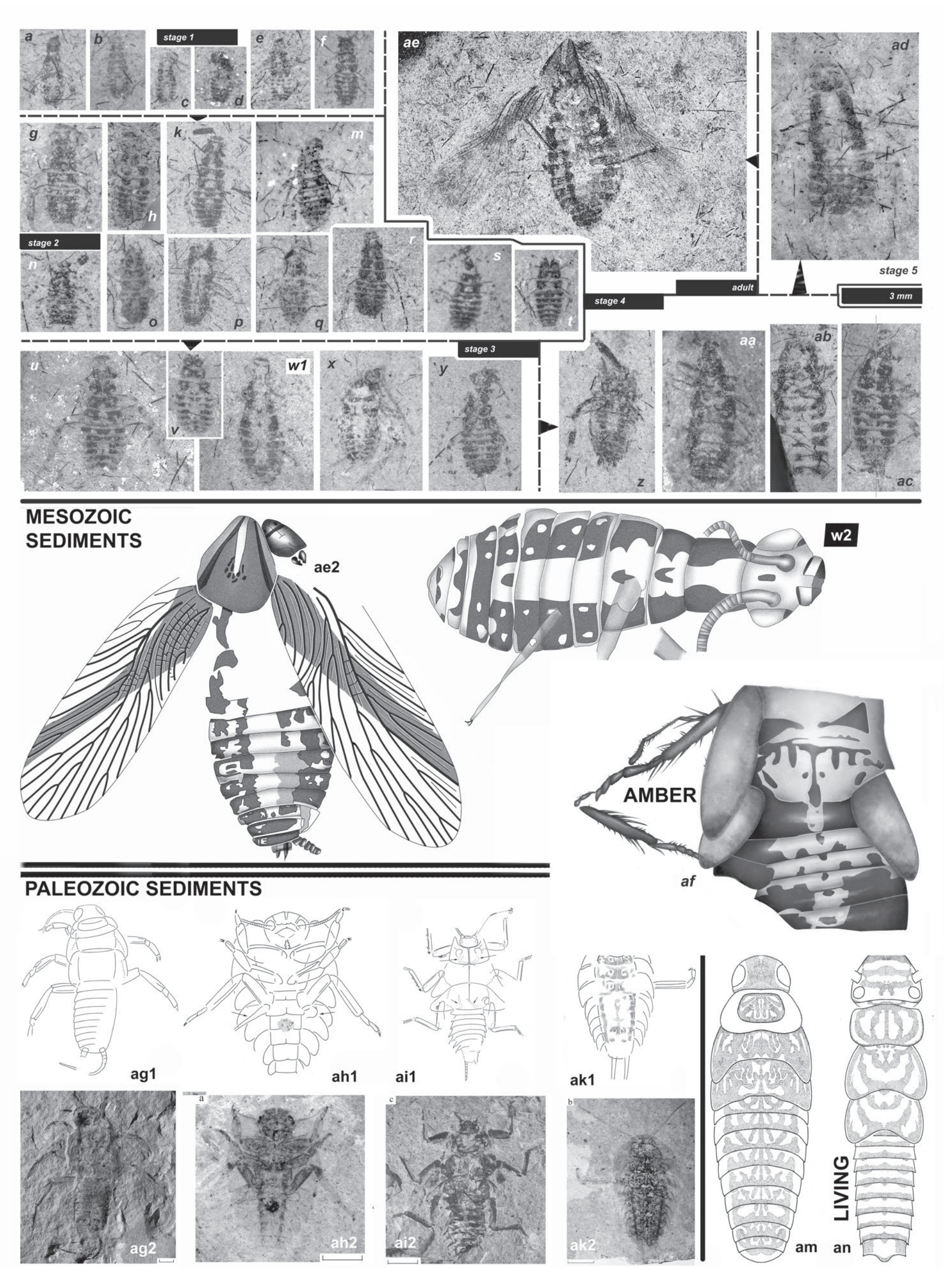

Fig. 1. Mesozoic and Paleozoic aquatic cockroaches and relatives. Orig. by P. Vršanský, H. Sendi, D. Aristov.

“Fleckenmergel” (Pliensbach–Toark) lithofacies trace fossils and ichnofabric from the Western Carpathians, the Pieniny Klippen Belt and the Betic Cordillera

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Hemipelagic marly limestones of Lower Jurassic (Upper Sinemurian–Toarcian) are named as spotted bioturbated limestones of “Fleckenmegel” lithofacies. The Central Western Carpathians Lower Jurassic Fleckenmergel limestones are regarded to the Janovky Fm (Gaździcki et al. 1979).

The comparison of these two areas is based on the general assumption that the Lower/Middle Jurassic Fleckenmergel sedimented on the inner-eastern fringes and ramps of northern Tethys in the Alpid region from Betic Cordillera, the Eastern Alps, the Central Western Carpathians, the Pieniny Klippen Belt, the Dinarides, the Mecsek, the Apuseni Mts and Timor (Mišík 1959; Tyszka 1994; Wieczorek 1995).

The Central Western Carpathians were located on the northern passive margin of the Tethys during the Early Jurassic, approximately at 30°N in the tropical climatic belt.

Paleogeographical area of the Pieniny Klippen Belt was situated north westward from the Central Western Carpathians paleogeographical area (Golonka & Wierzbowski 2006). The Betic Cordillera was situated in wide area of the westernmost Tethys approximately at 20°N. Distance between these areas during Lower Jurassic can be estimated up to 1500 km.

The most important feature of the “Fleckenmergel” spotted limestone is macroscopic well contrasted trace fossils. Comparison of two geographically different areas Betic Cordillera, the Central Western Carpathians and the Pieniny Klippen Belt shows identical assemblage of trace fossils (Tab. 1). Trace fossils were distributed in various depths of substrate and tierings. Primary lamination or sedimentary textures are rare. The most of the volume of these limestones is bioturbated. Compaction of clay layers is estimated on 80 % according to deformation of trace fossils.

Assemblage of traces is composed from vagile deposit feeders that attain the biggest diameters of burrows (*Lamellaeichnus*, *Paleophycus, Planolites, Thalassinoides*). Deposit feeders with smaller diameters of burrows occupy deeper part of sediment (*Teichichnus* isp., *Zoophycos*). Deepest part of substrate with low water content between and below of redox boundary contains burrows of sessile producers (*Chondrites*, *Pilichnus*, *Trichichnus*). The comparison of trace fossils from these paleogeographically distant regions of the Western Carpathians and the Betic Cordillera, we can assume similar paleoecological conditions: dysoxia of the bottom substrate, contribution of organic matter to the basin and comparable dynamics of sedimentation. The most distinctive ichnological connection of “Fleckenmergel” lithofacies in the Central West Carpathians and the Betic Cordillera are *Teichichnus* isp. and *Lamellaeichnus imbricatus*. These trace fossils have been found only in the Lower Jurassic “Fleckenmergel” lithofacies. Available data show important ichnofacial differences, occurrence of *Zoophycos* seems more frequent in the Carpathians regions than in the Betic Cordillera (Tab. 1).

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	Pieniny Klippen Belt Central Western Carpathians	External - Median Subbetic		
		I.	II.	III.
Alcyonidiopsis isp.			■	
Chondrites intricatus	■	■	■	■
Chondrites targionii	■	■	■	■
Lamellaeichnus imbricatus	■	■	■	■
Nereites isp.			■	
Palaeophycus heberti	■		■	
Planolites isp.	■	■	■	■
Taenidium isp.				■
Teichichnus isp.	■	■	■	■
Thalassinoides isp.	■		■	■
Trichichnus linearis	■		■	■
Zoophycos isp. *	■			

Tab. 1. Occurrences of trace fossils in Lower Jurassic limestones of “Fleckenmergel” lithofacies in the areas of the Betic Cordillera, the Central Western Carpathians, the Pieniny Klippen Belt. I. Arroyo Mingarrón, II. Fuente Vidriera, III. La Cerradura. * – occurrence of *Zoophycos* is noted from the Betic locality the Iznalloz Section (Median Subbetic) close to the Arroyo Mingarrón (Reolid et al. 2018).

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New biostratigraphic data across the Jurassic–Cretaceous transition in the Theodosia area of Crimea (southern Ukraine)

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New calcareous nannofossil material has been obtained from the Dvuyakornaya Formation in Dvuyakornaya Bay, 2 km west of the well-studied Theodosia lighthouse cliffs (Bakhmutov et al. 2018). The section was previously studied by Platonov et al. (2014) for calpionellids. The sequence is predominantly one of mudstones, approaching 300 metres in thickness here, with (as at Theodosia in the top of the formation) hard grainstones/microbreccias, normally no thicker than 30–40 centimetres, and siderite bands and rarer coarse breccias. One such thicker breccia caps the section, and it has been taken by Russian authors to be the same as that on the shore at Theodosia lighthouse.

We have sampled the top 24 metres of the cliff profile recorded by Guzhikov et al. (2012, see Fig. 4.), for micropalaontology and paleomagnetism.

Studied samples provide rare to abundant calcareous nannofossil assemblages, with poor to moderate preservation. This is in accordance with the previous studies of calcareous nannofossils in the Theodosia area (Halásová *in* Bakhmutov et al. 2018).

In total, 49 calcareous nannofossil taxa have identified from Dvuyakornaya Bay. The most significant components of the assemblage represent ellipsagelosphaerids (genera *Watznaueria* sp. and *Cyclagelosphaera* sp.) followed by the genera *Nannoconus* sp., *Conusphaera* sp. and *Zeugrhabdotus* sp. Redeposited specimens from the older Jurassic strata have been also recognized (e.g. *Lotharingius hauffii*, *Parhabdolithus robustus*).

Nannoconids are represented only by the “early” forms: *Nannoconus infans*, *N. erbae*, *N. compressus*, *N. puer* and *N. globulus minor* are present through the entire section, as well as other biostratigraphically important taxa such as *Helenea chiastia* and nannoliths *Faviconus multicolumnatus* and *Polycostella beckmannii*. This composition of the assemblage is that documented in the uppermost Tithonian, NJT 17a Nannofossil Subzone (*sensu* Casellato 2010). The marker species for the base of the NJT 17b Nannofossil Subzone, *Nannoconus wintereri*, has been not found.

Some species give clues to the stratigraphic position of the section relative to the Jurassic–Cretaceous boundary (the base of the Alpina Subzone): The first occurrence (FO) of *Hexalithus geometricus* (one uncertain specimen in the lower part of the section has been identified) is known only in the middle of M19n.2n. Moreover, the FOs of *Nannoconus steinmannii minor*, *N. kamptneri minor*, *N. steinmannii steinmannii*, *N. kamptneri kamptneri* and *Cretarhabdus octofenestratus*, have not been recorded, which would indicate that no bed so far sampled is above the middle of M19n.2n.

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Bivalve shell beds in hiatal successions on pelagic carbonate platforms (Pieniny Klippen Belt, Western Carpathians)

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Pelagic carbonate deposits formed by a thin-shelled bivalve *Bositra buchi* were geographically widely distributed in the Tethys Realm during the Middle Jurassic. Here, to evaluate conditions that allowed stratigraphic persistence of the filament microfacies and led to the formation of peculiar, metre-scale shell beds with *Bositra*, we assess preservation of *Bositra buchi* in thin sections in the Pieniny Klippen Belt and Peri-Klippen units (Western Carpathians), representing a bathymetric transect from platform tops with shell beds up to slope environments where filaments are dispersed with spicules and radiolarians.

First, we find that inner sides of *Bositra* valves are luminescent and enriched in Sr and Mn, indicating that aragonite portions are recrystallized rather than dissolved. Therefore, concentrations with *Bositra* are not diagenetically enhanced, i.e., are not formed by calcitic relicts only. Second, thin rims of bladed-fibrous isopachous cements (a characteristic feature of *Bositra* preservation in shell beds) do not coat upward-facing sides of valves covered by micrite whereas they fully coat elevated portions of the same valves. Therefore, these isopachous cements were precipitated at very high rates in a stable skeletal framework formed by densely-packed valves of *Bositra*, simultaneously with mud winnowing and with micrite deposition in shelters. Third, bladed and fibrous-acicular low-Mg calcite cements show blotchy luminescence and highly irregular Mg distribution, indicating that they were precipitated as high-Mg calcite cements. We suggest that bottom currents probably simultaneously increased *Bositra* production by increasing (1) food supply and (2) cementation rate by renewal of saturation of pore waters at platform tops. The production of larger shells probably further triggered cement precipitation because it allowed the formation of stable skeletal framework with sufficiently larges cavities that were flushed with gentle currents. However, mud-winnowing currents were not strong enough to rework densely-packed framework of *Bositra* valves after cement rims were precipitated. The rapid cementation and the rarity of iron staining and low concentrations of Fe in shell beds indicate that assemblages of *Bositra* in shell beds do not represent long-term hiatal or lag concentrations. In spite of their association with the major Callovian-Early Oxfordian hiatus, *Bositra* shell beds are not environmentally- or biostratigraphically condensed and rather represent composite shell beds that were accrued at decadal or centennial timescales. They are not diagenetic relicts and primarily record superdominance of these bivalves at ecological time scales uniquely associated with high food supply and with instantaneous cementation.

Current problems with selecting a J/K boundary

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Today in the course of active updating and development (on the basis of the GSSP and GSSA concept) International Chronostratigraphic Chart in general and, the Mesozoic in a particular, among the most relevant and sharp stratigraphy problems still there is a level division of a Cretaceous system (GTS–2012) and J/K boundary in particular. For almost 200 years, an attempt to solve this problem has been raised by researchers at the regional and global levels, discussed at numerous symposiums, colloquiums, meetings, conferences and covered in a number of publications by several generations of stratigraphs around the world. In the last three decades Subcommission on Cretaceous Stratigraphy (SCS) with the Working Groups that make important decisions on global questions of level division, carrying out boundaries between systems, series, stages and making GSSP. It was not succeeded to solve this problem at the regional and global level yet (Hoedemaeker 1987; Grabowski 2011; Schnabl et al. 2015; Wimbledon et al. 2017). But it is nearing completion (Wimbledon 2017). At the present stage more than 300 section are studied worldwide, more than 3500 taxons and the marking layers are established, but making decision on the choice of GSSP for unratified stages of the Jurassic and Cretaceous systems remains the Working Groups relevant (Granier et al. 2019). Considering emergence of new actual material and new researches techniques the problem remains unresolved. It is as follows. Despite almost 200-year history of studying of a Cretaceous system, stages of lower department and partially top (except for Cenomanian, Turonian, Santonian and Maastrichtian) have the status of unratified. It concerns also stages of the Upper Jurassic (Oxfordian, Tithonian). Boundaries Lower Cretaceous and partially the Upper Cretaceous of stages have no approved stratotype. Stages and substages of Cretaceous systems as the main subdivisions of International Chronostratigraphic Chart have the status of unratified. There is debatable a boundary problem between Jurassic and Cretaceous systems and also the provision of a Berriassian stage in International Chronostratigraphic Chart (System boundary has to correspond to boundary of the lower stage).

Delay of making decisions on the choice of events and locations of boundary stages (GSSP) is explained by the following factors (Hoedemaeker 1987; Grabowski 2011; GTS 2012; Schnabl at al. 2015; Lopez-Martínez et al. 2017; Wimbledon 2017; Granier et al. 2019):

1. Accumulation of sediments happened in two different major paleogeographic units – Tethys and Panthalassa, plus much smaller areas in austral and isolated basins in boreal regions. Of these, much more of Tethys survives, and it has the richest fossil biotas. Differences are traced in the tropic and subtropic forms of biotas which could migrate to other regions only in the presence of relations between basins and disappear quickly at their absence. At long relations between basins the general forms for a number of regions are traced. The smaller areas in austral and isolated basins in boreal regions species endemics (or euryhaline biotas) could develop. Thus, definition high (global) correlation potential of a biotic event refers to areas where correlation is possible – in Tethys, California, Mexico, Andes, Tibet and Far East. For regions with a poor and rare biota, existence of endemics species for which it is

impossible to use biotic potential (Tithonian–Valanginian) the global correlation is possible with use of a magnetostratigraphy.

2. The sections discussed now – applicants for GSSP, are located mainly in regions of development of Tethys sediments. The issue of GSSP is not resolved yet, it will probably be in Tethys as biotic markers of calpionellids, calcareous nannofossil, calcareous dinoflagellates, ammonites) and magnetozones are identified on the extensive geographical area and have the potential for wider circulation. For correlation with the isolated regions of Canada, Greenland, Great Britain, Svalbard, Greenland, Spitsbergen, Russia to use results of a magnetostratigraphy. Primary markers should be chosen among biotic events (among that groups which characterized by the highest correlation potential), and magnitochrons have to serve as a secondary markers.

3. Low level of availability of results of researches at the international level. To create the database with replenishment of information on features of sections, physical and chemostratigraphical study and results of other methods and techniques.

Solutions have to include:

1. Choice of the main events and correlation levels. When determining the main event (primary marker) of carrying out boundary J/K and stages Late Jurassic and a Cretaceous system the leading role should be provided biotic (but at the same time to consider all range micro- and macrofossils) and magnetostratigraphical (Grabowski 2011; Schnabl et al. 2015; Lopez-Martínez et al. 2017; Wimbledon 2017; Granier et al. 2019). Respectively, and the interregional correlation of boundaries of a system and stages has to be based on a bio- and magnetostratigraphical methods. Primary markers at the same time have to belong to microfossils (the high concentration on 1 cm^3 of breed, degree of safety allows to define autochthonous and allochthonous forms, meet on sites where there are no macrofossils (existence the thicknesses different facies), environments, sensitive to any changes). In spite of the fact that for the partition of the Mesozoic ammonites play an important role, their value for the choice of GSSP of stages Late Jurassic and Cretaceous and, respectively, J/K boundary decreases in consecrate with an endemic and provinciality of species that is caused by falling of sea level and the regressive nature of stages boundaries and the system (Hoedemaeker 1987). Signs of these events are reflected in complexes of fossils (for example, existence shallow-water and deep-water forms (calpionellids and radiolaria), representatives the euryhaline of faunas (ostracoda, etc.), that is existence of the mixed complexes uneven-age, the different facies, different degree of safety). In a case with ammonites sign of falling of sea level is the insignificant quantity of versions which cross boundary, an endemic and provinciality. If there is no updating of fauna at the level of families, then the event was more catastrophic. The maximum of regression is fixed by disappearance (destruction) of almost all fauna of ammonites before the restoration period. Fixation of such signs in cuts can be used for correlation the different facies of thicknesses. Problem of such boundaries is migration in time. They are considered as transitional layers between systems, series, stages and is diachronous. In a case with J/K boundary (and, perhaps, other stages) this event was shown at top of Upper Jurassic (Tithonian) and continued to the Middle Berriassian, and in different regions is fixed by various marks of absolute age from 140.07 (possibly more young) to 146.02 (perhaps ancient) Mya.

Result (Wimbledon 2017): No fossil species has anything like a global distribution in the Tithonian–Berriasian interval. Though *Calpionella alpina* is the most widespread.

The base of M18r does not coincide with any consistent biotic marker at sites recently studied for magnetostratigraphy, and the same is true of the base of M19n.2n.

The traditional Berriasella jacobi Subzone will play no part in any definition of the base of the Berriasian, nor can the species *Berriasella jacobi* [=*Strambergella jacobi*].

Calpionellids (calibrated with magnetostratigraphy) provide the most effective primary J/K boundary marker, the *Crassicollaria* to *Calpionella* turnover, *i.e.* the Colomi/Alpina subzone boundary.

In June 2016, the Berriasian Working Group voted, by a large majority (76 %), to adopt the *Crassicollaria/Calpionella* turnover and base of the Alpina Subzone as the primary marker for the base of the Berriasian Stage.

2. Creation parallel biostratigraphical of scales. On J/K boundary and in a Cretaceous system the choice of a biotic event can be among various groups of organisms. It is necessary to develop scales on other groups of organisms for the purpose of calibration of biotic markers with a standart bio- and magnetostratigraphical scale, more exact interregional correlation and fixing the levels dating.

Result (Wimbledon 2017):

This level is bracketed by a number of nannofossil FADs.

New finds of Tethyan calcareous dinoflagellate cysts in the Andes indicate their usefulness and potential as secondary markers.

3. Choice of a section of the region, applicant for GSSP. Today the majority of the studied sections regarding J/K boundary and stages of the Cretaceous system remained and are located generally in the regions belonging to the Tethyan Realm. Sections of the areas belonging Panthalassa were destroyed subduction crust and remained only in the north of the Pacific Ocean, other sites (boreal, austral) occupy insignificant territories within which there were isolated pools. Therefore for the choice and establishment of GSSP sections of the Tethyan Realm have to be considered by the main applicant sections undoubtedly. Besides, they are best of all studied with use of different methods (bio-, magneto-, chemostratigraphy, etc.) and techniques and contain a large amount of various biotic material which can apply for the status of primary marker (calpionellids).

4. Aapplication of methods of a physical stratigraphy (in particular, a magnetostratigraphy without combination of biotic events) (Dzyuba 2012) and chemostratigraphy for the purpose of search of key episodes for correlation the sections Tethyan with sections of other territories (global correlation) were not effective (Dzyuba at al. 2013; Schnabl et al. 2015).

5. Search of effective correlation tools, which will connect other regions with Tethyan area (Wimbledon 2017):

Correlative advances in Argentina are exciting, and amplification of the first paleomagnetic results and of recent *C. alpina* finds are anticipated.

In austral regions, most notably in the Andes, some of the Tethyan nannofossil marker species have been identified (alongside endemic ammonites), including species which are proxies for the base of the Alpina Subzone, as they have in Tibet.

In Siberia, at one site, Nordvik, it is possible to approximate the horizon of Calpionella alpina (in mid M19n.2n): close below the base of the Tehamaensis (belemnite) Zone and close above the ‘floating’ Taimyrensis (ammonite) zonal base.

Earlier finds of calcareous nannofossils in Siberia have yet to be followed up. Identifications there of calcareous dinoflagellates have great potential, and it is to be hoped they will provide proxies for calpionellid datums, as in austral regions.

6. Theoretical and applied aspects of carrying out geological boundaries. Carrying out boundary J/K becomes complicated formation of sediments in the conditions of a peripheral part of Mezo-Tethys, prevalence of the coastal and shallow facias sensitive to any changes of the physical, chemical and biotic factors of the environment caused by tectonic events which derivatives are change of global sea level (transgression,

regression), magmatic activization, etc. Respectively such events find the reflection in material structure of sediments and geological boundaries types (Tuzyak 2018). Therefore J/K boundary in section can be discordant and presented by the mixed uneven-age and different facias complexes (an example, boundaries of K_1/K_2 (Bakayeva & Tuzyak 2016), K/Pg, the Neogene (GTS 2012)). Also the discrepancy of lithologic and biostratigraphial boundary can be traced. For example, lithologic boundaries can be presented by layers of volcanic breeds (tuf, tuffit, bentonite clays, etc.), and biostratigraphical to be fixed much above lithologic.

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Upper Jurassic–Lower Cretaceous belemnites reveal the geological history of the Outer Western Carpathians (Czech Republic): exemplified by the Štramberk cliff

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Huge accumulation of belemnite rostra have been recorded in the complex structure of the Štramberk limestone (Š-12 „pocket“ Kotouč quarry) – within neptunic dykes infilled by clastic sediments of the Plaňava Formation assigned to the Lower Cretaceous in age. By complicated and various tectonic and exogenous processes, sedimentary structures of the Baška elevation were deposited and eroded throughout individual stratigraphic intervals (Upper Jurassic–Lower Cretaceous). Resistent belemnite rostra that were a part of sedimentary associations belonging to different environments had been reworked into younger lithostratigraphic units and deposited along tectonic fault of the Štramberk limestone. Highly diversificated belemnite assemblage of different ages contains all ontogenetic stages, however, the most common specimens are juvenile and immature individuals. Only few mature or gerontic stages with clear morphological features are preserved. Nevertheless, a relative good preservation of some individuals provided sufficient data for systematic classification. The assemblage is formed by families Duvaliidae (*Duvalia*, *Berriasibelus*, *Conobelus*, *Pseudobelus*, *Castellanibelus*) and Belemnopseidae (*Hibolithes*, *Adiakritobelus*) with typical representatives of the Upper Tithonian through the Lower Hauterivian interval. The Barremian taxa *Mesohibolites* and *Conohibolites* (Belemnopseidae) are also relatively common inside the studied material, however, oftenly poorly preserved. Stratigraphically, these taxa were compared with other findings within the Tethyan Realm including the Mediterranean Province (e.g. Janssen 1997, 2003; Janssen & Clement 2002; Mutterlose & Wiedenroth 2008). The largest diversity is represented by the Berriasian through the Valanginian species with characteristic replacement of taxa after the extinction event in the Lower/Upper Valanginian boundary. Presented individuals are typical for different environments (after Mutterlose & Wiedenroth 2008; cf. Janssen et al. 2009 for discussion) corresponding to their different life habits. Therefore, based on morphological differences and paleoecological dependences of species in the studied material, as well as changing in paleoenvironment affected by an extensive reworking during time it should partly reveal complicated sedimentary history of the Outer Western Carpathians.

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Late Jurassic–Early Cretaceous brachiopods of the Bakony Mountains (Hungary), and the Weissert event

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The studied brachiopod material was collected from 10 well-dated sections and 11 other localities in the Bakony Mountains, Hungary. The sections straddle the stratigraphic interval from the Kimmeridgian to the Barremian. The brachiopod material is extremely diverse and abundant in international standard: the 1313 identified specimens represent 34 species of 14 genera. The overwhelming part belongs to the Pygopidae (1043 specimens); the most abundant genera of the family are: *Antinomia* (419), *Triangope* (323), *Pygope* (225) and *Pygites* (76). Nucleatidae are represented by 183 specimens; rhynchonellids appear subordinately (87 specimens).

The brachiopod fauna, collected bed-by-bed, together with ammonoids from 10 sections, offers exceptional possibility to determine the stratigraphic ranges of the brachiopod species at a level of substage or even ammonoid zone. Our present data base is almost unique; similar results were published only from the Polish Carpathians (Pieniny Klippen Belt), (Barczyk 1991; Krobicki 1994, 1996).

The stratigraphic ranges recorded in the Bakony sections show that the five most abundant brachiopod species occurred from the Late Kimmeridgian to the Berriasian (partly even to the Early Valanginian). Further six species appeared in the Early Tithonian, some of them occurred also in the Early Valanginian. A less diverse assemblage was restricted to the Late Berriasian to Early Valanginian interval. None of the above mentioned species crosses the base of the Late Valanginian; most of them disappeared abruptly at this level. A fundamental faunal change appeared in the lowermost ammonoid zone of the Late Valanginian. In the Hárskút sections (HK-12, Édesvíz) a poorly preserved, almost monospecific brachiopod fauna (*Fortunella praemoutoniana*, *Lingularia* sp.) was collected in the Verrucosum Zone. Lingulides are regarded as typical “disaster taxa”; on the other hand, the minute *F. praemoutoniana* was found exclusively this horizon, what may point to special adaptation to harsh environment. Considering all above pieces of information, we postulate a biotic crisis in the marine biota at the time of the Verrucosum Zone in the area studied. Afterwards, an abundant and diverse brachiopod fauna appeared in the Late Valanginian, but with a complete turnover of species within the genera *Nucleata* and *Triangope. Pygope* and *Antinomia* disappeared ultimately. The species *Pygites diphyoides*, which was not recorded in lower stratigraphic levels, abounds in masses in the Hauterivian. This abundant assemblage of low diversity persisted to the Barremian.

The complete turnover of brachiopod species at the Verrucosum Zone and the appearance of disaster forms, restricted to the same horizon, are synchronous and are apparently in causal relationship with the Weissert oceanic anoxic event, proved by isotope geochemical study in the section HK-12 by Főzy et al. (2010).

The effect of the Valanginian Weissert event on the change of brachiopod faunas can be recognized in other parts of Europe. The brachiopod ranges, published from the Polish Carpathians (Krobicki 1996), are interrupted in the Valanginian Verrucosum Zone; on the other hand, no turnover was recorded after this hiatus. In the sections of the Gargano peninsula (southern Italy), platform drowning, nannoconid crisis and mass accumulation of brachiopods were recorded synchronously with the Weissert event (Graziano & Ruggiero Taddei 2008). The monospecific mass occurrence of *Peregrinella* brachiopods was interpreted as a chemosynthesising community fostered by methane-bearing cold seeps brought by local fracture system. This local phenomenon could hardly be in causal relationship with the global anoxia, but the synchroneity is remarkable. The common triggering factor might be a peak of activity of the Paranà Large Igneous Province (Erba et al. 2004).

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The Jurassic–Cretaceous boundary in China

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The Jurassic to Cretaceous transition beds occur widely in China. Marine sediments are extensively distributed in southern Tibet and terrestrial strata dominantly in the Junggar basin of Xinjiang, northern Hebei-western Liaoning, and the Songliao Basin, from west to east. At Gyangze, Tibet, the strata are divided into the Weimei and Jiabula formations. At Nagarze, they are divided into the Weimei and Sangxiu formations. Previous work has reported diverse ammonite species of *Haplophylloceras* and *Himalayites* in the Weimei Formation, and a few species of *Spiticeras* in the lower Jiabula and Sangxiu formations. The present study has found the bivalve *Inoceramus* and nannofossil assemblages in the lower Jiabula and Sangxiu formations. The nannofossil assemblage of *Nannoconus steinmannii steinmannii*, *N. steinmannii minor* and *Watznaueria barnesae* indicate a Berriasian age. The boundary is marked by the appearance of the ammonite *Spiticeras* and the nannofossil assemblage of *Nannoconus st. steinmannii–N. st. minor–Watznaueria barnesae*. The boundary transition in terrestrial facies is mostly in reddish sediments yielding few age-dating fossils. In the Junggar basin, Xinjiang, northwest China, Jurassic–Cretaceous sequences have been studied using integrated lithostratigraphy, biostratigraphy, chronostratigraphy, cyclostratigraphy and magnetostratigraphy. These indicate that the age of Qigu Formation ranges from late Callovian to Oxfordian, the Kalaza Formation is Kimmeridgian in age, and the overlying Qingshuihe Formation belongs to the earliest Cretaceous. A clear unconformity exists between the Kalaza and Qingshuihe formations. In northern Hebei and the western Liaoning area, Upper Jurassic to Lower Cretaceous strata are well preserved. This area is the type locality for the terrestrial J/K boundary in China. In the previous biostratigraphic work, this boundary was referred to a higher position, one of much younger age, which caused a big controversy because of the discrepancy between the local biostratigraphy and the international time scale. The pronounced provincialism of terrestrial fauna and flora obstructs global correlation. The J/K boundary involves the Tuchengzi, Zhangjiakou and Dabeigou formations, in ascending order. The Tuchengzi Formation has produced an isotopic age of 139 Ma at its top, and the J/K boundary is within the formation. The Zhangjiakou and Dabeigou formations contain the Jehol Biota of Early Cretaceous. In the Songliao Basin, The Huoshilin Formation is the first basin-fill sedimentary–volcanic sequence. The formation yields plant fossils. The spore and pollen assemblage shows a blooming age of Early Cretaceous, but megaspore fossils and magnetostratigraphy indicate a Late Jurassic age. The Huoshilin Formation, therefore, is the potential succession to locate the Jurassic–Cretaceous boundary.

Kimmeridgian Stage: its boundaries, subdivision, paleobiogeography, and stratigraphical correlations in Europe

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The Kimmeridgian Stage was distinguished in 1850 by A. d'Orbigny, who "derived this name from the village of Kimmeridge, England, where the type section has been described…it is.. the Kimmeridge Clay and the Weymouth beds of Fitton" (Arkell 1946, p. 6). In consequence the base of the Stage was correlated with the base of the Kimmeridge Clay Formation in Ringstead Bay in Dorset, England. It was defined biostratigraphically by Salfeld (1913) on the lineage of Subboreal ammonites of the family Aulacostephanidae at the place where an older genus *Ringsteadia* was replaced by a younger genus *Pictonia,* which corresponds to the boundary between the ammonite chronozones Pseudocordata and Baylei. This definition of the base of the Kimmeridgian in term of ammonite stratigraphy has been recently accepted by the International Subcommission on Jurassic Stratigraphy (Morton 2007), although the Dorset Coast section is unsuitable for modern definition of this boundary in term of the Global Stratotype Section and Point (GSSP). The currently proposed GSSP for the base of the Kimmeridgian Stage is placed in a very complete succession of mudrock deposits of the foreshore at Flodigarry, Staffin Bay, Isle of Skye, northern Scotland – where it is defined by changes in the Subboreal ammonites at the boundary between Pseudocordata and Baylei zones, and independently in the Boreal ammonites of the family Cardioceratidae between Rosenkrantzi and Bauhini zones, in the place where an older genus *Amoeboceras* is replaced by younger genus *Plasmatites* (Matyja et al. 2006). Furthermore, dinoflagellate cysts, magnetostratigraphy and carbon isotope data from the same section provide auxiliary markers, and significantly enlarge its correlation potential. Mineralogy of the strata has also permitted here a direct Re-Os radiometric dating of the Oxfordian–Kimmeridgian boundary to 154.1±2.2 Ma (Selby 2007). At the time of writing of this abstract, the proposal for the position of the base Kimmeridgian GSSP has been put forward for considered for ratification with the International Subcommission on Jurassic Geology.

The acceptance of the base of the Kimmeridgian at the base of the Baylei Zone as the GSSP global standard has important stratigraphical consequences because of innapopriate correlation in the past between the Subboreal/Boreal and the Submediterranean/Mediterranean zonal schemes. The boundary proposed correlates with the boundary between the Hypselum and the Bimammatum ammonite zones in the Submediterranean–Mediterranean subdivision, i.e. it runs much lower than that previously accepted (Wierzbowski et al. 2016, and older references therein).

The problem of the upper boundary of the Kimmeridgian Stage is strictly correlated with recognition of the Tithonian Stage. The Tithonian was established by A.Oppel in 1865 but for a long time this name was referred to the Tethyan deposits only, and even sometimes was treated as an invalid because "not formed upon a place name" (Arkell 1946), but on the Greek mythological name (Tithon was a human spouse of Eos, goddess of the dawn). It has been reasonably accepted thereafter (Arkell 1956) because "it is too late to abolish it after a hundred years of continuous use," and it is widely used nowadays as the name of the youngest Jurassic stage (Zeiss 2003). The base of the Tithonian Stage is normally accepted at the base of the Submediterranean/Mediterranean Hybonotum Zone, which more or less precisely correlates with the Subboreal, and the transitional Subboreal–Submediterranean "biome francogermanique" zones i.e. the Gigas Zone, the Elegans Zone, and the Klimovi Zone. Thus, the upper boundary of the Kimmeridgian Stage (*sensu gallico*) runs in the middle of the British "Kimmeridgian *sensu anglico*" and mostly below the occurrence of ammonites of the genus *Gravesia*. This definition is, however, in accordance with the original definition of the Stage by A. d'Orbigny (although paradoxically resulted from a wrong stratigraphical correlation, cf. Arkell 1946).

The Kimmeridgian Stage is subdivided into two substages: the Lower Kimmeridgan and the Upper Kimmeridgian with their boundary running at the base of the Mediterranean–Submediterranean Acanthicum Zone, which corresponds approximately to the base of the Subboreal Mutabilis Zone in a narrow meaning of this zone (above the Askepta Subzone).

The detailed subdivision of the Kimmeridgian Stage in Europe is strictly correlated with the existence of ammonite paleobiogeographic units, each of them characterized by a different ammonite faunas. Four main ammonite bioprovinces are recognized during Kimmeridgian in the territory of Europe, each of them is characterized by different groups of ammonites: 1. the Mediterranean Province with occurrences of lytoceratids and phylloceratids, as well as of the special groups of Perisphinctidae – subfamilies Passendorferiinae and Idoceratinae; 2. the Submediterranean Province with Ataxioceratidae, and several groups in common with Mediterranean Province such as Oppeliidae and Aspidoceratidae; 3. the Subboreal Province with Aulacostephanidae, and 4. the Boreal Province with Cardioceratidae. These provinces occupied various areas from the oceanic Tethys basin (Mediterranean) in the south, and the deep neritic zone of the northern Tethyan shelf (Submediterranean), to the intermediate generally shallow-water zone of so-called European archipelago (Subboreal), and the semi-enclosed Boreal sea in the north.

Despite the existence of the bioprovinces, of mostly latitudinal character and fairly uniform ammonite faunas, there existed during Early Kimmeridgian strongly faunistically contrasted biogeographical units of a local extent, which can be recognized within the particular provinces. Such units are interpreted herein as subprovinces. Their origin was stimulated by the tectonic movements during the latest Oxfordian and the Early Kimmeridgian, which resulted in marked changes in the depositional environments over wide areas of northern and central Europe. The development of land-barriers, and/or shallow water carbonate platforms caused additionally allopatric speciation of the particular ammonite lineages, such as the Aulacostephanidae lineage during the Early Kimmeridgian, and appearance of its two separate branches – this of *Pictonia* and *Rasenia* in NW Europe (NW European Subprovince of the Subboreal Province), and that of *Vineta*, *Vielunia*, *Pomerania–Pictonites* and *Eurasenia* in NE Europe (NE European Subprovince of the Subboreal Province) (Enay 1980; Wierzbowski et al. 2016). Whereas the NW European Subprovince was rather strongly isolated from the Submediterranean Province (except for a short migration event of Subboreal ammonites during the *Rasenia cymodoce* Subchron in the Aquitaine Basin, see Hantzpergue 1989), the NE European Subprovince had the open-marine connection with Submediterranean Province, which resulted in migrations of Subboreal and sometimes even Boreal ammonites ranging deep into Submediterranean Province (even in southern Germany and Switzerland). Such a patchy pattern of paleobiogeographic units was characteristic of the Early Kimmeridgian.

A marked change in paleogeography of Europe took place at the end of the Early Kimmeridgian and during the Late Kimmeridgian. Marine transgression at the transition between the Early and Late Kimmeridgian during the late Hypselocyclum and the Divisum chrones resulted in disappearance of the shallow-water carbonate platforms, and in a wide occurrence of deeper-water limestones and marls often with intercalations of the *Nanogyra* lumachelles, distinguished sometimes as the "Virgulien substage" or Virgulien facies type (from common oyster *Nanogyra virgula*). These deposits covered wide areas of Europe belonging to Submediterranean Province, and partly to adjoining Subboreal Province. Very characteristic ammonite faunal communities occurred during late Early Kimmeridgian, and the early Late Kimmeridgian (the Mutabilis Chron) along the middle of the European shelf and these have been originally distinguished by Hantzpergue (1989) as a characteristic faunal assemblage of the "franco-germanique" biome. This characteristic paleobiogeographic unit (biome or ecotone) continues further east to central Poland (Kutek & Zeiss 1997), and even more eastward to central part of European Russia (Rogov et al. 2017). The wide transgression affecting this area resulted also in the abrupt appearance of Subboreal ammonites of the family Aulacostephanidae, mostly of the genus *Rasenioides* which evolved here subsequently into a genus *Aulacostephanoides*, as well as the Tethyan representatives of the family Ataxioceratidae, and a marked northward distribution of Aspidoceratidae ranging into Subboreal Province (see e.g. Matyja & Wierzbowski 2000). The next strong transgressive impulse occurred at the base of the Eudoxus Chron, and it brought here Subboreal ammonites of the genus *Aulacostephanus*, and then successively Submediterranean ammonites (e.g. Birkelund et al. 1983; Hantzpergue 1995). The end of Kimmeridgian in the Tethyan Shelf is marked by development of the local (endemic) groups of ammonites mostly coming from Ataxioceratidae – it is the case of development of the genus *Gravesia* in the "biome franco-germanique" (see Hantzpergue 1995), but also of new lineages of ammonites in once more strongly differentiated Subboreal Province: (1) the genus *Sarmatisphinctes* in NE European Subboreal Subprovince which evolved successively during Early Tithonian into first *Ilowaiskya* of the family Virgatitidae (Kutek & Zeiss 1997); (2) the genus *Subdichotomoceras* in NW European Subboreal Province which possibly gave rise to *Pectinatites* and other Subboreal-Boreal ammonites of the Tithonian (see e.g. Enay et al. 2014, and earlier references therein). The marked changes at the end of the Kimmeridgian resulted also in the total decline of the Subboreal Aulacostephanidae, and the Boreal Cardioceratidae.

The correlation of the ammonite subdivisions of the Kimmeridgian is usually done on the basis of the detailed analysis of the sections, in which ammonites indicative of the particular biogeographical units occur, such as Subboreal/Boreal ammonites and Submediterranean ammonites in the Lower Kimmeridgian (Wierzbowski et al. 2016) or Submediterranean and Mediterranean ammonites in the Upper Kimmeridgian (e.g. Scherzinger et al. 2016). Biostratigraphical data may be compared with the astrochronological time scale, which was elaborated in detail for particular parts of the Kimmeridgian succession and correlated with the biostratigraphical subdivisions of the Lower Kimmeridgian (Boulila et al. 2010) and of the Upper Kimmeridgian (Huang et al. 2010).

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New data on the Lower to Middle Jurassic transitional beds of the Czertezik Succession, Pieniny Klippen Belt, Poland

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A new study of the classical area of occurrence of the Czertezik Succession between the Zamkowa Hill and the Pieniński Stream in a central part of the Pieniny Klippen Belt (PKB) in Poland has revealed the presence of uppermost Pliensbachian, Toarcian and possibly Aalenian deposits – so far either not known from that succession or referred wrongly to other successions. This discovery has important stratigraphical and paleogeographical implications because both the detailed stratigraphy and the position of the Czertezik Succession in the PKB remain the problem of controversial interpretations: see Birkenmajer (2007, 2017) versus Wierzbowski et al. (2004).

The oldest deposits studied are represented by spotty limestones and marls. They yielded ammonites described in the past by R. Myczyński (Birkenmajer & Myczyński 1994), which belong to the genus *Pleuroceras* and are indicative of the uppermost Pliensbachian Spinatum Zone. In thin-sections the deposits are spiculite wackstones, passing upwards into spiculite packstones. The spotted deposits were interpreted as belonging to the Pieniny Succession, tectonically "wedged in between two klippes of white/gray crinoidal limestone (Smolegowa Limestone Fm., Czertezik Unit)" (Birkenmajer 2007). The deposits show, however, sedimentological transition into the overlying crinoidal limestones at the southern slopes of the Wielka Pustelnica Mt., and thus have to be included into the Czertezik Succession. The topmost part of the spotty limestones is covered with a thin ferrugineous crust, and overlain by a sharp erosional contact with crinoidal limestones containing abundant lithoclasts. The lithoclasts, up to 1–2 cm in diameter, include: fragments of spotty limestones; clasts of grey, microbial(?) limestones; red to yellow-green fragments of ferrugineous stromatolites/large oncoids consisting of hematite, chlorites, chamosite and ankerite; phosphorites, and abundant quartz grains. Hematite–chlorite mineral assemblages are also present in patches of a red matrix in the lower part of crinoidal limestones. This part of crinoidal limestones is about 1–1.5 m thick, and is overlain by, ca. 45 m thick, typical crinoidal limestones of the Smolegowa Limestone Fm. and Flaki Limestone Fm., attributed to the Bajocian (Wierzbowski et al. 2006).

The following observations are given in order to determine the stratigraphical position of the crinoidal limestones with lithoclasts, representing the lowermost part of the crinoidal unit: (1) a small fragment of an ammonite, attributed to Dactylioceratidae, suggesting the Early? to Middle Toarcian age, has been found in a red ferruginous clast; (2) red to yellow-green crusts, stromatolite encrustations and oncolites are commonly encountered in condensed Toarcian deposits in the successions representing southern parts of the Pieniny Klippen Basin and adjoining parts of the middle Carpathians basins (Wierzbowski et al. 2012). The nature of all the clasts suggests that the strongly condensed original Toarcian deposits were eroded during the synsedimentary deformation, which also affected some underlying spotty limestones of the Pliensbachian age and grey limestones, which were presumably deposited before the full onset of crinoidal sedimentation. The same applies to quartz grain derived from unknown magmatic or sedimentary rocks. The deformation may have resulted in the development of submarine scarps settled by crinoidal gardens, which yielded material for the formation of crinoidal limestones. The tectonic deformations, culminating in final development of the crinoidal limestones with lithoclasts, could be placed in the Late Toarcian–Aalenian. The discussed deposits of the Czertezik Succession show marked similarity to those from the eastern part of the PKB (Priborzhavske, Perechin, Novoselitsa, Beňatina sections) and possibly of western Slovakia (Podbiel-Červená Skala section), which represent a transitional zone between the Czorsztyn Ridge and the Kysuca–Pieniny Basin.

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Progress with selecting a GSSP for the Berriasian Stage (Cretaceous) – illustrated by sites in France and Italy

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Since 2009 the Berriasian Working Group (ISCS, ICS) has been searching for the best sequence globally to represent the Tithonian/Berriasian (Jurassic/Cretaceous) boundary. To take this forward, it has made field assessments of more than sixty localities, documenting their sequences, fossil biotas and magnetostratigraphy. Only on such a sound factual basis could the best boundary markers be distinguished, prior to selecting a GSSP. Founded on this substantial study of new localities and reassessment of others, in 2016, the base of the Alpina Subzone was chosen as the most consistent marker for the base of the Berriasian: this horizon showing a well-documented turnover of calpionellid taxa, a turnover that has the widest geographical distribution of any biotic event in the J/K interval. These decisions on a primary marker were shared with, and discussed with, a wider community at the Vienna Cretaceous Symposium in 2017. There the WG agreed, again, to try to select a GSSP site that yielded, at least, results for magnetostratigraphy, calpionellids, ammonites and calcareous nannofossils, so as to give the greatest possibilities for correlation to more distant regions.

In 2018, at the Berriasian workshop in Kroměříž, discussion focussed on consideration of a shortlist of seven GSSP candidates: Puerto Escaño (Spain), Brodno (Slovakia), Fiume Bosso (Italy), Torre de’ Busi (Italy), Rio Argos (Spain), Kurovice (Czech Republic), and the Drôme/Haute Alpes (Vocontian Trough) plexus of sites (Le Chouet, Font de St Bertrand, Haute Beaume, Charens & Tr*é* Maroua)(France). In a debate on the biotic and magnetostratigraphic attributes of each locality, their assets and negative points were assessed. fSome sites were rejected because they lacked a full complement of defining characters or had other specific defects: Puerto Escaño (condensation & aberrant nannofossil distribution), Brodno (lack of ammonites and incomplete M18r), Torre de’ Busi (no ammonites, aberrant calpionellid distribution), Kurovice (tectonised intervals close to the boundary level), and Rio Argos (no magnetostratigraphy).

In addition, a very extensive profile at Theodosia (Ukraine), for which there had been great hopes, was ruled out, because no coherent calpionellid zonation could be established. The final conclusion was that profiles at Fiume Bosso and in the Vocontian Basin provided the best candidates, and that documentation of these should continue, in preparation for their consideration as GSSPs – to be followed by a formal WG vote. That vote will be concluded in May 2019.

Oxfordian to Lower Berriasian pelagic carbonates from the Yavorets syncline (Western Balkan Mountains): microfossil biostratigraphy and microfacies

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The pelagic carbonates in the Yavorets syncline are the easternmost part of the narrow band of exposures with WNW–ESE to W–E trend that crop out between the west state border and the Iskar River Gorge (Western Balkan Mts, Bulgaria). They represent a continuous sequence divided into three formations: Yavorets Fm. (holostratotype, grey medium-bedded micritic limestones); Gintsi Fm. (pink and grey nodular, intraclastic and micritic limestones, "Ammonitico Rosso"-type); and Glozhene Fm. (grey regularly-bedded micritic to intraclastic limestones, Biancone-type). These sediments take part of the Western Balkan Carbonate Group and span the Callovian–Oxfordian to the Berriasian (Sapunov 1976). Calpionellid and calcareous dinocyst biostratigraphy and microfacies were made in this study, from the topmost Yavorets Fm. to approximately the top-Glozhene Fm. The extremely rich and diverse chitinoidellid, calpionellid and calcareous dinocyst associations and their vertical distribution allowed the detailed zonation of the pelagic sediments. Definition of chitinoidellid and calpionellid zones followed those of Pop (1994) and Lakova & Petrova (2013) and that of calcareous dinocysts – Ivanova in Lakova et al. (1999).

The successive chitinoidellid and calpionellid zones (and subzones) were documented: the *Chitinoidella* Zone (*Dobeni* and *Boneti* subzones); the *Praetintinnopsella* Zone; the *Crassicollaria* Zone (*Remanei*, *Intermedia* and *Colomi* subzones); and the *Calpionella* Zone (*Alpina* and *Remaniella* subzones). The calpionellids confirmed the Early to Late Tithonian age of the topmost strata of the Gintsi Formation and provided new evidence for the Late Tithonian and the earliest Berriasian age of rocks of the Glozhene Formation. The Jurassic/Cretaceous boundary was drawn in the lower part of the Glozhene Formation, by the last occurrence of *Calpionella elliptalpina* Nagy and the "explosion" of the spherical form of *Calpionella alpina* Lorenz. This age assessment was supported and expanded down-section by the dinocyst zonation that corresponds from the *C. fibrata* and *C. parvula* zones (Oxfordian, Yavorets Fm.) to the *St. proxima* Zone (Lower Berriasian, Glozhene Fm.).

Based on the dominant microfossil constituents and carbonate textures, a set of four successive microfacies has been identified through the section studied. From base to top these are: radiolarian microfacies (Yavorets Fm. – base of the Gintsi Fm, Oxfordian); *Saccocoma* microfacies (Gintsi Fm., Kimerridgian–Upper Tithonian); *Globochaete* microfacies (Glozhene Fm., Upper Tithonian); and calpionellid microfacies (Glozhene Fm., Upper Tithonian–Lower Berriasian). Calcified radiolarians and "pelagic ooids" are the most characteristic components for the rocks of the Yavorets Fm. Radiolarian microfacies is predominantly represented by radiolarian–peloidal packstones and rarely by radiolarian–intraclastic–peloidal packstones. The indicative microfossils for the Gintsi Fm. are the pelagic crinoids *Saccocoma* sp. The nodular limestones of this formation were identified to as *Saccocoma* wackestones, radiolarian–*Saccocoma* wackestones and radiolarian–*Globochaete*–*Saccocoma* wackestones, whereas the intraclastic limestones were found to be predominantly represented by *Saccocoma*–intraclastic rudstones. The notable abundance of both *Globochaete alpina* and calpionellids in the rocks of the Glozhene Fm. led to the distinction of the *Globochaete*- and the calpionellid microfacies. The former microfacies is composed of radiolarian–*Saccocoma*–*Globochaete* wackestones and radiolarian–*Globochaete* wackestones, whereas the latter consists predominantly of calpionellid wackestones, and rarely, by both radiolarian–spicule–calpionellid wackestones and calpionellid–radiolarian–spicule wackestones.

From microfossil constituents and carbonate textures, it can be inferred that the sediments of the Yavorets and Gintsi formations were accumulated on a structural high of the basin floor, whereas those of the Glozhene Formation were deposited into a deep-water basin environment (Flügel 2004, and references therein).

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