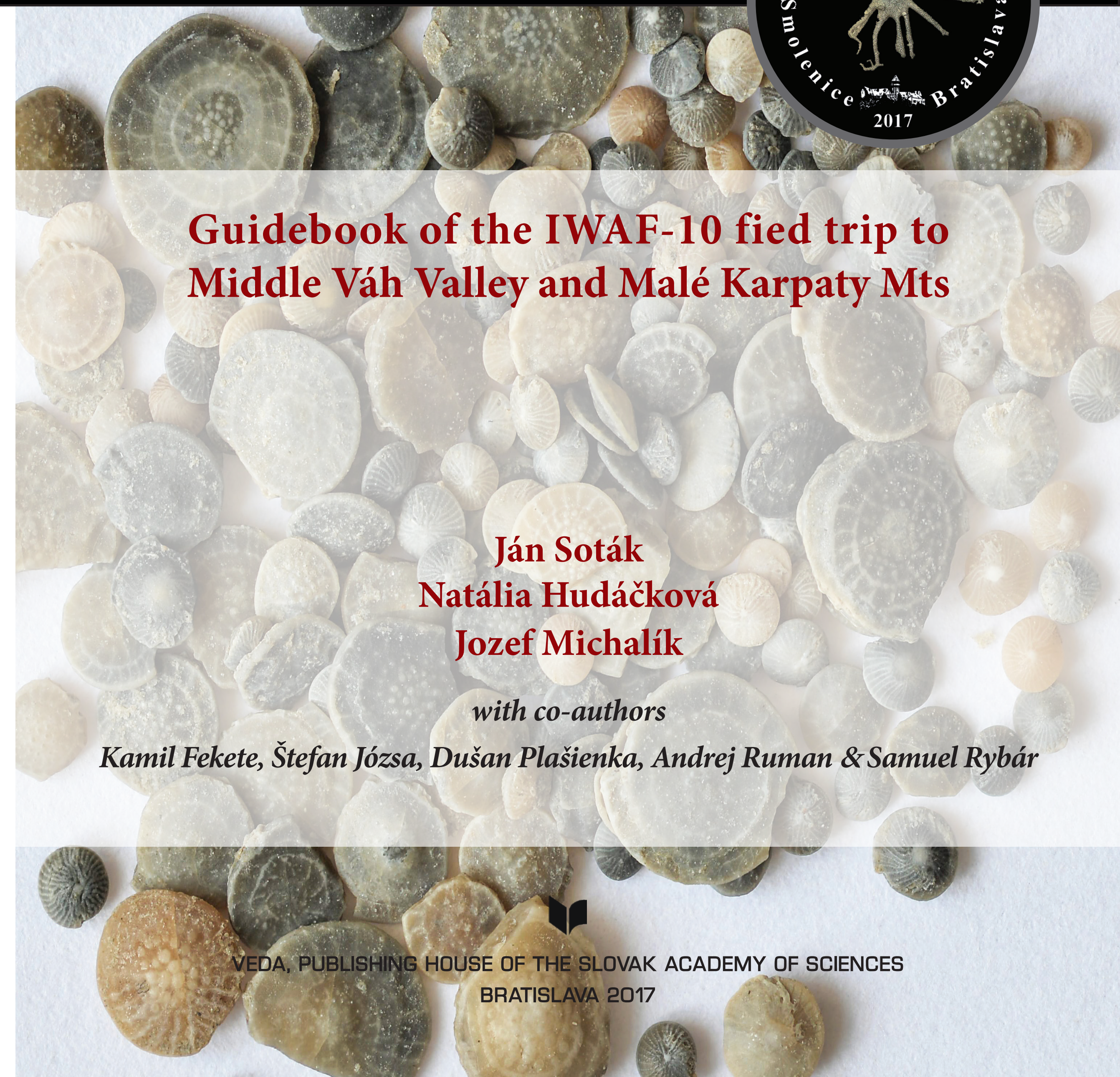
Microfauna and biostratigraphy of the Mesozoic and Cenozoic formations of the Western Carpathians



Guidebook of the IWAF-10 fied trip to Middle Váh Valley and Malé Karpaty Mts

Ján Soták
Natália Hudáčková
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with co-authors

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Preface

The stratigraphical analysis is one of the oldest methods of reading the geological record. Stratigraphy has over time undergone a vigorous development, that is at present culminating in the tendency to define more precisely definition of the geological time scale on the level of bioevents, golden spikes, time surfaces, magnetochrones etc. The stratigraphic hierarchy reaches a peak in the GSSP (Global Stratotype Section and Point), that represents internationally accepted standard stratotype sections and points for definition of stratigraphic boundaries. A new trend of stratigraphical research is based on the calibration of the Earth's time with global changes of paleoenvironments in a response to paleoclimatic changes, orbital factors, astrochronological and solar effects, eustatic cycles, atmospheric influences, and catastrophic events etc. Nowadays stratigraphy also combines mathematical logic with stratigraphic principles allowing to control inputs and results.

The stratigraphic research has a two-hundred-year-old tradition in the Western Carpathians. During this period of stratigraphic work, numerous names of the stratigraphic units became worldwide known (e.g., Púchov Marls, Magura Sandstone, Meliata Series etc.) and represent historical stratotypes at the territory of Slovakia. Intensive stratigraphic studies of the Mesozoic and Cenozoic formations of the Western Carpathians took place from the 1960s to 1970s, when their biostratigraphic subdivision, lithostratigraphical classification, and systematics of the fossil groups were elaborated (e.g., Cretaceous and Paleogene Foraminifera – Salaj & Samuel 1966, Samuel & Salaj 1968, Scheibnerová 1961, Jendrejáková 1968, Samuel et al. 1972, large foraminifers – Vaňová 1972, Köhler 1967, Köhler in Gross et al. 1980, 1993, Triassic dasycladacean algae – Bystrický 1964, calpionellids and calcareous dinocysts – Borza 1969, Incertae sedis – Borza & Mišík, 1976, Mišík & Borza 1978, Neogene micro- and macrofossils – Cicha et al. 1975 etc.). High standard of biostratigraphic work in the Western Carpathians was achieved by organizing the 18th European Colloquy on Micropaleontology in Czechoslovakia in the year 1983 (Samuel & Gašparíková 1983).

Biostratigraphic knowledge about taxonomy and systematics of microfossil groups, such as calpionellids, calcareous nannofossils, radiolarians, conodonts, palynomorphs, Triassic and Jurassic foraminifers, Jurassic and Cretaceous algae, Neogene foraminifers has been improving over next decades (Salaj et al. 1983, Papšová in Buček et al. 1991, in Kovács et al. 1996, Ožvoldová & Peterčáková 1992, Ožvoldová & Frantová 1997, Mišík et al. 1999, Soták 1987, Soták & Mišík 1993, Reháková 1995, Reháková & Michalík 1997, Vašíček et al. 1994, Halásová 1999, Reháková 2000, Andrejeva Grigorovič et al. 2001 etc.). The stratigraphic studies of the Western Carpathians enhanced in the second half of the 20th century by new trends of high-resolution and integrated stratigraphy. More striking enforcement of these research trends has been defended due to the lack of laboratory facilities for analysis of stabile isotopes, radioisotopes, magnetostratigraphy, cathodoluminiscence etc. Despite of this, the studies from the Western Carpathians achieved international level in some boundary stratotypes (e.g., Triassic-Jurassic boundary in the Kardolina and the Furkaska sections, Jurassic-Cretaceous boundary in the Brodno and the Hlboča *sections – Michalík et al. 2007, 2009, 2013, Grabowski et al. 2010), in the reference sections for identification of some stratigraphic events (e.g., oceanic anoxic events from the Rochovica section, Upper Cretaceous oceanic red-bed formations in the Široká and the Vršatec sections), in the records of the hyperthermal events and indicators of cooling in the Paleogene formations of the Kršteňany, Pucov, and Kocurany sections etc. (Michalík et al. 2008, Michalík & Soták in Hu et al. 2005, Soták 2010, Soták et al. 2007, 2011 etc.). Laboratory equipment for obtaining results of higher quality in biostratigraphic and paleoenvironmental research has been acquired from the European Structural Funds through the key geoscientific project 'Centre of Excellence for Integrative Research the Earth's Geosphere' at the Geological Institute of the Slovak Academy of Sciences in Banská Bystrica (2009–2015, project leader J. Soták).*

The 10th International Workshop on Agglutinated Foraminifera in Slovakia (Smolenice Castle, April 19th–23th, 2017) provides a good occasion to upgrade the micropaleontological knowledge of the Western Carpathian units by publishing a new monograph 'Microfauna and Biostratigraphy of the Mesozoic and Cenozoic Formations of the Western Carpathians'. The monograph presents microfauna assemblages and biostratigraphic data from reference localities of the Western Carpathian units in the Middle Váh Valley, the Malé Karpaty Mts, the Brezovské Karpaty Mts, and the Vienna Basin. These areas were selected to demonstrate foraminiferal assemblages from different stratigraphic formations (from the Middle Cretaceous to the Middle Miocene), their phylogenetic changes, events of radiation and extinction, colonization of basinal substrates, environmental stress conditions, bathymetric changes, and high-resolution biostratigraphy. Such a content of the monograph might be appreciated mainly by researches and students dealing with foraminiferal micropaleontology, biostratigraphy, environmental micropaleontology, paleoceanography, paleoclimatology, and other fields of geosciences.

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) is gratefully acknowledged. The research was also supported by the APVV-0212-12 Project as well as by the grants 2/0034/16 and 2/0057/16 of the VEGA Scientific Agency. Laboratory works on extraction of microfossils and geochemical analysis have been carried out at the Earth Science Institute of the Slovak Academy of Sciences by Dana Troppová, Iveta Ivaničová, Hana Demeterová, Alžbeta Svitáčová, Branislav Ramaj, and Juraj Šurka, who are thanked for their help and field assistance. Technical help is also acknowledged for providing of microfossil extraction by Zdenka Keblovská (Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava). Authors also express their thanks to the Nafta a.s. for providing borehole material from the Gbely Repository.

Ján Soták and co-authors

Volume is dedicated to oustanding work of Josef Salaj and Ondrej Samuel in the Carpathian micropaleontology and foraminiferal research

The remembrance of RNDr. JOZEF SALAJ, DrSc.

Adriena ZLINSKÁ and Ján SOTÁK

Dr. Jozef Salaj was born on January 11, 1932 in Želovce near Veľký Krtíš. After graduation at the Faculty of Geology and Geography of Charles University in Prague, where under the supervision of excellent pedagogues, such as Prof. J. Augusta and Prof. J. Špinar as well as academics V. Pokorny, R. Kettner and O. Kodym, he received apart from geology also solid knowledge about paleontology and stratigraphy.

In August 1956, he joined the State Geological Institute of Dionýz Štúr in Bratislava (SGIDŠ). Right from the start, he focused on geological mapping and microbiostratigraphical research of the Myjava Hills. As first he cartographically and stratigraphically defined lithostratigraphic units of the Senonian and the Paleogene, known as the Paleogene Gosau Development. He created the first concept of the Cretaceous and Paleogene biostratigraphic division which was accepted for the whole Mediterranean area.

Concomitantly he also engaged in research of the Cretaceous marly and flysch sequences of the Tatric and Fatric units. He proved their Barremian-Aptian, Albian and Cenomanian age.

Between years 1961–1965 he was mainly focused on the Cretaceous and Paleogene sediments of the Middle Váh Valley, especially, in the Manín and Klape units. He paid special attention to the Cretaceous formations that were previously dated only by rare macrofauna findings.

His sphere of research gradually spread to the entire Pieniny Klippen Belt (PKB). He significantly contributed to the refinement of individual lithostratigraphic units, but also brought a new perspective on the paleogeographic evolution of the most complex tectonic units of the Western Carpathians. Along with his closest associates, he demonstrated a continuous sedimentation between the Middle and the Upper Cretaceous and diachronic age of the Upohlav conglomerates. He demonstrated the presence of Sennonian deposits in the Manín Unit, Paleocene and Lower Miocene age of sediments of the Peri-klippen area. As a result of these facts, he fundamentally changed the interpretation of tectonic evolution of the PKB, Paleogene transgression to Central Carpathian basins, and the paleogeographic position of the Manín Unit.

In the early sixties, intensive studies of Triassic foraminifers began worldwide. In line with this trend and in collaboration with other authors, he focused on this current issue and worked on it during the following years, which ranked him among the leading experts of fossil microorganisms. As first he significantlly contributed to the division of Triassic complexes of the Western Carpathians on the basis of foraminifers, biozonation and interregional correlations of this system. He published the results of his research in numerous articles and in cooperation with K. Borza and O. Samuel in the monography "Triassic foraminifers of the West Carpathians" (1993). Publications about the Triassic attracted a great international acclaim.

In years 1967–1974, the focus of his research moved to North Africa, where he worked in the "Service Géologique de Tunisie" in Tunisia. He presented new findings at the VI African Micropalaeontological Colloquium (1974), and was its general secretary. On this occasion, he presented a proposal to the wide community of professionals about Cretaceous and Paleogene hypostratotypes for the Mediterranean area. In a cooperation with K. Pozaryska and J. Szczechurova (1976), they suggested Paleocene developments in the area of El Kef for the Paleocene stratotype in marine development. The stratotype boundary between the Cretaceous and the Paleocene in this area was approved at the International Geological Congress in Washington. Dr. Salaj suggested that stratotypes for the Middle (Harien) and the Upper (Mellégien) Paleocene were also in this area.

Results of his research activities in Tunisia were published in numerous articles and in a comprehensive monograph "Microbiostratigraphie du crétacé et du paléogéne de la Tunisie septentrionale et orientale (hypostratotypes Tunisiens)". In 1976, based on this work, he was awarded by the title of Docteur d'Etat (as DrSc.) in Paris (Université de Paris VI). In 1982, he defended his doctoral dissertation thesis on the Triassic foraminifers of the Western Carpathians and the Mediterranean area at the Presidium of the Czechoslovak Academy of Sciences in Prague.

After the return from Tunisia and two-year work stay in Libya and Iraq, he was actively involved in the microbiostratigraphic research on sheets

1:25,000 in the Middle Váh Valley and worked on the formulation of regional geological maps (1:50,000) of the Myjava Hills, Brezovské and Čachtické Karpaty Mts with explanatory notes in a co-operation with other geologists. As first, here as well as in the Manín area, he pointed out on the possibility of occurrence of hydrocarbons on the basis of favorable geological setting (Salaj, 1966).

He was working for a relatively long time on a monograph about geology of PKB and the Peri-klippen zone of the Middle Váh Valley. It was published together with geological map of this area at 1:50,000 in 1995.

He also applied his rich experience in organizing the 18th European Micropalaeontological Colloquium in Czechoslovakia as a general secretary as well as in international microbiostratigraphical research in various IGCP projects. But equally important is his contribution to co-operation in some special biostratigraphical studies at Columbia University (ESRI) and Amoco Co. in Tunisia.

Within international co-operation in the various bilateral agreements of SGIDŠ, he actively participated in research of Mesozoic, especially, Triassic formations. As a coordinator, in co-operation with E. Trifonova, D. Gheorghian and V. Coronet, he was involved in the development of an interregional microbiostratigraphical scheme of the Triassic of the Western Carpathians, the Balkans and Helenids on the basis of foraminifers.

Since 1994, RNDr. J. Salaj, DrSc. worked at the Geological Institute of the Slovak Academy of Sciences. This opportunity gave him a creative space for completion of unfinished issues about the Cretaceous and Paleogene of Tunisia and Slovakia, which he published in a series of articles and extensive compendia in the edition of “Zemný Plyn a Nafta Hodonín” magazine (1997a, b; 1998a, b, c; 1999 etc.). He contributed significantly to the scientific education of young domestic and foreign researchers, especially, in the field of micropaleontology. In the following years, he also educated PhD students from North Africa at the Faculty of Natural Sciences of Charles University in Prague.

In 2000, on behalf of the 60th anniversary of the SGIDŠ, he was awarded by a Golden Commemorative Medal for science development and promoting of Slovakia abroad. He published his substantial works on the stratigraphy of the Súľov Paleogene, taxonomic revisions of foraminifers, and paleoclimatic researches in Geologica Carpathica (1997, etc.), Mineralia Slovaca (2001), and others. He worked on new grant projects VEGA and APVV focused mainly on microbiostratigraphical research of the Upper Cretaceous and Paleogene formations in the PKB, Manín and Klape units. In addition to research work, he was involved in organizing important international events such as the International Symposium on Cretaceous in Vienna in 2000, the 17th Congress of the Carpathian-Balkan Geological Association in Bratislava in 2002, the IGCP workshops, research programs at Columbia University (ESRI) and others.

In 2005, the Presidium of Foundation on Foraminiferal Research at the Smithsonian Institute in Washington nominated RNDr. J. Salaj, DrSc. on the "Cushman Award" which is one of the most important micropaleontological awards obtained by only few European scientists.

In 2007, the Presidium of the Slovak Academy of Sciences honored his scientific contribution with the "SAS prominent figure of the year 2007". For the development in the field of micropaleontology, he received a letter of thanks on the occasion of the 8th Czech-Slovak-Polish Palaeontological Conference held at SGIDŠ.

During his extremely fruitful professional life, RNDr. Jozef Salaj, DrSc. published more than 300 scientific contributions with the highest scientific credit and great international acclaim. He represented a generation of the post-war period, thanks to which micropalaeontology and stratigraphy of Central European countries have reached a high scientific level. His research, however, exceeded the level of local science and brought progress to micropalaeontology and stratigraphy across the Tethyan realm.

RNDr. Jozef Salaj, DrSc. passed away on February 18, 2011 in Bratislava.

RNDr. ONDREJ SAMUEL, DrSc. - 15. death anniversary

Adriena ZLINSKÁ

Dr. Ondrej Samuel was born on February 10, 1931 in Palárikovo, near Nové Zámky. He graduated at the Faculty of Geology and Geography of Comenius University in Bratislava in 1956. During the last year of his studies, Dr. Samuel was an assistant of D. Andrusov. From 1956 to 1994 he was employed at the State Geological Institute of Dionýz Štúr (SGIDŠ), as a deputy director (1972–1982), head of the Paleontology Department (1982–1983), and head of the Biostratigraphy Department (1982–1993). At the SGIDŠ he was also elected to chairman of the convocation (1980–1994) and member of the editorial board (1972–1994). From 1963 to 1986 he was a scientific redactor of the editorial series "Západné Karpaty" (Western Carpathians), the sequence "Paleontológia" (Paleontology), and a long-time scientific redactor of the edition "Geologické práce – Správy" (Geological Works – Reports) (1964–1997), "Mineralia Slovaca" (1973–1995), "Časopis pro mineralogii a geologii" (Magazine for Mineralogy and Geology) or "Časopis Českej geologickej spoločnosti" (Magazine of the Czech Geological Association) (1985–1994).

Thanks to his wide scientific and management abilities, he was a member of various scientific institutions. Within the scientific board for Earth and Space Sciences of the Slovak Academy of Sciences, he worked for the

Commission for Geology and Geography. He was a chairman of the Terminological Commission and a deputy chairman in the Board for Geology and Geography of the Czechoslovak Stratigraphical Commission of the Czechoslovak Academy of Sciences, as well as a member of the Common Scientific Board of ÚÚG (General Office of Geology), SGIDŠ and the Czechoslovak (and Slovak) National Committee. Beside scientific activities, he was also active in organizing various scientific undertakings, for instance, X Anniversary Meeting of CBGA (Carpathian-Balkan Geological Association) in Czechoslovakia (1973) and XIII National Geological Conference of the Slovak Geological Society (SGS). It is especially important to mention his meritorious activities for the Slovak Geological Society. He became its member in 1960, he was appointed a secretary in 1974, and served as a deputy chairman from 1982 to 1994. From 1983 to 1995 he was a president, representing Czechoslovakia (and from 1993 Slovakia) in CBGA, where he was a member of the International Subcommittee for Paleontology. He was a chairman of the board for defense of candidate dissertation thesis (CSc.), specialization Paleontology, and an alternating chairman of the board for defense of doctoral dissertation thesis (DrSc.).

In 1964, he defended his candidate dissertation thesis (CSc.) entitled "Microbiostratigraphy of external and internal flysch of eastern Slovakia, Paleogene of the Klippen Belt and Central-Carpathian Paleogene". He obtained the Doctor of Sciences (DrSc.) degree in Bratislava in 1972.

During his scientific-research activities, his major specialization was stratigraphy of the Paleogene, the Cretaceous, and later also of the Triassic as well as paleontology of foraminifers. The published monographs about these issues are so far the most complex reviews and represent the stratigraphic value of foraminifers in the Western Carpathians. He described more than 70 new taxa whose validity has been recognized in most cases also in the prestigious monograph "Foraminiferal Genera and Their Classification" (by Loeblich - Tappan), published in New York (1988). His works have had influence on improvement of the accuracy of flysch sequences and the Klippen belt at the territory of Slovakia, which also improved the theory about paleogeographic and also tectonic development of the Western Carpathians. An important feature of his published works is also a comparison of planktonic foraminifers with other fossil series (giant foraminifers, nanoplankton, palynology) and biozoning of the Cretaceous and the Paleogene, which enables interregional stratigraphic parallelism and correlation with the international geochronological scale.

Beside monographic works, he had also an essential contribution to three volumes of the Stratigraphic Dictionary (1983, 1985, 1988) which he not only edited but he was also one of its major authors. These thee volumes represent the first lithobiostratigraphic classification of the Western Carpathian system. Chronostratigraphic and synoptic table, reflecting the present state of chronostratigraphy at the world-wide scale, is a suitable part of the Stratigraphic Dictionary in the first (1980) and also the second (1987) edition. Beside the aforementioned works, he also participated on two volumes of The Encyclopedia of Geological Sciences (1983) and The Encyclopedia of Slovakia. Reference-Terminology Dictionary (2000), specialization paleontology, is a result of his long lasting activity in the Terminological Commission. It contains 3500 entries.

His scientific·research activities were awarded on international forums, for example, during the scientific meeting about the Eocene in Hungary, where he was honored by a medal for his contribution in solving problems on microbiostratigraphy of the Paleogene in Europe. For his extensive international cooperation in Central Europe, he was awarded by a honor plaque of the Hungarian Geological Institute, Polish Geological Institute (1970), Central Geological Institute in Prague (1979), as well as by honor memberships in the Poland Geological Society (1990), Czechoslovak Society for Mineralogy and Geology of the ČSAV (1990), Slovak Geological Society (1997), and the Hungarian Geological Society (1998). The Committee of SGS awarded him by a medal of Ján Slávik (1982) for his extensive activities in the Slovak Geological Society.

His work was also awarded by national authorities. He obtained the governmental award "The Best Worker of the Geological Survey" (1969) and a state governmental award for his loyalty to the employer in 1971. He was awarded by a Dionýz Štúr plaque for his contribution to the development of geology (1974) and a SGIDŠ honor plaque (1980). For his contribution to Earth sciences, he was awarded by a Dionýz Štúr golden plaque as well as by the Slovak Academy of Sciences (1991). In 2000, at the occasion of the 60th anniversary of foundation of the State Geological Institute of Dionýz Štúr, he was awarded by the medal for his contribution to the development of geology and propagation of Slovakia abroad.

He published about 250 scientific works in national and international journals and proceedings from various symposiums and meetings. There are also numerous (about 200) unpublished research reports as well as five monographs in which he presented the most complex morphological descriptions and the stratigraphic value of Western Carpathian foraminifers. In the following works, he described more than 70 new taxa:

Foraminifera of the Western Carpathians • Cretaceous (J. Salaj – O. Samuel, 1967; SGIDŠ, in German)

Microbiostratigraphy and Foraminifera of the Slovak Carpathian Paleogene (O. Samuel – J. Salaj, 1968; SGIDŠ, in English)

The Geology of the Eastern Slovakia Flysch (B. Leško – O. Samuel, 1969; SAV, in Slovak)

Microfauna and Lithostratigraphy of the Paleogene and adjacent Cretaceous of the Middle Váh Valley (West Carpathians) (O. Samuel – K. Borza – E. Köhler, 1972; SGIDŠ, in English)
Triassic Foraminifera of the West Carpathians (J. Salaj – K. Borza – O. Samuel, 1983; SGIDŠ, in English).

A very valuable feature of the mentioned works is a comparison of planktonic foraminifers with other fossilized groups, mainly large foraminifers, and biozoning of the Cretaceous and the Paleogene on the basis of planktonic foraminifers that enables intercontinental parallelism and correlation with international geochronological stratigraphic scale. This gives European and global weight to his works in the microbiostratigraphic field.

The value of his publications is also enhanced by the fact that they deal with synonymics and taxonomic value of species which were paralelly described in the former Soviet Union and in western contries. This critical approach made his publications to be internationally recognized, which is best proven by the great international interest about results of his research and by numerous quotations practically emerging in all prestigious scientific journals.

The research works of RNDr. O. Samuel, DrSc., represent a certain milestone in the development of micropaleontology in our country. They influenced present opinions on stratigraphy and in such a way also on geology, tectonics and paleogeography of the Cretaceous and the Paleogene of the Western Carpathians in Slovakia. His results have exceeded the regional frame and they are important contribution to those scientific disciplines at international level.

RNDr. Ondrej Samuel, DrSc. passed away on December 20, 2002 in Bratislava.

1. An outline of the geological structure and evolution of the Western Carpathians

Dušan PLAŠIENKA and Ján SOTÁK

The Western Carpathians form an arcuate mountain belt located in the northernmost part of the European Alpidic orogenic system, being linked with the Eastern Alps and Eastern Carpathians to the west and east, respectively. The outer Carpathian zones outline a northward convex orogenic bend formed during the latest stages of tectonic evolution, while the inner parts show a complex history with several phases of contraction and extension throughout the Mesozoic and Cenozoic.

Similarly as other collisional mountain systems, the Western Carpathians are characterized by an along-strike zoned structure. Three major parts of the WC orogenic system have been distinguished (e.g. Froitzheim et al., 2008). Their boundaries are accompanied by narrow zones with intricate internal structure. Based on occurrence of the specific, palaeogeographically independent units, which were at least partially deposited on an oceanic crust, these narrow zones are regarded as oceanic sutures and/or ancient plate boundaries. There are two such suture zones present in the Western Carpathian edifice – the Meliata suture separating the Internal and Central Western Carpathians (IWC and CWC, respectively), and the Pieniny Klippen Belt (PKB) that divides the CWC and the External Western Carpathians (EWC – see Fig. 1). The southern limit of the western Carpathian orogenic system is formed by the mid-Hungarian fault system, whilst the outer limit is the Carpathian mountain front overriding autochthonous sediments of the Carpathian foredeep (continuation of the Alpine Molasse Zone), which covers the southern flanks of the downbended North European Platform.

The Alpidic tectonic evolution of the Western Carpathian orogen exhibits a generally northward progradation of the principal compression events and nappe stacking processes. The IWC experienced the main deformation during the “Neo-Cimmerian” (Middle Jurassic up to Albian) orogenic movements related to closure of the Neotethyan (Meliata) oceanic domain, whereas structures of the CWC units were completed by the “Palaeo-Alpine” (Eo-Alpine), or “pre-Gosauian” tectogenesis in mid-Cretaceous times (before the Coniacian). 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 Middle Penninic Oravic domain and the northern Austroalpine (CWC) margin. The final “Neo-Alpine” stage was governed by complex movements generated by subduction of the North Penninic Magura Ocean and formation of the EWC accretionary wedge (Flysch Belt) 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).

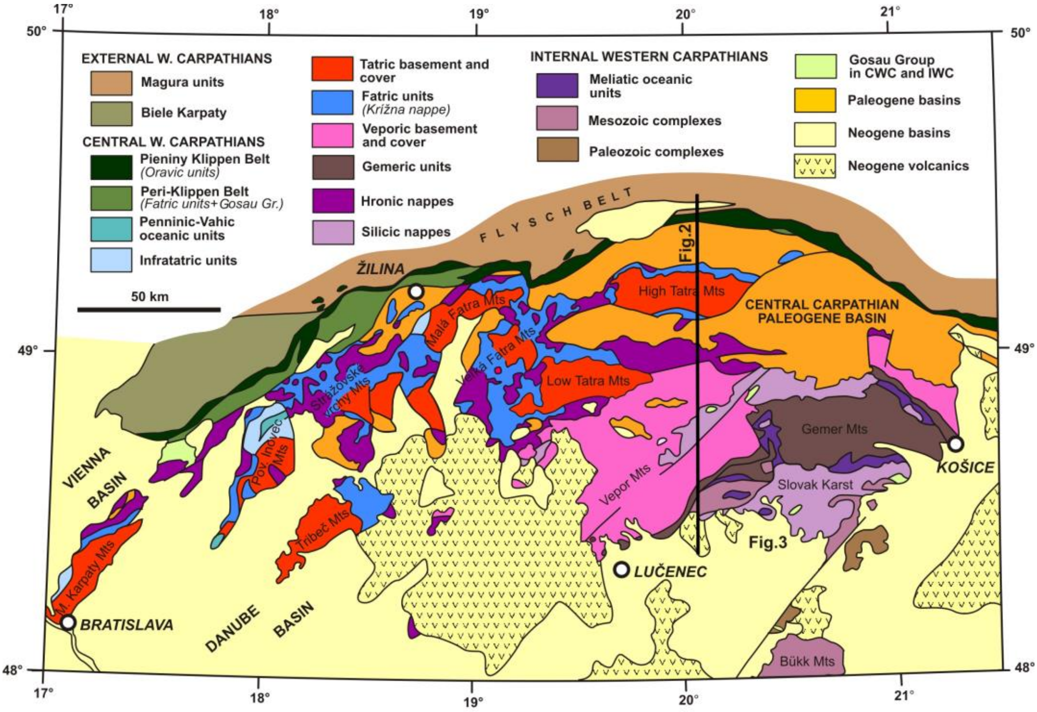


Fig. 1. Simplified map showing distribution of the principal tectonic units of the Western Carpathians.

The Internal Western Carpathians (IWC), or Pelso Megaunit in other terminology (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. In general, the IWC may be characterized as the orogenic retro-wedge exhibiting southern polarity of thrusting movements, which was active mainly during the early stages of tectonic development of the Western Carpathian orogenic system during the Late Jurassic and Early Cretaceous, after closure of the Meliata Ocean. Connections of the Meliata oceanic domain to the Neotethyan realm are still debated; its name was derived from occurrences of Triassic to Jurassic oceanic sediments and ophiolitic mélanges occurring in the southern Carpathian zones, originally described near village Meliata (Kozur & Mock, 1973). Based on sedimentary rock record and geochronological data, the Meliata Ocean opened by continental rifting during the Anisian (Pelsonian), spread out during the Middle–Late Triassic and closed by subduction in the Middle to early Late Jurassic (e.g. Mock et al., 1998). Leftovers of this oceanic domain form the Meliata Unit, which is a strongly imbricated accretionary complex of very low-grade to HP/LT metamorphosed deep-marine pelagic sediments, bodies of olistolite-bearing mass-flows and ophiolitic mélanges (for the latest review see Lačný et al., 2016). The Meliata Unit is already a part of the north-vergent pro-wedge of the CWC thrust system and overthrusts the Gemeric basement-cover sheet and is overridden by the Turnaic and Silicic cover nappe systems (Fig. 2).

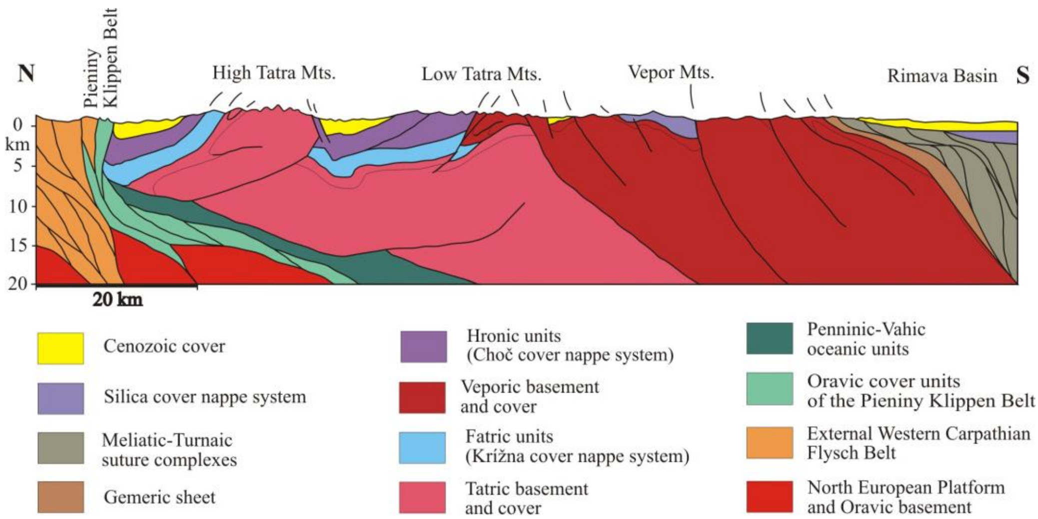


Fig. 2. Generalized cross-section of the Central Western Carpathians. For the location see Fig. 1.

In Cretaceous times, shortening relocated to the north-vergent CWC zones. Sequential growth of the CWC pro-wedge in the mid-Cretaceous time interval (120–90 Ma) included stacking of both the thick-skinned, gently southward-inclined thrust sheets reinforced by the pre-Alpine crystalline basement complexes (Gemeric, Veporic and Tatric basement-cover thrust sheets from top to bottom), and detached thin-skinned cover nappes (Silicic, Hronic and Fatric nappe systems). The CWC units largely correspond to the Austroalpine tectonic system of the Eastern Alps (e.g. Schmid et al., 2008).

The Silicicum (Silica Nappe s.l.) is the highermost cover nappe system occurring in the southern CWC zones (Vepor-Gemer area, Slovak Karst Mts – see Figs 1 and 2). Being detached along the Upper Permian evaporites, the sedimentary succession of the Silica nappes includes Lower Triassic continental clastic red-beds, Middle to Upper Triassic carbonates dominated by platform facies (e.g. the Wetterstein and Dachstein fms), and remnants of thin Lower to Middle Jurassic deposits. Middle Triassic carbonates bear vestiges of the Pelsonian rifting event that is commonly interpreted as the break-up phase of the Neotethyan Meliata Ocean. Based on the facies architecture, nappes of the

Silicicum should have been derived from the shelf areas of the northern Tethyan passive margin (e.g. Haas et al., 1995).

The Silica Nappe is thrust over the Neotethyan accretionary complexes (Meliata and Turňa units) and over the Gemeric basement-involved thrust sheet. The latter is composed of Lower Paleozoic, low-grade volcano-sedimentary complexes intruded by small Permian granitoid bodies and covered by the Pennsylvanian, Permian and Lower Triassic continental clastic deposits overlain by relics of Middle Triassic carbonates. Mississippian marine sediments occur in a separate, northernmost partial tectonic unit just at the contact with the underlying Veporicum.

The Veporicum is a crustal-scale basement wedge, the middle of three which originated during the Palaeo-Alpine thrust stacking in the CWC. Its surface part in central Slovakia forms a large half-dome structure exposing dominantly pre-Alpine basement complexes in the centre and Upper Paleozoic – Mesozoic cover units on the peripheries (Fig. 1). These are overridden by the Gemeric basement sheet and by the unmetamorphosed Silicic cover nappes. The Veporic basement is composed of medium- to high-grade metamorphic complexes intruded by large Variscan granitoid plutons. The cover complexes include Upper Paleozoic and Lower Triassic continental clastic deposits and Middle to Upper Triassic platform carbonates and intra-shelf basinal deposist in the southern Veporic zones (Foederata Succession). In contrast, the cover rocks in the northern Veporic zones (Veľký Bok Succession) are characterized by Upper Triassic clastics of the Keuper facies and various Jurassic to Lower Cretaceous limestone formations showing affinity to the Fatric (Krížna) successions. From the palaeogeographic point of view, the Veľký Bok Succession was deposited on the southern margin of a wide basinal area (Zliechov Basin) from which the Fatric nappes were derived (Fig. 3; Plašienka, 2003a, b; Michalík, 2007).

The Veporic basement and cover complexes, particularly in the southern part, display metamorphic and structural associations revealing deep burial during the Lower Cretaceous stacking period and exhumation by an orogen-parallel extension and unroofing during the Late Cretaceous (cf. Plašienka et al., 2016, and references therein).

The Zliechov Basin north of the Veporic domain was rifted during the Early Jurassic in connection with the Pangea breakup and opening of the Central Atlantic with the eastward propagating Alpine Atlantic rift system. Rifting caused faulting and drowning of the Triassic carbonate platform revealed by Lower Jurassic syn-rift sediments like scarp breccias, sandy-crinoidal limestones and hemipelagic marlstones of the Fleckenmergel facies. The Middle Jurassic to Lower Cretaceous thermal subsidence brought about basin deepening up to bathyal depths recorded by sediment-starving eupelagic succession of nodular, cherty and siliceus limestones, radiolarites and maiolica-type limestones. The Zliechov Succession is terminated by the mid-Cretaceous

(Albian–Cenomanian) syn-orogenic, coarsening-upward flysch sequence that reflects commencement of basin shortening and input of terrigenous clastic material derived from uplifting inner Carpathian zones (Veporic-Gemeric-Meliatic thrust stack).

The Fatric (Krížna) cover nappe system was detached along the Lower Triassic shales and evaporites and includes also Middle Triassic shelf carbonates, Upper Triassic clastics and evaporites (Carpathian Keuper Fm) and Rhaetian fossiliferous limestones. Except the prevalent deep-water Zliechov Succession, the frontal partial Fatric nappes include also more shallow-water Vysoká-Belá Succession derived from the northern margin of the Zliechov Basin corresponding to the southern flanks of the South Tatric Ridge (Fig. 3). The most characteristic feature of this margin setting is presence of Urgon-type limestones, mainly in form of resedimented bioclastic aprons. The Urgonian limestones occur also in the Manín Unit which as part of the so-called Peri-Klippen Zone (Fig. 1).

Detached Fatric sedimentary successions overrode as a widespread, but relatively thin allochthonous sheet the underlying basement-involved Tatric Unit (Figs 1 and 2), while the Fatric basement was underthrust below the Veporic wedge. The structural evolution of the Tatric-Fatric-Veporic thrust system and emplacement mechanism of the Fatric cover nappes were described in several papers (e.g. Plašienka, 2003b; Prokešová et al., 2012).

The Variscan high-grade metamorphic basement and granitoids of the Tatric thick-skinned sheet are overlain by the Permian and Mesozoic cover deposits, mainly composed of Lower Triassic continental clastic deposits, Middle Triassic carbonates, Upper Triassic Keuper clastics and various Jurassic to Lower Cretaceous limestones showing a similar subsidence history to that of the Zliechov Basin. The youngest syn-orogenic flysch sediments of the Tatric Unit indicate the termination of the thrusting processes in the CWC during the late Turonian, when the Tatric deep-water basinal area was invaded by the Fatric Krížna Nappe.

The Hronic Superunit (Choč Nappe in older terminology) is the highermost pre-Cenozoic allochthonous thrust system of the CWC overlying the Fatric substratum. Hronic units are predominantly composed of Middle–Upper Triassic platform, as well as intra-shelf basinal carbonates and Lunz-type clastics. In the southern parts, they are underlain by the Pennsylvanian to Lower Triassic continental clastic complexes with huge Permian basaltic lava flows (so-called melaphyres). Condensed Jurassic to Lower Cretaceous limestone strata are confined to the lowermost Hronic partial nappes in the outer CWC zones, including the Hauterivian synorogenic siliciclastic turbidites as the youngest member.

The Lower–Middle Jurassic rifting along the outer Tatric edge culminated by the continental breakup and opening of the South Penninic-Vahic oceanic tract – the eastern prolongation of the Ligurian-Piemont Ocean (Alpine

Atlantic). The breakup process is recorded by thick prisms of scarp breccias, for example in the Borinka Unit of the Malé Karpaty Mts (Fig. 3; Plašienka, 2003a, 2012). However, no remnants of the presumed Vahic oceanic crust are preserved at the present surface structure, but its possible vestiges are represented by slivers of the Upper Jurassic – Lower Cretaceous abyssal pelagites and Upper Cretaceous wildflysch sediments cropping out in the Považský Inovec Mts (Figs 1, 2, 3 – Belice Unit; Plašienka, 2012 and references therein). The youngest, Senonian strata of the Belice Unit are overridden by the (Infra)Tatric basement nappe.

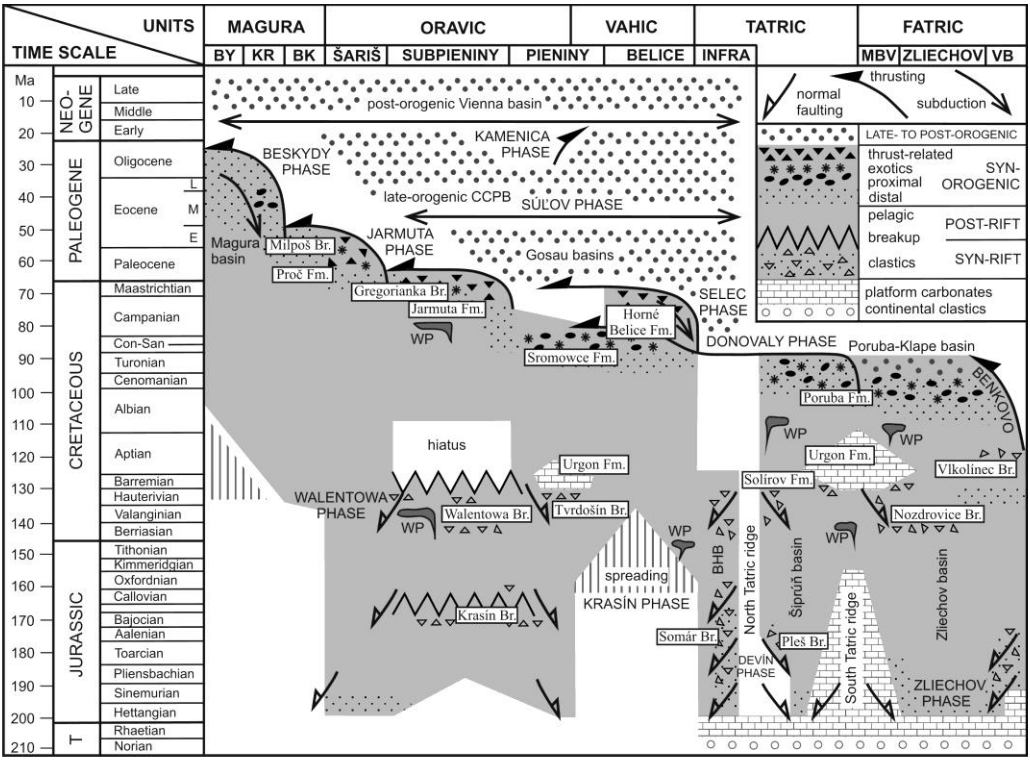


Fig. 3. Synoptic summary of syn-rift and syn-orogenic events in the outer Central Western Carpathian zones and Pieniny Klippen Belt. The scheme shows principal tectonic rifting and thrusting events revealed by sedimentary record (adapted from Plašienka, 2012). Abbreviations: BY – Bystrica; KR – Krynica; BK – Biele Karpaty; MBV – Manín-Belá-Vysoká; VB – Veľký Bok; BHB – Borinka-Humienec basin; WP – within-plate basalts.

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 and 2). The PKB is a narrow (merely several km), but lengthy (up to 600 km) zone characterized by intricate internal structure and a very variable lithology of the detached Jurassic to Paleogene sediments involved. During more than a century of detailed research, these have been subdivided into numerous lithostratigraphic and tectonic units of distant provenances, hence witnessing excessive shortening and subsequent dispersal within this restricted zone. The PKB is therefore often considered as a suture, in spite of lack of ophiolite complexes. In many places, the PKB is formed by isolated blocks of “klippen” (stiff Middle Jurassic to Lower Cretaceous limestones) embedded in the “klippen mantle” (soft Lower Jurassic and Upper Cretaceous to Paleogene shales, marls and flysch formations). The peculiar block-in-matrix structure of the PKB is the result of intense tectonic disintegration due to thrust stacking, out-of-sequence imbrication, and superimposed backthrusting and transpressional and transtensional movements.

Concerning the composition, the most distinctive feature of the PKB is ubiquitous presence of units restricted to it, which were derived from an independent palaeogeographic zone in a presumably Middle Penninic position, known as the Oravicum (Fig. 3). This includes the ridge-related Czorsztyn and basinal Pieniny (Kysuca) successions in particular, but various “transitional” successions are present as well (e.g. Birkenmajer, 1977, 1986). The Oravic units only include Jurassic to Lower Eocene sediments evolving from the late Lower to early Middle Jurassic hemipelagic dysoxic deposits (Fleckenmergel facies, black shales). Considerable change occurred during the Bajocian, when the Czorsztyn Ridge uplifted due to a strong rifting event, which is recorded by rapid shallowing up to emergence indicated by sudden terrigenous input and deposition of sandy-crinoidal limestones. The Bathonian stage shows a break-up discordance due to opening of the Penninic-Vahic oceanic tract, followed by post-rift subsidence and deposition of red nodular limestones of the ammonitico rosso facies until the Tithonian, when shallow marine biogenic sedimentation returned and persisted until the Hauterivian in places. This oscillation in subsidence was ascribed to several rifting pulses related to opening and breakup of the South Penninic (Bathonian) and North Penninic (Early Cretaceous) oceanic realms (Plašienka, 2003a). Subsequently, the Czorsztyn Succession records emersion and karstification during the Barremian and Aptian (Aubrecht et al., 2006). The final subsidence from the Albian onward gave rise to red pelagic marlstones of the couches rouges facies and terminated by syn-orogenic flysch deposits at the end of Cretaceous. On the other hand, the contemporaneous Kysuca-Pieniny succession exhibits continuous deep-marine pelagic sedimentation throughout Jurassic and Early Cretaceous, which terminates by the late Turonian to early Campanian flysch clastics with bodies of “exotic” conglomerates (cf. Marschalko, 1986 and references therein).

The structurally lowermost Oravic element is the Šariš Unit (Plašienka, 2012), occurring in the eastern segment of the PKB in particular. It was derived from the northern slopes of the Czorsztyn Ridge and presently overrides the EWC Magura Unit. The Šariš unit is a strongly imbricated and disintegrating, but generally continuous succession of deep-water, strongly condensed pelagic sediments starting from the earliest Jurassic up to Campanian, followed by

Maastrichtian–Lower Eocene calcareous flysch with large olistolite-bearing mass-flows (Fig. 3). The main Mesozoic members are syn-rift clastics of the Gresten facies, Liassic to Bajocian spotted marlstones (Fleckenmergel), Bathonian–Oxfordian radiolarites, Kimmeridgian red Aptychus marls, Tithonian–Neocomian maiolica-type spotted and cherty limestones, Aptian to Cenomanian spotted marlstones, black siliceous shales and radiolarites, and Turonian–Campanian red pelagic shales of the CORB type.

During the Late Cretaceous, the growth of the Western Carpathian orogenic wedge progressed by consumption of the South Penninic-Vahic Ocean and accretion of the Oravic continental ribbon in the Paleocene (Fig. 3). Detached Oravic sedimentary units created an incipient fold-and-thrust belt, which was later transformed into the PKB. Subduction of the outer oceanic branch – the North Penninic-Magura Ocean started in the Eocene and was completed during the Miocene.

Beyond the PKB, the EWC include the Flysch Belt and the Carpathian foredeep covering the southern margin of the North European Platform, which is underthrusting the EWC as far as the PKB. The EWC Flysch Belt corresponds to the frontal accretionary wedge of the Carpathians orogen consisting predominantly of the Cretaceous–Miocene deep-marine clastics scraped off the subducted oceanic basement and intervening continental fragments of the Magura (North Penninic) Ocean. It includes the inner belt of the Biele Karpaty and Magura units, which are connected with the Eastern Alpine Rhenodanubian Flysch Belt to the west, but are wedging out towards the Eastern Carpathians. The outer Silesian-Krosno zone is linked with the Eastern Carpathian Moldavides (see e.g. Picha et al., 2006 for the review).

The Cretaceous – Cenozoic evolution of the Western Carpathian orogenic wedge growing by frontal accretion was accompanied also by several hinterland extensional collapse stages, such as the Late Cretaceous exhumation of the Veporic metamorphic dome and subsidence of the Senonian–Middle Eocene Gosau-type basins (cf. Plašienka & Soták, 2015, and references therein). Due to continuing subduction of the North Penninic-Magura oceanic crust and reorganization of the plate movements in the Tethyan realm, the upper CWC-IWC (Inner Carpathian) plate experienced further extensional events with opening of the Upper Eocene – Lower Miocene Central Carpathian Paleogene Basin in the fore-arc and the South Slovakian – North Hungarian Basin in the retro-arc position (Kováč et al., 2016). The final Miocene story is characterized by significant tectonic processes like the Lower Miocene CCW rotation of the Carpathian part of the AlCaPa block escaping from the Alpine collision, and Middle Miocene back-arc extension of the extensive Pannonian basin system associated with lithospheric thinning and voluminous Middle–Upper Miocene calc-alkaline andesitic-rhyolitic to ultimate Pliocene–Quaternary alkaline basaltic volcanism (Fig. 1).

I. Field tripe route in the Middle Váh Valley

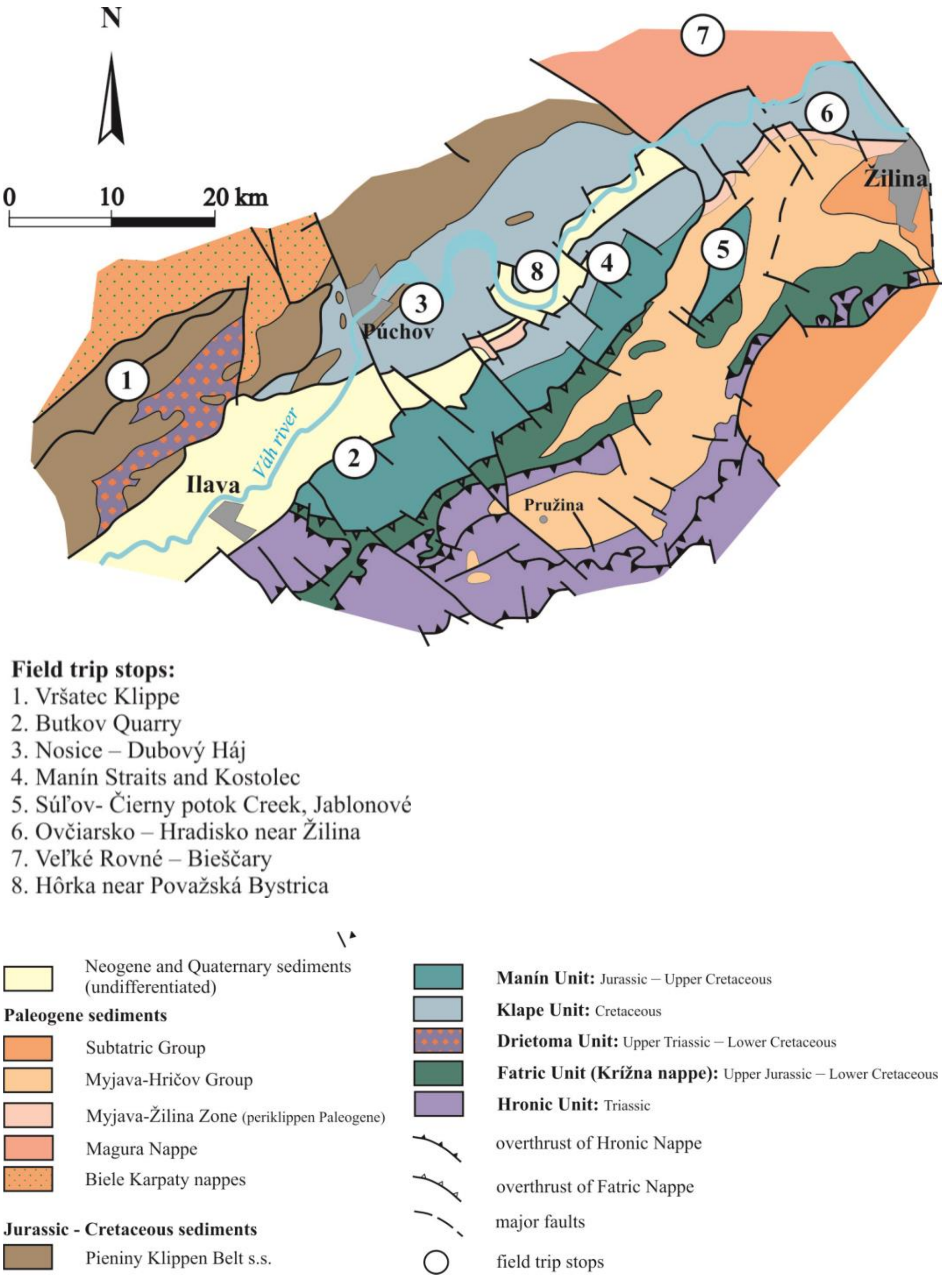


Fig. 4. Simplified geological map of Middle Váh Valley.

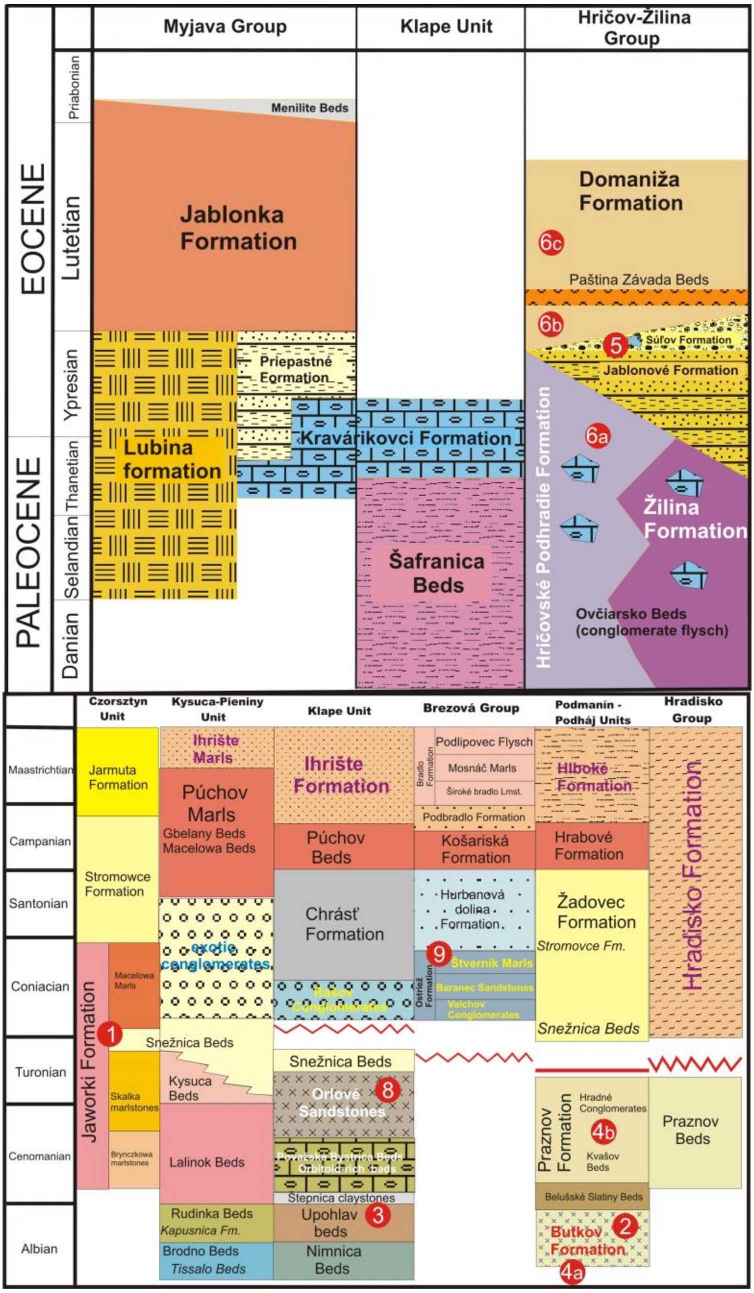


Fig. 5. Lithostratigraphic column of the Cretaceous and Paleogene formations of the PKB, Peri-Klippen belt units and the Gosau-type formations in the Middle Váh Valley and Brezovské Karpaty Mts with indication of field trip sites.

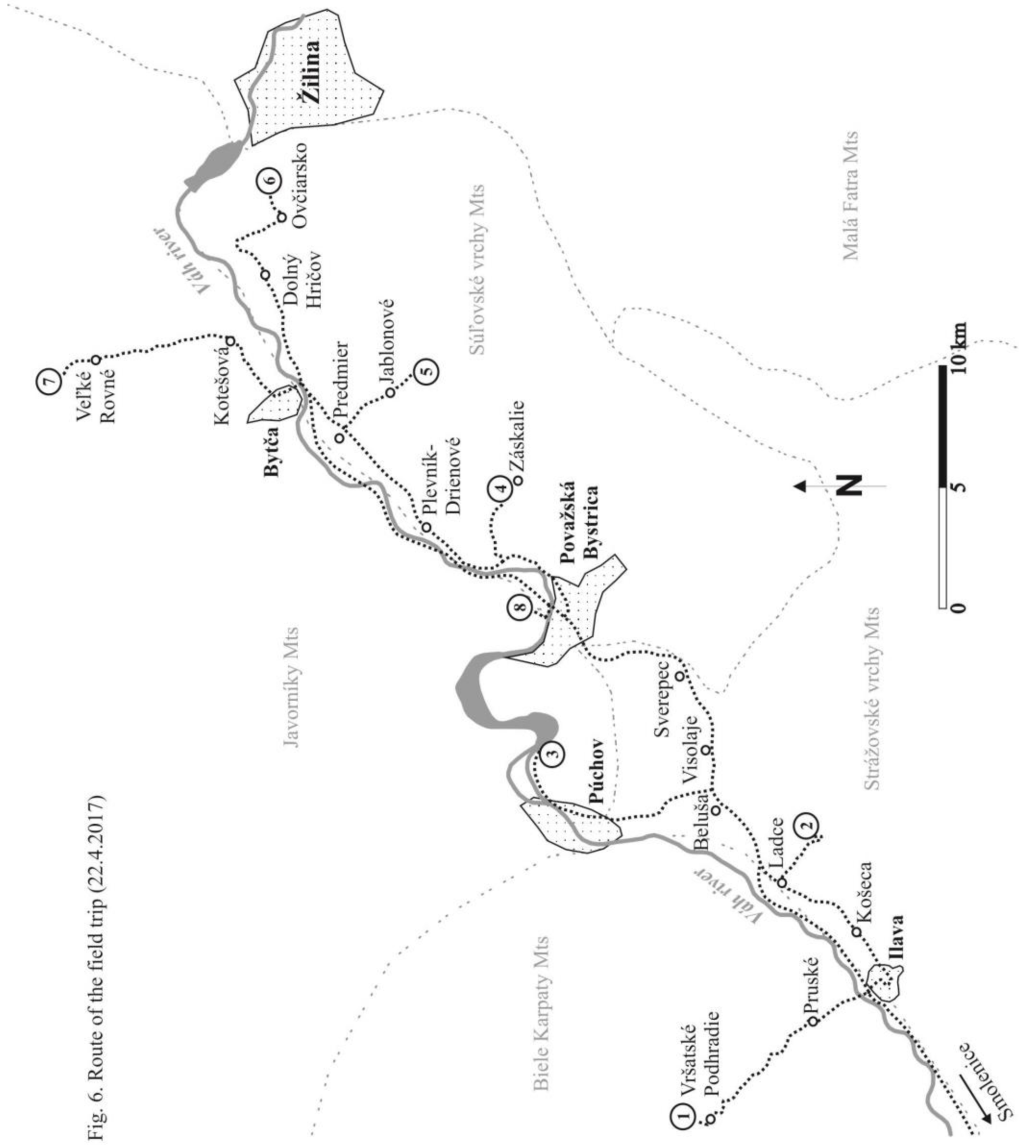


Fig. 6. Route of the field trip (22.4.2017)

2. Geology of the Strážovské vrchy Mts

Geological structure of the Strážovské Vrchy Mts

Jozef MICHALÍK

An extensive, dissected mountain range fringes the left bank of the Váh River between the towns of Žilina and Trenčín. The mountains is separated by the Jastrabie Saddle from the Považský Inovec Mts on the S, by the Fačkov Saddle from the Lúčanská Malá Fatra on E. Four basins: Rajec-, Žilina-, Púchov- and Ilava basins are limiting the mountains slopes on NE, N and W. The relief of the mountains is moderate, ranging in altitude from 250 to 1214 above the s.l. Most water streams issuing in the mountains (Rajčianka, Pružinka, Mojtín, Podhradie and Teplička brooks drain into the Váh River. Only streams issuing on the s slopes (Nitra, Tužinka, Nitrica, Belianka, Radiša, Bebrava) flow through both the Bánovce- a Upper Nitra depressions into the Nitra River.

The Strážovské Vrchy Mts is a typical “core” mountains range. Its geological structure can be traced on 300 square kilometers large area with several megasynclines and megaanticlines (Fig. 7). In spite of its particularity, the mountain structure is assymetric with an crystalline “core” situated far on the SE periphery. The Mesozoic complexes comprise almost all Centro-Carpathian units starting with the Tatric through the Manín Unit, Fatric Belá and the Krížna nappes, the Choč Unit of Hronic with the Čierny-, Biely Váh and the Bebrava partial nappes, or with the Middle and Upper Cretaceous sequences of the Accretionary (“Periklippen”) Belt including olistostromatic Kostelec and Klape bodies. The Paleogene and Neogene covers are preserved in rests of intra - mountain basins.

The superfial nappe structure is characterized by partial imbrications and nappe slices, the masses of Choč and Strážov nappes were affected by the Savian back thrusting. Finally, the area was dissected by NW-SE and NNW-SSE transversal fault systems concealing the original zonal architecture.

The Tatric crystalline core is typical of migmatite, amphibolite and paracrystalline mantle rocks dominating over granitoids. Neosome layers (or intrusions ?) pass through migmatites of several types in paraschists complexes preserving its original pre-Alpine structure. Its Mesozoic cover sequence commences with Scythian quartzose sandstones of the Lúžna Formation overlain by Middle Triassic carbonates (Gutenstein Limestone, Ramsau Dolomite). The Carpathian Keuper is transgressively overlain by Jurassic complex of black shales with limestone and silicite intercalations (rests of Rhaetian sediments are preserved near to the Valaská Belá village only) and by

Lower Cretaceous cherty limestones. The Albian claystones contain large paraconglomerate bodies.

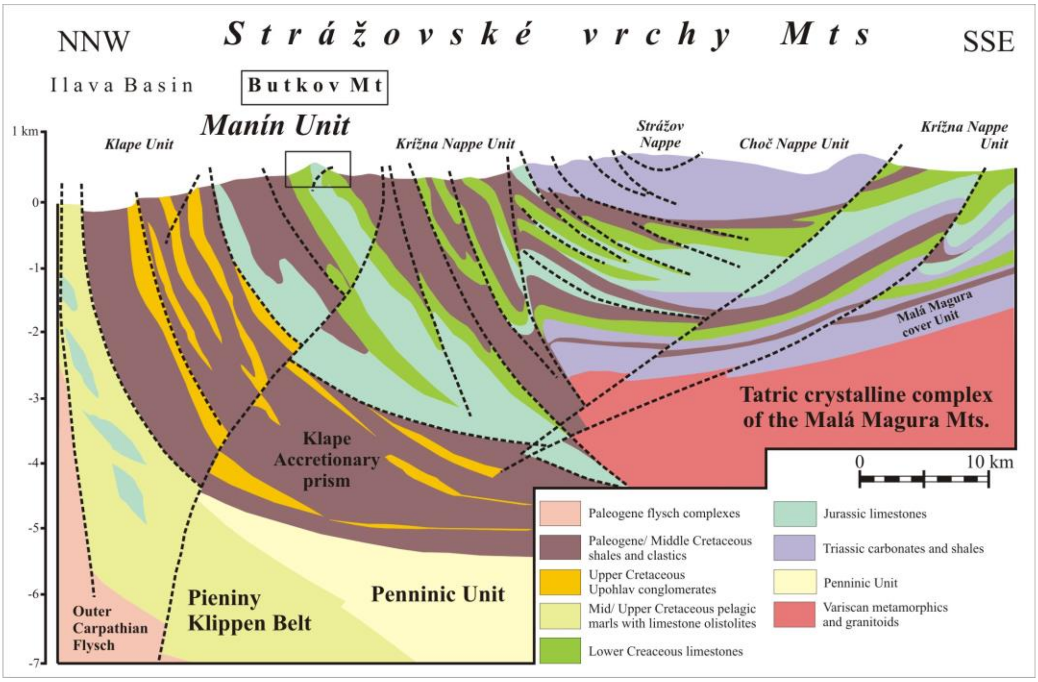


Fig. 7. Geological cross-section through the Strážovské vrchy Mts shows the structure of the western edge of the Central Western Carpathioans (adapted from Michalík and Žítt, 1988).

The Manín Unit regarded as a marginal element of either Tatric or Fatric tectonic system. The sequence starts with Triassic members in the SW part of the mountains, whereas Lower Jurassic limestones lie on the base of the sequence in northernmore areas. There are at least three different structures recognizable in the area: the Manín zone, the Jelenia skala – Podmanín - Skalica zone and the Butkov body. The Manín type of the sequence is developed in shallower facies (red nodular limestones prevail in the Jurassic sequence), the Butkov type comprises also middle Jurassic silicites. Lower Cretaceous sequence consists of pelagic limestone facies, followed by carbonate platform products (it started during Late Hauterivian in Manin, but as late as in Aptian in the Butkov area). The sequence is covered by Late Albian – Cenomanian marls and by Upper Cretaceous flysch facies.

Development of Triassic sequences in both the Belá (marginal nappe slice) and Zliechov units of the Krížna Nappe is comparable. However, Jurassic sediments are represented by crinoidal limestones in the Belá Unit, while the Jurassic sequence of the Zliechov Unit consists of Hettangian Kopieniec Fm, Liassic "Fleckenkalk", Adnet limestone, Dogger silicites of the Ždiar Fm, and by Malm dark marlstones of the Jasenina Formation. Similarly, Lower Cretaceous carbonates with frequent gaps are covered by “Urgonian” limestones and by black Albian limestones (resembling the Manín sequence) in the Belá Unit, while Berriasian hemipelagic biancone (Osnica Fm) and spotted Valanginian to Aptian limestones (Mráznica Fm) with small volcanoclastic bodies represent Lower Cretaceous sequence of the Zliechov Unit. Albian and Cenomanian strata are represented by shaly Poruba Formation passin upwards into distal flysch.

The Choč Unit is represented by Permian shales with paleobasalt bodies and by thick complex of Triassic carbonates. In frontal part of the nappe, Jurassic and Lower Cretaceous limestone sequence is preserved. It terminates with Hauterivian/Barremian marls with sandy admixture containing abundant grains of chromium spinels.

The Bebrava Unit is characterised by the Anisian Steinalm Limestone with small bioherm bodies and by frequently brecciated Wetterstein and Upper Triassic dolomites.

The Strážov Nappe is the highest tectonic unit in the nappe structure. The sequence commences with Anisian grey foraminiferal, crinoidal and bioherm limestones of the Wetterstein type. They are overlain by Upper Triassic dolomites.

Paleogene sequences fill rest of basins both in the Paleoalpine suture (the Hričov Zone) and in the intra - Carpathian Rajec Basin. The Mesozoic substrate was karstified prior to the transgression, the karstic holes were filled by bauxite and laterite wastes. The base of the Paleogene sequence is diachronic, becoming younger from outer zones into orogene. The sequence consists of thick carbonate breccias and conglomerates with occasional algal reef bodies (in the marginal zone).

Neogene sediments fill several pull-apart basins on the Peri-Pieninian Fault separating the mountain range from the Pieniny Klippen Belt. In the mountains, they form only small erosive relics on levelled surfaces and denudation terraces.

3. Geology of the Pieniny Klippen Belt and adjacent zones in the Middle Váh Valley

Dušan PLAŠIENKA and Ján SOTÁK

Introduction

Owing to the picturesque landscape and tectonic peculiarities, the Pieniny Klippen Belt (PKB) is considered as the most conspicuous regional zone of the Western Carpathians. It forms a narrow (merely several km), but lengthy (up to 600 km), arched stripe that separates the External Western Carpathians (EWC – Flysch Belt, Tertiary accretionary wedge) from the Central Western Carpathians (CWC – Cretaceous basement/cover nappe stack). The PKB involves predominantly Jurassic, Cretaceous and Paleogene sediments with variable lithology and intricate internal structure. During almost two centuries of intense research, these have been differentiated into numerous lithostratigraphic and tectonic units of originally distant palaeogeographic provenances, hence witnessing excessive shortening and dispersal within this restricted zone.

The purpose of this short overview is to present some new results and ideas developed during the recent investigations focussed on structural evolution of zones along the EWC/CWC boundary, i. e. the PKB and adjacent units in western Slovakia.

Structure of the Pieniny Klippen Belt

From the historical perspective, the term “Pieninische Klippenzug” was introduced by Neumayr (1871). Since then the Pieniny Mts at the present Polish-Slovak borderland have served as the PKB type area from both the litho-biostratigraphic, as well as structural-tectonic viewpoints (e.g. Uhlig, 1907; Birkenmajer, 1977, 1986; Sikora, 1974; Książkiewicz, 1977; Ratschbacher et al., 1993; Jurewicz, 2005; Plašienka et al., 2012; Oszczypko & Oszczypko-Clowes, 2014). However, even more complicated PKB type area occurs in western Slovakia along the Váh River Valley and in Orava region (Stur, 1860; Andrusov, 1931, 1938, 1974; Scheibner, 1968; Maheľ, 1989; Mišík, 1994; Salaj, 1994a, b, 1995; Schlögl et al., 2009; Plašienka & Soták, 2015). In addition to the typical Oravic units, the PKB in a broader sense incorporates also the frontal CWC units there, particularly those of the Fatric cover nappe system (Manín, Klape, Drietoma units). These occur along the inner PKB side in the so-called Periklippen Zone (Maheľ, 1980). These two PKB parts – the PKB s.s. (Oravic units) and the Periklippen Zone, are in principle considerably different by their composition and evolution, but share some common features, namely the ubiquitous presence of thick and deformed Upper Cretaceous to lower Paleogene deposits, which are otherwise nearly absent in the CWC regions. Therefore the unified term Považie-Pieniny Belt has been proposed for the PKB in this broader sense (Froitzheim et al., 2008).

The Považie-Pieniny Belt includes numerous sedimentary successions exhibiting very variable lithology and complex internal structure. During a long-term detailed research, a lot of lithostratigraphic and tectonic units representing different and partially unrelated paleogeographic settings were distinguished. Juxtaposition of rock complexes of originally distant provenances, extreme shortening and lateral dispersion within a very narrow zone invokes to consider the PKB as a suture, even though the ophiolite complexes do not contribute to its present surface structure. On the other hand, the original fold-and-thrust structures with several superimposed nappe units are still readily recognizable in some PKB sectors.

Several large-scale tectonic systems are partly or fully incorporated and/or closely juxtaposed to the PKB (Fig. 8). From bottom to top (and generally from N to S), these are the Magura Nappe, Biele Karpaty Unit, Oravic Superunit (PKB sensu stricto), frontal elements of the CWC Fatric nappe system and overstepping Senonian to Eocene complexes. The large Magura Nappe of the EWC Flysch Belt (Senonian–Oligocene, predominantly flysch lithologies) is in the contact with PKB in north-western and eastern Slovakia. In the Middle Váh Valley, the PKB directly contacts the Bystrica Subunit, which otherwise occupies a central position in the Magura Belt. The contact has a character of oblique slip dextral-reverse fault zone indicating backthrusting, since the PKB units are overturned towards the S in the Kysuca and Orava regions. In the Orava region and further east in eastern Slovakia, the PKB neighbours the Oravská Magura-Krynica Unit, which is dominated by the Eocene–Oligocene, Magura-type sandstones. The Biele Karpaty Superunit is the innermost element of the SW part of the EWC Flysch Belt where it is juxtaposed to and partly underlies the outer elements of the PKB. It is characterized by a special composition (rich carbonate material in clastic formations), restricted stratigraphic extent (Cretaceous–Lower Eocene; Potfaj, 1993; Švábenická et al., 1997) and very low thermal and deformational reworking (Hrouda et al., 2009). It consists of several thrust sheets, the two higher being in a direct contact with the PKB.

Oravic units

The Oravic Superunit (a.k.a. "Pieninic" units or "Pienides" in older literature – e.g. Andrusov, 1974, or PKB s.s. – Maheľ, 1980) embraces the typical PKB units of their own, which are characterized by the peculiar "klippen tectonic style" (block-in-matrix structure).

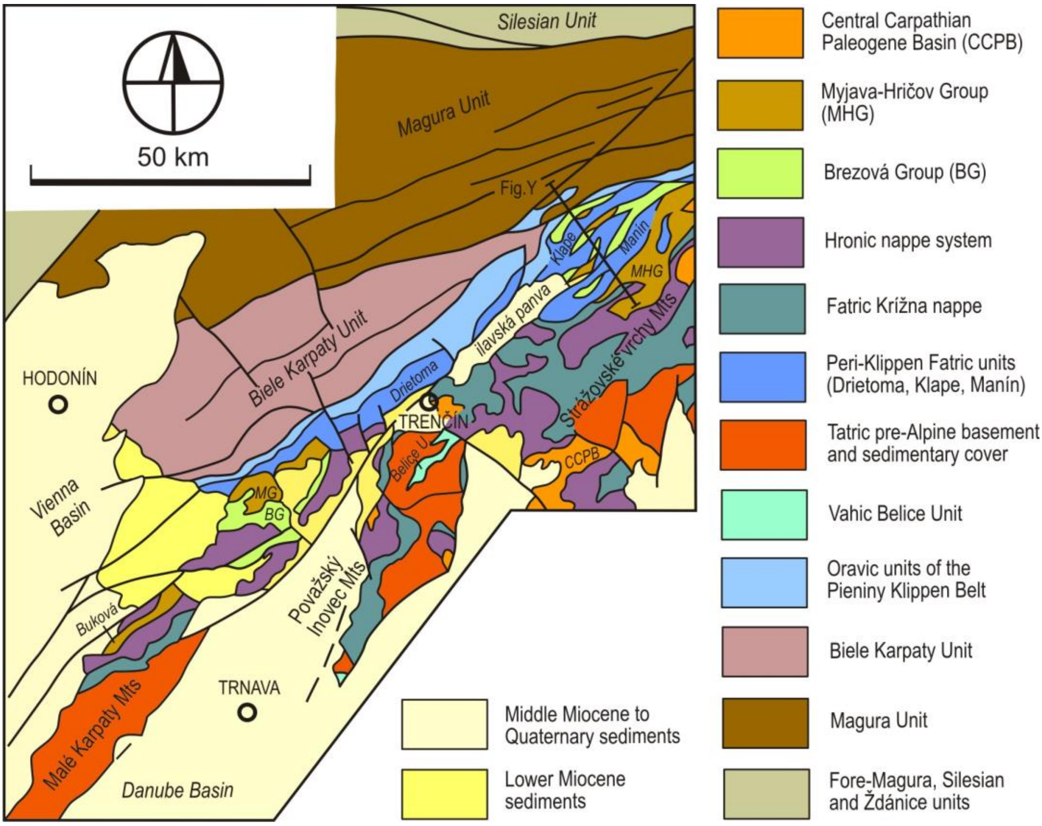


Fig. 8. Tectonic sketch map of the Pieniny Klippen Belt and neighbouring zones in western Slovakia.

The lowermost element of the eastern PKB s.s. is represented by the recently defined Šariš Unit (Plašienka et al., 2012). In the Middle Váh Valley, it is represented only by tiny slices of Maastrichtian–Lower Eocene, deep marine, pelagic (variegated shales) and clastic (turbidites, mass-flows) deposits. The latter are known as the Jarmuta and/or Proč Fm and involve also chaotic olistostrome bodies with olistoliths dominantly derived from the overlying Subpieniny Nappe.

For the higher nappe sheet of the PKB, we use the old Uhlig's term Subpieniny Nappe (Uhlig, 1907). This includes the most widespread Czorsztyn Succession, as well as the Pruské, Niedzica, Czertezik and similar "transitional" successions derived from the Czorsztyn Ridge and its slopes. Lithology and stratigraphy of these successions were described in detail in numerous papers (e.g. Birkenmajer, 1977, 1986; Mišík, 1979, 1994). The submarine, but temporarily emergent Czorsztyn Ridge is characterized by Lower Jurassic to Aalenian hemipelagic spotted marls, Middle Jurassic (Bajocian) syn-rift, sandy-crinoidal limestones and scarp breccias (Aubrecht & Szulc, 2006), Middle–Upper Jurassic red nodular limestones of the ammonitico rosso facies and various uppermost Jurassic to Lower Cretaceous shallow-marine fossiliferous limestones. The ridge was emerged during the Barremian–Aptian, which is recorded by widespread karstification and fissure fillings by younger sediments (Aubrecht et al., 2006). The uneven rugged surface was then covered by variegated hemipelagic marls of the couches rouges facies ranging from the Albian up to the Campanian. The youngest sediments of the Czorsztyn-type successions are the Upper Senonian Jarmuta-type calcareous sandstones overlain by olistostrome breccias (Nemčok et al., 1989) containing material derived from the still higher Pieniny Nappe. The Subpieniny Unit is characterized either by imbricated thrust stacks and duplexes, or by a "mature" klippen style with small blocky klippen composed of massive Middle–Upper Jurassic limestones embedded within a soft matrix of Upper Cretaceous marls.

The highermost Oravic tectonic unit of the PKB – the Pieniny Nappe – includes several differing lithostratigraphic successions as well (Pieniny s.s., Kysuca-Branisko, Podbiel-Orava, Nižná). It was derived from the southern foots of the Czorsztyn Ridge at the transition to the South Penninic–Vahic oceanic domain. The Pieniny-type successions are typically composed of Lower–Middle Jurassic spotted marlstones of the Fleckenmergel facies and black shales, Middle–Upper Jurassic radiolarites, Tithonian–Barremian maiolica-type cherty limestones (e.g. Michalík et al., 2009), mid-Cretaceous dysoxic shales and bioturbated marlstones, Cenomanian–Turonian variegated pelagic marls, and Coniacian–Santonian deep-marine turbiditic clastics, including polymict conglomerates. The Pieniny Nappe is folded and imbricated, but generally continuous. In the western PKB part, it is dominated by the basinal Kysuca Succession.

The Oravic units were derived from an independent palaeogeographic position around the Middle Penninic swell known as the Czorsztyn Ridge, which was a continental ribbon separated by oceanic domains from the Central Carpathian (Austroalpine) plate to the south and from the North European Platform to the north (South Penninic-Vahic and North Penninic-Rhenodanubian-Magura Oceans, respectively – e.g. Plašienka, 2003, 2012).

Fatric units

The "non-Oravic" units of the CWC–Austroalpine provenance incorporated into the PKB are generally assigned to the Fatric Superunit (Krížna and related nappes – cf. Fig. 8). These are units preferably located in the Middle Váh River Valley, where they occur in a superposition over the Oravic units within the south-eastern zone of the PKB designated as the "Periklippen Belt" by Maheľ (1980, 1983). Three large units compose the "non-Oravic" Periklippen zone. The Drietoma Unit, which comprises the Upper Triassic (Carpathian Keuper Fm) – Cenomanian, chiefly basinal succession, predominates in the SW part of the PKB (Hók et al., 2009). It shows close structural links to the overlying CWC nappe systems – the Fatric Krížna Nappe and Hronic Nedzov Nappe, as well as to the Albian–Cenomanian synorogenic flysch with "exotic" conglomerates. The latter provide a connection to the huge Klape Unit, which prevails in the Middle Váh Valley.

The Klape Unit covers about 12 km wide and 20 km long area in the Middle Váh Valley (Fig. 8). It is composed of several imbrications with repeating successions. Individual slices are steeply NW-dipping with overturned lithostratigraphic successions, separated by synforms filled with the overstepping Gosau sediments (Fig. 9). The Klape Unit includes a sedimentary succession from the Early Jurassic up to the Late Cretaceous. The only few tens of meters thick Jurassic to Lower Cretaceous sequence is composed of deep-marine pelagic sediments – Lower Jurassic spotted marlstones of the "Fleckenmergel" facies, followed by Middle–Upper Jurassic siliceous limestones and calcareous radiolarites and then by Lower Cretaceous cherty and marly limestones. It is noteworthy that these Jurassic sediments are considerably different from sediments of the Klape klippe that gave the name to the whole unit, which is a blocky megaolistolith formed by comparatively shallow-marine Jurassic massive or thick-bedded, variegated sandy-crinoidal, cherty and nodular limestones. This and several other similar olistoliths are resting in the mid-Cretaceous flysch deposits.

More than thousand meters thick, Aptian to Turonian clastic sequence (the Klape Flysch) represents the main constituent of the Klape Unit. This includes Aptian to Lower Albian dark hemipelagic calcareous shales that are passing into a coarsening- and thickening-upward "wildflysch" turbiditic sequence of the Albian to Lower Cenomanian age with huge bodies of conglomerates and boulder beds. The Cenomanian shallowing is registered by calcareous sandstones and sandy marls rich in orbitolinas, while the late Cenomanian to early Turonian strata are represented by a concluding sequence of massive neritic to littoral sandstones with oyster banks (Orlové Fm).

The conglomerates have a very variegated composition with a number of rock types, which were carefully studied and described e.g. by Mišík et al. (1977), Mišík & Sýkora (1981), Marschalko (1986), Mišík & Marschalko (1988), Birkenmajer (1988), Birkenmajer et al. (1990). In the Carpathian literature, the Cretaceous conglomerates of the PKB and adjacent zones, and those of the Klape Unit in particular, have often been classified as "exotic". The reason is that composition of conglomerates is extraordinarily variegated, suggesting derivation from wide terrains with a complex geological structure, moreover some components could have been derived only from very distant, improbable sources, and the provenance of a part of them is not known at all (e.g. the Carboniferous coal). Besides of many common rock types, the components of the exotic, so-called Upohlav conglomerate include for instance basinal Triassic limestones, Upper Jurassic platform limestones, Urgonian limestones with serpentinite clasts, Permian A-type granites with Lower

Cretaceous FT cooling ages (Uher & Pushkarev, 1994; Kissová et al., 2005), large amount of calc-alkaline volcanics of uncertain age (Permian, Upper Jurassic–Lower Cretaceous?), Upper Jurassic glaucophanites (Dal Piaz et al., 1995; Faryad & Schreyer 1997), prevailing Cr-spinels in heavy mineral spectra (Mišík et al., 1980; Jablonský et al., 2001) etc. Clasts are perfectly rounded, pointing to river transportation, whereas the size of pebbles, cobbles and boulders of up to 3 meters in diameter implies a very short transport system. However, no possible source areas of such material can be found in the actual geological structure of the surrounding zones.

To explain the source of these exotic clasts, the concept of a temporarily active Cretaceous "exotic ridge", or "Pieniny (ultra-Pieninic) cordillera" was developed many decades ago. Birkenmajer (1988) named this structure as the Andrusov Ridge in honour of the prominent Carpathian geologist Dimitrij Andrusov who developed the earliest concept of the exotic ridge. After the advent of plate tectonic theory, the exotic ridge has been interpreted as a compressional tectonic structure in an active margin setting – imbrications of obducted oceanic material or subduction mélange transiently outcropped along the outer structural high of an accretionary palaeoprism (Mišík & Marschalko, 1988), subduction complex exhumed in the rear part of the South Penninic – Vahic accretionary wedge (Maheľ, 1989), or a magmatic island arc (Birkenmajer, 1988). Exotic pebble material would indicate Triassic opening of the corresponding oceanic basin and its Late Jurassic – Early Cretaceous closing (e.g. Birkenmajer, 1988; Dal Piaz et al., 1995). However, this concept is in a severe contradiction with the geological record of all other PKB and neighbouring units, where no such events can be documented. On the other hand, these events surely occurred in the southern Western Carpathian zones, where they were associated with opening and closing of the Meliata Ocean. Hence the alternative model developed by Plašienka (1995, 2012; Kissová et al., 2005) presumes the Fatric affiliation of the Klape Unit and its wildflysch complexes, which were fed by clastic material derived from the Meliata and Silica units forming an uplifted and eroded supra-Veporic thrust stack adjacent to the Klape Basin in mid-Cretaceous times.

The SE-most constituent of the Periklippen Belt is the Manín Unit. Its Lower Jurassic–Cenomanian sequence (including the characteristic Urgon-type platform limestones) closely relates to the ridge-type successions of the Fatric Superunit (e.g. the Belá Unit in the Strážovské vrchy Mts – Maheľ, 1978). However, many other authors prefer the Tatric affiliation of the Manín Unit (e.g. Rakús & Hók, 2005).

The Manín Unit is composed of relatively shallow-water formations including Lower Jurassic cherty sandy-crinoidal limestones to sandstones, and Middle–Upper Jurassic red nodular limestones. The Lower Cretaceous strata are represented by maiolica-type pelagic limestones, marly and cherty limestones and the most conspicuous member of the Manín Unit – the Aptian and lower Albian Urgonian platform limestones (Borza et al., 1987; Michalík & Vašíček, 1987; Michalík & Soták, 1990; Michalík, 1994; Rakús & Hók, 2005; Michalík et al., 2012). These are overlain by a drowning-related hardground and then followed by Albian dark pelagic marls (Butkov Fm) passing gradually into a coarsening-upward Cenomanian–Turonian turbiditic sequence with boulder beds and olistoliths (Praznov Fm; e.g. Marschalko, 1986). The surface structure of the Manín Unit is dominated by the mid-Cretaceous hemipelagic and flysch formations, older stiff limestones build several large "klippen", which are in fact brachyanticlines (Manín and Butkov Hills; Plašienka et al., 2017; Šimonová & Plašienka, 2017). Contrary to earlier views, the Senonian sediments in the Klape and Manín Zone are supposed to represent a post-nappe, Gosau-type cover (cf. Salaj, 2006; Plašienka & Soták, 2015) containing also resedimented pebble material from the Klape Flysch (Rašov Fm). The mid-Cretaceous formations of the Manín Unit are overridden by the frontal elements of the typical Fatric Krížna Nappe from the SE.

Overstepping complexes

The Periklippen Zone is characterized also by the ubiquitous presence of Senonian to Middle Eocene sediments of the Gosau Supergroup deposited in the wedge-top basins above the underlying frontal Fatric and partly also Hronic nappes. In the westernmost part of the PKB and CWC (Malé Karpaty Mts; Fig. 8), these consist of the lower Gosau, Senonian Brezová Group, and the upper Paleocene–Lutetian Myjava Group in a situation analogous to the position of Gosau sediments in the Northern Calcareous Alps (NCA, e.g. Wagreich & Marschalko, 1995). The Gosau deposits in the NCA and Malé Karpaty Mts are interconnected through the "Giesshübl Syncline" drilled in the substratum of the Neogene Vienna Basin (e.g. Wessely, 1992). In the Middle Váh Valley, the southern boundary of the PKB against the CWC is followed by deformed Palaeocene–Lower Eocene sediments known as the "Periklippen Paleogene" (Myjava-Hričov Group – Figs 8, 9). In general, the Brezová and Myjava-Hričov Groups are characterized by pelagic marls and calcareous flysch formations with a frequent shallow-water biogenic detritus and Maastrichtian–Paleocene, reef-derived olistoliths.

Olistoliths in the PKB

Owing to the block-in-matrix structure of many sectors of the PKB, the klippen were almost unequivocally regarded as tectonically separated blocks embedded in a softer matrix. Only a few large blocks were interpreted as sedimentarily emplaced slides of e.g. the Paleocene reef bodies or Mt Klape klippe. In eastern Slovakia, Nemčok (1980) speculated that the entire PKB represents a gigantic olistostrome body sandwiched between the Paleogene flysch complexes of the Magura Unit and Central Carpathian Paleogene Basin. This rather strange view was based on correct small-scale observation (Nemčok et al., 1989), but overestimated in a large view. Plašienka et al. (2012) and Plašienka (2012) corrected the olistostrome concept in a way that olistostromes do occur, but only as terminal syn-orogenic formations of all Oravic units, whilst the PKB as a whole is still a principally tectonic phenomenon. Recently, Golonka et al. (2014) enlarged the olistostrome model also to the Váh River Valley in western Slovakia, considering also e.g. the Butkov and Manín hills as megaolistoliths. However, it is well known from the earliest research in this area (Stur, 1860) and confirmed many times afterwards that these are perfectly shaped, doubly-plunging anticlines. The erroneous opinion of Golonka et al. (2014) inspired Plašienka et al. (2017) to critically discuss this problematic issue and to present a systematic classification of olistostromes/olistoliths based on genetic criteria. This model is presented in Fig. 8 and distinguishes five basic types of olistoliths:

(i) The first type of olistoliths is represented by blocks of Paleocene, mostly Thanetian algal-coral reefs (Kambühel Limestone) embedded in a coeval or slightly younger matrix of neritic calcareous sandstones and marls associated with tempestites, turbidites and slump bodies (Paleocene–Lutetian Myjava-Hričov Group in Figs 8, 9). They are generally related to shallow-marine environments, where the bioherms were disintegrated by storms or seismic events and transported only for a short distance; partly they correspond to in situ patch reefs. Blocks of Kambühel Limestones occur in a narrow, but long strip along the southern boundary of PKB from Austria up to western Ukraine (see e.g. Marschalko & Kysela, 1980; Köhler et al. 1993). They are associated with exo-olistoliths of Upper Cretaceous bioherms and Urgonian limestones derived from the adjacent Manín Unit. These olistoliths are designated as type (1) in Fig. 9.

(ii) Type (2) olistoliths are similar to type (1), but older – Upper Cretaceous (Coniacian–Santonian and Maastrichtian). These are again formed by re-deposited rudists- and orbitoids-bearing bioherms and biostromes associated with conglomerates, allodapic limestones, tempestites and marlstones of nearly the same age (endo-olistoliths), as well as with exo-olistoliths of Urgonian and Triassic limestones (Senonian Brezová Group in Figs 8,9). Types (1) and (2) olistoliths originated within actively deforming piggyback basins in a wedge-top position (Gosau-type; cf. Plašienka & Soták, 2015).

(iii) The third olistolith type (3) is represented by the so-called Kostolec group of limestone klippen resting within the Albian–Cenomanian hemipelagic and turbiditic deposits (Butkov and Praznov fms, respectively) of the southernmost partial subunit of the Manín Unit, just below the overriding Central Carpathian Krížna nappe (Fig. 9). According to Rakús & Marschalko (1997) and Rakús & Hók (2005), the Jurassic–Lower Cretaceous sedimentary successions of these klippen are similar to coeval deposits of the Manín Unit. These authors, together with Marschalko & Kysela (1980), Marschalko (1986) and Plašienka & Soták (2015), interpreted the Kostolec klippen as olistoliths, which assumption was also corroborated by technical works like trenching and drilling.

(iv) The most spectacular olistoliths (type 4) in the Middle Váh Valley occur in the Klape Unit (Fig. 9). These are solitary extraneous slide blocks measuring tens to hundreds of metres in diameter, the distinctive Mt Klape klippe (Fig. 9) being the largest one. The Klape and other similar olistoliths are embedded in hemipelagic and distal turbiditic sediments of Aptian–Early Albian age, i.e. their emplacement preceded the climax of coarsening-upward, synorogenic deposition of the Klape Flysch. In contrast to the deep-water Jurassic formations of the Klape Unit itself, these olistoliths are composed of more shallow-water carbonates (reddish sandy-crinoidal and nodular limestones), which were likely derived from the southern margin of the Klape Basin at the earliest stages of its inversion. Original palaeogeographic position of this basin and tectonic affiliation of the Klape Unit is a subject of debate and controversial views. According to Plašienka (1995a, b, 2012), the Klape Unit is a frontal constituent of the Fatric (Krížna) cover nappe system rooted far south in the Central Carpathian zones and emplaced in the present position during the late Turonian stage. If so, the Klape Flysch originated in a place distant from its present location in the PKB, and has therefore nothing in common with development of the Upper Cretaceous–Palaeogene (Coniacian–Lutetian) accretionary wedge in front of the Central Western Carpathian units (PKB and adjacent zones), as well as its olistoliths do not relate to the later PKB evolution.

(v) The fifth type (5) of olistoliths/olistostromes in the PKB is the only in which views of Golonka et al. (2014), and also Nemčok (1980), can be accepted. The Paleocene olistostromes of the Šariš Unit (Milpoš Breccia Member of the Jarmuta-Proč Formation – e.g. Plašienka, 2012) represent syn-thrusting foredeep-trench, mass-flow deposits composed of material derived from destructive frontal edges of overriding Subpieniny and Pieniny thrust sheets of the developing PKB. Olistostromes carry huge olistoliths (sedimentary klippen) of Jurassic–Lower Cretaceous formations. Besides olistoliths in sedimentary breccias, chaotic slide masses and solitary slide sheets are also common, providing a transition from thrusting-related movements of imbricated allochthonous nappe units within the prograding accretionary wedge towards gravitational sliding of their liberated frontal masses into the foreground trench depression.

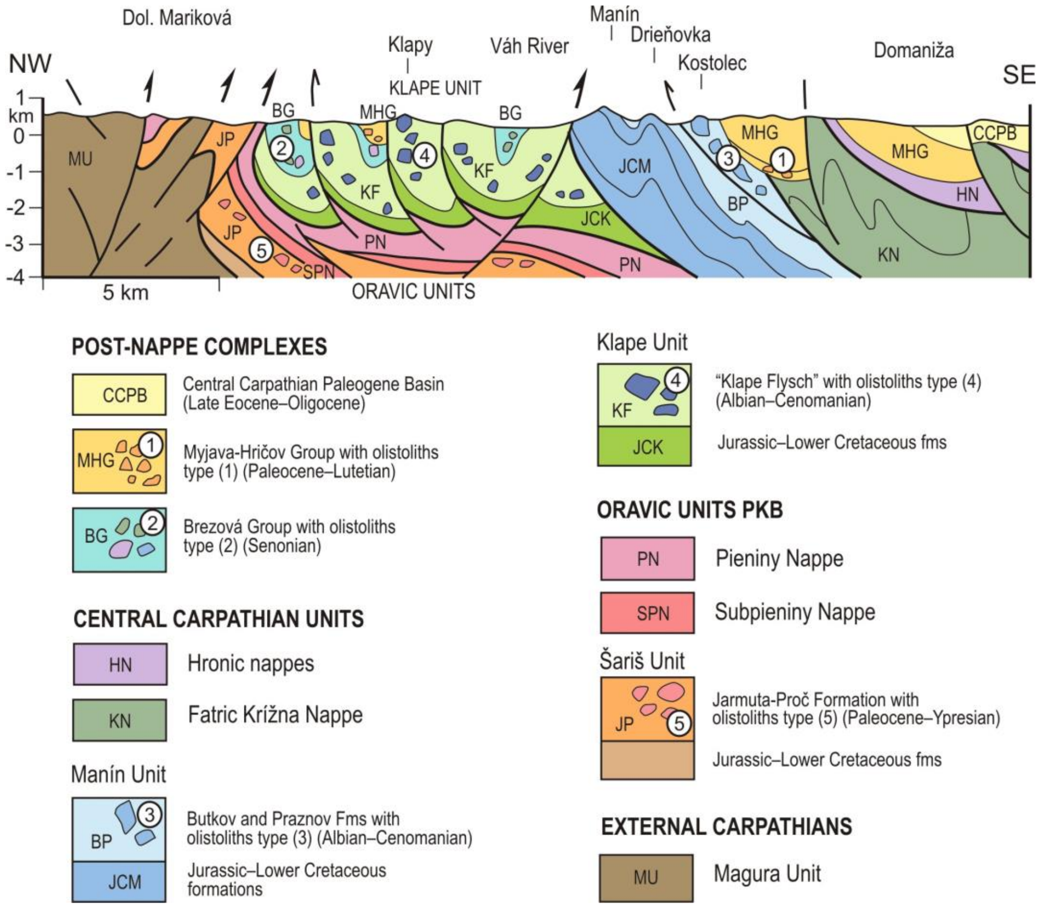


Fig. 9. Vertically exaggerated cross-section of the Pieniny Klippen Belt and neighbouring zones in Middle Váh Valley (see location in Fig. 8). Various types of olistoliths in the Oravic and Fatric units and in the Gosau complexes are distinguished (see text for explanation). Adapted from Plašienka et al. (2017).

Tectonic evolution

Superposition of the PKB nappe units was strongly modified by post-Oligocene deformation, but it is still well recognizable in several places. The structural position, age range of included sedimentary successions and the inferred age and composition of coarse-grained synorogenic clastic deposits reveal that the stacking of the PKB units progressed from the mid-Cretaceous emplacement (most probably late Turonian) of the Fatric nappes followed by sequential thrusting of the Oravic units with the piggyback Fatric and Gosau complexes. The Pieniny Unit overrode the Subpieniny around the Cretaceous/Paleogene boundary. Then thrusting propagated northwards throughout the Paleocene–Lower Eocene (Subpieniny + Pieniny over Šariš) and terminated by the local Lower Miocene thrusting of the Šariš Unit and the overlying nappe and overstepping complexes above the inner Magura elements. This compressional tectonic scenario was transiently interrupted by extension events and followed by the Late Eocene transgression and Oligocene subsidence of the large-scale Central Carpathian Paleogene Basin in a fore-arc position (e.g. Soták et al., 2001; Kováč et al., 2016).

Renewed compression/transpression and wrench faulting then occurred during the Lower Miocene (Ratschbacher et al., 1993; Kováč & Hók, 1996; Šimonová & Plašienka, 2017). In spite of this complicated tectonic history, the data about the post-depositional thermal history indicate that the PKB sediments were never buried to considerable depths, and all the deformation occurred in the brittle field. For this reason it is assumed that shallow thrusting did not generate a significant burial and the PKB units must have always occupied a high structural position. This would indicate a prevailingly footwall-propagating, "piggy-back" mode of thin-skinned thrusting.

Summing up, the overall tectonic scenario for the PKB includes piggy-back mode of forward thrusting, formation of a fold-and-thrust belt capped by synorogenic sedimentary basins and some out-of-sequence thrusting as the principal tectonic processes during the Late Cretaceous and earliest Paleogene, followed by Middle Eocene extension and Late Oligocene–Early Miocene transpression and backthrusting responsible for the steepening and narrowing of the PKB that acquired its final structural style.

Field stop 1: Vršatec – Upper Cretaceous microfauna of the oceanic red beds

Štefan JÓZSA

GPS: 49°04'15.6"N; 18°09'18.4"E

During the Late Cretaceous and early Tertiary a major change in oceanic sedimentation took place in the Tethys represented by the sedimentation of deep-sea red shales and marls (Hu et al., 2005). The purpose of the field stop is to show the typical Cretaceous oceanic red beds (CORB's) from the Pieniny Klippen Belt (PKB). The PKB represents a narrow strongly deformed structure generally spanning along the northern course of Slovakia (Fig. 10A) and a small part of the Polish sector in the Pieniny Mts Both the general geology and the landscape of the PKB is very characteristic with the presence of the so-called "klippen" represented by the competent rocks mostly limestones forming hills and softer marly or flysh sediments filling the depressions between these klippen as the so-called "klippen envelope". The klippen are mostly unevenly distributed in a form of a tectonic or sedimentary melange (Andrusov & Scheibner, 1968). The PKB is commonly interpreted as a relic of a continental fragment in a middle Penninic position (e.g. Plašienka, 2003a; Froitzheim et al. 2008) and includes a variety of tectonic and sedimentary units compressed into only a few kilometres narrow zone (e.g Birkenmajer, 1977; Mišík et al., 1996; Plašienka & Mikuš, 2010) (Fig.10 A; figs. 12, 13). The two most contrast units in the Slovak part of PKB are earmarked as the basinal deep water development of facies in the Kysuca and the shallower development of facies in the Czorstyn unit. The Vršatec klippe belongs to the Czorstyn unit with the shallower bathymetry. During the sedimentary history of this unit an event of emergence of the so-called Czorstyn swell (Mišík, 1994) led to the erosion and carstification of the uppermost Jurassic - Lower Cretaceous strata (Aubrecht et al. 2006). Later between ?Late Aptian – Albian the erosional surface was submerged and covered by organodetritic red beds of Chmielowa Formation (Aubrecht et al., 2006; Jamrichová et al., 2012). Later the further submergence led to the typical sedimentation of marly brick red calcareous oceanic sediments of the Pustelnia Fm (Sýkora et al., 1997; Aubrecht et al., 2006). Unlike the type locality of the Czorstyn castle klippe in the Polish sector of PKB the Vršatec klippe represents the largest klippe of the Czorstyn unit. The synonym used for the Senonian red marl formations in the Western Carpathians from the so-called Považie – Pieniny Belt is widely designated as the so-called "Púchov" type facies which represents the oldest known lithostratigraphic unit from the Western Carpathians described by Štúr (1860). From the CORB's belonging to the PKB the first descriptions of important index species of some planktonic foraminifera originate such as *Sigalia decoratissima carpathica* (Salaj & Samuel), *Dicarinella hagnyi* Scheibnerová or *Bollitruncana carpathica* (Scheibnerová, 1963) (Pl. 1, Fig. 14). The most recent works in the area include the microbiostratigraphy of the CORB's from a section under the Vršatec castle klippe (Fig. 10 D) which span from the Upper Albian – Lower Campanian (Boorová in Sýkora et al. 1997, Boorová in Aubrecht et al. 2006). In the visited saddle section (Fig. 10 C; Fig. 11 C) the CORB's are tectonically reduced and represented only with the Turonian – Coniacian strata (H. helvetica – D. concavata planktonic foraminiferal Zones) (Józsa unpubl. data). This zone includes the U. jankoi deep water foraminiferal (DWAF) Zone of Geroch & Nowak (1984). The DWAF assemblages from the CORB's of the Polish sector of PKB were recently analysed by Bąk et al., 1995 and Bąk (1997).

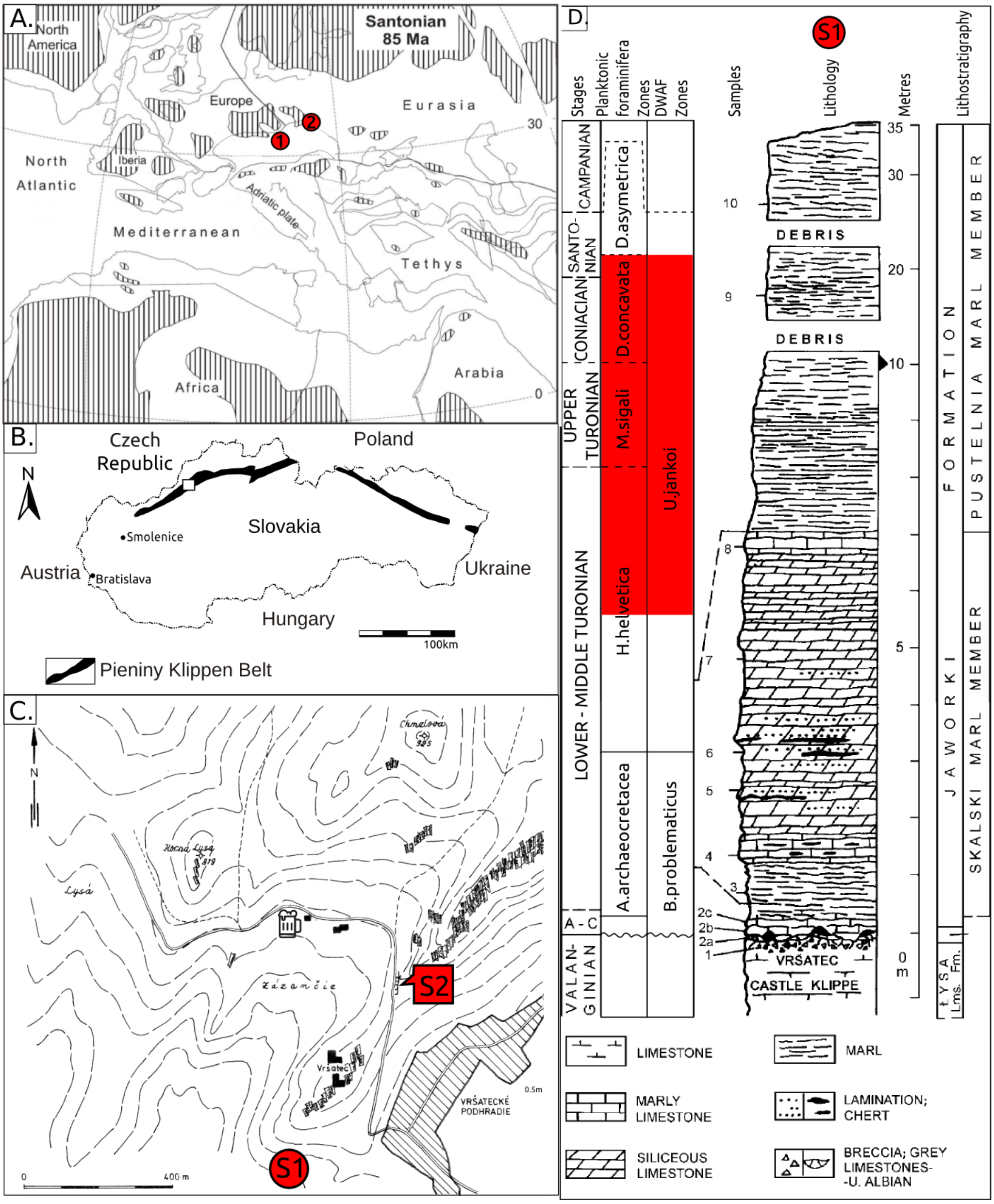


Fig. 10. A: Palaeographic map of western Tethys (85 Ma, Santonian) showing the localities of CORB's. 1. Western Carpathians. 2. Pieniny Klippen Belt (after Hu et al. 2005). B: General sketch of Slovakia with the Pieniny Klippen Belt tectonic unit (black area) and the smaller scale topographic map of the Vršatec castle area (white square) C: S1, S2 Position of the sections with the Upper Cretaceous red beds. D: Lithologic profile of the S1 section (according to Sýkora et al., 1997, modified).

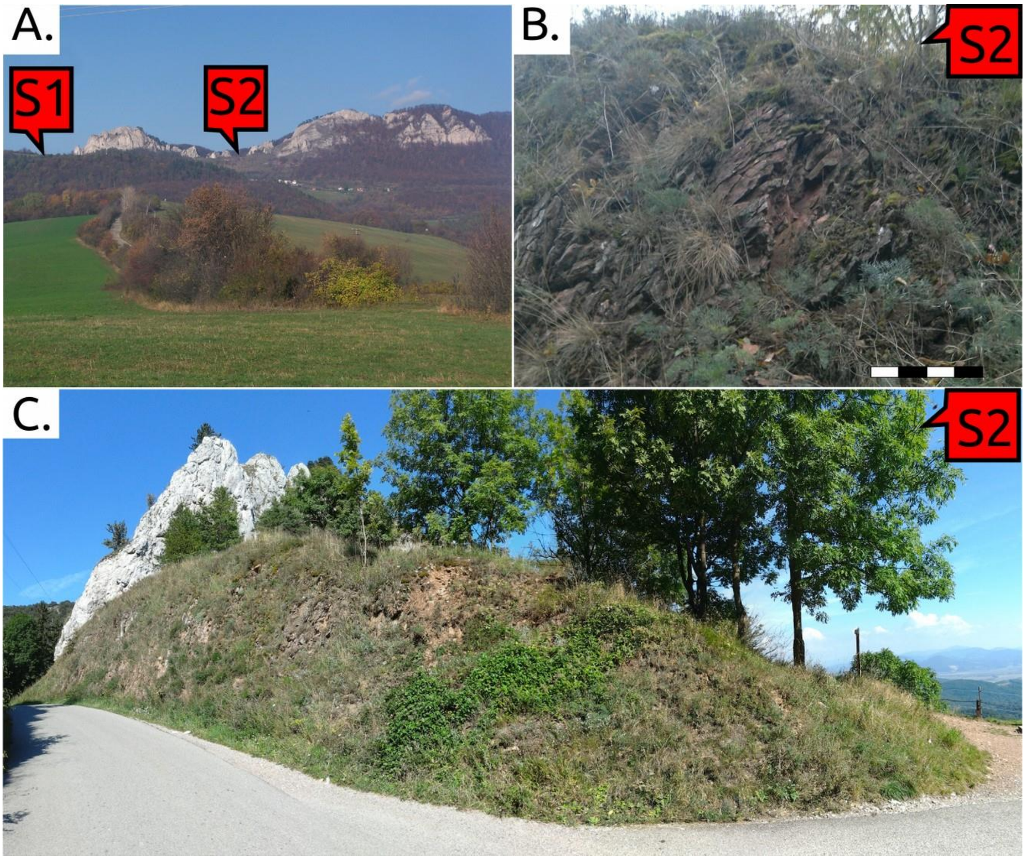


Fig. 11. A: General view of the Vršatec Klippe with the section position in the saddleback between the Vršatec Klippe (S2) and the original section of Sýkora et. al. (1997), (S1). B: Cleavaged brick red marls of the Pustelnia Marl member on the S2 section. C: Panorama of the S2 section with Bajocian light limestones of the Chmeľová klippe in the background.

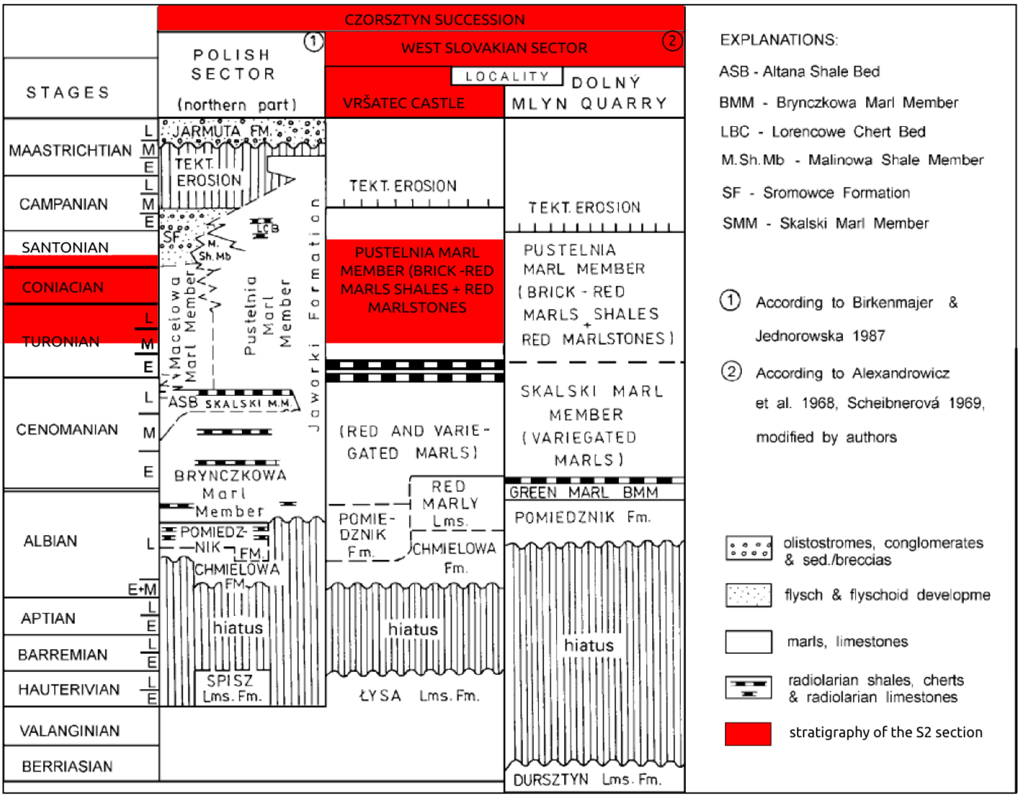


Fig. 12. Correlation of lithostratigraphic units of the Czorsztyn Succession in the Western part of the Pieniny Klippen Belt (2) with the Polish territory (1) (according to Birkenmajer & Jednorowska, 1987, Alexandrowicz et al., 1968, Scheibnerová, 1969 in Sýkora et al., 1997, modified).

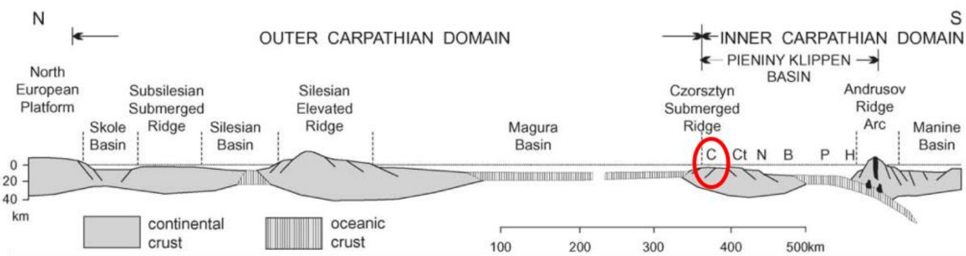
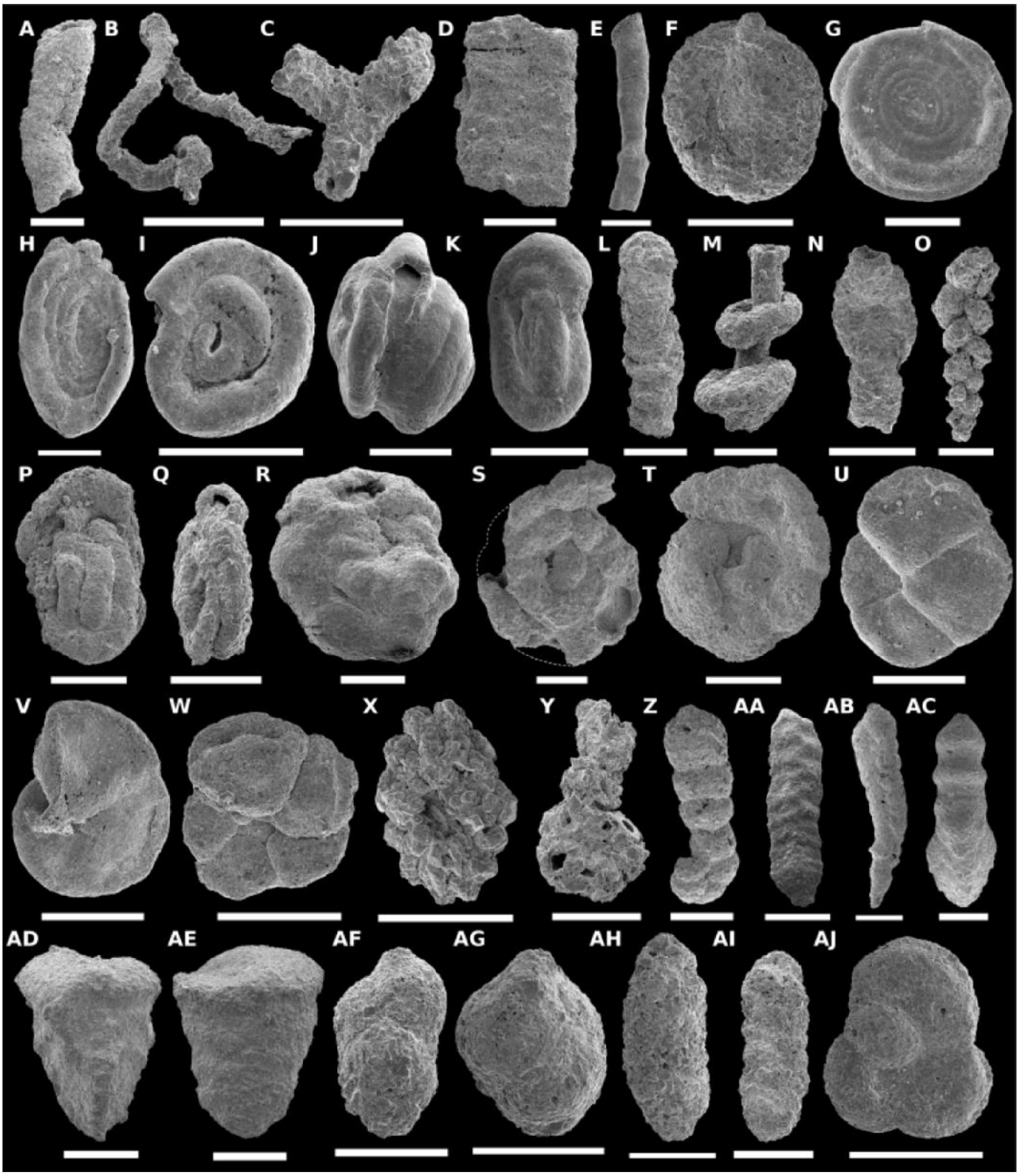


Fig. 13. Palinspastic position of the Polish Outer and Inner Carpathian basins during the Aptian – Lower Campanian (Birkenmajer, 1986 in Hu et al. 2005). Pieniny Klippen Belt successions/units: C, Czorsztyn Ridge; Ct, Czertezik; N, Niedzica; B, Branisko; P, Pieniny; H, Haligovce; AR, Andrusov Exotic Ridge; Ma, Manín Basin.



Pl. 1. A–C: *Rhizammina* spp.; D: *Nothia excelsa* (Grzybowski, 1898); E: *Rhabdammina* sp.; F: *Placentammina grzybovskii* (Schubert); G: *Ammodiscus cretaceous* (Reuss); H: *Ammodiscus peruvianus* Berry; I: *Glomospira gordialis* (Jones & Parker, 1860); J: *Glomospira charoides* (Jones & Parker); K: *Glomospira serpens* (Grzybowski); L: *Subreophax scalaris* (Grzybowski); M: *Hormosinella distans* Brady; N: *Reophax helveticus* (Haeusler); O: *Parvigenerina* sp.; P–G: *Glomospira irregularis* (Grzybowski, 1896); R: *Paratrochamminoides acervulatus* (Grzybowski); S–T: *Trochamminoides grzybowski* Kaminski & Geroch; U: *Haplophragmoides kirki* Wickenden; V: *Haplophragmoides walteri* (Grzybowski); W: *Haplophragmoides gigas minor* (Nauss); X: *Ammomarginulina aubertae* Gradstein & Kaminski; Y: *Ammobaculites agglutinans* (d'Orbigny); Z: *Bulbobaculites problematicus* (Neagu); AA: *Spiroplectinella israelskyi* (Hillebrandt); AB: *Spiroplectammina navarroana* Cushman; AC: *Tritaxia gaultina* (Morozova); AD: *Gaudryina carinata* Franke; AE: *Marssonella oxycona* (Reuss); AF:

Uvigerinammina praejankoi Neagu; AG: *Uvigerinammina jankoi* Majzon; AH: *Gerochammina obesa* Neagu; AI: *Gerochammina stanislawi* Neagu; AJ: *Ammosphaeroidina pseudopauciloculata* (Mjatliuk, 1966). A, F, J, M, O, AC, AF, AD, AE H. helvetica Zone (Lower-Lower Middle Turonian), B, G, H, I, K, N, R, S, V, W, Y, AA, AB, AG M. sigali Zone (Upper Middle-Upper Turonian), L, P, T, U, X, Z, AH, AI, D. concavata Zone (Coniacian-Lower Santonian).

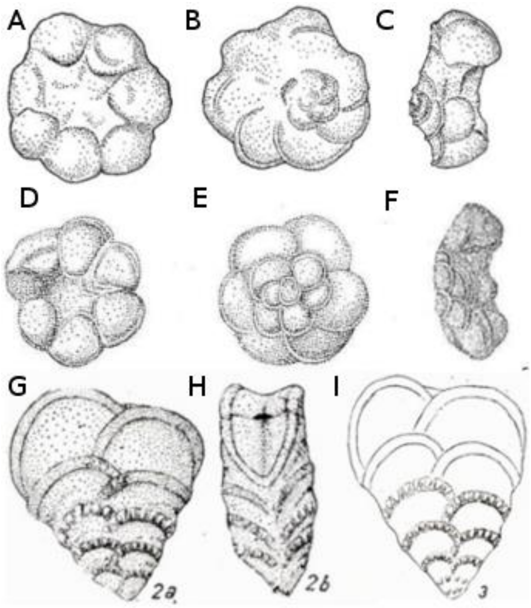


Fig. 14. Original figures provided to the first descriptions of the stratigraphically important species of planktonic foraminifera from the CORB's of the Slovakian PKB. A–C: *Bollitruncana carpathica* (Scheibnerová, 1963); D–F: *Dicarinella hagni* (Scheibnerová, 1962); G–I: *Sigalia carpathica* (Salaj & Samuel, 1963). B, E, G, I, dorsal views, A, D, umbilical views, C, F, H peripheral views.

Field stop 2: Butkov Quarry – Mesozoic foramtions of the Manín Unit and Albian-Cenomanian microfauna of the Butkov Marlstones

Jozef MICHALÍK, Ján SOTÁK, Daniela BOOROVÁ and Kamil FEKETE

GPS: 49°01'32.0"N; 18°19'01.9"E

Fig. 15. Panoramic view to the Butkov Quarry with exposed sequence of the Jurassic – Lower Cretaceous formations of the Manín Unit.

Butkov Quarry is the most comprehensive outcrop of the Manín Unit in the central Western Carpathians. In the Manín Unit (Fig. 15), hemipelagic **Ladce Fm** is built of bedded „Maiolica" limestone facies. The ammonite fauna, calpionellids and dinoflagellates confirm its Early Valanginian age (Vašíček and Michalík, 1986; Borza et al., 1987; Michalík and Vašíček, 1987; Měchová et al., 2010; Michalík et al., 2005). Upper Valanginian / Lower Hauterivian „Maiolica" facies was covered by less oxygenated but intensively bioturbated dark-gray marly **Mráznica Formation** limestones. Unlike the Ladce Formation, darker colour of fossil traces contrasts with surrounding rock limestone matrix). Occurrence of fine clastic admixture and terrestrial plant remains indicates more humid climate (Michalík et al., 2012, 2014). Although benthic hard-shelled fauna mostly absents, abundant ammonites, microfossils, calcareous nannofossils and non-calcareous dinoflagellates indicate Late Valanginian Furcillata- and Early Hauterivian Radiatus-, Loryi and Nodosoplicatum zones.

The **Kališčo Formation** recorded stabilization of bottom and increased diversification of benthic fauna upwards. Occasional occurrence of calciturbidite interlayers is an important feature of the Kališčo Formation. The shape of chert nodules has been controlled both by sponge bodies and by activity of burrowers, many of them originated by silicification of sponge colonies. According to frequent ammonites, calcareous nannofossils and non-calcareous dinoflagellates, the age of this pelagic cherty limestone sequence is

Late Hauterivian Sayni- and Ligatus zones (Michalík et al., 2005, 2012 and 2014).

Gray micritic limestones of the **Lúčkovská Formation** contain fairly frequent benthic remnants (brachiopods, sponges, bivalves, crinoids and echinoids) often grouped around firm particles in the bottom (Michalík and Žítt, 1988; Michalík et al., 2005). Brackish non-calcareous dinoflagellates (*Muderongia*) dominated during lowstand conditions, while neritic (*Oligosphaeridium*, *Spiniferites*) and oceanic (*Pterodinium*) dinoflagellates prevailed during higher nannoplankton and microplankton diversity of transgressive and highstand intervals (Skupien in Michalík et al., 2005). Similarly, radiolarians reached their maximum of abundance during maximum flooding intervals. Calcareous nannofossil assemblage belongs to the Lithraphidites bollii- up to the Early Barremian Micracantolithus hoschulzii Zone. The basal part of the Lúčkovská Fm yielded ammonites of the Late Hauterivian Balearites Zone; earliest Late Barremian Vandenheckii Zone was proved higher up (Vašíček and Michalík, 1986; Michalík et al., 2005, 2014; Vašíček, 2010). The uppermost parts of the formation are affected by submarine erosion and slumping.

The "Urgonian" facies has been studied by Andrusov (1929), Mišík (1957; 1990), Borza (1980), Lefeld (1974), Michalík and Vašíček (1984) or by Michalík and Soták (1990). Masse and Uchman (1997) discussed different time span of West Carpathian formations composed of Lower Cretaceous carbonate platform carbonates. Carbonate platform sequence in the Manín Unit is divided into two formations.

The **Podhorie Formation** is built of well-bedded cherty biodetrital carbonates representing slope deposits of a prograding carbonate platform with thickness of 65 – 80 m. They have been called as "black stone" by local peoples.

The Manín **Formation** is composed of a core complex of the limestone platform. It is built of massive organogenic limestones ("pale stone" of local quarrymen), 45 – 60 m thick. The most picturesque rocky parts of the famous Manín Strait have been formed by erosion in these rocks.

The **Butkov Formation** is a thick shaly argillite complex which covers the "Urgonian" limestones of the Manín Formation. Andrusov (1959) designated these shales as the "Butkov cement marls" (Fig. 16). The lithostratigraphic name of the Butkov Formation within the Podmanín Group has been introduced by Kysela, Marschalko and Samuel (1982) according to the Mt Butkov. The formation reaches about 150 – 160 m thickness in the Ladce cement quarry.

Manín and Butkov Formations appear be most interesting part for the IWAF-10 participants, first containing large orbitolinid and small benthic microfauna and second one rich planktonic and agglutinated microfauna.

Fig. 16. Rhytmical-bedded sequence of the green-yellow marlstones of the Butkov Fm

Manín **Formation** forms the upper part of the Lower Cretaceous limestone platform sequence. They are composed of grey to pale grey thick-bedded to massive limestones (biosparite, biomicrosparite to biomicrite) with clasts of neritic organisms like thick bivalve shells, bryozoans, crinoids, serpulid tubes, solenoporids, corals, red algae (*Ethelia alba* Pfender, *Solenopora*, *Pycnoporidium*), green algae (*Lithocodium aggregatum* Elliot). Microfossils *Koskinobullina* cf. *socialis*, *Sabaudia minuta*, *Patellina* sp., *Colomiella mexicana*, *C. recta*, *Calpionellopsella maldonadoi*, *Cadosina semiradiata*, *Colomisphaera* cf. *heliosphaera*, *Didemnoides moreti*, *Gemeridella minuta*, *Pieninia oblonga*, ostracods, ophiuroid particles occur less frequently. Pellets, intraclasts, quartz silt and glauconite grains, pyrite and phosphate occur subordinately.

The lower part of the Manín Fm is formed by biopelsparite with fragments of heterozoan skeletons (crinoids, bivalves) with microborings, occurring in aggregates. Bioclasts are penetrated, corroded by vertical microborings. Similar manner of clasts corrosion could be compared with microborings from shallow water *Trypanites* ichnofacies carbonates from the Northern Calcareous Alps, Austria and SE France (Schlagintweit et al., 2008).

The upper part the Manín Fm consists of biosparite with heterozoan clasts of sponge, crinoid and bivalve skeletons and more frequent skeletal clasts of photozoan organisms (corals, green algae) are accompanied by small gastropods. Outer layer of clasts is micritized due to activity of boring algae proving for shallow environment within photic zone. The sequence is topped by a prominent hard-ground surface furrowed by grooves and holes of drilling and etching fossil infaunal organisms.

Orbitolinids provided a first appearance in Globigerinelloides ferreolensis – Globigerinelloides algerianus zones, which resembles a start of the "Orbitolina level" on the base of Gargasian immediately above the Selli Level (Cherchi et al., 1978; Raspini, 2012), (Fig. 17). Contemporary appearance of supposedly oligotrophic to mesotrophic globigerinelloid foraminifers could indicate closing of the "Globigerinelloides Eclipse" known from the Selli Level (Luciani et al. 2001, Graziano 2013). The oldest large foraminifers belong to *Praeorbitolina wienandsi* and *Mesorbitolina lotzei*, limiting by their LO the Bedoulian / Gargasian boundary (Schroeder et al., 2010). Orbitolinid foraminifers from higher beds already belong to *Mesorbitolina*, detecting Mid Aptian- (Parva Biozone) and Upper Aptian (Texana Biozone) parts of the sequence. This succession not only reflects fylogenesis of the *Mesorbitolina gr. parva – texana* group, but also orbitolinid ecologic succcession from mostly discoidal Mid Aptian forms to more expressively conical Upper Aptian morphotypes. Prevalence of discoidal and micritized orbitolinid tests in the Lower limestones limestones can indicate their resedimentation into deeper slope environment during storm and high tides (cf. Pittet et al., 2002). Rised terrigenous runoff to basin probably reflected also in dominance of microsphaeric orbitolinid tests in Lower Aptian limestones, as the higher nutrient input supported their asexual reproduction (Villas et. al., 1995). On the other hand, more conical and non-altered orbitolinid tests from the foramol limestone facies with prevalence of heterozoan carbonate productivity of the Manín Formation recorded shallower carbonate platform environment with high water energy and with oligotrophic regime.

The Manín Fm is topped by a prominent hard-ground surface, which is colonized by belemnites (*Neohibolites minimus*), urchins, etc., and furrowed by grooves and holes of drilling and etching fossil infaunal organisms. Sponge borings *Entobia* Bronn were distinguished in the „Manín hard ground" sealing the carbonate sequence. Spherical chambers of the latter ichnospecies are commonly not touching, with diameter of 3 to 11 mm. Minute tunnels less than one mm wide radiate in all directions from the chamber. They occur more than 10 cm below the hard-ground surface, which continues on the wall of a few meters deep caverns. Merged borings could remind elongated borings of molluscs, *Gastrochaenolites*. This trace fossil was created under slowed sedimentation rate.

The "Urgonian" complex of the Manín Fm is covered by indistinctively bedded dark gray, blue-gray and green-gray calcareous marlstones of the Butkov Formation. These eupelagic marlstones are very rich planktonic foraminifers, however, an agglutinated foraminifers are also abundantly present in silty marlstones.

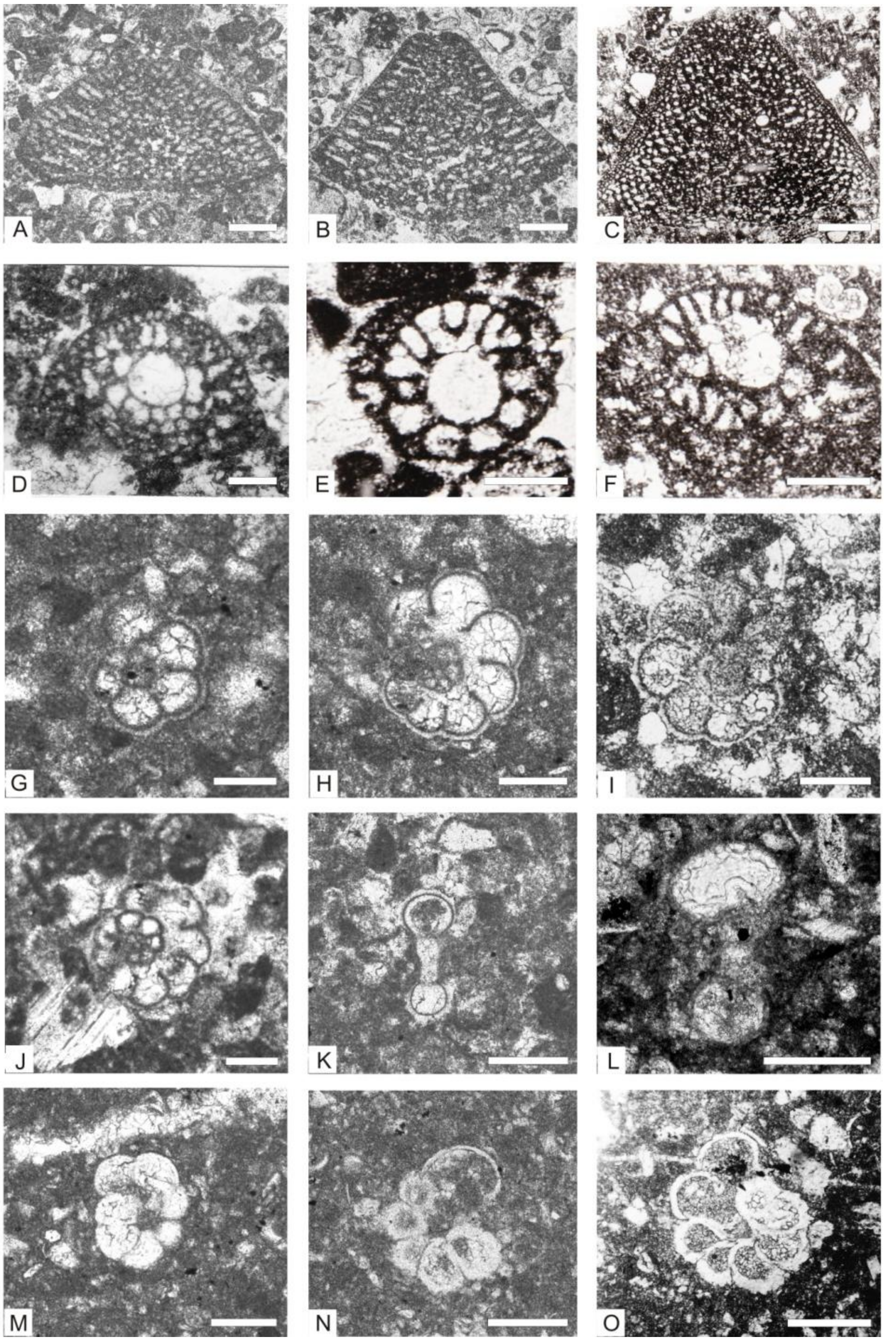

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Fig. 17. A–F: Orbitolinid foraminifers from “Urgonian-type“ limestones of the Manín Unit. A: *Mesorbitolina* cf. *texana* (Roemer), Butkov; B–C: *Mesorbitolina parva* (Douglas), Butkov (B), Skalica Klippe (C); D: *Mesorbitolina parva* (Douglas) – *M. texana* (Roemer), transitional form, Butkov; E: *Mesorbitolina texana* (Roemer), Mráznica; F: *Mesorbitolina minuta* (Douglas), Mráznica; (C, E, F – adopted from Köhler, 1980); G–L: Planktonic foraminifers from limestones of the Podhorie Fm, Butkov: G: *Globigerinelloides aptiensis* Longoria, Bt-1E 298; H–I: *Globigerinelloides ferreolensis* Moullade, Bt-1E 306, Butkov 8E/52; J: *Globigerinelloides algerianus* Cushman and Ted Dam, Bt 1E-302; K: *Globigerinelloides ferreolensis* Moullade, Bt-1E 299; L: *Globigerinelloides barri* Bolli, Bt-1E 339; M–O: *Hedbergella trocoidea* Gandolfi, Bt-1E 337, Bt-1E 325, Bt-4E/81V. Scale bars: 0.1 mm.

The foraminifer association from the base of the Butkov Fm is dominated by *Thalmanninella* species with raised periumbilical ridges and sutural supplementary apertures (Fig. 18). Based on this, they belong to species of *Thalmanninella appeninica*, *Th. brotzeni*, *Th. globotruncanoides* and *Th. gandolfi*. *Thalmanninella* species are associated with *Praeglobotruncana stephani*, *P. gibba*, etc. Small-sized hedbergellids are very rich, comprised of *Hedbergella infracretacea*, *H. planispira* and *H. delrioensis*. The presence of *Thalmanninella* species provide an evidence of the late Albian – early Cenomanian age, belonging to Thalmanninella appeninica – Th. globotruncanoides zones. Stratigraphic gap between the topmost part of the Manín (Urgonian-type) Fm and Butkov Fm lasted from Early to Middle Albian.

Higher part of the Butkov Fm refers a change in rotaliporid foraminifer by appearance of plano-concex species of *Thalmanninella reicheli* and *Th. deckeri*. These new species (descendents of *Th. globotruncanoides*) occurred in the Mid Cenomanian biozone, which is documented in the Butkov Fm

The Butkov Fm also contain a rich microfauna of agglutinated foraminifera (Fig. 19). Their abundance increasing upward from epifaunal to shallow- and deep infaunal assemblages. Epifaunal species comprise of *Glomospira charoides, Glomospirella gaultina*, *Ammodiscus tenuissimus*, *A. cretaceous*, *A. gorlicensis*, *Bathysiphon witta*, etc. More common are trochmininids and related plani- to trochospiral species in the middle part of the Butkov Fm They comprise of *Trochammina wetteri*, *Trochammina vocontiana*, *T. ripstonensis, Haplophragmoides concavus, H. kirki, H.* cf. *bulloides, Plectorecurvoides aff. alternans* etc. These shallow infaunal habitats are associated with deep-infaunal species, like *Ammobaculites carpathicus*, *Gaudryina jendrejakovae, G. dacica*, *Clavulinoides gaultinus*, *Dorothia granata*, *Marsonella oxycona*, *Textulariopsis rioensis*, etc. Calcareous benthic foraminifers are represented by species *Gavelinella intermedia*, *Valvulineria infracretacea, Oolina* cf. *oxystona*, *Dentalina soluta*, etc.

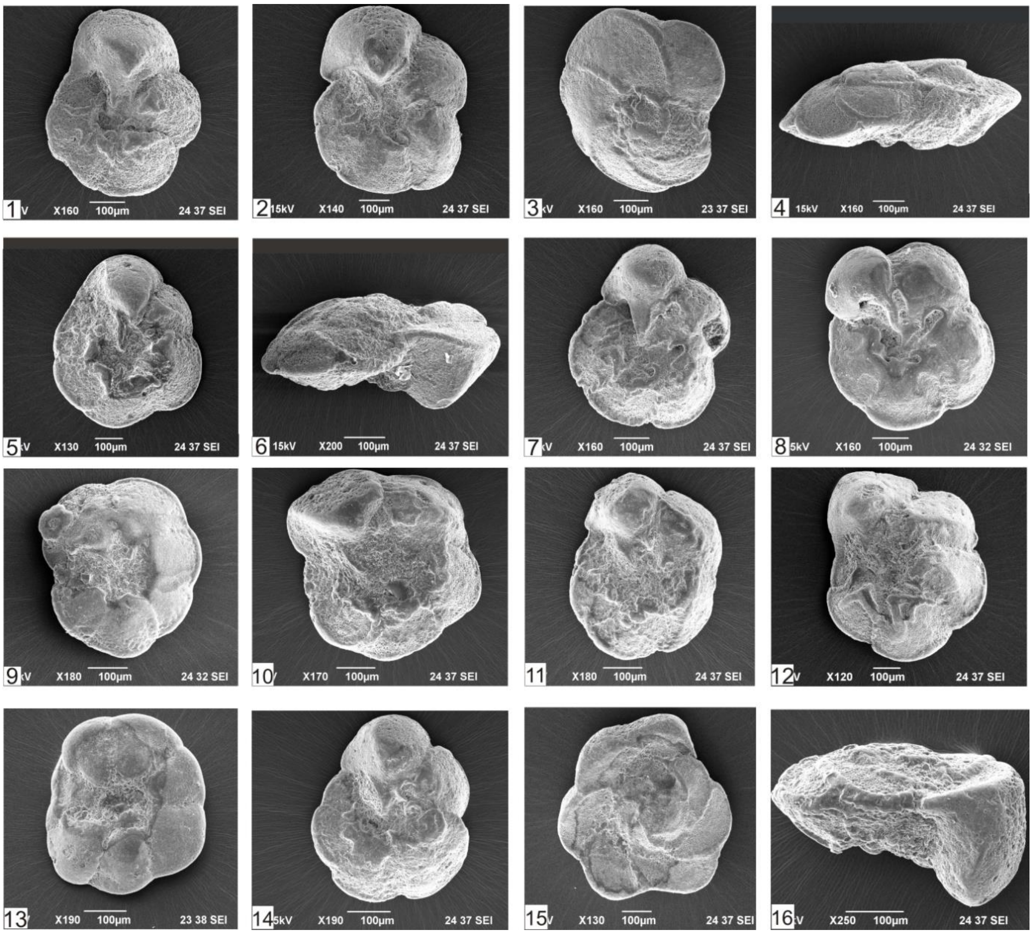
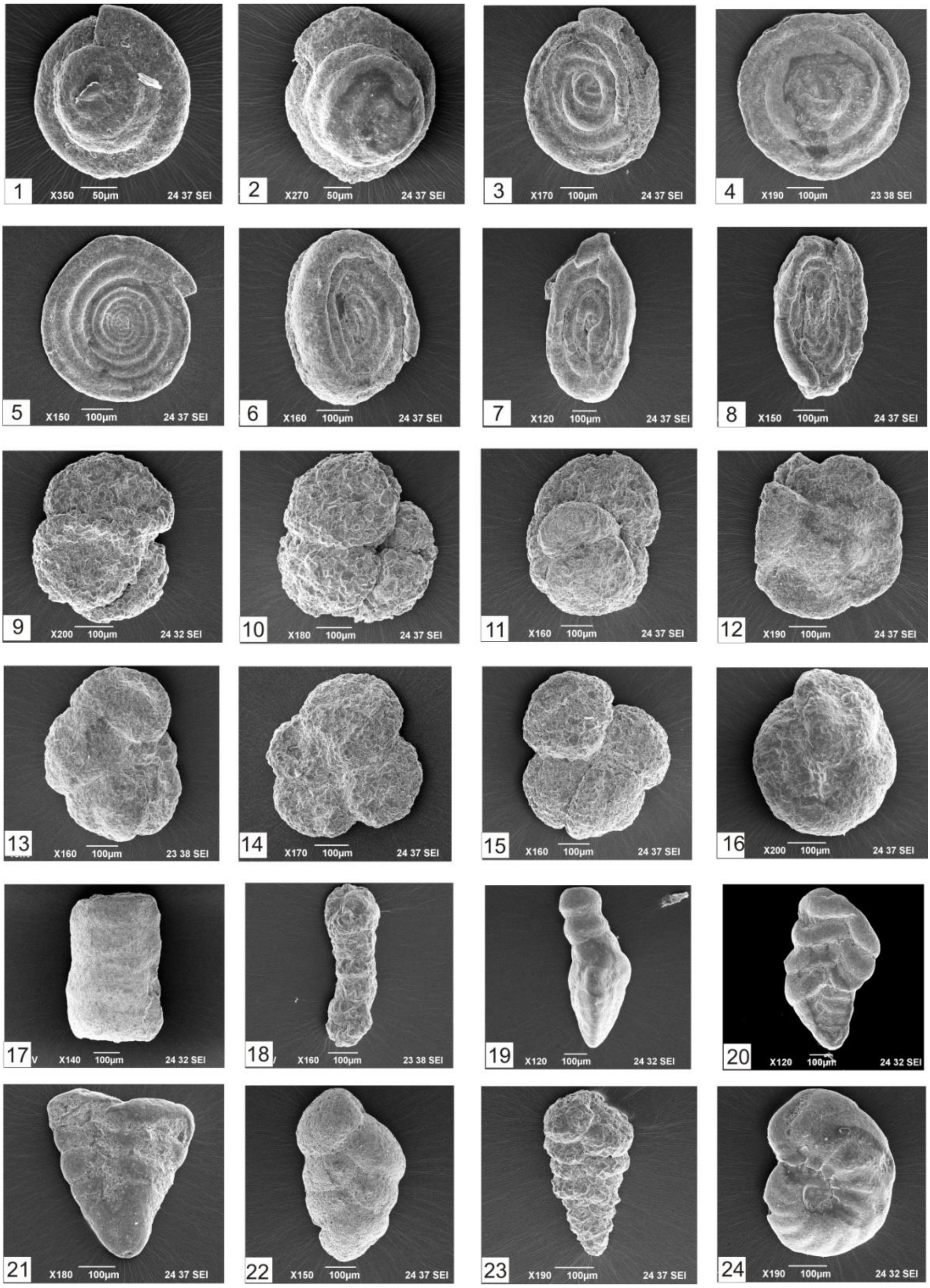


Fig. 18. Planktonic foraminiferal microfauna from the Upper Albian – Middle Cenomanian sediments of the Butkov Fm. 1–4: *Thalmanninella appeninica* (Renz, 1936); 5–6: *Thalmanninella brotzeni* Sigal, 1948; 7–9: *Thalmanninella globotruncanoides* (Sigal, 1948); 10–12: *Thalmanninella gandolfi* (Luterbacher & Premoli Silva, 1962); 13: *Praeglobotruncana gibba* (Klaus, 1960), 14–16 *Thalmanninella reicheli* (Mornod, 1950).

Fig. 19. Benthic foraminiferal microfauna from the Upper Albian – Middle Cenomanian sediments of the Butkov Fm. 1-2: *Glomospira charoides* Jones & Parker, 1860; 2-3: *Glomospirella gaultina* (Berthelin, 1880); 5: *Ammodiscus tenuissimus* (Grzybowski, 1898); 6: *Ammodiscus cretaceous* (Reuss); 7-8: *Ammodiscus gorlicensis* Gryzbowski; 9-11: *Trochammina wetteri* Stelck & Wall; 12: *Trochammina vocontiana* Moullade, 1960; 13: *Haplophragmoides concavus* (Chapman);14-15: *Haplophragmoides kirki* Wickenden; 16: *Haplophragmoides* cf. *bulloides* (Reuss); 17: *Bathysiphon witta* Nauss; 18: *Ammobaculites carpathicus* Geroch; 19: *Clavulinoides gaultinus* (Morozova); 20: *Gaudryina jendrejakovae* Weidich; 21: *Marsonella oxytoma* (Reuss); 22: *Dorothia granata* (Berthelin); 23: *Textulariopsis rioensis* (Carslay); 24: *Gavelinella intermedia* (Berthelin).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Field stop 3: Nosice – Dubový háj: Albian – Early Cenomanian microfauna of the Klape Unit (Upohlav Fm)

Ján SOTÁK

GPS: 49°07'31.9"N; 18°21'52.7"E

The locality represents the Cretaceous flysch-type formations of the Pieniny Klippen Belt, which belong to the Upohlav Formation (sensu Salaj 1995a). The lower part of the Dubový háj section is formed by thin-bedded turbidites, which are overlapped by thick bodies of coarse-grained conglomerates. The alternation of the turbiditic sequences with conglomerates is developed in six megarhythms with total thickness of about 180 m (Marschalko & Samuel 1975).

Flysch sandstones show typical structures of turbiditic deposition with complete succession of the Bouma-type intervals. Sedimentary structures of the sandstone beds are developed as normal grading, lamination and cross ripple-bedding intervals. The base of sandy turbidites and conglomeratic channels is frequenty eroded by flute casts, which documented a high traction force of the depositional flows. These flows were able to transport huge blocks and boulders up to 3.5 m in size. Coarse-grained beds are occasionally intercalated by mudstones, which were deposited by hemipelagic sediments and shelfal muds, which are rich in remains of shallow-water organisms such as orbitolinids, gastropods, etc. The sedimentary sequence reveals a gradual decrease of the turbiditic and conglomeratic beds and inrease of thick intervals of homogenous mudstones (so-called Štepnica Claystones *sensu* Salaj, 1995a).

The turbiditic sediments of the Upohlav Formation provide an evidence of marginal facies the deep-water submarine fans, which conglomerates were derived from extrabasinal sources. The conglomerates provide a polymictic composition, comprising of Triassic and Jurassic limestones, dolomites, Triassic quartzites, sandstones and arcoses, vein quartz, igneous and metamorphic rocks (Marschalko 1986; Zaťko and Sýkora 2006, Ivan et al. 2006). Mišík and Sýkora (1981) have distinguished pebbles of Upper Jurassic neritic limestone with *Protopeneroplis striata*, *Conicospirillina brasiliensis*, *Cladocoropsis mirabilis*, *Clypeina jurassica* and Cretaceous limestone with *Orbitolina* sp. Such limestones, associated with dark-grey lydites, bluschists, rich spinel grains (also in agglutinated material of orbitolinid tests), is considered as exotic rocks for the Klippen belt conglomerates. The source of these conglomerates must have been in complicated mountain system with ophiolite formations, such as “Andrusov ridge” (e.g. Mišík & Marschalko 1988), or in exotic ultragemeric units (e.g. Plašienka 1995).

The stratigraphic age of the Upohlav Fm has been determined on the basis of planktonic foraminifers *Thalmanninella appeninica*, *Thalmanninella brotzeni*, *Planomalina buxtorfi*, *Praeglobotruncana stephani* and *Pseudothalmanninella ticinensis* (Marschalko & Samuel, 1975), (Fig. 21). This association comprises of species with lowest occurrences in Late Albian (*Th. appeninica*, *Th. gandolfi*, *P. stephani*) and species with highest occurrences in the Late Albian (*Ps. ticinensis*, *Pl. buxtorfi*). Considering that, the stratigraphic age of the Upohlav Fm at the Dubový háj section corresponds to Late Albian.

Agglutinated foraminifera are rather monospecific, dominated by *Dendrophrya* sp., sometimes completed by *Glomospirella gaultina*, *Haplophragmoides nonioninoides*, *Spiroplectinata complanata praecursor*, *Arenobulimina presslii*, *Marsonella oxycona*, and calcareous benthic species *Gavelinella ammonoides*, *Epistomina paucicamerata*, etc. Nevertheless, very important components of agglutinated forms are orbitolinids, which occur as large-sized discoidal tests in washing residues (Fig. 20).

Fig. 20. Orbitolinid foraminifers from claystones of the Upohlav Fm at the Dubový háj locality. They form a low conical tests with coarsely agglutinated ventral side and cellular surface on the dorsal side.

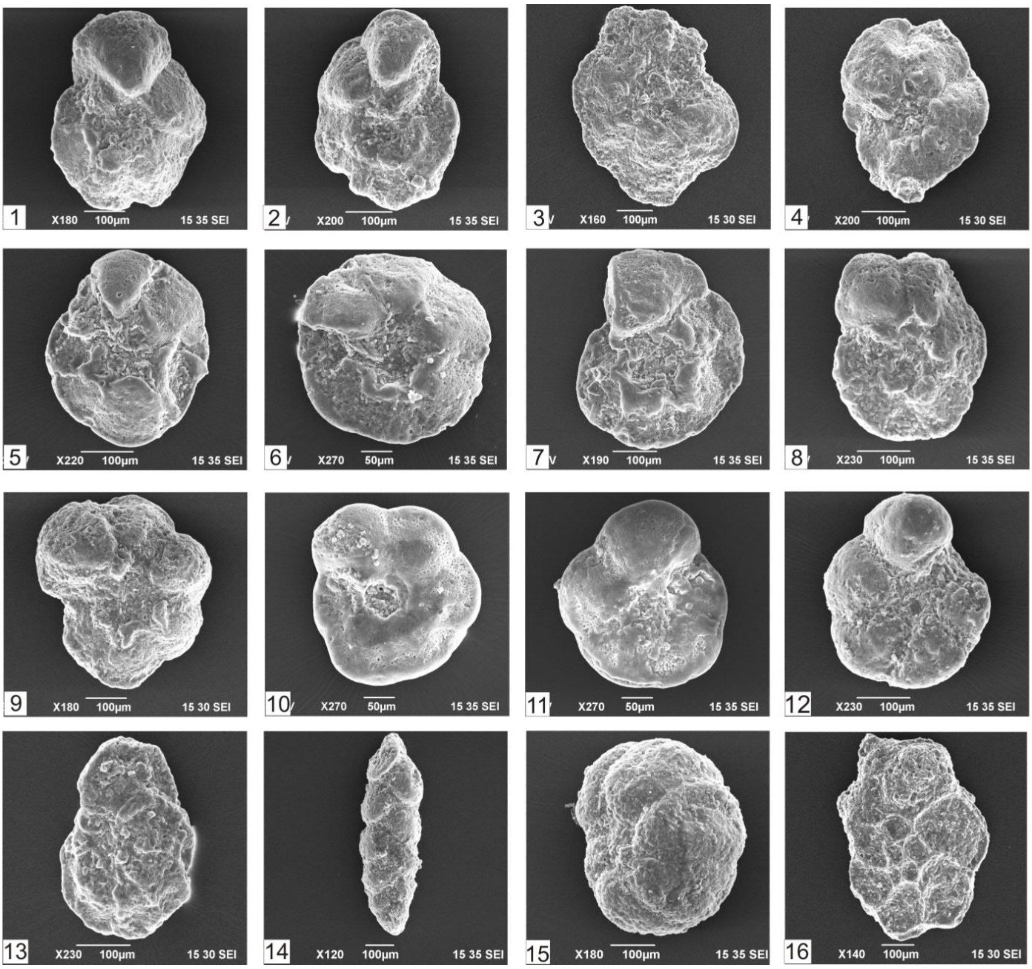


Fig. 21. Foraminiferal microfauna of the Upohlav Fm from the Dubový háj section near Nosice village (Late Albian). 1–4: *Thalmanninella appeninica* (Renz, 1936); 5–6: *Thalmanninella brotzeni* Sigal, 1948; 7–8: *Thalmanninella gandolfi* (Luterbacher & Premoli Silva, 1962); 9–10: *Pseudothalmanninella ticinensis* (Gandolfi, 1942); 11–12: *Praeglobotruncana stephani* Gandolfi, 1942; 13: *Planomalina buxtorfi* (Gandolfi, 1942); 14: *Spiroplectinata complanata praecursor* Moullade, 1966; 15: *Gavelinella ammonoides* (Reuss); 16: *Epistomina paucicamerata* Ohm, 1967.

Field stop 4: Manín Straits and Kostolec: Urgonian-type carbonate platform facies with orbitolinids, Late Albian and Cenomanian planktonic and agglutinated microfauna (Praznov Fm)

Kamil FEKETE, Ján SOTÁK and Jozef MICHALÍK

GPS: 49°08'23.5"N; 18°30'25.6"E

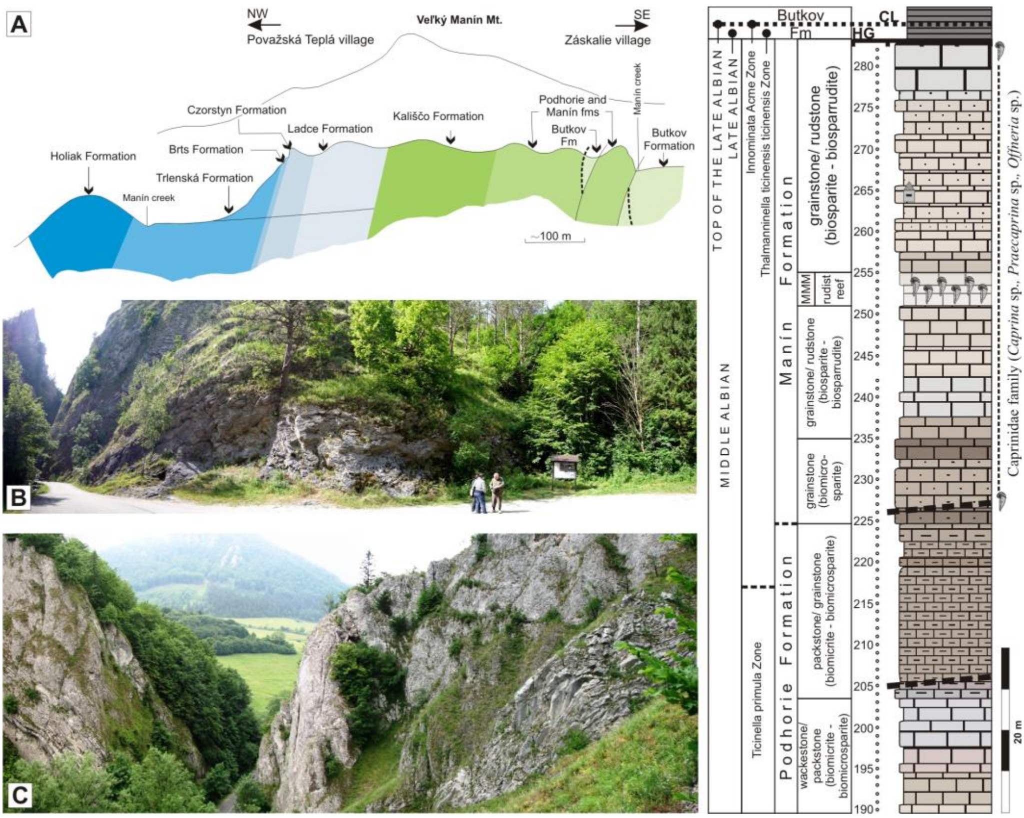


Fig. 22. Fig. 22. A: Schematic cross-section of the Jurassic-Cretaceous formations in the Manín Straits; B: A view on the Manín Straits with rock walls formed by limestones of the Manín Fm., C: Panoramic view from Mt Kavča to Kostolec Klippe; D: Litostratigraphic column of the Manín and Podhorie Fms. in the Manín Straits section.

The Manín Straits, outcropping a sequence of Jurassic – Cretaceous beds of the Manín Unit is situated in the area of Strážovské vrchy Mts, northeast of the Považská Teplá village (Fig. 22).

The first observation from this site came from Štúr (1860), he described dark grey limestones with cherts and light grey limestone conglomerates as an equivalent of the Štramberk-type limestones. Andrusov (1945) examined a sequence of Mesozoic rocks within a geological research of the Pieniny Klippen belt. First detailed section in the Manín Straits has been described by Mišík (1957) as the first thorough bed-by-bed microfacies study in Western Carpathians at all. More detailed investigations of later authors (e.g., Köhler, 1980; Rakús, 1984; Michalík and Vašíček, 1984; Boorová, 1991; Boorová and Salaj, 1996, Fekete et al., 2017 in press) brought new findings considering lithostratigraphy, fossil assemblages and competed with its interpretations within the Manín Unit.

Beginning of the section in the Manín Straits lithologicaly encovers Hettangian – Aalenian **Holiak, Trlenská** and **Brts** fms followed by Bathonian – Kimmeridgian **Czorstyn Formation** (*Ammonitico Rosso*), Tithonian – Valanginian **Ladce Formation** and Hauterivian – ?Barremian **Kališčo Formation**. Dominant part of the Manín Straits consist of the typical member of the Manín Unit – organodetrital Lower Cretaceous "Urgonian-type" limestones (Fig. 22).

The carbonate platform sequence in the Manín Straits starts with upper slope facies of organodetrital limestones of the Podhorie Formation and passes upwards into peri-reef facies of the Manín Formation, with lateral replacement of these two to a considerable extent coeval parts of one area of sedimentation (carbonate platform and its slope). Thickness of these Urgonian-like facies attains around 100 m.

Their basal part (up to 45 m) is represented by mainly grey to darker grey thick bedded to massive cherty limestones of the **Podhorie Formation** with fine debris of echinoderms, sponge spicules of various morfotypes, rare thin- and thick walled filaments, radiolarians of the Spumellaria type, *Ostracoda* div. sp. and fragments of echinoid spines in lower parts representing more distal part of the formation. Upwards, they completely disappear and sedimentary environment becomes shallower. Predominately allochems (bioclasts), without reef-building organisms derived from the carbonate platform occur in the limestones.

Planktonic foraminifers, *Ticinella roberti* (Gandolfi), (Fig. 23 A-D), *Ticinella primula* Luterbacher (Fig. 23 E-F), *Ticinella* cf. *madecassiana* (Sigal), (Fig. 23 G-H), *Ticinella* cf. *praeticinensis* (Sigal), (Fig. 23 K) and *Globigerinelloides bentonensis* (Morrow) of the Ticinella primula Zone (Verga & Premoli-Silva, 2004) mark the Middle Albian interval. Benthic foraminifers are represented by *Bolivinopsis* aff. *capitata* Yakovlev, *Glomospirella gaultina* Berthelin, 1880, *Mayncina bulgarica* Laugh Peybernès & Rey, *Sabaudia minuta* Hofker, 1965, *Turriglomina? anatolica* Altiner, Peybernès & Rey, 1968, *Dentalina* sp., *Haplophragmoides* aff. *vocontianus* Moullade, *Valvulineria* sp., *Anomalina* sp., *Frondicularia* sp., *Spirillina* sp., *Patellina* sp. *Lenticulina* sp., *Gaudryina* sp. and *Meandrospira* sp. Rare colomiellids, *Colomiella mexicana* Bonet, *Colomiella recta* Bonet, (Fig. 23 N,O), *Colomiella* sp., redeposited calpionellids, *Crassicollaria parvula* Remane, *Calpionela alpina* Lorenz, *Lorenziella hungarica* Knauer & Nagy and calcareous dinoflagelates, *Calcisphaerula innominata* Bonet, *Cadosina semiradiata olzae* (Nowak) occur. Calcareous nannoplankton is represented by *Watznaueria barnesiae* (Black *in* Black & Barnes, 1959) Perch-Nielsen, *Watznaueria biporta* Bukry, 1969, *Cyclagelosphaera* sp., *Watznaueria cynthae* Worsley, 1971, *Cretarhabdus* sp., *Micrantholithus obtusus* Stradner, 1963 and *Nannoconus bucheri* Brönnimann, 1955. *Didemnoides moreti* (Durand Delga) and *Globochaete alpina* Lombard, are also rarely present. Limestones contain quartz clasts, muscovite leaflets and sporadic glauconite grains.

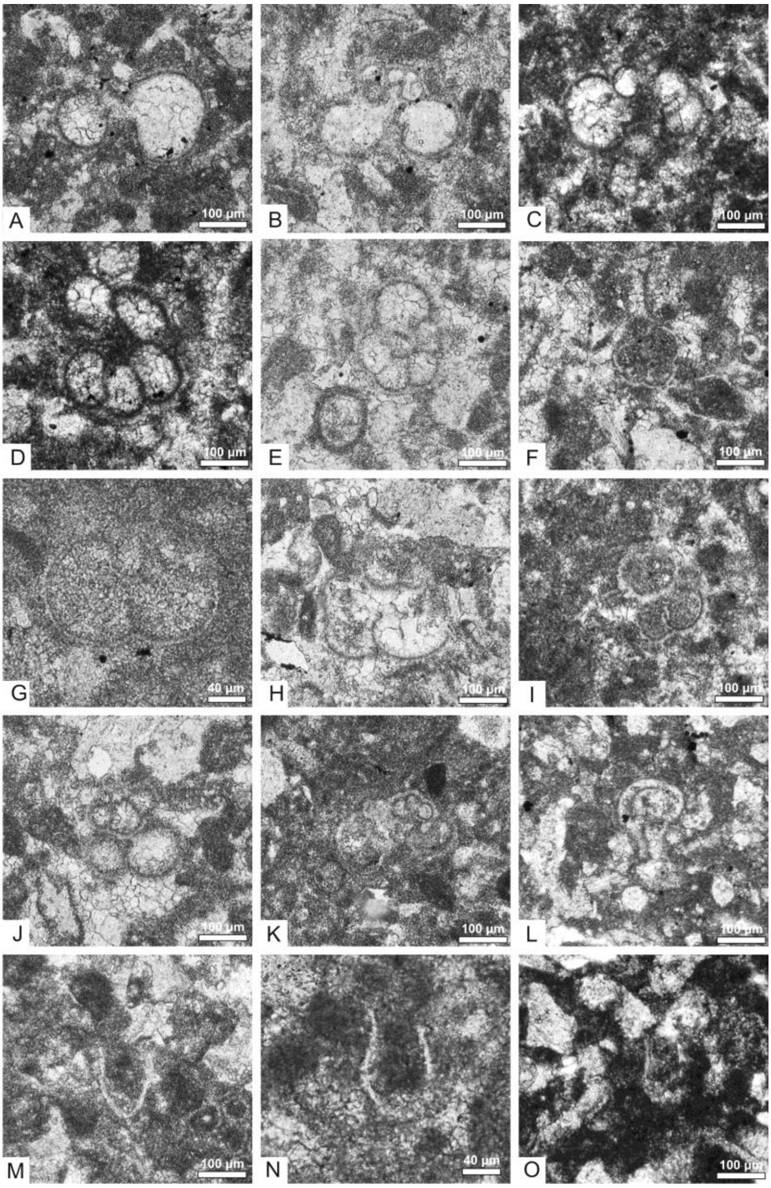


Fig. 23. Foraminiferal and tintinid microfauna of the Podhorie Fm limestones from the Manín Straits section; A–D: *Ticinella roberti* (Gandolfi); E–F: *Ticinella primula* Luterbacher; G–H: *Ticinella* cf. *madecassiana* (Sigal); I–J: *Ticinella* sp.; K: *Ticinella* cf. *praeticinensis* (Sigal); L: *Globigerinelloides bentonensis* (Morrow); M-N: *Colomiella mexicana* Bonet; O: *Colomiella recta* Bonet.

The Podhorie Formation passes upwards continuously into light grey massive strongly recrystallized limestones of the **Manín Formation** (around 55 m thick) with accumulations of rudists shell fragments of Caprinidae type (*Caprina* sp., *Praecaprina* sp., *Offneria* sp.) associated with bivalves and gastropods. Their special status, uniqueness and character allow to designate the Malý Manín Member which has not been previously recognized and which has not been defined from other localities of the Manín Unit. The typical foraminiferal association of these caprinids bearing beds consist of well rounded orbitolinids (Fig. 24A, B, C, D) with the presence of *Palorbitolina* ex gr. *lenticularis* (Blumenbach), *Valserina brönnimanni* Schroeder et Conrad and *Paleodictyonus barremianees* (Moullade). Less frequent constituents are represented by fragments of gastropods, crinoids, bryozoans, small benthic foraminifers (*Miliolida* sp., *Textularia* sp.) and rare planktonic foraminifers (textularid and miliolid forms).

Orbitolinid fauna determined and assigned to the Barremian by E. Köhler, was probably redeposited as evidenced by the fact that they are present in clasts (Fig. 24 E, F).

The Manin Formation is terminated by hardground surface, overlain by marls and marlstones of the **Butkov Formation** with association of rare benthic and current planktonic foraminifers included into the Late Albian Thalmanninella ticinensis ticinensis Zone by Boorová (1990). A thin layer (3-5 cm) of grey, brownish weathered so called calcisphaerulid limestone occured in the basal part of the Butkov Formation. Cross sections of three-dimensional trace fossils *Chondrites* Sternberg 1833 filled with high-contrast dark matter are visible as spots in polished section (Fig. 25 K). Among other trace fossils, *Trichichnus* isp. Frey 1970 and *Pilichnus* isp. Uchman, 1999 can be observed.

Based on rich microfossil association, age of calcisphaerulid limestone has been stated to the top of the Late Albian. Planktonic foraminifers of the Thalmanninella appenninica Zone (e.g. Premoli Silva and Verga, 2004) represented by the index form *Thalmanninella appenninica* (Renz) (Fig. 25 A) and other such as *Planomalina buxtorfi* (Gandolfi) (Fig. 25 F), *Pseudothalmanninella ticinensis ticinensis* (Gandolfi) (Fig. 25 D), *Pseudothalmanninella ticinensis conica* (Gašpariková et Salaj) (Fig. 25 B), *Praeglobotruncana delrioensis* (Plummer, 1931), *Praeglobotruncana stephani* (Gandolfi) (Fig. 25 C), *Muricohedbergella delrioensis* (Carsey), *Murico-*

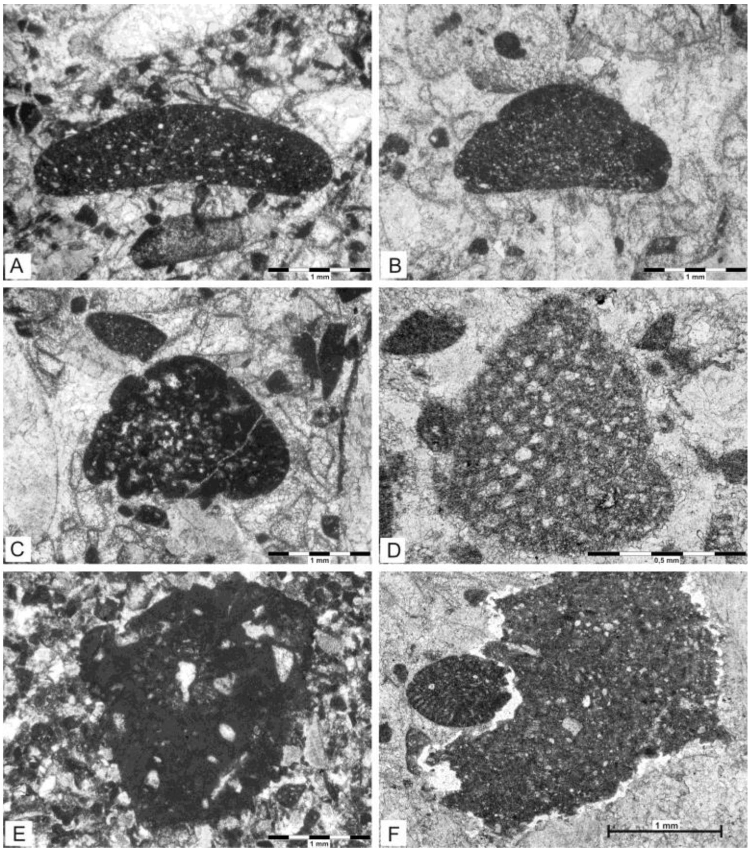


Fig. 24. Large foraminiferal microfauna of the Manín Fm limestones from the Manín Straits section (determined by E. Köhler): A: *Palorbitolina lenticularis* (Blumenbach); B: *Valserina brönnimanni* Schroeder et Conrad; C: *Paleodictyonus barremianees* (Moullade); D: *Orbitolinopsis* sp., M229. Evidence of redeposition of large foraminiferal microfauna found in the Manín Fm limestones.

-hedbergella planispira (Tappan), *Globigerinelloides caseyi* (Bolli, Loeblich et Tappan) (Fig. 25 H), *Ticinella raynaudi* (Sigal) (Fig. 25 I) and *Heterohelix* sp. (Fig. 25 J) were identified. Benthic foraminifers are rare, represented mostly by *Nodosaria* sp. and *Textularia* sp.

From calcareous dinoflagellates, *Calcisphaerula innominata* Bonet (Fig. 25 E) occurs commonly, *Pithonella ovalis* (Kaufmann) (Fig. 25 J), *Pithonella trejoi* Bonet (Fig. 25 E), *Bonetocardiella conoidea* (Bonet) (Fig. 25 F) occur occasionally. Rare *Cadosina oraviensis* (Borza) and *Colomisphaera gigantea* (Borza) of the Innominata Acme Zone included into Late Albian by Reháková (2000). Other fossil remains are represented by fragments of echinoids as well as filaments, thick-walled bivalves and bioclasts.

The Butkov Formation rests upon the calcisphaerulid limestone.

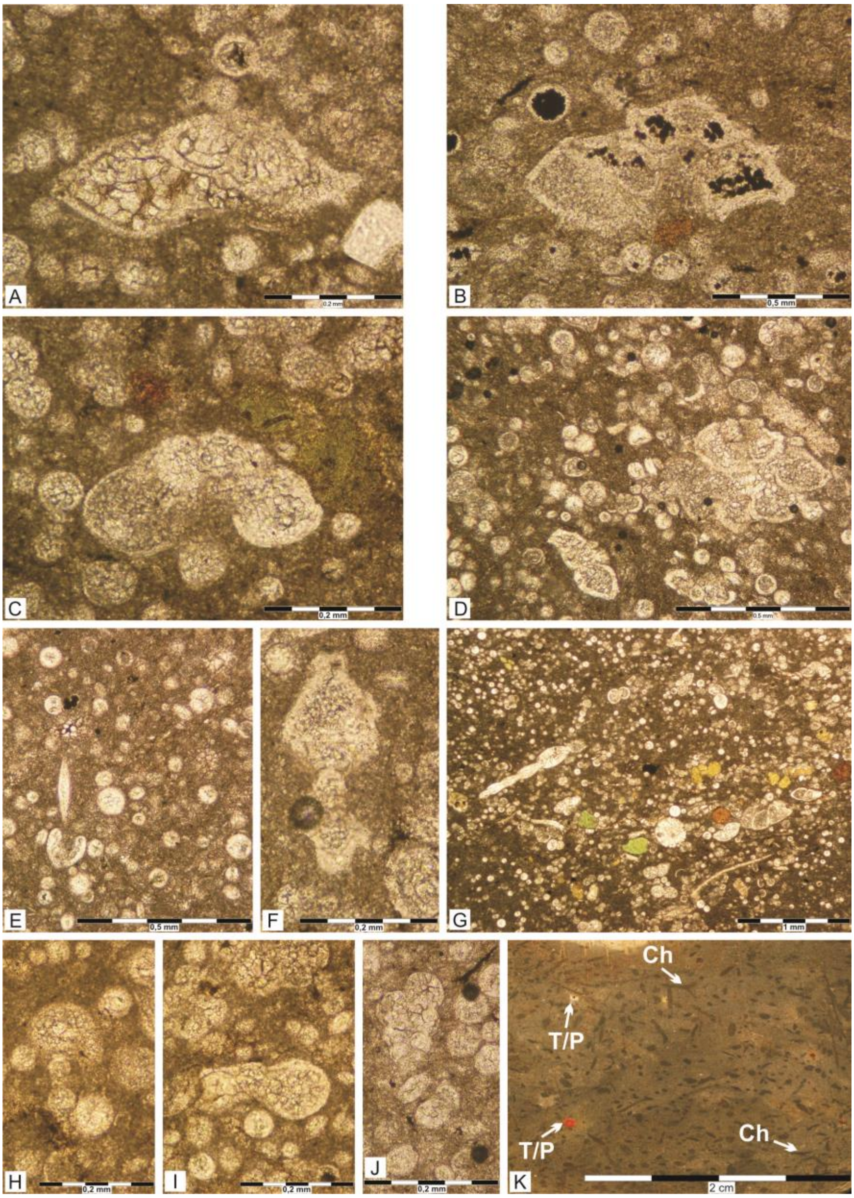


Fig. 25. Calcisphaerulid limestone. A: *Thalmanninella appenninica* (Renz); B: *Pseudothalmanninella ticinensis conica* (Gašpariková et Salaj); C: *Praeglobotruncana stephani* (Gandolfi); D: *Pseudothalmanninella ticinensis ticinensis* (Gandolfi); E: Calcisphaerulid microfacies: *Calcisphaerula innominata* Bonet, *Pithonella trejoi* Bonet (approximately at the center on the left); F: *Planomalina buxtorfi* (Gandolfi, 1942), *Bonetocardiella conoidea* (Bonet) (on the left below *Pithonella trejoi*); G: Calcisphaerulid foraminiferal biomicrite (calcisphaerulid foraminiferal wackestone/ packstone), localy directed allochems; H: *Globigerinelloides caseyi* (Bolli, Loeblich and Tappan), I: *Ticinella raynaudi* (Sigal); J: *Heterohelix* sp., just below it *Pithonella ovalis* (Kaufmann); K: Fossil traces in polished section (dark spots) of calcisphaerulid limestones.

Manín and Kostolec units are surrounded by pelitic and thin-rhythmical bedded sediments of the Podmanín Group. The limestones are exposed i cores of the large-scale brachyanticlines (e.g. Drieňovka) or they form olistoliths in the mid-Cretaceous flysch complexes (Plašienka et al. 2017), (Fig. 26).

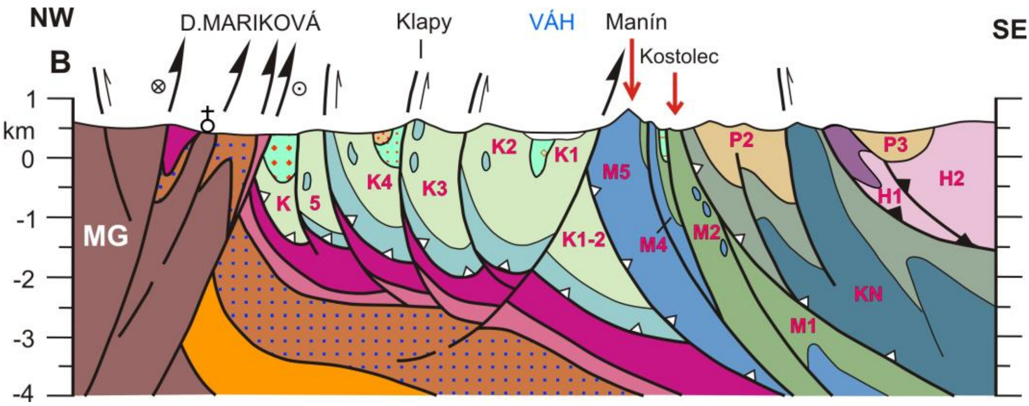


Fig. 26. Position of Manín – Kostolec sites (Field stop 4) in geological cross-section of of the Manín Unit and adjacent zones in the Middle Váh Valley (adapted from Plašienka & Soták 2015). Abbrevations: M4-M5 – Manín Unit (Jurassic-Lower Cretaceous), M1-M2 – Manín Unit, Podmanín Group (Albian – Turonian), KN – Krížna Nappe, H1-H2 – Hronic Superunit, K – Klape Unit, 1-2 (Jurassic Lower Cretaceous), 3-4 (Aptian – Turonian), P – Paleogene sediments of the Myjava-Hričov Group, MG – Magura Superunit.

Fig. 27. Grey-green claystones in flysch-type sediments of the Praznov Formation in vicinity of Kostelec village.

The Podmanín Group is formed by the Butkov Formation (Late Albian – Early Cenomanian), Praznov Formation (Sphaerosiderite Beds, Belušské Slatiny Fm, Cenomanian – Early Turonian) and Hradná Conglomerates (Mid Cenomanian – Early Turonian). Mudstones and flysch-type sediments of the Praznov Fm (Fig. 27) occur in vicinity of Kostolec and Záskalie villages. Their microfauna is very ich rich in content or planktonic foraminifers, calcareous benthic and arenaceous foraminifers (figs. 28, 29). The most frequent planktonic foraminifers belong to species *Praeglobotruncana stephani*, which provided the first appearance in Late Albian and attained the acme during Cenomanian (Premoli Silva & Verga, 2004). This species is associated with further species of *Praeglobotruncana* lineage, such as *P. gibba*, *P.* cf. *delrioensis* and *P. hilalensis*. Praeglobotruncanids as a mixed-layer dwellers became dominant since the Albian – Cenomanian boundary due to cooling and depth-habitat reorganization (Ando et al. 2010). Planktonic foraminiferal association is completed by rotaliporids (*Thalmanninella gandolfi*) and hedbergellids.

Agglutinated foraminifers are highly diversified with various morphogroups of shallow infaunal and epifaunal species. Tubular, spherical and subcylindrical morphogroups are represented mostly by *Rhizammina* sp., *Hyperammina* sp., *Psammosiphonella* sp., *Psammosphaera irregularis* and *Reophax cylindracea*. They are associated with flattened planispiral, trochospiral and streptospiral species such as *Ammodiscus nitidus*, *A.* cf. *peruvianus*, *A. pennyi*, *Trochammina* cf. *vocontiana*, *T.* cf. *ribstonensis*, *Ammosphaeroidina pseudopauciloculata*, *Glomospira glomerata*, etc. The agglutinated microfauna is completed by species *Epistomina limbata*, *Tritaxia gaultina*, *T. gaultina jucunda*, *Textulariopsis* aff. *rioensis*, *Gaudryina jendrejakovae*, etc.

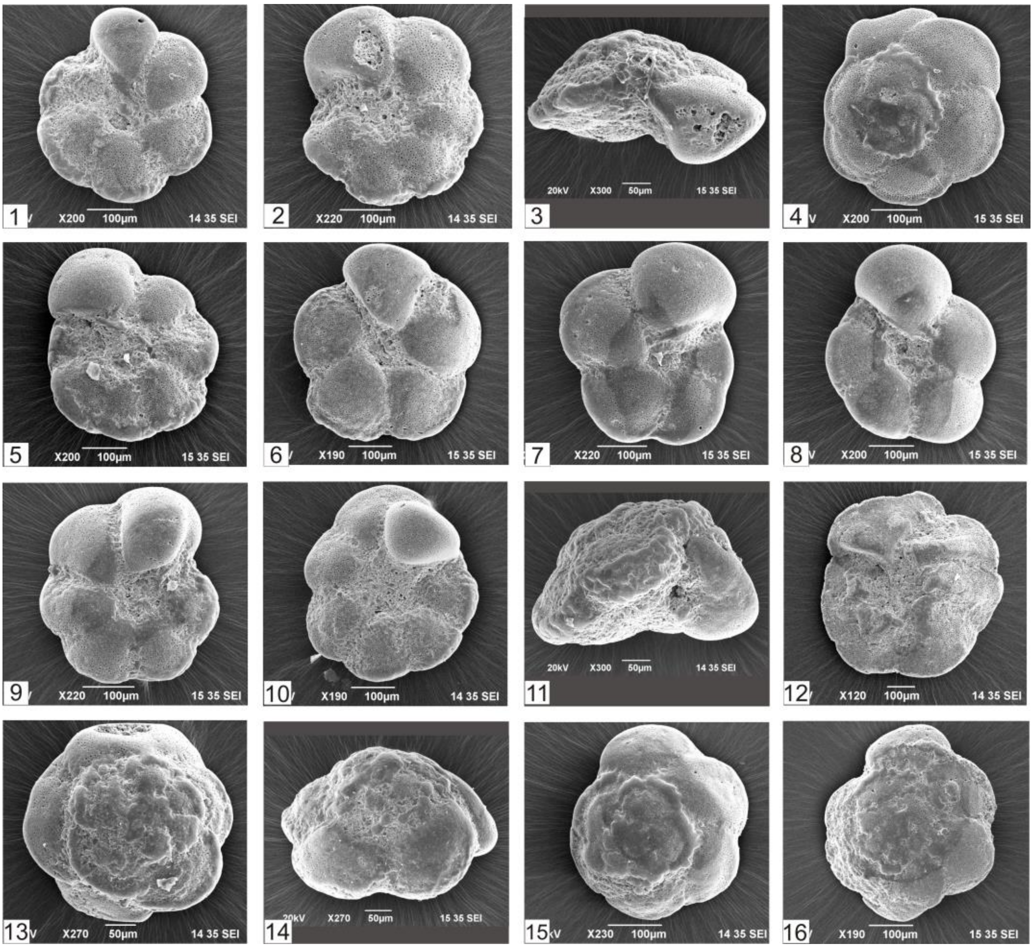
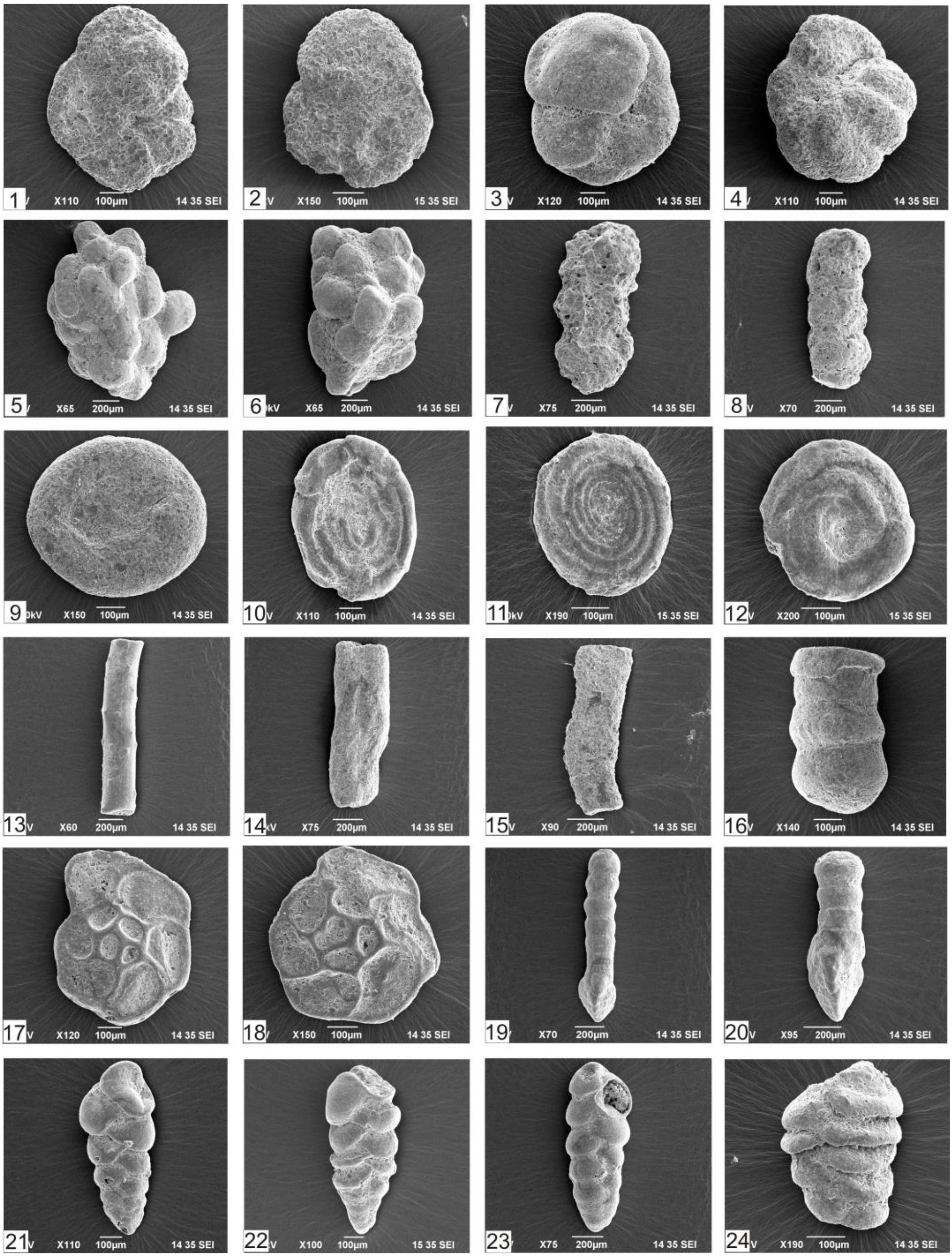


Fig. 28. Late Albian – Cenomanian planktonic foraminifers from the Praznov Formation at Kostolec locality. 1–6: *Praeglobotruncana stephani* (Gandolfi, 1942); 7–9: *Praeglobotruncana* cf. *delrioensis* (Plummer, 1931); 10–11: *Praeglobotruncana hilalensis* Bar, 1972; 12: *Rotalipora gandolfi* (Luterbacher & Premoli Silva 1963); 13–16: *Praeglobotruncana gibba* (Klaus, 1960).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9 X150 100μm 14 35 SEI
10 X110 100μm 14 35 SEI
11 X190 100μm 15 35 SEI
12 X200 100μm 15 35 SEI
13 X60 200μm 14 35 SEI
14 X75 200μm 14 35 SEI
15 X90 200μm 14 35 SEI
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23 X75 200μm 14 35 SEI
24 X190 100μm 14 35 SEI

Fig. 29. Late Albian – Cenomanian benthic foraminifers form the Praznov Formation at Kostolec locality. 1–2: *Trochammina* cf. *vocontiana* Moullade, 1960; 3: *Ammosphaeroidina pseudopauciloculata* (Mjatliuk, 1966); 4: *Trochammina* cf. *ribstonensis* Wickenden, 1932; 5–6 *Glomospira glomerata* Höglund, 1947; 7–8: *Reophax cylindracea* Chapman, 1892; 9: *Psammosphaera irregularis* (Grzybowski, 1896), 10: *Ammodiscus* cf. *peruvianus* Berry, 1928; 11: *Ammodiscus nitidus* Parr, 1942; 12: *Ammodiscus pennyi* Cushman &Jarvis, 1928; 13: *Rhizammina* sp.; 14–15: *Hyperammina* sp.; 16: *Psammosiphonella* sp.; 17–18: *Epistomina limbata* Tappan; 19–20 *Tritaxia gaultina jucunda* (Arnaud-Vanneau, 1980); 21–23: *Textulariopsis aff. rioensis* (Carsay); 24: *Gaudryina jendrejakovae* Weidich, 1990.

Field stop 5: Súľov: Late Paleocene – Eocene formation of conglomerates and scarp breccias with pelagic interbeds in the deep-water basin (planktonic and agglutinated microfauna)

Ján SOTÁK, Zuzana PULIŠOVÁ and Silvia OZDINOVÁ

GPS: 49°10'02.2"N; 18°34'34.8"E

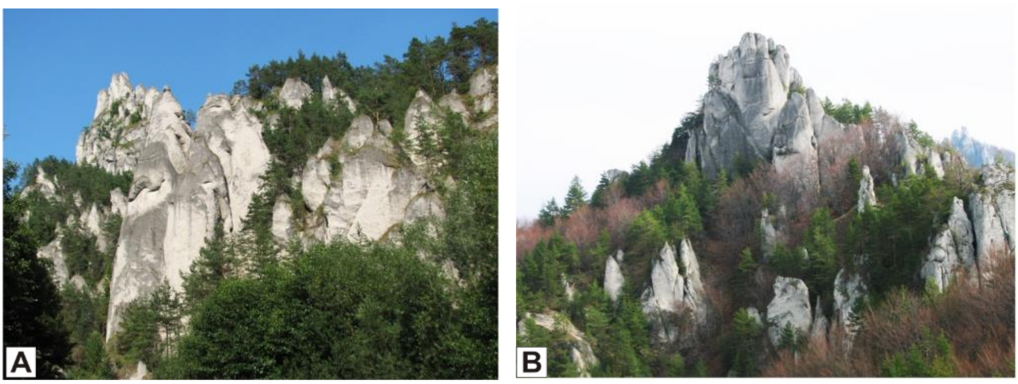


Fig. 30. Rocky crests in the Súľovské vrchy Mts A. Súľov Gorge; B. Roháč Gorge

The Súľov conglomerates occur in the Middle Váh Valley (Fig. 30) as a coarse-grained lithosomes of the Súľov-Domaniža Basin (SDB). This basin is superposed on the frontal units of the Central Western Carpathians (CWC). Stratigraphic assesment of the Súľov conglomerates is outlined by their superposition above the Upper Paleocene to Lower Eocene limestones and carbonatic sandstones of the Jablonové Formation, as well as above the flysch sediments with blocks of biohermal limestones of the Hričovské Podhradie Formation and their conglomerate lithosomes (Ovčiarsko Member). Their stratigraphic age was dated predominantly by using of large foraminifers from underlying formations (Samuel et al., 1972) and planktonic foraminifers from overlying formation (i.e. Domaniža Fm - Samuel & Salaj 1968; Samuel et al., 1972). The conglomerates are superposed by flysch sediments of the Domaniža Fm, which Lutetian age is proved by planktonic foraminifers and nannofossils (Samuel, 1972; Peterčáková, 1984).

Foraminifers from basal part of the Súľov Fm belong the Late Paleocene biozones (Zone P3–P4 *sensu* Berggren & Pearson 2005), comprising of marker species like *Globanomalina pseudomenardi*, *Morozovella acuta*, *M. praeangulata*, *A. nitida*, *Acarinina mckannai*, *Subbotina triloculinoides*, etc. Towards to higher lithosomes the conglomerate interbeds contain morozovellids of *M. velascoensis* group and *M. acuta* (Zone E2), associated with FO of *M. subbotinae* (Zone P5) and

Parasubbotina inaequispira (Zone E1). Considering that, the conglomerates from lower part of the Súľov Fm belongs to the Late Thanetian – Early Ypresian (Ilerdian), (Fig. 31).

Foraminiferal associations from middle part of the Súľov Conglomerates differ by almost completly absence of morozovellids and predominance of acarininids of middle Ypresian to Early Lutetian biozones (e.g. *Acarenina pseudotopilensis*), and those appeared in Zone E5 (*A. wilcoxensis, A. pentacamerata*) and Zone E7 (*Turborotalia frontosa)* Therefore, the conglomerates of the middle part of the Súľov Fm are constrained for mid Ypresian to early Lutetian age (Fig. 31).

Uppermost part of the Súľov Fm belongs to the Paštinná Závada Beds, defined as the Súľov-type conglomerates in claystone- and flysch-type sediments of the Domaniža Basin (sensu Buček & Nagy in Mello et al. (2011). Claystone interbeds contain a rich acarininid and morozovellid species (e.g. *Acarinina bullbrooki, A. punktocarinata, A. coalingensis, Morozovella gorrondatxensis*, *M. gracilis*, *Igorina wartsteinensis*, *I. salisburgensis*, *Subbotina senni*, *Parasubbotina hagni*, etc.). Some of them are regarded as a marker species of the Early Lutenian Zone in the Western Carpathians (Acarinina Bullbrooki = Acarinina Crassata Densa Zone sensu Samuel & Salaj, 1968, *M. gorrondatxensis sensu* Orue-Etxebarria et al. 2014), (Fig. 31).

Claystone interbeds from each parts of the Súľov Fm contain the agglutinated foraminifers, as well (Fig. 32). Their associations comprises of *Psammosiphonella cylindrica, Bathysiphon gerochi*, *Nothia robusta, Trochamminoides subcoronatus, T. contortus, T. proteus, T.?* cf. *dubius, Paratrochamminoides olszewskii, P. deflexiformis*, *Haplophragmoides horridus, Ammodiscus cretaceous, A. serpens* and *Psammosphaera irregularis*. Increasing content of agglutinated foraminifers from the Early Ypresian to Early Lutetian implies an initial collapse subsidence of the basin to bathyal depth and its deepening-upward to abyssal depth with DWAF-type microfauna of agglutinated foraminifers in uppermost part of the Súľov Fm (Paštinná Závada Beds).

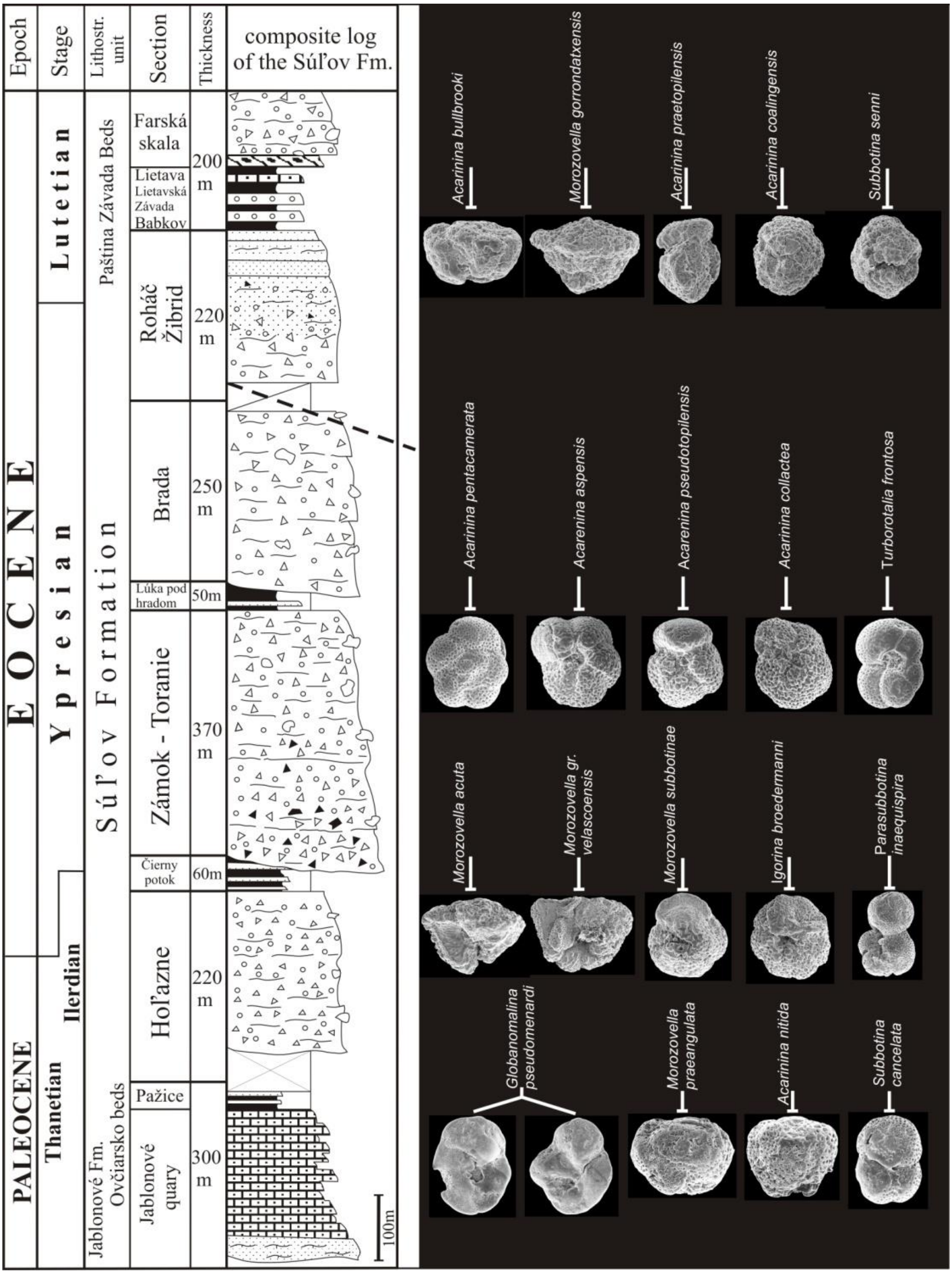


Fig. 31. Distribution of foraminiferal index species in the composite log of the Súľov Formation.

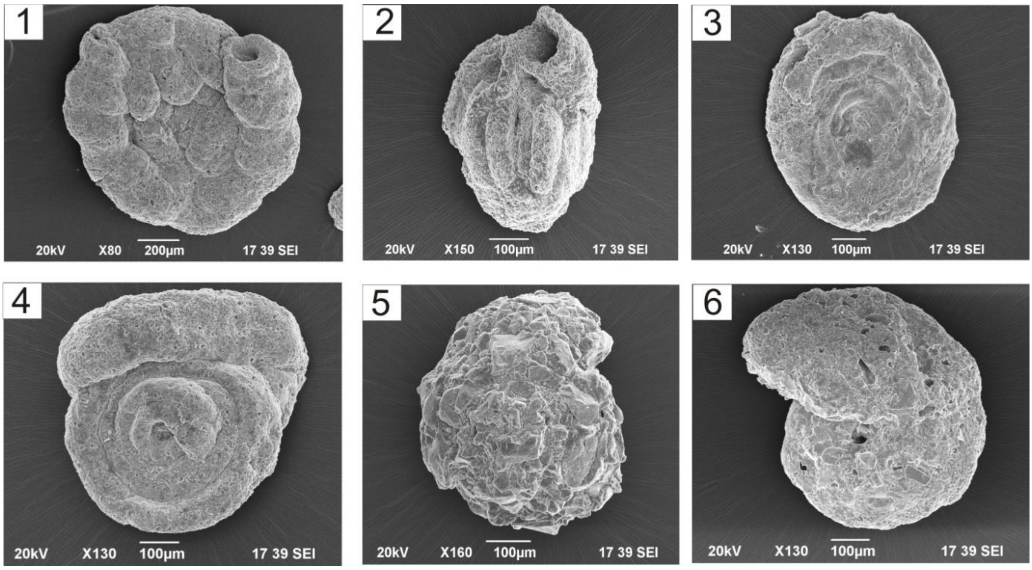


Fig. 32. Agglutinated foraminifera from the Súľov Formation. 4–1: *Trochamminoides proteus*; 4–2: *Paratrochamminoides olszewskii*; 4–3 *Ammodicus cretaceous*; 4–4: *Trochamminoides? dubius*; 4–5: *Psammosphaera* cf. *fusca*; 4–6 *Haplophragmoides excavates*.

Field stop 6: Ovčiarsko – Hradisko near Žilina: Paleocene microfauna of the Hričovské Podhradie Fm, Early to Middle Eocene microfauna of red marlstones and flysch-type mudstones (Žilina and Domaniža fms)

Ján SOTÁK

GPS: 49°22´17.5″N; 18°68´98.0″E

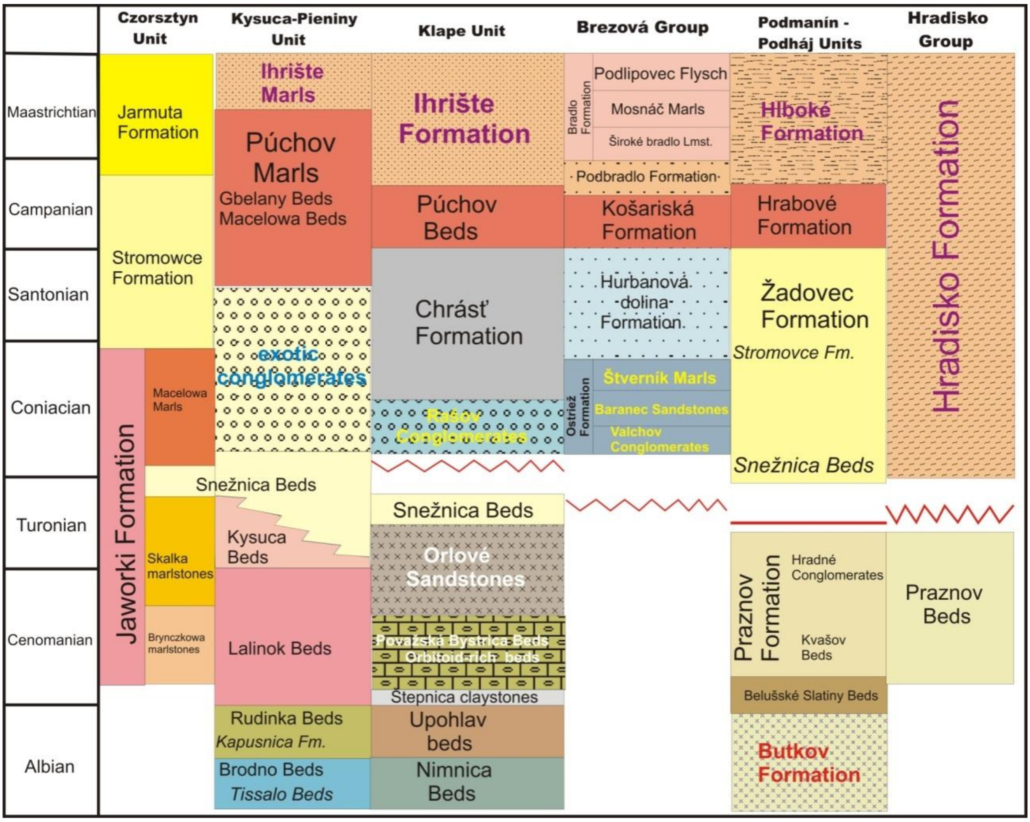


Fig. 33. Lithostratigraphic column of the Cretaceous formations of the PKB units, Brezová Group and related formations in the Middle Váh Valley area.

The area westward of Žilina city is composed of the Cretaceous – Paleogene formations belonging to Hričov-Žilina Zone, Súľov-Domaniža Basin and Klape Unit. Upper Campanian – Maastrichtian marls of the Hradisko Fm contain abundant planktonic foraminifera of globotruncanids and heterohelicids (*Abathomphalus mayaroensis*, *Gansserina gansseri*, *Contusotruncana fornicata*, *Racemiquembelina fruticosa*, etc). This formation passes into dark-grey calcareous marls of the Hričovské Podhradie Fm, illustrating the microfaunal turnover at the K/T boundary with the planktonic foraminiferal survivors represented by impoverished assemblage ofsmall-sized parasubbotinids and subbotinids. The Middle Paleocene associations are significantly enriched by large-sized foraminifers like angular and discoidal morozovellids (e.g. *M. angulata*, *M. acuta*, *M. conicotruncana*), numerous species of globanonalinids (e.g. *G. pseudomenardi*, *G. compressa*), muricate acareninids (e.g. *A. strabocela*, *A. soldadoensis*), and others.

Benthic foraminifers are not frequent in hemipelagic sediments of the Hričovské Podhradie Fm They consistmostly of calcareous deep-water taxa like *Gavelinella beccariformis*, *Anomalinoides rubiginosus*, *Cibicidoides proprius*, etc. (Pl. 2).

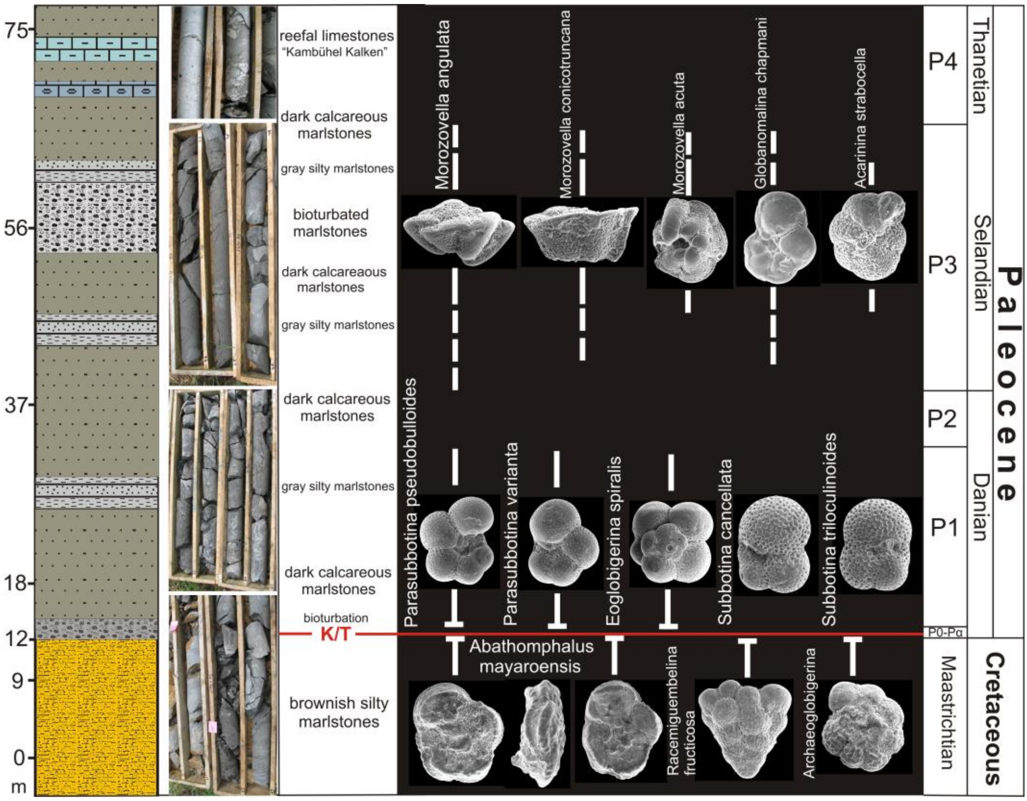
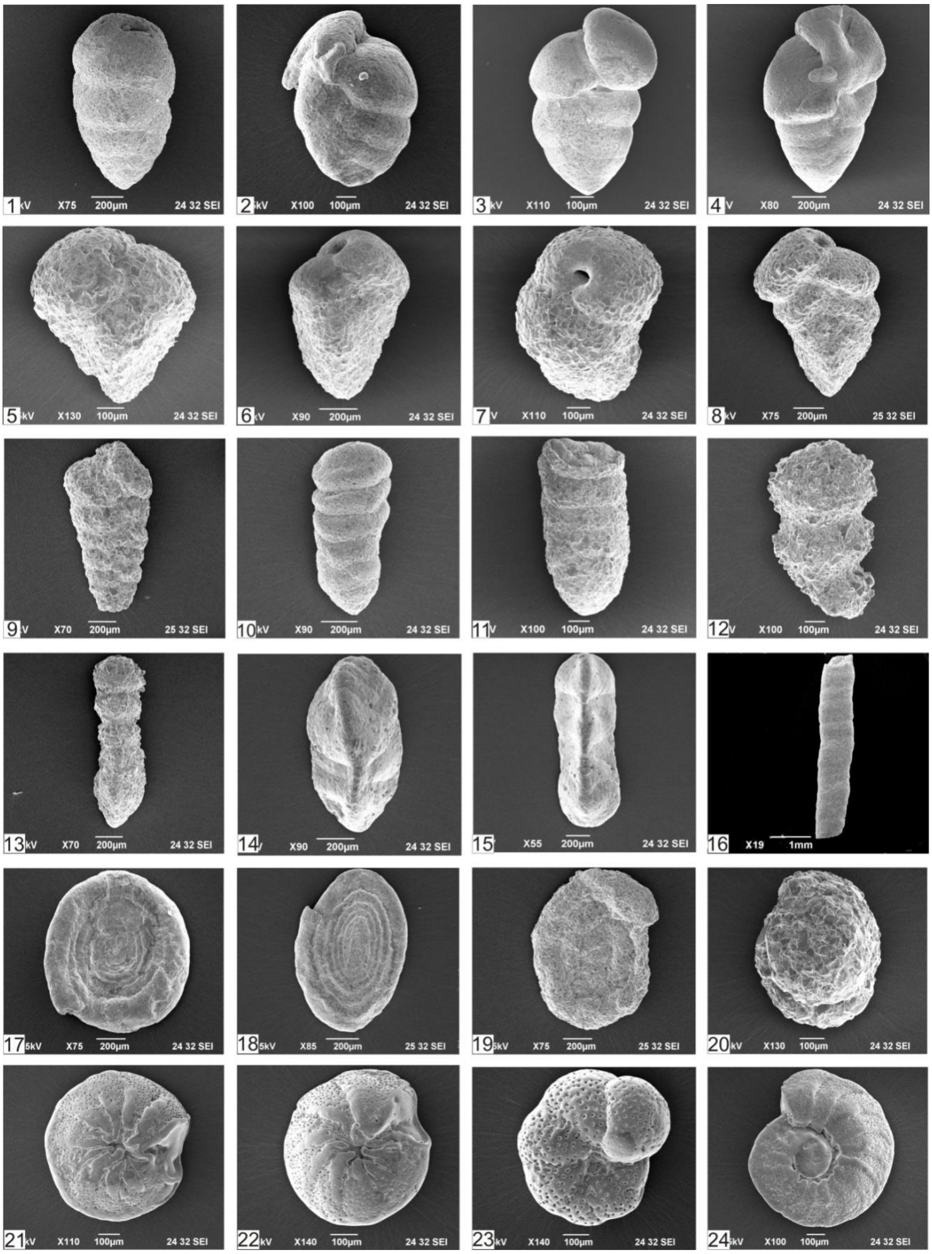


Fig. 34. Planktonic foraminifers and mikrobiostratigraphy of the Hradisko Fm and Hričovské Podhradie Fm in area of Žilina (borehole ZA-1, Loc. Hradisko).

Their content rapidly increases with blooming of conical and tapered morphotypes of ataxophragmiid foraminifers in dark-colored marlstones higher in the the Hričovské Podhradie Fm. These foraminifers are dominated by large-sized species of *Remesella varians*, *Gaudryina pyramidata*, *Karreriella (Gaudryina) brady*, *Karreriella (Gaudryina) lodoensis*, *Rectoprotomarsonella rugosa*, *Clavulinoides globulifera* and *C. trilaterus*. The association is completed by *Reophax globosus*, *Bathysiphon robustus*, *Ammodiscus glabratus*, *A.* cf. *peruvianus, Trochamminoides dubius, Recurvoides* sp., and other characteristic taxa (Fig. 34). A high abundance of ataxophragmiid foraminifers, which lived in deep infaunal microhabitats, suggests elevated food fluxes and dysaerobic conditions on the see floor (cf. Kaminski et al. 1988). Presence of the species *Remessela varians* might reslect the shallowing of the basin as according to Van Den Akker et al. (2000) this species was noted in deposits of inner shelf to upper bathyal depth. The shalowing is also supported by the resedimentation of shallow-water reefal limestones into the deeper bathyal marls of the Hričovské Podhradie Fm (so-called Kambühel Limestones).

Lithostratigraphic transition from the Hričovské Podhradie Fm to Žilina-Domaniža fms is dated approximatelyaround the Paleocene/Eocene boundary (Fig. 35). Red marlstones of the uppermost part of the Žilina Fm are rich in agglutinated foraminifers (Pl. 3) with dominance of large-sized glomospiral species, belonging to *Repmanina charoides* and *Glomospira* cf. *gordialis*. These glomospiral species are associated with flattened-planispiral species like *Ammodiscus glabratus* and *A. cretaceous*. The association is complemented by *Paratrochamminoides olszewskii*, *Saccammina grzybowski*, *Dorothia beloides, Dentalina gracilis*, *Morozovella acuta* and *M. formosa*. *Repmanina*/*Glomospira* associations of the Žilina Fm correlates with the so-called „*Glomospira*-acme“, which is related to the Paleocene – Eocene Thermal Maximum (Galeotti et al. 2004, Kaminski & Gradstein 2005, etc.). The rapid proliferation of glomospirids and ammodiscids is inferred in increased food sources represented by methane-oxydizing bacteria as a concequence of increased methane release during the Paleocene Eocene Thermal Maximum (PETM), (Thomas, 2003). The consequence of the increased methane release was probably also the increased acidity of the oceans and shallowing of the calcite compensation depth (CCD), which led to dissolution of deep-sea carbonates and subsequently to dominance of agglutinated taxa such as *Glomospira* spp., *Repmanina charoides* and ammodiscids (Arreguín-Rodriguez et al. 2013, Kaminski et al. 1996).

Red marstones of the Žilina Fm grade upwards to weakly calcareous and non-calcareous variegated claystones (Hájik Mb). This change is also reflected by the foraminiferal microfauna, which consists exclusivelly fromagglutinated taxa (Pl. 4). These post-PETM associations of agglutinated foraminifera are dominated by the species *Reticulophragmium amplectens*, which corresponds to so-called Reticulophragmium Acme (sensu Kaminski et al. 1996). This event, which is followed by the *Glomospira* Acme, has been used as a biostratigraphic marker of the Middle Eocene partial range zone (Cyclammina Amplectens Zone sensu Geroch & Nowak 1984). Occurrence of such stratigraphically-significant maximum of *Reticulophragmium amplectens* was recorded also in the Middle Eocene sediments of the North Atlantic - western Tethyan basins, dated on the basis of calcareous nannoplankton as NP 15–NP 16 Zones (Kaminski 2005).



Pl. 2. Microfauna of benthic foraminifers from the Hričovské Podhradie Fm in Hradisko locality (borehole ZA-1). 1–4: *Remesella varians* (Glaessner, 1937); 5–7: *Gaudryina pyramidata* Cushman,1926; 8: *Karreriella (Gaudryina) brady* (Cushman, 1911); 9: *Karreriela (Gaudryina) lodoensis* Israelsky, 1951; 10–11: *Rectoprotomarsonella rugosa* (Hanzlíková 1953); 12: *Reophax globosus* Sliter, 1968; 13: *Clavulinoides globulifera* (Ten Dam & Sigal 1950); 14–15: *Clavulinoides trilaterus* (Cushman, 1926); 16: *Hyperammina elegans* (Cushman and Waters), 1928; 17: *Ammodiscus glabratus* Cushman & Jarvis; *18*: *Ammodiscus* cf. *peruvianus* Berry, 1928; 19: *Trochamminoides dubius* (Grzybowski, 1921); 20: *Recurvoides* sp.; 21-22: *Gavelinella becariformis* (White, 1928); 23: *Anomalinoides rubiginosus* (Cushman, 1926); 24: *Cibicidoides proprius* Brotzen (1948).

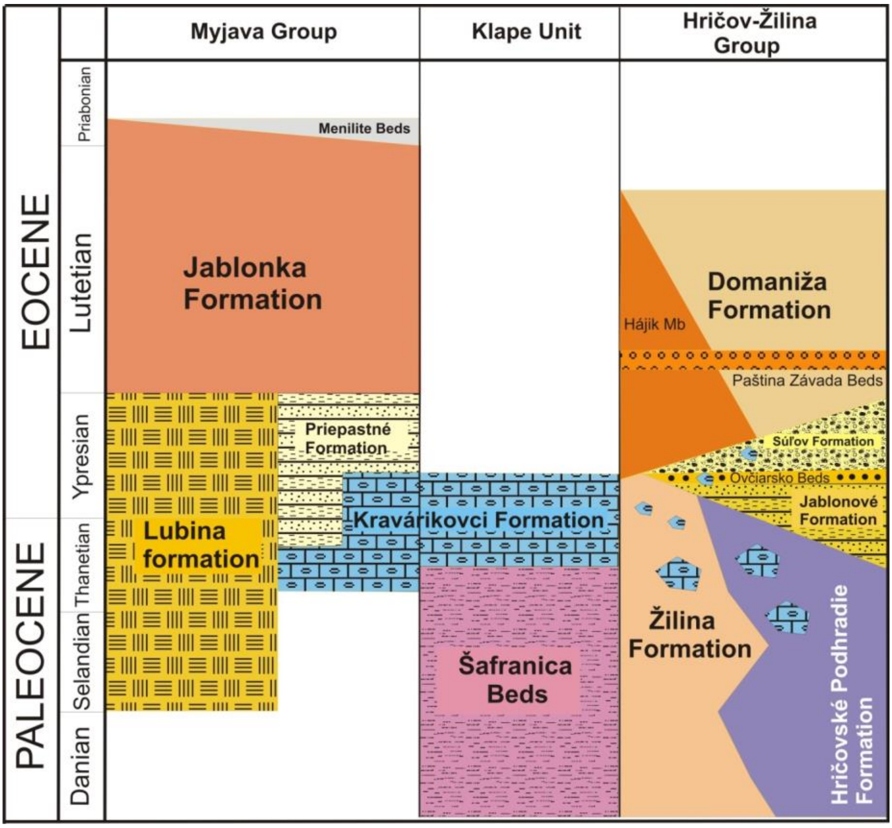
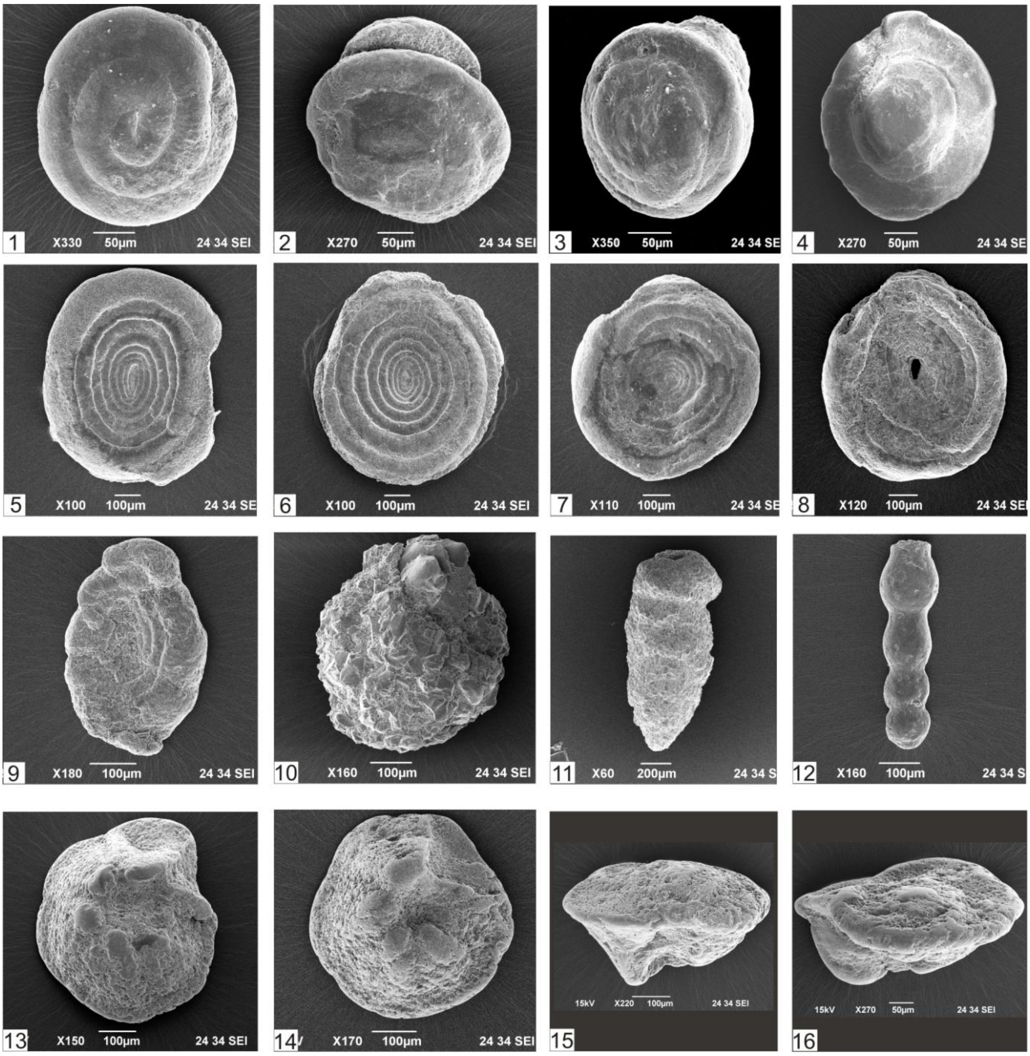


Fig. 35. Lithostratigraphic column of the Paleogene formations of the PKB units, Myjava Group and related formations in the Middle Váh Valley (Hričov-Žilina Group).

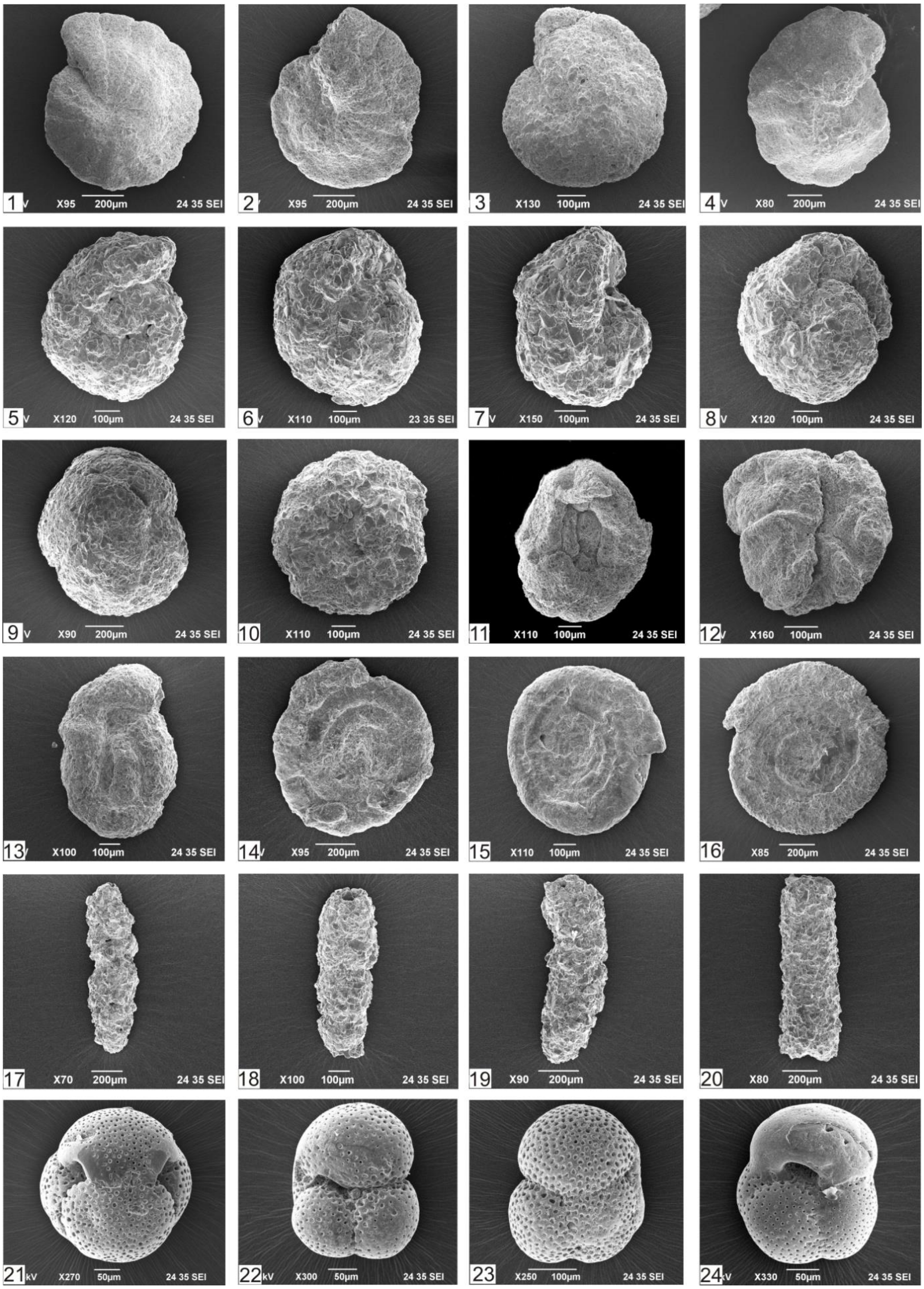
Cyclamminids are associated mainly with recurvoids, comprising of *Recurvoides enormis* and *Recurvoides* sp. Foraminiferal biofacies are completed by *Ammosphaeroidina pseudopauciloculata*, *Trochamminoides dubius*, *Trochamminoides subcoronatus*, *Paratrochamminoides gorayskii*, *Ammodiscus bornemanni*, *Ammodiscus tenuissimus*, *Karrerulina conversa*, *K.* cf. *horrida and Rhabdammina cylindrica.*

Planktonic foraminifers are represented by species *Globigerinatheka kugleri*, *Turborotalia frontosa*, *Subbotina eoceana*, *Subbotina patagonica*, etc. They provide biostratigraphic data for the Middle Eocene age, corresponding to Globigerinatheca Kugleri Zone (E9 sensu Berggren & Pearson, 2005).

The abrupt appearance of *Reticulophragmium amplectens* in the Middle Eocene formations of the Žilina - Domaniža Basin is a consequence of global paleoceanographic conditions and paleobathymetric changes. The morphotype of this species corresponds with the definition of shallow infaunal morphogroups, which indicate less oxygenated conditions, elevated trophic continuum and bathyal to abyssal depth below the CCD during the deposition of greenish and variegated claystones of the Domaniža Fm (Hájik Mt).



Pl. 3. Early Eocene foraminifers from red marlstones of the Žilina Fm (Early Eocene). 1–4: *Repmanina charoides* (Jones & Parker, 1860); 5–6: *Ammodiscus glabratus* Cushman & Jarvis; 7–8: *Ammodiscus cretaceous* (Reuss, 1845); 9: *Paratrochamminoides olszewskii* (Grzybowski, 1898); 10: *Saccammina grzybowski* (Schubert); 11: *Dorothia beloides* Hillebrandt; 12: *Dentalina gracilis* d´Orbigny; 13–15: *Morozovella acuta* (Toulmin, 1941); 16: *Morozovella formosa* (Bolli, 1957).



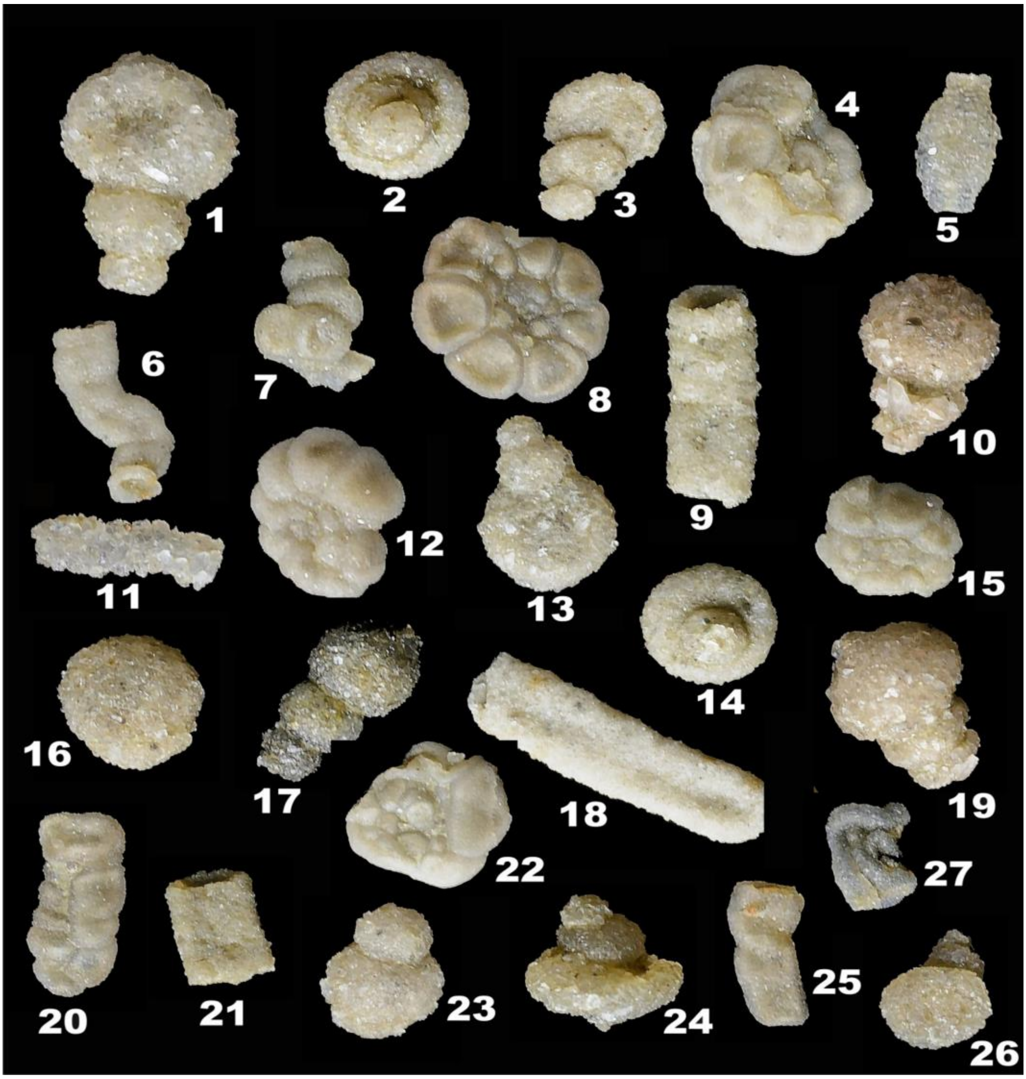
Pl. 4. Middle Eocene microfauna of agglutinated and planktonic foraminifers from variegated claystones near Ovčiarsko and Bitarová villages (Hájik Mb.). 1–4: *Reticulophragmium amplectens* (Grzybowski); 4-8: *Recurvoides anormis* (Mjatliuk, 1970); 9: *Ammophaeroidina pseudopauciloculata* (Mjatliuk, 1966); 10: *Recurvoides* sp.; 11: *Trochamminoides dubius*

(Grzybowski, 1901); 12: *Trochamminoides subcoronatus* (Grzybowski, 1896); 13: *Paratrochamminoides gorayskii* (Grzybowski, 1898); 14–15: *Ammodiscus bornemanni* (Reuss, 1863); 16: *Ammodiscus tenuissimus* (Grzybowski, 1898); 17: *Karrerulina conversa* (Grzybowski, 1901); 18–19: *Karrerulina* cf. *horrida* (Mjatliuk, 1970); 20: *Rhabdammina cylindrica* Glaessner, 1937; 21: *Globigerinatheka kugleri* (Bolli, Loeblich & Tappan, 1957); 22–24: *Turborotalia frontosa* (Subbotina, 1953).

The uppermost formation of the Súľov-Domaniža Basin is formed by deep-water claystones with fine-grained turbidites (Domaniža Fm *sensu* Samuel 1972). The claystones of the Domaniža Fm are dark-coloured, argillaceous and weakly calcareous. They are occasionaly intercalated by laminated and rippled sandstones from higher intervals of Bouma-type turbidites, indicating a low-energy environment of deposition.

Foraminiferal assemblage of the Domaniža Fm is very rich, containing a large-sized and coarsely-agglutinated tests (Pl. 5). The most common foraminiferal species belong to Reophacidae. They comprise of species *Reophax pilulifer*, *R. globosus* and *R. duplex.* The foraminiferal associations are complemented by species *Paratrochamminoides deflexiformis*, *Trochamminoides coronatus*, *T. subcoronatus*, *T. proteus*, *Pseudonodosinella elongata*, *Hormosina trinitatensis*, *Psammosiphonella cylindrica*, *Rhizammina* sp., *Bathysiphon taurinensis*, *Nothia excelsa*, *Rhizammina* sp., *Psammosiphonella cylindrica*, *Glomospira irregularis*, *Psammosphaera scruposa*, etc.

The planktonic foraminifers of the Domaniža Fm consist of morozovellids and acarininids, which provide biostratigraphic data for a Middle to Late Lutetian age of the Domaniža Fm (E9 – Acarenina topilensis Zone).



Pl. 5. Agglutinated foraminifers of the Domaniža Fm (Middle Eocene). 1, 10, 13: *Reophax globosus* Brady, 1884; 2, 14: *Saccammina* sp.; 3, 24, 26: *Hormosina trinitatensis* Cushman & Renz, 1946; 4, 15: *Trochamminoides subcoronatus* (Grzybowski 1896); 5: *Pseudonodosinella elongata* (Grzybowski, 1896); 6, 25: *Rhizammina* sp.; 7: *Subreophax* aff. *scalaris* (Grzybowski, 1896); 8: *Paratrochamminoides deflexiformis* (Noth, 1912); 9: *Bathysiphon* sp.; 11: *Psammosiphonella cylindrica* (Glaessner, 1937); 12: *Trochamminoides coronatus* (Brady, 1879); 16: *Psammosphaera scruposa* (Berthelin, 1880); 17, 19: *Reophax pilulifer* Brady, 1884; 18: *Bathysiphon taurinensis* Sacco, 1893; 20: *Trochamminoides proteus* (Karrer, 1866); 21: *Nothia excelsa* (Grzybowski, 1898); 23: *Reophax duplex* Grzybowski, 1896; 27: *Glomospira irregularis* (Grzybowski, 1896). Magn. 20 x for all..

Field stop 7: DWAF associations of the Upper Eocene turbiditic formations of the Magura Unit

Ján SOTÁK, Dušan STAREK and Vladimír ŠIMO

GPS: 49°18'34.2"N; 18°34'17.4"E

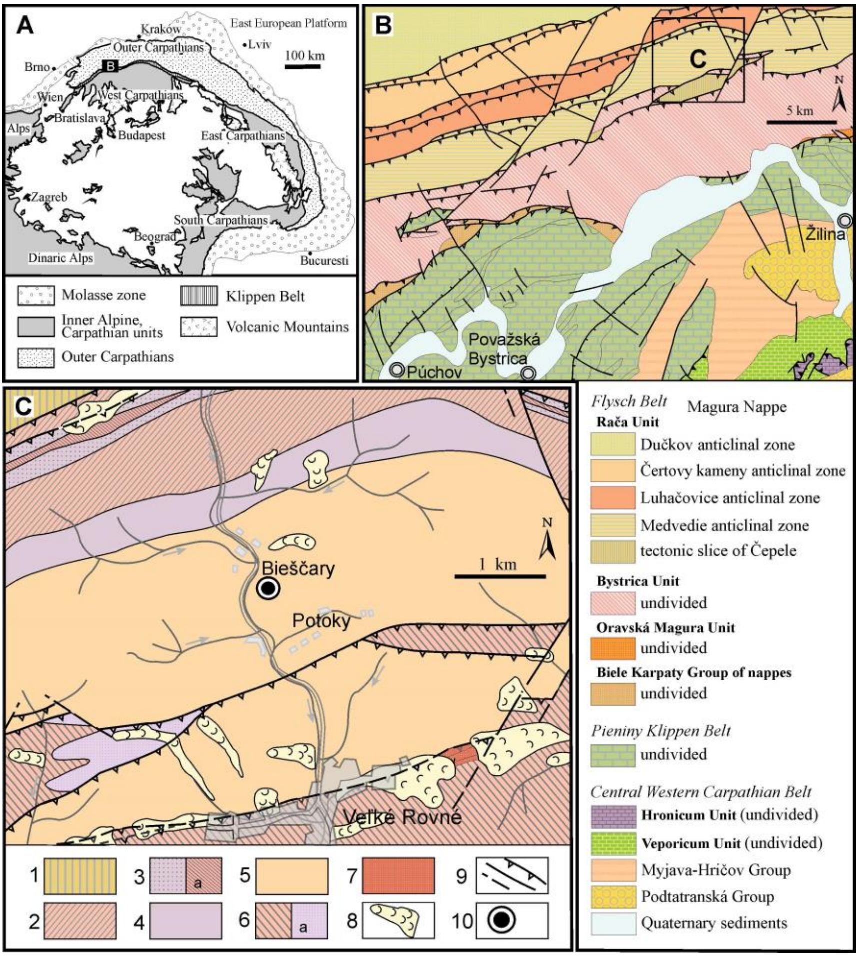


Fig. 36. A – location of study area within the Alpine-Carpathian orogen; B – tectonic sketch of the Middle Váh Valley (after Mello et al., 2005, modified); C – geological sketch of the outcrop area in surroundings of Veľké Rovné village (after Mello et al., 2005, modified).

Bieščary quarry is located in the region of the Veľké Rovné Valley in the Javorníky Mountains of the Slovak-Moravian Carpathians (Fig. 36). Eocene turbiditic sandstones exploited in the quarry are more than 80 m thick and relatively rich in various sedimentary structures and trace fossils (Starek & Pivko, 2001, Starek & Šimo, 2015).

The Bieščary quarry sedimentary succession belongs to the Magura Nappe of the Flysch belt in the NW part of the Western Carpathians (Fig. 36A), which was formed mostly during the Late Alpine tectonic stages. In the Magura Nappe, the Rača, Bystrica and Krynica (= Orava-Magura) tectono-facies units are distinguished from the north to south (Birkenmajer & Oszczypko, 1989; Mello et al., 2011). In the Rača Unit, the sedimentation advanced from the Soláň Formation (Campanian – Early Paleocene), through the Beloveža Formation (Early Paleocene – Middle Eocene) and the Luhačovice Formation (Middle Eocene) to the Zlín Formation (Early to Late Eocene, maybe younger - Oszczypko-Clowes, 2001). The Zlín Formation is divided into the Vsetín, Babiše (Teťák, 2005), Kýčera and Bystrica beds (Mello et al., 2011).

In the Bieščary quarry (Fig. 36C), over 120 beds of the sandstones of the Kýčera Beds are exposed. They are about 80 m thick (Fig. 37A). The thick-bedded (up to 2.5 m thick), mostly fine- to medium-grained sandstones of the Magura Sandstone-type (e.g. Stráník, 1965; Teťák, 2008) are interbedded with thin-bedded sequences (Fig. 37A–C). Mudstone beds are usually some dm up to several m thick. They are organic-rich and weakly calcareous.

Sedimentary structures in the sandstones are relatively abundant. In thicker sandstone beds (>10 cm), massive bedding is the most common (S3 interval *sensu* Lowe, 1982), with intervals showing a uniform size fraction, locally fining upwards with a relatively sharp transition to siltstone and mudstone intervals, or with a thin normally graded interval (Ta – *sensu* Bouma, 1962) in the basal part. The graded interval is usually formed by a poorly sorted fine-grained conglomerate to coarse-grained sandstone, or by a sandstone with dispersed coarser clasts. Poorly developed parallel lamination and cross-beddings are represented subordinately in thicker beds. The lower bedding surfaces are mostly plain, with common small-size erosional current marks and occasional load casts. The amalgamations of beds are frequent (cf. Starek & Pivko, 2001). These sandstone beds reflect deposition from high-density turbidite currents. Thin sandstone beds (<10 cm thick) are usually a component of thin-bedded packages with the prevalence of mudstones. These sandstones show frequent occurrence of the Bouma intervals (Ta-e) (*sensu* Bouma, 1962), typical of medium-grained turbidites, or T1-8 (*sensu* Stow & Shanmungam, 1980) as well as E1-3 intervals (*sensu* Piper, 1978), typical of fine-grained turbidites.

The sedimentary succession is interpreted as a mid-fan lobe complex of a deep-sea fan with alteration of distributary channels-proximal lobes and interchannel-interlobe parts (Starek & Pivko, 2001; cf. also Staňová & Soták, 2002, 2007; Potfaj et al., 2002; Teťák, 2008, 2010). The current mark measurements of these deposits is directed from the E-NE to W–SE (Starek &

Pivko, 2001), which correspond with palaeocurrent systems of the Magura Basin in wider area of the Javorníky Mts (Teťák, 2008).

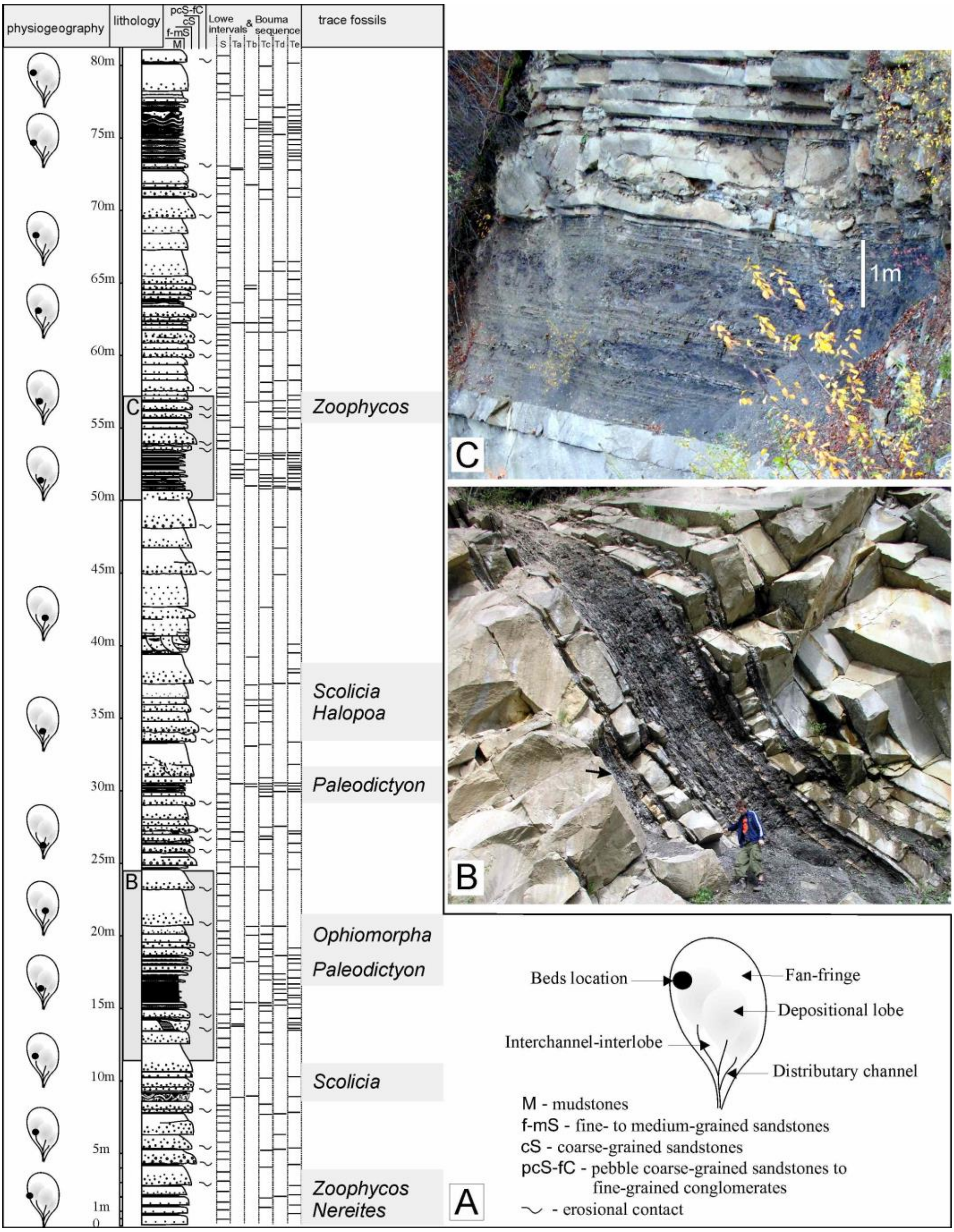
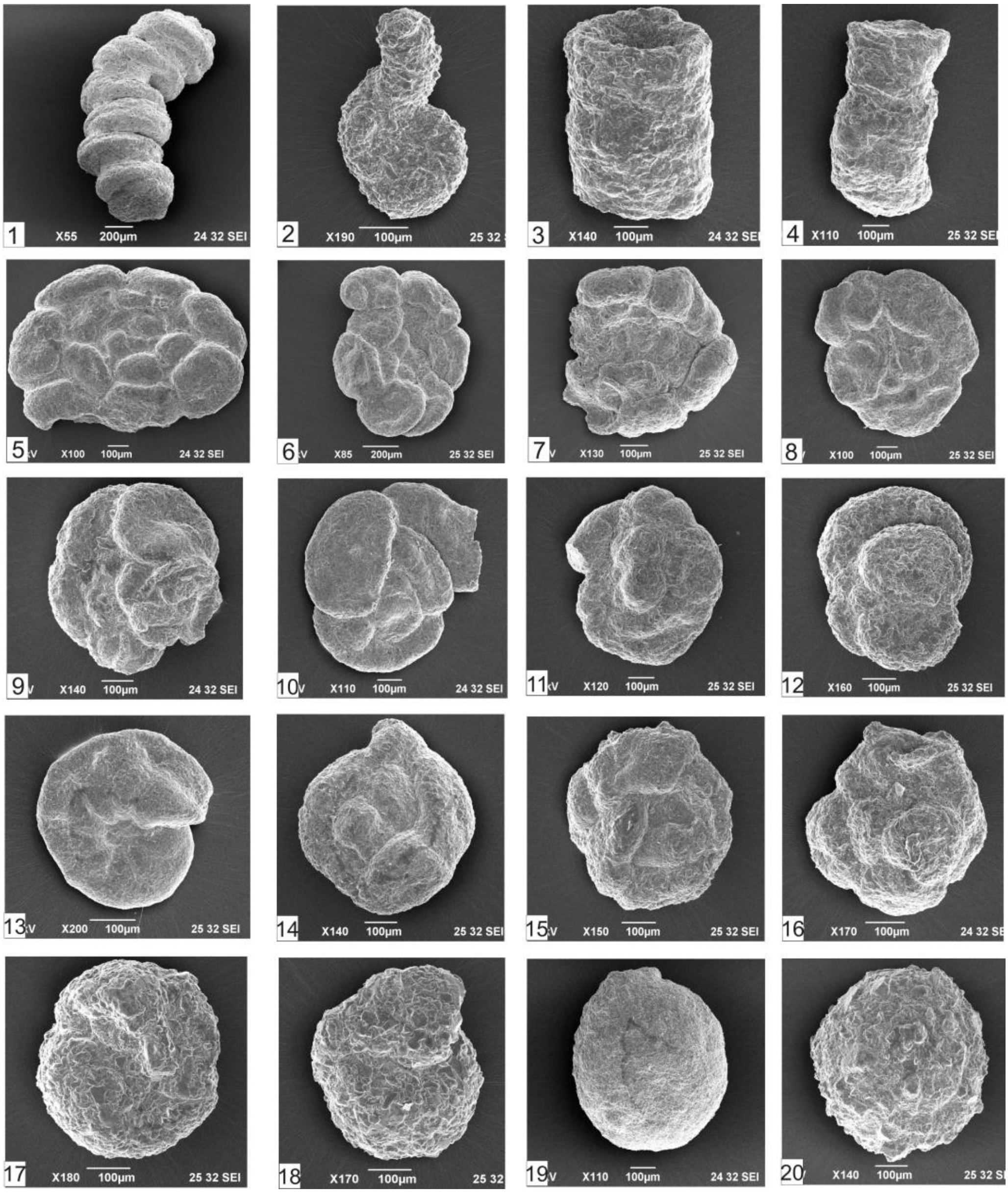


Fig. 37. A: Sedimentological log of Kýčera Beds of the Bieščary quarry; thick-bedded sandstones with thin-bedded and mudstone interbeds are interpreted as distributary channel-levee complex in the middle part of deep-sea fan; B: Mudstone megabeds are formed by levee or overbank deposits in the interchanel area.

Fig. 38. Trace fossils from the turbiditic sediments of the Kýčera beds in the Bieščary quarry. A: sole of bedding plane with meandering *Scolicia strozzii.* B: sole with *Halopoa annulata*; C: upper bedding plane with *Zoophycos brianteus* (adopted from Starek & Šimo, 2015).

Turbiditic sequence in the Bieščary quarry is characterized by six different ichnospecies (Starek & Šimo, 2015), (Fig. 38). Well exposed turbiditic sandstones contain the deep-sea Nereites ichnofacies. The trace fossils *Ophiomorpha rudis, Halopoa annulata* and *Scolicia strozzii* are mainly common in thick-bedded sandstones. They represent the Ophiomorpha rudis ichnosubfacies. *Paleodictyon strozzii, Nereites irregularis,* and *Zoophycos brianteus* occur in a series of thin- to medium bedded fine grained turbiditic sandstones intercalated with mudstone shales. They belong to the Paleodictyon–Nereites ichnosubfacies. The sedimentological interpretation of the turbidity facies and the distribution of the trace fossils suggest that the recognized ichnosubfacies probably express a non-bathymetric facies trend from channel axis, levee to overbank or inter-channel/interlobe areas of a deep sea fan (Starek & Šimo, 2015).

Turbiditic formation of the Kýčera Beds at the Bieščary quarry contains a rich microfauna of deep-water agglutinated foraminifera (DWAF), (Pl. 6). Their major components are trochamminids, represented by large-sized species of *Trochaminoides proteus*, *T. subcoronatus*, *T. dubius*, *T. variolarius*, *Paratrochamminoides olszewskii* and *P. irregularis*. Trochamminids are associated with tubular forms, like *Bathysipthon gerochi*, *Bathysiphon* sp., *Nothia robusta*, *Subreophax pseudoscalaris* and *Psammosiphonella discreta*. Assemblage of agglutinated foraminifers is completed by small-sized forms with sphaerical and planispiral to streptospiral tests, belonging to species of *Psammosphaera irregularis*, *P. fusca*, *Hyperammina elongata*, *Haplophragmoides walteri*, *Recurvoides anormis*, *R. lamella, R. nucleosus, Lituotuba lituiformis, Glomospira gordialis*, etc. Missing of calcareous benthic and planktonic foraminifers and DWAF-type of agglutinated species points to lower bathyal to abbysal depositional depth below the CCD.



Pl. 6. Eocene agglutinated foraminifera from the Kýčera Beds at the Veľké Rovné Bieščary locality. 1: *Subreophax pseudoscalaris* (Samuel, 19776); 2: *Lituotuba lituiformis* (Brady, 1879); 3: *Nothia robusta* (Grzybowski 1898); 4: *Bathysiphon* sp.; 5–7 *Trochamminoides proteus* (Karrer, 1866); 8–10: *Trochamminoides subcoronatus* (Grzybowski, 1896); 11: *Trochamminoides dubius* (Grybowski, 1901); 12: *Paratrochamminoides olszewskii* (Grzybowski, 1898); 13–14: *Paratrochamminoides irregularis* (White, 1928); 15: *Haplophragmoides walteri* (Grzybowski, 1898); 16: *Recurvoides lamella* (Grzybowski, 1898); 17–18: *Recurvoides nucleolus* (Grzybowski, 1898); 19: *Psammosphaera irregularis* (Grzybowski, 1896); 20: *Psammosphaera fusca* (Schulze 1875).

Field stop 8: Hôrka near Pavažská Bystrica town: Orlové Sandstone with oyster coquinas (Cenomanian – Early Turonian)

Jozef MICHALÍK and Ján SOTÁK

GPS: 49°07'56.4"N; 18°26'41.7"E (49°.09´21.59″N; 18°28´10.46″E, resp.)

Fig. 39. Orlové Sandstone with oyster banks and coquinas. Locality: Hôrka near Považská Bystrica (photo by J. Rantúch).

Upper Cenomanian – Lower Turonian sediments of the Klape Unit are represented by the Orlové Sandstone (Fig. 39). The Orlové beds were recognized as sandstones with *Exogyra columba* already by A. Boué (1830) and D. Štúr (1860). Orlové Sandstone is one of the most mysterious parts of the Klape Unit sequence. They form up to 700 m thick lithosomes of shallow-marine sandstones, which are developed above the deep-water conglomeratic and turbiditic sediments of the Upohlav Formation (Late Albian-Early Cenomanian). Andrusov and Scheibner, 1960 described finding of ammonites *Acanthoceras rhotomagense* (d´Orbigny) on the base of the Orlové Sandstone, which is a guide fossil of the upper part of the Middle Cenomanian.

The Orlové Sandstone contains rests of autochthonous faunal association including rich oysters *Rhynchostreon suborbiculatum* (Lamarck), serpulids, fragments of molluscs, sponge spicules, ostracods and foraminifers.

Salaj (1990, 1995) referred on the occurrence of *Dicarinella imbricata* (Morno) from Orlové – Hôrka and Vrtižer (Chrasť) localities (figs. 40, 41).

The Hôrka section is encovered in a forest path above former gas station. Study of sedimentology and stratigraphy (Marschalko and Samuel, 1980; Marschalko and Kysela, 1980) differentiated several genetic sandstone types with different stratigraphic position.

Fig. 40. Numerous shells of *Rhynchostreon* in Orlové Sandstone bed. Hôrka Hill section.

Orlové Sandstone comprises of rich oyster shell accumulations up to bivalve coquinas. The sandstones provide a typical shallow marine sedimentary structures, such as crustacean burrows, dense bioturbation, tidal cross-ripple lamination, frequent fossil leaves (Platanus), etc. Their shallow-marine origin was documented by Marschalko (1986) and Marschalko and Kysela (1980), which tried to interpret this complex as a huge olistolite body slumped into deeper flysch basin. On the other hand, Salaj (1995b) regarded the clastic wedge as a huge delta deposited by rivers flowing down of approaching Paleoalpine thrust front.

On both localities, calcite grains form more than 50 percent of the rock, subangular to round quartz grains are frequent, granulometrically well sorted. Spectrum of heavy minerals in the Hôrka section is represented by glaucophane, zircon, apatite, chloritoid, biotite, muscovite, garnet and tourmaline, it indicates source from metamorphic schists, less from magmatic rocks. Idiomorph quartz crystals occur seldomly. On the other hand, the heavy minerals spectrum of the Chrasť locality is more uniform, being formed by garnet, chloritoid, chlorite, biotite and muscovite only (Labajová, 2004, unpubl. master thesis).

Organic fragments are represented by oyster shell fragments, agglutinated foraminifers, non-axial sponge spicules, more rarely by silicisponge monoaxon spicules, ostracods, coralline algal fragments, serpulids (*Glomerula solitaria* Regenhardt, *Serpula prolifera* Goldfuss) and echinoderm debris. Oysters *Rhynchostreon suborbiculatum* (Lamarck) are strongly dominating, their incremental growth lines indicate that they survived usually at least 5-6 life cycles of non-interrupted growth. Oysters are accompanied by less frequent bivalves *Protocardia* sp., *Inoceramus* sp., *Pecten* sp., brachiopods and by ichnofossis *Paleophycus* sp. and *Planolites* sp. (Rantuch, 2009, unpubl.). Preservation of fossils excludes transport longer than a few hundred meters (Labajová, l.c.).

Fig. 41. Bivalve coquina densely packed by oyster shells and another molluscs (*Protocardia*, *Coelosmilia*, etc.).

Orlové Sandstone are poor in content of the microfauna, comprising of only several benthic foraminifers, such as *Cyclammina* sp., *Haplophragmoides* sp., *Glomospira* sp., *Arenobulimina* sp., *Dorothia* aff. *praeoxycona*, *Bolivinopsis* sp., *Verneuilina* sp., *Gaudryina* sp., *Marginulina* sp., *Dentalina* sp., *Reophax* sp., *Praeglobotruncana* sp. (Fig. 42).

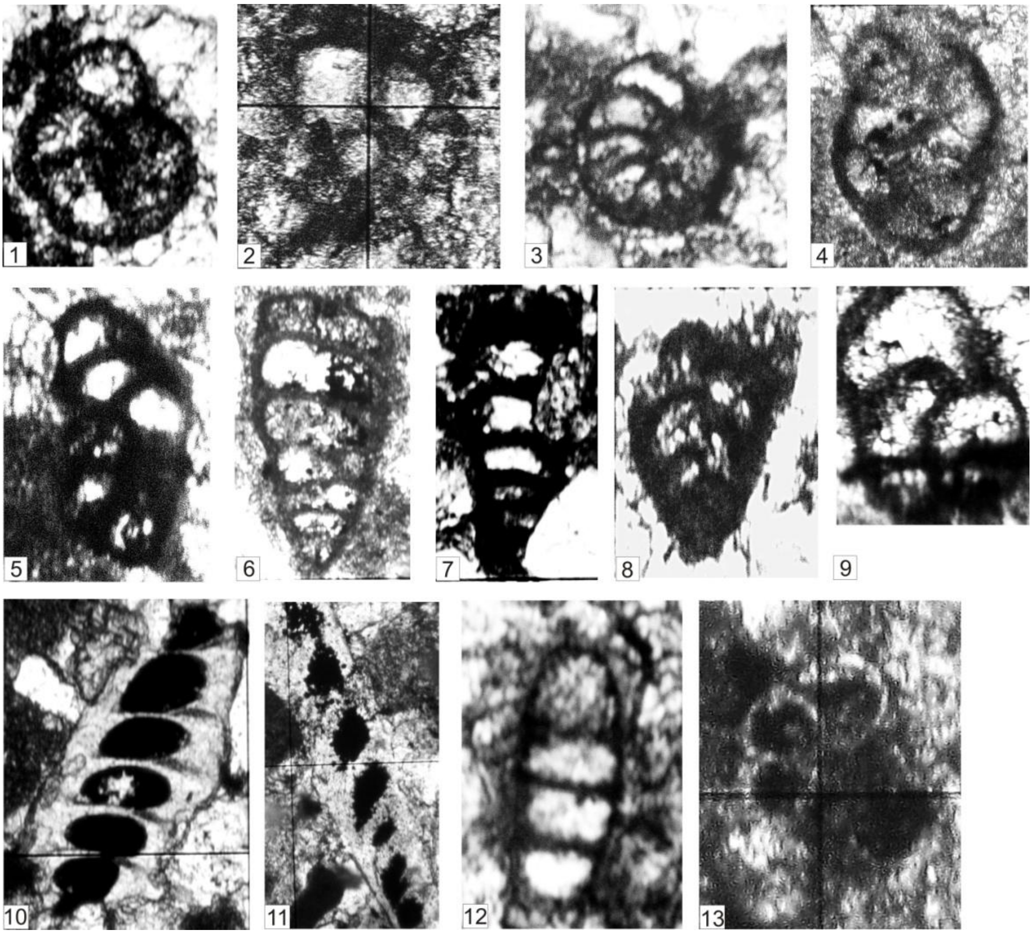


Fig. 42. Thin-sections of different foraminiferal tests from fine-grained sandstones of the Orlové beds. 1: *Cyclammina* sp. (with visible alveolar structure); 2: *Haplophragmoides* sp.; 3: *Glomospira* sp.; 4: *Arenobulimina* sp.; 5: *Dorothia* aff. *praeoxycona*; 6: *Bolivinopsis* sp.; 7: *Verneuilina* sp.; 8: *Gaudryina* sp.; *Marginulina* sp.; 9: *Dentalina* sp.; 10: *Reophax* sp.; 11: *Praeglobotruncana* sp..

II. Field tripe route in the Malé Karpaty Mts, Brezovské Karpaty Mts and Vienna Basin

Field trip stops:

9. Brezová pod Bradlom – Baranec
10. Hradište pod Vrátnom
11. Cerová – Lieskové
12. Kršlenica – Plavecký Mikuláš
13. Sološnica – abandoned quarry
14. Hrabník pit near Sološnica
15. Devínska Kobyla
16. Devín Castle

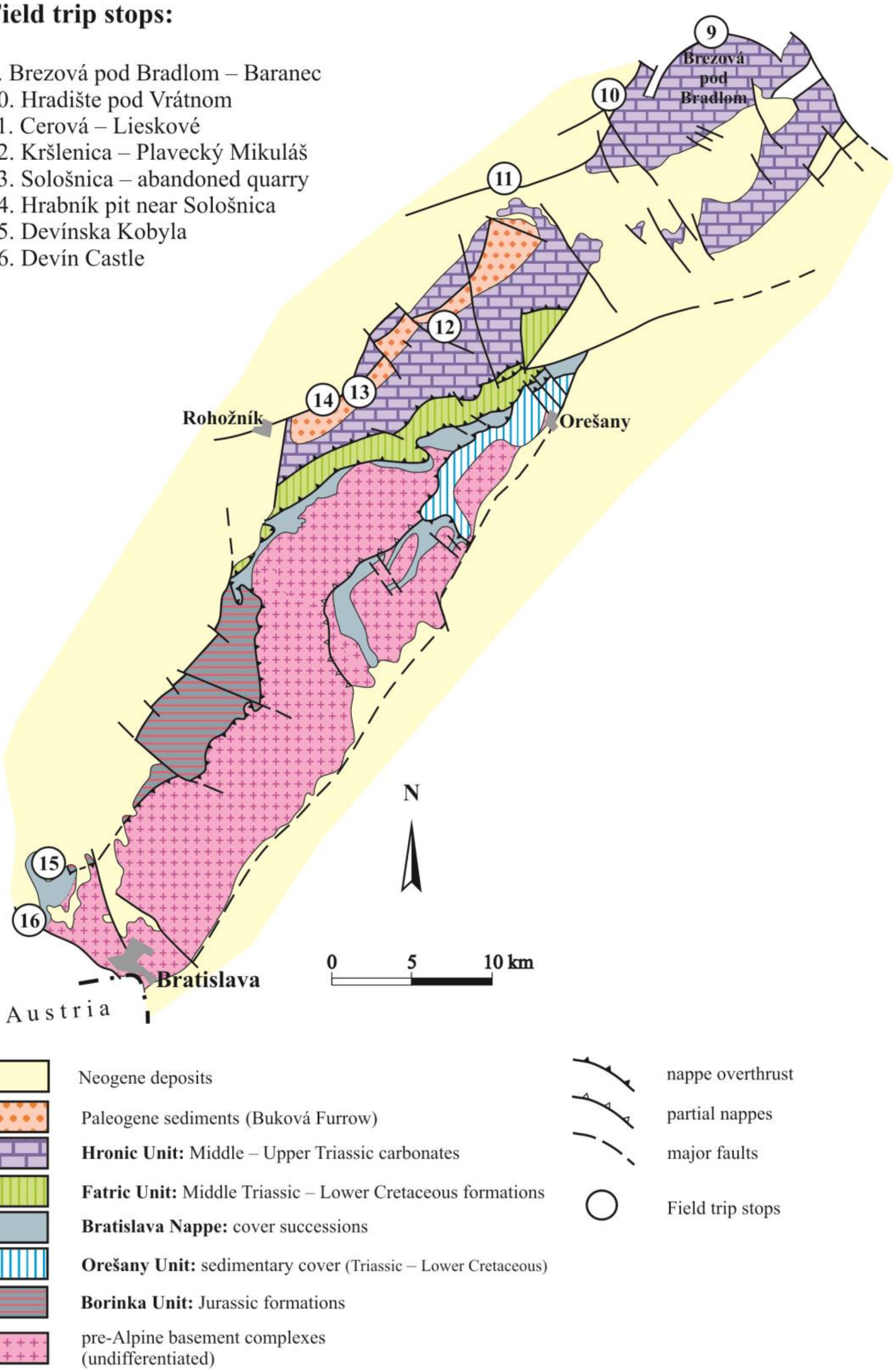


Fig. 43. Simplified geological map of the Malé Karpaty Mts.

Fig. 44. Route of the field trip (23.4.2017).

4. General structure of the Malé Karpaty and Brezovské Karpaty Mts

Jozef MICHALÍK, Dušan PLAŠIENKA and Ján SOTÁK

The Malé Karpaty Mts represents an elongated horst structure of the pre-Miocene basement surrounded by large Neogene basins. The horst is separated by SW-NE trending normal and oblique-slip faults from sediments of the Vienna Basin in the NW and the Danube Basin in the SE. As the easternmost segment of the CWC, the Malé Karpaty Mts form an important link between the Eastern Alps and Western Carpathians (Maheľ, 1987; Plašienka et al., 1991; Häusler et al., 1993). The substantial part of the Malé Karpaty Mts is built up by the Tatric basement-cover superunit. Superficial cover nappe systems – Fatric (Krížna) and Hronic (Choč) overlie the Tatric substratum in the northern part of the mountains only (Fig. 45).

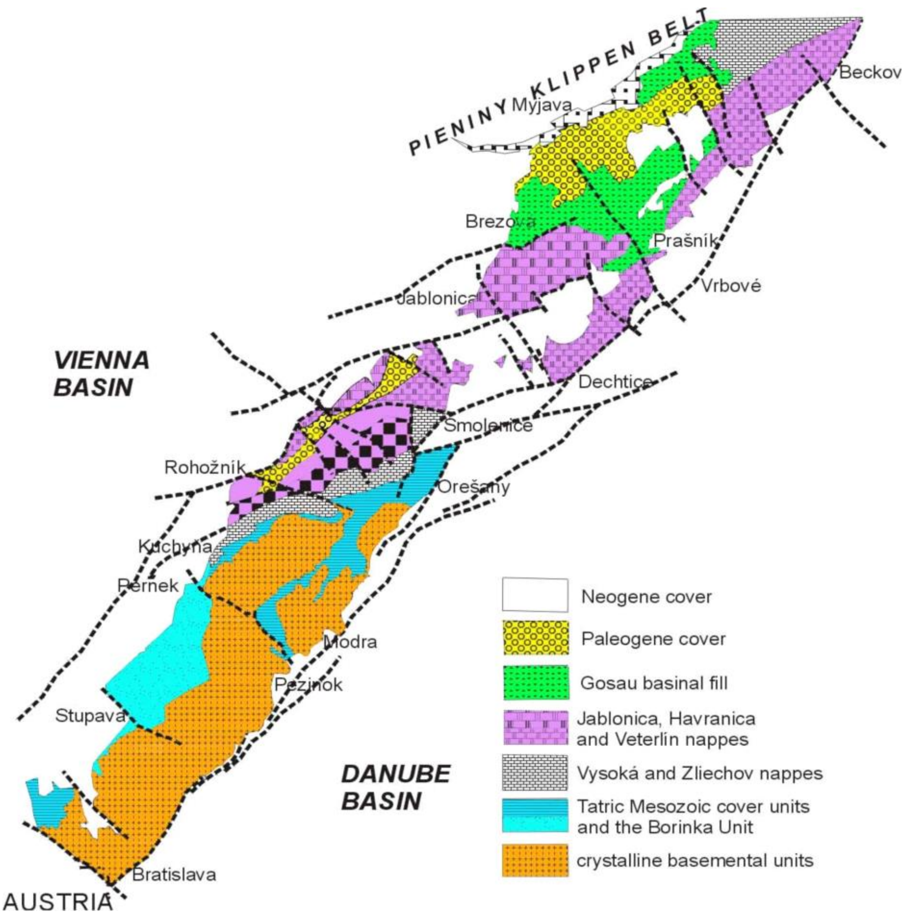


Fig. 45. Simplified tectonic map of the Malé Karpaty Mountains (Plašienka, 2016).

The Tatric units

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

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

Post-Variscan sedimentary cover of the Bratislava Nappe (Fig. 46) starts with only locally preserved Upper Permian coarse-grained clastics. These are followed by ubiqui-tous Lower Triassic quartzites and variegated shales overlain by Middle Triassic shallow-marine carbonate complex (Gutenstein Lime-stone and Ramsau Dolomite). Younger Trias-sic sediments are not preserved due to deep erosion during Early Jurassic rifting, but occa-sional clasts of Rhaetian fossiliferous lime-stones occur in Jurassic breccias. In places, even the Early to Middle Jurassic limestones directly overlay pre-Alpine basement rocks and form Neptunian dykes in them (Kadlubek; cf. Plašienka 2012 and references therein).

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

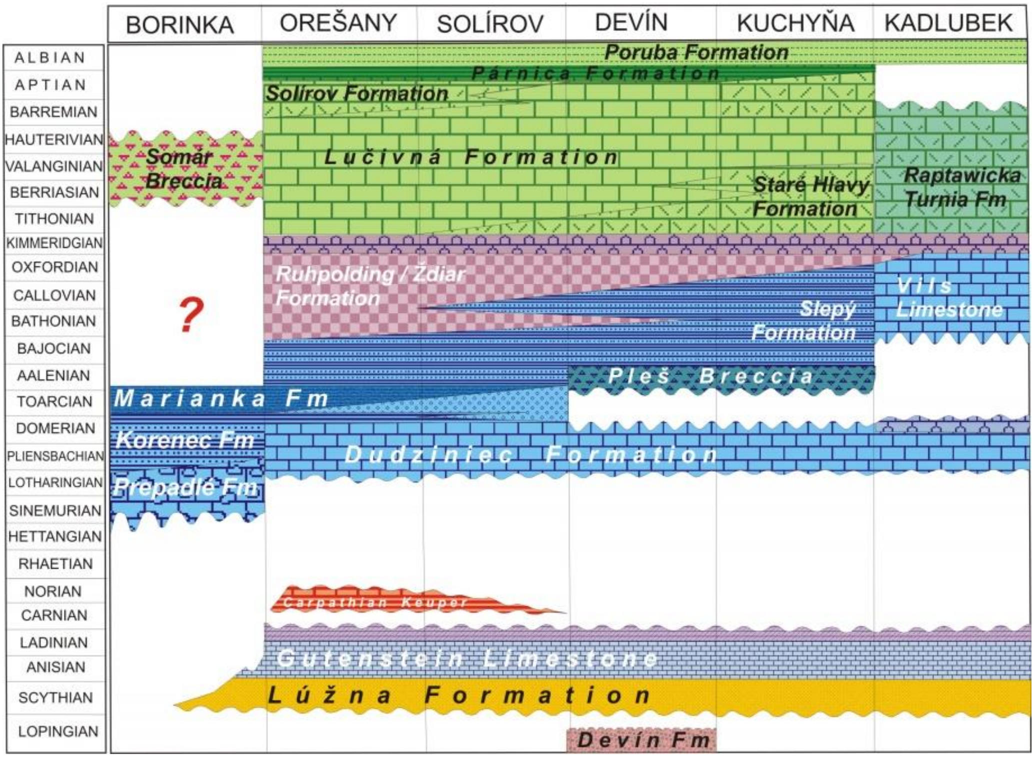


Fig. 46. Schematic lithostratigraphical table showing development of Mesozoic sediments in Tatric units of the Malé Karpaty Mts (Plašienka, 1989).

The lowermost structural position of the Tatric nappe stack is occupied by the Borinka Unit occurring in a subautochthonous position below frontal parts of the Bratislava Nappe, which is exposed on the NW slopes of the Malé Karpaty (Figs. 47, 48). It forms the biggest “blue spot” to be seen on general geological maps of the Slovakian Western Carpathians, which suggests a significant amount of Juras-sic sediments present there (altogether more than 1 km thick), in contrast to the other parts of the Western Carpathians. In spite of this, most probably only Lower to Middle Jurassic strata are preserved, with an unexposed rela-tionship to underlying complexes. They are composed of syn-rift, coarse-grained polymict breccias, black shales, spiculitic marlstones and turbiditic sandstones.

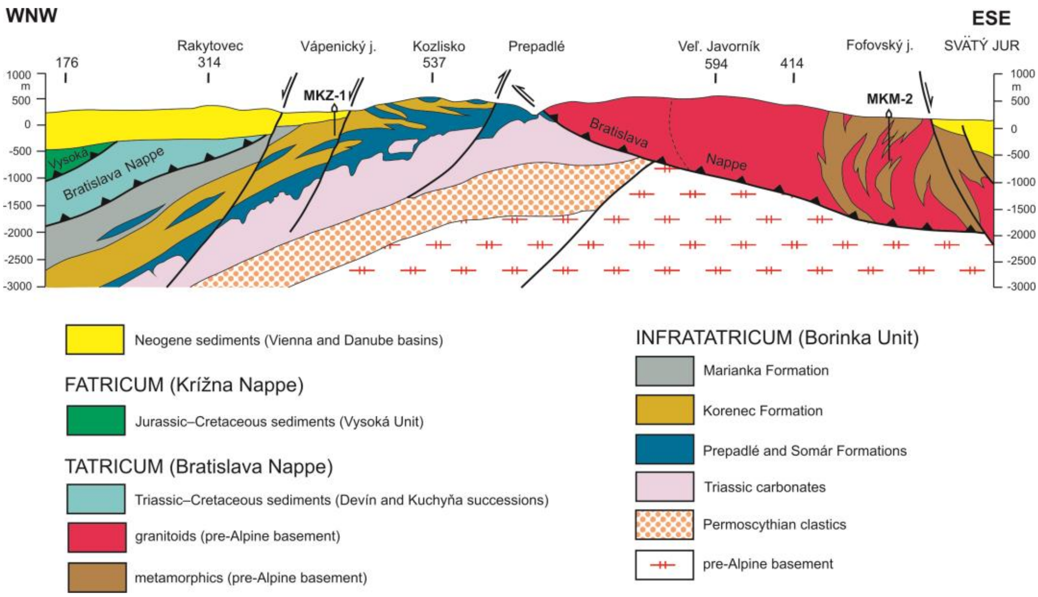


Fig. 47. Geological cross-section of the southern part of the Malé Karpaty Mts (Plašienka, 2016).

The original palaeogeographic settings of the syn-rift Jurassic successions of the Ta-tricum in the present Malé Karpaty Mts was tentatively reconstructed based on their pre-sent structural positions and thrusting direc-tion, sedimentary transport directions and likely position of sources of the coarse-grained terrigenous clastic material (Plašienka et al., 1991; Plašienka, 1995a, b, 2003, 2012). The model outlined in the Fig. 48 assumes development of Jurassic asymmetric halfgrabens flanking the South Penninic (Ligurian-Piemont-Vahic) Ocean.

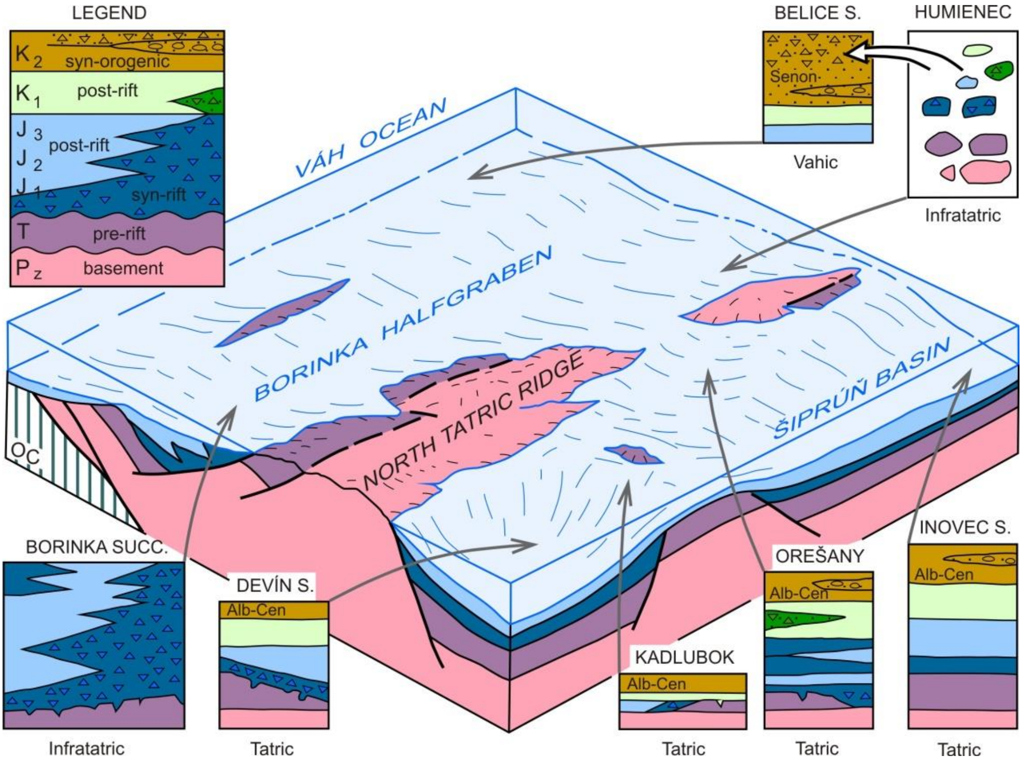


Fig. 48. Blockdiagram illustrating the palaeogeographic relationships of lithostratigraphic succes-sions positioned along the northern Tatric continental margin facing the Váh Ocean to the NW and the Tatric Šiprúň basin to the SE (in present coordinates). Approximately Late Jurassic situation. (Adopted from Plašienka, 2012).

Upper Cretaceous sequence in the westernmost part of the Central Western Carpathians

The Gosau development in the Brezovské Karpaty Mts and the Myjava Upland

The Myjava Upland along with adjacent hilly mountains are considered as a continuation of oil-producing basement of the Vienna Basin. The most productive oil reservoirs in the Vienna Basin are located in Triassic carbonate complexes. The Triassic carbonates in the Brezovské Karpaty Mts are traditionally ascribed to the Jablonica Nappe. This presumption, although not supported by geometrical analysis of the mountain structure, has been based on facies correlation. There are affinities of this sequence with the Strážov-, Havranica-, and Veterlín nappes of the Central Western Carpathians, but also with the Ötscher (?Göller) Nappe of the Northern Alps. By detailed mapping (MICHALÍK et al., 1994a) has recognized several tectonic slices in these mountains. The Dobrá Voda 1 borehole (1190 m deep, cf. Michalík et al., 1992a) penetrated a basinal Middle Triassic sequence with thick Reingraben Formation and a basinal Middle Triassic carbonate development below thick Jablonica Nappe platform carbonate complexes of equivalent age.

The Brezovské Karpaty Mts form an extensive horst-like morphostructure emerging through the Upper Cretaceous and Miocene sedimentary cover. The Jablonica Nappe has a simple monoclinal structure, distorted by faults. Underlying slices belonging probably to the Choč Nappe crop out in two deformed elevated zones along the border of the Dobrá Voda- and the Hradište depressions. Strong tectonization and general vergency proved back-thrusting movements of the platform carbonate block of the Jablonica Nappe.

Triassic carbonates of the Brezovské Karpaty Mts are affected by three systems of transversal faults. The oldest system (N-S, or NNW-SSE, respectively) is concentrated near both Hradište pod Vrátnom- or Dobrá Voda villages, where it creates a series of narrow slice bodies. The next system (E-W) divides blocks of different elevation amplitude. Similar movements created also the Dobrá Voda Depression itself. The post-Oligocene or Post-Savian age is assumed as source of all disjunctive structures described. The youngest "Sudetian" system (NW-SE), probably late Miocene in age, cuts all the structures observed.

Analogous to the Gosau Group of the Northern Calcareous Alps (e.g. Wagreich & Marschalko, 1995) the Upper Cretaceous – Paleogene complexes in the Myjava Upland represent a distal part of the accretionary belt of the Central Carpathian orogene system. They are in contact with the frontal parts of the Centrocarpathian superficial nappes and with the margin of the Pieniny Klippen Belt. They have been affected by Neoalpine orogenetic deformations.

The oldest (? late Turonian – early Coniacian) sediments of the Late Cretaceous megacycle are represented by fresh-water oncolite limestones of the **Pustá Ves Formation**. They occur on the NE termination of the Malé Karpaty Mts, and in the Stratená Mts on the base of the Upper Cretaceous sequence, as well. However, the distribution of these rocks is not congruent with the configuration of successive „Gosau-type“ basins. Three outcrops are known in both the Brezovské- and Čachtické Karpaty Mts area. The first one, the Hrdlákova skala rock, W of Čachtice, overlying Anisian Gutenstein Limestone, has been erroneously regarded as Triassic in age by Hanáček (1954). The outcrops near the Černík gamekeeper´s cottage N of Chtelnica, and on the Mladé Háje Hill SE from the Pustá Ves settlement were described by Mello in Salaj et al. (1987). In the last locality , the formation rests on Middle Triassic Wetterstein Dolomite and it is in a tectonic contact with Eggenburgian conglomerates. Pebbles of these limestones were found in the Coniacian Valchov Conglomerate (Borza, 1962) and in the Karpatian Jablonica Conglomerate (Mišík, 1986). The Pustá Ves Formation is represented by brown biomicritic limestones with ostracods, gastropods, algae (*Munieria grambasti*, other characeans and several new freshwater taxa). Algal nodules attain a size of several centimeters in diameter. Cracks and desiccation pores occur frequently. The almost complete absence of terrigeneous admixture indicates shallow water lacustrine sedimentation on a pediplained surface of the Paleoalpine superficial nappe system. The freshwater origin of the Pustá Ves limestone was indicated by isotopic analyses of Kantor & Mišík (1992) from the Hrdlákova skala locality ($\delta^{13}C$= -9.49‰, $\delta^{18}O$= -7.87 ‰). The algal *Munieria grambasti sarda*, which is another indicator for fresh-water environment, was described from late Santonian / early Campanian sediments of the Austrian Eastern Alps (Schlagintweit & Wagreich, 1992) and the Hungarian Transdanubian Midmountains (Gellai & Toth, 1982). It was further recorded from Coniacian/Santonian sediments of the Slovakian Stratená Mts (Bystrický, 1978) and from the Romanian Borod Basin (Dragastan, 1978).

The Gosau-like Brezová Group sequence in the Brezová region begins with the **Valchov Conglomerate Member** (of the tripartite **Ostriež Formation**), lying on the eroded surface of the Triassic carbonates of the Jablonica Nappe. Its matrix is red. Sedimentological features point out a facies of braided rivers and subaerial deltas. The conglomerates contain local material derived almost exclusively from carbonate rocks. In the vicinity of Brezová they contain mostly Triassic and Lower Jurassic rocks, and pebbles of freshwater Schizophyta limestones, as well. However, the localities closer to the Pieniny Klippen Belt (near Bzince) contain also pebbles of „exotic“ rocks, redeposited from the „Upohlava“ conglomerates: rhyolites (maximum of 8 %, diameter to 25 cm), rarely basic volcanites, grey siliceous conglomerates containing vein quartz and quartzite clasts (with diameters up to 30 cm), Urgonian limestone with rare chromium spinel and Mid Cretaceous sandstone with partially euhedral quartz with zonally arranged inclusions, Barmstein Limestone with Upper Jurassic shallow water microorganisms (*Protopeneroplis striata*, *Anchispirocyclina lusitanica*, *Clypeina jurassica*). The matrix of the conglomerate is characterized by small rock fragments (dedolomitized dolomite lithoclasts), echinoderm skeletal fragments and chalcedony spicules of silicisponges. Several yellow clayey intercalations with dolomite clasts are inserted in the sequence.

The Valchov Conglomerate is heterochronous: while the Early Coniacian age is indicated by foraminifers close to Brezová, intercalations with Campanian microfaunas have been reported east of Bzince by Borza (1962). Laterally, the Valchov Conglomerate may be substituted by a thin layer of dolomite breccia. When streams or deltas were lacking on the ancient dolomitic seashore, the the Baranes Sandstone Member overlies directly the substratum. The southernmost erosional relics of the Senonian sequence crop out below the Korlátka castle near Rozbehy. They contain Upper Campanian carbonate conglomerates and breccias with *Orbitoides tissoti* (Köhler & Borza, 1984).

The Valchov Conglomerate is an equivalent of the Kreuzgraben Formation but probably also of the lower part of the Streiteck Formation of the Gosau Group in the Eastern Alps.

The conglomerates are overlain by the **Baranec Sandstone Member**. The sequence, 50–150 m thick, consists of thick-bedded (250–400 cm) coarse, indistinctly graded sandstones to microconglomerates. They represent sedimentary rhythms terminated by bedded (20–30 cm) sandstone with parallel or wavy bedding. The higher part of the sequence contains more frequent organic debris. It passes laterally into sandy limestone with *Actaeonella gigantea*. Heavy mineral spectrum (Salaj & Priechodská, 1987) is dominated by tourmaline, magnetite and ilmenite. Zircon, rutile, chlorite, chloritoid, amphibole and limonite occur subordinately, zoisite and garnets are rare. OBERHAUSER (1968) stated the presence of chromite.

The Ostriež Formation is capped by the **Štverník Marl Member** (150 m). Grey marls are intercalated by calcareous fine grained sandstones and fine conglomeratic beds. Fine muscovite leaflets and dispersed aleuritic quartz and calcite grains (up to 1 %) occur in the marl. Authigene minerals are represented by chlorite, tourmaline and apatite. The Late Coniacian foraminiferal microfauna is dominated by *Marginotruncana angusticarinata* and *Sigalia deflaensis* (Salaj & Samuel, 1966; Maheľ, 1987). Planktonic forms prevail (90 %) over benthic organisms. Small outcrops near the dam NW from the Baranec Hill yielded following foraminifers: *Sigalia deflaensis*, *Falsomarginotruncana pseudolineana* (Pessagno), *Falsomarginotruncana angusticarinata* (Gandolfi), *Dicarinella renzi* (Gandolfi), *Concavatotruncana concavata* (Brotzen). Benthic foraminfers (10 %) are represented by: *Stensioeina praeexculpta* (Keller), *Gyroidina praeglobosa* Brotzen, *Anomalina (Gavelinella) moniliformis* Reuss, *Anomalina (G.) ukrainica* Vassilenco, *Valvulineria lenticula* (Reuss), *Dorothia* *crassa* (Marsson), and *Verneuillina tricarinata* (d'Orbigny). Nannoplankton indicates the late Coniacian Micula decussata Zone, which is equivalent to the foraminiferal Sigalia deflaensis Zone (Salaj & Gašparíková, 1983).

The **Hurbanova Dolina Formation** is represented by a 500-600 m thick flysch sequence of alternating graded calcareous sandstones, sandy marls and sandy limestones. The Lower and the upper part correspond to outer platform environments, while agglutinated foraminifers and thin coal seams occur in the middle part of the sequence. Foraminiferal microfaunas of the *Sigalia carpathica*-, *Ventilabrella decoratissima*- and *Globotruncanita elevata* – Ventilabrella alpina zones, rich nannoplankton assemblages of the Tetralithus obscurus Zone (Salaj & Gašparíková, 1983), and gastropod-rich horizons and coal seams (Salaj & Priechodská, 1987) have been recorded. The mentioned authors correlated this formation with the Grabenbach Formation of the Northern Alps. Despite the brackish / limnic character of sedimentation in the upper part, they supposed sedimentary depth up to three thousands (!) meters. The association of heavy minerals is characterized by tourmaline, rutile, zircon, ilmenite, magnetite and chromite. Hyperstene, staurolite, zoisite, chlorite, chloritoid, pyrite and limonite occur subordinately, amphibole, epidote and garnets are rare.

The Lower Campanian **Košariská Formation** (Púchov Marl Fm) is characterized by variegated (mostly red) marls containing a foraminiferal microfauna („*Globotruncana* biomicrite“). It is dominated by planktonic forms of the Globotruncana Arca Zone. The rich nannoplankton assemblages correspond to the Early Campanian Broinsonia parca Zone (Bystrická et al., 1983). The formation is up to 50 m thick and resembles the Púchov Formation (Malinowa Formation of Birkenmajer, 1977), and the East-Alpine Nierental Formation (Wagreich & Marschalko, 1995). The association of heavy minerals consists of garnets and chromite.

Štúr (1860) described four localities in the environment of Púchov (north of the Hrabovka-, Vieska-Bezdedov-, Brezie- and Ihrište villages) with occurrence of Lower Campanian red marls. He named them Púchov Marl. Kantorová & Andrusov (1958) introduced the new term Gbelany Marl for variegated Lower Campanian marls. Birkenmajer (1977) questioned the valitidy of the name Púchov Marl and suggested a new name Malinowa Formation. According to SALAJ (1995), the Štúr´s name is correct and there is no reason to substitute it.

Generally, the Upper Campanian and Maastrichtian flysch sequences have high content of carbonate. They comprise calcarenite sandstones, sandy *Orbitoides* limestones, microconglomerates with „exotic“ pebbles and Inoceramus limestones. These formations comprise two separate facies belts:

1. The central zone is characterized by a prevalence of flysch sedimentation. The **Podbradlo Formation** (500 m) consists of calcarenite sandstones and Inoceramus marlstones with Middle Campanian (*Globotruncana arca*) and

Lowermost Maastrichtian (*Globotruncana falsostuarti*) foraminifers, rich nannoplankton and microconglomerate layers. The latter contain pebbles of mica schists, phyllites and diabases. The association of heavy minerals is dominated by zircon, rutile, limonite over hyperstene, epidote, tourmaline, chlorite, chromite, ilmenite and magnetite. Zoisite, garnets, staurolite and biotite occur rarely.

The **Bradlo Formation** is a flysch, 200 m in thickness. It represents the Maastrichtian part of the basinal sequence. In its lower Maastrichtian part clastic limestones called as the **Široké Bradlo Member are intercalated**. Beside prevailing bioclasts, it contains rare grains of quartz, tourmaline, garnets and disthene. The limestones form two bodies (Cp3 - Maa1; Maa1-3) separated by the **Mosnáčka Marlstone Member** (Maa1). It is identical with the facies occurring in the Gosau Basin near Grünbach in Eastern Alps (Salaj & Began, 1983). The formation terminates with the **Podlipovec Flysch Member**. This member is rich in tourmaline, zircon, magnetite, limonite. Epidote, zoisite, garnets, rutile, chlorite, apatite, and ilmenite occur seldomly.

The Paleogene sequence is represented by the Thanetian – Cuisian Lubina Formation. It may be subdivided by the basal U Kravárikov Conglomerate (with heavy mineral association resembling the Zwieselalm Fm of the Eastern Alps) and the Priepasné Flysch Member in upper part.

2. The external zone of the Paleoalpine Accretionary Belt is represented by the **Surovina Facies Belt**. The Upper Campanian and Maastrichtian **Polianka Formation** is 300 – 450 m thick, being characterized by a marly development with fine grained sandy input at the base and with frequent foraminiferal microfaunas. Its heavy mineral association is dominanted by zircon, rutile, tourmaline, chlorite, magnetite, limonite over chromite and other minerals. It is overlain by Middle Paleocene (Montian) to lower Eocene (Cuisian) Dedkov Vrch Formation of organogene sandstones and coralgal (Kambühel) limestones and by Lutetian Jablonka Formation of fine-rhythmic flysch with red clays on the base.

Remnants of Upper Cretaceous rocks in the Malé Karpaty Mts

The Malé Karpaty Mountain structure consists of several superposed nappe units comprising the Prealpine basement, its Mesozoic cover, superficial nappes and post-tectonic cover complexes. Crustal dissection produced by long-term extensional tectonic regime controlled Alpine Tatric dismembering into individual basement sheets. The Paleoalpine superficial nappes with their Upper Cretaceous and Paleogene post-tectonic cover were overprinted by Neoalpine back-thrust tectonics. During Miocene, with the opening of the Vienna and Danube basins, both the Paleogene and Lower Miocene complexes were incorporated into the Malé Karpaty horst structure (Michalík, 1984).

The nappe structure of the Biele Hory mountain group is covered by a sequence comparable to the Gosau Group of the Northern Calcareous Alps. Variegated breccias are filling smal cavities, fissures and depressions on the surface of carbonate complexes in this part of the mountains. They consist of mostly angular clasts derived from local material, cemented by yellowish and red argillaceous matrix. The breccias resting on Tatric and Fatric units and composed of several types of Mesozoic carbonate and clastic rocks (subordinately also of crystalline schists) with low content of matrix have been named as the **Bartalová Breccia**.

Another type of breccia type occurs on Triassic carbonates belonging to the Ötscher (?Göller) Nappe.This type which is named **Kržľa Breccia** consists of angular and semirounded clasts of Triassic Annaberg Limestone and Gutenstein Dolomite embedded in red argillaceous or clayey matrix. In several places, an alternation of this breccia with monomict dolomite breccia has been observed. In the Omlaď borehole and in the Sološnica quarry, the Kržľa Breccia is covered by the transgressive Upper Paleocene sequence.Činčura (1990, 1992) interpreted these sediments as Prae-Tertiary karstification products preserved in residual cave cavities.Gašpariková et al. (1992) found rests of globotruncanid (?) foraminifers and nannoplankton in breccias in a borehole mentioned above near to the Sološnica village.

However, 1.5 km to NE, on the top of the Mt Veľká Vápenná (Rauchsturm), pale fine grained limestone conglomerates to sandstones rest directly on red breccias and siltstones with ripplemarks, filling depressions and cavities in Middle Triassic limestones. The matrix of the Cretaceous limestones contains Lower Maastrichtian planktonic foraminifers. Remarkably, clasts of these limy sandstones were derived from shallow water Upper Jurassic limestones of the Tressenstein type, which are not preserved in the underlying Veterlín partial nappe.

Field stop 9: Baranec – Brezová p. Bradlom: Coniacian microfauna of the Štvernik Marlstones

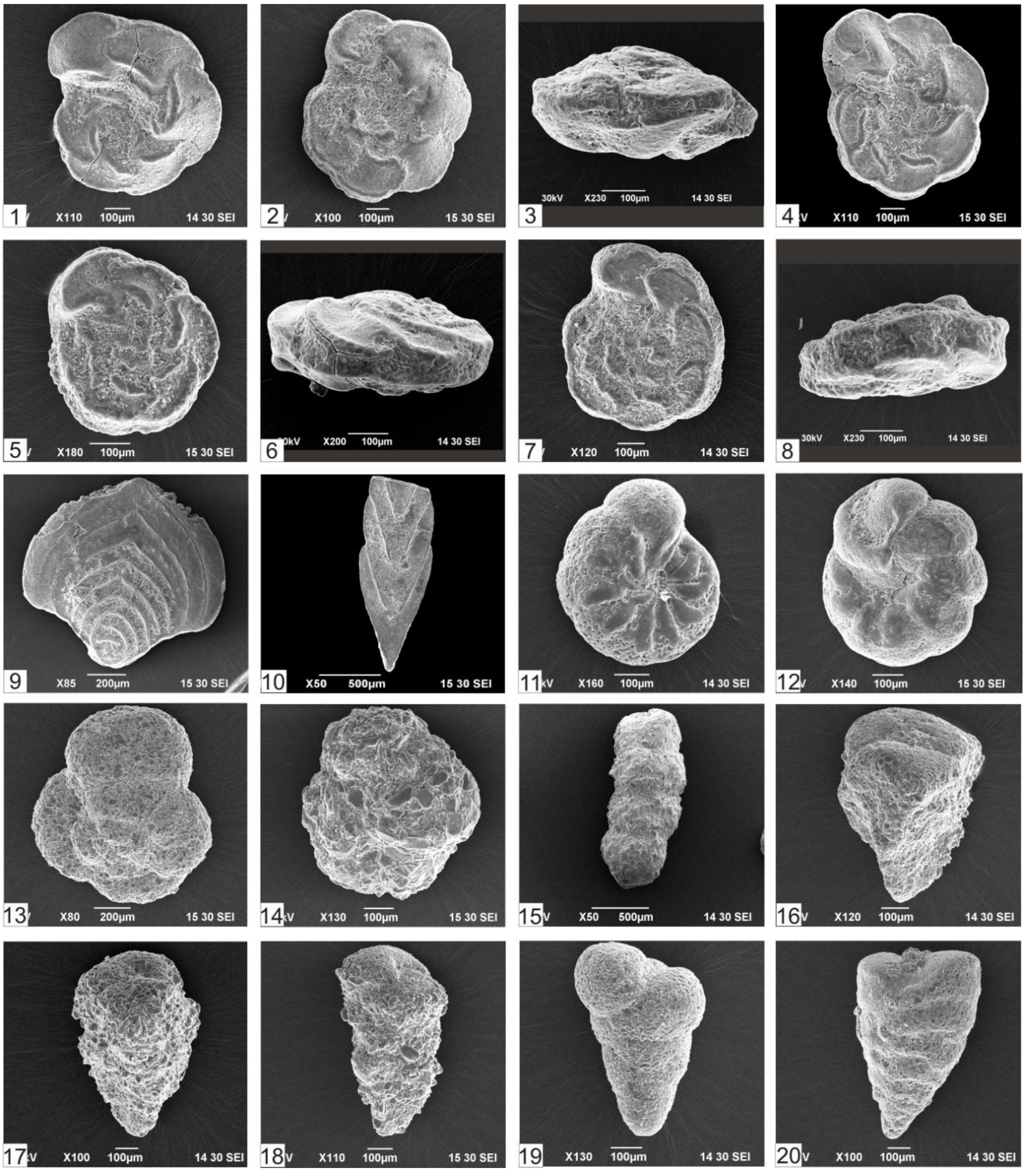
Ján SOTÁK

GPS: 48°39'47.7"N; 17°33'11.2"E

The deposition of Upper Cretaceous formations of the Brezová Group (equivalent of the Gosau Group in the Eastern Alps), began as basal conglomerates and breccias of the Valchov Conglomerate Member. These continental sediments overly the Triassic complexes of the higher Subtatric nappes (Jablonica nappe) and overlapped by transgressive shallow-neritic sediments of the Baranec sandstones (50–150 m thick). The Baranec sandstones lateraly pass into sandy limestones with gastropods *Actaeonella gigantea* and *A. laevis*. Early Coniacian age of the Valchov conglomerates and Baranec sandstones is inferred from younger sediments of Štvernik Marlstones, which contain Late Coniacian microfauna (Samuel et al. 1980). Foraminifers indentified in the Štvernik Marlstones (Fig. 49) belong species *Marginotruncana angusticarinata*, *Globotruncana linneiana*, *G. lapparenti*, *Dicarinella concavata*, *Marginotruncana coronata*, *M. renzi*, *M. desioi*, *Hedbergella infracretacea*, *Heterohelix globulosa*, *Plectofrondicularia vaughani*, *P. marreyae*, *Gavelinella ammonoides*, *G. praeinfrasantonica*, *Stensioeina praeexsculpta*, *Gyroidina praeglobosa*, *Anomalina (Gavelinella) moniliformis*, *Valvulineria lenticula*, *Gaudryina pyramidata*, *G. pseudocollinsi*, *Trochammina wetteri*, *Recurvoides* sp., *Reophax cylindricus*, *Marsonella oxycona*, *Praedorothia* sp., etc. (Pl. 7).

According to the index planktonic species, the Štvernik Marlstones belong to the Dicarinella Concavata Zone (Coniacian).

Fig. 49. Štvernik Marlstones. Outcrop of grey calcareous marlstones at the Baranec locality near Brezová pod Bradlom.



Pl. 7. Coniacian foraminifers of the Štvernik Marlstones. Locality Baranec near Brezová pod Bradlom, Brezovské Karpaty Mts 1–3: *Marginotruncana angusticarinata* (Gandolfi 1942); 4–6: *Globotruncana linneaina* d´Orbigny, 1839; 7, 8: *Globotruncana lapparenti* Brotzen, 1936; 9: *Plectofrondicularia vaughani* Cushman, 1927; 10: *Plectofrondicularia morreyae* Cushman, 1929; 11: *Gavelinella praeinfrasantonica* (Mjatliuk, 1947); 12: *Gavelinella ammonoides* (Reuss); 13: *Trochammina wetteri* Stelck & Wall; 14: *Recurvoides* sp.; 15: *Reophax cylindricus*, Wells, 1986; 16: *Gaudryina pyramidata* Cushman, 1926; 17, 18: *Gaudryina rugosa* d´Orbigny, 1840; 19: *Dorothia* sp.; 20 – *Marsonella oxycona* (Reuss, 1860).

Upper Cretaceous sequence of the Brezová Group ischanging upward to flysch-type sediments of the Hurbanová dolina Formation, which contain the Santonian association of foraminifers, like *Sigalia carpathica*, *Ventilabrella decoratissima*, *V. alpina*, *Neoflabellina deltoidea*, *Globotruncana fornicata*, *G. elevata*, *Gavelinella pseudoexcolata*, *Stensioeina exculta*, *Anomalina (Gavelinella) sculptilis*, etc.

Above the Hurbanová dolina Fm, there is a sharp transition into variegated and red-coloured marlstones of the Košariská Fm They might be correlated with the *Globotruncana*-bearing marls, which were denoted as Púchov Marls by Štúr (1860) or Gbeľany Marls sensu Liebus & Schubert (1903). Variegated marlstones of the Košariská Fm are also rich mainly in planktonic foraminifers, which belong to species *Globotruncana arca*, *G. scutilla*, *G. ventricosa*, *G. linneiana*, *Globotruncanita stuartiformis*, *Marginotruncana coronata*, *M. marginata*, *Ventilabrella glabrata*, *V. alpina*, *Heterohelix reussi*, etc. Benthic foraminifers are represented by the species of *Dorothia crassa*, *Verneuilina dubia*, *Neoflabellina rugosa*, *Pullenia reussi*, *Eponides frankei*, *E. heidingeri*, *Stensioenia exsculpta*, etc. The stratigraphic age of the Košariská Fm corresponds to the Globotruncana Arca Zone, which is equivalent to the Lower Campanian.

Campanian – Maastrichtian sediments of the Brezová Group are represented by Podbradlo, Bradlo and Polianka Formations. They are formed out of *Orbitoides*-bearing limestones (Široké Bradlo Lms.), *Inoceramus* marls (Mosnáčov Fm) and sandy marlstones and grey-greenisch marls with *Abathomphalus mayaroensis*, *Gansserina gansseri*, *Globotruncana falsostuarti*, *G. arca*, *G. ventricosa*, *Racemiguembelina varians*, etc.

Field stop 10: Hradište pod Vrátnom: Coarse clastic early Miocene transgressive facies of the Vienna Basin and microfauna of the Lužice Fm

Samuel RYBÁR, Andrej RUMAN, Natália HUDÁČKOVÁ, Michal ŠUJAN, Tomáš KLUČIAR and Petronela NOVÁKOVÁ

GPS: 48°38'12.9"N; 17°29'45.0"E

The outcrops are found in a quarry north from the Hradište pad Vrátnom village. This quarry lies directly on the border between the Brezovské Karpaty Mts and Vienna Basin (Fig. 50). This locality was previously studied by Baráth and Kováč (1988) who draw some conclusion on the paleoenvironment and the occurring trace fossils. Based on the geological map of Káčer et al. (2005) the locality is ranked into the Podbranč conglomerate Member (Lužice Formation). Baráth and Kováč (1988) and Vass (2002) describe these sediments as conglomerates to breccias with clasts reaching from pebble to boulder size. The Eggenburgian age is, unfortunately, extrapolated from the Podbranč section where a characteristic pectenid assemblage occurs (Andrusov, 1938; Čtyroký, 1959).

The outcropping clastic sediments onlap onto the pre-Neogen (Triassic) basement discordantly (Fig. 50A, B). The basement rocks are exclusively composed of dolomites (Hauptdolomite). Overlaying Eggenburgian sediments are arranged in multiple cycles. The cycles may be divided into two distinct groups (lower and upper). The lower group is represented by megabreccias which pass into poorly rounded and poorly sorted conglomerates (Fig. 50B, C). Surface of the breccia boulders is intensively eroded by trace fossils (bivalves, sponges; Fig. 50D). Beds are occasionally moderately inclined and arranged into foresets. The upper cycles consist of steeply inclined, S to SW dipping, coarse grained sandstones and conglomerates. The pebbles are well rounded and sorted. The sandstones are massive, and the conglomerates show normal to inverse gradation.

Onlaps of the coarse clastic sediments indicate a transgressive contact, but tectonics probably played and equal if not the key role in the creation of this accommodation space. The megabreccias point to a major fault scarp degradation taking place at active cliffs. The overlaying, normal to inverse graded conglomerates point to a mass gravity transport occurring at a fandelta foresets. These fandeltas were sourced by the ongoing erosion of the preexisting dolomitic footwall (Fig. 51). Additionally the marine environment is supported by the presence of abundant bioturbation documented by Baráth and Kováč, (1988).

Our study can confirm some of the conclusions of Barát and Kováč (1988), especially the documented sedimentary textures, structures, and the interpretation of active cliffs. Nonetheless, we speculate that the interpreted "rocky medio and infralittoral" is inaccurate for the upper group of sediments. For this group of sediments we propose deposition by mass gravity movements on numerous major fandelta foresets. These sediments then entered a narrow juvenile, starved depocenter of the NE Vienna Basin.

In conclusion we can distinguish two distinct sedimentary paleoenvironments stacked above each other. 1. Megabreccias associated with a fault scarp degradation on active cliffs 2. Alteration of steeply dipping sandstones and conglomerates connected to fandelta foresets.

Sediments studied in this locality were barren for foraminiferal microfossils. Nonetheless in multiple wells from the Slovak part of the Vienna Basin, the Eggenburgian sediments were sporadically recorded in the Bresty 1, Bištava 3 and Koválov 5 (in the depth of around 800 m resp. 950 m), Šaštín 11, 12, 13, and Lakšárska Nová Ves 2,3,4,5,6,7 wells (in the depths of 1500-2000 m). In the mentioned wells the Eggenburgian deposits consisted mainly from mudstones, muddy sands and sands. On the base of this sequence a green glauconitic conglomerates was documented. The analyzed samples from these wells yielded a very poor assemblage of benthic foraminifers (*Heterolepa dutemplei, Fontbotia wuellerstorfi, Bolivina antiqua, Lingulina costata, Cibicides* sp. and *Elphidium* sp.).

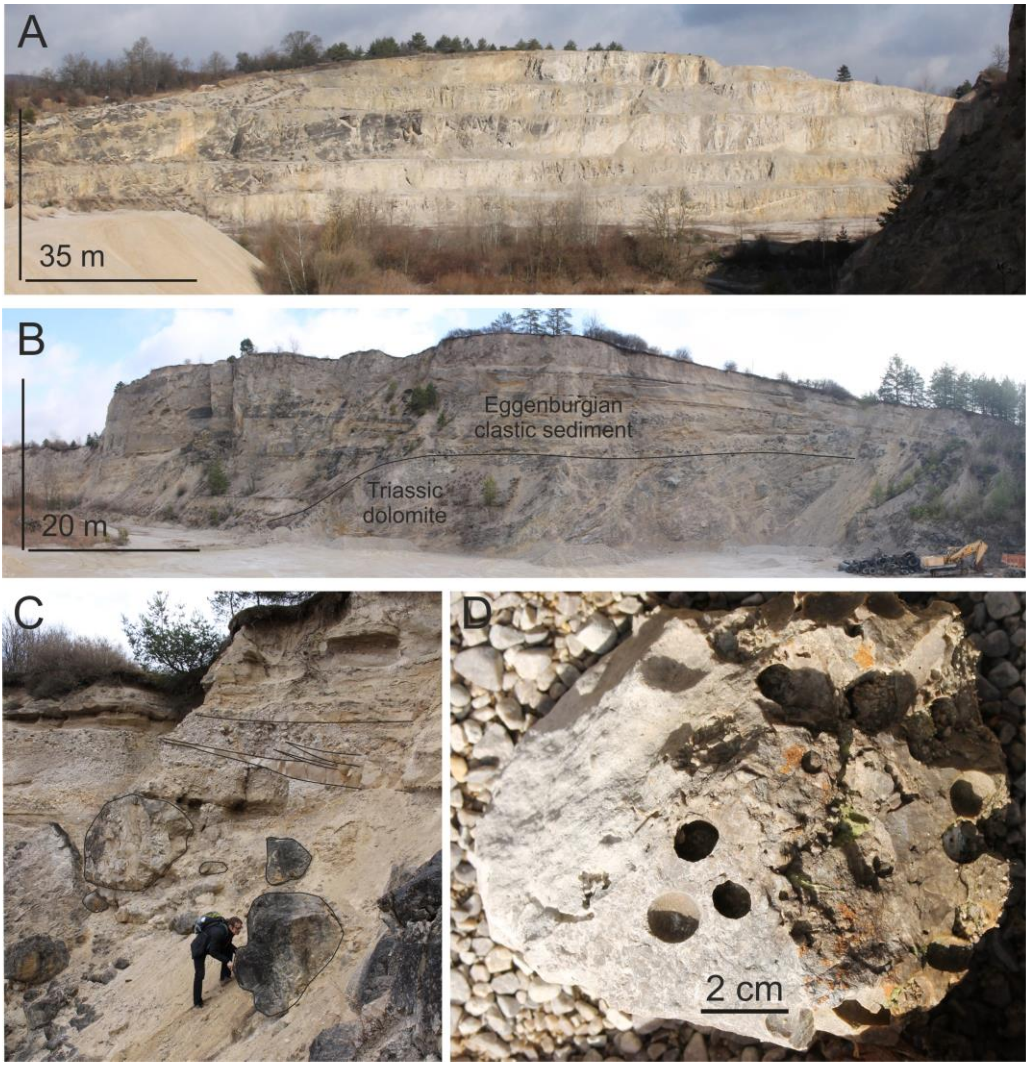


Fig. 50. A: South quarry wall; B: West quarry wall with highlighted contact between the Triassic dolomites and Eggenburgian clastics; C: Highlighted contact between the megabreccias and steeply inclined sandstones and conglomerates; D: Trace fossils.

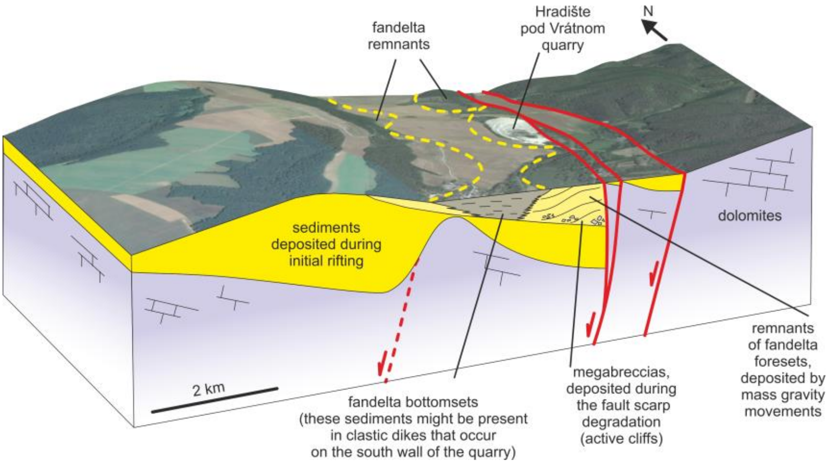


Fig. 51. Block-diagram of the facies distribution in the vicinity of the Hradište pod Vrátnom quarry. Topography adopted from Google Earth software.

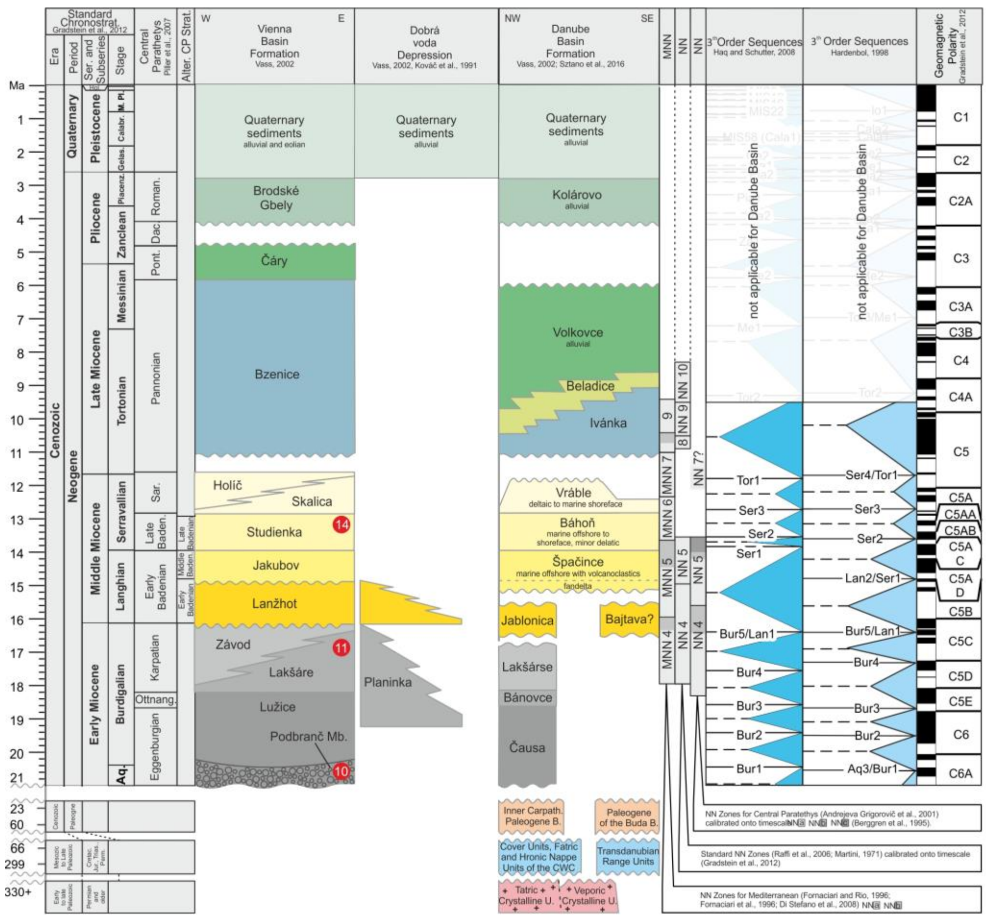


Fig. 52. Lithostratigraphic column of the Neogene formations of the Vienna Basin and their correlation with the Danube Basin. Field trip sites are marked in the Vienna Basin.

Field stop 11: Cerová-Lieskové: Karpatian (late Burdigalian) microfauna of the deep-water calcareous clays

Natália HUDÁČKOVÁ, Andrej RUMAN and Ján SCHLŐGL

GPS: 48°35'18.6"N; 17°24'09.3"E

Fig. 53. Main outcrop face of the locality.

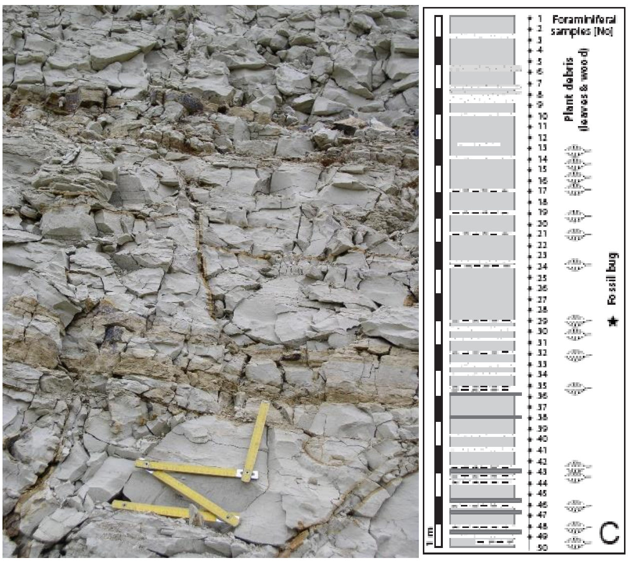


Fig. 54. Detailed photo of the beds focused on the tempestite layers.

Cerová-Lieskové village (Fig. 53) is located at the foothills of the Malé Karpaty Mountains (N–E Vienna Basin). During the Miocene, this NNE–SSW sedimentary basin was part of the Central Paratethys. Here outcropped uppermost Burdigalian (equivalent of Karpatian in the Paratethyan stratigraphic chart, Harzhauser and Piller, 2007) deposits are massive, locally laminated calcareous clay and clayey silt with thin tempestites (up to 5 mm thick) of the Lakšárska Nová Ves Formation (Špička and Zapletalová, 1964). In the uppermost part of the section are abundant plant remains and several thin sandstone and several intercalated thin sandstone layers (Fig. 54). The relief of the Vienna Basin during the Karpatian is difficult to reconstruct because of the later tectonic reconfiguration of the whole Carpathian area. Based on recent studies, it appears however that the sea floor of the basin was very irregular, with several submarine elevations (ridges), representing tilted blocks of underlying Alpine and Western Carpathian units (Fodor, 1995), which probably started to uplift at that time. The Cerová-Lieskové locality was situated on the slope of such a submarine elevation (uplifting Male Karpaty Mts).

Fifty samples were collected from the section with a sampling spacing of ~40 cm for benthic and planktic foraminiferal analyses. Associated microfossils including radiolarians, ostracods, fish otoliths, coleoid statoliths, bathyal shark teeth and diatoms were also found in the samples (Fig. 55). Macrofossils include vertebrates (fishes) and invertebrates (small sized bivalves and gastropods, scaphopods (Harzhauser et al., 2011), nautilids, coleoids, regular and irregular echinoids, brittle stars, siliceous sponges and crustaceans (Hyžný and Schlögl, 2011). Plant debris, wood fragments, well preserved leafs and even spikes are present too. At least 2 demosponge species (most probably belonging to Polymastidae, Hadromedrida) are preserved intact but flattened (Lukowiak et al. 2014). Other exceptionally preserved fossils are nautilid jaws with chitinous lamellae still present, similarly preserved coleoid jaws, organic black bands around the nautilid shell edge (Schlögl et al., 2011), articulated skeletons of several *Callianopsis* species, articulated isopod moults with both parts of the exoskeleton preserved in situ (Hyžný and Schlögl, 2011). Mollusc shell microstructures have been analysed under secondary electron microscopy (SEM) and the crystallographic nature of shell carbonate was analyzed using Raman spectroscopy (Jobin Yvon, HR800), both proved the fossils are exceptionally well-preserved.

A plant assemblage of Cerová-Lieskové is preserved in a relatively deep, upper-slope marine environment with high sedimentation rates. The plant assemblage consists of conifers represented by foliage of *Pinus hepios* and *Tetraclinis salicornioides*, a seed cone of *Pinus* cf. *ornata*, and by pollen of the *Cupressaceae, Pinaceae, Pinus* sp. and *Cathaya* sp., angiosperms are represented by *Cinnamomum polymorphum, Platanus neptuni, Potamogeton* sp. and lauroid foliage, by pollen of *Liquidambar* sp., *Engelhardia* sp. and *Craigia* sp., in particular also by infructescences (*Palaeotriticum* Sitár, including *P. mockii* Sitár and *P. carpaticum* Sitár, probably representing herbaceous monocots that inhabited coastal marshes, similar to the living grass *Spartina*). This plant assemblage demonstrates subtropical climatic conditions in the Vienna Basin with paleovegetation represented by evergreen woodland with pines and grasses in undergrowth, similar to vegetation inhabiting coastal brackish marshes today (Kvaček et al. 2014)

A late Karpatian age of the deposits is determined based on the co-occurrence of the foraminiferal taxa *Uvigerina graciliformis* and *Globigerinoides bisphericus*, and the absence of *Praeorbulina*. The Lowest Occurrence (LO) of *U. graciliformis* delineates the base of the Karpatian stage, the LO of *G. bisphericus* occurs within Zone M4b of Berggren et al. (1995) and correlates with the late Karpatian, and the LO *of Praeorbulina* occurs at the base of the Badenian stage (Cicha and Rögl, 2003). The Karpatian is consistently considered to be timeequivalent to the latest Burdigalian.

Planktic foraminiferal associacion is composed mainly of temperate shallow dwellers, globigerinids – *Globigerina praebulloides* and *G. bulloides* accompanied by tenuitellinids, locally with mass abundances of *Casigerinella boudecensis*. Warm to temperate water taxa as *Globigerinoides bisphericus* (sensu Cicha et al. 1998) and *G. triloba* are rare.

Benthic foraminiferal assemblages are dominated by infauna to deep infauna (Fig. 56). *Bolivina fastigia*, *Bolivina hebes*, *Bulimina marginata*, *Bulimina elongata* and *Uvigerina* spp. represent dysoxic–suboxic index species. Only in the rare sedimentary layers in the upper part of the profile the oxiphylic genera *Cibicides* and *Cibicidoides* occur. Analysed 35 samples from upper two thirds of profile yield Kaiho´s (1994) BFOI index values ranging from −30 to −20 when oxic indicators are absent, and from 2.2 to 4.2 when oxic indicators are present. BFOI index values between 0 and 15 correspond to DO (dissolved oxygene) ranging from 1.2 to 2 ml/l, and are classically seen as dysoxic or low oxic conditions (e.g., Tyson and Pearson, 1991). Paleodepth analyses (following Hohenegger, 2005) allow us to estimate water depths of 240– 330 m. Based on the methods of Murray (1973, 1991), samples show Fisher α values ranging from 5.5 to 8 and Shannon H values from 1.9 to 2.6 typical for the shelf and deep sea assemblages.

In the lower part of the profile specimens of *Bathysiphon filiformis* (Fig. 55) are very abundant and reach of big dimensions. This assemblage probably represents recolonization after slips of shallower siliciclastic material from the onshore sedimentary facies. They are accompanied by *Spiroloculina canaliculata*, *Lenticulina calcar* and *Uvigerina* sp.

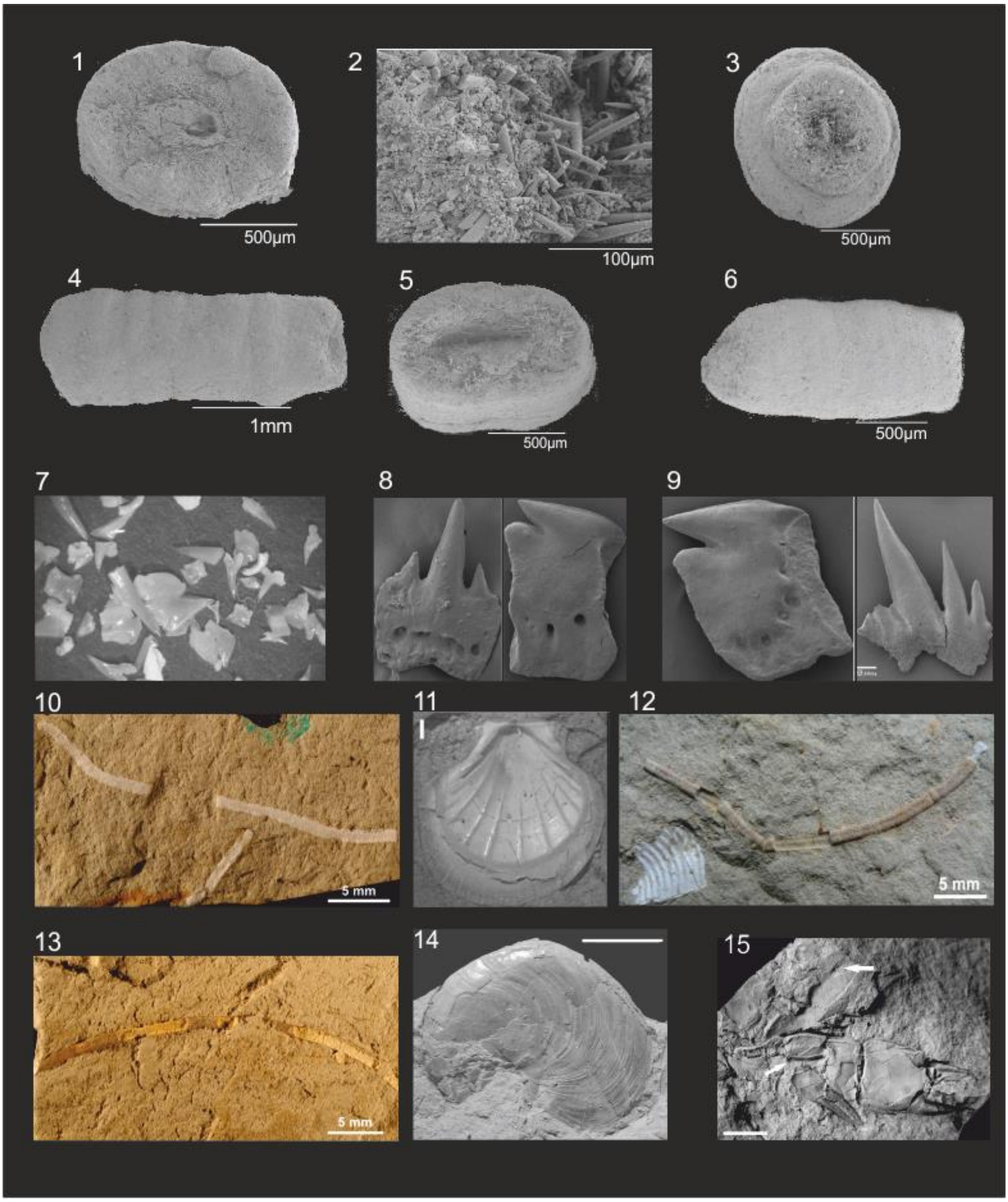


Fig. 55. Karpatian (late Burdigalian) fauna from calcareous clays in the Cerová-Lieskové locality. 1, 2, 3, 4: *Bathysiphon filiformis* Sars, CL 14; 5, 6: *Bathysiphon filiformis* Sars, CL 16; 7: fish teeth, CL 17; 8, 9: Miocene squaliform sharks *Etmopterus* and *Miroscyllium* sp. CL 17-18; 10: *Bathysiphon filiformis* Sars, CL 13-14; 11: *Parvamusium felsineum* (Foresti) CL 16-17; 12: *Bathysiphon filiformis* Sars, CL 16-17 with *Balantium collina* (Janssen and Zorn); 13: *Bathysiphon filiformis* Sars, CL 24; *Aturia* sp. CL 19; 15: *Callianopsis marianae* Hyžný and Schlögl

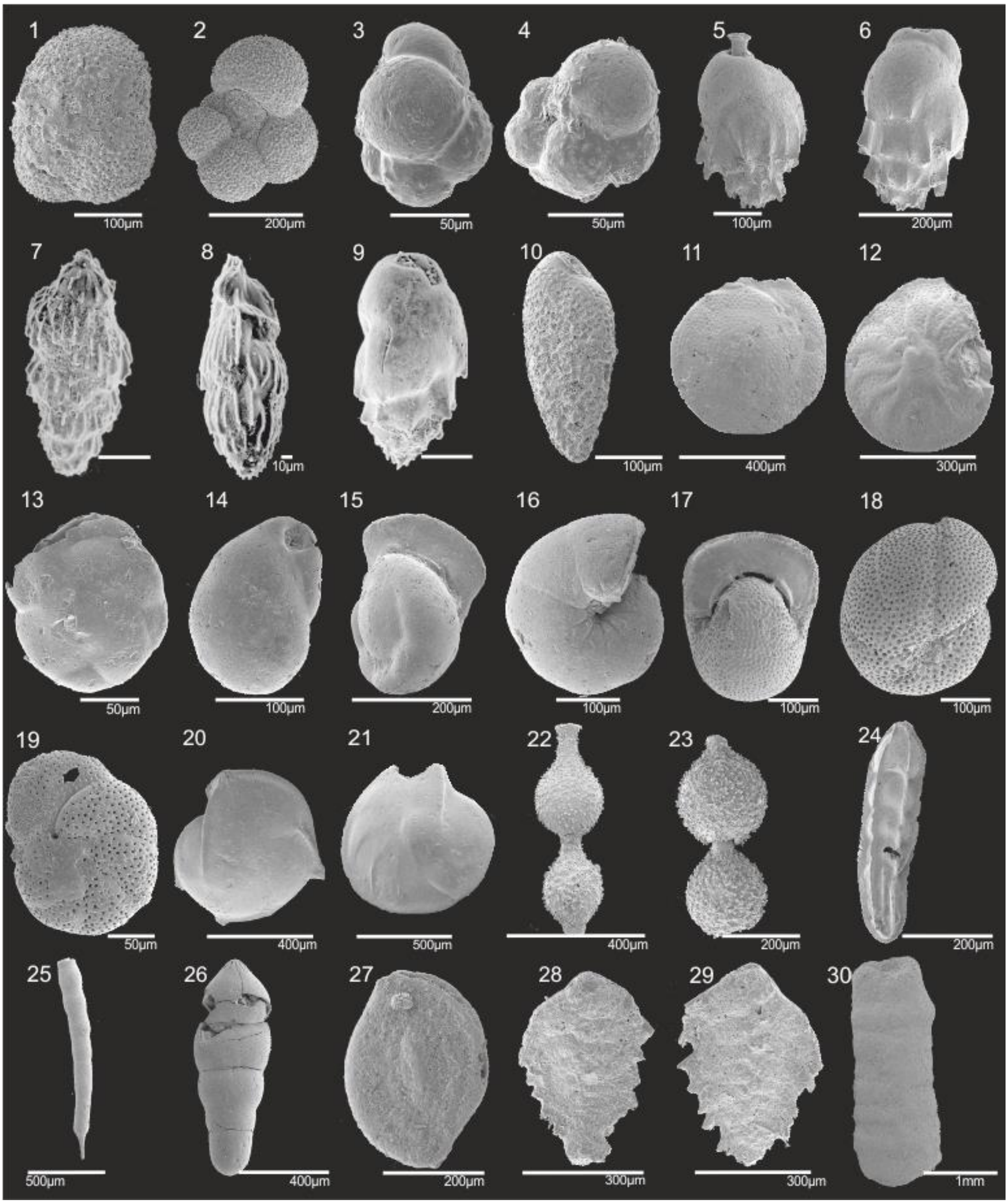


Fig. 56. Karpatian (late Burdigalian) foraminiferal microfauna from calcareous clays in the Cerová Lieskové locality (most common taxa). 1: *Globigerinoides* sp., CL42; 2: *Globigerina bulloides* d'Orbigny, CL41; 3, 4: *Cassigerinella boudecensis* Pokorný, CL41; 5: *Uvigerina acuminata* Hosius, CL45; 6: U. cf. *uniseriata* Jedlitschka, 7: *U. graciliformis* Papp et Turnovsky CL 16; 8: *Trifarina* cf. *angulosa* (Williamson, 1858), CL6; 9: *Bulimina buchiana* d'Orbigny CL41; 10: *Bolivina hebes* Macfayden CL42; 11: *Heterolepa dutemplei* (d'Orbigny) CL14; 12: *Cibicidoides ornatus* (Cicha et Zapletalová) CL16; 13: *Cassidulina laevigata* d'Orbigny, CL41; 14: *Globocassidulina subglobosa* (Brady) CL16; 15, 16: *Hansenisca soldanii* (d'Orbigny) CL16; 17, 18: *Melonis pompilioides* (Fichtel & Moll) CL 13; 19: *Valvulineria complanata* (d'Orbigny); 20: *Lenticulina* cf. *clypeiformis* (d'Orbigny) Cl 14; 21: *Amphicoryna*

hirsuta (d'Orbigny), CL 14; 22: *Chrysalogonium rudis* (d'Orbigny) CL32; 23: *Plectofrondicularia digitalis* (Neugeboren), CL 13; 24: *Laevidentalina elegans* (d'Orbigny) CL 13; 25: *Pseudonodosaria brevis* (d'Orbigny) CL 13; 26: *Spirosigmoilina tenuis* (Czjzek) CL 42; 27, 28: *Spirorutilus carinatus* (d'Orbigny, 1846) CL 43; 29: *Bathysiphon filiformis* Sars CL 45.

Field stop 12: Kršlenica in Plavecký Mikuláš village Ladinian – Carnian limestones of the Veterlín Nappe and their microfauna

Jozef MICHALÍK and Ján SOTÁK

GPS: 48°30'29.6"N; 17°18'24.9"E

Fig. 57. Panoramic view on the southern slope of the Kršlenica Hill.

Northern part of the Malé Karpaty Mts is formed by nappe slices pile, thrust backward on the margin of central western Carpathians (Michalík 1984, Plašienka et al. 1991). These bodies (designed as the “higher” nappes, namely Veterlín-, Havranica- and Jablonica nappes) consist of huge Triassic carbonate sequences similar to these preserved in the Ötscher- or the Göller nappes of the Northern Limestone Alps.

The Ladinian/Carnian sequence represents non-terrigenous clastic infilling of a tensional basinal system in external rim of the Alpine-Carpathian carbonate shelf (Michalík, 1993, 1994). During Early Carnian, basinward prograding reef front (preserved in the Havranica partial nappe) filled the basin (nowadays in the Veterlín partial nappe) by a slope talus megabreccia (Michalík et al., 1999). In contrary with similar situation in the South-Alpine St Cassian Basin, the bottom of the Veterlín Basin has been covered by fine carbonate debris not resistant to dolomitization fluids (instead of clay matrix which enabled unique fine preservation of the famous Cipit blocks).

The middle part of the Kršlenica section (Fig. 60) developed in a slope facies yielded findings of *Gondolella polygnathiformis* Budurov & Stefanov, *Gladigondolella tethydis* (Huckriede) and other conodonts (Papšová in Michalík et al., 1993). According to Vrielynck (in de Graciansky et al., 1998), the co-occurrence of the two former species is typical of the Aonoides- and Austriacum zones of Early Carnian. On the other hand, the occurrence of foraminifer *Aulotortus pregaschei* (Koehn-Zaninetti) along with sporadic *Galeanella* cf. *panticae* higher up in the section indicates early Late Carnian age of the prograding platform wedge sediments containg the coral fauna. This fauna is composed of Protoheterastraeidae (*Protoheterastraea, Carpathiphyllia* gen. n., *Pontebbastraea* gen. n.), Volzeiidae (*Volzeia*), Margarophylliidae (*Margarosmilia*), and Stylophyllidae (*Protostylophyllum* gen. n.). These are characterized either by particular (minitrabecular, and non-trabecular, i.e., fascicular: Roniewicz 1989, Roniewicz & Morycowa 1989, 1993) microstructures or by large-scale features (thick wall, tabuloid endotheca). According to Roniewicz & Morycowa (1993), such a faunal composition is typical of the pre-Alaunian time.

With the exception of *Carpathiphyllia regularis* sp.n., all species of this fauna strongly resemble this from the Cipit limestone boulders from marly S. Cassiano Formation in the Dolomites, Southern Alps. The age of these deposits is estimated to be early Late Carnian (Russo et al., 1991). The taxonomic affinity of the Malé Karpaty fauna and that of the Dolomites one suggests that both faunas lived in close geographical proximity each to other. This affinity is interesting from the ecological point of view, too: due to different environments in which the faunas developed, the coral-bearing deposits of both the regions were of different facies. The Veterlín reef builders were mostly represented by *Tubiphytes obscurus*, *Thaumatoporella porostromates*, calcareous algae, sponges and other organisms. Although the corals lived rather subordinately in the inner part of the reef only, a small collection under examination obtained from light, hard biodetrital limestone came from a diversified fossil assemblage (Fig. 58), as the only eight found specimens represent as many as six different genera. The fauna consists of four solitary species and two others with a phaceloid growth form. Although variable in taxonomic composition, this fauna belongs to a non-reef category due to solitary and phaceloid growth forms and epithecal walls of corals. These features characterise rather a low hydrodynamic environment (Roniewicz & Stolarski 1999), (Fig. 59).

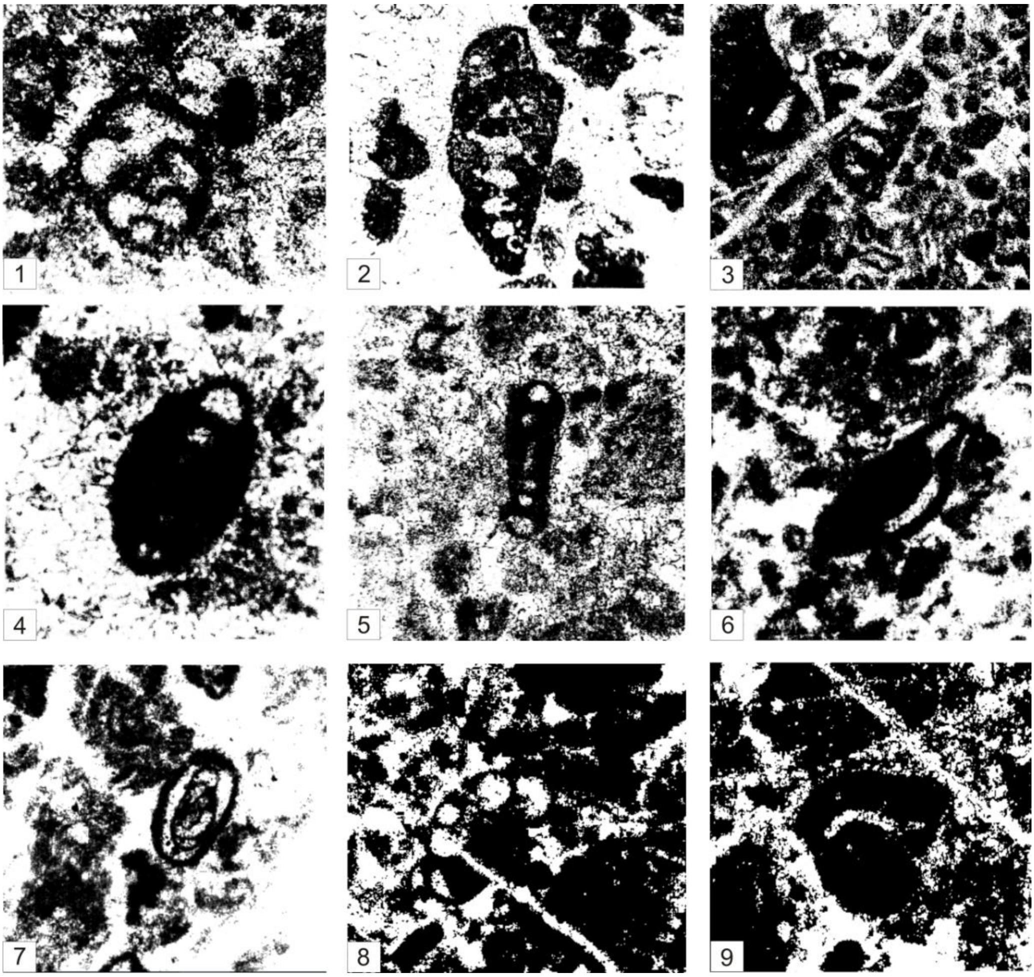


Fig. 58. Foraminiferal microfauna from the Ladinian/Carnian limestones of the Veterlín reef complex (Loc. Kršlenica, Veterlín, Jablonica). 1: *Valvulina azouzi* Salaj; 2: *Reophax* aff. *tzankovi* Trifonova; 3: *Paleolituonella meridionalis* Lupert; 4: *Ophthalmidium* cf. *triadicum* (Kristan); 5: *Arenovidalina amylovoluta* Ho; 6: *Ophthalmidium fusiformis* (Trif.); 7: *Gsolbergella spiroloculiformis* (Oravec-Scheff.); 8: *Oberhauserella* aff. *alta* Fuchs; 9: *Galeanella* aff. *panticae* Koehn-Zanin, & Broen.

Despite of abundant coral findings of the Ladinian-Carnian span of time, which have been reported from several European localities, only those from Italy (Dolomites) have a complete palaeontological documentation, thanks to perfectly preserved aragonitic coral skeletons (Cuif 1977, or Montanaro-Gallitelli 1976). Kolosváry´s data (1957, 1958 ab, 1963, 1966), who studied Ladinian/Carnian corals from Slovakia, and among others these from the Malé Karpaty Mts, need a re-examination, as his descriptions and illustrations are insufficiently treated and do not permit adequate comparisons. New coral findings in the Wetterstein facies of the Veterlín and Havranica partial nappes

(Roniewicz & Michalik, 2002) enabled stratigraphical correlation between both West Carpathian and South Alpine coral-bearing beds.

Fig. 59. Hydrozoan growths in reefal part (bed No 40) of the Kršlenica section.

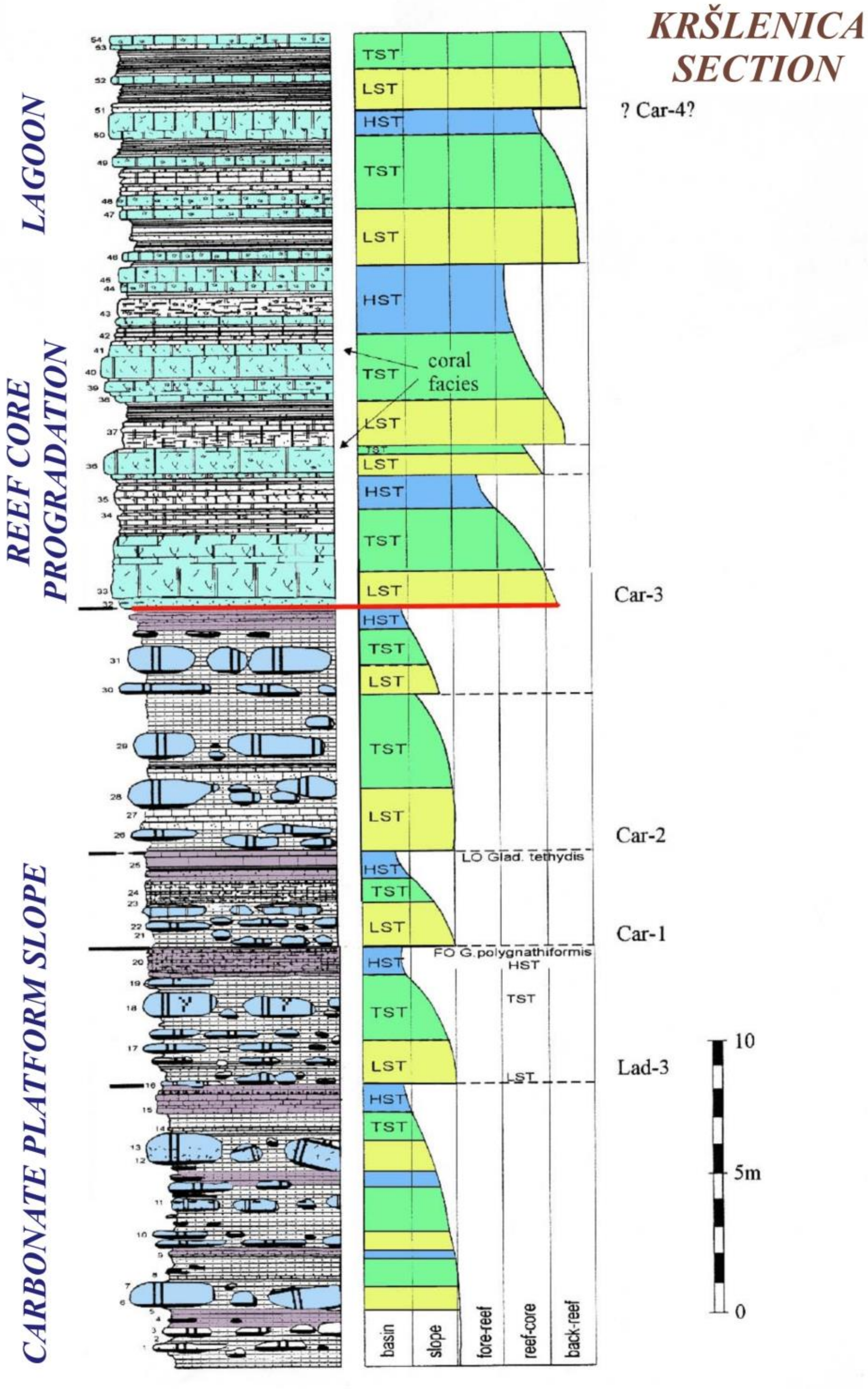


Fig. 60. The Kršlenica section: a correlation of lithological log with important faunal occurrences.

Field stop 13: Sološnica - Jelenia hora - Mt Roštún (Veľká Vápenná): Paleocene – Early Eocene transgressive formations with large foraminifers

Ján SOTÁK and Jozef MICHALÍK

GPS: 48°45´47.73″N; 17°23´81.88″E

Fig. 61. General view to Sološnica quarry with Ypresian sandy limestones underlying by Kržľa-type breccias and the Annaberg limestones (in the left).

Post-nappe formations of the Malé Karpaty Mts are related to Gosau sedimentary cycle and accomodation of the Buková Paleogene Basin. Pre-transgressive formations are formed by breccia-type sediments (so-called Bartalová and Kržľa Breccia) and various fissure-filling and paleokarst sediments (Fig. 61). The internal sediments of paleokarst fissures are formed by red-coloured calcisiltites and calcisparites with regoliths, prismatic algal aggregates of *Microcodium*?, Fe-oxides, etc. Marine fissures at the Mt Roštún (Veľká Vápenná) are filled by *Globotruncana*-bearing micritic sediments, which contain the clasts of the Jurassic shallow water limestones with *Clypeina jurassica*, Upper Cretaceous intraclastic and pisolitic limestones. Senonian age of these dykes is indicated by planktonic species like *Globotruncana linneiana*, *Contusotruncana* sp., *Globotruncana* cf. *falsostuarti*, etc., but their possible redeposition is also constrained.

Different type of fissure fillings is formed by shallow-water sediments with corraline alge, coated grains and initial ooids, miliolid foraminifers

(*Miliola* sp., *Pyrgo* sp.), serpulid worms, thick-walled bivalves and thithoclasts of volcanic rocks (paleobasalts). These limestones also contain large foraminifers of the Miscellaneidae, which allow to determine their Paleocene or Early Eocene age. The Miscellaneidae are represented by species of *Miscellanea miscella* (d´Archiac & Haime, 1853), *M. yevettae* (Leppig, 1988) and *Miscellanites iranicus* (Rahaghi). Triassic carbonates complexes of the Veterlín Nappe were fractured, karstified and infiltrated by Senonian pelagic sediments and later by Paleocene platform-type sediments.

Karst-formed surfaces on the Mesozoic units were flooded during the Ypresian transgresion, as well. This is well documented on the field-stop 13 - Sološnica quarry. The Triassic limestones of the Veterlín Nappe were uplifted, exposed and karstified in Pre-Ypresian time. The Annaberg limestones in right-side of the quarry are strongly fractured, brecciated and deeply infiltrated by red soils. This provided an evidence of continental weathering and karstification before the Paleogene transgression.

The new sedimentary cycle is represented by the sandy limestones of the Jelenia hora Formation, which discordantly overlain the Kržľa Breccias and Triassic limestones. The stratigraphic age of the was determined on the basis of nummulitids, alveolinids and another large foraminifers of the sandy limestones. Among abundant nummulitids, the following species were determined (Vaňová, 1963): *Nummulites burdigalensis burdigalensis* Harpe, *N.* cf. *inkermanensis* Schaub and *N. partschi partschi* Harpe. They are associated with *Assilina placentula* (Deschayes), *Discocyclina* sp., *Orbitoclypeus* sp., etc. Based on mentioned species, the Nummulites-bearing limestones in Sološnica quarry belong to the early Eocene (Vaňová 1963). Köhler (in Gross & Köhler, 1989) assigned the large foraminifers from these limestones to Early Eocene (Cuisian) assemblage with *Nummulites burdigalensis* Harpe, *N. partschi* Harpe, *N. aquitanicus* Benoist, *Assilina plana* Schaub, *Discocyclina archiaci* (Schlum.), etc.

Sandy limestone and calcareous sandstones in Sološnica quarry belong to the Jelenia hora Formation, which represent the basal sediments of the Buková Paleogene basin (Malé Karpaty Group *sensu* Buček 2012). This formation is composed of various clastic, organodetrital and organogenic sediments with coralline algae, corals, bryozoans, sesile foraminifers (*Miniacina* sp., *Acervulina* sp.), agglutinated foraminifers (*Haddonia praeheissigi* Samuel, Köhler & Borza, *Haddonia heissigi* Hagn), etc. (see Buček 2012). Large foraminifers from basal formations of the Malé Karpaty Mts comprise of Ilerdian association with *Nummulites atacicus* Leymerie, Cuisian association with *Nummulites burdigalensis* Harpe and Early Lutetian association with *Nummulites* aff. *gallensis* Heim (Köhler in Gross & Köhler, 1989). According to Buček (2012), the nummulitic species of the Jelenia hora Formation belong to shallow-water benthic zones from SBZ 6? to SBZ 12 (*sensu* Sierra-Kiel et al. 1998), which correspond to Latest Thanetian to Late Ypresian (Fig. 62).

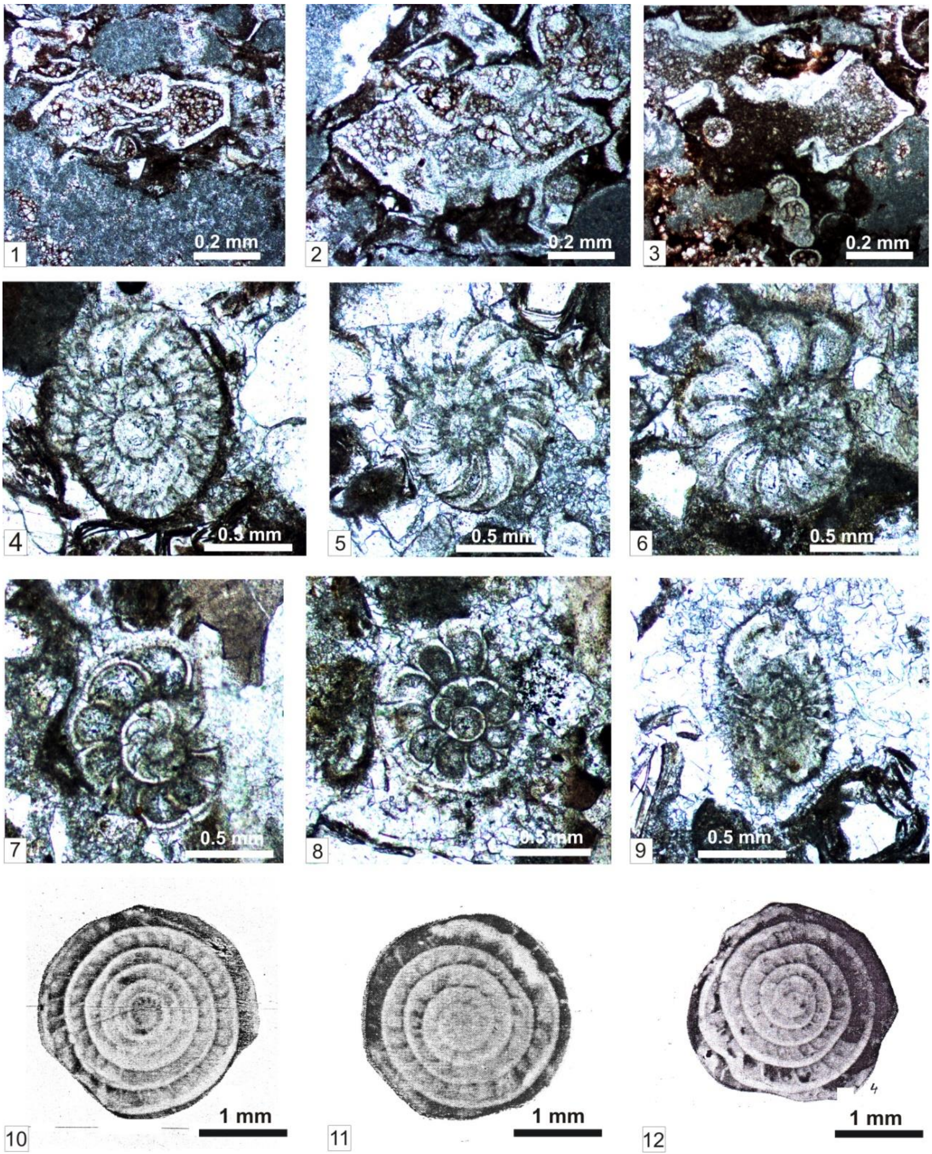


Fig. 62. Foraminiferal microfauna from the fissure-filling sediments in the Mesozoic limestones of the Veterlín Nappe (1–9: Locality Mt Roštún) and basal sediments of the Paleogene formations of the Malé Karpaty Mts (Jelenia hora Fm, 10–11, Locality Sološnica quarry, adopted from Vaňová, 1962). 1: *Globotruncana linneiana* d´Orbigny, 1839; 2: *Globotruncana falsostuarti* Sigal Em Dupeuble, 1969; 3: *Globotruncana* sp.; 4: *Miscellanea miscella* (d´Archiac & Haime, 1853); 5–6, *9: Miscellanea* aff. *yvettae* Leppig, 1988; 7–8 *Miscellanea* aff. *juliettae* Leppig, 1988; 10–11: *Nummulites burdigalensis* Harpe, 1926; 12: *Assilina placentula* (Desh., 1838).

Field stop 14: Hrabník pit near Sološnica: Late Eocene – Oligocene microfauna of the turbiditic formations of the Buková Depression

Ján SOTÁK and Jozef MICHALÍK

GPS: 48°27'27.1"N; 17°13'37.6"E

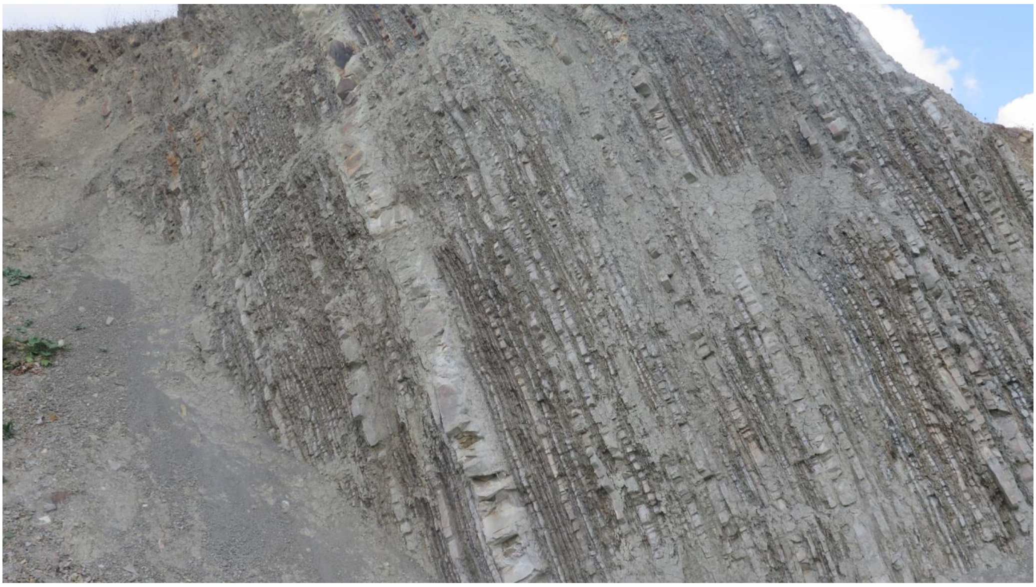
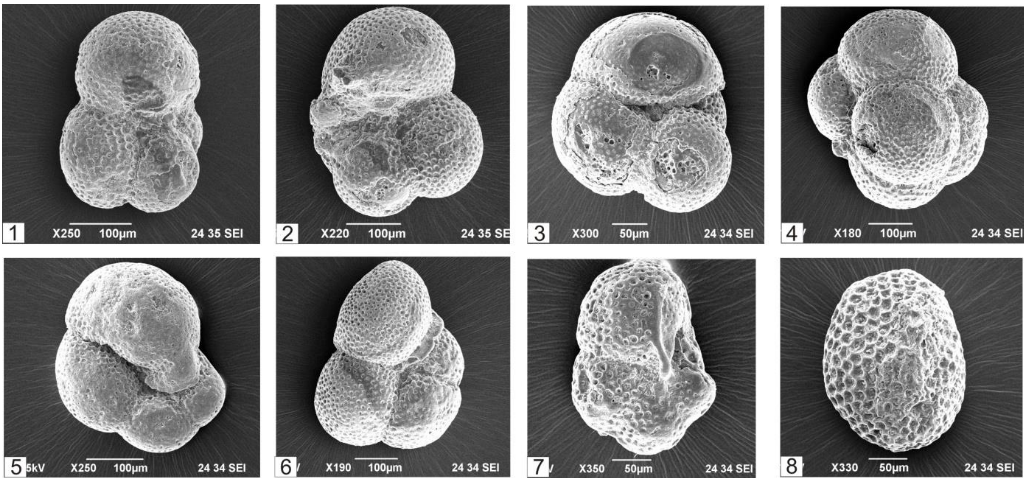


Fig. 63. Thin-bedded turbidites of the Hrabník Fm (Loc. Hrabník pit)

Hrabník Formation (Fig. 63) is exposed NW of Vajarská Hill at the S border of the Buková Furrow. Sedimentary sequences consist of thin-bedded turbidites, which are intercalated by grey weakly calcareous up to non-calcareous (menilitic-type) shales. Lower part of the sequence is formed by sediments of basin-floor fans with „Zebra-type“ turbidites. The sequence shows a thickening-upward tendency, passing to thick-bedded channelized sandstones up to homogenous massive sandstones.

The age of the Hrabník Fm has been determined as the Lower Oligocene – Kiscellian (Marko et al. 1990). Beside of redeposited nannofossils from the Middle and Late Eocene, the Hrabník Fm comprise of *Cyclicargolithus floridanus*, *Reticulofenestra* cf. *lockeri*, *Helicosphaera reticulata*, *H. bramlettei*, *Zygrhablithus bijugatus*, *Pontosphaera multipora*, *Coronocyclus nitescens*, and another species belonging to the NP 22–NP 23 Zone (Šútovská in Marko et al. 1990). Foraminiferal microfauna of the Hrabník Fm is very poor, consisting of mainly redeposited species such as *Globigerina eoceana*, *Acarinina spinuloinflata*, *Globigerinatheca subconglobata*, *„Hasterigerina“* cf.

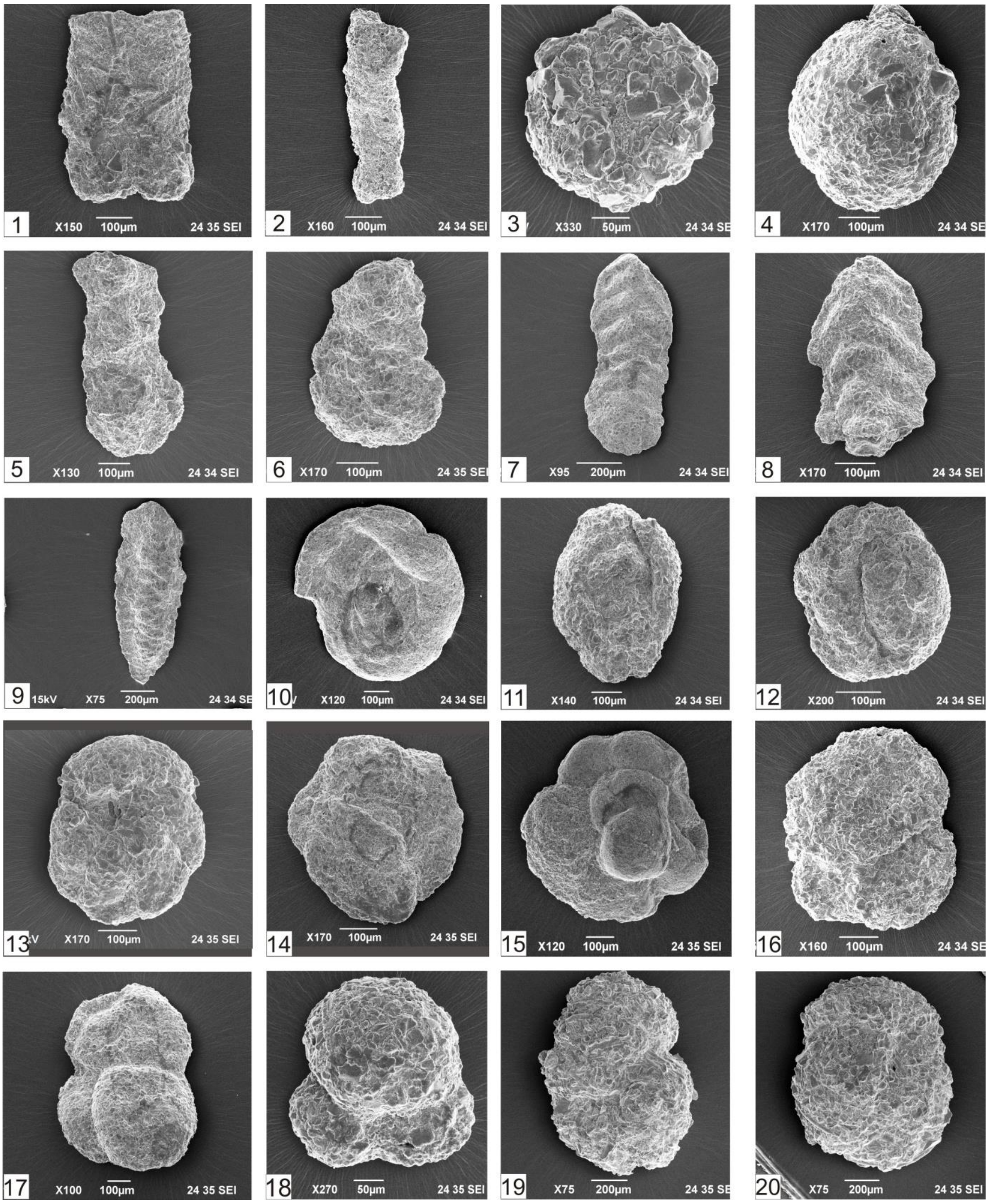
bolivariana, etc. Autochthonous species of planktonic foraminifera consist of *Dentoglobigerina venezuelana, Turborotalia ampliapertura, Subbotina eoceana, Paragloborotalia nana, Globorotaloides permicrus, G. suteri, Zeaglobigerina? connecta*, etc. (Pl. 8).



Pl. 8. Planktonic foraminifers from the Hrabník Fm. 1–2: *Subbotina eoceana* (Guembel, 1868), 3: *Dentoglobigerina venezuelana* Spezzaferi, 1994; 4: *Catapsydrax martini* Spezzaferi, 1994; 5–6: *Turborotalia ampliapertura* Bolli et al. 1988; 7: *Globorotaloides permicrus* Blow & Banner, 1962; 8: *Zeaglobigerina? connecta* (Jenkins 1964).

In spite of impoverishment of agglutinated misrofauna in the Oligocene formations of the Western Carpathians, the Hrabník Fm display a relatively good-quality and abundance of agglutinated foraminifers. They consist of species *Nothia excelsa*, *Bathysiphon microraphidus*, *Hyperammina* aff. *subnodosiformis, Rhabdammina* sp., *Saccammina* sp., *Psammosphaera irregularis, Spiroplectammina spectabilis, Trochamminoides dubius, Haplophragmoides* aff. *horidus, Recurvoides* sp., *Trochammina* sp., *Trochamminoides variolarius, Paratrochamminoides* aff. *challengeri*, *Ammobaculites agglutinans* (Pl. 9). Calcareous benthic foraminifera comprise of species *Bulimina coprolithoides*, *Lagena* sp., *Hansenina soldani*, et.

The turbidite sequence is deformed by en echelon-type of folds (Marko et al. 1990). The folded turbidite sequence is overlain with angular discordance by clays and sands containing Lower Miocene foraminiferal associations (*Uvigerina bononiensis*, *U. posthantkeni*, *Globigerinoides trilobus*, etc.). This fact proves the Oligocene/Lower Miocene age of folding of the Hrabník Fm. The folds were generated in dextral transpression shear zone within the Buková Furrow (Fig. 64).



Pl. 9. Agglutinated foraminifers from the Hrabník Fm. 1: *Bathysiphon microraphidus* (Samuel 1977); 2: *Hyperammina* aff. *subnodosiformis* Grzybowski, 1898; 3: *Psammosphaera irregularis* (Grzybowski, 1896); 4: *Psammosphaera* sp.; 5–9: *Spiroplectammina spectabilis* (Grzybowski, 1898); 10–12: *Trochamminoides dubius* (Grzybowski, 1901); 13: *Haplophragmoides* aff. *horidus* (Grzybowski, 1901); 14: *Trochammimoides* sp.; 15: *Trochamminoides variolarius* (Grzybowski, 1898); 16–18: *Trochammina* sp.; 19: *Ammobaculites agglutinans* d´Orbigny, 1846; 20: *Recurvoides* sp.

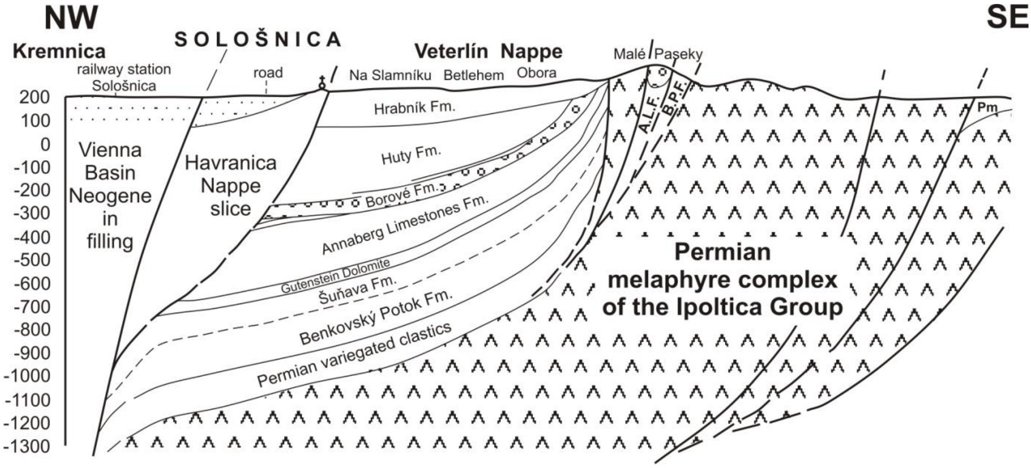


Fig. 64. Geological cross-section of the NW margin of the Malé Karpaty Mts showing a half-syncline filled by the Oligocene sediments of the Hrabník Fm. The syncline is bounded by the Dúbrava Fault on the NW and the reverse faults in tectonic contact of the Choč Unit and higher nappe units (Michalík, 1993).

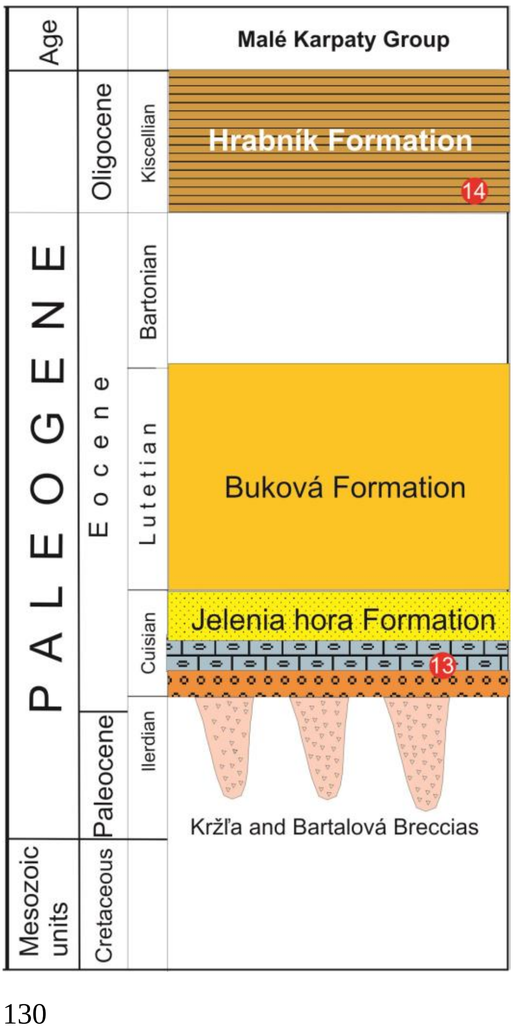


Fig. 65. Lithostratigraphic column of the Paleogene formations of the Malé Karpaty Group (adapted from Buček 2012) with indication of field trip sites.

Field stop 15: Devínska Kobyla: Middle Miocene (Upper Badenian) benthic foraminifera of the marginal sediments of the Vienna Basin (Sandberg Mb.)

Natália HUDÁČKOVÁ and Andrej RUMAN

GPS: 48°12'02.4"N 16°58'27.3"E

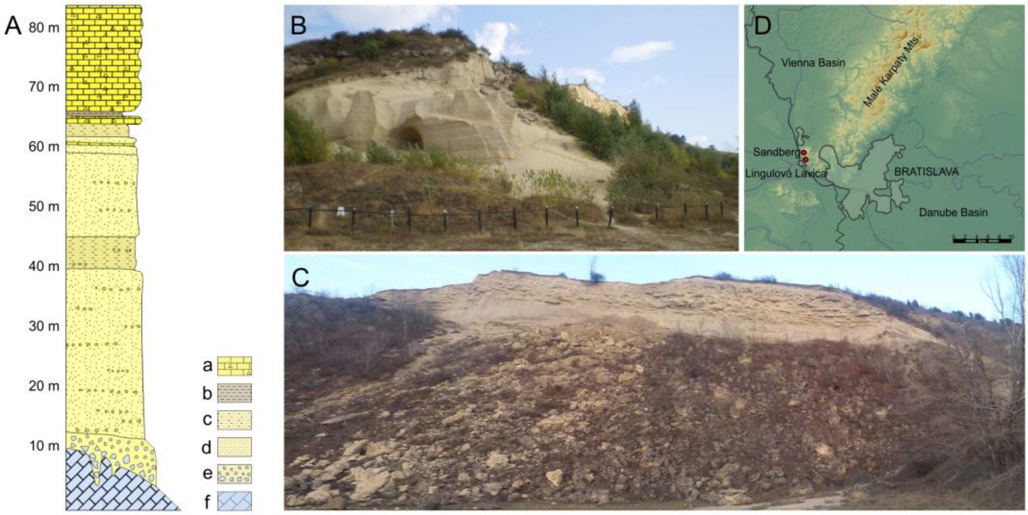


Fig. 66. A: Simplyfied lithological scheme of the locality Sandberg. a) calcareous limestones and breccias, b) clay, c) sandy clay, d) sand and sandstone, e) breccias and conglomerates, f) mesozoic limestones. Hyžný et al., 2012. B: View on the massive, hevily bioturbated, sands exposed in the NW part of the quarry. Photo by Rybár, 2010; C: The main wall of quarry. Massive, bioturbated sands and sandstones are overlain by the detrital coralline algae limestone and silts. Photo by Rybár, 2015. D: Geographical position of the Sandberg and Lingulová Lavica sites.

The locality **Devínska Nová Ves – Sandberg** (Upper Badenian; Bulimina-Bolivina Zone; Vienna Basin) is situated at the southern border of the village Devínska Nová Ves and on the north-western foothills of Devínska Kobyla hill (Fig. 66). This former sand pit is made up of two levels with overall ca. 90 m height.

The site is characterized by the Upper Badenian sediments of marginal transgressive facies, marine sands, sandy limestone, algal limestone and gravel layers, which are overlying of the Early Cretaceous and Early Jurassic carbonates.

The presence of the *Flabellipecten besseri*, *Oppenheimopecten aduncus*, *Aequipecten malvinae*, *A. elegans*, *Hinnites crispus*, *Codakia leonina*, *Acanthocardia turonica*, *Megacardita jouanneti*, *Conus fuscocingulatus* and *Cryptoplax weinlandi* confirme the Badenian age. It corresponds with the end of the MN 6 mammal biozone. On the other hand, the findings of nannoplankton suggest the NN 6 biozone, what corresponds with the mammal biozone of MN 7/8. Thus there is a discrepancy between the age of this site determined by the calcareous nannoplankton and terrestrial mammal remains. Due to its accessibility, fossil richness and well developed marginal sediments it has been identified as a Vienna Basin faciostratotype of the Sanberg Member (Baráth et al., 1994). The Lower Sarmatian age of the sediments from the uppermost part of the sequence is confirmed by calcareous nannoplankton - *Calcidiscus premacintyrei*, First Occurence and First Common Occcurence of *Calcidiscus macintyrei* (Hyžný et al., 2012).

Vertical profile reveals the discordant erosive contact between the Badenian basal breccia, gravel and conglomerates and Mesozoic carbonates of the Devín succession (Tatric Unit; Lower Jurassic and Lower Cretaceous). Above, a coarse to fine grained detrital, ochre colored, sands onlaped in the sublitoral environment directly onto the Mesozoic basement. Sand, sandstone and siltstone beds are locally intercalated by gravel. Within the sand, a few decimeters thick lenses of angular polymict breccia with calcareous cement occur. The breccia is composed of phyllite, amphibolite, quartz, quartzite and limestone derived from the Devínska Kobyla pre-Neogene basement. Abundant amphibolite content within the conglomerates of the Sandberg site is assumed as a result of material transport along the coastline.

Middle part of the section is build up by massive bioturbated sand to cross-bedded sand with gravel intercalations. At the top, benches of calcareous sandstone are paved by fine grained sand, detrital coralline algae limestone and silt with abundant *Amphistegina mamilla* (forming more than 80% of the sediment weiht; Bitner et al., 2014), a species typical of a seagrass environment. The assemblage consists also of epiphytic *Asterigerinata planorbis*, *Lobatula lobatula*, *Anomalinoides badenensis*, *Textularia gramen* and rare *Reussella spinulosa* and *Planostegina costata*. In the uppermost sample large portion of elphidia is present together with bad preserved small miliolide foraminiferal tests (Pl. 10, Tab. 1).

From the abundance of *Amphistegina mammilla* in the upper part of the studied section, the environment may be interpreted as shallow, oligotrophic, well oxidized warm water with seagrasses (di Bella et al., 2005). Other foraminiferal species also show affinity to seagrasses (*Lobatula lobatula*), diverse keeled *Elphidium* sp. and *Reussella* sp. as well). The presence of *Miniacina miniacea* (Pallas) documents the occurrence of caverns, produced in algal biostromes/bioherms, which are also preferred by micromorphic brachiopods in shallow water (Bitner et al., 2014).

Laterally, carbonate sand is replaced by bioturbated sandstone and further (towards the former coast) passes into the breccia and coarse grained calcareous sand with normal gradation. The Sarmatian Karlova Ves Member is rarely preserved here.

Rich terrestrial and marine vertebrate and invertebrates fauna, with more than 300 species, was discovered here since the ninetheen century (Hörnes, 1848, 1851-1856, 1859-1870; Hoernes and Auinger, 1879-1891; Kornhuber, 1865; Schaffer, 1908; Horusitzky, 1917; Sieber, 1934; Koutek and Zoubek, 1936; Ondrejičková, 1987; Hyžný et al., 2012). Red algae coralline limestones from the Sandberg sandpit were studied by Schaleková (1969) and Coletti et al. (2016). Švagrovský (1981) published an extensive systematic monograph focused on the Devínska Kobyla molluscs. The crustaceans have been described in the works of Lőrenthey and Beurlen (1929); Bachmayer (1962) and Hyžný (2011), brachiopods and bryozoans in work of Bitner et al. (2014) Many papers have been devoted to the vertebrates of the Sandberg site and adjacent numerous Devínska Kobyla Hill localities (Thenius, 1952; Holec, 1985, 2001, 2006; Holec and Sabol, 1996; Holec and Schlögl, 2000; Sabol and Holec, 2002; Schlögl and Holec, 2004). Overall view on the fauna, flora and geological settings brings Feráková et al. (1997).

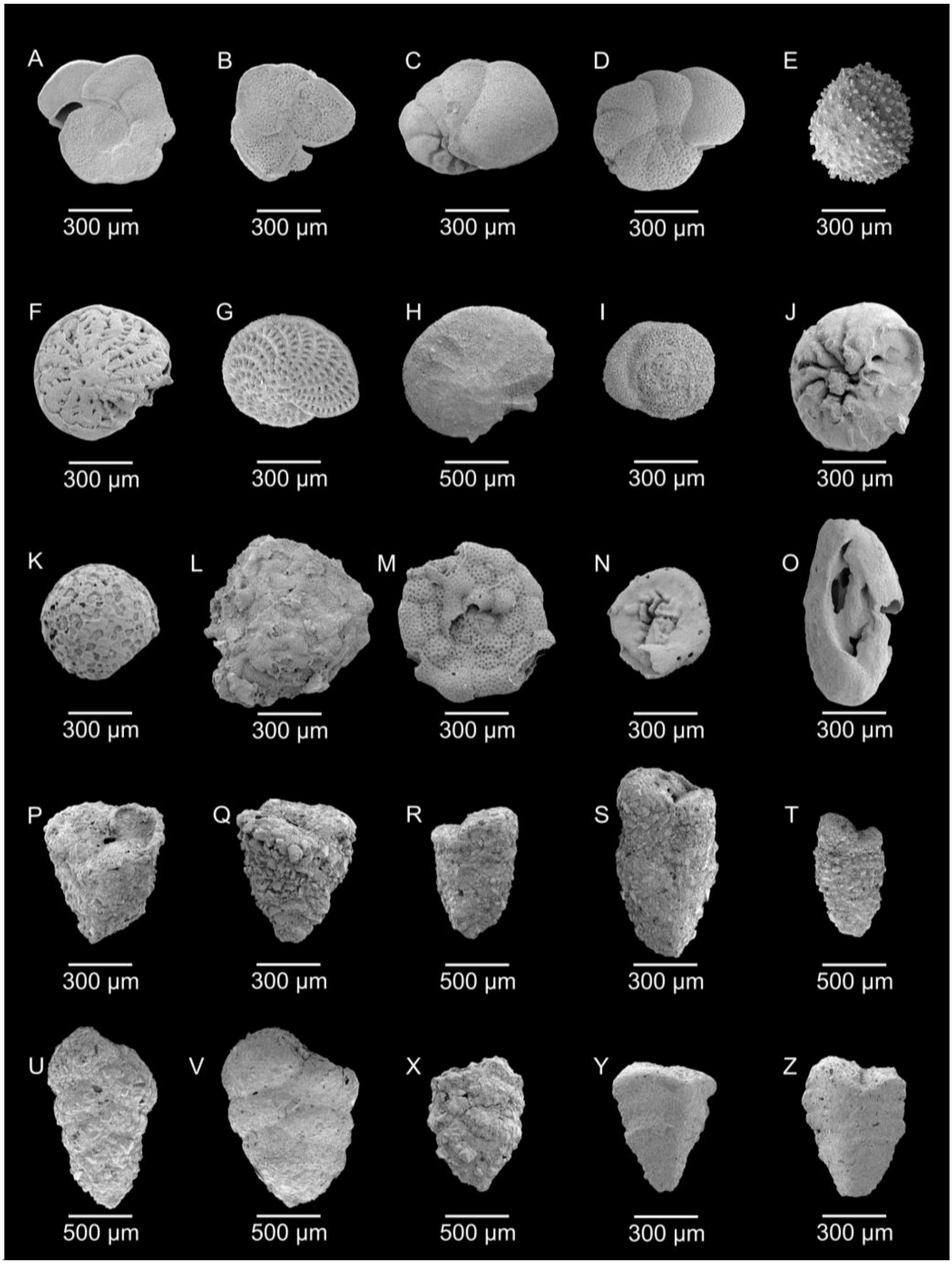
Lingulová Lavica site (Lingula Beds)

GPS: 48°10´44″N; 16°59´48″E

The site is situated above the vineyards of the Devín village, on the southern slopes of the Devínska Kobyla hill.

The outcrop is represented by a 1.5 m thick sequence of fine grained, ochre to grey coloured, sands and sandstones. Rich benthic foraminiferal associations are partly recrystallized, no planktic forms were recorded from this site. The fossil fauna is dominated by foraminifers (Pl. 11), molluscs, polychaetes, bryozoans, brachiopods, arthropods, echinoids, fish and shark remains. The presence of the brachiopod *Lingula* cf. *dregeri* is typical for this locality. According to Švagrovský (1981), presented *Flexopecten scissus* is in the Central Paratethys known from the Badenian sediments solely.

The lower part of the sequence at Lingulova lavica is rich in flattened elongated forms of foraminifers (*Bolivina dilatata, B. pokornyi, B.* sp. *Bulimina elongata*) representing mainly deep infauna and typifying dysoxic environments (Kaiho, 1994). In the upper part of the sequence at Lingulová lavica, the sediments are coarser and foraminiferal assemblage dominated by unkeeled *Elphidium* and *Ammonia* suggests shallower eutrophic environment because these genera are able to absorb nutrients even in dysoxic (*Ammonia even* in anoxic) conditions (Murray, 2006). In the uppermost part, the keeled elphidia, *Asterigerinata planorbis* and textulariids dominate, we can assume environment of shallow, oligotrophic, well oxidized water with seagrasses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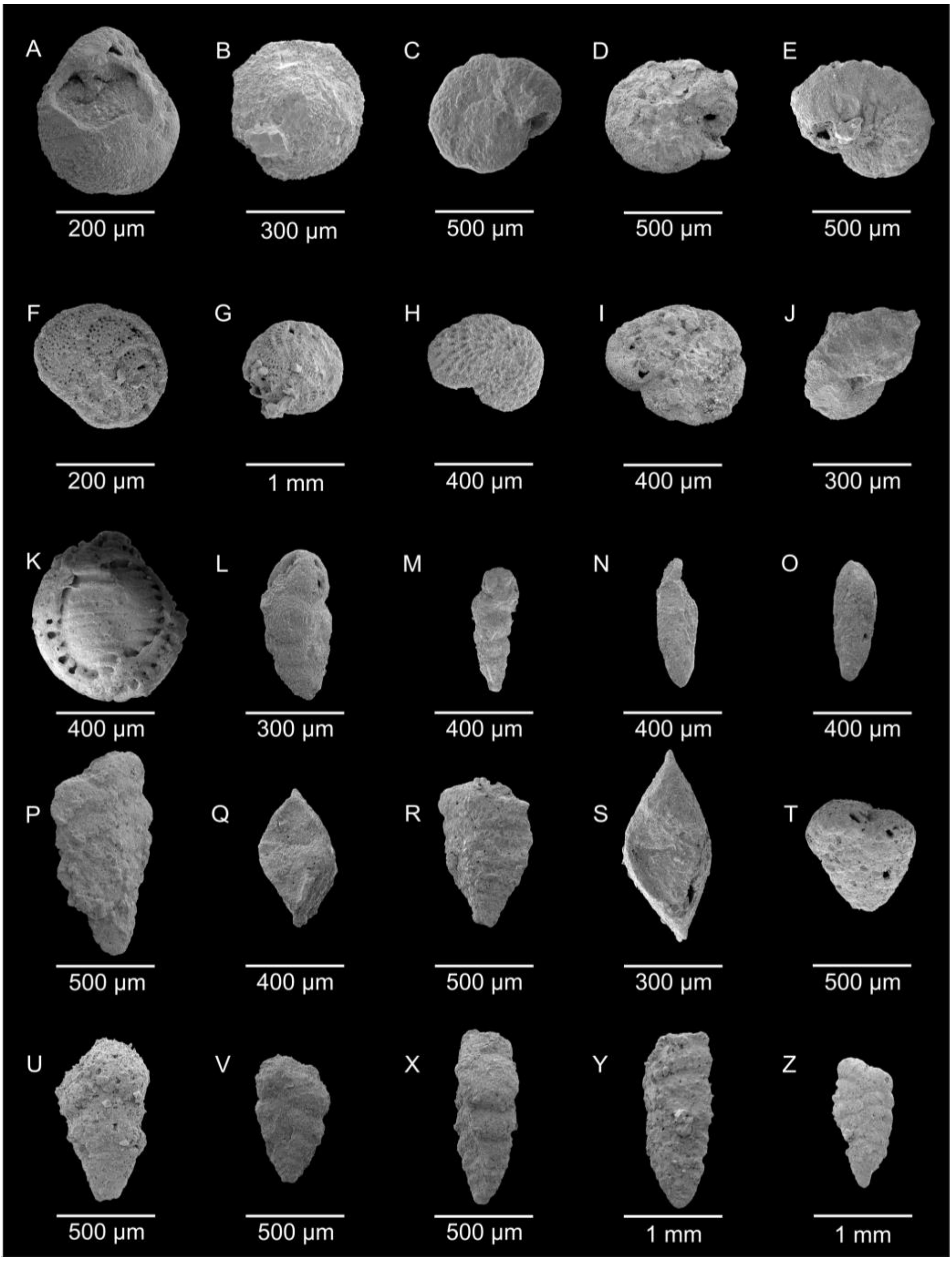
Pl. 10. Foraminifera from the Devínska Nová Ves – Sandberg site. A: *Lobatula lobatula* (Walker & Jacob, 1798); B: *Lobatula lobatula* (Walker & Jacob, 1798); C: *Ceratocancris haueri* (d'Orbigny, 1839); D: *Cibicides ungerianus* (d'Orbigny, 1846); E: *Globulina punctata* d'Orbigny, 1846; F: *Elphidium rugosum* (d'Orbigny, 1846); G: *Elphidium crispum* (Linnaeus, 1758); H: *Planostegina costata* (d'Orbigny, 1846); I: *Heterolepa dutemplei* (d´Orbigny, 1846); J: *Ammonia inflata* (Seguenza, 1862); K: *Sphaerogypsina globulus* (Reuss, 1848); L: *Planorbulina mediterranensis* d'Orbigny, 1826; M: *Planorbulina mediterranensis* d'Orbigny, 1826; N: *Rosalina bradyi* (Cushman, 1915); O: *Pseudotriloculina consobrina* (d'Orbigny, 1846); P: *Textularia pala* Czjzek, 1848; Q: *Textularia pala* Czjzek, 1848; R: *Spiroplectammina sagittula* (Defrance, 1824); S: *Spiroplectammina sagittula* (Defrance, 1824); T: *Spiroplectammina sagittula* (Defrance, 1824); U: *Textularia gramen* var. *maxima* Cicha & Zapletalova, 1965; V: *Textularia gramen* d'Orbigny, 1846; X: *Pseudogaudryina* sp.; Y: *Semivulvulina pectinata* (Reuss, 1850); Z: *Semivulvulina pectinata* (Reuss, 1850).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Pl. 11. Foraminifera from the Lingulová Lavica site. A: *Cassidulina crassa* (Reuss, 1850); B: *Asterigerinata planorbis* (d'Orbigny, 1846); C: *Lobatula lobatula* (Walker & Jacob, 1798); D: *Ammonia inflata* (Seguenza, 1862); E: *Hanzawaia boueana* (d'Orbigny, 1846); F: *Eponides repandus* (Fichtel & Moll, 1798); G: *Elphidium crispum* (Linnaeus, 1758); H: *Elphidium fichtellianum* (d'Orbigny, 1846); I: *Elphidium fichtellianum* (d'Orbigny, 1846); J: *Nonion commune* (d'Orbigny, 1846); K: *Borelis melo* (Fichtel & Moll, 1798); L: *Bulimina elongata* d'Orbigny, 1846; M: *Virgulopsis tuberculatus* (Egger, 1857); N: *Bolivina* sp.; O: *Bolivina* sp.; P: *Textularia mariae* d'Orbigny, 1846; Q: *Textularia mariae* d'Orbigny, 1846; R: *Semivulvulina pectinata* (Reuss, 1850); S: *Semivulvulina pectinata* (Reuss, 1850); T: *Sahulia conica* (d'Orbigny, 1839); U: *Textularia* cf. *gramen* d'Orbigny, 1846; V: *Textularia gramen* d'Orbigny, 1846; X: *Textularia gramen* var. *maxima* Cicha & Zapletalova, 1965; Y: *Spiroplectammina sagittula* (Defrance, 1824); Z: *Spiroplectammina sagittula* (Defrance, 1824).

Tab. 1. Foraminifera abundances from the Middle Miocene (Upper Badenian) Devínska Nová Ves – Sandberg and Lingulová Lavica sites (Hyžný et al., 2012).

Table 1.	Lingulová Lavica 1	Lingulová Lavica 2	Lingulová Lavica 3	Lingulová Lavica 4	Lingulová Lavica 5	Lingulová Lavica 6	Lingulová Lavica 7	Sandberg (3.3)	Sandberg (2.4)
Ammonia ex gr. vienesis (d'Orbigny, 1839)	1	1	1	1	1	0	0	1	0
Ammonia inflata (Seguenza, 1862)	0	0	0	0	0	0	1	0	0
Amphistegina mammilla (Fichtel & Moll, 1798)	0	0	0	0	0	0	0	0	1
Asterigerinata planorbis (d'Orbigny, 1846)	1	1	1	1	1	0	1	1	0
Bolivina antiqua d'Orbigny, 1846	1	0	1	0	0	0	0	0	0
Bolivina pokornyi Cicha & Zapletalová, 1963	0	0	0	0	0	0	0	1	0
Bolivina sp. indet d'Orbigny, 1843	1	0	0	0	0	0	0	0	0
Bolivina spathulata (Williamson, 1858)	1	1	1	0	1	0	1	0	0
Borelis melo (Fichtel & Moll, 1798)	0	1	1	1	0	1	0	0	0
Bulimina elongata d'Orbigny, 1826	1	1	1	0	1	0	1	0	0
Bulimina intonsa Livental, 1929	1	0	0	0	0	0	0	0	0
Cancris auriculus (Fichtel & Moll, 1798)	0	0	0	0	0	0	0	0	1
Cassidulina carinata Silvestri, 1896	1	0	0	0	0	0	0	0	0
Cassidulina laevigata d´Orbigny, 1826	1	0	1	0	1	0	0	0	0
Cibicides boueanum (d´Orbigny, 1846)	0	0	0	0	1	0	0	0	1
Cibicides sp. indet de Montfort, 1808	0	0	0	0	1	0	0	0	0
Cibicides ungerianus ornatus (Cicha & Zapletalová, 1963)	0	1	1	0	1	0	0	1	1
Conorbella sp. indet Hofker, 1951	0	0	1	1	0	0	0	0	0
Dorothia scabra (Brady, 1884)	0	0	0	0	0	1	0	0	0
Elphidium aculeatum (d´Orbigny, 1846)	1	0	0	0	1	0	0	0	0
Elphidium aff. crispum (Linnaeus, 1758)	0	0	0	0	1	1	0	0	0
Elphidium cf. fichtellianum (d'Orbigny, 1846)	0	0	0	1	0	0	0	0	0
Elphidium crispum (Linnaeus, 1758)	1	1	1	1	0	0	1	0	1
Elphidium fichtellianum (d'Orbigny, 1846)	1	1	1	0	1	0	1	0	1
Elphidium macellum (Fichtel & Moll, 1798)	0	0	0	0	0	0	0	0	1
Elphidium rugosum (d´Orbigny,1846)	0	0	1	1	0	0	0	0	0
Elphidium sp. indet. de Montfort, 1808	0	0	0	0	0	0	0	1	0
Fursenkoina acuta (d'Orbigny, 1846)	0	1	0	0	1	0	1	0	0
Globigerina ex gr. praebulloides Blow 1959	1	0	0	0	0	0	0	0	0
Globocassidulina aff. subglobosa (Brady, 1881)	0	0	0	0	1	0	1	0	0
Hanzawaia boueana	1	0	0	0	0	0	0	0	0
Haynesina cf. depressula (Walker & Jacob, 1798)	0	0	0	0	0	0	0	0	1
Heterolepa aff dutemplei (d´Orbigny, 1846)	0	0	0	0	1	0	0	0	0
Heterolepa dutemplei (d´Orbigny, 1846)	1	0	1	0	0	1	1	0	0
Heterostegina depressa d´Orbigny, 1826	0	0	0	0	0	0	0	0	1
Lobatula lobatula (Walker & Jacob, 1798)	1	0	1	1	1	0	1	0	1
Melonis pompilioides (Fichtel & Moll, 1798)	1	1	1	0	1	0	1	0	0
miliolida indet	0	1	0	0	0	1	0	0	0
Miliolinella circularis (Bornemann, 1855)	0	0	0	0	0	1	0	0	0
Miliolinella sp. Wiesner, 1931	0	0	0	1	0	0	0	0	0
Miniacina miniacea (Pallas, 1766)	0	0	0	0	0	0	0	0	1
Nodobaculariella sp. indet Cushman & Hazawa, 1937	0	0	0	0	1	0	0	0	0
Nonion aff communae (d´Orbigny, 1846)	0	0	1	0	0	0	0	0	0
Nonion communae (d´Orbigny, 1846)	0	0	0	0	0	0	1	0	0
Nonion sp.	1	0	0	0	0	0	0	0	0
Pappina neudorfensis (Toula, 1900)	0	0	0	0	0	0	1	0	0
Planorbulina mediterranensis d'Orbigny, 1826	0	0	0	0	0	0	0	0	0
Porosononion granosum (d´Orbigny,1826)	1	1	1	0	0	0	1	0	0
Pullenia bulloides	1	1	0	1	1	0	1	0	0
Pyrgo depressa (d´Orbigny,1826)	0	1	1	0	0	0	0	0	0
Quinqueloculina aff akneriana d´Orbigny, 1846	0	0	0	0	1	0	0	0	0
Quinqueloculina sp.	0	0	1	0	0	0	0	0	0
Reussella spinulosa (Reuss, 1850)	1	0	1	0	1	0	1	0	1
Rosalina austriaca (d´Orbigny, 1846)	1	0	0	0	0	0	0	0	1
Rosalina obtusa d´Orbigny, 1846	0	1	0	0	0	0	0	0	0
Rotalia sp.	0	0	1	1	0	0	0	0	0
Spirorutilus carinatus (d´Orbigny, 1846)	1	0	0	0	0	0	0	0	0
Textularia laevigata d'Orbigny, 1826	1	1	1	1	1	1	1	0	0
Textularia spp. Defrance, 1824	0	0	1	0	0	0	1	0	0
Trifarina angulosa (Williamson, 1858)	1	0	0	0	0	0	0	0	0
Trifarina bradyi Cushman, 1923	0	0	6	0	1	0	0	0	0
Uvigerina semiornata d'Orbigny, 1826	1	0	0	0	1	0	1	0	0
Virgulopsis sp. Finlay, 1939	1	0	0	0	0	0	0	0	0
Virgulopsis spinea (Cushman, 1936)	0	0	0	0	1	0	0	1	0

Field stop 16: Devín Castle rock

Jozef MICHALÍK and Ján MADARÁS

GPS: 48°10'27.8"N; 16°58'38.1"E

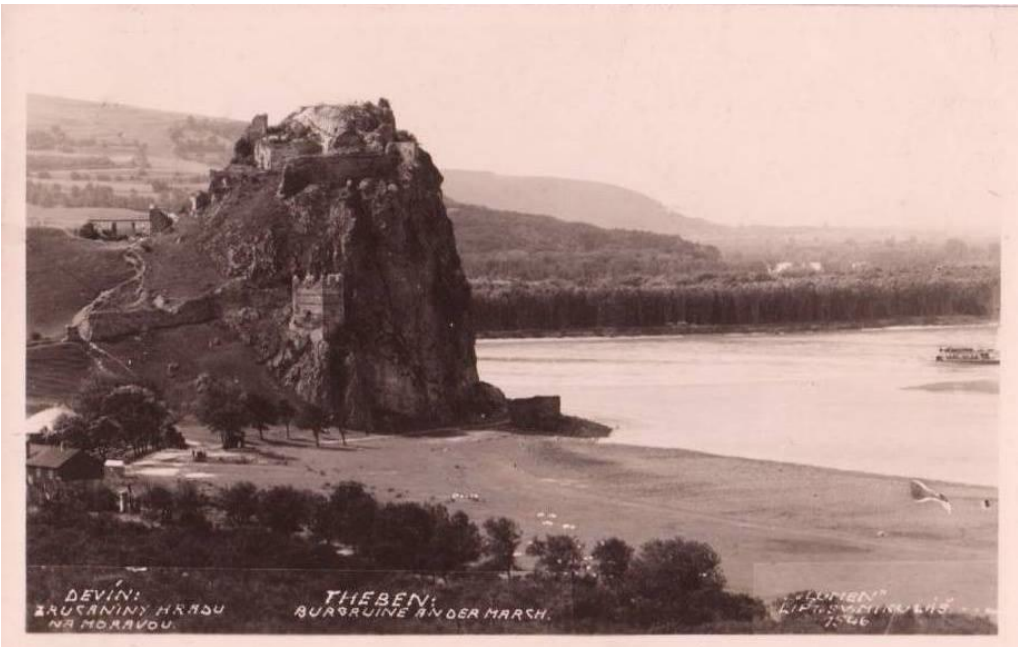

Fig. 67. Historical view on the Devín Castle above Danube and Morava rivers.

Prominent rock cliff (elevation 212 meters) at the confluence of the Danube and Morava rivers served as an ideal strategic fortification place (figs. 67, 68). Its owner could control an important branch of trade route (the Amber Road) from Baltic Sea towards Mediterranean Europe. The site has been fortified since the Neolite, through the Bronze and Iron ages, as well as during Celtics and Romans settlement. The name of the castle could be derived from an old Indo-European/Proto-Slavic stem “*deiv”* with apophony “*doiv”* related to visual perception (“*watchtowers or observation point”*), or from “*div”* ("*evil spirits place*"). More popular explanation is a derivation from the old Slavic word *deva* (*girl*). In this case, "*devin grad*" means " *girl´s castle*".

Devín castle belongs to the oldest castles in Slovak territory being firstly mentioned in written sources in 864, when Louis the German besieged the Knight Rastislav in one of frequent wars between the Franks and Great Moravia respectively in the "castle of Dowina". Its defensive role was supported by smaller forts nearby on the Devínska Kobyla Hill. A pre-romanesque church was built in the castle approximately between 850 and 863/870. The interior of the church was decorated with frescoes painted by colors originated (according to chemical analysis) in northern Italy. Two styluses discovered by later research indicate administrative or education work of local priests. Along with other artifacts, six graves dated to the Great Moravian era were found near the church and are attributed to members of a retinue of the local ruler and their family members.

In the 13th century (1271), a stone castle has been integrated into the western frontier of the Hungarian Kingdom (the reference to a *castelanus de Devin* appeared in 1326). In 1323, the Devín Castle became the possession of the heads *(ispáns)* of the county. A palace was added in the 15th century, fortification was reinforced during wars against the Ottoman Empire. The Castle was never taken, but after Ottomans were finally defeated, it ceased to be an important border fortress and was no longer used by the military. Nevertheless, in 1809, after the Siege of Pressburg, was the castle (still considered a threat) destroyed by the retreating forces of Napoleon I of France. Since the 19th century as its history inspired several romantic poets, followers of Ľudovít Štúr, Devín has become an important Slovak national symbol.

Fig. 68: View of the Maiden Tower above the confluence of Danube and Morava rivers

The frontal part of the huge Bratislava Nappe is build up of phyllite cover of allochthonous granitoid massif with sporadic dykes of aplite and pegmatite (Kováč et al., 1991, Plašienka et al., 1991, Plašienka,1999), (Fig. 69). Imperfectly exposed Devín Formation outliers cropping out near eastern gate of the Devín Castle are the oldest member of the Mesozoic sedimentary cover sequence. They consist of gray-greenish conglomerates and breccia with clasts of granite, vein quartz, phyllite, variegated shales and basic volcanites. Vozárová and Vozár (1988) supposed their Permian age.

The Lower Triassic Lúžna Formation builds the summit part of the Devínska Kobyla Hill, and the Devín Castle Hill, as well. It is composed of quartzose sandstones with fine-grained to glassy quartz matrix which contains pebbles of white vein quartz, rosa rhyolite and black turmalinite (Mišík and Jablonský, 1978; Mišík, 1986). The well and trench, separating the majestic Devín Citadella from the proper Castle, have been excavated in “Campilian” yellow- gray claystones. Below the bridge, Middle Triassic Ramsau Dolomite crops out in the trench. It is represented by thin layered gray to dark gray crumbling carbonates with smell of bitumen and with inexpressive claey interlayers. The upper part is transformed into monomict dolomite breccia, building eastern slope of the Citadella rock. The Gutenstein Limestone Formation crops out on opposite slopes of the Devínska Kobyla Hill. It is represented by dark bituminous rocks, often with lamination (alternation of thin fine detrital an micritic limestone). Graded fine breccia layers occur frequently. The presence of these rocks in clasts of the Pleš Breccia (Fig. 70) indicates that the Gutenstein Formation had originally much much greater extent, being considerable eroded during Early Jurassic. This erosion completely removed the Carpathian Keuper complex strata.

Dolomite breccia is non-conformably covered by the polymict Pleš Breccia (Michalík,1984), consisting of clasts of various size (several centimetres to five-six meters). This breccia builts up the most morphologically eminent part of the castle hill, occupied by the Citadella (Baliak et al., 1997; Pipík et al., 2004).

Erosional groves up to variously deep neptunian dykes are observable below the breccia base. Individual clasts are formed by gray dolomite, dolomite laminite, dolomitized limestone with pseudomorphoses after gypsum crystals, gray shelly limestone, cherty and phosphatized limestone, sometimes even by speleothemes (Mišík, 1980), biomicrite with remnants of Rhaetian bivalves and foraminifers (Kochanová et al., 1967), phosphatized limestone with upper Liassic ammonites (Rakús, 1996). Michalík et al., (1994) revealed Lower Jurassic brachiopods of the Mediterranean type (Vörös, 1977; 1982) in clasts of dark gray biomicrite from the western rock wall. Michalík (1984) identified the breccia body with the Pleš Breccia of Toarcian age, which originated during Early / Middle Jurassic tensional stress of central Carpathian microplate due to opening of the Penninic Rift.

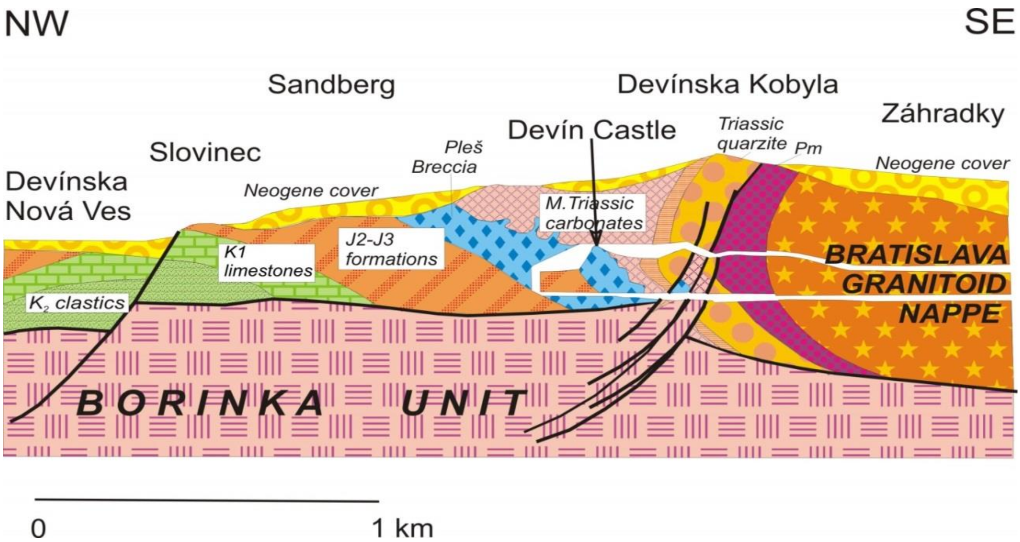

Fig. 69. Schematic geological cross-section (W-E) across the Devínske Karpaty Mts group (Plašienka, 1987; Michalík & Vlčko, 2011).

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

Two limestone blocks fallen from western rock wall of the Devín (Citadella) Castle rock consisted of dark brown-gray fine biosparite and contained shell fragments of *Securithyris adnethensis* (Suess) and few specimens of *Linguithyris aspasia* (Meneghini) (Michalík et al., 1994). Presence of these typically "Tethyan" forms (Vörös, 1977, 1982, 1984) in brachiopod fauna of the Pleš Breccia clasts should prove for its Mediterranean character. It is worth of mention that the brachiopod association from the Tatric Kuchyňa Unit in the Malé Karpaty Mts (Michalík et al., 1994) is of the "European" character. Microscopic study of clasts from the Pleš Breccia Fm under luminiscent microscope indicates multiplicated effect of stress deformation and origin of successive generations of calcite veinlet infillings.

Fig. 70. Citadella rock built of the Pleš Breccia viewed from the east.

Carbonate clasts with preserved internal structure occur within rocks fragments are formed by oolitic limestones (oosparites), bioclastic limestones (biosparites), pelsparites and limestones with abundant algal nodules. Carbonates are affected by early selective dolomitization (facies selective dolomitization), typical of peritidal and shallow neritic facies zones. The luminiscence of original rock is low, ooid laminae are orange. The matrix between clasts is bright orange red, what indicates raised Sr content. In marine phreatic environment small cavities formed in original rock were affected by early cementation phase of dolomitization, and subsequently filled by isopachyal cement. Aggregates of cementing newly originating carbonate and veinlets cutting it, are of orange luminiscent colour. In more advanced stage of dolomitization, cortex growth subsequently combined and closed relict pores. Freatic syntaxial cement brights orange to pale red, zonal banding creating the “dog teeth” pattern indicates mode of growth of rhomboid carbonate crystals into free space in cavities and crevices of the rock. Clasts of the Pleš Breccia Formation were derived from shallow marine facies zone of the Triassic carbonate platform. Less frequent Rhaetian and Lower Jurassic rocks came from open neritic deposits. Thus, the subsidence in the Devín Unit of the Tatric started in latest Norian being followed by sedimentation of Rhaetian limestones. The Pleš Breccia body accumulated on a foot of synsedimentary formed fault scarp on the Tatric margin after Toarcian. The destruction of sedimentary sequence in adjacent Tatric zones and forming of depositionary space for accumulation of slope debris was enabled by tensional stress on arising Penninic Rift margin.

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