Field Trip PRE-2
Lower to mid-Cretaceous of the Western Carpathians, Slovakia – Cretaceous sediments in the western part of the Central Carpathians

JOZEF MICHALÍK[1], DANIELA REHÁKOVÁ[2], DUŠAN PLAŠIENKA[2] & ROMAN AUBRECHT[2]

[1]Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P.O. Box 106, 840 05 Bratislava, Slovak Republic <jozef.michalik@savba.sk>. [2]Comenius University, Šafárikovo námestie 6, P.O. Box 440, 814 99 Bratislava 1, Slovak Republic.

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Route: Vienna–Bratislava

Stop 1. Devinska Nova Ves
Stop 2. Tmavý Jarok, Vysoká Hill
Stop 3. Hrušové, Nové Mesto Nad Váhom
Stop 4. Vršatec, top of the Javornik hill at Pruské, Vršatské Podhradie village
Stop 5. Butkov Quarry, Ladce
Stop 6. Mojtin Valley, road cuts Beluša–Belušské Slatiny–Mojtín
Stop 7. Skalica Rock, Dolný Moštenec village near Povaszka Bystrica

back to Vienna

Introduction to the central Western Carpathians geological structure

The pre-Senonian (pre-Coniacian) nappe edifice of the Central West Carpathians consists of three principal superunits from bottom to top: the Tatricum, the Fatricum and the Hronicum. The Tatricum is built of pre-Alpine crystalline basement and its Mesozoic (locally also Upper Paleozoic) sedimentary cover, both the Fatricum (Krížna Nappe s.l.) and the Hronicum (Choč Nappe s.l.) turned into superficial cover nappe systems. The youngest, generally synorogenic flysch sediments involved in these nappe systems are dated as Early Turonian in the Tatricum, Cenomanian in the Fatricum and Hauterivian in the Hronicum (see PLAŠIENKA in MICHALÍK et al., 2000). As the Gosau sediments sealing the nappe structure in the northern part of the Malé Karpaty started with Coniacian clastics, the “pre-Gosau” or “Mediterranean” orogenic phase is assumed as the main thrust phase in the Central Western Carpathians. However, this is valid only for the final, rather short-termed emplacement event of superficial nappe sheets, while the preceding shortening of their original basement should have lasted several to several tens of m.y.
The Tatric system was associated with a thick ribbon of sialic crust which was responsible for paleogeographic, sedimentological and structural pecularities of their sequences. The Fatric Nappe system is composed of décollement cover nappes originated in areas south of the present Tatricum. By definition, the Fatricum is composed of both the Vysoká and Krížna partial nappes. Fatric nappes clearly overlie the Tatric cover and are usually overlain by rocks of the “higher” (generally Hronic) nappes. Intrinsic complications arise in the frontal Fatric parts and in the Periklippen area, where the relationships of Fatric units to their substratum cannot be defined in a rigorous way. Unlike the Krížna Nappe proper, the Klape and Manín units underwent repeated subsidence, deep-sea sedimentation and strong deformation after their final nappe emplacement.
Considerations of Triassic sedimentary formations in the “higher” nappes sometimes inferred a presence of nappes of the “ultra-Hronic” affiliation (the Strážov Nappe in the Strážov Mts, or the Nedze Nappe in the Malé Karpaty Mts). These units would be

characterized by involvement of Wetterstein and Dachstein Formations as diagnostic Triassic facies and were therefore regarded as the "Gemeric", and later, after both the Silica Nappe and the Silicicum were defined, as the "Silicic". However, sedimentation in higher nappes of both the Malé Karpaty and Strážov Mts continued until late Early Cretaceous. Therefore, all "higher" nappes in the "core mountains area" are regarded here as constituents of the Hronicum sequence, i.e. the Choč Nappe s.l., which usually starts with a thick Upper Paleozoic volcano-sedimentary complex – the Ipoltica Group ("Melaphyre Series"), nowhere present below the Silicic Unit, spatially restricted to the southern Central West Carpathian zones (the Veporic and the Gemeric domains).

The nappe structure of the northern Tatricum

The Tatricum is a thick-skinned upper crustal sheet comprising pre-Alpine crystalline basement and its Upper Paleozoic to Mesozoic sedimentary cover. The basement consists of low to medium grade, locally high grade metamorphosed Lower Paleozoic volcano-sedimentary complexes and Variscan granitoid plutons. Upper Carboniferous and Permian sedimentary and volcanic rocks form thick complexes in the northern part of the Považský Inovec Mts. only, and these of Permian age in the Kozel Unit of the Malá Fatra Mts. Elsewhere, the Alpine cover sequence started usually with Scythian transgressive clastics (the Lúžna Formation).

The Tatric Superunit was individualized as a composite, fault-dissected domain with attenuated the continental crust during two-phase Early Jurassic rifting and inverted to an imbricated crustal thrust stack during Late Cretaceous shortening (PLAŠIENKA in MICHALÍK et al., 2000). The present northern edge of the Tatricum represents one of the principal tectonic boundaries in the Western Carpathians; it is analogous to the thrust faults separating Penninic and Lower Austroalpine units in the Alps. However, it is usually hidden below superimposed cover nappes and Upper Cretaceous to Tertiary (post) orogenic basin fills. Therefore, the reconstruction of paleotectonic evolution of this boundary zone has to be based on indirect criteria.

Latest Cretaceous to Paleogene dextral transpression and Neogen sinistral transtension obliterated many of primary nappe structures. NW parts of the Malé Karpaty and the Považský Inovec Mts were also affected by the backthrust of cover nappes along the SE margin of a broad wrench corridor which encompasses the northernmost Tatric elements, the NE prong of the Northern Calcareous Alps in the basement of the Vienna Basin and in the Brezovské Malé Karpaty Mts, the Periklippen and Pieniny Klippen belts and the Biele Karpaty Subunit of the Magura Unit (PLAŠIENKA et al., 1991).

The Fatric (Krížna) cover nappe system

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

The Krížna Nappe is generally subdivided into the Vysoká and Zliechov-type successions. The Vysoká Succession contains shallow-water Jurassic sediments similar to the Tatric (High Tatra-type successions), while the Zliechov one is a deep-water Jurassic-Cretaceous succession. In central Slovakia, both units form independent nappe bodies, the Vysoká-type forming slices or duplexes (Belá-, Ďurčiná-, Havran units) at the sole of the huge Zliechov Nappe. At the western (Malé Karpaty Mts) and eastern termination of the Central Western Carpathians (the Branisko and the Humenné Mts) the Vysoká type becomes the main constituent of the Fatricum and the Zliechov type gradually wedges out.

According to the evolutionary tectonic model of the Křížna Nappe, the principal Zliechov Unit was formed at the expense of a wide basinal area floored by strongly stretched and thinned continental crust (MICHALÍK, 2007). In mid-Cretaceous times, the Zliechov Basin was progressively shortened through underthrusting of its basement and tegument complexes below the Veporic thrust wedge. The sedimentary fill was detached along the Upper Scythian shale and evaporite complex and formed an initial fold-and-thrust stack prograding outwards. After complete elimination of the Zliechov Basin substratum, its Tatric and Veporic margins came into collision and the Křížna stack was pushed over the frontal South Tatric ramp, from which frontal Fatric elements (Vysoká and Manín-type), with slope and ridge-related sedimentary successions, were torn off. Finally, during Late Turonian, Fatric nappe elements gravitationally glided northwards in a diverticulation manner from the South Tatric elevation over the unconstrained basinal northern Tatric areas.

From the paleogeographical point of view, the Vysoká Nappe was derived from northern marginal parts of the Zliechov Basin in which slope and ridge facies prevailed (PLAŠIENKA et al., 1991). The Anisian Vysoká Formation represents 200–250 m thick carbonate ramp sediments of the Gutenstein type. The upper member of this formation bears marks of hypersaline environment, such as dolomitization and pseudomorphs after evaporite minerals. The successive Ramsau Dolomite is about 40–60 m thick. Limestones in the uppermost part of this carbonate complex are comparable with the Opponitz Limestone laterally passing into brecciated and cellular dolomites. The Carpathian Keuper complex, although tectonically reduced, attains 200–300 m thickness in several places. The Upper Rhaetian Fatra Formation is represented by a sequence of neritic fossiliferous limestones, overlain by Hettangian thick shaly sediments (about 100 m) of the Kopieniec Formation. Lower Jurassic sandy crinoidal limestones pass into well-bedded cherty crinoidal limestones (the Vývrat Formation), nodular crinoidal limestones and red nodular marlstones (the Prístodolok Formation) and massive crinoidal limestones with ripple- and oblique bedding and with Bathonian fossils. They represent debris aprons along a submarine slope on the basin margin.

The topmost part of Upper Jurassic nodular limestones is dated as the Late Tithonian by a rich microplankton association of the *Crassicolaria* Zone. Lower Cretaceous sequence consists of the massive Padlá Voda Limestone Formation and of schistose marly limestones of the Hlboč Formation. Pelagic formations are terminated by biodetrital Bohatá Limestone Formation. The carbonate complex is terminated by the Albian Poruba Formation of pelagic marls (frequently silicified or tectonically reduced).

During Late Cretaceous–Paleogene dextral transpression, mostly Mesozoic Fatric and Hronic nappes complexes in the NW part of the Malé Karpaty Mts were dissected into numerous duplexes, slices or even "immature" klippen and partly thrust back over the Tatric. The bedding is steeply NW-wards dipping in the eastern parts of the mountains, but the dip decreases eastwards.

The Hronic (Choč) cover nappe system

Pre-progenitor of the term Choč Nappe and/or Hronicum is the "alpinähnliche Fazies" distinguished in the Malé Karpaty Mts. As in all concepts, the "higher Subtatric nappes" are considered as the highest tectonic units in the "core mountains belt", the main contradiction and/or difference lies in their assignment to a superior unit. On the other hand, these complexes show many similarities with sequences of the Ötscher-, or the Göller Nappes of the Northern Calcareous Alps.

Cretaceous sequences in the nappes of the Central Western Carpathians

Lower Cretaceous sequences in the Western Carpathians were mainly deposited in hemipelagic basinal environments. Shallow marine sediments occuring mainly in pebbles of younger conglomerates point out on increased importance of transitional facies – olistoliths, slope debris, slumped bodies, near-slope fans, fluxoturbidites, etc. Top Jurassic/lowermost Cretaceous Outer Carpathian carbonate platforms, including the famous Štramberk reef, were destroyed during Early Cretaceous tensional basins formation. On the other hand, Upper Hauterivian to Lower Albian carbonate platforms, mostly connected by elevated crustal blocks, developed in the Central Carpathians. Subsequently, they were mostly destroyed by erosion following tectonic uplift.

Lower Cretaceous sequences

The Upper Jurassic/Lower Cretaceous limestone sequence in the Tatric Unit of the Malé Karpaty Mts starts with (Kimmeridgian) nodular limestone, and the Tithonian/Berriasian Oberalm Formation with intercalations of turbiditic Barmstein Limestone. The Oberalm Formation consists of brownish grey micritic wackestones. Locally, even Late Berriasian age (*Calpionellopsis* Zone) is proved. In the Kuchyňa Unit, a proximal facies with calciturbidite beds is developed, named as the Staré Hlavy Formation. The source platform limestone complex correlated with the Raptawicka Turnia Formation was studied in the Kadlubek Unit. The major part of the Lower Cretaceous sedimentary record is represented by Berriasian-Barremian schistose marly limestones similar to the Schrambach Formation or by well-bedded cherty limestone sequence of the Lučivná Formation.

The Upper Jurassic and Lower Cretaceous sequence of the Vysoká Nappe (the Fatric Unit) is represented by pelagic limestone facies. Kimmeridgian and Tithonian limestones belong to the condensed “Ammonitico Rosso” complex of reddish nodular limestone with sole limestone breccia beds.
The Padlá Voda Formation consisting of almost massive, pale wackestone to packstone represents the Early Berriasian *Calpionella* Zone. Several layers contain microbreccia composed of Tithonian and Lower Berriasian limestone clasts. The microfauna is rare, being represented by poorly preserved aptychi, fragments of belemnites or ammonite nuclei remnants. Valanginian–Lower Barremian Hlboč Formation is represented by well-bedded marly biomicrites (partly silicified wackestone–packstone) with dark chert nodules. The pelagic formations are covered by organogenic limestones of neritic origin called the Bohatá Formation. The overlying Albian Poruba Formation is more or less preserved (frequently silicified) and consists of brownish grey marls and siltstones.

Upper Cretaceous sequences

Small cavities, fissures and depressions on the surface of carbonate complexes in this part of the mountains are filled by variegated breccias consisting of angular clasts derived from local material, cemented by yellowish and red argillaceous matrix. Breccias resting on Tatric and Fatric units and composed of few 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 occurs on Triassic carbonates belonging to the Ötscher (?Göller) Nappe. It is named as the Kržľa Breccia: it consists of angular and semirounded clasts of 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. The Kržľa Breccia is covered by the transgressive Late Paleocene sequence.

The Gosau development in the northern part of the Malé Karpaty Mts
The oldest (? Late Turonian–Early Coniacian) sediments of the Late Cretaceous (Gosau) megacycle are represented by fresh-water oncolite limestones of the Pustá Ves Formation. 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 Gosau-like Brezová Group sequence in the Brezová region starts with the tripartite Ostriež Formation. The basal Valchov Conglomerate Member with red matrix rests on eroded surface of Triassic carbonates of the Jablonica Nappe. This facies (probable equivalent of the Kreuzgraben Formation or of the lower part of the Streiteck Formation of the Gosau Group in the Eastern Alps) of braided rivers and subaerial deltas contain local material derived almost exclusively from carbonate rocks. The Valchov Conglomerate is heterochronous: while the Early Coniacian age is indicated by foraminifers close to Brezová, intercalations with Campanian microfaunas have been reported E of Bzince. When streams or deltas were lacking on the ancient dolomitic seashore, the Baranes Sandstone Member overlies directly the substratum. 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 and sandy limestone with *Actaeonella gigantea*. 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.
The Hurbanova Dolina Formation is represented by a 500–600 m thick flysch sequence of alternating graded calcareous sandstones, sandy marls and sandy limestones correlable with the Grabenbach Formation of the Northern Alps. Lower Campanian Košariská Formation (~ Púchov Marl Formation) is characterized by variegated (mostly red) marls containing a foraminiferal microfauna (“*Globotruncana*” biomicrite). Upper Campanian and Maastrichtian flysch sequences comprise calcarenite sandstones, sandy *Orbitoides* limestones, microconglomerates with “exotic” pebbles and *Inoceramus* limestones and limestone turbidites (the Široké Bradlo Member).

Outline of the mountains structure

The Malé Karpaty Mountain
Several superposed nappe units comprising the Prealpine basement, its Mesozoic cover, superficial nappes and post-tectonic cover complexes were affected by Alpine crustal dissection produced by long-term extensional tectonic regime. It controlled 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. The nappe structure of the Biele Hory mountain group is covered by a sequence comparable to the Gosau Group of the Northern Calcareous Alps. 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 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.

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.
The Myjava Upland along with adjacent hilly mountains are considered as a continuation of oil-producing basement of the Vienna Basin. Analogous to the Gosau Group of the Northern Calcareous Alps, 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.

Triassic carbonate complexes 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.

Geological structure of the Strážovské Vrchy Mts
An extensive, dissected mountain range fringes the left bank of the Váh River between the towns of Žilina and Trenčín. The mountain 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. Mountains slopes on NE, N and W are limited by four basins: Rajec-, Žilina-, Púchov- and Ilava basins. 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- and 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. In spite of its particularity, the mountain structure is asymmetric with a 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.
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 Formation, Liassic “Fleckenkalk”, Adnet limestone, Dogger silicites of the Ždiar Formation, 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 Formation) and spotted Valanginian to Aptian limestones (Mráznica Formation) with small volcanoclastic bodies represent Lower Cretaceous sequence of the Zliechov Unit. Albian and Cenomanianstrata 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. 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.

Itinerary of the Field Trip

(Jozef Michalík[1], Daniela Reháková[2] & Roman Aubrecht[2])

[1]Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P.O. Box 106, 840 05 Bratislava, Slovak Republic <jozef.michalik@savba.sk>. [2]Comenius University, Šafárikovo námestie 6, P.O. Box 440, 814 99 Bratislava 1, Slovak Republic.

Stop 1. Devínska Nová Ves – Slovinec rock cliff (D. Reháková & J. Michalík)
Coordinates: E 16°58'16.9", N 48°12'05.2".
Location: Devínska Kobyla Hill.
Tectonic unit: Tatric Superunit, Devín Unit.

An Upper Jurassic and Lower Cretaceous succession is exposed in the Slovinec rock cliff wall near the Sandberg pit and Devínska Nová Ves village. Thirty-seven samples were taken in meter-intervals from the rock wall for microfacies analysis and detection of stratigraphically important microfossils. The profile line starting from the gallery entrance in the western part of the Slovinec cliff toward right upper edge of the rock documented Upper Jurassic to Lower Berriasian microfacies. The microfacies study confirmed its overturned position already supposed by tectonic study of the Devín Unit (PLAŠIENKA, 1989).

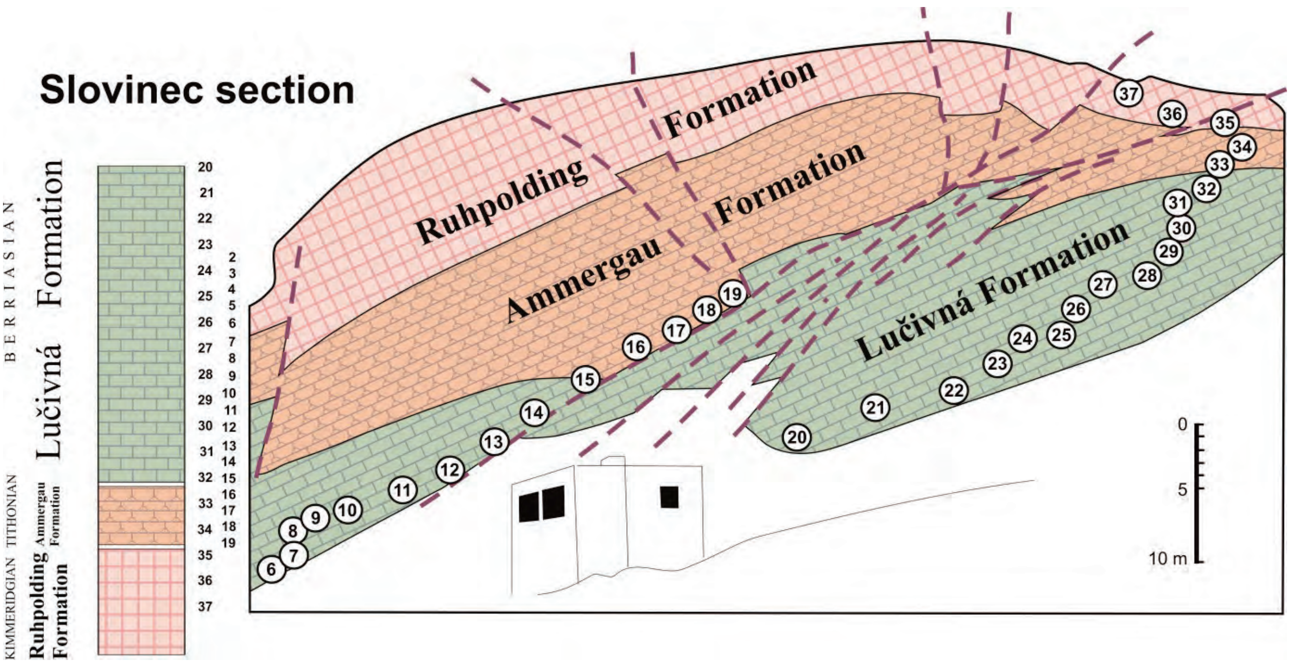
The upper part of the outcrop is built of the oldest part of the sequence attributed to the Ammergau Formation. It consists of reddish-grey to grey-brown fine grained cherty limestone. The sequence of beds 35–37 consists of marly pseudomicrosparitic wackestone to mudstone, passing into thin shales with thin silicite lenses. It contains fine scattered detritus, locally concentrated in thin laminae.

Lučivná Formation (Text-Fig. 1: Beds 1–15, 20–32)
This part of the sequence is formed by grey to greyish brown cherty limestones. They represent recrystallized mudstone (microsparite) to biomicrosparitic wackestone passing to the bedded and thin-bedded limestone above bed 5. Limestone beds are locally intercalated by thin marly laminae. Some beds contain thin fine detrite bands. Cherts are dark black grey in colour, forming nodules or stratiform layers. In beds 8 to 10 slump structures could be indicated by imbrication of cherts.

The rock is locally penetrated by abundant fractures filled by calcite; the matrix is silicified in cherty intervals. Epigenetic pyrite is scattered in matrix. Pyrite and clay minerals concentrate in frequent thin stylolites and it locally cuts contours of bioclasts. Very rare silty clastic quartz grains and muscovite leaflets are present, too. The matrix is locally slightly silicified being penetrated by calcite fractures oriented perpendicularly to metamorphous lamination.

Very rare and mostly fragmented calpionellid loricas (often hardly determined due to damage of collars) are represented by *Calpionella alpina* LORENZ, seldom *Calpionella elliptica* CADISCH, *Crassicollaria parvula* REMANE, *Crassicollaria* sp., *Tintinnopsella carpathica* (MURGEANU & FILIPESCU), microproblematicum *Didemnum carpaticum* MIŠÍK & BORZA, spores of *Globochaete alpina* LOMBARD, calcified radiolarians, fragments of crinoids, ophiuroids, ostracods, bivalves and aptychi were identified. Bioclasts are indistinctly oriented by pressure. This part of the sequence was correlated with the Lučivná Limestone Formation, its Early Berriasian age being indicated by calpionellid association of the standard *Calpionella* Zone (*Calpionella* Zone, *Alpina*- and the *Elliptica* subzones in REHÁKOVÁ & MICHALÍK, 1997).

Ammergau Formation (Text-Fig. 1: Beds 16–19, 30–34)
Globochaete-*Saccocoma* microfacies was recognized in grey-greenish limestones with indistinctly nodular texture. Spores of *Globochaete alpina*, and *Saccocoma* sp. planktonic crinoids are accompanied by rare aptychi, bivalves, ostracods and very seldom oblique sections resembling calpionellid loricas. Silicified beds contain silicified sponge spicules and radiolarians. Kimmeridgian to Tithonian age of this part of sequence is supposed on the base of microfossils mentioned above.



Text-Fig. 1: Schematic view from eastern side on the Slovinec rock cliff near the Devínska Nová Ves interpreting lithological and tectonic situation (MICHALÍK in PLAŠIENKA, 1989, adapted). Ruhpolding Formation (Beds 35–37).

Stop 2. Tmavý Jarok (J. Michalík & D. Reháková**)**
Coordinates: E 17°13'45.0", N 48°25'50.2".
Location: Rohožník, small narrows in a valley below the Vysoká Hill.
Tectonic unit: Fatric Superunit, Vysoká Nappe.

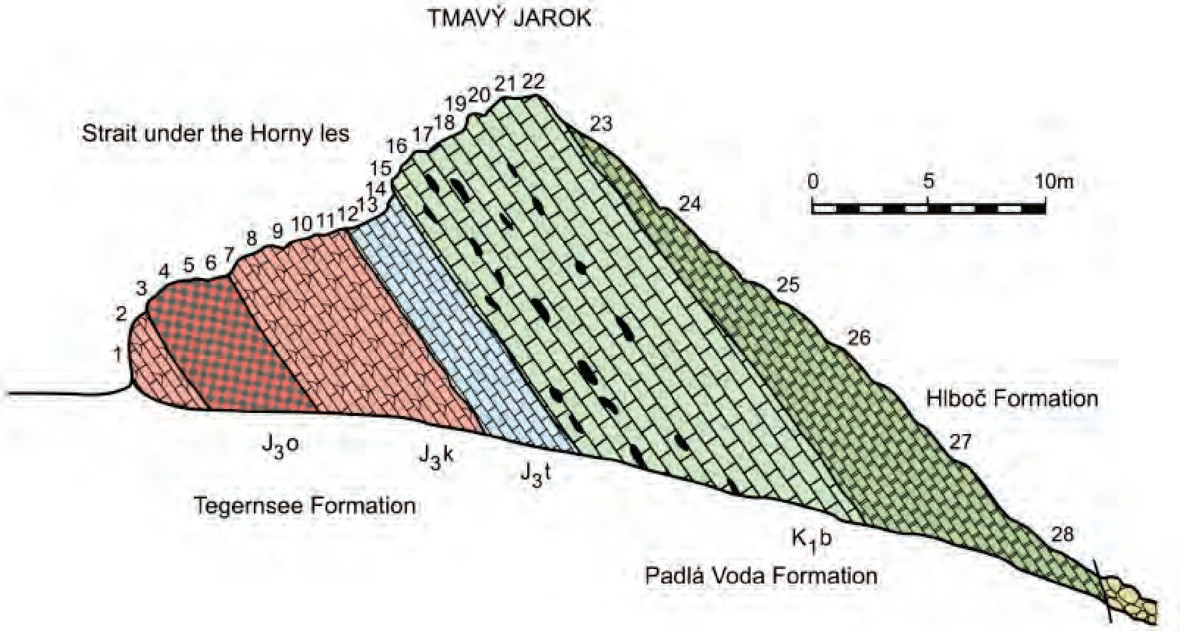
Small creek cut small narrows in Upper Jurassic and Lower Cretaceous carbonate sequence of the Vysoká Nappe. 28-meter-long section documents steep monoclinal dip studied in detail (BORZA et al., 1987; KOVÁČ et al., 1991).

Oxfordian reddish brown and pink nodular cherty limestones (1–8.5 m) attributed to the Tegernsee Formation (or Niedzica Limestone Formation sensu BIRKENMAJER, 1977). Limestones pass upwards into irregularly bedded cherty limestone with radiolarite layer (Text-Fig. 2). The nodules consist of pelbiomicrosparite or pelsparite with fragments of bivalves, ostracods, crinoids, foraminifera, cherty limestones contain calcified radiolarians and sponge spicules. According to dinoflagellate cyst zonation (REHÁKOVÁ, 2000) the presence of *Colomisphaera fibrata* (NAGY), *Cadosina parvula* (NAGY) determines the Oxfordian age of the sequence.

Nodular limestone sequence attributed to the Czorsztyn Formation by BORZA & MICHALÍK (1988) is formed by pink, red, reddish-brown and pink-grey microsparite. The Kimmeridgian part with abundant *Saccocoma* sp., *Stomiosphaera moluccana* WANNER and

Carpistomiosphaera borzai (NAGY) (9–11.5 m) contains thin crinoidal intercalations. The age of the upper, lithologically similar part (12–14 m) is dated by cyst association *Colomisphaera pulla* (BORZA), *Carpistomiosphaera tithonica* NOWAK, *Parastomiosphaera malmica* (BORZA), as well as by calpionellids *Longicollaria dobeni* (BORZA) and *Chitinoidella boneti* DOBEN as Early Tithonian. In the highermost part of the sequence pseudonodular and light-grey micritic limestones contain Late Tithonian crassicollarian association with *Crassicollaria intermedia* (DURAND-DELGA), *Cr. massutiniana* (COLOM) and *Cr. parvula* REMANE identifying the standard *Crassicollaria* Zone (REHÁKOVÁ & MICHALÍK, 1997).

Grey thick bedded micritic limestones with cherts (14,5–28 m) belong to the Padlá Voda Formation (BORZA & MICHALÍK, 1988). Microfossils *Calpionella alpina* LORENZ, *C. elliptica* CADISCH, *Tintinnopsella carpathica* MURGEANU & FILIPESCU indicate Early Berriasian age. *Calpionellopsis simplex* has been found in the uppermost layer. The Padlá Voda Formation is followed by schistose limestones of the Hlboč Formation preserved above the rocky narrows.



Text-Fig. 2: Schematic cross section of the Upper Jurassic and Lower Cretaceous limestone formations in the Rohožnícka Valley, Tmavý Jarok section (BORZA & MICHALÍK, 1988).

Stop 3. Hrušové (facultative)

Coordinates: E 17°45'50.30", N 48°46'22.51".
Location: Small valley in the N slope of Mestská Hora Hill by town of Nové Mesto nad Váhom.
Tectonic unit: Hronic Superunit, Nedze Nappe.

The section exposed by small quarry and by shallow roadcut consists of Upper Jurassic and Lower Cretaceous rocks of the Nedze Nappe belonging to the highest parts of the superficial nappe pile in the area. Detailed biostratigraphy has been described by ONDREJÍČKOVÁ et al. (1993). The lower part consists of nodular pale rose limestones of Tithonian age. They are covered by pale chalky Biancone limestones with rich content of well-preserved calpionellids, nannoplankton and radiolaria of Berriasian age.
Trenčin-Zamarovce: a short coffee stop in a rest station on the motorway.

Stop 4. Vršatec (R. Aubrecht)
Coordinates: E 18°09'35.6", N 49°04'16.7".
Location: Top of the Javornik hill above the Vršatecké Podhradie village near Pruské.
Tectonic unit: Pieniny Klippen Belt, Czorsztyn- and Orava Units.

The Vršatec Klippen group is the largest one in the entire Pieniny Klippen Belt. They crop out above the Vršatecké Podhradie village, NW of the Ilava town. Two largest tectonic blocks belong to the Czorsztyn Unit: The Vršatec Castle- and the Javornik klippe. They are formed by Middle Jurassic–Lower Cretaceous carbonates (including relatively thick, coral-dominated biohermal limestones) capped by Upper Cretaceous marls. MIŠÍK (1979) dealt in detail with sedimentology of two blocks in an E–W oriented transect based on seven stratigraphic sections. He suggested that the blocks consist of two tectonic slices with different stratigraphic successions.

According to this hypothesis, Middle Jurassic Smolegowa and Krupianka crinoidal limestone in the first slice is overlain by Upper Jurassic biohermal limestones (the Vršatec Limestone). In contrary, in the second slice, Middle Jurassic crinoidal limestone is overlain by the Czorsztyn Limestone Formation. However, SCHLÖGL et al. (2009) have found that both blocks are built of only one succession, probably with variable facies composition. Geopetal infillings within brachiopod shells indicate that crinoidal limestones are *overlying* the biohermal limestones. Moreover, biostratigraphic data prove that the biohermal limestone is older than thought before, probably of Middle Jurassic age.

The Vršatec Limestone is formed by white to pinkish biohermal limestone with corals, calcareous sponges, and locally with bivalves and brachiopods. They are laterally replaced or overlain by both pink and grey peri-biohermal limestone and breccia.

Based on bivalves, the biohermal limestones were assigned to the Oxfordian (MIŠÍK, 1979). However, these bivalves are stratigraphically inconclusive (GOLEJ, pers. comm.). One neptunian dyke cutting the limestone yielded uppermost Bajocian/lowermost Bathonian ammonite *Nannolytoceras tripartitum* RASPAIL. Moreover, most of the dykes are filled by filamentous microfacies (*Bositra* Limestone), which is restricted mainly to the Bathonian–Callovian in the Czorsztyn Unit. Oxfordian deposits are already characterized by the *Protoglobigerina* microfacies. Thus, based on the infillings of the neptunian dykes, the age of the biohermal and peribiohermal limestones is probably Early Bajocian. The exposed part of the limestones is at least 15 metres thick.

The Smolegowa- and Krupianka Limestone Formations are formed by grey to reddish crinoidal grainstone overlying the biohermal Vršatec Limestone. The top of the biohermal facies is marked by thin Fe-/Mn-crusts and impregnations. In contrast, the boundary between the peribiohermal facies and crinoidal limestone seems to be gradual in most sections. Because of lack of stratigraphically more valuable fauna, the age of crinoidal limestones is based on the dating of equal crinoidal deposits in the area as the Bajocian. The thickness is around 35 metres.

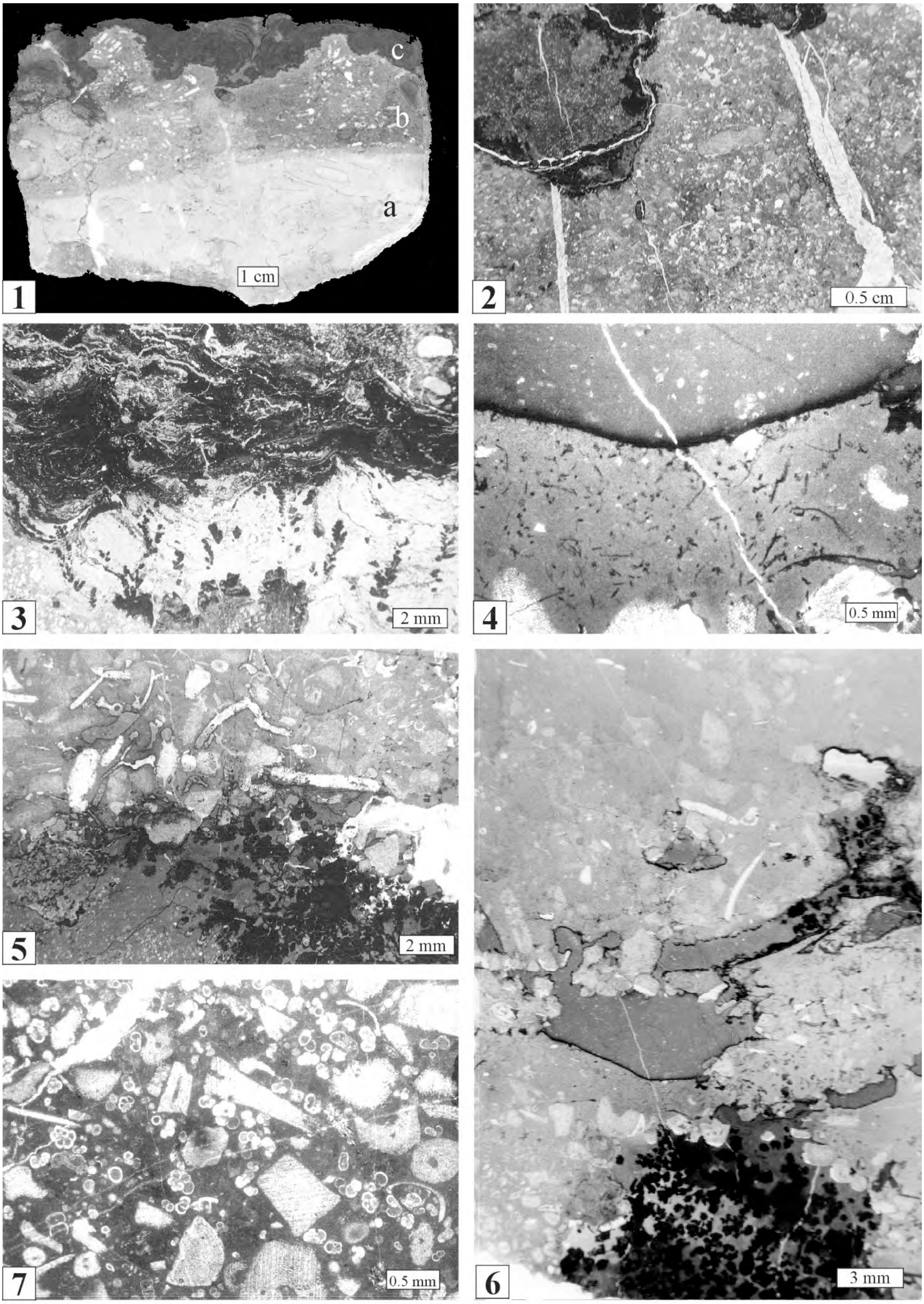
The Czorsztyn Limestone Formation consists of red micritic, locally nodular limestones. Based on ten detailed stratigraphic sections along both blocks, the thickness of this formation vary between 0.2 to more than 15 metres. There is invariably a 0.5–2 cm-thick Mn-crust at the base of the formation, marking the hiatus between the crinoidal and red micritic limestones. Based on ammonites and on data from other sections, the age of the whole formation is Bathonian to Early Tithonian. The thickness of the Bathonian–?Callovian deposits, which are separated from the overlying red micritic limestones by another Mn-/Fe-hardground, attains few cm up to 3.5 metres. The deposits contain mainly filaments (filamentous packstones), juvenile gastropods, benthic foraminifers and crinoidal ossicles. The *Protoglobigerina* microfacies characterizing overlying massive limestones suggests their Oxfordian age. The massive limestones pass gradually into massive red micritic limestones with the *Saccocoma* microfacies. Ammonite fauna including *Orthaspidoceras uhlandi* (OPPEL) and *Hybonoticeras hybonotum* (OPPEL) indicates a Kimmeridgian and Early Tithonian age.

The Dursztyn Limestone Formation consists of massive, red, pinkish or yellowish micritic limestones. Locally, they can be rich in crinoidal ossicles (forming lenses of crinoidal packstones) and fine shelly debris. The *Saccocoma* microfacies pass gradually into the *Crassicollaria* and *Calpionella* microfacies. The Middle Tithonian to Early Berriasian age of the formation is based on calcareous dinoflagellates and calpionellids.

Cretaceous deposits are represented by red marls and marlstones. A tectonic contact of the Upper Tithonian to Berriasian white to pinkish *Calpionella* limestones with red marls and marlstones is exposed in the road cut in the saddle above the Vršatské Podhradie village. Limestone and marl sequence is in a reverse position. Normal sedimentological contact between Dursztyn Limestone Formation and red Púchov marls is visible on the foot of the Vršatec Castle Klippe, where the signs of karstification of the Lower Cretaceous limestones can be observed. The marls are of Late Cenomanian to Campanian age.

As the sections in the Pieniny Klippen Belt represent isolated blocks and tectonic lenses which were rotated along several axes, paleomagnetic analyses are necessary for the reconstruction of their original palaeogeographic position. AUBRECHT & TÚNYI (2001) analysed neptunian dyke orientations in four sections in the Pieniny Klippen Belt. They include the Vršatec Castle Klippe (Text-Fig. 3-1), Babiná quarry, Mestečská skala and Bolešovská dolina. In majority, neptunian dykes are cut in Bajocian–Bathonian crinoidal limestones (Smolegowa- and Krupianka Limestone Formations) and consist of red micrites or biomicrites. They contain mainly juvenile bivalves or rarely the *Globuligerina* microfacies. These microfacies indicate that the dykes range from the Bathonian to Oxfordian. Exceptionally, neptunian dykes of Tithonian and Albian age were found in the Vršatec klippe. They represent rejuvenation of older dykes (MIŠÍK, 1979).

Text-Fig. 3-1 (page 71): Slabs and microphotos of microfacies from the Vršatec area. A: Slab showing Lower Cretaceous limestone (a), covered by Upper Albian organodetrital limestone (b) and by P-Fe stromatolite (c) which forms the base of pelagic Albian deposit. Note uneven surface between the Upper Albian limestone and the stromatolite cover. The surface has been most likely shaped by karstic dissolution. It provides an evidence of repeated emersion of the sedimentary area still after the first phase of Late Aptian flooding. B: Two veinlets filled by blocky calcite, cutting Lower Cretaceous organodetritic limestone but not continuing to the Albian stromatolitic hardground above. Their age is then pre-Albian and their filling could be of fresh-water origin. C: Albian stromatolite (with ptygmatitically folded calcite veinlets – the upper part of the photo) and bush-like (*Frutexites*-type) stromatolites growing in the Albian sediment towards the stromatolite. The latter means that the sediment represents a filling of larger cavity and the stromatolite above it grew on the roof of the cavity. D: Network of boring organism traces, most likely fungi (note local branching) filled by Mn-oxides in the Lower Cretaceous limestone below the base of the Albian sediments. E: Geopetal filling of leached bivalve shells in Lower Cretaceous limestone (above) contradicts with the location of Albian sediment (below). It indicates that the Albian sediment has been deposited in a (most likely karstic) cavity. F: Bizarre cavities in the Lower Cretaceous limestone filled by Albian micrite. Their geopetal filling enables proper orientation of the photo, in spite of position of the Albian stromatolite and sediment (below). They most probably represent filling of a larger karstic cavity. G: Upper Aptian–Lower Albian crinoidal-foraminiferal wackestone to packstone, recording the first flooding phase after hiatus.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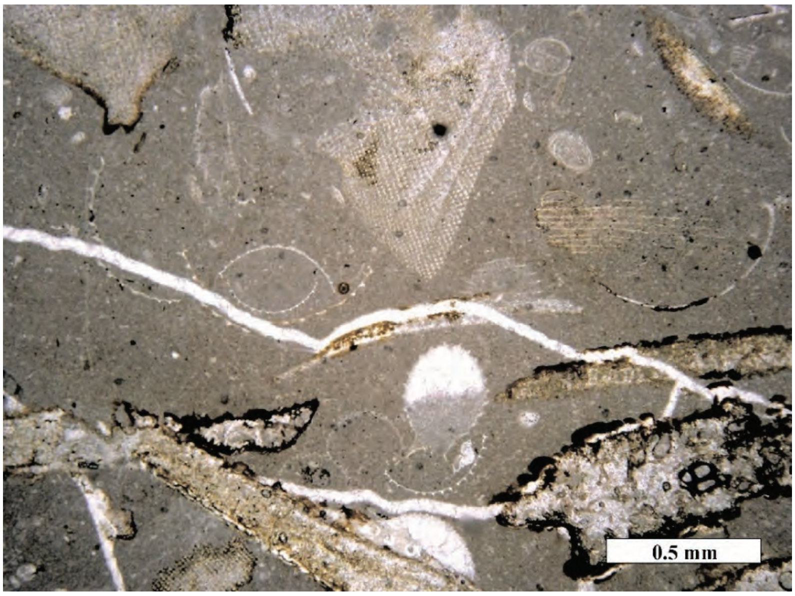


Text-Fig. 3-2: Cross-sections of cave-dwelling ostracods *Pokornyopsis feifeli* (TRIEBEL) in a neptunian dyke filling from the Vršatec Castle klippe.

The neptunian dykes (but also crevices in the breccias and even cavities in the stromatactis mud-mounds at Babiná and Slavnické Podhorie) show presence of *Pokornyopsis feifeli* (TRIEBEL) (Text-Fig. 3-2), ancestors of recent ostracod *Danielopolina* which is a common cave dweller in the so-called anchialine caves (AUBRECHT & KOZUR 1995). The measurements of the neptunian dykes and their evaluation, with utilizing of paleomagnetic correction, enable estimating the paleogeographic orientation of the Czorsztyn Ridge as NE–SW (with N–S to ENE–WSW variations). This direction points to the NW-SE oriented Jurassic extension in that area. Paleomagnetic inclination ranging between 21º and 46º, with mean point of about 33º, indicates that the Czorsztyn Ridge was located approximately at 10–30º paleolatitudes in the Middle Jurassic.

The Czorsztyn Unit is the shallowest Pienidic Unit of the West Carpathian Pieniny Klippen Belt. After the Hauterivian, a hiatus encompassing almost the whole Barremian and Aptian occurred in this unit. Tithonian–Lower Cretaceous limestones are overlain by pelagic Albian marlstones and marly limestones. The nature of this hiatus was frequently discussed in the literature: some authors favoured submarine non-deposition and erosion (BIRKENMAJER, 1958, 1975), whereas others proposed emersion of the ridge (MIŠÍK 1994).

Recently, most of the formerly known sites were re-examined and new sites with preserved contact between the Albian and the underlying formations of the Czorsztyn Unit were found. At two sites, Albian marlstones and limestones are in contact with Lower Cretaceous, Tithonian or older rocks. In Jarabiná, Barremian–Aptian erosion reached Kimmeridgian red micritic limestones but clasts of limestones with “filamentous” microfacies indicate that Bathonian–Callovian limestones had to be uncovered too. At Horné Sŕnie, where the deepest erosion level was stated, Albian deposits overlay Bajocian–Bathonian crinoidal limestones. Except of deep erosion, unequivocal signs of subaerial exposure and karstification (karren)-landform with vertical drainage grooves, small cavities in the bottom rock filled with later sediment, bizarre fractures and veinlets filled with calcite, were revealed, mainly in the Horné Sŕnie and Lednica sites. Erosion was followed by pelagic deposition, documented by Albian marlstones and limestones with pelagic fauna. In this time, the paleokarst surface was bored by boring bivalves and overgrown by deep-water Fe-Mn to phosphatic stromatolites. This suggests a very rapid relative sea-level rise, most likely due to platform collapse and drowning.

Several relics of the Albian marlstones overlying Lower Cretaceous limestones, together with some Albian neptunian dykes cutting the underlying rocks, were found in the Vršatec klippen. Most of them were summarized by MIŠÍK (1979); two localities were revealed recently. The basement below the Albian sediments is commonly irregular due to karstification and animals boring activity. Small caverns in Lower Cretaceous limestones filled by Albian sediments are common too. Albian pelagic marlstones contain belemnites (*Neohibolites minimus* LISTER), bivalves *Aucellina* sp. and numerous planktonic foraminifers *Ticinella roberti* (GANDOLFI), *Thalmanninella ticinensis* (GANDOLFI), *Hedbergella infracretacea* (GLAESSNER), *Thalmanninella apenninica* (RENZ), *Planomalina buxtorfi* (GANDOLFI) and many agglutinated foraminifers. The foraminifer assemblage indicates Albian to Cenomanian age of the overlying beds. Deep-water bacterial Fe-Mn-P stromatolites, oncoids and frutexites are common in the basal parts, sometimes directly overgrowing the underlying limestone. Higher up, radiolarian cherts were found in Cenomanian–Turonian marlstones at the southernmost Vršatec klippe (SÝKORA et al., 1997) which testifies rapid sea-level rise after drowning of the swell.

In the Albian sediments on six localities (two from Vršatec), detrital admixture including chrome spinels was found (JABLONSKÝ et al., 2001). Such minerals, derived from an unknown ophiolitic source area are common in the Albian deposits of the Klape Unit, the Tatric and Fatric units, but they were not found in the Czorsztyn Unit so far. The presence of Albian ophiolite debris in the Czorsztyn Unit is very surprising and contradicts to the classical paleogeographic schemes where the Czorsztyn Swell formed an isolated ridge, surrounded by deep troughs during Albian, still.

Stop 5. Butkov Quarry (J. Michalík)
Coordinates: E 18°19’21.23”, N 49°01’28.58”.
Location: Large quarry on the N slope of the Butkov Hill, Ladce BERGER Cement factory.
Tectonic unit: Manín Unit.

Jurassic to Lower Cretaceous sequence of the Manín Unit is exposed on fifteen-levels quarry (Text-Fig. 4). Lower Jurassic strata are built of sandy limestones, followed by Mid-Jurassic shaly siliceous rocks and Callovian/Tithonian Ammonitico Rosso nodular limestone complex. After a Berriasian gap, the Cretaceous sequence starts with hemipelagic carbonate deposition. Until now, hundreds of ammonite specimens were collected in it and put in the orthostratigraphic scale. Vertical distribution of ammonites and aptychi was laterally correlated with the distribution of calcareous microplankton (calpionellids, calcareous and non-calcareous dinoflagellates and nannoplankton).

Early Valanginian age of deposition of thin bedded pale marly Ladce Formation limestone has been proved by ammonite fauna of the *Campylotoxus* Zone. Sedimentation of this formation terminated during Late Valanginian (between *Peregrinus*- and *Furcillata* Zones). Ammonite findings were correlated with the aptychi distribution. The Valanginian age has been proved by calpionellids of the Calpionellites standard zone (the Darderi- and the Major subzones) and calcareous dinoflagellates. Moderately to poorly preserved *Nannoconus* spp. and *Watznaueria barnesae* constitutes 40–90 % of low-diversified calcareous nannofossil assemblage which allowed distinguishing of the Calcicalathina oblongata NK-3 Zone (the *Rucinolithus wissei* NK-3A Subzone). Seldom, poorly preserved non-calcareous dinoflagellate association belongs to the Spiniferites Zone.

The boundary between the Ladce Formation and overlying Mráznica Formation is not sharp (somethimes it is stressed by a calciturbidite layer). The *Verrucosum* and *Peregrinus* Zones were identified due to presence of subzonal ammonite species only. Ammonite remnants are abundant in Upper Valanginian part of the Mráznica Formation. They belong to the *Furcillata* Zone. Late Hauterivian age of the Mráznica Formation has been identified by the ammonite association of the *Balearis* Zone.

Text-Fig. 4: Jurassic to Lower Cretaceous sequences of the Manín Unit in the Butkov Quarry.

Sequence of marly limestones contains very rare microfossils of the *Tintinnopsella* Zone, rare remaniellids show rather the erosion of older deposits. Calcareous nannofossils belong to the Late Valanginian *Tubodiscus verenae* Subzone (NK–3). Cosmopolitan representatives (*Watznaueria barnesae, Cyclagelosphaera margerelii, Rhagodiscus asper, Zeugrhabdotus embergeri, Cretarhabdus* spp.*, Micrantholithu*s spp.) together with Tethyan taxa (*Conusphaera mexicana, Cyclagelosphaera deflandrei, Cruciellipsis cuvillieri* and *Nannoconus* spp.) created nannofossils assemblages. In the Upper Valanginian and Lower Hauterivian rare boreal taxa has been noticed (*Micrantholithus speetonensis, Crucibiscutum salebrosum, Nannoconus pseudoseptentrionalis*). Palynological study shown rather the rich association of Late Valanginian to Lower Hauterivian non-calcareous dinoflagellates belonging to *Cymososphaeridium validum* (Cva) Zone determined by LEEREVELD (1997a, b).

Hauterivian age of pelagic cherty Kališčo Formation limestones has been proved by ammonites of the *Radiatus*- and *Ligatus* Zones. *Tintinnopsella carpathica* is very seldom in Kališčo Formation. Calcareous nannofossils allowed to determine NC-4A and NC-4B Subzones equivalent to the lowermost ammonite *Nodosoplicatum* Zone. Low content of nannoconids and abundance of *Micrantolithus hoschulzii* is a characteristic feature of Early Hauterivian nannofossil associations. Association of non-calcareous dinoflagellates belongs to the *Muderongia staurota* (Mst) Zone, which is correlated with ammonite *Radiatus*- and *Nodosoplicatum* zones. The *Nodosoplicatum* Zone is proved also by the first appearence of *Coronifera oceanica* and by presence of coeval nannofossils.

The basal part of grey bedded micritic limestones of the Lúčkovská Formation contains ammonites of Late Hauterivian *Balearis* Zone. Ammonites collected proved the Pulchella and *Compressissima* zones, and the basal part of Late Barremian *Vandenheckii* Zone. Sporadic *Tintinnopsella carpathica* was continuously observed in lower part of formation. The calcareous nannofossil assemblage belongs to the *Litraphidites bollii* Zone (NC-5B Subzone). If compared with the Kališčo Formation, nannoconids abundance increased. A block from the eastern part of the 7th etage (BK-7/V) belongs to the Early Barremian *Micratholithus hoschulzii* Zone, NC-5D Subzone. The Lúčkovská Formation yielded rich palynomorphs. Lower Barremian *Subtilisphaera scabrata* (Sca) and Upper Barremian *Odontochitina operculata* (Oop) dinozones were identified in the uppermost part of formation.

Dark grey bituminous limestones of the Podhorie Formation contain bad preserved, corroded dinoflagellates similar to Upper Barremian or younger types.

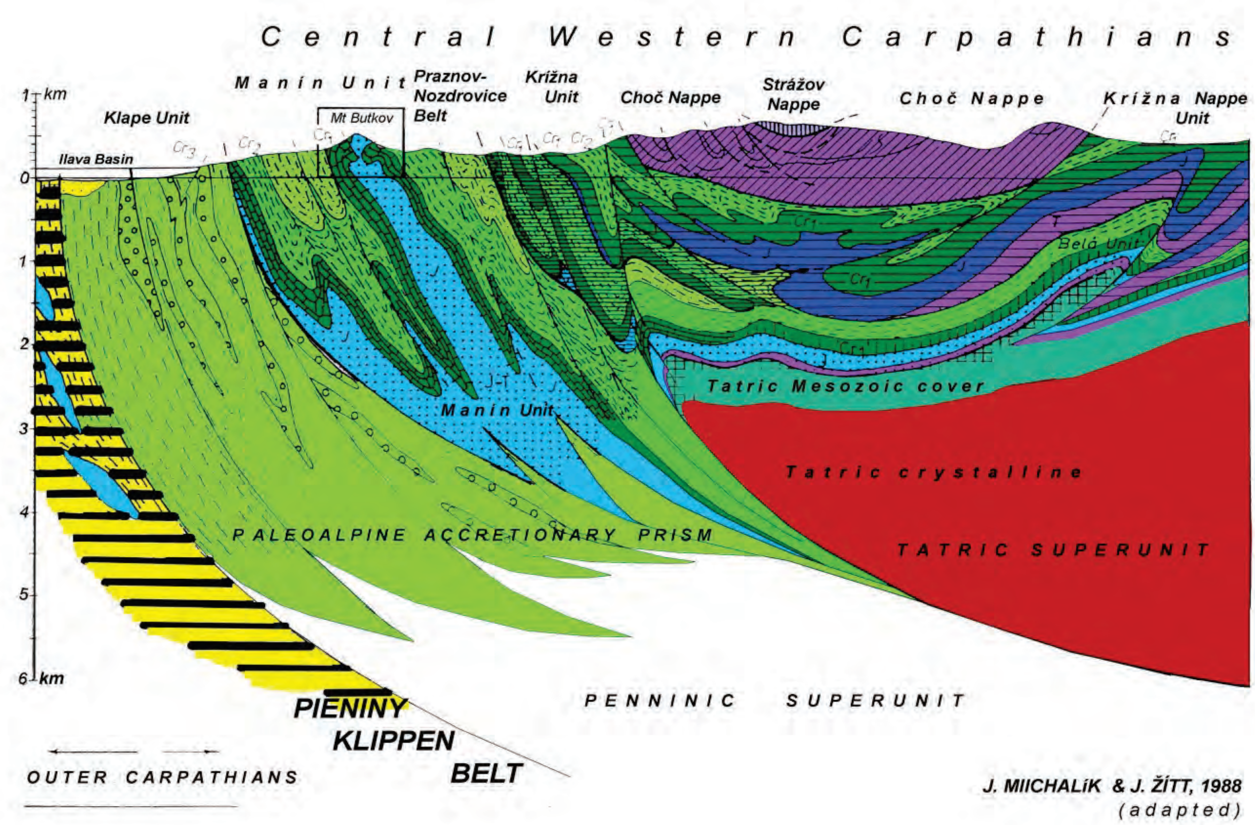
Dark grey marlstones of the Butkov Formation contain rich dinoflagellate association. On the base of their spectra it is possible to correlate it with the Late Albian ammonite *inflatum*- and *dispar* Zones. Very rare findings of the species *Eiffelithus turriseiffelii* in the Butkov Formation allow to set the Albian age of formation or assign the base of the *Eiffelithus turriseiffelii* Zone (CC9) sensu PERCH-NIELSEN (1985).

On the base of sequence stratigraphy study of the Lower Cretaceous formations mentioned above it was possible to recognize nine sequence boundaries. Comparison of non-calcareous dinoflagellates with sea-level fluctuation has shown the dominance of brackish species (*Muderongia*) during the lowstand conditions, and on the other hand, prevalence of neritic (*Oligosphaeridium, Spiniferites*) and oceanic (*Pterodinium*) species during transgressive and highstand intervals.

Stop 6. Mojtin Valley (J. Michalík)

Coordinates: E 18°21’23.25”, N 49°01’06.53”.
Location: Road cuts Beluša–Belušské Slatiny–Mojtín.
Tectonic unit: Klape Unit, Manín Unit, Krížna Nappe.

The roadcut between Beluša, Belušské Slatiny and Mojtín villages cuts frontal parts of the superficial nappe system in the Strážovské Vrchy Mts. It starts in slices of the Klape Unit covered by remnants of Neogene infilling of the Váh River depression. The road passes a well of mineral (sulphur) water penetrating along marginal faults of the basin. The Manín Unit forms an anticlinal fold with a core of Jurassic and Lower Cretaceous formations rimmed by mid- and Upper Cretaceous complexes (Text-Fig. 5). The unit is thrust westward onto the Klape Unit. From the eastern side, it is overthrust by a transitional unit, built of Cretaceous limestones and shales. The higher unit belongs to the frontal part of the Krížna Nappe, formed by Lower Cretaceous marly limestones of the Mráznica Formation, of the Aptian volcanic and shaly complex and of the Albian shaly Poruba Formation. The following Choč Nappe forms the second rocky narrows, built of Jurassic crinoidal and nodular limestones, Lower Cretaceous Biancone limestones, and the youngest member of sequence in this unit – Barremian shales with detritus of chromspinel grains. The highest part of the pile consists of Triassic limestones of the Strážov Nappe. The plateau where the Mojtín village is situated, is covered by bauxite weathering products below the base of Paleogene sedimentary infilling of a younger intra-Carpathian basin.



Text-Fig. 5: Cross-section through the front of the Central Carpathian nappe units.

Stop 7. Skalica Rock (J. Michalík & D. Reháková)
Coordinates: E 18°26'02.80", N 49°04'41.82".
Location: Rocks above meadows by the Dolný Moštenec village.
Tectonic unit: A "klippe" of the Manín Unit.

Prominent rock cliff exposes Upper Aptian–Lower Albian part of the sequence similar to the Manín Unit (Text-Fig. 6, 7). It consists of organodetrital limestones. The locality has been studied by ANDRUSOV & KOLLÁROVÁ-ANDRUSOVOVÁ (1971); RAKÚS (1977); BORZA et al. (1979); MARSCHALKO & KYSELA (1980); MICHALÍK & VAŠÍČEK (1984). In detail, the sequence consists of two different parts.

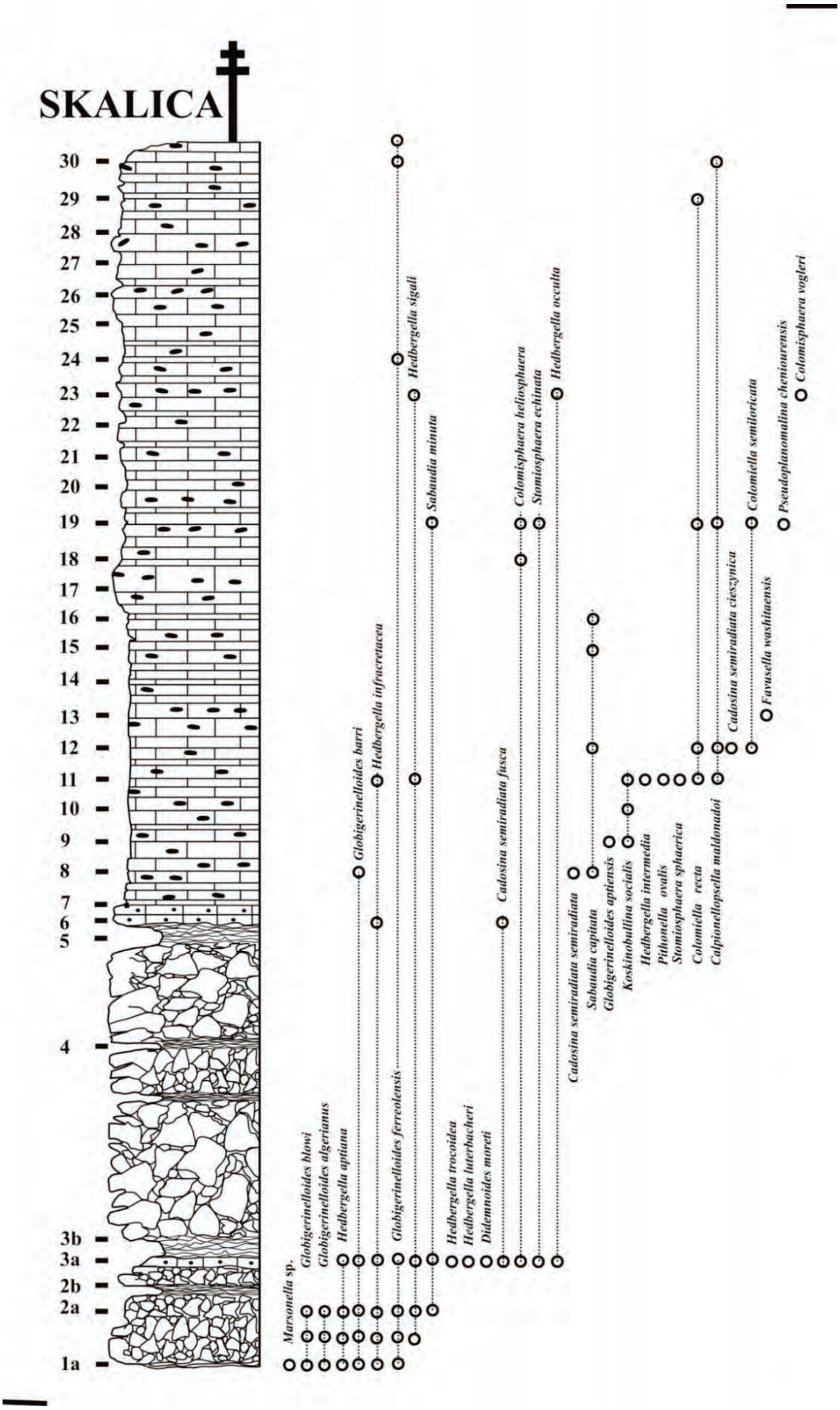
Six thick layers formed by breccia of "Urgonian-type" limestones crops out in the lower part of the rock wall. The clasts are 4 to 70 cm in diameter (some of them attain several meters), they consist of pelbiointrasparite (grainstone to rudstone). Clasts are cemented by glauconitic biodetrital wackestone with fragments of belemnite rostra.

Text-Fig. 6: The outcrop of the Skalica Rock succession above the meadows close to Dolný Moštenec.

Foraminifers are represented by *Globigerinoidelloides blowi*, *G. algerianus*, *G. ferreolensis*, *G. barri*, *Hedbergella aptiana*, *H. sigali*, *H. trocoidea*, *H. luterbacheri*, *H. infracretacea*, occurring along with *Cadosina semiradiata fusca*, *Sabaudia minuta*, *Colomisphaera heliosphaera*. Each of the layers is topped by greenish grey marl containing numerous (mostly fragmented) fossils, mainly belemnites (*Mesohibolites fallauxi* and *Neohibolites inflexus* cf. *angelanicus*), brachiopods, echinoids and ammonites. ANDRUSOV & KOLLÁROVÁ-ANDRUSOVOVÁ (1971) and VAŠÍČEK (in MICHALÍK & VAŠÍČEK, 1984) reported findings of *Melchiorites* cf. *melchioris* (TIETZE), *Acanthohoplites* ex gr. *bigoureti* and *Phylloceras* (*Hypophylloceras*) *moreti* (MAHMOUD) indicating the *Melchioris* Zone of Late Aptian.

The highest marlstone bed is covered by thick (90–120 cm) layer of glauconitic biodetrital packstone. It contains echinoids, seldom planktonic foraminifers (Hedbergella and Globiogerinelloides) and cysts (*Cadosina semiradiata semiradiata*). Framboidal pyrite occurs frequently.

The upper part of the sequence is built of thick bedded blackish grey biomicrite packstone- to wackestone of spongolitic facies with large loaf cherts. They contain *Koskinobullina socialis*, *Pithonella ovalis*, *Colomiella recta*, *C. semiloricata*, *Calpionellopsella maldonadoi*. Their age has been estimated as Early Albian by BORZA et al. (1979). The sequence represents a peri-basinal development of the Manín sequence.



Text-Fig. 7: Skalica Rock succession.

References

ANDRUSOV, D. & KOLLÁROVÁ-ANDRUSOVOVÁ, V. (1971): Transgression du Crétacé moyen dans ľunité de Manín (Zone des Klippes. Vallée du Váh, Slovaquie). – Geologický Zborník (Geologica Carpathica), **22**, 149–157, Bratislava.

AUBRECHT, R. & KOZUR, H. (1995): Pokornyopsis (Ostracoda) from the submarine fissure fillings and cavities in the Late Jurassic of Czorsztyn Unit and the possible origin of the Recent anchialine faunas. – Neues Jahrbuch für Geologie und Paläontologie: Abhandlungen, **196**, 1–17, Stuttgart.

AUBRECHT, R. & TÚNYI, I. (2001): Original orientation of neptunian dykes in the Pieniny Klippen Belt (Western Carpathians): the first results. – Contributions to Geophysics and Geodesy, **31**/3, 557–578, Warszawa.

BIRKENMAJER, K. (1958): Geological Guide in the Pieniny Klippen Belt. I – Geological outline of the Klippen Belt. – Wydawnictwa Geol. Warszawa, 135 pp., Warszawa (in Polish).

BIRKENMAJER, K. (1977): Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. – Studia Geologica Polonica, **45**, 159 pp., Krakow.

BORZA, K. & MICHALÍK, J. (1988): Biostratigraphy of Upper Jurassic and Lower Cretaceous formations in the Vysoká Nappe, Male Karpaty Mts. – Knihovna zemniho plynu a nafty, Miscellanea Palaeontologica, **II**/1, 6a, 203–214, Hodonin (in Slovakian).

BORZA, K., KOHLER, E. & SAMUEL, O. (1979): New stratigraphic and tectonic data on the Skalica klippe. – Geologické práce, Správy (Bratislava), **72**, 97–112, Bratislava.

BORZA, K., MICHALÍK, J. & VAŠÍČEK, Z. (1987): Lithological, biofacial and geochemical characterization of the Lower Cretaceous pelagic carbonate sequence of Mt. Butkov (Manín Unit, Western Carpathians). – Geologický Zborník (Geologica Carpathica), **38**/3, 323–348, Bratislava.

JABLONSKÝ, J., SÝKORA, M. & AUBRECHT, R. (2001): Detritic Cr-spinels in Mesozoic sedimentary rocks of the Western Carpathians (overview of the latest knowledge). – Mineralia Slovaca, **33**, 487–498, Bratislava (In Slovak with English summary).

KOVÁČ, M., MICHALÍK, J., PLAŠIENKA, D. & PUTIŠ, M. (Ed.) (1991): Malé Karpaty Mts. Geology of the Alpine-Carpathian junction. Excursion guide. – Geological Institute of Dionýz Štúr, 82 pp., Bratislava.

LEEREVELD H. (1997a): Upper Tithonian-Valanginian (Upper Jurassic-Lover Cretaceous) dinoflagellate cyst stratigraphy of the western Mediterranean. – Cretaceous Research, **18**, 385–420, London.

LEEREVELD H. (1997b): Hauterivian-Barremian (Lower Cretaceous) dinoflagellate cyst stratigraphy of the western Mediterranean. – Cretaceous Research, **18**, 421–456, London.

MARSCHALKO, R. & KYSELA, J. (1980): Geology and sedimentology of the Klippen Belt and Manín Unit between Žilina and Považská Bystrica. – Západné Karpaty, Seria Geológia, **6**, 7–79, Bratislava (In Slovak with English summary).

MICHALÍK, J. (1984): Some remarks and interpretation of geological development and structure of the NW part of the Malé Karpaty Mts (Western Carpathians). – Geologica Carpathica, **35**, 489–504, Bratislava.

MICHALÍK, J. (2007): Sedimentary rock record and microfacies indicators of the latest Triassic to mid-Cretaceous tensional development of the Zliechov Basin (central Western Carpathians). – Geologica Carpathica, **58**/5, 443–453, Bratislava.

MICHALÍK, J. & VAŠÍČEK, Z. (1984): To the early mid Cretaceous development: the age and environmental position of the „Skalica Breccia". – Geologický Zborník (Geologica Carpathica), **35**, 559–581, Bratislava.

MICHALÍK, J., PLAŠIENKA, D., REHÁKOVÁ, D., SALAJ, J., SOTÁK, J. & ČINČURA, J. (2000): Excursion into westernmost Central Carpathians (Slovakia) – fieldtrip B, Monday, August 28, 2000. – 6th International Cretaceous Symposium, August 27th to September 4th, 2000, Vienna, Austria. 39 p., Wien.

MIŠÍK, M. (1979): Sedimentological and microfacial study in the Jurassic of the Vršatec (castle) klippe (neptunic dykes, Oxfordian bioherm facies). – Západné Karpaty, Seria Geológia, **5**, 7–56, Bratislava (In Slovak with English summary).

MIŠÍK, M. (1994): The Czorsztyn submarine ridge (Jurassic-Lower Cretaceous, Pieniny Klippen Belt): An example of a pelagic swell. – Mitteilungen der Österreichischen Geologischen Gesellschaft, **86** (1993), 133–140, Wien.

ONDREJÍČKOVÁ, A., ŽECOVÁ, K., ŽÍTT, J. & MICHALÍK, J. (1993): Calpionellid, radiolarian and calcareous nannoplankton associations near Jurassic / Cretaceous boundary (Hrušové section, Čachtické Karpaty Mts, Western Carpathians). – Geologica Carpathica, **44**/3, 177–188, Bratislava.

PERCH-NIELSEN, K. (1985): Mesozoic calcareous nannofossils. – In: BOLLI, H.M., SANDERS, J.B., PERCH-NIELSEN, K. (Eds.): Plankton stratigraphy, 329–426, London (Cambridge University Press).

PLAŠIENKA, D. (1989): Tectonics and paleotectonics of Tatric Mesozoic complexes of the Malé Karpaty Mts: Partial report of the ŠPZ II-4-5/01 Project. – MS, Geol. ústavu SAS Archive, Bratislava (In Slovak).

PLAŠIENKA, D., MICHALÍK, J., GROSS, P. & PUTIŠ, M. (1991): Paleotectonic evolution of the Malé Karpaty Mts – an overview. – Geologica Carpathica, **42**, 195–208, Bratislava.

RAKÚS, M. (1977): Supplements to the Jurassic and Cretaceous lithostratigraphy and paleogeography of the Manín series in the middle Váh valley. – Geologické práce, Správy, **68**, 21–38, Bratislava (in Slovak).

REHÁKOVÁ, D. (2000): Calcareous dinoflagellate and calpionellid bioevents versus sea-level fluctuations recorded in the West-Carpathian (Late Jurassic/Early Cretaceous) pelagic environments. – Geologica Carpathica, **51**/4, 229–243, Bratislava.

REHÁKOVÁ, D. & MICHALÍK, J. (1997): Evolution and distribution of calpionellids – The most characteristic constituents of Lower Cretaceous Tethyan microplankton. – Cretaceous Research, **18**/3, 493–504, London.

SCHLÖGL, J., MICHALÍK, J., PLAŠIENKA, D., AUBRECHT, R., REHÁKOVÁ, D., TOMAŠOVÝCH, A., BUČOVÁ, J., MIKUŠ, V., SÝKORA, M. & GOLEJ, M. (2009): Jurassic to Lower Cretaceous deposits of the Pieniny Klippen Belt and Manín Unit in the Middle Váh Valley (Biele Karpaty and Strážovské vrchy Mts, western Slovakia). Field trip guide, Jurassica VIII, Vršatec, 8.–11.10.2009. – Geologia, **35**/3/1, 119–181, Krakow.

SÝKORA, M., OŽVOLDOVÁ, L. & BOOROVÁ, D. (1997): Turonian silicified sediments in the Czorsztyn succesion of the Pieniny Klippen Belt (Western Carpathians, Slovakia). – Geologica Carpathica, **48**/4, 243–261, Bratislava.