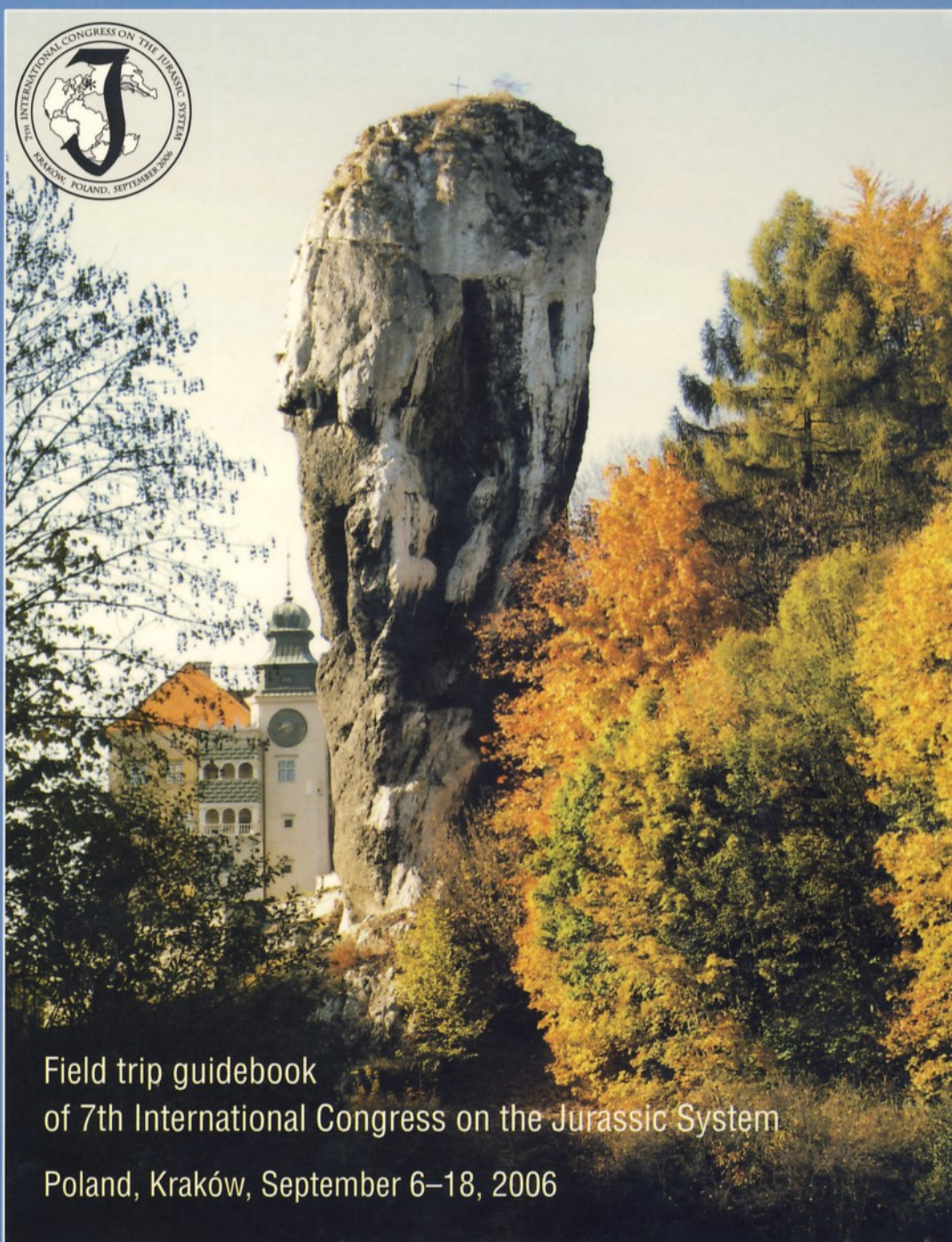




Ministry of the Environment

JURASSIC OF POLAND

AND ADJACENT SLOVAKIAN CARPATHIANS



Field trip guidebook
of 7th International Congress on the Jurassic System
Poland, Kraków, September 6–18, 2006



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Edited by: A. Wierzbowski, R. Aubrecht, J. Golonka, J. Gutowski,
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FIELD TRIP B3 — INSIDE TETHYS

Itinerary: Kraków – Myślenice – Chyżne – Trstená – Podbiel – Oravský Podzámok – Brodno – Vršatec – Slávnické Podhorie – Košeca – Hatné – Suchá Hora – Zakopane – Tatra Mts. – Nowy Targ – Obłazowa – Rogoźnik – Kraków

PIENINY KLIPPEN BELT OF WESTERN SLOVAKIA

The general structure of the Pieniny Klippen Belt (PKB) and its geological evolution are presented in the introduction to field trip A. The West Slovakian sector of the PKB shows many features in common with the Polish sector, but it displays some differences, too (Aubrecht *et al.*, 1997).

The West Slovakian sector is essential to the palaeogeographic and sedimentological reconstruction of some unusual deposits attributed to the Czorsztyn Succession in its broad meaning. These include: (1) the coral bioherms of early Middle Jurassic age, which only site in PKB is in Vršatec Klippen (see stop B3.5), (2) the stromatactis mud-mounds of late Middle Jurassic age in Slávnické Podhorie Klippe (see stop B3.6), and (3) cross-bedded crinoidal limestones of Bajocian age in Hatné Klippe (stop B3.7).

The PKB successions correspond mostly to these distinguished in Poland but with minor differences (e.g. the Kysuca Succession/Unit corresponds to the Branisko Succession *etc.*). There exist, however, some successions/units, which have not their counterparts in the Polish sector of PKB. It is e.g. the case of the Orava (Podbiel) Succession (stop B3.2 at Podbiel–Červená skala, and Orava Castle) characterized i. a. by occurrence of nodular limestones of latest Pliensbachian to Toarcian age (Adnet Fm.).

Finally, some outcrops in West Slovakian Pieniny Klippen Belt show full sequence of deposits usually poorly or incompletely exposed in Poland, e.g. Bajocian to Oxfordian of the deep water Pieniny Succession (stop B3.1 at Halečková Klippe).

Stop B3.1 — Halečková Klippe (quarry) (Fig. B3.1A) — Bajocian to Oxfordian calcareous and radiolarite sequence of the Pieniny Succession

Roman Aubrecht, Michał Krobicki, Alfred Uchman

Halečková Klippe is situated SW of the small town of Trstená, near the main road connecting Trstená and Tvrdošín. In the old abandoned quarry, a part of the Pieniny Succession (deep-water sequence of the Pieniny Klippen Basin) is visible in tectonically overturned position (Fig. B3.2). The uppermost part of the quarry shows the Fleckenkalk/Fleckenmergel-type facies of the Podzamcze Limestone Formation (former Supra-Posidonia Beds — Bajocian); the middle part displays grey-brown, manganiferous radiolarites of the Sokolica Radiolarite Formation (uppermost Bajocian–Upper Callovian), whereas the lower parts of the quarry — the Czajakowa Radiolarite Formation (grey-greenish radiolarites of the Podmajerz Radiolarite Member, Upper Callovian–Lower Tithonian). The Podzamcze Limestone Fm. yields abundant plant detritus with

well known discovery of a fern *Otozamites graphicus* (Fig. B3.3) described by Sitár and Jablonský (1997). Radiolarian assemblages of the Sokolica and Czajakowa Radiolarite formations have been studied by Ožvoldová (1992). The radiolarian fauna from Sokolica Radiolarite Formation (2 samples) is rich and diversified. It includes: *Acanthocircus suboblongus* (Yao), *Crucella theokaftensis* Baumgartner, *Emiluvia cf. splendida* Carter, *Eoxitus hungaricus* Kozur, *Halesium* sp., *Homoeoparonaella argolidensis* Baumgartner, *Hsuum maxwelli* Pessagno, *Hsuum mirabundum* Pessagno et Whalen, *Paronaella* sp., *Pseudodictyomitrella* cf. *hexagonata* (Heitzer), *Striatojaponocapsa plicarum* (Yao), *Tetraditryma pseudoplana* Baumgartner, *Triactoma jonesi* (Pessagno), *T. tithonianum* Rüst, *Tritrabs* cf. *exingi* (Pessagno), *T. hayi* (Pessagno), *T. rhododactylus*

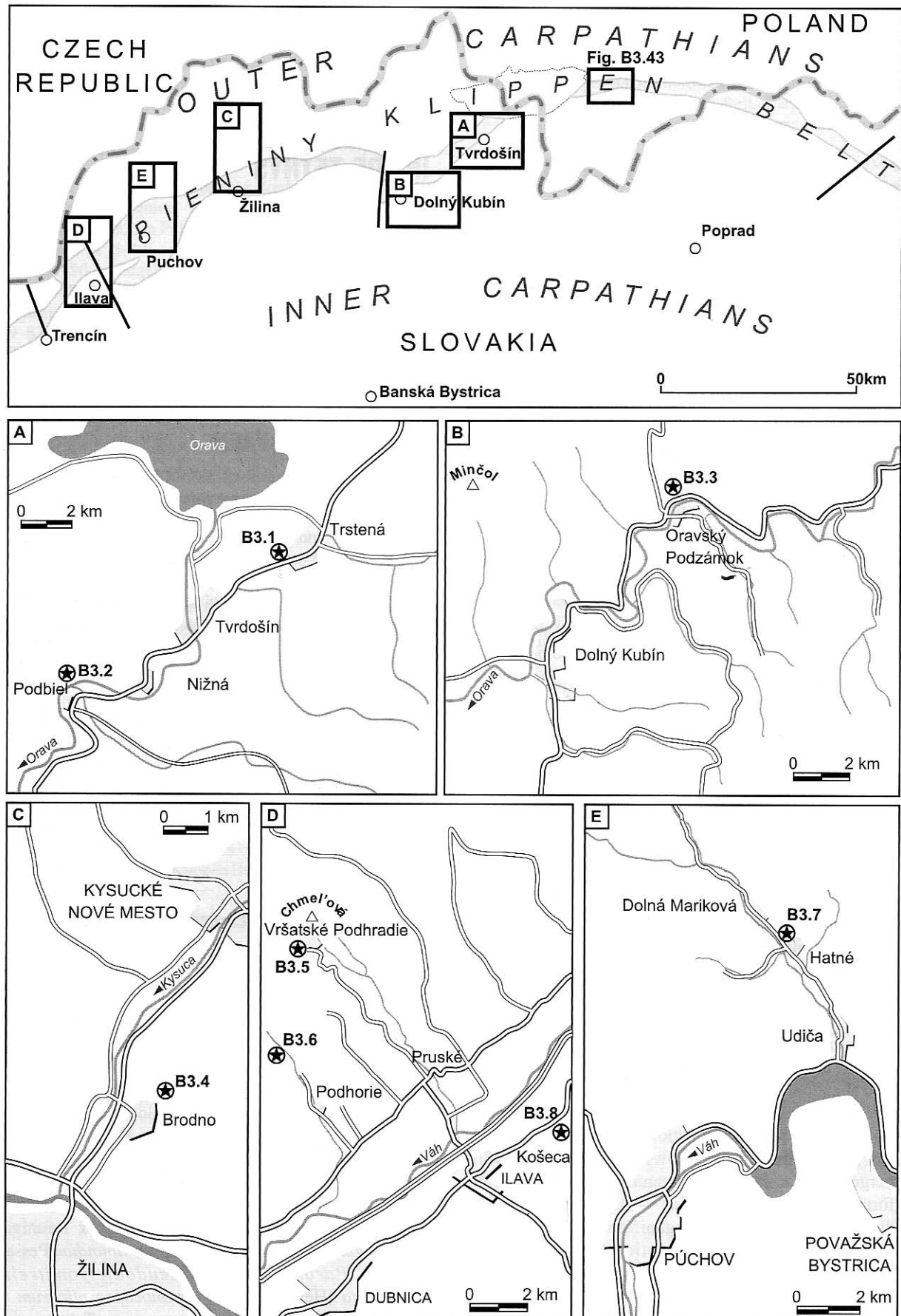


Fig. B3.1. Western Slovakian and Polish part of the Pieniny Klippen Belt and locations of visited outcrops — stop points

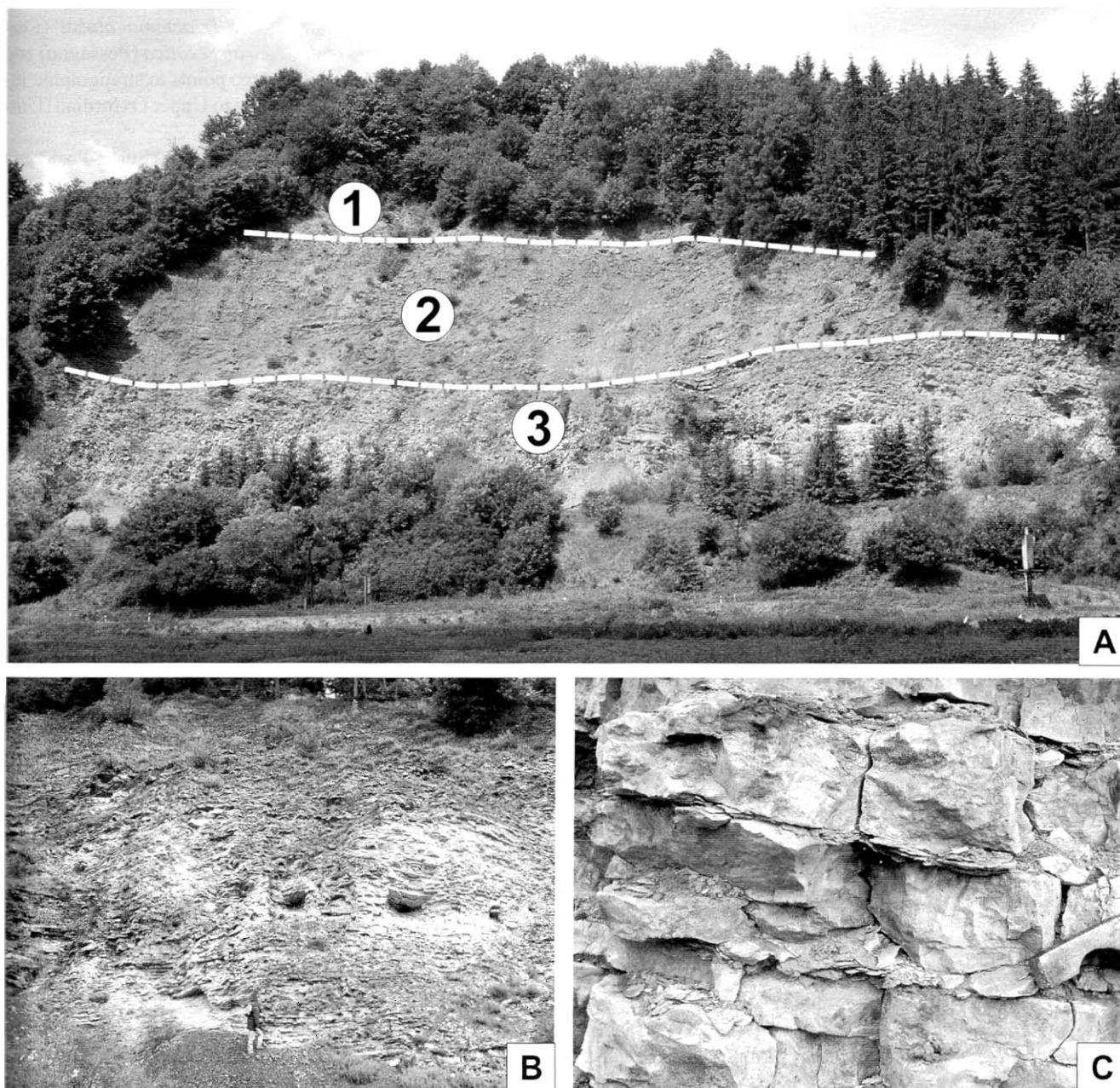


Fig. B3.2. View on the Halečková Klippe, with the individual lithostratigraphic units (A):
1 — Podzamcze Limestone Fm. (grey spotty limestones); 2 — Sokolica Radiolarite Fm. (dark/black manganiferous radiolarites); 3 — Podmajerz Radiolarite Mbr. of the Czajakowa Radiolarite Fm. (green radiolarites) (B, C)

Baumgartner, *Archaeodictyomitra exigua* Blome, *A. rigida* Pessagno, *A. primigena* Pessagno et Whalen, *Archaeospongopurum imlayi* Pessagno, *Dictyomitrella kamoensis* Mizutani et Kido, *Emiluvia premyogii* Baumgartner, *Eucyrtiedellum* sp., *Monosera unumaensis* (Yao), *Obsacapsula* sp., *Parahsuum* sp., *Praezhamoidellum convexum* (Yao), *P. japonicum* (Yao), *P. yaoi* Kozur, *Protunuma ochinensis* Matsuoka, *P. turbo* Matsuoka, *Spongocapsula palmerae* Pessagno, *Stichocapsa* sp., *Tricolocapsa ruesti* Tan Sin Hok, *T. cf. undulata* (Heitzer), *Unuma* sp. and ?*Theocapsomma* sp. The taxa are indicative of the Lower to Middle

Callovian. The radiolarian assemblage from the lowermost part of the Czajakowa Radiolarite Formation contains *Acaeniotyle diaphorogona* Foreman, *Andromeda podbielensis* (Ožvoldová), *Angulobracchia digitata* Baumgartner, *Archaeodictyomitra* sp., *Archaeospongoprunum imlayi* Pessagno, *Bernoullius dicera* (Baumgartner), *Cinguloturris carpatica* Dumitrica, *Emiluvia sedecimporata salensis* Pessagno, *Higumastra imbricata* (Ožvoldová), *H. aff. inflata* Baumgartner, *Homoeoparonaella argolidensis* Baumgartner, *Hsuum brevicostatum* (Ožvoldová), *H. maxwelli* Pessagno, *Mirifusus guadalupensis* Pessagno, *M. medio-*



Fig. B3.3. Leaf of *Otozamites graphicus* found at Halečková locality (Podzamcze Limestone Fm.)

dilatatus mediodilatatus (Rüst), *Obesacapsula morroensis* Pessagno, *Orbiculiforma* sp., *Paronaella broennimanni* Pessagno, *P. kotura* Baumgartner, *P. mulleri* Pessagno, *Podobursa triacantha* (Fischli), *Ristola procera* (Pessagno), *Spongocapsula palmerae* (Pessagno), *Staurosphaera antiqua* Rüst, *S. tympanica* (Ožvoldová), *Tetraditryma pseudoplena* Baumgartner, *Tetratrabs zealis* (Ožvoldová), *Triactoma blakei* (Pessagno), *T. cornuta* Baumgartner, *T. jonesi* (Pessagno), *Tritrabs casmaliensis* (Pessagno), *T. ewingi* (Pessagno), *T. exotica* (Pessagno) and *T. hayi* (Pessagno). The assemblage points to Upper Callovian–Lower Oxfordian (Unitary Association 5–6). The stratigraphically highest radiolarite beds of the Czajakowa Radiolarite Formation contain following radiolarian fauna: *Angulobracchia biordinale* Ožvoldová, *Acanthocircus variabilis* (Squinabol), *Emiluvia ordinaria* Ožvoldová, *E. oreia* Baumgartner, *E. pessagnoii* Foreman, *E. sedecimporata elegans* (Wiśniowski), *E. sedecimporata salensis* Pessagno, *Homoeoparonaella argolidensis* Baumgartner, *Hsuum brevicostatum* (Ožvoldová), *Mirifusus guadalupensis* Pessagno, *M. mediodilatatus baileyi* Pessagno, *Podobursa spinosa* Ožvoldová, *P. triacantha* (Fischli), *Staurosphaera antiqua* (Rüst),

Tetratrabs bulbosa Baumgartner, *Triactoma blakei* (Pessagno), *T. jonesi* (Pessagno), *Tritrabs exotica* (Pessagno) and *T. hayi* (Pessagno). The assemblage points to stratigraphic interval from upper Lower Oxfordian to Upper Oxfordian (Unitary Association 7–8).

In the Podzamcze Limestone Formation (“Supra-Posidonia Beds”) trace fossils are very abundant (Fig. B3.4). They include *Chondrites*, *Planolites*, *Thalassinoides* and rare *Teichichnus* (Fig. B3.4G). They occur against totally bioturbated background, displaying distinct cross-cutting relationships. *Thalassinoides* and *Planolites* are cross cut by *Chondrites*. Totally bioturbated background points to total reworking of sediment near the sea floor and well oxygenated bottom conditions.

Normally graded bedding is common in some radiolarite beds of the Sokolica Radiolarite Formation. Trace fossils are abundant and well visible. *Chondrites* and *Planolites* are most frequent (Fig. B3.4F). *Thalassinoides* is less frequent. In the graded beds, density of bioturbational structures increases towards the top, where they occur against totally bioturbated background. The graded bedding and style of ichnofabric indicate that at least a part of beds was deposited by diluted density currents.

Within Czajakowa Radiolarite Formation radiolaritic cherts are interbedded with very thin, commonly millimetric intercalations of green shales rich in calcium carbonate. Trace fossils *Planolites*, *Chondrites*, and rarely *Thalassinoides* occur in some beds (Fig. B3.4A–E). They are relatively poorly visible and never abundant. There are no evidences of primary lamination. Therefore, it can be supposed that the trace fossils occur against totally bioturbated background. This, in turn, indicates well-oxygenated sediments.

Diagenetic fabric is common. It includes solution seams, nodularity (Fig. B3.4D), stylolites and calcite veins. Probably, intensive diagenetic processes obliterated primary fabric to a large degree, including trace fossils.

In some beds, layers with normally graded bedding are present. The layers display sharp base and silt grain size in the lower part. The grain size decreases gradually towards the top. Trace fossils, if present, occur outside of the silty layers, except for *Chondrites*. The layers with graded bedding were deposited probably by diluted density currents. This idea was suggested in case of radiolarites of the Niedzica Succession by Kwiatkowski (1981).

The density of bioturbational structures and their size decreases from the Podzamcze Limestone Formation to the Sokolica Radiolarite Formation, and then to the Czajakowa Radiolarite Formation. This can be interpreted as an increase of environmental stress related to decreasing amount of food, which in turn is related to deepening of sea of the Pieniny Klippen Basin from Early to Late Jurassic, according to the general trend in this part of the Tethys.

At nearby locality Halečková-bowling alley, stratigraphically higher member of the Czajakowa Radiolarite Formation (red radiolarites of the Buwałd Member) crops out. Mišík *et al.* (1991) have found distal turbidites there with fine acidic volcanoclastic material coming from an unknown distant source.

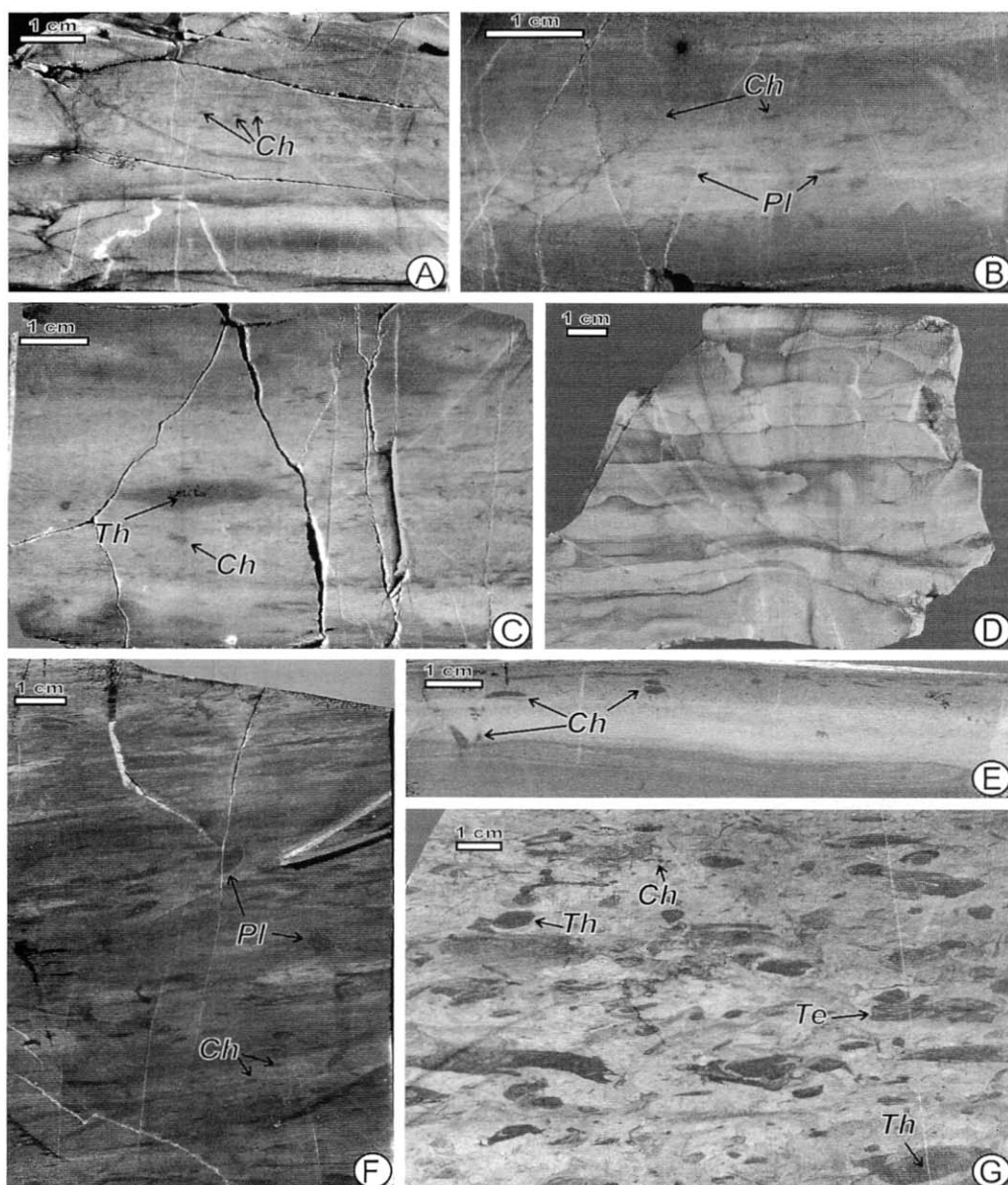


Fig. B3.4. Trace fossils within Podzamcze Limestone Formation (G); Sokolica Radiolarite Formation (F) and Czajakowa Radiolarite Formation (A-E)

Ch — Chondrites; Pl — Planolites; Te — Teichichnus; Th — Thalassinoides

Stop B3.2 — Podbiel–Červená Skala (Fig. B3.1A)

Jano Schlögl, Miloš Rakús, Roman Aubrecht

The locality is situated approximately 500 m NE of the Podbiel railway station, in the E part of the Oravská Magura Mts. (Fig. B3.5). The klippe consists of Lower Liassic to Lower Cretaceous deposits (Borza *et al.*, 1994), belonging to one of the transitional units of the Pieniny Klippen Basin deposited between the former Czorsztyn Ridge and the Kysuca-Pieniny Basin. The whole succession is in overturned position. This klippe has been the key section of the Podbiel Unit as designated by Andrusov (1938). Later, Haško (1978) described analogous development as the Orava Unit and he included in it succession at Podbiel locality. This unit is no longer considered as typical for the Orava area only, as new occurrences of the same succession in the middle part of the Váh Valley have been recently found (Schlögl *et al.*, 2000).

The following section and its stratigraphical interpretation are compiled from the observations of the authors and older data of Andrusov (1931) and Borza *et al.* (1994) (Fig. B3.5A, C).

1. Allgäu Formation: It is the oldest known part of the section. It consists of spotted marly limestones and marlstones (Fleckenmergel/Fleckenkalk). The strata are of Late Sinemurian (Lotharingian) age. The rich ammonite fauna, described by Andrusov (1931), comes from both these deposits and younger ones. It comprises taxa of Late Sinemurian (Lotharingian) and also Pliensbachian (Early Carixian) age. The deposits of Allgäu Formation are not exposed here anymore.

2. Kozinec Formation: It consists of grey marlstones with thin beds of grey spotted marly limestones. The ammonite fauna, including *Echioceras* ex gr. *raricostatoides* (Vadász), *Lep-*

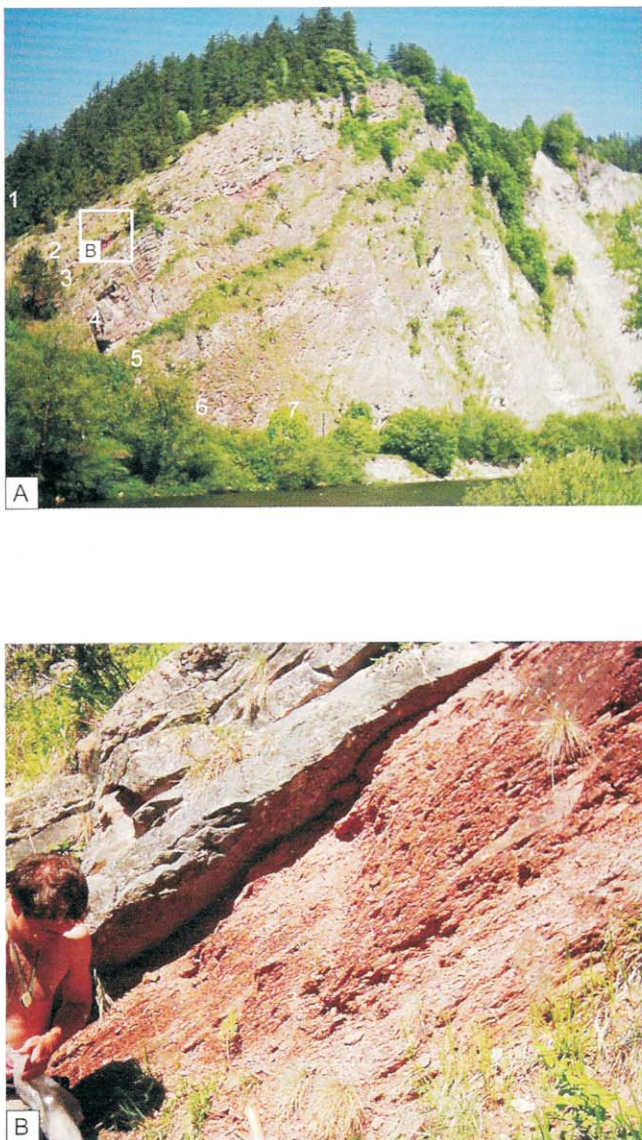
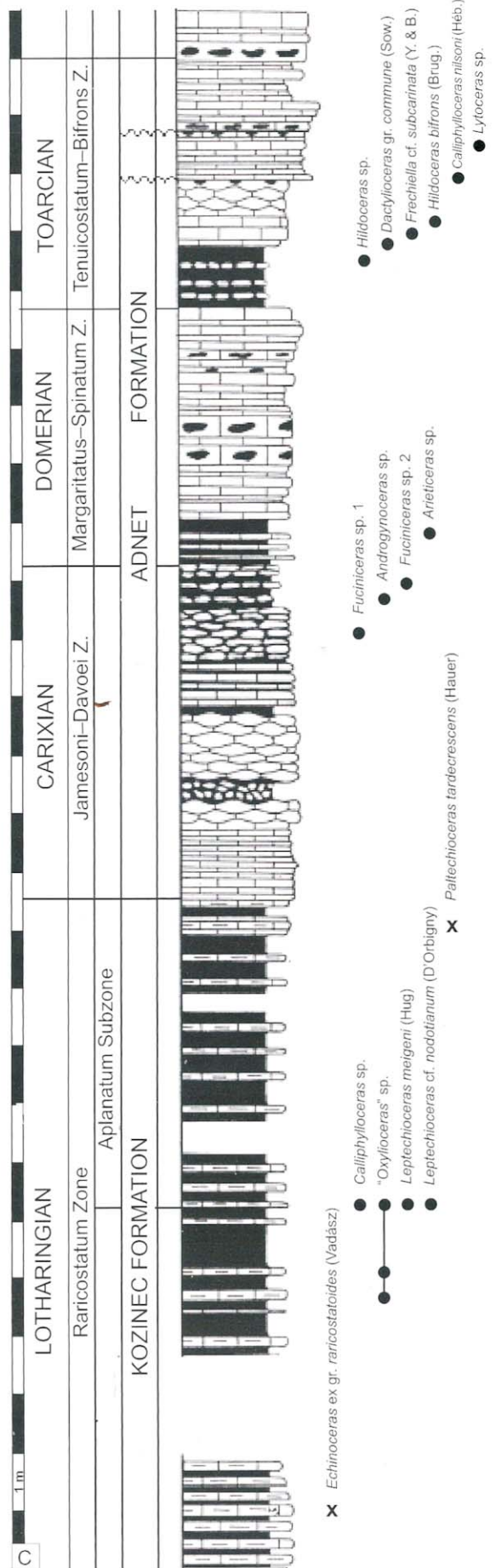


Fig. B3.5. Podbiel-Červená Skala Klippe: general view (A), detail view of the Toarcian red marls — Adnet Fm. (B) and lithostratigraphic column (C) of the Kozinec Fm. to Adnet Fm. interval

1 — Allgäu Fm. (grey spotted marlstones and marly limestones — no more exposed); 2 — Kozinec Fm. (grey marlstones with thin beds of spotted marly limestones); 3 — Adnet Fm. (red marls and marly nodular limestones with ammonites, red limestones with cherts and red crinoidal limestones); 4 — Red cherty limestones and red indistinctly nodular limestones; 5 — Czajakowa Radiolarite Fm. (green and red radiolarites); 6 — Czorsztyn Limestone Fm. (red to grey, sometimes nodular cherty limestones); 7 — Pieniny Limestone Fm.



techioceras cf. *nodotium* (d'Orbigny), *Calliphylloceras* sp., *Leptechioceras meigeni* (Hug), "*Oxynoticeras*" sp., *Gleviceras* sp. proves Late Sinemurian (Late Lotharingian) age. Upper part of the formation consists of light grey and reddish marly limestones and marlstones with *Paltechioceras tardecrescens* (Hauer). Due to poorly exposed section the thickness of the formation can be only roughly estimated between 11 and 15 m.

3. Adnet Formation: Red bedded, sometimes nodular, locally cherty limestones with intercalations of red marls (Fig. B3.5B). The formation yielded a rich ammonite fauna including Pliensbachian (Carixian and Domerian) and mainly Toarcian taxa. These are as follows: *Androgynoceras* sp., *Fuciniceras* sp. 1, *F.* sp. 2, (Carixian); *Arietoceras* sp. (Domerian); *Lytoceras* sp., *Calliphylloceras nilsoni* (Héb.), *Hildoceras* sp., *H. bifrons* (Brug.), *Dactylioceras* gr. *commune* (Sow.), *Haugia* sp., *Frechiella* cf. *subcarinata* (Young & Bird) (Toarcian). The uppermost beds of the formation show a marked hardground surface with Fe-crusts and concretions, at the contact with red, more or less crinoidal limestones. The formation attains 12 m in thickness.

4. Red platy, in the upper part nodular, cherty limestones: From the microfacies point of view they are wackestones with calcified radiolarians, sponge spicules, filaments and planktonic foraminifers. The red nodular limestones occur in the upper part only (approx. 4 m thick). Because of stratigraphical position between well biostratigraphically documented underlying and overlying deposits, the deposits in question are considered as early Middle Jurassic in age. The deposits are 11 m in thickness.

5. Czajakowa Radiolarite Formation: It consists of green radiolarites with marly intercalations in the lower part, fol-

lowed by red radiolarites in the upper part. Radiolarian assemblage with *Podobursa triacantha* (Fischeli), *Tritrabs exotica* (Pessagno), *T. casmaliaensis* Pessagno, *Higumastra imbricata* (Ožvoldová) and *Hsuum maxwelli* Pessagno indicates Late Callovian to Late Oxfordian age of the formation. The entire thickness is around 12 m.

6. Czorsztyn Limestone Formation: Thick bedded indistinctly nodular limestones with cherts are of radiolarian-*Saccocoma-Globochaete* microfacies. Uppermost part already yields calpionellids of the Chitinoidea Zone. The stratigraphic range can be stated as Kimmeridgian–Middle/Upper Tithonian. It is around 15 m in thickness.

7. Pieniny Limestone Formation: Light grey, thin bedded limestones with reddish to greenish tint, with rare cherts. These are wackestones to mudstones with *Crassicollaria* assemblages, indicating Late Tithonian age. Overlying grey, thick bedded "biancone"-type limestones contain calpionellids of the Berriasian age (Calpionella and Calpionellopsis zones). Upper part of the formation is built of spotted grey marly limestones with black cherts with calpionellids of Early Valanginian to Barremian age (Calpionellites and Tintinopsella zones). The Barremian age was also proved by nannoconid association. The ammonite fauna collected from these limestones indicates Valanginian to Early Barremian age. The formation is c. 100 m thick.

8. Dark grey laminated calcareous claystones with intercalations of spotted marly limestones, sandstones and variegated marls. They contain a poorly preserved foraminiferal association, dominated by planktonic forms such as *Globigerinelloides*, *Ticinella* and *Thalmaninella*.

Stop B3.3 — Oravský Podzámok–Orava Castle (Fig. B3.1B) — Orava Succession (Sinemurian–Tithonian/Berriasian)

Roman Aubrecht

The locality comprises a klippe standing as a conspicuous isolated rock in the Orava Valley crowned with the Orava Castle. It was studied in detail by Andrusov (1931). Later, this classical locality became one of the type sections of actually distinguished deep-water Orava Succession of Haško (1978). In the tectonically complicated section (Fig. B3.6), following lithostratigraphic units can be distinguished from the base: spotted marly limestones with ammonoids (Allgäu Fm.: Upper Sinemurian), greenish-grey limestones (Koziniec Fm.: Pliensbachian), pale grey weakly spotted limestones with belemnites (Upper Pliensbachian), red pseudonodular limestones (Adnet Limestone: Toarcian), green and red silicites and siliceous limestones (Aalenian–Oxfordian), red nodular limestone (Czorsztyn Lst. Fm.: Kimmeridgian), and pale grey micritic limestone (Pieniny Lst. Fm.: Tithonian–Berriasian).

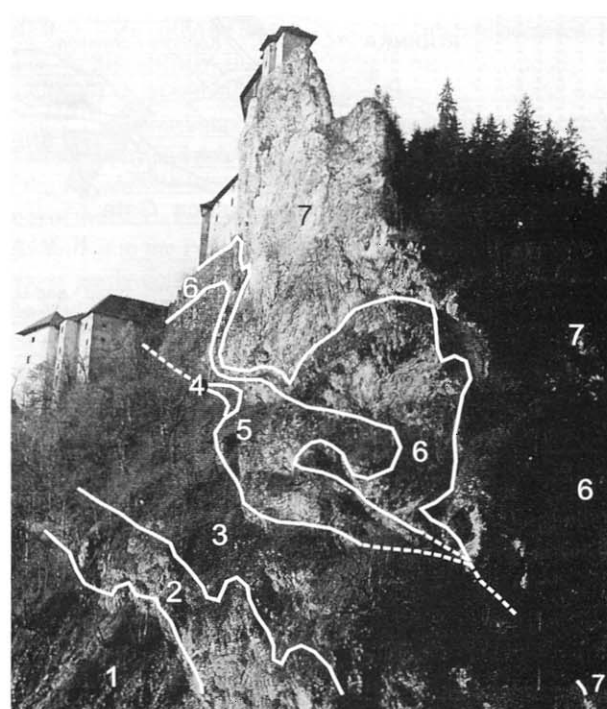


Fig. B3.6. Classic view on the Oravský Podzámok Klippe

The individual lithostratigraphic units (after Andrusov, 1931; modified): 1 — Allgäu Fm., 2 — Koziniec Fm., 3 — pale grey spotted limestones, 4 — Adnet Fm., 5 — green and red silicites and limestones, 6 — Czorsztyn Lst. Fm., 7 — Pieniny Lst. Fm.

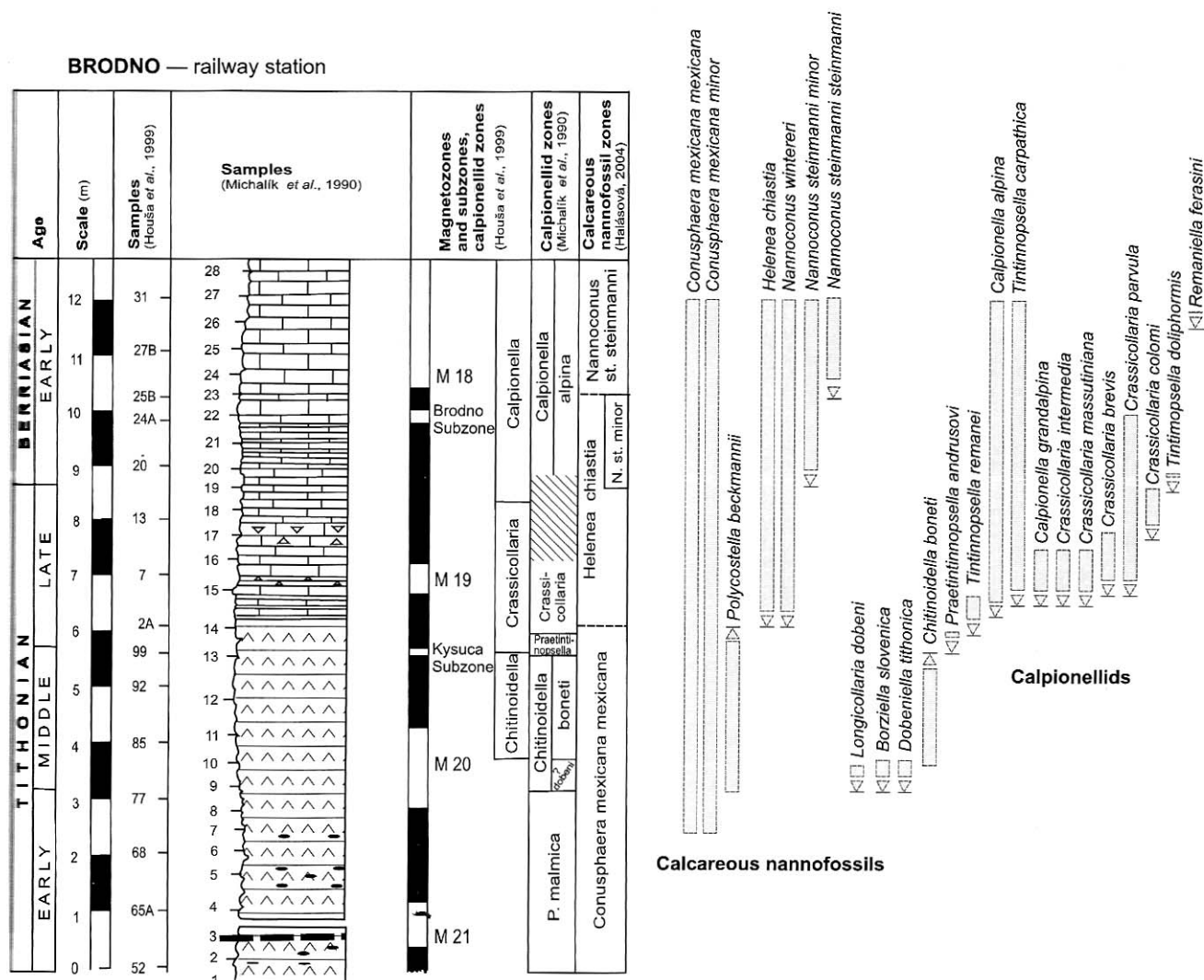


Fig. B3.10. Correlation between biostratigraphic and magnetostratigraphic schemes of the Brodno section

For explanations see Fig B3.9

Results of magnetostratigraphic investigations close to the Jurassic/Cretaceous boundary were correlated with micropalaeontological data by Houša *et al.* (1996) (Fig. B3.10). According to their results, the base of the standard Crassicollaria Zone lies approximately in the middle of M-20n magnetozone, the base of the standard Calpionella Zone, i. e. the Jurassic/Cretaceous boundary lies in the younger part of the older half of the magnetozone M-19n. The calcareous nannofossils distribu-

tion was correlated with the magnetostratigraphic polarity chrons close to the Jurassic/Cretaceous boundary. In the interval of the M 20 to M 19 magnetozones two distinct nannoevents were recognised: the dominance of nannoliths of *Polycostella beckmannii* (calpionellid Chitinoidea Zone) and the appearance of calcareous nannofossil association with coccolith species *Helenea chiasia* (calpionellid Crassicollaria Zone) (Fig. B3.10).

Stop B3.5 — Vršatec Klippen (Fig. B3.1D) — Czorsztyn Succession (Bajocian to Berriasian); Middle Jurassic biohermal limestones; palaeomagnetic interpretations

Jano Schlögl, Adam Tomašových, Roman Aubrecht

The Vršatec Klippen are the largest in Slovak territory and in the entire Pieniny Klippen Belt. They are situated above the Vršatské Podhradie Village, NW of the Ilava Town. This locality consists of two tectonic blocks that belong to

the Czorsztyn Unit: the Vršatec Castle Klippe and the Javorník Klippe (Fig. B3.11). They are formed by a succession of the Middle Jurassic–Lower Cretaceous carbonates that are capped by the Upper Cretaceous marls. Importantly, this local-

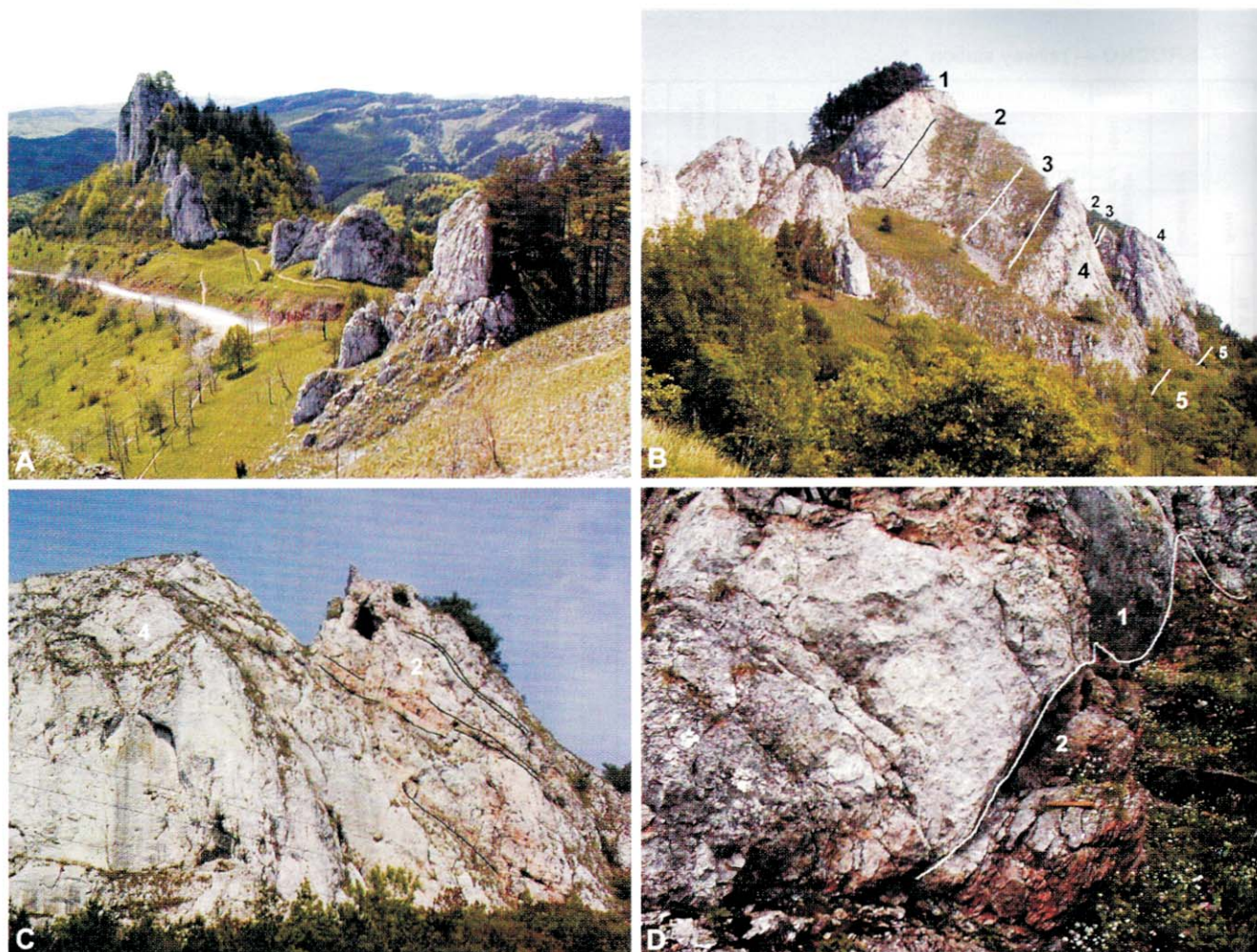


Fig. B3.11. Views of Vršatec Klippen: A — general view on the Vršatec Castle Klippe (photographed from the peak of Javorník); B — Javorník Klippe, view from the castle; C — detailed view on the SE wall of the Vršatec Castle Klippe (note numerous neptunian dykes in the left part of the wall — within Bajocian crinoidal limestones); D — detail of the contact between the biohermal Vršatec Limestone and the crinoidal limestones

The numbers in figures match the numbers of the formations in the text

ity exposes relatively thick, coral-dominated biohermal deposits, which are absent or very rare in other Jurassic successions of the Pieniny Klippen Belt. Mišík (1979) described in detail sedimentologic features of the 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, the first slice contains the Upper Jurassic biohermal limestones that are overlying the Middle Jurassic crinoidal limestones. In the second slice, the Middle Jurassic crinoidal limestones are overlain by the Czorsztyn Limestone Formation. The contact between the two slices should lie within the crinoidal limestones of Middle Jurassic age. This hypothesis, however, is in contradiction with new litho- and biostratigraphic data indicating that only one succession is present in the blocks, probably with high horizontal and lateral variations in facies composition. The new results are as follows: firstly, based on geopetal infillings within brachiopod shells, the crinoidal limestones are overlying the biohermal

Vršatec Limestone; secondly, biostratigraphic data indicate that the Vršatec Limestone is older than it has been interpreted so far, probably still of Middle Jurassic age.

The stratigraphy of the Vršatec Klippen is shown in Fig. B3.12. The beds are in overturned stratigraphic position:

1. The Vršatec Limestone is formed by white to pinkish biohermal limestones with corals and calcareous sponges, and locally with bivalves and brachiopods. The biohermal limestones are laterally replaced or overlain by pink and grey peribiohermal limestones and reef breccia. The core of the reef is probably preserved near the hilltop of the Javorník block. Voids and small caverns in the biohermal limestone contain internal sediment, scarce stromatolites of the LLH type and algae *Verticillodesmis clavaeformis* Dragastan and Mišík (1975). The peribiohermal limestones contain scarce corals, brachiopods, bivalves, sessile foraminifers, crinoidal ossicles, bryozoans, juvenile gastropods, calcified silicisponges and ostracods. The voids size ranges up to decimetres in size and they are filled with laminated muddy limestone with cross-bedding that results from re-

placement of inflow openings. Bioclasts in the voids and small caverns are mostly represented by ostracods. These crustaceans together with unknown pellet-producers might represent original inhabitants of the caverns.

Based on bivalves (Kochanová, 1978), the biohermal limestones were assigned to the Oxfordian by Mišík (1979). However, the bivalves described by Kochanová (1978) are stratigraphically inconclusive (M. Golej, pers. comm.). Of the neptunian dykes cutting through the peribiohermal limestones, one contains ammonites *Nannolytoceras tripartitum* of the latest Bajocian and/or Early Bathonian age. Moreover, most of the dykes show filamentous microfacies, which in Carpathian area is restricted to Aalenian–Callovian. Thus, based on the infillings of the neptunian dykes, cutting through the limestones, the biohermal and peribiohermal Vršatec Limestones can be probably assigned to Bajocian. The exposed part of the limestones is at least 15 metres thick.

2. The Smolegowa and Krupianka limestone formations consist of grey to reddish crinoidal grainstones that overlie the biohermal Vršatec Limestone (Fig. B3.12). The top of the biohermal facies of the Vršatec Limestone is marked by thin Fe/Mn crusts and impregnations. In contrast, the boundary between the peribiohermal facies of the Vršatec Limestone and crinoidal limestones seems to be gradual in most sections. Only some brachiopods were collected from the base of the crinoidal formations, including long-ranged taxa such as *Acanthothiris spinosa* (Linnaeus), *Strirrhynchia subechinata* (Oppel), *Apringia* aff. *polymorpha* (Oppel) with possible stratigraphic range Bajocian–Callovian. Because of lack of the stratigraphically more valuable fauna, the age of crinoidal limestones is based on the datation of the corresponding crinoidal deposits in the neighbouring areas as Bajocian. The thickness is estimated around 35 metres.

3. The Czorsztyn Limestone Formation consists of red micritic, locally nodular limestones. As based on ten detailed stratigraphic sections along both blocks, the thickness of this formation ranges between 20 cm and more than 15 metres. There are invariably 0.5–2 cm-thick Mn-crusts at the base of the formation, marking the hiatus between the crinoidal and red micritic limestones. The ammonites, indicate stratigraphical interval from Bathonian to Lower Tithonian. The thickness of the Bathonian deposits, which are separated from the overlying red micritic limestones by another Mn/Fe hardground, attains from few centimetres up to 3.5 metres. The Bathonian deposits contain mainly filaments (filamentous packstones), juvenile gastropods, benthic foraminifers and crinoidal ossicles. The overlying massive limestones show the *Globuligerina* microfacies, suggesting the Oxfordian age. The massive limestones pass gradually into massive red micritic limestones with the *Saccocoma* microfacies, and ammonite fauna including *Orthaspidoceras uhlandi* (Oppel) and *Hybonoticeras hybonotum* (Oppel) indicative of Kimmeridgian and Lower Tithonian.

4. 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 passes gradually into the *Crassicollaria* and *Calpionella* microfacies. The Middle Tithonian to Early Berriasian age of the formation is based on calcareous dinoflagellates and calpionellids.

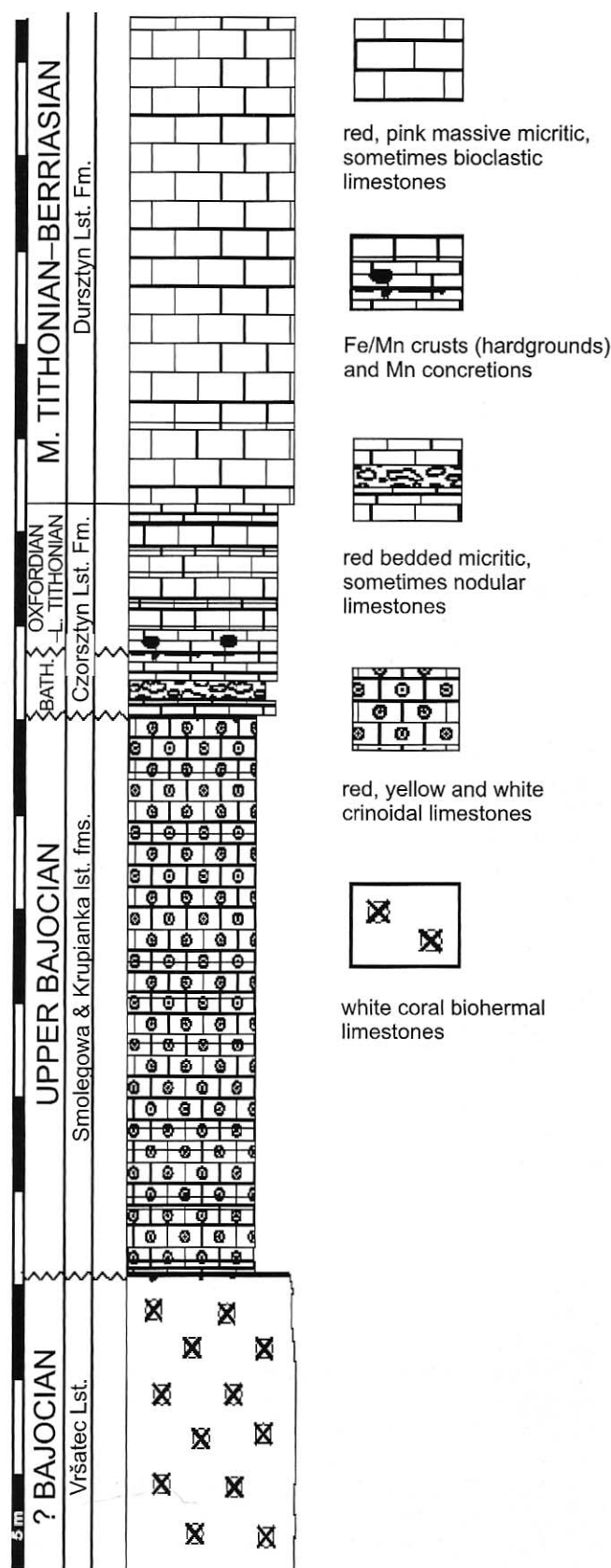


Fig. B3.12. Simplified and schematized section through the Vršatec Klippen

5. The Cretaceous deposits are represented by red marls and marlstones. A tectonic contact of the Upper Tithonian to Berriasian white to pinkish *Calpionella* limestones with the red marls and marlstones is exposed in the saddle above the village of Vršatské Podhradie. The sequence of limestones and marls is in reverse position. The marls are of Late Cenomanian to Campanian age.

As the sections in the Pieniny Klippen Belt represent isolated blocks and tectonic lenses which have been rotated along several axes, palaeomagnetic analyses are necessary for the reconstruction of their original palaeogeographic position. Aubrecht and Tünyi (2001) analysed neptunian dyke orientations in four sections in the Pieniny Klippen Belt. They include the Vršatec Castle Klippe, Babiná Quarry, Mestečská Skala and Bolešovská Dolina. In majority, the neptunian dykes are cutting the Bajocian–Bathonian crinoidal limestones (Smolegowa Limestone and Krupianka Limestone fms., Fig. B3.11) 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 at the Vršatec locality. However, they represent rejuvenation of the older dykes (Mišík, 1979).

The measurements of the neptunian dykes and their evaluation, with utilizing of palaeomagnetic correction, enable estimation of the palaeogeographic orientation of the Czorsztyn Ridge (Aubrecht, Tünyi, 2001). The mean orientation of the neptunian dykes is NE–SW (with N–S to ENE–WSW variations), thus indicating the most probable orientation of the Czorsztyn Ridge during the Middle Jurassic. This direction points to the NW–SE oriented Jurassic extension in that area. The palaeomagnetic inclination ranging between 21° and 46°, with mean point of about 33°, indicates that the Czorsztyn Ridge was located approximately at 10–30° palaeolatitudes in the Middle Jurassic.

Stop B3.6 — Slávnické Podhorie Klippe (Fig. B3.1D) — stromatactis mud-mound (Middle Jurassic, Czorsztyn Succession)

Roman Aubrecht

The site occurs in the middle part of Váh River valley, at the Slávnické Podhorie Village (Fig. B3.13), in the foothills of the Biele Karpaty Mts. It represents a tectonically overturned klippe exposed in an abandoned quarry revealing a stromatactis mud-mound core. A 32 m long profile was sampled in the southern part of the quarry (Fig. B3.14, Aubrecht *et al.*, 2002).

The major part of the quarry cuts the Middle Jurassic crinoidal limestones (Smolegowa Limestone Formation) that is stratigraphically older than the mud-mound. In the crinoidal limestones at the base of the section, a fragment of the ammonite *Parkinsonia* was found indicating the uppermost Bajocian or lowermost Bathonian. The Bajocian–Bathonian brachiopod fauna has been collected from the crinoidal limestones by Pevný (1969) and Aubrecht *et al.* (2002): *Morrisithyris* aff. *phillipsi* (Morris), *Monsardithyris buckmani* (Davidson), *M. ventricosa* (Zieten), *Linguithyris bifida* (Rothpletz), *Zeilleria waltoni*

(Davidson), *Z. emarginata* (Sowerby), *Z. aff. subbucculenta* Chapuis-Dewalque, *Loboidothyris perovalis* (Sowerby), “*Terebratula*” *retrocarinata* Rothpletz, “*Terebratula*” *varicans* Rothpletz, *Antitychina puchoviensis* Pevný, *Acanthothiris* sp., *Gnathorhynchia trigona* (Quenstedt), *Sphenorhynchia* aff. *plicatella* (Sowerby), *S. rubrisaxensis rectifrons* (Rothpletz), *Rhactorhynchia subtetrahedra* (Davidson), “*Rhynchonella*” aff. *obsoleta* (Sowerby), *Cymatorhynchia quadriplicata* (Sowerby), ?*Weberithyris* sp., ?*Caucasella trigonella* (Rothpletz), *Parvirhynchia* sp. The directly overlying micritic limestones (mudstones) are therefore of ?Bajocian–Bathonian age, although some forms of brachiopods as *Caucasella* and *Weberithyris* found beneath suggest even younger, Bathonian–Callovian age of the lowermost part of the micritic limestones. This could be also supported by *Pygope* aff. *janitor*, but this species has been collected from the debris and not been found in the section.

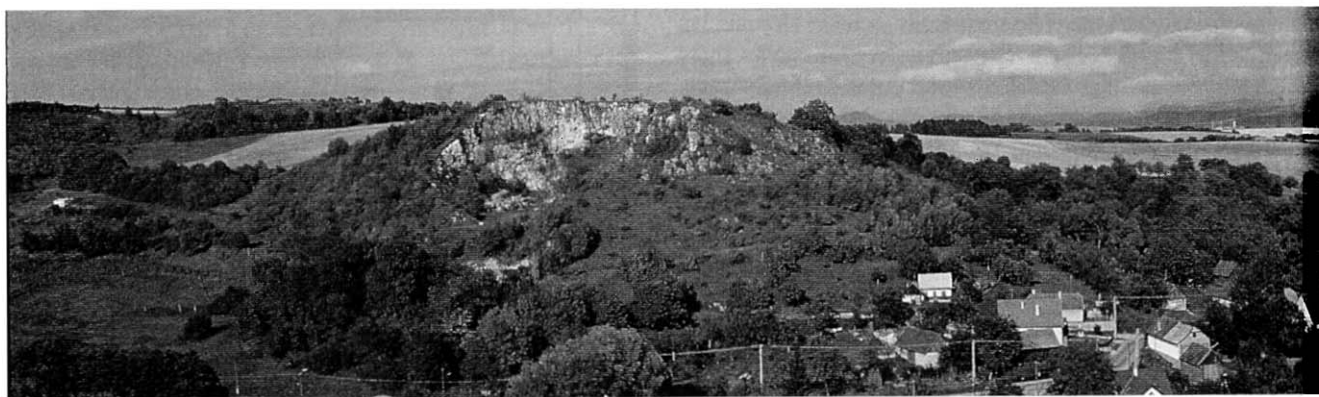


Fig. B3.13. Slávnické Podhorie and the research field site above the village

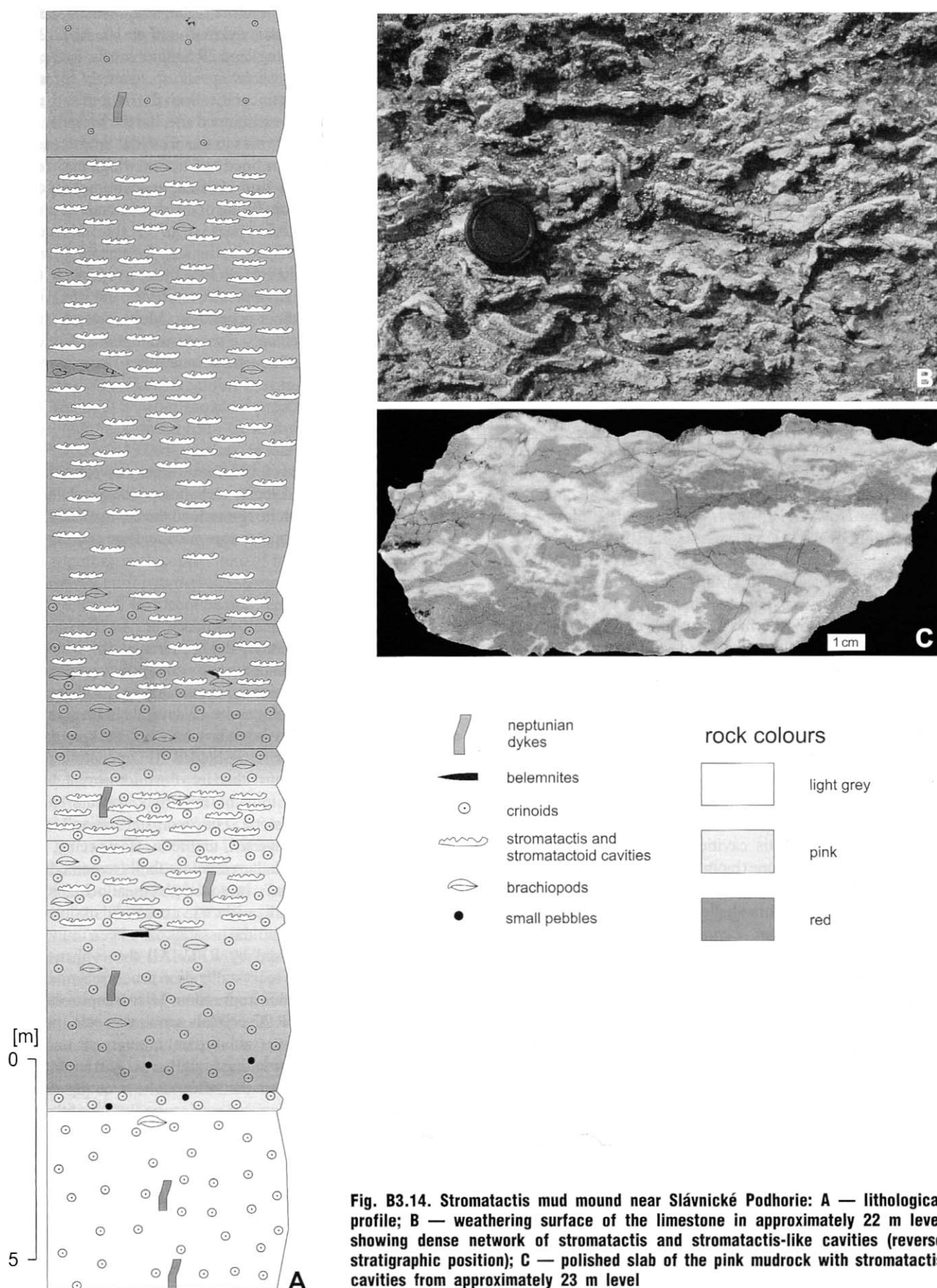


Fig. B3.14. Stromatactis mud mound near Slávnické Podhorie: A — lithological profile; B — weathering surface of the limestone in approximately 22 m level showing dense network of stromatactis and stromatactis-like cavities (reverse stratigraphic position); C — polished slab of the pink mudrock with stromatactis cavities from approximately 23 m level

The mudstones that overlie the crinoidal deposits are dominated by a microfacies with *Bositra* sp. filaments, which are known to occur up to the end of Callovian. As only very rare foraminifers *Globuligerina* sp. have been found in the mudstones, mass occurrence of which is indicative of the Oxfordian in the Pieniny Klippen Basin, the deposits in question are markedly older than Oxfordian.

The stratigraphically lowest unit of the examined section consists of crinoidal limestones (0–13 m), passing gradually upwards into pink and red micritic limestone (13–32 m). Stromatactis cavities appear as low as the crinoidal limestone (9–13 m) but they reach their maximum in the micritic limestones (15–28 m, Fig. B3.14). At the 28 m level, the stromatactis cavities disappear. Since the stromatactis cavities are approximately parallel to stratification, the examined section may probably represent the core part of the mound. As the klippe is just a large tectonic block, no transition to the offmound facies has been observed.

Crinoidal limestones represent skeletal packstones to grainstones with micritic to sparitic matrix. The sparite occurs in the parts where the micrite has been winnowed. It is a clear blocky calcite, locally with margins rich in inclusions. Where the stromatactis cavities occur, the matrix is locally pelmicritic to sparitic. However, in contrast to the clear blocky calcite mentioned above, the spar is mostly represented by a short-bladed fibrous calcite. It is obviously related to the radial fibrous calcite (RFC) filling of the stromatactis cavities as there is a very indistinct transition to its first, short-bladed generation. The sediment has been relatively poorly sorted. Besides crinoidal ossicles, sand-sized detrital quartz grains are abundant. Bryozoan fragments, echinoid spines, ostracod tests, foraminifers (*Lenticulina* sp.), agglutinated foraminifers (*Ophthalmidium* sp.) and fragments of bivalves and brachiopods are ubiquitous. Upsection, bivalves and brachiopods gradually prevail and filament shells appear, passing to the overlying mudstones. Many allochems are affected by heavy micritization and microborings.

The pink, red to yellowish mudstones form the main host rock of the stromatactis cavities and are predominantly of a wackestone to packstone (biomicrite, biopelmicrite) and even to grainstone (biopelsparite) type. Thin-shelled bivalves (mainly *Bositra* sp.), thin-shelled ostracods and foraminifers such as *Ophthalmidium*, *Lenticulina*, *Patellina*, *Spirillina*, *Dorothia*, sessile nubeculariid foraminifers, nodosariid foraminifers and “microforaminifers” occur. Detritus of thicker-walled bivalves (commonly dissolved and replaced by micrite) and brachiopods, rare gastropods, juvenile ammonites, echinoid spines and serpulid worm tubes is quite common. Calcareous sponges, silicisponge spicules, fragments of solitary corals and bryozoans are very rare. Crinoidal ossicles, which are common in the lower part of the section, are less frequent in the mudstone. Rare quartz grains occur, too. Some brachiopod shells are observed, initially filled by short-bladed RFC and later by pendant fine-grained calcite grains (crystal “silt”). The rest of the shells are filled by clear blocky calcite. The relatively monotonous “filamentous” microfacies (packstone) with its micritic matrix, free of peloids, also represents the main part of the micritic limestones at top of the section (28–32 m), where the stromatactis cavities do not occur. Unlike in

the lower levels, signs of bioturbation are ubiquitous. The same material fills the neptunian dykes found at 10, 12.5, 22.89 (dyke with breccious filling) and 29.5 meter levels. In the top-most part of the section, *Globuligerina* sp. sparsely appears.

The typical stromatactis cavities with flat bottom and undulated top are present in the examined site, but the irregular ones are also present. Some cavities in the crinoidal limestones appear to have roof and floor lined by micrite, which may represent a microbial crust (a kind of initial endostromatolitic lining). The first and the main filling of the stromatactis cavities is represented by RFC. The first phase of RFC is short-bladed and almost identical with that penetrating into the surrounding host rock. This phase is gradually followed by long crystals without sharp boundary. Apart from these two phases, the RFC filling represents just one distinct generation. Multi-generation fillings have been observed only if some interruptions of micritic or thin intercalations of cryptic stromatolites occur. In some thin sections, tests of cave-dwelling ostracods *Pokornyopsis* sp. have been found. These ostracods indicate that part of the stromatactis cavities formed an open network through which the ostracods and their larvae could migrate (Aubrecht, Kozur, 1995). Around the 28 m level, the stromatactis cavities give way to shelter porosity filled by clear drusy blocky calcite, predated by a dog-tooth calcite rim around the cavity. The shelter porosity gradually disappears topwards and the sediment becomes free of the voids.

Stromatactis cavities are often separated from the host rock by stylolites but commonly the boundary of the cavity is not clear since the cement commonly penetrates into the host rock matrix. The rock then attains the appearance of a biomicrite with numerous fenestral-like voids, commonly grading into areas where the spar dominates. In such places, patches of matrix or individual allochems, and even detrital quartz grains, are enclosed in the spar. The boundary between the spar and the host-rock shows that the short-bladed RFC penetrates more easily into pelmicritic matrix than into the micritic one. Intense penetration of the spar into the host rock appears as a recrystallization of a mudstone. The “recrystallization” is even more distinct when an “inverted” umbrella effect occurs, where the micrite and peloids sheltered below shells remained intact during “recrystallization”. In some places allochems were also affected by recrystallization, e.g. a crinoidal ossicle overgrown by RFC. Some crinoidal ossicles have been found to be completely neomorphosed by RFC. All these phenomena seem to represent a true recrystallization process. Some facts, however, contradict to this impression. Microscopic observations revealed that the RFC crystals grow, as a rule, perpendicularly to the substrate (with typical convergent undulose extinction and convex twinning lamellae away from the substrate), no matter whether the substrate is a cavity wall or a “floating” allochem. Few cases of cross-cutting of the allochems by the RFC crystals are found. The RFC crystals and their short-bladed analogues (in the case of limited space) always diverge away from the allochems (Fig. B3.15). Therefore, they cannot represent a product of mudstone matrix recrystallization. Nevertheless, it is not quite clear which part of the RFC grew freely into the cavities and which part grew at the expense of unknown matter that supported the “floating” allochems.

Internal sediment precedes or postdates the RFC filling of the stromatactis cavities. In the crinoidal limestones, the internal sediment of stromatactis cavities displays similar composition as the host rock. In the mudstones, the internal sediment is either sterile micrite or pelmicrite, sometimes containing small fragments of “filaments” and thin-shelled non-sculptured ostracods. The micrite is usually laminated and sometimes disturbed by bioturbation.

Blocky calcite represents the latest filling of the stromatactis cavities and of some fenestral-like voids in the micrite. It is either pure or contains inclusions. The crystals commonly possess twinning lamellae. The transition from the RFC to blocky calcite is gradual but sometimes the two phases are separated by microstylolites. Occasionally, crystal silt instead of blocky calcite forms the latest filling. Some cavities had empty centers. Blocky calcite also fills the late veinlets cutting the rock. Unlike the host rock and the RFC, which remained intact by ferricyanide staining, the late blocky calcite reveals clear zonation. The blocky calcite then represents a filling that originated in oscillating more or less reducing conditions, whereas the host rock and RFC were formed in oxidizing environment. As revealed by CL petrography, some initial scalenohedral blocky calcite grew solely from the top of the cavity forming an asymmetric microstalactitic filling. This, together with some signs of leaching of the previous RFC filling, indicate that at least part of the blocky calcite originated in a vadose environment. Timing of the emersion is difficult to estimate because some stromatactis voids are still not completely cemented. The Czorsztyn Unit emerged during the Barremian–Aptian and then probably from the Neogene until present. Therefore a relatively long time period is available to form the blocky calcite. The blocky calcite filling of the veinlets, cutting the whole rock is also most probably tied to the period of emersion, as resulted from the isotope data (see below).

Carbon and oxygen stable isotopes were analysed in order to reconstruct the process of mud-mound cementation (Fig. B3.16). The oxygen isotopic values obtained from the brachiopod shells at Slavnické Podhorie display relatively narrow range of $\delta^{18}\text{O}$ between -2.8 and -3.0 ‰ versus PDB but the $\delta^{13}\text{C}$ range is wider, varying from 0.5 to 1.3 ‰ versus PDB. The oxygen values from brachiopod shells are surprisingly depleted both with respect to the mean values of Jurassic marine water cements (approximately -1.4 ‰ PDB, see Lohmann, 1988), and to the mean values of other constituents such as micrite, RFC and “recrystallization” spar. Most of the latter constituents, except for some extreme samples, were apparently derived from normal marine water. Blocky spar, which fills the remaining voids, is evidently depleted in ^{18}O . This suggests either thermal or, more likely, meteoric overprints. Blocky calcite filling the late veinlets, is even more depleted in ^{18}O with a slight negative shift in ^{13}C , which is characteristic for freshwater impact, with lighter carbon derived most likely from a pedogenic reservoir. Extreme values in some micrite and RFC samples, depleted in ^{18}O , seem to be also influenced by late freshwater diagenesis.



Fig. B3.15. Allochems surrounded by radiating RFC crystals

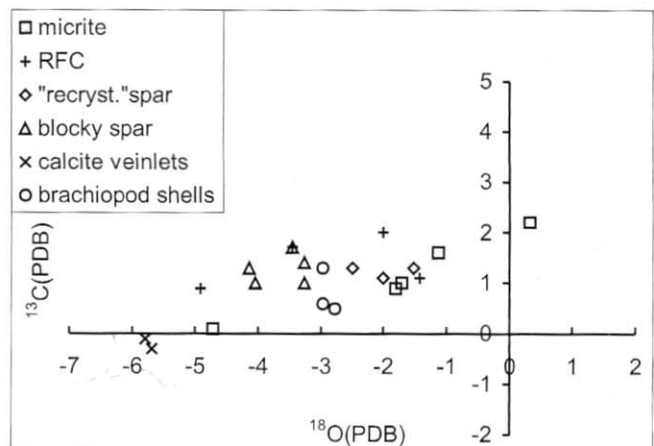


Fig. B3.16. Diagram of oxygen and carbon isotope ratios from the host rock, various generations of cavity fillings, and brachiopod shells as a reference material

Stop B3.7 — Hatné Klippe (Fig. B3.1E) — cross-bedded Bajocian crinoidal limestones (Czorsztyn Succession)

Roman Aubrecht

The locality Hrádok at Hatné Village belongs to the Czorsztyn Unit of the Pieniny Klippen Belt. It represents the klippe of red crinoidal limestones of Bajocian age (Krupianka Limestone Formation) passing upwards, in the uppermost preserved part, to red nodular limestone (Czorsztyn Limestone Formation). It is cut by Marikovský Creek into two parts. The examined part of the klippe is cut by a quarry occurring directly at the road connecting Udiča and Dolná Mariková villages, near the cemetery of the Hatné Village. The locality has been mentioned by Pevný (1969), who described its brachiopod fauna in detail. He reported the following Middle Jurassic brachiopods from this locality: *Lobidothyris perovalis* (Sow.), *Gnathorhynchia trigona* (Quenst.), "*Rhynchonella*" *balinensis* (Suess) and *Aulacothyris concava* (Parona). Later this locality was mentioned by Salaj (1994) as a site with the thickest preserved red crinoidal limestone formation in examined by him area. The latest paper published was that of Aubrecht and Sýkora (1998).

Crinoidal limestones forming the main portion of the klippe display sedimentary features which are not typical for similar sediments known from the Czorsztyn Unit. Their sedimentary area appear to be shallower and more dynamic than that of the other localities of the Krupianka Limestone Formation. The red crinoidal limestones are thick bedded, with frequent cross-beddings (Fig. B3.17), a feature which is very rarely encountered in this formation. Cross-bedding in the lower part of the section tends from left to right side of the quarry, while in the upper parts an opposite direction appears, with some beds showing both directions. The individual beds are not always continuous; some of them wedge out as observed in the quarry face.

The highest part of the Krupianka Limestone Formation consists of thin-bedded (with beds about 10–20 cm thick) crinoidal limestones with undulating bedding planes. Colour of the limestones depends on their character, i.e. the cross-bedded strata are of light grey, white to yellowish in colour, whereas the structureless or parallel-bedded ones are red. The crinoidal limestones contain rich siliciclastic and dolomitic admixture of sand to small pebble size (up to 1 cm); some beds have intraclasts derived from the underlying layers, concentrated at the bottom.

In the upper western part of the quarry, a steep onlap of the white crinoidal limestones onto the red ones is observable. The contact is stair-shaped which can be related to syn-sedimentary tectonics. The white crinoidal limestones contain also up to 5 cm clasts derived from the red crinoidal limestones, close to this contact. These features reflect clearly a dynamic water environment; the sediments were most likely deposited above the wave base. The higher part of the formation displays gradual deepening of the sedimentary area and cessation of the wave activity.

Microfacies analysis displays also a large difference between the white (cross-bedded), and red (parallel-bedded) crinoidal limestone. The former represents crinoidal biosparite (grainstone) whereas the latter is biomicrite (packstone), with more diversified skeletal composition. The grainstones evi-

denced more dynamic sedimentation where the red mud was winnowed from the interstices.

The biota and clastic contents in both kinds of limestones are, however identical, though in somewhat different ratios (the red limestones have more diversified skeletal composi-

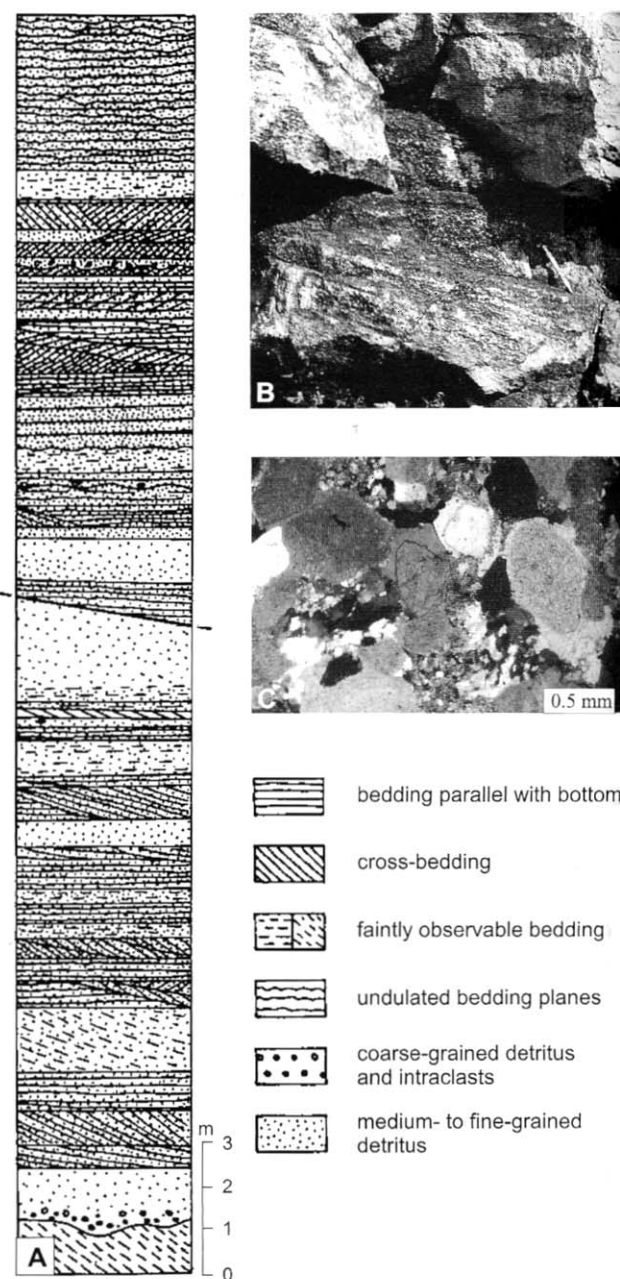


Fig. B3.17. A — lithological and sedimentological profile through middle part of the quarry wall; B — northward dipping cross-bedding in the upper part of the quarry; C — two close detrital quartz grains with syntaxial rims forming a compromise boundary between them (after Aubrecht, Sýkora, 1998; slightly modified)

tion). The main portion of sediment consists of crinoid ossicles. Preservation of the crinoid skeletons is very poor; their stems were disintegrated completely (exceptionally some pluricolumnals even with attached cirri have been found), with individual ossicles frequently broken. This indicates Z4 zone of deposition of Głuchowski (1987) i.e. the near-shore shallow water environment which is consistent with other sedimentological observations. Crinoidal detritus is usually full of small inclusions (even of cloudy appearance), but the syntaxial rims are clear.

Except crinoidal ossicles, also bryozoan fragments, echinoid spines, bivalve and brachiopod shells are ubiquitous; gastropod shells and serpulid tubes are rare. In one instance, a poorly preserved fragment of coral or calcareous sponge was found. An absence of foraminifers in the sediment is striking. The sediment was strongly effected by compaction, as indicated by frequent pressure-solution features among the skeletal detritus up to the formation of frequent stylolites. They represent the latest diagenetic stage as they cut fully developed syntaxial rims on echinoderm particles.

Yellowish dolomitic and/or dedolomitized clasts are frequent in the sediment. They are either micritic or crystalline. In case of dedolomitization the crystals are often oriented inward the clast, indicating dedolomitization after redeposition. They sometimes possess Liesegang's stripes indicating their weathering on land. Around the dolomitic clasts, thin limonitic films are developed frequently, related to iron expulsion during dedolomitization. The only rare faunal relics in dolomitic clasts were thin ostracod shells.

Most of quartz grains in the sediment display signs of corrosion which is typical for alkaline environment inside limestone. However, at the very top of a bed about 4 m above the bottom of the section (parallel bedded red crinoidal limestone), the quartz grains possess syntaxial authigenic quartz overgrowths (Fig. B3.17C). They cut neither the surrounding crinoidal ossicles nor their syntaxial rims. Instead, they use to copy the original

shape of surrounding grains and fill the pores, hence they represent relatively early diagenetic phase. These overgrowths exhibit often undulatory extinction in continuation to the detrital core. The undulosity was either caused by effect of pressure in the sediment after formation of the authigenic overgrowths (see late compactional features mentioned before) or it originated by strict copying of the detrital crystal structure during growth. In some instances of close opposite growing of the rims, straight compromise boundaries were formed between them. The first variant seems more probable. In some cases, the remnants of microquartz (chalcedony) was found, connected with authigenic rim. It is clear that the overgrowths were not formed in late diagenetic phases under burial conditions, as indicated by their occurrence only in one bed, filling of pores, and pre-dating of all the diagenetic phases including syntaxial rim formation on crinoidal detritus. An interpretation of this phenomenon is that the overgrowths represent part of the silcrete sequence, developed during emergence of the crinoidal sand shoal.

Red, partly nodular limestones (base of the Czorsztyn Limestone Formation) are preserved only at top of the eastern part of the quarry, which is relatively thrown down along a small normal fault. They are wackestones to packstones (locally grainstones), with calcified sponge spicules and crinoidal ossicles being dominant skeletal components. Bivalve and brachiopod shells, together with gastropods, juvenile ammonoids, echinoid spines and bryozoan fragments occur less commonly. The diversity of skeletal components is, however, remarkably higher than in the underlying crinoidal shoal complex. The dominance of micrite, together with absence of the siliciclastic admixture are indicative of deepening of the sedimentary area and flooding of land areas of the Czorsztyn Swell. The sediment itself is penetrated by veinlets filled by clear blocky calcite. These veinlets are, however, cut by numerous stylolites, which then appear to be the latest diagenetic phenomenon in the limestone.

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 are separated by the Jastrabie Saddle from the Považský Inovec Mts. on the South, and by the Fačkov Saddle from the Lúčanská Malá Fatra on East. Four basins: Rajec, Žilina, Púchov and Ilava are limiting the mountains slopes on North-East, North and West. The relief of the mountains is moderate, ranging in altitude from 250 to 1214 m a.s.l. Most water streams issuing in the mountains (Rajčianka, Pružinka, Mojtn, Podhradie and Teplicka brooks) drain into the Váh River. Only streams issuing on the south slopes (Nitra, Tuzinka, 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 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 Palaeogene and Neogene covers are preserved in rests of intra — mountain basins.