GEOLOGICA CARPATHICA, 45, 6, BRATISLAVA, DECEMBER 1994
343 - 356

MIDDLE JURASSIC SCARP BRECCIAS WITH CLEFTS FILLED BY OXFORDIAN AND VALANGINIAN-HAUTERIVIAN SEDIMENTS, KRASIN NEAR DOLNÁ SÚČA (PIENINY KLIPPEN BELT, SLOVAKIA)

MILAN MIŠÍK, MILAN SÝKORA and ROMAN AUBRECHT

Department of Geology and Paleontology, Faculty of Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovak Republic

(Manuscript received March 7, 1994; accepted in revised form June 16, 1994)

Abstract: Extensional synsedimentary faulting (neptunian dykes and submarine scarp breccias) took place during the Bathonian-Callovian and was reactivated during the Oxfordian and Berriasian. Six lithostratigraphic units were characterized microscopically by the frequencies of their constituents. Red, sometimes sterile micrite cement in the voids display marine pattern according to O, C isotopes. Terrigenous admixture in the Lower Cretaceous limestones testified to the existence of an emerged elevation along the outer part of the Czorsztyn sedimentary zone. A new lithostratigraphic unit - Krasin Breccia - is introduced.

Key words: Carpathians, Pieniny Klippen Belt, Jurassic, Lower Cretaceous, limestone lithology, neptunian dykes.

Introduction

Middle Jurassic crinoidal limestones are the substantial component of the Krasin klippe. Already Štúr (1860, p. 40) compared them correctly with the Middle Jurassic "Vilserkalk" (Vils Limestone) of the Eastern Alps. Our detailed lithological study was carried out in the newer quarry (Fig. 1), now also abandoned. The following units may be discerned there:

Unit A: Smolegowa Limestone - white bedded to massive crinoidal limestones with *Teloceras blagdeni*, with small fragments of dolomites, rarely penetrated by red neptunian dykes and void fillings. They also form the whole crest of the Krasin klippe. Age: Bajocian.

Unit B: Krasin Breccia - grey, pinkish and red brecciated crinoidal limestones (submarine scarp-breccia), massive; with small dolomite fragments and frequent void fillings, penetrated by neptunian dykes of red micritic limestone, roughly of the same age. Supposed age: Bajocian - Bathonian.

Unit C: Krupianka Limestone - grey fine-grained crinoidal limestones with brown chert nodules and red crinoidal limestones with loafy weathering forms. They are limited only to the northern confines of the klippe; the best outcrops may be found in the old quarry, now entirely covered by vegetation. Supposed age: Callovian.

Unit D: Vršatec Limestone - light grey and pinkish bioherm breccia with dolomite lithoclasts. It fills only pocket (cleft) in the left upper part of the quarry. Supposed age: Oxfordian.

Unit E: Walentova Breccia - breccias formed by clasts of red crinoidal limestones and small fragments of white *Crassicollaria*-bearing limestones. They fill clefts with variable thickness (maximum 25 - 30 m) penetrating Middle Jurassic limestones. Supposed age: Valanginian - ? Hauterivian.

Unit F: Red marls with intercalations of fine-grained limestones with *Hedbergella* were found only in a cleft between the points 14 and 15. Supposed age: Hauterivian.

During a short inspection of the quarry in exploitation twelve years ago, we found a thin intercalation of red nodular Czorsztyn Limestone. The intercalation was also mentioned by Began (1969, p. 59). A similar intercalation only 1.5 m thick is also present in the Middle Jurassic crinoidal limestone sequence of the Mestečská Skala klippe (Aubrecht 1992).

The Krasin klippe differs from the standard Czorsztyn Succession by several peculiarities: 1 - the presence of submarine breccias of Middle Jurassic age, 2 - the removal of upper Jurassic limestones by erosion (except the Oxfordian bioherm limestone filling a cleft), 3 - the overlying of Lower Cretaceous sediments by Middle Jurassic limestones in the large clefts.

Microscopical characteristics of the lithostratigraphic units

Unit A - Smolegowa Limestone (Birkenmajer 1977): White bedded to massive crinoidal limestone with very rare void fillings - Bajocian. Biosparites and biolithosparites. Organic remnants: almost exclusively echinoderm plates (mostly crinoidal columnalia), almost without twinning lamellae, with syntaxial rims; rare bryozoan fragments, ostracods, echinoid spines. Variable amount of detrital quartz (maximal size in the individual thin-sections oscillated between 0.2 - 1.3 mm), isolated orthoclases (up to 2 mm), current intraclasts of dolomicrites, rarely pelmicrites.

Voids. Sample No. 12: the void of 7 cm in diameter filled by yellowish poorly laminated micrite with the "crystal silt", without organic remnants and detrital quartz. Sample No. 11: the void is lined by radiaxial cement (Pl. I: Fig. 1), the younger filling is represented by red laminated micrite (17 lamines in 1 cm, average laminae thickness about 0.5 mm), oblique and graded microbedding caused by calci-siltite grains; without organic remnants and quartz. Oxygen and carbon isotopes of the red micrite display marine patterns: $\delta^{13}C = 2.7$ ‰, $\delta^{18}O = 0.0$ ‰ PDB.

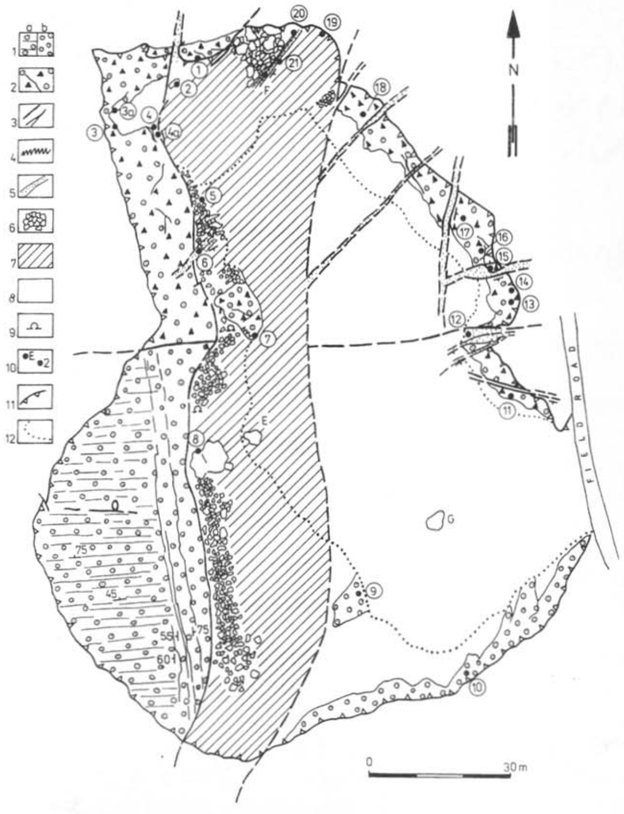

Fig. 1. Geological situation in the quarry (scheme): **1** - white and light-grey crinoidal limestones (a - bedded, b - massive) - Bajocian; **2** - Krasin Breccia (blocks of crinoidal limestone in a similar matrix) - Bathonian - Callovian; **3** - neptunian dykes with filling of Middle Jurassic age (dyke "O" is filled by bioherm breccia probably of Oxfordian age); **4** - hardground; **5** - neptunian dykes with Lower Cretaceous filling; **6** - Lower Cretaceous breccia in large clefts; **7** - debris covering Lower Cretaceous sediments; **8** - debris; **9** - cave; **10** - points of sampling; **11** - margin of the quarry; **12** - outlines of the bench.

Sample G (exploited block): void about 10 cm in diameter, lined by the isopachous radiaxial-columnar cement (1 cm thickness) filled by inclusions; only the calcite veinlets cutting it contain clear calcite grains. The isotopic composition of the radiaxial cement: $\delta^{13}C = 2.8$ ‰, $\delta^{18}O = -1.2$ ‰ PDB, testifies that precipitation from marine water is consistent with current opinions concerning this type of cement (Tucker & Wright 1990). White micrite filling in the void center is poorly laminated, sterile (without organic remnants), with crystal silt and some quartz grains. The isotopic composition: $\delta^{13}C = 3.0$ ‰, $\delta^{18}O = -1.6$ ‰ PDB (analysed by J. Hladíková). Another void in the same block is also lined by radiaxial cement, but its middle part is filled by white pelintrapseudosparite with echinoderm plates, agglutinated foraminifers, a brachiopod fragment and angular quartz grains.

The age of this lithostratigraphic member was confirmed near the point 12 by the ammonite *Teloceras* ex gr. *blagdeni* (SOW.) determined by M. Rakús indicating Middle-Upper Bajocian. Brachiopods were present near the points 9 and G, a coquina probably with *Bositra buchi* was found on the crest.

Unit B - Krasin Breccia: Submarine scarp breccia containing pinkish and grey crinoidal limestones in clasts as well as in the matrix, with void fillings and neptunian dykes - Bajocian -Bathonian. There is no equivalent in Birkenmajer's (1977) terminology of lithostratigraphic terms, therefore the new name Krasin Breccia is suggested. The generalized description is based on 30 thin-sections involving fine-grained breccia and individual clasts of crinoidal limestones.

Clasts of some dm to m size of the pinkish, grey and violet crinoidal limestones are involved in a matrix with similar patterns. The clasts differ mutually by colour, amount of terrigenous admixture and micrite. Some rare, well pronounced stylolites were found. The thickness of the submarine scarp breccia is about 60 m. No direct age criteria were found. *Terebratula* sp. (point 7) belongs, according to M. Siblík to the Middle Jurassic terebratulids.

Thirty thin-sections were evaluated from individual clasts (intraclasts), fine-grained breccia (several clasts in a thin-section) and mostly from matrix. The most frequent was crinoidal microfacies (22/30), spiculite - crinoidal microfacies occurred 6 times (6/30), while spiculite (1/30) and "Filamentous" microfacies (1/30) occurred rarely. Biosparites prevail over intrabiosparites and biomicrites (mostly packstones); intrabiomicrites and biopelmicrites are rare.

In the biosparites an association of echinoderm plates + bryozoans + nubecularids is regularly present; the biomicrites display the association of echinoderm plates + sponge spicules (mostly rhaxa).

Echinoderm plates, including somewhat larger crinoidal columnalia, possess syntaxial rims; the lack of pressure twinning lamellae may be stressed (some rare thicker lamellae are present). Both features differentiate them from the Lower Cretaceous crinoidal limestones. In the biomicrites, the echinoderm plates are corroded and without syntaxial rims. The frequency of the echinoderm plates is 30/30 = 100 % (they occurred in all thin sections).

The representation of bryozoan fragments, mostly uniserial types, is 25/30. Sponge spicules occurred in half of the studied samples (15/30). The clusters of rhaxa filled by radial-fibrous calcite are characteristic, some monaxon spicules filled by calcite also occur. In spite of the presence of silicisponge spicules, chert nodules as well as the traces of dispersed silicification are totally missing. Nubecularids are most frequent among the foraminifers (13/30 - Pl. II: Fig. 1). Single *Lenticulina* sp. with thick walls perforated by the boring algae, *Nodosaria* sp., *Dentalina* sp. and in biomicrites also *Ophthalmidium* sp., *Spirillina* sp., agglutinated foraminifers and single "microforaminifers" (Pl. II: Figs. 2, 3) occurred. Rare ostracods were present in 11 thin-sections (11/30). Echinoid spines (9/30), bivalvian fragments (9/30), brachiopods (8/30), small gastropods (4/30), "filaments" (4/30), single fish teeth (2/30) and juvenile ammonite complete the enumeration. The rariety of the "filaments", juvenile bivalves of *Bositra*-type is suprising.

The maximum size of the angular clastic quartz in the individual thin-section oscillated between 0.2 mm and to 1.2 mm (average 0.5 mm); it was locally so abundant that the designation sandy limestone would be appropriate. Single grains of orthoclase (its proportion to the quartz is approximately 1:100) were found in six thin sections (6/30), microcline 2x, plagioclase 1x. Very rare biotite was registered 5x, chlorite 2x, zircon 2x. Authigenic quartz was totally missing, authigenic feldspar was exceptional (1x).

Dolomite lithoclasts were rarely found (3x) when compared with the underlying member - white crinoidal limestone; siltstone lithoclasts were in two thin-sections.

Peculiar "grains" of alumosilicates (authigenic clay minerals ?) and Fe-colloids exhibit thin rims of radial-fibrous calcite, probably formed during their dehydratation shrinking.

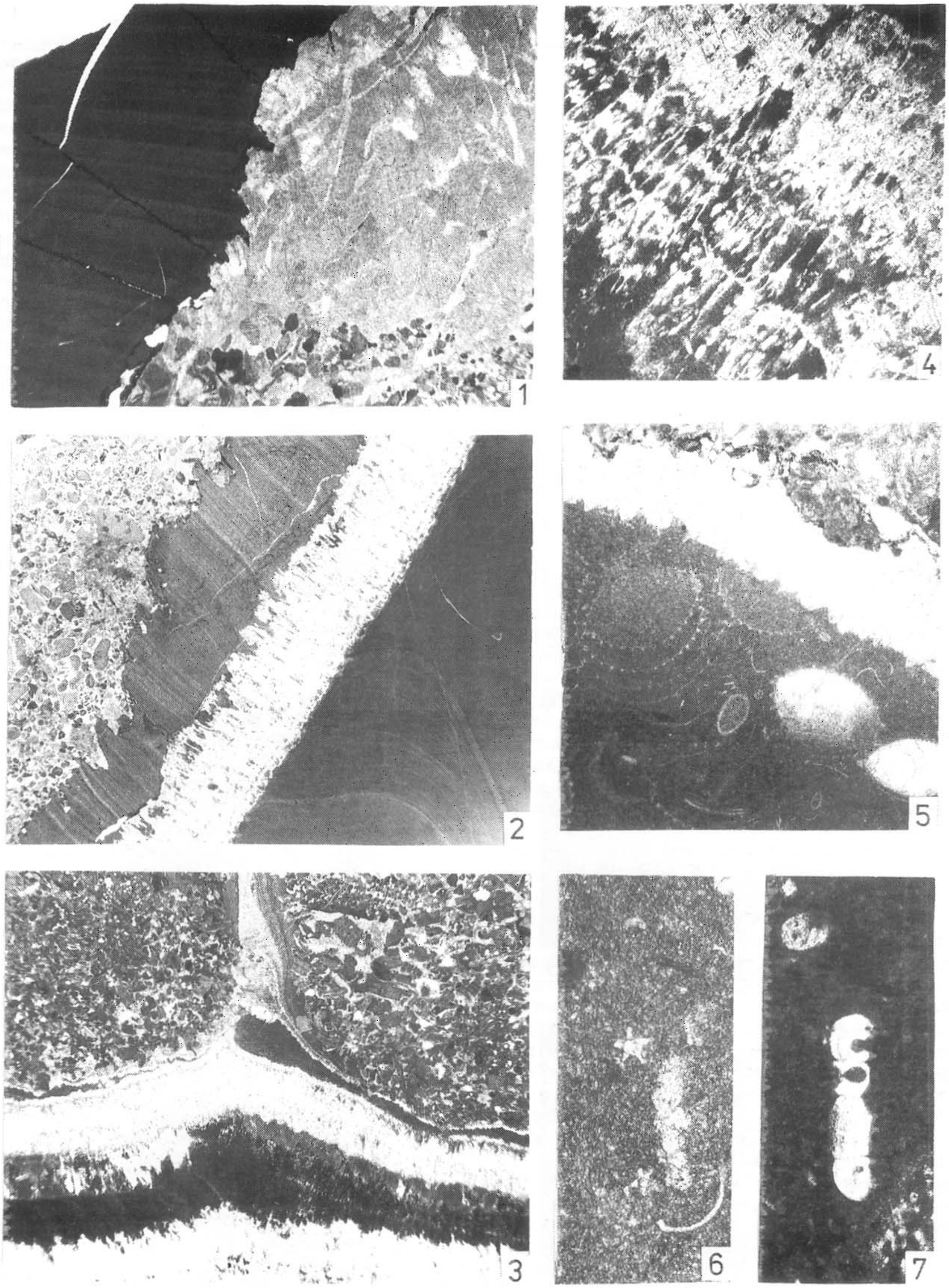

Plate I: **Fig. 1** - Void in the white crinoidal limestone filled by an older radiaxial cement cut by microstylolite; the younger filling is from red laminated micrite ($\delta^{13}C=2.7$ ‰, $\delta^{18}O$ ‰) with faint oblique lamination. Bajocian of the Czorsztyn Succession, Krasin klippe near Dolná Súča, sample 11, x7. **Fig. 2** - Microdyke with bent micritic laminae without microfossils; the filling was cut by a thin fracture inducing recrystallization. Pink crinoidal brecciated limestone, Bathonian-Callovian, sample 5a, x4. **Fig. 3** - Void in the same limestone with double oscillation of radiaxial cement and internal micritic sediment; sample 6a, x4. **Fig. 4** - Detail from Fig.2, recrystallization of micrite induced by the calcite aggregate sealing a thin crack, x22. **Fig. 5** - Ornamented ostracods *Pokornyopsis* - specialized dwellers of the voids (coelobites) in the red micritic internal sediment; sample 18, x22. **Fig. 6** - Tiny star-shaped bioclasts probably from the ostracod ornamentation; as above, x80. **Fig. 7** - *Globochaete* sp. in the red biomicrite-wackestone from the neptunian dyke; Bathonian - Callovian; sample 4a, x80.

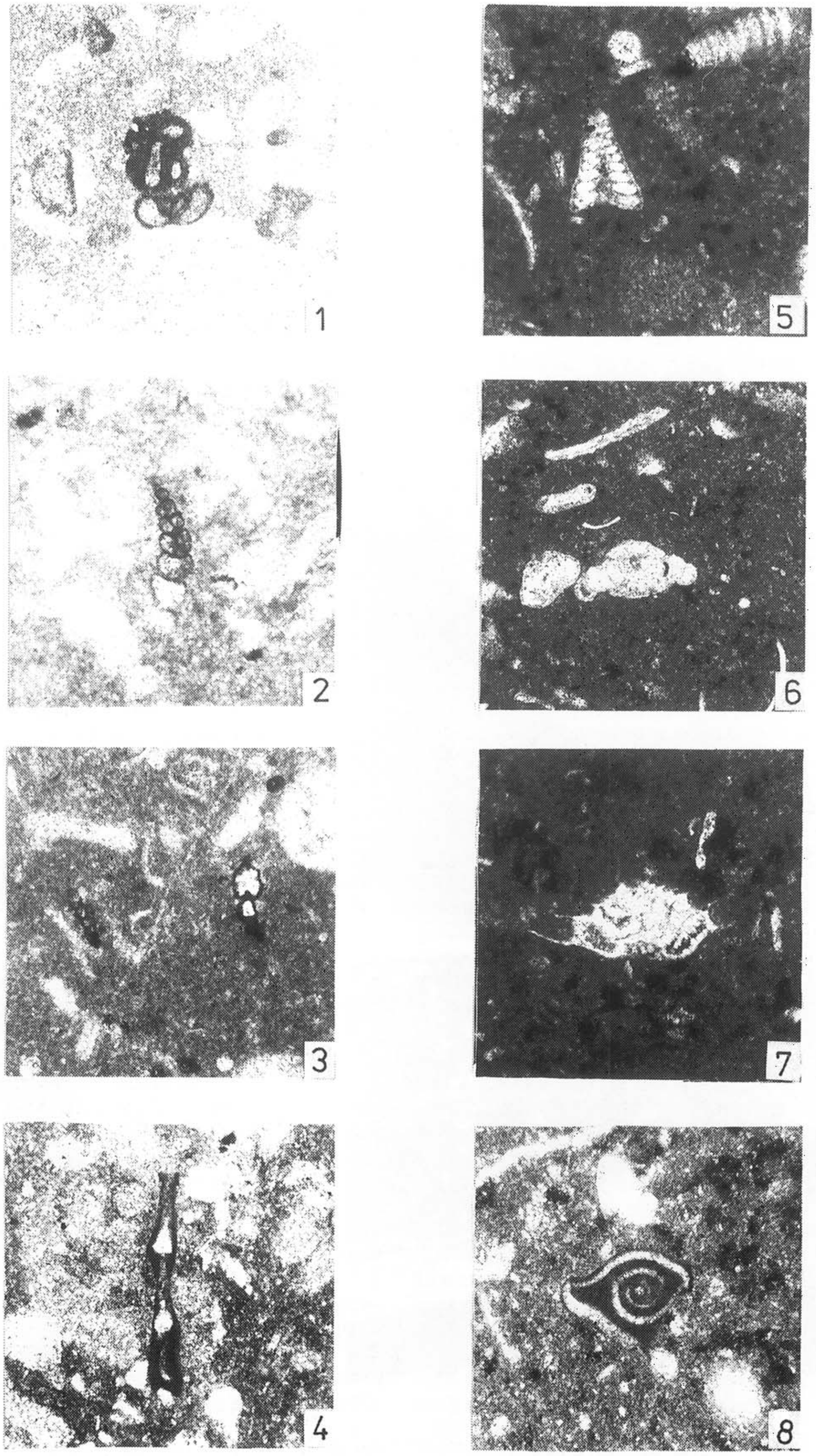

Plate II: Fig. 1 - Nubecularid foraminifer in pink sandy biomicrite-packstone; Bathonian - Callovian of the Czorsztyn Succession, Krasin klippe near Dolná Súča, sample 14/I, x60. **Fig. 2** - "Microforaminifer" (chitineous basal membrane of juvenile foraminifer) in the biomicrite; as above, sample 3/1, x120. **Fig. 3** - The same, sample 16/III, x80. **Fig. 4** - *Nodophthalmidium* sp. in the red biomicrite; filling of a synchronous dyke in the pink breccious crinoidal limestone, Bathonian - Callovian, sample 3/II. **Fig. 5** - *Trocholina* sp., as above, sample 4/I, x80. **Fig. 6** - *Trocholina* sp. as above, x60. **Fig. 7** - *Schakoinella* cf. *spinata* Blau, as above, x80. **Fig. 8** - *Ophthalmidium* sp., as above, x80.

Void filling. Small filled voids and neptunian microdykes were encountered in 11 of the 30 thin-sections. The most tiny voids are filled with two cement generations: the isopachous radiaxial calcite filled by inclusions and the younger one formed by clear blocky calcite. The voids about 2 cm in size also contain in their central parts an internal sediment - red micrite. Points of calcite scalenohedra stick from the columnar cement into the red laminated micrite (Pl. III: Fig. 1). Several laminae with crystal silt are sterile, the others contain only ostracods including ornamented *Pokornyopsis* sp. (3/30), specialized coelobites (Pl. I: Figs. 5, 6; Mišík 1979; Aubrecht & Kozur, in prep.). Most laminae belong to the biomicrites (wackestones) with marine microfauna: rhaxa, *Ophthalmidium* sp., "microforaminifers", tiny *Patellina* sp., *Trocholina* sp., isolated crinoidal plates and fucoids - light grey worm galleries in red micrite. It is noteworthy that many microorganisms occurring in the voids are absent in the surrounding rock. The lamination patterns show that the majority of small voids is horizontally elongated, and the subvertical ones are rare (Pl. I: Fig. 3). Two generations of the radiaxial cement separated by red micrite with ostracods and "microforaminifers" occur (Pl. II: Figs. 2, 3).

Mostly red sterile micrite with crystal silt (Pl. III: Fig. 1) is the youngest internal sediment. In some cases the set of the younger red laminae discordantly overlies the older grey laminae with an angle of 30° (Pl. III: Fig. 4). The phenomenon was caused either by the change of inflow slot or by the block tilting. The diagenetic growth of the radiaxial cement into the grey micritic internal sediment represents an interesting case (Pl. I: Figs. 3, 4). There is no evidence of temporal emersion; and the gravitational (stalactitic) cement typical for the vadose zone was not found.

Isotope analyses for the internal laminated micritic sediment, though sterile, rendered the patterns of the normal marine water. Among 6 samples from the Czorsztyn Unit (Fig. 2) only two samples from the Vršatec locality had positive values of $\delta^{18}O$; they were in the Oxfordian bioherm limestones (Mišík 1979) where a slightly higher salinity could exist. The values of $\delta^{18}O$ from 0.0 to -1.7 ‰ and positive values of $\delta^{13}C$ ascertained in the voids and dykes of the Middle Jurassic crinoidal limestones characterize a normal marine environment. Then, there is no

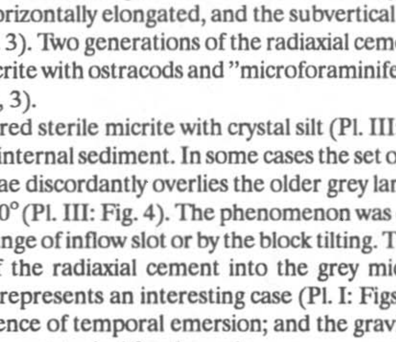

Fig. 2. Isotopic composition of the laminated micritic filling of the voids and neptunian dykes in the Jurassic limestones of the Czorsztyn Succession. **1** - neptunian dyke from the pink breccious crinoidal limestone of the Middle Jurassic age, Krasin, sample 11; **2** - void in the white Bajocian crinoidal limestones, Krasin, sample 4G; **3** - void in the Oxfordian bioherm limestones, Vršatec, sample 5b; **4** - the same, sample 22; **5** - neptunian dyke in the white Bajocian crinoidal limestone, Bolešov Valley, sample e; **6** - neptunian dyke in the Middle Jurassic pink crinoidal limestone, Kyjov, sample 2b. Analysed by J. Hladíková.

evidence that red mostly sterile micrite in the voids was derived from the redeposited terra-rosa sediments.

Hardgrounds. A set of thin hardgrounds with Fe-crusts occurred only near the point 7. It was developed in the rosy biomicrite-packstone with dominating rhaxa, echinoderm plates etc. Tiny oncolites are also present (Pl. IV: Fig. 2); intraclasts of older brown hardgrounds and some thin Mn-coatings occur. Pits in the hardground bored by bivalves and filled by red micrite were found.

Neptunian dykes. They are mostly about 5 cm thick, filled by red micrite. The dyke in the point 3 has a direction of dipping and a dip angle of 60/55°. The majority of the dykes possess a distinct lamination parallel to the dyke walls; in the cases of graded bedding the filling of a horizontal joint can be assumed (it was proved by the polarity structures in fucoids and the umbrella effect under the juvenile bivalvian shells). Originally vertical fractures filled by a set of laminae perpendicular to the fracture walls were also found (Pl. I: Fig. 2). The cases of neptunian dyke filling by younger microdykes are frequent (Pl. III: Fig. 3; Pl. IV: Fig. 1).

The filling of dykes consists mostly of red micrite, rarely of biomicrite-wackestone. Bioclasts are similar to those of the red filling of the voids: ostracods including specialized genus *Pokornyopsis*, foraminifers like *Ophthalmidium* (Pl. II: Fig. 8), small *Trocholina* (Pl. II: Figs. 5, 6), *Nodophthalmidium* (Pl. II: Fig. 4), *Schackoinella* cf. *spinata* Blau (Pl. II: Fig. 7), "microforaminifers", nubecularids, further "filaments", rhaxa, echinoderm plates, *Globochaete* sp. (Pl. I: Fig. 7), single gastropod, ammonite, fish tooth and recrystallized stromatolites. Clastic quartz is exceptional. There are no direct criteria for age. The association of microorganisms enables us to suppose approximately the same age or a slightly younger age than the surrounding strata.

Unit C - Krupianka Limestone (Birkenmajer 1977): Grey fine-grained crinoidal limestones with brown cherty nodules and red crinoidal limestones with the loafy weathering-shape (Bathonian-Callovian). They crop out only in the old quarry and near the northern confines of the Krasin klippe.

Microscopic description of the fine-grained siliceous limestone: biomicrite - packstone, rhaxa - echinoderm microfacies. Rhaxa with corroded outlines are filled with chalcedony; echinoderm plates were not affected by silicification. Besides abundant clastic quartz up to 0.4 mm in size, single grains of orthoclase-pertite, zircon and tourmaline occurred.

A thin-section from the brown chert nodule indicates that the original sediment was crinoidal biomicrite. Most of the echinoderm plates are partly silicified and rimmed by syntaxial scalenohedral points not touched by silicification (scalenohedral overgrowths were formed during or after the silicification). A single bryozoan may be discerned. The intersticial mass is from fine-grained "chalcedony", almost untransparent due to the Fe-pigmentation. Clastic quartz grains lack the overgrowth. Chalcedony veinlets are frequent. Similar brown cherts are known from the limestones of the same age in another klippe near Mikušovce.

Unit D - Vršatec Limestone (Mišík 1979): Grey and pinkish fine-grained carbonate breccia with bioclasts of bioherm organisms - most probably Oxfordian. Microscopic characterization from 11 thin-sections: biolithite or biosparrudite; fore-reef facies. Organic remnants: echinoderm plates including crinoidal columnalia predominate, frequent hydrozoan fragments (Pl. V: Fig. 1), rare corals (Pl. V: Fig. 7), several bivalves with thick shells, oysters with vacuolar structures (Pl. V: Fig. 4), inoceramid types with thick prismatic layer, rare gastropods with thick spired conch (Pl. V: Fig. 6), nubecularids fixed on clasts, rare agglutinated foraminifers, bryozoan fragments, echinoid spines and serpulid tubes.

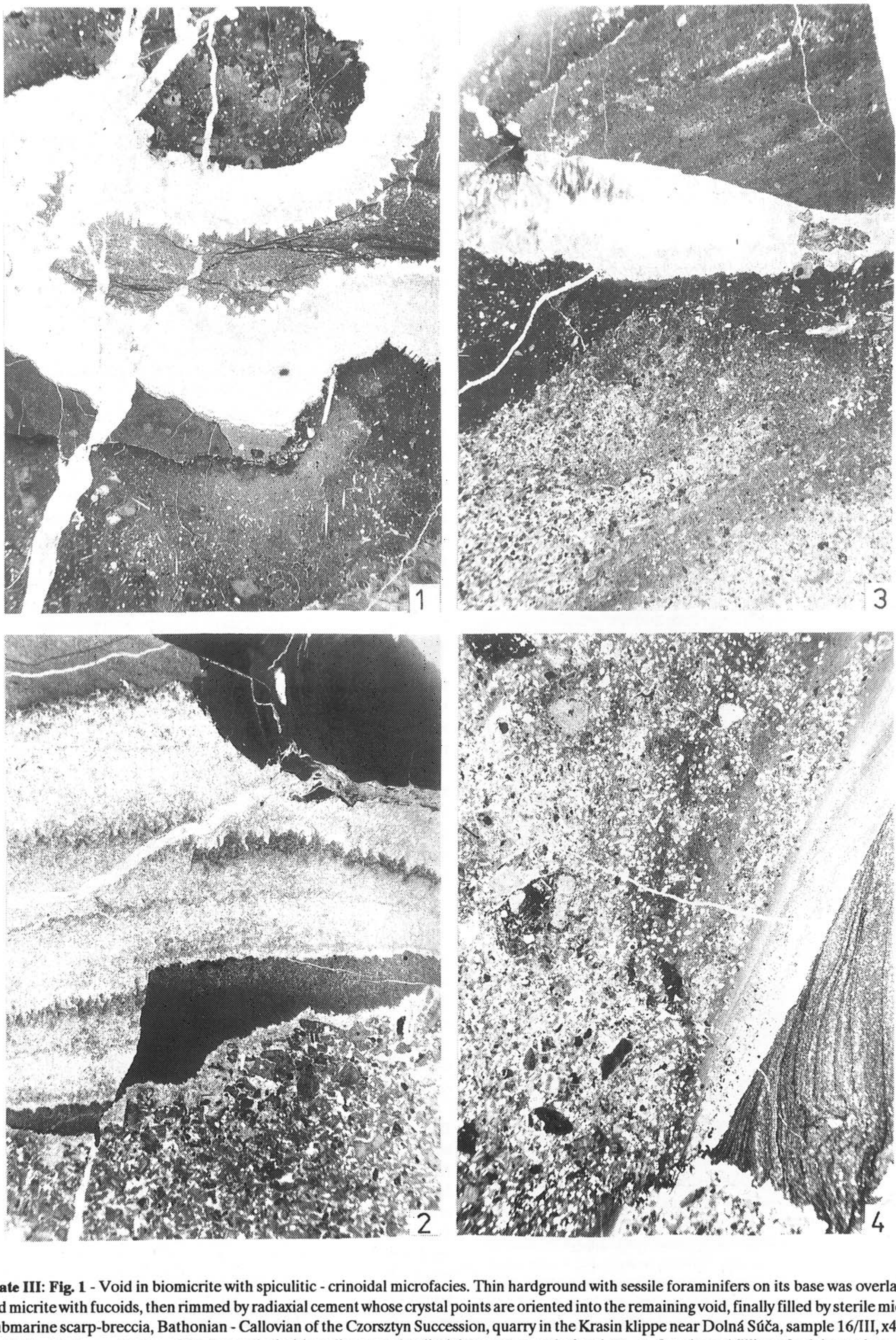

Plate III: **Fig. 1** - Void in biomicrite with spiculitic - crinoidal microfacies. Thin hardground with sessile foraminifers on its base was overlain by red micrite with fucoids, then rimmed by radiaxial cement whose crystal points are oriented into the remaining void, finally filled by sterile micrite. Submarine scarp-breccia, Bathonian - Callovian of the Czorsztyn Succession, quarry in the Krasin klippe near Dolná Súča, sample 16/III, x4. **Fig. 2** - Void with the oscillation of the internal micritic sediment and radiaxial cement, sample 6a, x4. **Fig. 3** - Laminated filling of a dyke cut by a crack filled with radiaxial cement along its margin and a clear blocky calcite in its central part; as above, sample 17, x4. **Fig. 4** - Void with double laminated filling (the younger lamination with angular disconformity); as above, sample 16/II, x4.

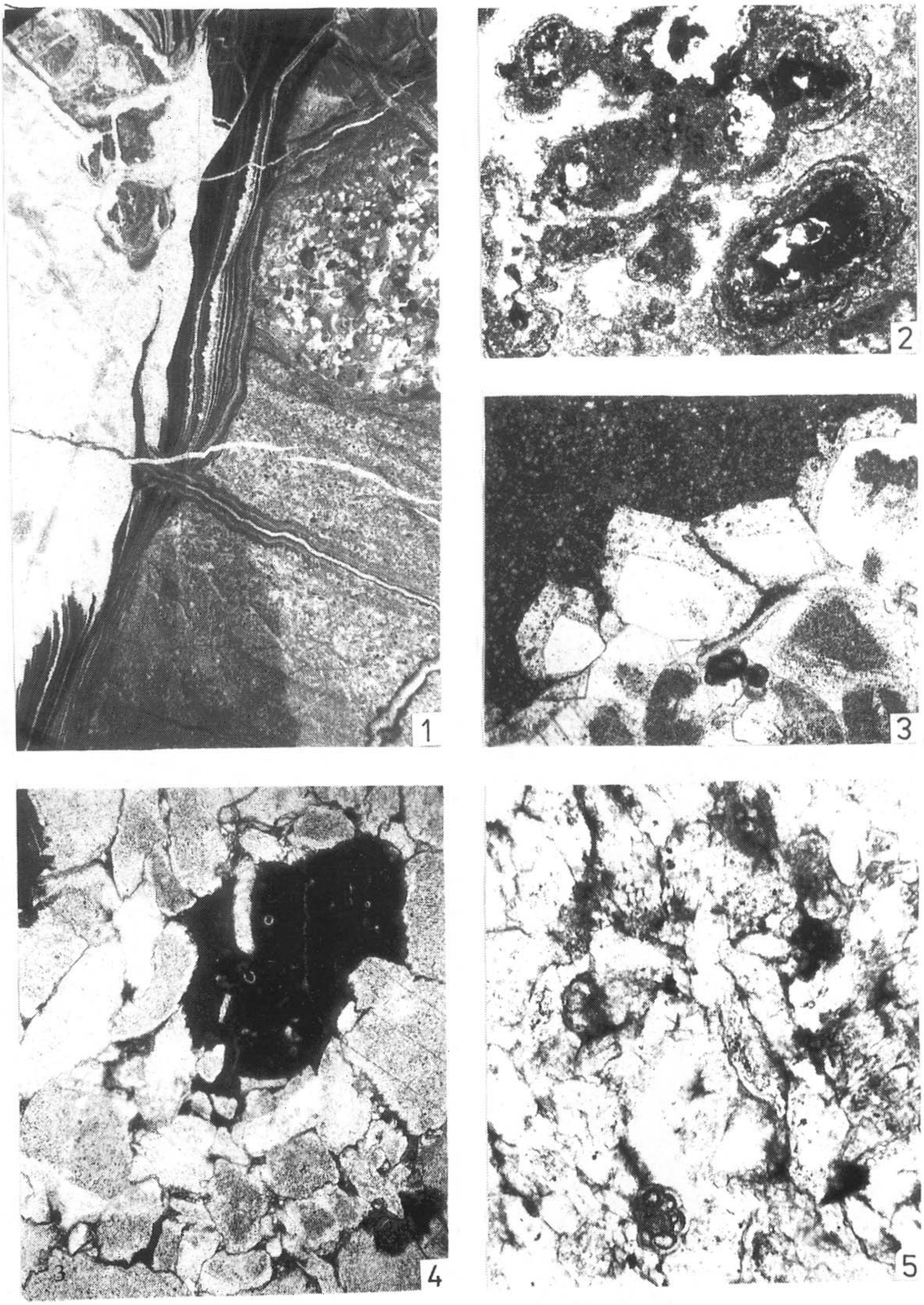

Plate IV: **Fig. 1** - Neptunian dyke in the pink breccious crinoidal limestones of Middle Jurassic age. Its filling was from laminated micrite (in the right lower corner the recrystallization of the laminae can be observed), disturbed by transversal microdykes. Quarry in the Krasin klippe near Dolná Súča, sample E, x7. **Fig. 2** - Oncolites from the hardground in the same limestones, sample 7/II, x50. **Fig. 3** - Syntaxial overgrowths on the echinoderm plates pointing into the void. The first overgrowth generation grew into the empty space and is composed by the clear calcite. Then the remaining void was filled by internal sediment and the second generation grew at the expense of the micritic filling, therefore it is full of inclusions. As above, x30. **Fig. 4** - Lithoclast of the *Crassicollaria* - bearing biomicrite (Upper Tithonian) in the Neocomian crinoidal limestone; sample a, x30. **Fig. 5** - Hedbergellas in the Hauterivian crinoidal biosparite. Filling of a cleft in the Middle Jurassic breccious crinoidal limestones, sample 14-15, x80.

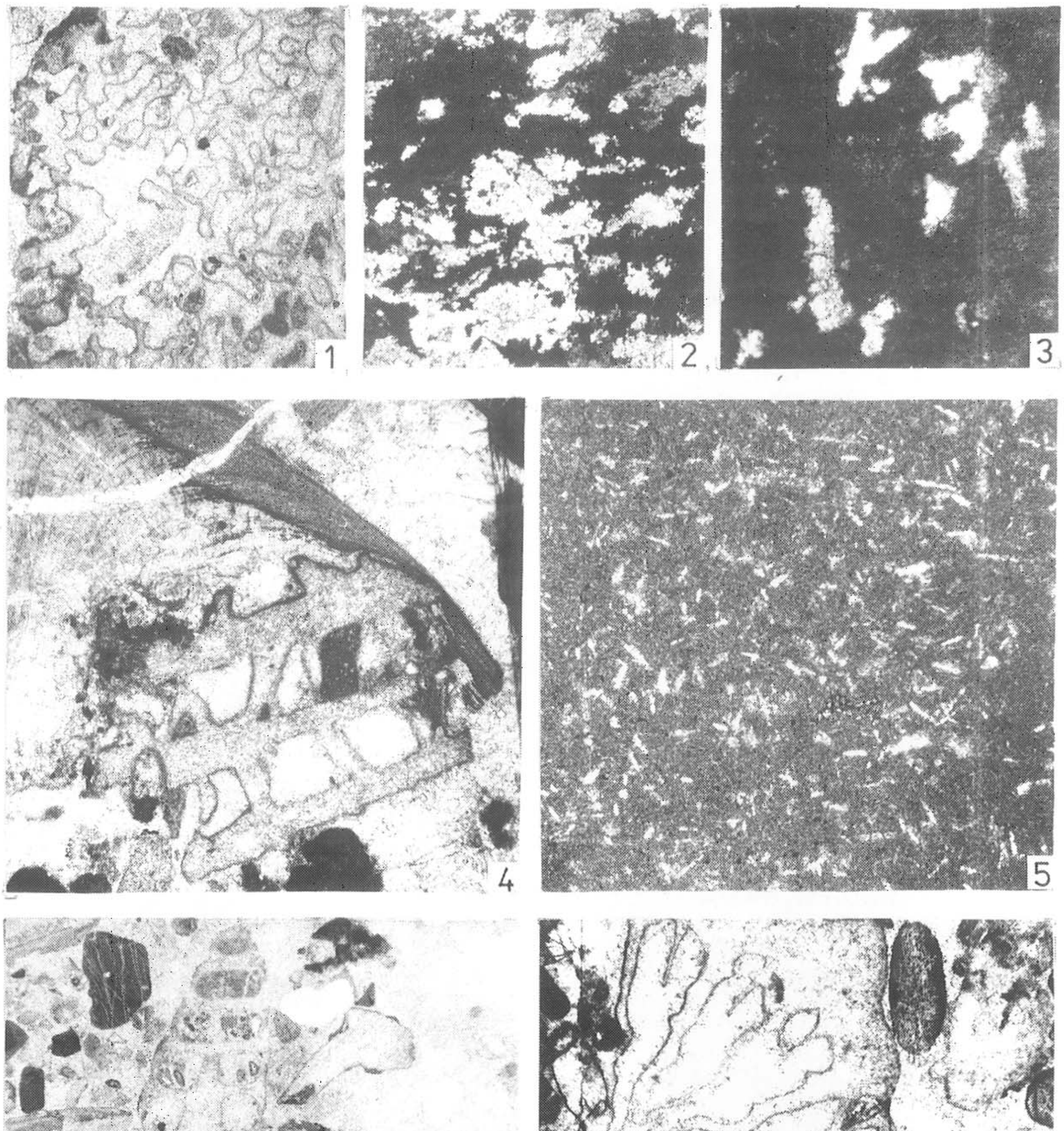

Plate V: Fig. 1 - Hydrozoa in the probably Oxfordian bioherm breccia; filling of a cleft in the Middle Jurassic crinoidal limestones. Quarry in the Krasin klippe near Dolná Súča, sample O, x13. **Fig. 2** - Phosphatic intraclast filled by arborescent calcite grains; fine-grained breccious crinoidal limestone of Neocomian age filling a cleft in the Middle Jurassic crinoidal limestones, sample 17 - 18, crossed polars, x30. **Fig. 3** - Pseudomorphs after the gypsum crystals in the Triassic dolomite; lithoclast from the fine-grained Neocomian breccious limestone, sample A, x30. **Fig. 4** - Fragment of a thick bivalvian shell from the Oxfordian bioherm breccia filling a cleft in the Middle Jurassic limestones; sample O, x13. **Fig. 5** - Pseudomorphs after tiny gypsum crystals, lithoclast in the Oxfordian bioherm breccia, as above, x30. **Fig. 6** - Gastropod, as above, x7. **Fig. 7** - Coral, as above, x13.

Abundant lithoclasts (up to 4 cm) belong almost exclusively to the Triassic dolomites. They are mostly dolomicrites with peculiar structures (Mišík & Aubrecht 1994) and frequent pseudomorphs after gypsum crystals (Pl. V: Fig. 5) and microconcretions ("bird eyes") and rare fenestrae, exceptionally with *Frondicularia* sp. Several lithoclasts possess red margins and Liesegang rings originated during exposure on dry land. Isolated siltstone lithoclasts and grains of clastic quartz up to 3 mm occur.

The cement is almost exclusively radiaxial calcite filled with inclusions; the younger generation - clear, isometric (blocky) aggregate occurs rarely in the pore centers.

As in the near localities Krivoklát - Vršatec - Mikušovce Oxfordian bioherm limestones with corals are known (Mišík 1979), an Oxfordian age is supposed for the described bioherm breccia. Abundant echinoderm plates and lack of calpionellid-bearing lithoclasts speak against the casual Cretaceous age.

Unit E - Walentowa Breccia (Birkenmajer 1977): Red and pinkish coarse-grained breccia and red crinoidal limestones with white micritic calpionellid-bearing clasts - Valanginian - Hauterivian. They represent the filling of the fracture in the Middle Jurassic crinoidal limestones, mainly of a large cleft 25-30 m thick, steeply inclined to the EES. Lithoclasts of the breccia belong mostly to the Middle Jurassic crinoidal limestones. The matrix is formed by red crinoidal limestone of the Lower Cretaceous age, sometimes in continuous beds (points 20, 21). Red crinoidal limestone and clayey limestone also fill thinner (cm - dm) clefts, especially eight dykes along the eastern margin of the quarry. The thickest of them (point 17) is parallel to the main cleft and perpendicular to the bedding in the klippe. The clasts of Middle Jurassic crinoidal limestones may attain the size 1 m (exceptionally 2 m); they are subangular to semioval. The clasts of the younger rocks (Callovian to Berriasian) occur only as small fragments under 5 mm.

From the red crinoidal limestones with small lithoclasts (matrix of the coarse-grained breccia and filling of dykes) 14 thin-sections have been thoroughly studied. They can be designated as biolithosparite, rarely biosparite or biolithosparrudite (point 20 with large columnalia); all samples belong to echinoderm microfacies. The echinoderm plates are sometimes affected by strong pressure twinning; they are bordered by microstylolites with a red coating of Fe-colloids and they lack syntaxial rims. In three cases (3/14) brachialia of planctonic roveacrinids were present. Other organic remnants are accessory: bivalvian fragments (5/14), phosphatic fish teeth (2/14), rhaxa filled by chalcedony (2/14), single bryozoan fragments and nubecularid foraminifera. The lack of foraminifers is surprising. Phosphatic intraclasts (10/14) containing arborescent calcite grains (Pl. V: Fig. 2) are characteristic; they were also found at the Babiná locality in the limestones of the same age. The size of the rare clastic quartz grains varied between 0.4 and 1.8 mm. Two samples also contain isolated grains of the orthoclase - perthite.

The insoluble residue separated from the fraction under 0.25 mm rendered the following heavy mineral assemblages: 71 % opaque and 26 % transparent grains; 3 % phosphatic aggregates. From 107 transparent grains the following proportions have been estimated: 58 % garnet, 15 % zircon, 15 % rutile, 10 % tourmaline, 1 % staurolite and 1 % titanite. There were 55 % of rounded zircon grains and 45 % of euhedral ones. The clear predomination of garnet indicates that the metamorphic rocks were the main component in the source area. Similar assemblages were also ascertained in the numerous samples from the Middle Jurassic crinoidal limestones of the Czorsztyn Unit (Aubrecht 1993).

Lithoclasts (up to 2 cm) of biomicrites with *Crassicollaria* sp. (Pl. IV: Fig. 4), *Globochaete alpina*, radiolarian molds filled by calcite - Upper Tithonian and other one with *Calpionella alpina* and *Crassicollaria intermedia* - Lower Beriassian, strongly affected by pressure solution, are the most characteristic components. Fragments of biomicrites with *Saccocoma* (Kimmeridgian - Lower Tithonian) or with "filament" microfacies are rare, as well as clasts of the radiaxial cement (2/14) and a fragment of laminated void filling. Lithoclasts of Triassic carbonate rocks are frequent: dolomites (sometimes dedolomitized, mostly dolomicrites with rare pellets, fenestrae and pseudomorphs after gypsum crystals - Pl. V: Figs. 3, 5), micrites, single fragments of fine-grained sandstone.

It is difficult to distinguish these Lower Cretaceous crinoidal limestones from those of the Middle Jurassic in the field. The following microscopic criteria are reliable: echinoderm plates intensively twinned and limited by microstylolites, phosphatic lithoclasts, larger and fracturated quartz grains, more frequent dolomite lithoclasts and especially lithoclasts of calpionellid-bearing limestones. Intensive chemical compaction (overcompaction) is considered as a sign of meteoric alteration (Tucker & Wright 1990, p. 343), but we have not found other criteria indicating the action of the meteoric waters.

The described Lower Cretaceous limestones from the clefts are more affected by pressure and their diagenesis was more intensive than that of the older surrounding limestones. This is an indicator of repeated tectonic activity (compression, stress) that has taken place along the fractures after their filling.

The abundance of Triassic dolomite fragments is surprising from the paleogeographical point of view. They cannot be derived as the redeposites from the Jurassic limestones; a primary source emerged during the Early Cretaceous should be supposed. The age determination Valanginian-Hauterivian is indirect, based on the following facts: presence of the Lower Berriasian lithoclasts, lack of the calpionellids in the matrix and occurrence of *Hedbergella* in the next rock type.

Unit F : Red fine-grained biodetritic limestone - Hauterivian. A thin (3 cm) intercalation in the red marly shales filling a cleft 15 cm thick. It corresponds partly to the Spiš Limestone of Birkenmajer (1977), which contained Hauterivian aptychi. In our samples hedbergellas were found (Pl. IV: Fig. 5). Their first occurrences in the Carpathians are dated as Late Hauterivian (Salaj & Samuel 1966). Hedbergellas were ascertained in an similar crinoidal limestone at Vršatec (Mišík 1979, p. 26).

The sample taken between the points 14 and 15 is a fine-grained well-sorted biosparite with hedbergellas - echinoderm plates microfacies. Several brachials of the planctonic *Roveacrinidae* with syntaxial rims and a lithoclast with *Crassicollaria* were present. Clastic quartz and glauconite are very rare.

Paleogeographical and tectonic interpretation

The Krasin klippe differs from the standard Czorsztyn Succession by the following peculiarities: the presence of submarine scarp-breccias in the Middle Jurassic (Krasin Limestone Breccia), the lack of Upper Jurassic limestones (except a cleft filled by Oxfordian bioherm limestone), the contact of the Lower Cretaceous crinoidal limestone with the Middle Jurassic one in the form of large cleft fillings.

Synsedimentary faults must have originated during the Bathonian - Callovian, forming a submarine scarp. The clasts of crinoidal limestones derived from it fell into the sediment also

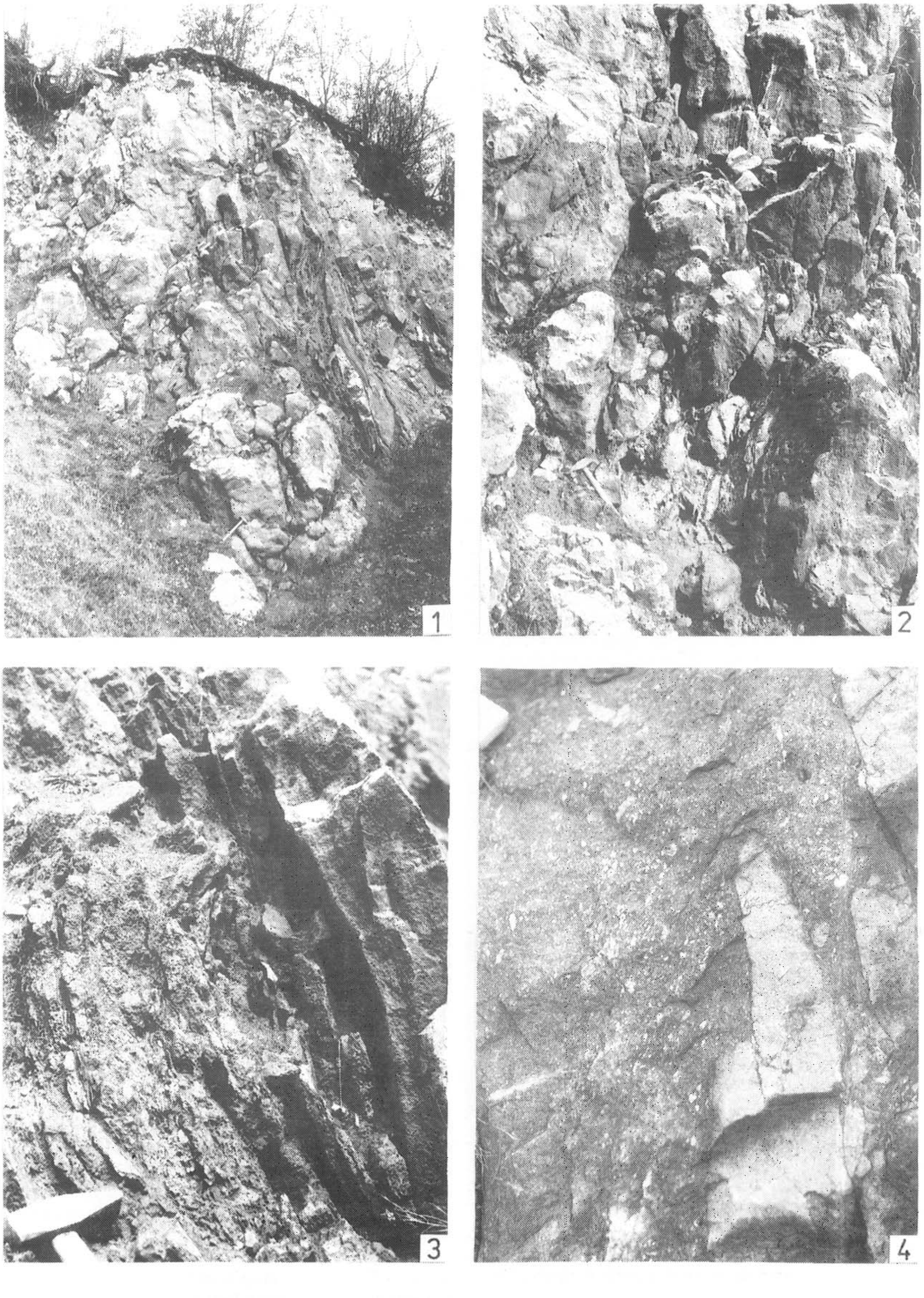

Plate VI: Fig. 1 - Coarse-grained blocks Lower Cretaceous breccia; northern wall of the quarry, Krasin klippe near Dolná Súča. **Fig. 2** - Detail from the Fig.1. **Fig. 3** - Beds of the crinoidal biosparites - rarer type of the Lower Cretaceous sediments; northern margin of the quarry. **Fig. 4** - Matrix of the Lower Cretaceous breccia containing small lithoclasts (some of them are of Berriasian age).

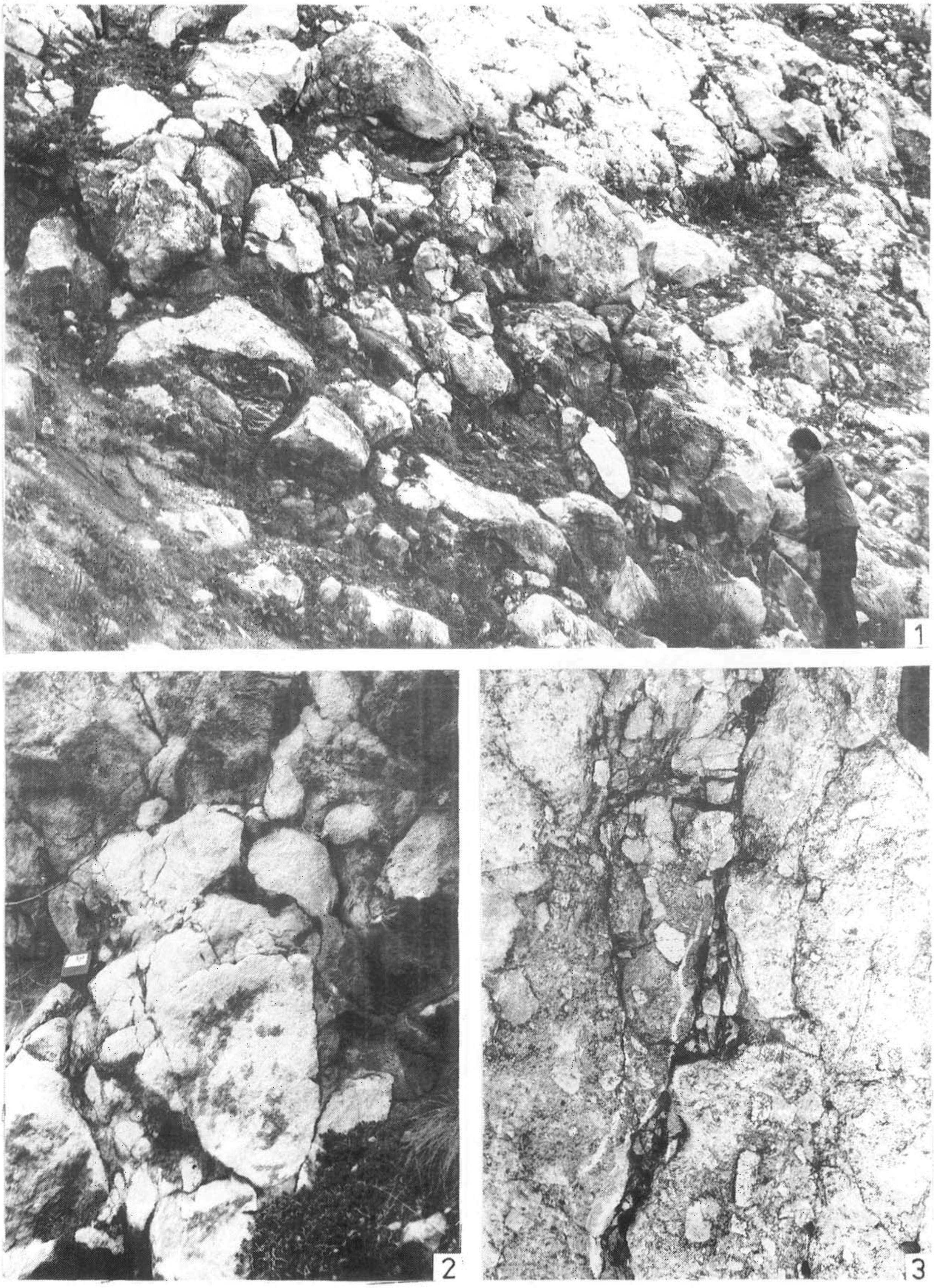

Plate VII: Fig. 1 - Block type of the Lower Cretaceous breccia; in the upper part of the Bajocian crinoidal limestones. Right wing of the quarry. **Fig. 2** - The same, near the point 8. **Fig. 3** - Bioherm breccia probably of Oxfordian age with Triassic dolomite lithoclasts - filling of a cleft in the Middle Jurassic limestones; western margin of the Krasin quarry.

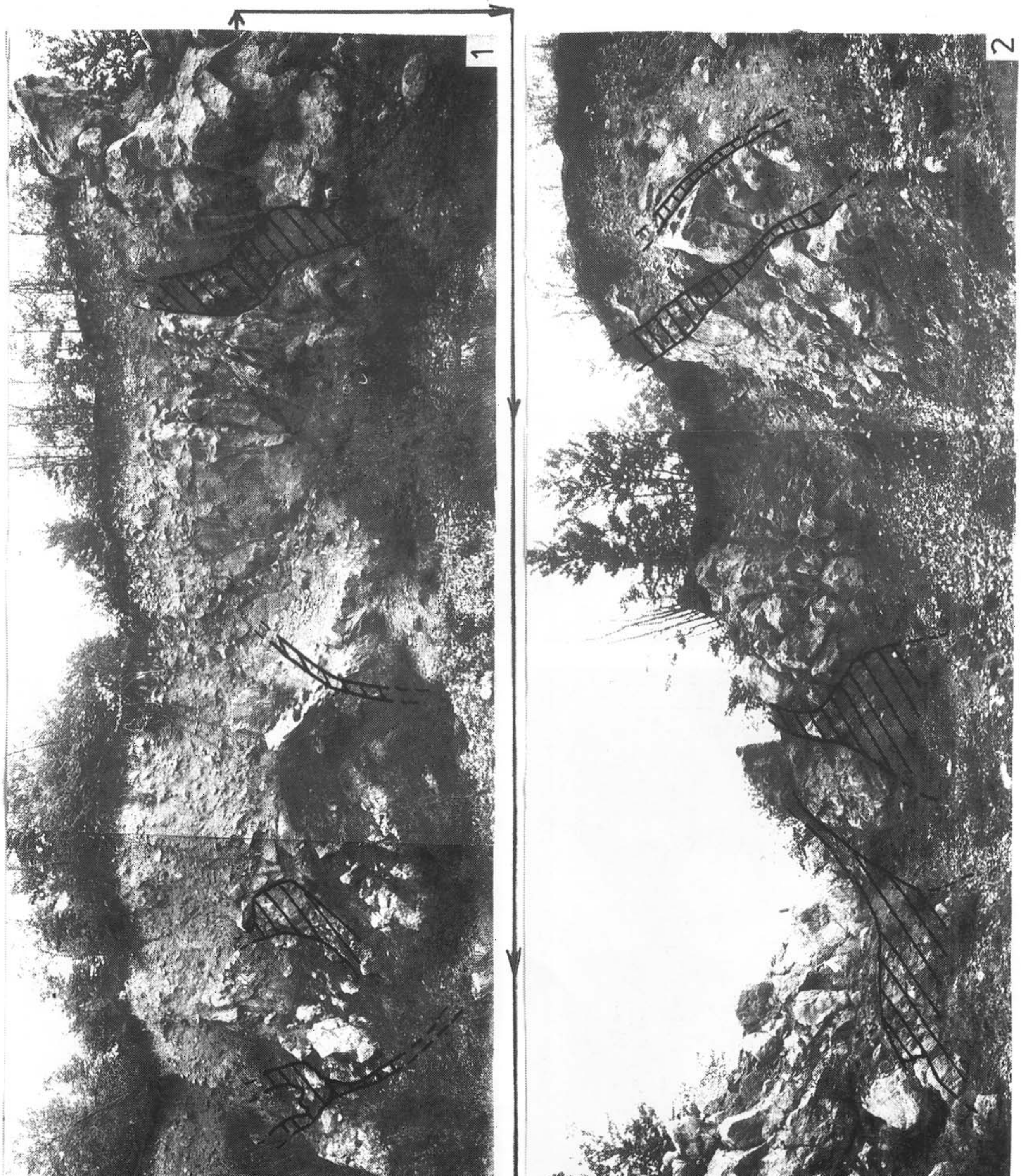

Plate VIII: Figs. 1,2 - Panorama of the eastern margin of the quarry. Middle Jurassic Krasin Breccia with Cretaceous cleft fillings.

formed by crinoidal detritus. The faults generating submarine scarps were accompanied by smaller fractures which were filled later by the red, mostly laminated limestone (neptunian dykes) containing contemporaneous marine microfauna, or only ostracods, specialized void-dwellers. The association of submarine scarp-breccias and neptunian dykes is frequent (e.g. in the Upper Jurassic Kyjov-Pusté Pole klippe - Mišík & Sýkora (1993); in the Quaternary sediments - Vachard et al. 1987). The activity of the synsedimentary faults was revived in the Lower Cretaceous (Fig. 3). The stratigraphical connection of the Lower Cretaceous sediments and an isolated occurrence of Oxfordian bioherm breccia with Middle Jurassic limestone in the form of large cleft filling may be explained in two ways:

I - The Upper Jurassic strata were tectonically amputated during the formation of the klippe (tectonic lens). In that case the mentioned large cleft filled by Valanginian - Hauterivian sediments also formerly penetrated through the overlying Upper Jurassic strata but due to their amputation only the lower "root" part within the Middle Jurassic limestones was preserved.

II - The Upper Jurassic and Berriasian strata were eroded before the Valanginian - Hauterivian; the sediments of the latter age were laid down immediately on Middle Jurassic limestones (Fig. 3). The erosion of some tens of meters thick strata should be better explained by an emersion than by a submarine erosion. As the lithoclasts of the Upper Jurassic biomicrites are very small and rarer than the clasts of Middle Jurassic crinoidal limestones, we suppose that Upper Jurassic limestones in the nearest neigbourhood should have been eroded before the Early Cretaceous. The erosion of the whole Upper Jurassic sequence prior to the Early Cretaceous was found nowhere in the Pieniny Klippen Belt up to now.

The primary absence of the Upper Jurassic sediments (a gap) is out of question, as the small clasts with filaments (Callovian - Oxfordian), with *Saccocoma* (Kimmeridgian - Early Tithonian) and especially with *Crassicollaria* (Upper Tithonian) and *Calpionella alpina* (Early Beriassian) in the Valanginian - Hauterivian limestones as well as the occurrence of the Oxfordian bioherm breccia signalize that all these strata should have been present nearby.

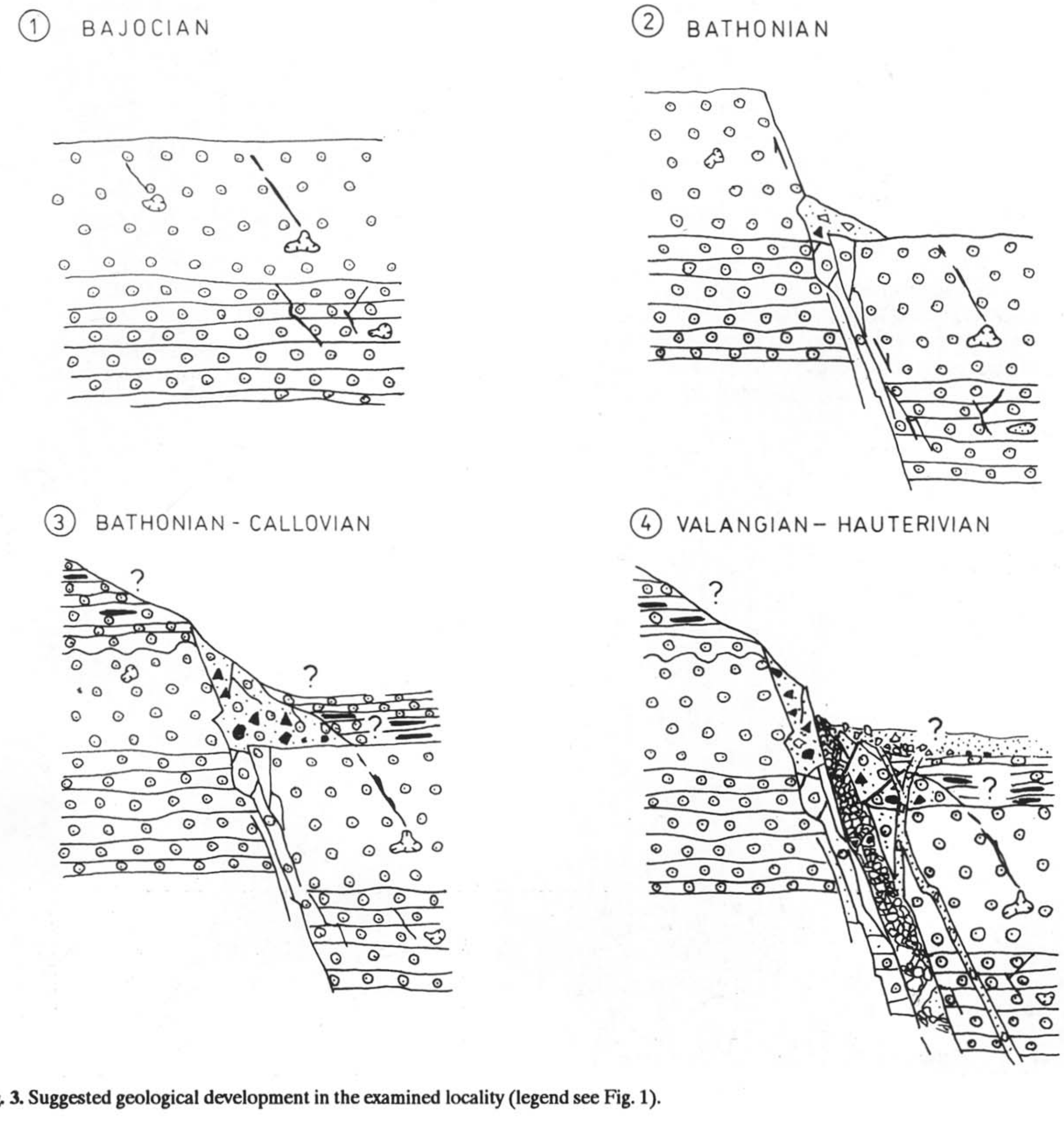

Fig. 3. **Suggested geological development in the examined locality (legend see Fig. 1).**

It is interesting from the paleogeographical point of view that in the source area the Lower Cretaceous limestones with clastics and the Triassic carbonates, mainly dolomites and crystalline schists (dominance of garnet in the heavy fraction) must have been eroded. They are the same components which were also typical the Middle Jurassic crinoidal limestones of the same Czorsztyn Unit. A long transport from the platform foreland (the present territory of Poland and the Czech Republic) must be excluded as in the Silesian sedimentary zone typical flysch sedimentation took place during Cretaceous. An origin from the Silesian Exotic Ridge is also improbable as the pelagic Neocomian limestones are known from the Magura Unit. The uncovered Triassic carbonates and metamorphic rocks formed an elevated zone (dry land during the Middle - Late Jurassic and Early Cretaceous) attached to the outer side of the Czorsztyn sedimentary area. This elevated zone should have been submerged during the Albian and then subducted under the Czorsztyn Unit, under the Pieniny Klippen Belt. The existence of such an elevation is an another reason against Birkenmajer's idea (1977 and other papers) about the so-called Magura Succession forming part of the Pieniny Klippen Belt. The pretended klippen with the Magura Succession belong to the Pieniny or Kysuca (Branisko) Successions, as he supposed in his earlier papers.

It was confirmed once more that the Jurassic limestones of the Pieniny Klippen Belt were exposed to the much more moderate P-T conditions than the similar limestones of the Central Carpathians. Pressure twinning lamellae in the crinoidal plates are rare, authigenic feldspars and authigenic quartz are almost entirely missing.

From the tectonic point of view, the studied Krasin klippe testifies to synsedimentary faulting with extension in the Middle Jurassic reactivated during Oxfordian and mainly during the earliest Cretaceous (large clefts filling) was later followed by compression. The strongest compression (transpression) which led to the formation of tectonic lenses (klippen) took place in the Senonian and Tertiary.

Some young faults (Late Neogene - Quaternary) accompanied by tectonic breccia cemented by sinter were identified in the quarry, as well as small caverns partly covered by speleothemes (e.g. drapery near the point 1). Two caves were uncovered by exploitation (see Fig. 1). They have been described by Mitter (1977).

References

Aubrecht R., 1992: Mestečská Skala klippe and its importance for stratigraphy of Czorsztyn Unit (Biele Karpaty Mts., Western Slovakia). *Acta Geol. Geogr. Univ. Comen., Geol.,* 48/I, 55 - 64.

Aubrecht R., 1993: Clastic admixture in Dogger crinoidal limestones of Czorsztyn Unit. *Geol. Carpathica,* 44, 105 - 111.

Began A., 1969: Geologische Verhältnisse des mittleren Waagtales. *Zbor. Geol. Vied., Západ. Karpaty,* 11, 55 - 103 (in Slovak, German summary).

Birkenmajer K., 1977: Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Stud. Geol. Pol.,* 45, 1 - 158.

Mišík M., 1979: Sedimentological and microfacial study in the Jurassic of the Vršatec (castle) klippe - neptunic dykes, Oxfordian bioherm facies. *Západ. Karpaty, Sér. Geol.,* 5, 7 - 56 (in Slovak, English summary).

Mišík M. & Aubrecht R., 1994: Source of rock fragments in the Jurassic crinoidal limestones of the Pieninicum (Klippen Belt, Western Carpathians). *Geol. Carpathica,* 45, 159 - 170.

Mišík M. & Sýkora M., 1993: Jurassic submarine scarp breccia and neptunian dykes from the Kyjov-Pusté Pole klippen (Czorsztyn Unit). *Miner. slovaca,* 25, 411 - 427.

Mitter P., 1977: Cave in Krasin. *Krásy Slov.,* 54, 5, 234 - 235 (in Slovak).

Salaj J. & Samuel O., 1966: Foraminifera der Westkarpaten Kreide. *GÚDŠ,* Bratislava, 1 - 291.

Štúr D., 1860: Bericht über die Übersichtaufnahmen des Wassergebietes der Waag und Neutra. *Jb. Geol. Reichsanst.,* 11, 17 - 151.

Tucker M.E. & Wright V.P., 1990: Carbonate Sedimentology. *Blackwell,* Oxford etc., 1 - 482.

Vachard D., Barrier P., Montenat Ch. & Ott d'Estevou Ph., 1987: Dykes neptuniens, breches internes et éboulis cimentés des escarpements de faille du détroit de Messine au Plio-Quaternaire. *Doc. et Trav. IGAL,* 11, 127 - 141.