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THE SOURCE OF ROCK FRAGMENTS IN THE JURASSIC CRINOIDAL LIMESTONES OF THE PIENINICUM (KLIPPEN BELT, WESTERN CARPATHIANS)

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Abstract: The Czorsztyn sedimentary zone was a part of the East-European Platform separated from it by passive rifting. The source supplying the clastic material in the Jurassic limestone of the Czorsztyn sedimentary area was an emerged ridge which bordered the outer margin of the Czorsztyn submarine elevation. Granitoids, clastic rocks of Permian, Triassic and Liassic, acid and also to a lesser extent basic volcanites, a huge amount of Triassic dolomites and some Liassic spongolites outcropped there. The very rare radiolarites might be of an exotic origin.

Key words: Western Carpathians, Pieniny Klippen Belt, Jurassic, clastic admixture, paleogeography.

Introduction

Middle Jurassic crinoidal limestones (white Smolegowa Lst. and red Krupianka Lst.) of the Czorsztyn Unit almost always contain small yellow clasts of Triassic dolomites and limestones and fragments of reddish shales probably from the Upper Triassic Keuper facies (Birkenmajer 1957; Birkenmajer 1977; Birkenmajer et al. 1960; Andrusov 1945). According to Birkenmajer, clastic quartz grains also proceed from the Triassic Werfenian sandstones. Since the abundance and size of the clasts diminished from the north to the south, transport from the north is supposed (Birkenmajer et al. 1960 p.46; Birkenmajer 1988 p.12). The maximum size of quartz clasts found by Birkenmajer (1963 p.37) in the white crinoidal limestones was 1.5 cm and 2 cm of carbonate rock fragments.

The extraordinary find of a group of large pebbles in the red nodular Middle Jurassic limestone of the Niedzica Unit probably transported amidst the roots of drifting trunks (Birkenmajer et al. 1960) enabled the reconstruction of other components of this northern source: quartz porphyries and their pyroclastic rocks, two-mica granites, aplites and gneiss. Birkenmajer (1988 p.12) concluded that clastic material transported during the Middle Jurassic from the northern margin of the Klippen Belt proceeded from the Triassic carbonate platform with local outcrops of Permian acid volcanites and Upper Carboniferous coal (coal fragments containing Carboniferous microspores were found in the Aalenian Flysch). The platform basement was formed by Variscan or Caledonian crystalline rocks. There is no doubt that in the Triassic the carbonate platform also included the space later differentiated as the Czorsztyn sedimentary area.

Now we will present the inventory of the small rock fragments identified by us in the Middle Jurassic crinoidal limestones of the Czorsztyn Unit completed by some data from the Upper Jurassic and Neocomian breccias of the same unit, as well as from the Liassic crinoidal limestones of the Nižná Unit (Lúty Potok, Orava). The situation of the localities is shown on Fig. 1.

Besides the terrigenous admixture of psammitic category, rare psefitic clasts (up to 11 cm) are concentrated in the thin intercalations e.g. localities: Babina, Mestečko, Sedliacka Dubová, Milpoš, Lúty Potok. Such very sporadic intercalations with pebbles are a product of exceptional events; we considered them as tempestites or tsunamites.

Rock inventory

Acid volcanites occur exceptionally. One pebble of greenish colour with a diameter about 1 cm displaying devitrification, feldspar phenocrysts and degraded biotite in the thin section came from the locality Sedliacka Dubová (Pl. I: Figs. 1,2).

Tuffite produced by acid volcanism (Pl. I: Fig. 3) was found at the locality Babina. Apart from clastic quartz grains, a small white pebble contained some phenocrysts of quartz with magmatic corrosion, silicified feldspar phenocrysts and degraded biotite embedded in the silicified matrix. A small lithoclast from the locality Hatné also belongs to the silicified volcanites (Pl. I: Fig. 4).

Felsitic lithoclasts with remnants of the spherulitic structure (Pl. I: Figs. 5,6) were present in the Liassic limestones of the Lúty Potok locality (Nižná Unit).

The Permian age of the acid volcanites is the most probable.

Basic volcanites. Small silicified lithoclasts of basic rocks were found only at the Milpoš locality. The remnants of the ophitic structure (Pl. II: Fig. 4) and fluidal structure are visible (Pl. II: Fig. 5 - this one could be produced by intermediary volcanism).

The Permian age is again most probable as Permian basalts (melaphyres) and rhyolites (quartz porphyries) are abundant in the European platform Permian. But with regard to the very rare occurrence of basic volcanic rocks a Triassic age cannot be entirely excluded.

Red silicite (jasper) linked on the volcanic activity was found only on the locality Sedliacka Dubová (Pl. II: Figs. 1, 2). The chalcedony-microquartz aggregate densely pigmented by hematite with rare metacolloidal structure lacks the organic remains. Some

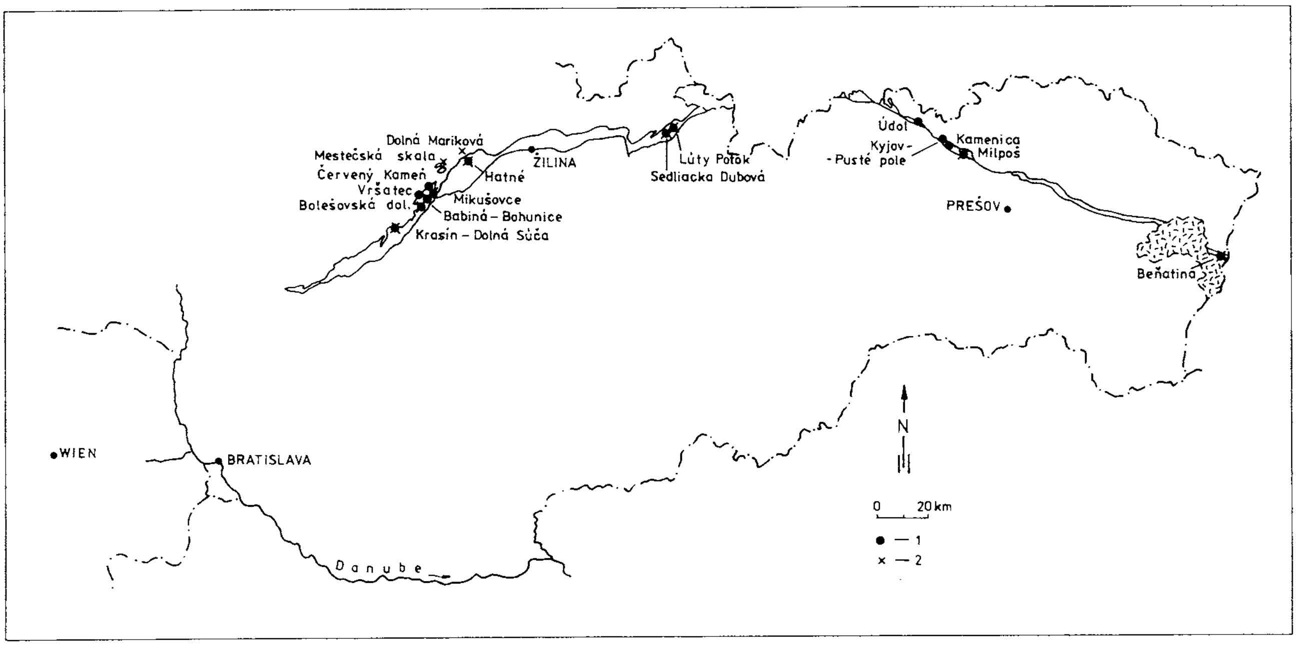


Fig. 1. Situation of the investigated localities. **1** - heavy mineral analyses from the psammitic admixture; **2** - thin section study of the lithoclasts from the crinoidal limestones. Localities Lúty Potok and Sedliacka Dubová belong to the Liassic of the Nižná Unit, all other localities represent Middle Jurassic of the Czorsztyn Unit (Mariková locality is correctly Hatné).

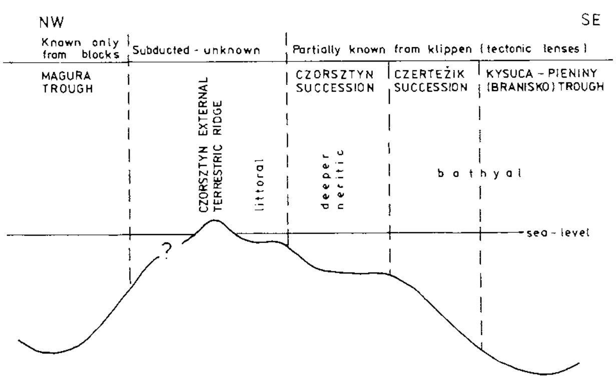


Fig. 2. External Czorsztyn Terrestrial Ridge might represent an insular arc during the Middle Jurassic. It may also be identified in the Upper Jurassic sediments but only in a few localities (e.g. Krasin-Dolná Súča). The major part of the Czorsztyn elevation was exclusively submarine.

outlines of automorphe quartz crystals are visible within the filling of previous voids. Analogic rocks occur within the conglomerate intercalations in the Lower Triassic quartzites of the Tatric Unit (Pl. II: Fig. 3) accompanied by Permian rosy rhyolite (quartz porphyry) fragments.

Dolomites are abundantly represented by fragments of mm size. They were mostly dedolomitized (Pl. III: Fig. 6), changed into yellow friable secondary limestone easily dissolved during the extraction of insoluble components by means of acetic acid. Dedolomitization already took place in the crinoidal limestone during the Middle Jurassic, but was probably intensified by the Quarternary hypergenetic processes. Bivalvian borings were observed on pebbles of some cm size (Pl. III: Figs. 1, 2). Dolomicrites are most frequent. Exceptionally they contain ostracods and foraminifers *Frondicularia*; pellets are common (dolopelsparite - Pl. III: Fig. 7). Pseudomorphs after gypsum crystals and microconcretions (Pl. III: Figs. 3,8) indicating a hypersaline environment of the sabkha type were found several times. Fenestral structures (shrinkage pores indicating temporal emersion) are very rare.

The admixture of clastic quartz grains in several dolomites is a peculiar feature (e.g. Pl. III: Fig. 5) as the Triassic dolomites of the Central Western Carpathians totally lack clastic quartz (silty quartz is exceptionally present in the dolomites of the Carpathian Keuper). The source of terrigenous quartz was obviously nearer to the littoral area bordering the East-European Platform than to the very large carbonate platform of the Northern Tethys. Some special structures (e.g. Pl. III: Fig. 4) unknown from the Central Carpathian dolomites occur.

Besides the Lower and Middle Jurassic crinoidal limestones the source supplying dolomites also operated locally during the Oxfordian and Lower Neocomian; dolomite fragments in these younger periods were even of the larger size (Krasin locality). The same source can be proved by the special pseudomorphs after gypsum crystals found in dolomite clasts within two different stratigraphic horizons at the mentioned locality.

Plate I: Lithoclasts of volcanic rocks. **Fig. 1** - Small pebble of acid volcanite with felsitic ground mass and feldspar phenocryst. Microconglomerate intercalation in the Liassic crinoidal limestones of the Nižná Succession, Sedliacka Dubová, quarry 300 m from the elevation point 691.1. Thin section No. 17 997, x95, crossed nicols. **Fig. 2** - The same. Thin section No. 20534, x80, polarised light. **Fig. 3** - Small pebble of acid tuffite with feldspar phenocryst in the Middle Jurassic crinoidal limestone of the Czorsztyn Unit, Babina quarry near Bohunice. Thin section No. 20 531, x26. **Fig. 4** - Lithoclast of a silicified volcanite (?) in the crinoidal limestone of the Czorsztyn Unit, Hatné. Thin section No. 5 899, x80, crossed nicols. **Fig. 5** - Lithoclast of a felsitized acid volcanite in the crinoidal limestone of the Nižná Unit. Lúty Potok near Krivá. Thin section No. 19 104, x95, crossed nicols. **Fig. 6** - Lithoclast of an acid volcanite with spherulitic structure. As above. Thin section No. 19 059, x95, crossed nicols.

PLATE I

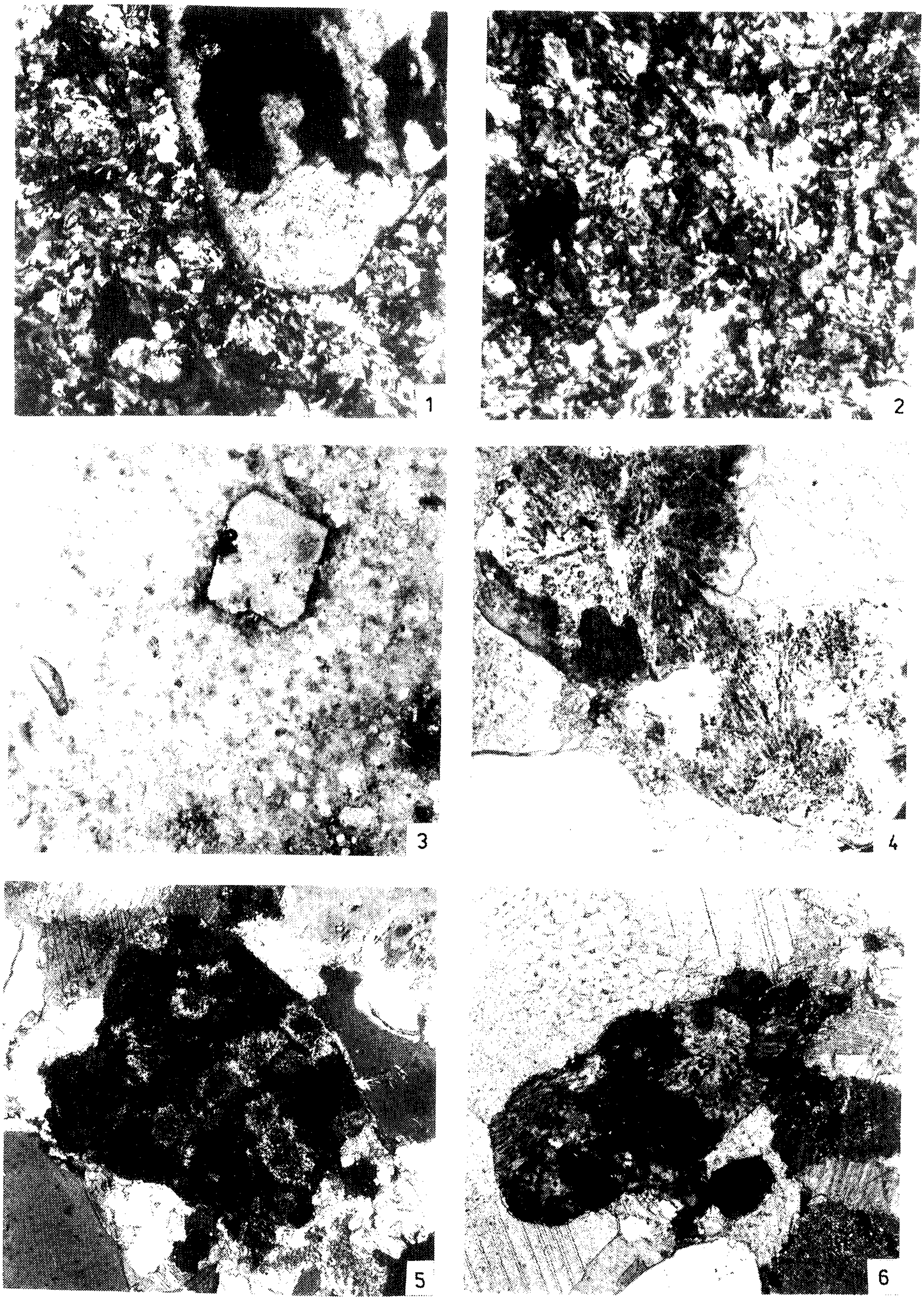
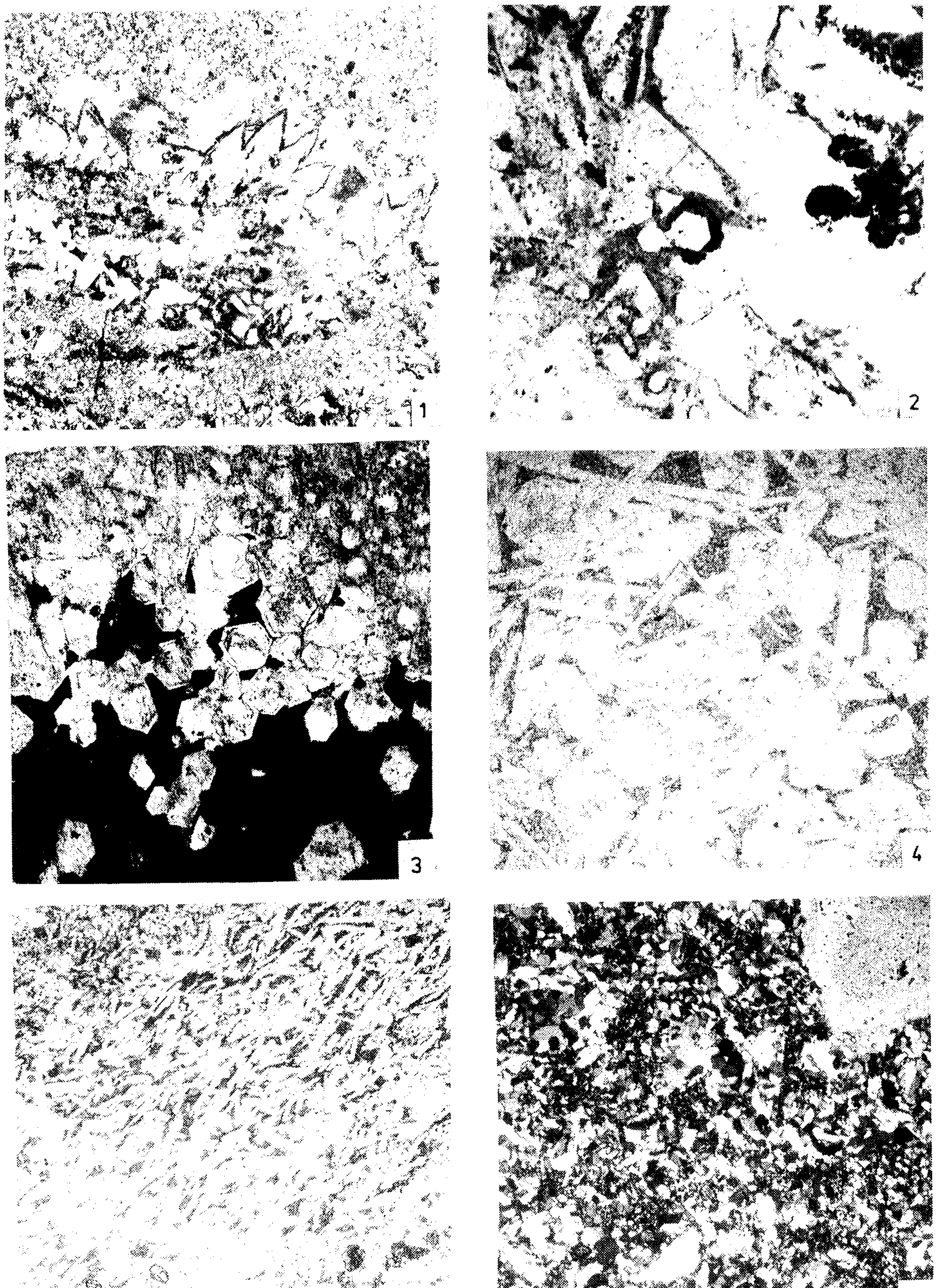


PLATE II



Spongolites. Spongolite lithoclasts with limonitic impregnation from the Milpoš locality displays fragments of siliceous sponge skeletons (Pl. IV: Fig. 1) and spicules of more complicated forms (Pl. IV: Fig. 2). Another rock fragment contained selectively pyritized monaxone spicules later replaced by hydrogoethite (Pl. IV: Fig. 3). The lithoclasts of grey silicites up to 6 cm in diameter with ghosts of spicules occur at the Babina locality (Pl. IV: Fig. 4). Spongolites with carbonate pigment comprised rare ostracodes and several *Nodosariid* foraminifers. Only the last mentioned type contained clastic quartz grains, the abundance of which should be expected in spongolites originating from the platform cover. Some small pebbles in crinoidal limestones possess a weathering crust formed probably during their exposure on dry land. The lack of calcite rhombs in the spongolites containing calcite pigment favours their origin from bedded spongolites and not from chert nodules; the rhombs used to be frequent in the nodular cherts (Mišík 1992).

The majority of the grey silicites is very fine, almost isotropic chalcedony (microquartz). This also supports their supposed Liassic age; Paleozoic silicites are always more recrystallized. Intercalations of the Liassic spongolites are abundant in the Tethyan realm including the Central Western Carpathians. It is surprising that no mention of spongolites occurs in the treatise about the platform Jurassic of Poland (Sokolowski et al. 1973).

Very rare recrystallized silicites containing an aggregate of coarser quartz grains (Pl. IV: Fig. 5) could be of Paleozoic age.

The proportion of the spongolites and vein quartz clasts should be estimated as 1:30.

Radiolarites. Some small pebbles of typical radiolarites with the phantoms of radiolarians occur at the Milpoš locality. The voids after dissolved radiolarians were filled by clear chalcedony (Pl. IV: Fig. 8), sometimes by calcite or chlorite (Pl. IV: Fig. 7). The very rare selectively pyritised radiolarians (Pl. IV: Fig. 6), later converted into the hydrogoethite, are promissing for eventual extraction which could betray the age of those radiolarites in the future.

The radiolarites are the only rocks in association which could be considered as exotic ones. They are not known from the Permian and Triassic platform cover of the North-European Continent. The older age can be excluded with regard to the very fine aggregate of SiO_2. Upper Triassic (most probably Carnian) red and white limestone with radiolarian silicites have been described by Kazintsova & Lozynyak (1987) from the Marmouresh Unit of the Flysch Belt (Ukrainian Carpathians). Red radiolarian chert nodules of Carnian age from the same area were also cited by Chernov & Slavin (1971). It is necessary to stress that our specimens of small radiolarite fragments were found only in the eastern section of the Pieniny Klippen Belt (Milpoš locality). As the same is valid for the small pebbles of basic volcanites, a hypothesis of their common origin from the continuation of Nord-Dobrogean Kimmerides or from the Meliata ocean could be suggested. Ianovici et al. (1961) described from Dobrogea Carnian and Lower Norian diabases as well as a laccolith of quartz porphyry penetrating Carnian sediments. Baltres (in Patrulius et al. 1976) mentioned Carnian bedded radiolarites (porcellanites) of black and red colour. Triassic radiolarites and basic volcanites are also known from the Meliata Unit, but their erosion during the Middle Jurassic and transport to the Czorsztyn sedimentary area is improbable because the collision and folding took place there only in the latest Jurassic. It is worth mentioning that a block of basic volcanite penetrated by neptunian dykes containing Upper Triassic foraminifers has been found by Soták (1985) in the Paleogene of the Flysch Belt (Moravia, Czech Republic). The problem requires further investigations.

Sandstones and siltstones. They occur much more rarely than the vein-quartz fragments (proportion about 1:15 to 1:20). The fine-grained sandstones (Pl. V: Fig. 1) contain calcite or siliceous cement. They most probably represent Lower or Upper Triassic (Keuper) sediments. Arcosic sandstones (Pl. V: Fig. 2) could belong to Permian sediments. Coarse-grained sandstone with corrosive calcite cement and partly calcified orthoclase was found at the Mestečko locality. Sandstones with calcite cement are probably Liassic.

Quartzites (orthoquartzites) with pavement structure are rare. A rosy arcosic quartzite containing plagioclases, rare orthoclase and a microcline with syntaxial overgrowth on the clastic core was found at the Krasin locality. The quartz grains derived from the quartzites can be sometimes identified due to the remnants of the syntaxial overgrowth on the rounded and coated grain (Pl. V: Fig. 3). The grain including the remnants of a syntaxial rim is corroded, so that the authigenic overgrowth cannot have occurred in the crinoidal limestone; in such a case at least partial automorph outlines and the presence of calcitic inclusions in the rim ought to be present. The quartzite fragments were derived most probably from the Lower Triassic quartzites.

Vein quartz is, after the dolomites, the second most abundant lithoclast type in the Lower and Middle Jurassic crinoidal limestones. Its clasts attain diameters up to 4 - 5 cm. The colour is mostly milky white, sometimes pinkish, exceptionally honey-yellow (Mestečko and Babina localities). The abundant vein quartz used to be generally derived from the epimetamorphic complexes, from the lateral secretion veins in the phyllites and greenschists but the fragments of such rocks are absent in our material. Thus a source of mature clastics must be supposed. The primary mature material (climatologically conditioned) can be excluded as carbonate fragments and only slightly kaolinized feldspars occur in the association. Redeposition of material from the Upper Carboniferous sedimentary rocks is the most probable source. A minor part of the vein quartz could be derived from the central parts of pegmatite bodies. Vein quartz mostly displays a cataclastic structure with undulatory extinction (Pl. V: Fig. 9). Chlorite was exceptionally present in the vein quartz (Sedliacka Dubová locality); no traces of ore minerals were

Plate II: Lithoclasts of volcanites and associated silicites. **Fig. 1** - Lithoclast of red silicite (jasper) without organic remnants, with phantoms of crystals sticking out into the former void (the crystals were pseudomorphosed by microquartz), supposed postvolcanic product of Permian acid volcanism. Lithoclast originating from the microconglomerate intercalation within the Liassic crinoidal limestone of Nižná Unit. Quarry 300 m W of the elevation point 691.1 near Sedliacka Dubová. Thin section No. 17 497, x30. **Fig. 2** - The same; outlines of crystals may be observed. Thin section No. 20 534, x80. **Fig. 3** - For the purpose of comparison: a pebble of analogic rock - red jasper with quartz crystals outlines (origin of the rock is most probably connected with Permian acid volcanism). The pebble originates from the Lower Triassic quartzites of the Tatric Unit, termination of Malé Karpaty Mts., Hainburg, Austria. Thin section No. 20 308, x30. **Fig. 4** - Small pebble of silicified basic volcanic rock in the Middle Jurassic crinoidal limestone, Czorsztyn Unit, Milpoš, Eastern Slovakia. Thin section No. 19 101, x30. **Fig. 5** - Silicified volcanite with fluidal structure. As above. Thin section No. 19 102, x27. **Fig. 6** - Silicified volcanite. As above. Thin section No. 19 101, x30, crossed nicols. Pebbles at the Figs. 4-6 were previously extracted by dissolving in HCl.

found. It is sometimes difficult to distinguish metaquartzite lithoclasts from those of vein quartz.

The extreme rarity of the metamorphic lithoclasts is surprising when compared with the domination of garnet in the heavy fraction. Maybe garnet is also redeposited from the Upper Carboniferous sediments; staurolite was only exceptionally found.

Granitoid detritus was mostly abundant in the intercalations of fine-grained conglomerates in the Liassic crinoidal limestones at the Sedliacka Dubová and Lúty Potok localities. Orthoclases, perthites (Pl. V: Fig. 5), graphic intergrowths of quartz and feldspars originating from pegmatites (Pl. V: Fig. 7) and K-feldspar with syntaxial overgrowth already formed in the mother rock (Pl. V: Fig. 7) were found. Syntaxial ovegrowth on K-feldspar formed within the Liassic limestone, from the Lúty Potok locality (Pl. V: Fig. 4), is an exceptional phenomenon. The proportion quartz: feldspar in this rock was 4:1; they were almost all K-feldspars, plagioclase is exceptional. In the Middle Jurassic crinoidal limestones the proportion quartz: feldspar is approximately 100:1. Single orthoclases occur in about a third of the thin sections (11/26) in the Krasin locality. The rarity of plagioclases is surprising.

Sporadic biotite also proved a granitoid source. According to the typology of zircons (Aubrecht 1993) the material originated from three magmatic complexes.

Association of the heavy minerals in the psammitic admixture

The first heavy mineral analyses from the Middle Jurassic crinoidal limestones were carried out by Halajová (1981 - manuscript). Aubrecht (1993) quoted her results and added new analyses from 14 localities.

The association of the transparent heavy minerals: garnet, zircon, rutile, tourmaline, apatite, ± staurolite and ± titanite is relatively constant within the whole course of the Pieniny Klippen Belt.

The typomorphy of the unrounded zircons gave the possibility of discerning three groups, probably from three different sources.

Zircons from the first source are very similar to those of the Central Western Carpathian granitoids (Broska & Uher 1991); similar conditions for their origin may be assumed.

The second source was not found up to now in Western Carpathian outcrops, but a similar zircon association was described by Uher (in Kováč et al. 1991) from the Miocene sediments of the Dobrá Voda Depression. Another similar zircon association was found by Jakabská (1992) in the Central Slovak neovolcanites. Naturally they cannot be taken into consideration as a source for Jurassic sediments.

The third source containing zircons of the P-types was previously known only from local sources such as granitoids from the Velence Mts. of Hungary (Gbelský & Határ 1982), from the leptynites of the Veporic Unit Čierny Balog Group (Krist et al. 1986) and Turčok granite (Uher & Gregor 1992). According to the new investigations of Broska et al. (1993) P-types of zircons are abundantly present in Permian acid volcanic rocks; they may be considered as a most probable source of such zircons in the crinoidal limestones of the Czorsztyn Unit.

In conclusion the heavy mineral association points to the existence of crystalline complexes formed by metamorphic rocks (garnet, staurolite), granitoids (zircon, apatite) and Permian acid volcanites (P-types zircons). According to the relatively high proportion of rounded zircons a part of the heavy minerals was probably redeposited from older sedimentary rocks.

Characteristics of the source area

The source area was formed by clastic rocks (sandstones, arcosic sandstones, siltstones, quartzites) of the Permian, Lower and Upper Triassic (Bunter sandstone and Keuper types), granitoids (represented by detritus only), crystalline schists (indicated by a high proportion of garnet and by quartz from the lateral secretion veins), acid volcanites (exceptionally also basic ones - Milpoš locality), a large amount of Triassic (especially Middle Triassic) dolomites, Liassic spongolites and sandy spongolites, maybe also by Liassic sandstones.

The single unexpected "exotic" element are the very rare radiolarite fragments (Milpoš) as the presence of radiolarites within the sediments of a platform cover is improbable. Chromspinels are absent except for several grains at the Beňatina locality.

The margin of the East-European Platform, its pre-Middle Jurassic rocks such as those which still outcrop in Poland and the Czech Massif must be considered as the probable source area. The actual platform margin is now hidden under the sediments of the Fore-Deep and under the overthrust Carpathian Flysch nappes. Crystalline rocks of the Brunovistulicum, Lower Devonian in the "old red" facies, Middle and Upper Devonian limestones, Dinantian limestones, Kulm facies, Upper Carboniferous sediments including Namurian coal were identified in the boreholes from the Moravian sector (Czech Republic); Triassic and locally also Permian were removed by pre-Jurassic erosion (Adámek 1986). The boreholes, which penetrated the Magura Unit in Poland, ascertained Proterozoic metamorphic rocks and Paleozoic sediments including Permian pyroclastic rocks. Mesozoic sediments were found only once in the Tokarnia IG-1 borehole.

However the terrigenous material found by us in the crinoidal limestones cannot be derived directly from the continuous East-European Platform since between it and the Czorsztyn sedimentary area a depression or an embryonal trough had already been formed by the Middle Jurassic.

The depression caught the terrigenous material transported from the platform. The deep water facies of this depression contrasting with the shallow-water crinoidal limestones of the Czorsztyn and Nižná Units are known only from the blocks. Blocks of marly limestones with Domerian and Toarcian ammonites near Lukoveček (Rakús 1987), and blocks of the Aalenian Posidonia shales by Koryčany in the Paleogene flysch of the

Plate III: Dolomite lithoclasts. **Fig. 1** - Bivalve borings in a lithoclast of Triassic dolomite. Thin conglomerate intercalation in the Middle Jurassic crinoidal limestones, Czorsztyn Unit. Quarry Babina near Bohunice. Thin section No. 20 304, x7. **Fig. 2** - Traces of bivalve borings in the Triassic dolomite; a pebble in the red Liassic crinoidal limestone of the Nižná Succession, Lúty Potok klippe, Orava. Polished section, natural size. **Fig. 3** - Pseudomorphs after gypsum crystals in a dolomite lithoclast from bioherm breccia, most probably of the Oxfordian age; Czorsztyn Succession, Krasin klippe near Dolná Súča. Thin section No. 20 372, x30. **Fig. 4** - Lithoclast of the Triassic dolomite with peculiar structure. As above. Thin section No. 20 402, x30. **Fig. 5** - Dolomite lithoclast containing clastic quartz grains; Liassic crinoidal limestone of the Nižná Succession, Lúty Potok klippe, Orava. Thin section No. 19 104, x48. **Fig. 6** - Small dedolomitized pebble of Triassic dolomite in the Neocomian fine-brecciated limestone; Czorsztyn Succession, Krasin quarry near Dolná Súča. Thin section No. 20 171, x30. **Fig. 7** - Triassic dolomite clast with pellets (dolopelsparite). As above. Thin section No. 19 287, x30. **Fig. 8** - Lithoclast of Triassic dolomite with pseudomorphs after gypsum crystals. As above. Thin section No. 19 287, x30.

PLATE III

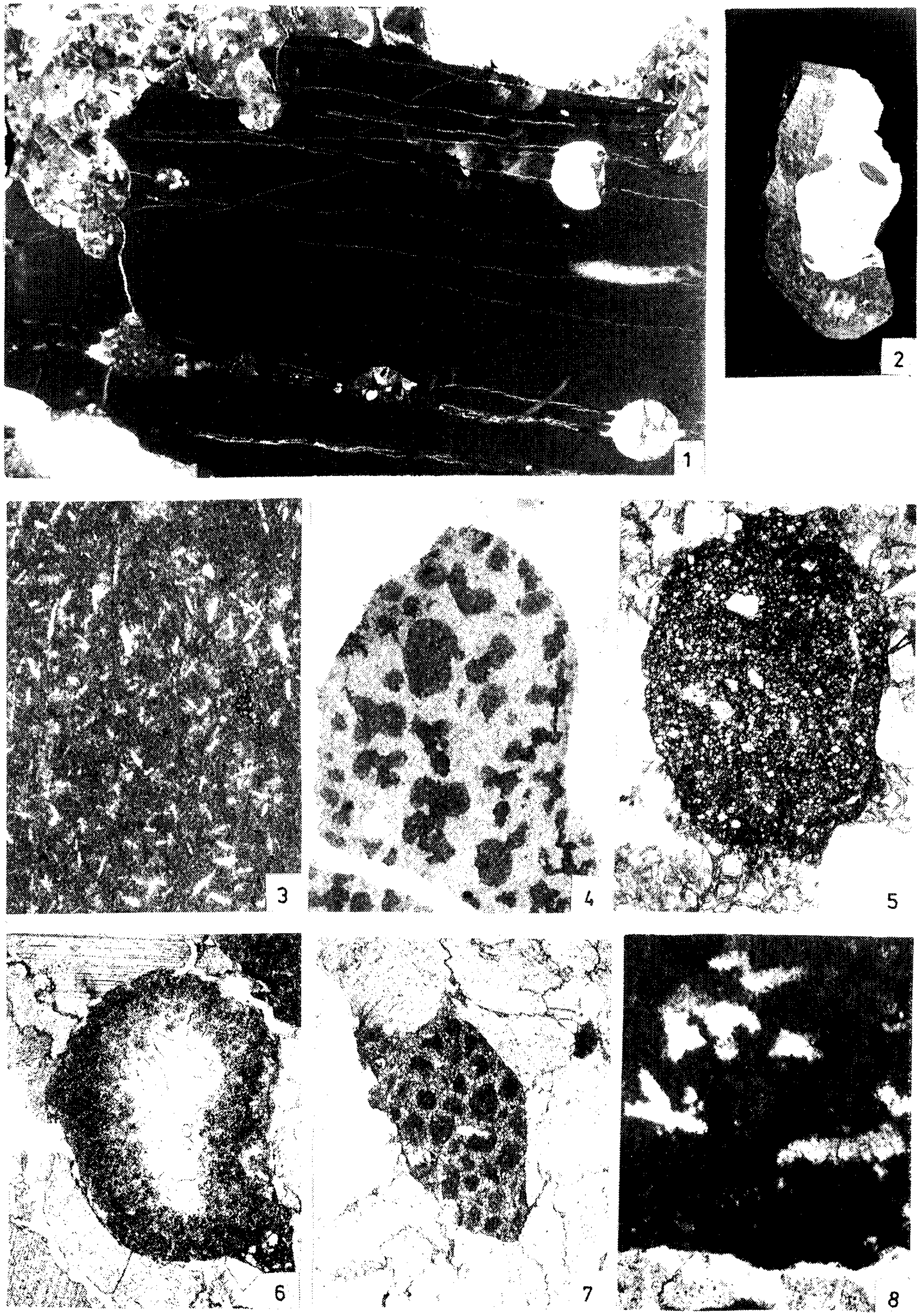
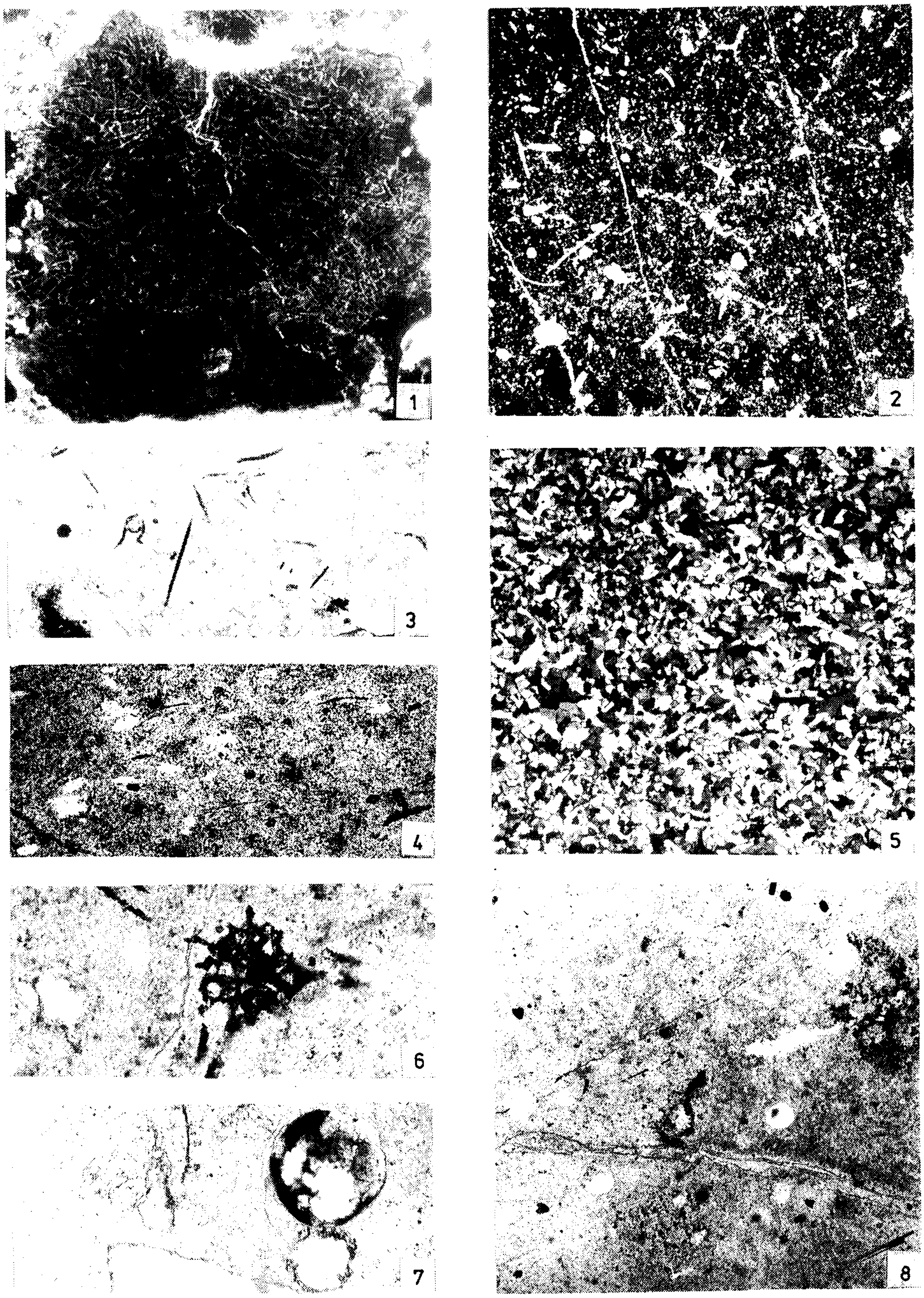


PLATE IV



Magura Unit, as well as blocks of Posidonia marls with Bathonian and Callovian fauna near Bachowice (Ksiazkiewicz 1956) are evidence of such a depression.

The source area was represented by an elongated land area or insular arc bordering the Czorsztyn sedimentary area from the outer side. This dry land was previously a part of the Eastern European Platform already separated from the main land by passive rifting in the Late Liassic and Middle Jurassic. The source area was designated by us as External Czorsztyn Terrestric Ridge (Fig. 2).

Our result may be confronted with data of Polish authors concerning terrigenous material from Middle Jurassic rocks. Though they are not related to the Czorsztyn or Nižná Units but to the neighbouring units, approximately the same source may be supposed for them.

Comparison with clastic material in the Middle Jurassic limestones of the Pieniny Klippen Belt in Poland

A group of 32 pebbles (the biggest with the diameter of 45 cm) was exceptionally found in the **Bathonian** red nodular limestone of **Niedzica Unit** (Birkenmajer et al. 1960). They were probably transported between the roots of a floating trunk. The majority were quartz porphyries and their pyroclastics; several granite-gneisses, gneisses, aplite and exceptionally algal limestone pebbles were found too.

The Szlachtowa Formation of the **Grajcarek Unit** (flyschoid **Toarcian-Aalenian**) contains small pebbles up to a diameter of 2 cm. (Krawczyk et al. 1987, Krawczyk & Slomka 1987). Sedimentary rocks usually predominate, but in rare cases metamorphic rocks are most numerous. From the sedimentary rocks they quoted dolomites, limestones (including oosparites, pelsparites and sandy limestones), fine-grained sandstones and siltstones, sandy claystones, silicites without microorganisms. Metamorphic rocks were represented by quartz-feldspar-micaceous schists, gneisses, metapsammites, quartzites; and magmatic rocks by acid effusive rocks (rhyolites or dacites, tuffs), lamprophyres, rare minetta-kersantite and perhaps granitoid fragments.

The authors derive the material from a source area formed by slightly metamorphosed probably Early Paleozoic complexes cut by acid volcanites, rarely also by more basic ones (lamprophyre); sedimentary cover was composed of Late Paleozoic and Triassic clastic and carbonate rocks. They placed such a source area on the so called Czorsztyn Geanticline. They assumed transport from the south because Birkenmajer now situates the Grajcarek sedimentary area externally from the Czorsztyn sedimentary area. It should be noted that according to the older Birkenmajer's conception (1957) this flyschoid Aalenian formed part of the Branisko (=Kysuca) Succession and its material should come from the "intra-klippen" area. In a more recent paper Birkenmajer (1977, p.30) quoted the Aalenian flysch from the Branisko Unit (up to 30 m thickness) and Czertezik Unit (up to 5 m), meanwhile its thickness in the Grajcarek Unit is estimated up to 220 m. As he supposed the transport from the so-called Czorsztyn Geanticline onto both sides, it is surprising that the proper Czorsztyn Unit comprises only Toarcian and Aalenian marls and not the flysch with the above mentioned rock fragments which should traverse the Czorsztyn sedimentary area on their way to the Czertezik and Branisko sedimentary zones. Even Birkenmajer (1977, p.38-41) did not cite any sandstone intercalations either from the Krempachy Marl Formation (formerly Opalinum Marls), or from the Skrzypny Shale Formation (formerly Murchisonae Beds) of the Czorsztyn Unit. Gašpariková (1982) also quoted from the Vršatec only marls and shales of Toarcian and Aalenian age. Scheibner (1962, p.631) suggested for the Murchisonae Beds a formal name Litmanová Beds which should have the priority with regard to the Birkenmajer's name Skrzypny Shale Formation; he found very rare sandstone intercalations only in the Czertezik Unit; no intercalations from the Toarcian and Aalenian of the Czorsztyn Unit were mentioned. The existence of a local submarine fan in the Grajcarek area is possible. The problem of the definition of the Grajcarek Unit and the place of its sedimentary area remains unresolved.

The comparison of the inventory of rock fragments types from our results and those of Polish authors confirms that they were derived from the same source named by us as the External Czorsztyn Terrestric Ridge. The accordance is almost perfect, only spongolites and very rare radiolarites were not found by the Polish authors.

Conclusions

In the Middle Jurassic crinoidal limestones of the Czorsztyn Unit and Liassic crinoidal limestones of the Nižná Unit, small fragments from clastic rocks (probably Permian, Triassic and Liassic), Permian acid volcanites, postvolcanic silicites-jasperoids, rare basic volcanites, abundant Triassic dolomites, Liassic spongolites and rare radiolarites were identified. All of them can be derived from the complexes known within the East-European Platform, only radiolarites and basic volcanites (both found only at the Milpoš locality) could eventually originate from the Triassic of the North-Dobrodgea type. Rare chromspinel grains occured only at the Beňatina locality. Both these localities are situated in the easternmost part of the Slovak section of the Pieniny Klippen Belt and perhaps belong to a different source area.

The clastic material in the Bajocian-Bathonian (and in small quantity also in the Oxfordian and Neocomian) limestones could not be transported directly into the Czorsztyn sedimentary area from the margin of the East-European Platform for it was already separated by the embryonal Magura Trough with the deposition of marls, clays and in the Oxfordian also radiolarites. Terrigenous material was derived from the Czorsztyn elevation which had

Plate IV: Lithoclasts of spongolites and radiolarites. **Fig. 1** - Limonitized probably Liassic spongolite in the Middle Jurassic crinoidal limestone; Czorsztyn Succession, Milpoš. Thin section No. 19 102, x45. **Fig. 2** - Lithoclast of probably Liassic spongolite formed by very fine chalcedony aggregate. As above. Thin section No. 19 103, x45, crossed nicols. **Fig. 3** - Small spongolite pebble. As above. Thin section No. 19 082, x45. **Fig. 4** - Lithoclast of probably Liassic spongolite with ghosts of monaxone spicules in the Middle Jurassic crinoidal limestone; Czorsztyn Succession, Babina klippe near Bohunice. Thin section No. 20 291, x30. **Fig. 5** - Lithoclast of a recrystallized silicite of unknown age in the Middle Jurassic crinoidal limestone. Czorsztyn Succession, Milpoš. Thin section No. 19 101, x30. **Fig. 6** - Selectively pyritized radiolaria (pyrite later converted into hydrogoethite) in the radiolarite lithoclast of unknown age. As above. Thin section No. 19 022, x170. **Fig. 7** - Radiolarite lithoclast with voids after dissolved radiolarians filled by calcite and chlorite. As above. Thin section No. 19 082, x86. **Fig. 8** - As above. The voids are filled with clear chalcedony. Thin section No. 19082, x45. All lithoclasts except Fig. 4 were extracted by dissolution of limestones in acetic acid, then thin section was made from their association.

PLATE V

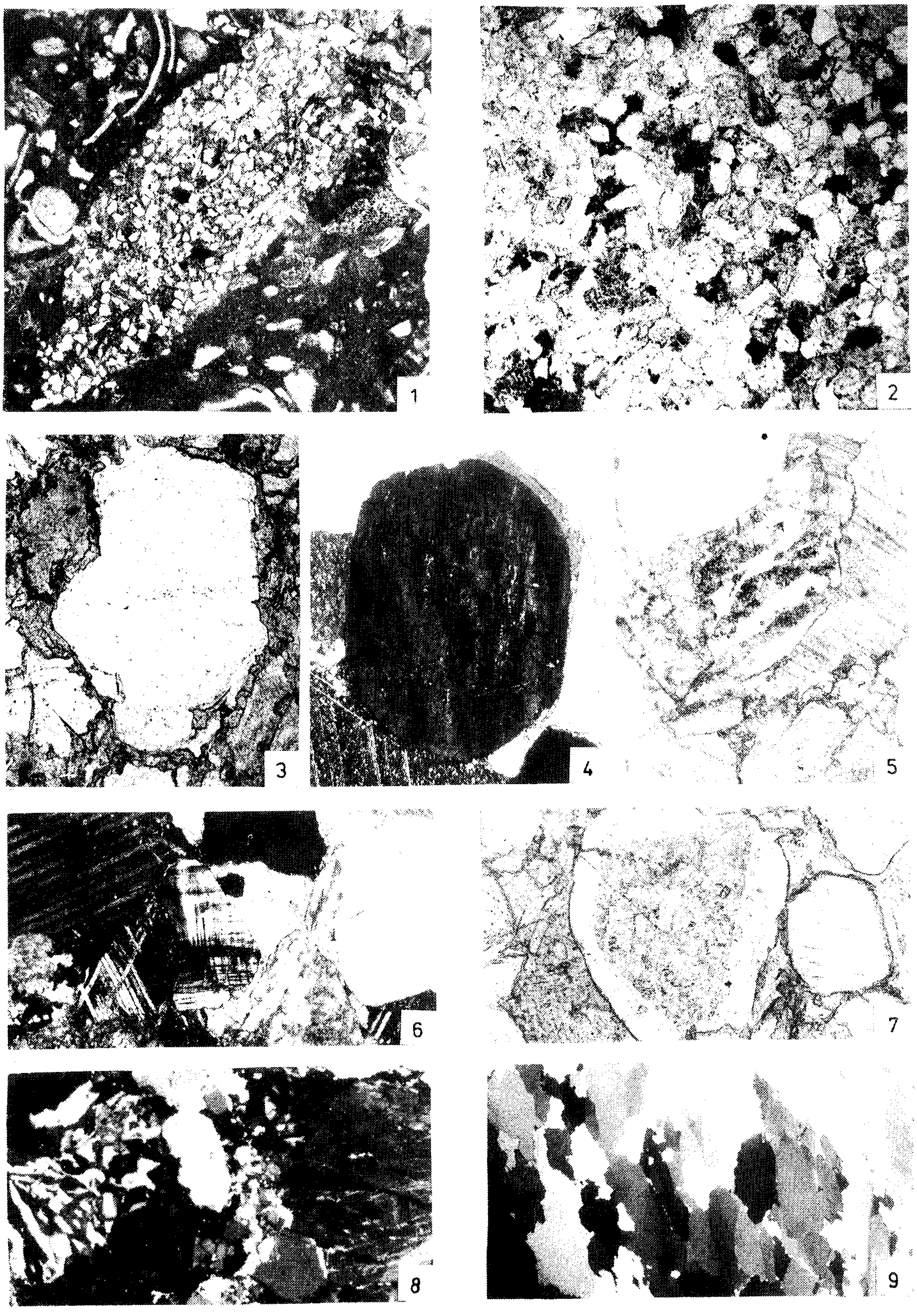


Plate V: Lithoclasts of sandstones, vein quartz, quartzites and granitoidal detritus. **Fig. 1** - Fine-grained sandstone in Middle Jurassic crinoidal limestone; Czorsztyn Succession, Vršatec. Thin section No. 7 120, x60. **Fig. 2** - Lithoclast of the arkosic sandstone in the Middle Jurassic crinoidal limestone; Czorsztyn Unit, Babina quarry near Bohunice. Thin section No. 20 290, x20. **Fig. 3** - Clastic quartz originating from Lower Triassic quartzite (corroded remnants of syntaxial overgrowth on a rounded grain covered by coating). Intercalation with pebbles in the Middle Jurassic crinoidal limestones; Czorsztyn Succession. Mestečská skala klippe near Púchov. Thin section No. 20 299, x40. **Fig. 4** - Syntaxial rim with partial automorph outlines - an overgrowth on the clastic feldspar (perthite) grain; terrigenous admixture in the Liassic crinoidal limestone, Nižná Succession, Lúty Potok klippe. Thin section No. 19 059, x95, crossed nicols. **Fig. 5** - Perthite grain in the sandy crinoidal limestone. As above. Thin section No. 19 059, x48. **Fig. 6** - Microcline in the sandy crinoidal limestone. As above. Thin section No. 19 104, x48, crossed nicols. **Fig. 7** - Grain of K-feldspar with syntaxial overgrowth formed still in the mother rock (corroded margin may be observed) in the sandy crinoidal limestone. As above. Thin section No. 19 059, x95. **Fig. 8** - Graphic intergrowth of quartz and feldspar and a perthite grain in the microconglomerate intercalation within the Middle Jurassic crinoidal limestone; Nižná Succession, Sedliacka Dubová klippe, 300 m W from the elevation point 691.1. Thin section No. 17 998, x40. **Fig. 9** - Small pebble of vein quartz in the Middle Jurassic crinoidal limestone; Czorsztyn Succession, Milpoš. Thin section No. 19 101, x27, crossed nicols.

been separated after the Triassic from the East-European Platform by passive rifting. The dry land (External Czorsztyn Terrestric Ridge) was situated on the outer side of the Czorsztyn sedimentary area, the Jurassic and Cretaceous sediments of which were preserved as klippen (tectonic lenses). As the Middle Jurassic to Neocomian sediments of the Czorsztyn Unit were deposited exclusively in the deeper neritic zone (Mišík in press) we suppose that not only the External Czorsztyn Terrestric Ridge but also its littoral sediments were subducted and liquidated during the tectogenesis (Fig. 2).

The Liassic (Sinemurian-Pliensbachian) crinoidal limestones of the Nižná Unit (Mišík et al. in press) contain the same clastic material but the routes by which it was transported are more difficult to follow. The sediments of that time range are unknown even among the blocks from the Magura Flysch Zone. In the Czorsztyn Unit the Middle Liassic sediments (marls) are known only at the Vršatec locality.

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