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ENVIRONMENTS AND SETTING OF THE JURASSIC/LOWER CRETACEOUS SUCCESSION IN THE TATRIC AREA, MALÉ KARPATY MTS.

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Abstract: This paper gives detailed evaluation of lithofacies, biostratigraphy and paleotectonics of the sections recording the Jurassic to Lower Cretaceous sedimentation in the Tatric Superunit of the Malé Karpaty Mts with a special emphasis on the Kadlubek treshold zone. The sequence consists of two distinct sedimentary megacycles. The Liassic megacycle was represented by the Dudziniec Formation resting with angular disconformity on the Triassic sequence. The Middle Jurassic to Lower Cretaceous megacycle is separated from the underlying sequence by a significant Toarcian condensation - erosion event. A tensional episode in the adjacent Penninic rift zone, which caused this event, was accompanied by the origin of a series of listric faults. Several systems of neptunian dykes have been recognized. The article also describes finds of biostratigraphically valuable microfauna and the distribution of the Upper Liassic brachiopod and bivalve associations from the Tatric area. The composition of these associations does not coincide with the division on the "Tethyan" and "European shelf" assemblages: the fauna of the basinal bottoms belongs to the former one, the inhabitants of the bottom elevations to the latter group.

Key words: Jurassic/Lower Cretaceous, carbonate microfacies, brachiopods, Tatric, Western Carpathians.

Introduction

The Malé Karpaty Mts. form a part of the horst structure along the external margin of the Central Western Carpathians. This late horst structure is superimposed on a nappe edifice formed by stacked allochthonous units of Tatric crystalline rocks, their Mesozoic cover and sedimentary cover nappes (Maheľ 1951, 1987). The Tatric Mesozoic cover occurs in various tectonic units (Fig. 1), representing at least three different sedimentary basins (Plašienka et al. 1991). The Borinka succession is the filling of a tilted halfgraben, situated along the southern margin of the Penninicum, divided from proper Tatric facies zones by a threshold like elevation (Plašienka 1987, correlated this structure with the Lungau threshold of the Eastern Alps). The Orešany, Solírov and Kuchyňa Successions represent basinal sequences in the more internal part of the Tatric realm, originally adjacent to the basin of the Devín Unit. The southern margin of the basin was bordered by an elevation, on which the sedimentary succession of the Kadlubek Unit was deposited.

The Kadlubek Succession

Kullmanová (1965), Maheľ et al. (1967) and Plašienka et al. (1991) characterized this succession as intrabasinal elevation deposits, consisting of condensed pelagic sediments (red nodular limestones, hardgrounds and neptunic dykes). However, no detailed sections analysed both lithologically and biostratigraphically have been published until now, yet.

The Mesozoic sedimentary sequence of the Kadlubek Succession begins with the Scythian **Lúžna Formation** covering the Variscian granite basement. The formation is up to 40 metres thick and composed of three members: the lower

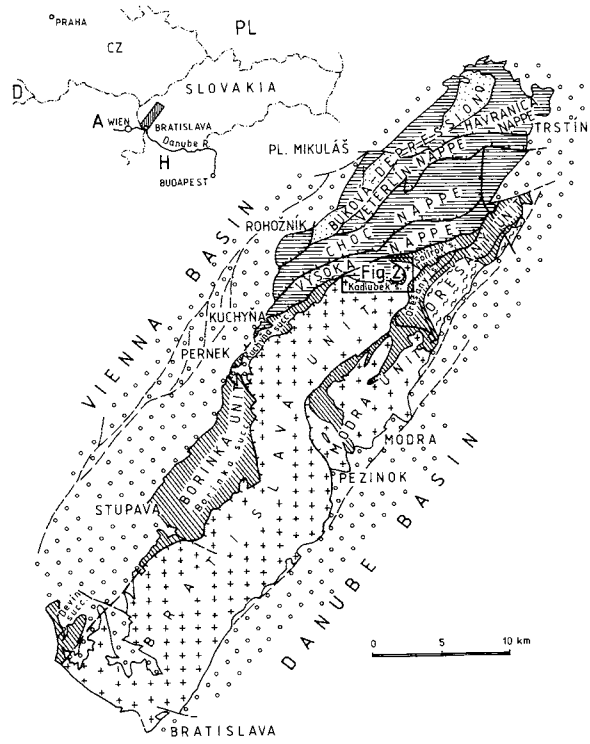


Fig. 1. Left upper corner: Location map of the Malé Karpaty Mts. (hatched quadrangle) in the frame of Slovakia. Lower part: Principal tectonic units of the Malé Karpaty Mts.
Crosses: granitoids; *twiddles:* slates; *diagonal hatching:* Tatric Mesozoic cover units; *horizontal hatching:* Mesozoic cover nappes; *dense stippling:* Paleogene cover; *stippling:* Neogene cover. The rectangle marks the location of Fig. 2.

quartzsandstones are rich in rounded pebbles of veiny quartz, tourmalinized rocks and dark siliceous rocks; the middle is formed by quartz sandstones with ripple-marks, and the third is a greywacke arcose sandstone. The Lúžna Formation is overlain by "Campilian" variegated claystones with sandstone intercalations (possible equivalent of the **Šuňava Formation**).

The complex of Middle Triassic **Gutenstein** limestones and dolomites is preserved in the western part of the Kadlubek Unit (Fig. 2). It reaches a thickness of 35 metres. Dark grey heavy bedded micritic dolomites, perhaps 7 metres thick, occur in its lower part. Above those, a thick complex of dark grey, thin-bedded micritic limestones appears, with intercalations of dolomite in its lower part. Indistinctly laminated thin- to thick bedded micritic limestones with incipient vermicular structure and dark grey limestone with detritus, deposited in fine laminae, occur in the upper part. In the eastern part of the Kadlubek Unit, the Gutenstein limestones are missing, and the Jurassic sequence rests directly on the Lower Triassic Lúžna Formation.

The Jurassic formations have a relatively small thickness (around 50 metres). They show features of condensed, relatively shallow-marine, although mostly pelagic carbonate sedimentation. A very thin bedded, brown grey, marly thin detrital limestone (the **Dudziniec Formation**, with intercalations of argillaceous limestones, sometimes with oblique lamination follows up-section. Above these, limestones with abundant crinoidal detritus and laminated layers occur. Still higher, red nodular limestones (**Adnet Limestone**) document a time - interval of stratigraphic condensation. Kullmanová (1965) mentioned findings of the Toarcian ammonites *Hildoceras bifrons* (Brughiére) and *Phymatoceras sp.*

We assume that the fillings of dykes, which penetrate the underlying carbonate sequence (especially the Middle Triassic Gutenstein Limestone in the Findel section: Fig.2), are also of the Toarcian age. The dykes fill a regular system of cracks inclined at an angle of 30 - 70° with respect to the bedding of the Gutenstein Limestone. Their thickness varies from millimetres to several metres. The dykes mostly are without internal structure, but in places signs of lamination, graded bedding and multi-staged filling may be observed in them. The filling of some dykes begins with the deposition of coarse crinoidal limestone overlain with brick red marlstone. The coarse crinoidal limestone contains clasts of light-coloured laminated limestones, in other dykes polymict breccia with weathered dolomite clasts occurs above micritic brick red marly limestones. It is possible that some of these dykes are already of Early Liassic age.

The complex of micritic massive to thick bedded limestones with lenses of internal breccias, in places also contains micritic thin bedded limestones (equivalent of the **Raptawicka Turnia Formation**). These represent the entire Middle and Upper Jurassic sequence. Thin bedded, pinkish-grey to light grey, slightly nodular and detrital limestone, with crinoidal layers and occasional cherts, up to about 15 m thick, contain belemnites and aptychi. Kullmanová (1965) mentioned Late Jurassic ammonites *Subplanites* cf. *pseudocolubrinus* (Kilian), *Sowerbyceras* cf. *tortisulcatum* (d'Orbigny), *Holcophylloceras* cf. *mediterraneum* (Neumayer).

Thin bedded grey micritic limestone with occasional dark grey chert lenses (**Oberalm Formation**), in places tectonized, represent the oldest Lower Cretaceous deposits. The preserved part of the sequence is scarcely a few metres thick.

The rocks overlying the limestone sequence are usually not exposed, but fragments of grey marly limestones, with Lower Albian planktonic foraminifers, occur in the eluvium.

Occasional dykes filled by red brown marlstone contain clasts of the Upper Jurassic *Saccocoma*- and the Berriasian calpionellid limestones. In the Egreš section, clasts of dark grey marly limestones with Upper Albian foraminifers also occur. The basinal shales of the **Poruba Formation** cover the underlying carbonates abruptly without a transition, in places even directly overlying the Lower Triassic quartzites. Pelitic grey marly shales, in which fine grained sandstones form only thin intercalations are dominant.

The Devín Succession

The sedimentary succession resting on a crystalline basement starts with the Upper Permian **Devín Formation**, which consist of breccias, polymict conglomerates, coarse and medium grained sandstones and shales. The breccias are composed of clasts of the underlying crystalline rocks and volcanics. The Lower Triassic quartzite of the **Lúžna Formation** contains pebbles of quartz, black siliceous and tourmalinized rock fragments.

The Middle Triassic carbonates of the Devín Succession generally represents the most completely preserved remnant of the Tatric Middle Triassic carbonate sequence of the Malé Karpaty Mts. It is more than 300 m thick. Thick bedded to massive dolomites, often brecciated and with a pelletal texture, form the lower and upper part of the complex. They contain pseudomorphoses after gypsum crystals, fragments of dasycladaceans, crinoids, and stromatolite layers (Mišík 1986). The middle part of the complex is composed of limestones locally dolomitized. Anisian crinoids were found in it (Kristan-Tollmann & Spendlingwimmer 1978).

The sequence of the Jurassic megacycle begins with the coarse **Pleš Breccia** (new term), which fills deep cracks and depressions in the eroded substratum. The greatest thickness found in the Devín area is several tens of metres. The clasts are composed of Middle Triassic Gutenstein limestones and dolomites, Rhaetian shelly limestones (Kochanová et al. 1967), and various types of Lower Jurassic limestones, containing arietitid ammonites, fish teeth of *Saurichthys* (Toula 1901; Mišík 1986) and brachiopods. Relics of condensed haematitic rocks or pink - coloured fine shelly limestones, which according to Mišík (l.c.) are reminiscent of Toarcian limestone, are found occasionally. The stratigraphic sequence appeares to be very similar to the Kadlubek and Kuchyňa Successions, and the sequence described may therefore belong already to the Middle Jurassic sedimentary megacycle.

Among the rocks overlying the Pleš Breccia in the Wait quarry, Andrusov (1969) distinguished a relict of a formation of black shales, which evidently are the equivalent of the **Mariatal Formation** of the Borinka Succession. The rocks overlying them include a complex of shales and silicates of the **Ruhpolding Formation**, which represents the higher part of the Middle Jurassic sedimentary megacycle.

Kimmeridgian nodular limestones, several meters thick, represent the **Tegernsee Limestone**. Upwards, they pass into well bedded grey-green locally silicified limestones of **Oberalm Beds**, 20 - 30 m thick. Their Early Berriasian age is proved by calpionellids.

The **Lučivná Formation** is composed of thick bedded, grey, grey-brown cherty limestones. Cherts also occur occasionally, arranged in layers, in places deformed by slump movements. The thickness of the formation exceeds 30 - 40 m. Its age is Late Berriasian to Valanginian. The younger part of the sequence is not known from outcrops.

The Kuchyňa, Solírov and Orešany Succession

The succession starts with the Lower Triassic **Lúžna Formation** which consists of quartzites, usually eroded down to varying levels before the deposition of the Jurassic sequence. Remnants

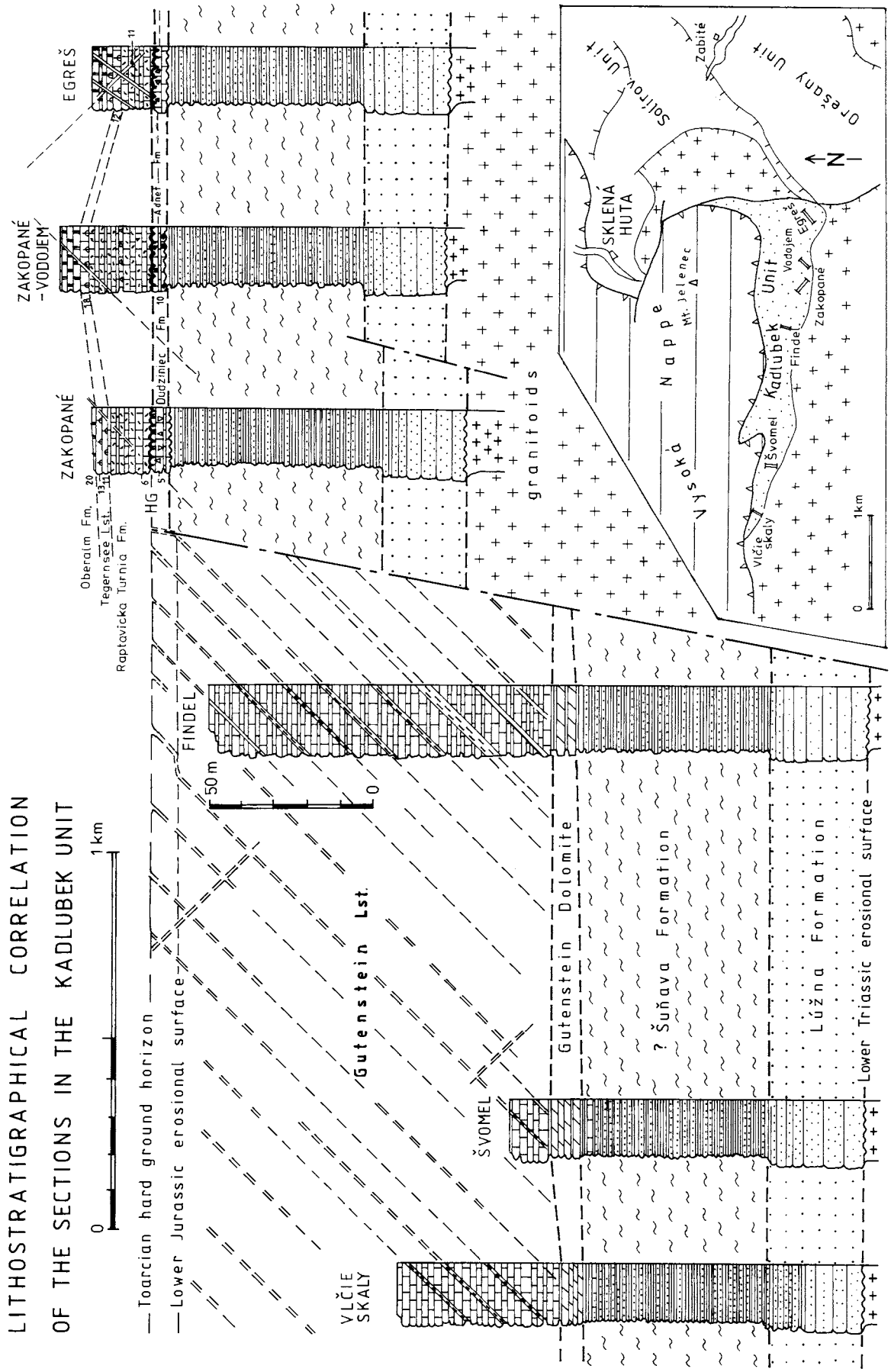


Fig. 2. Interpretational scheme of the sections in the Mesozoic sequences of the Kadlubek Unit. Location in the lower right corner (compare also with Fig. 1).

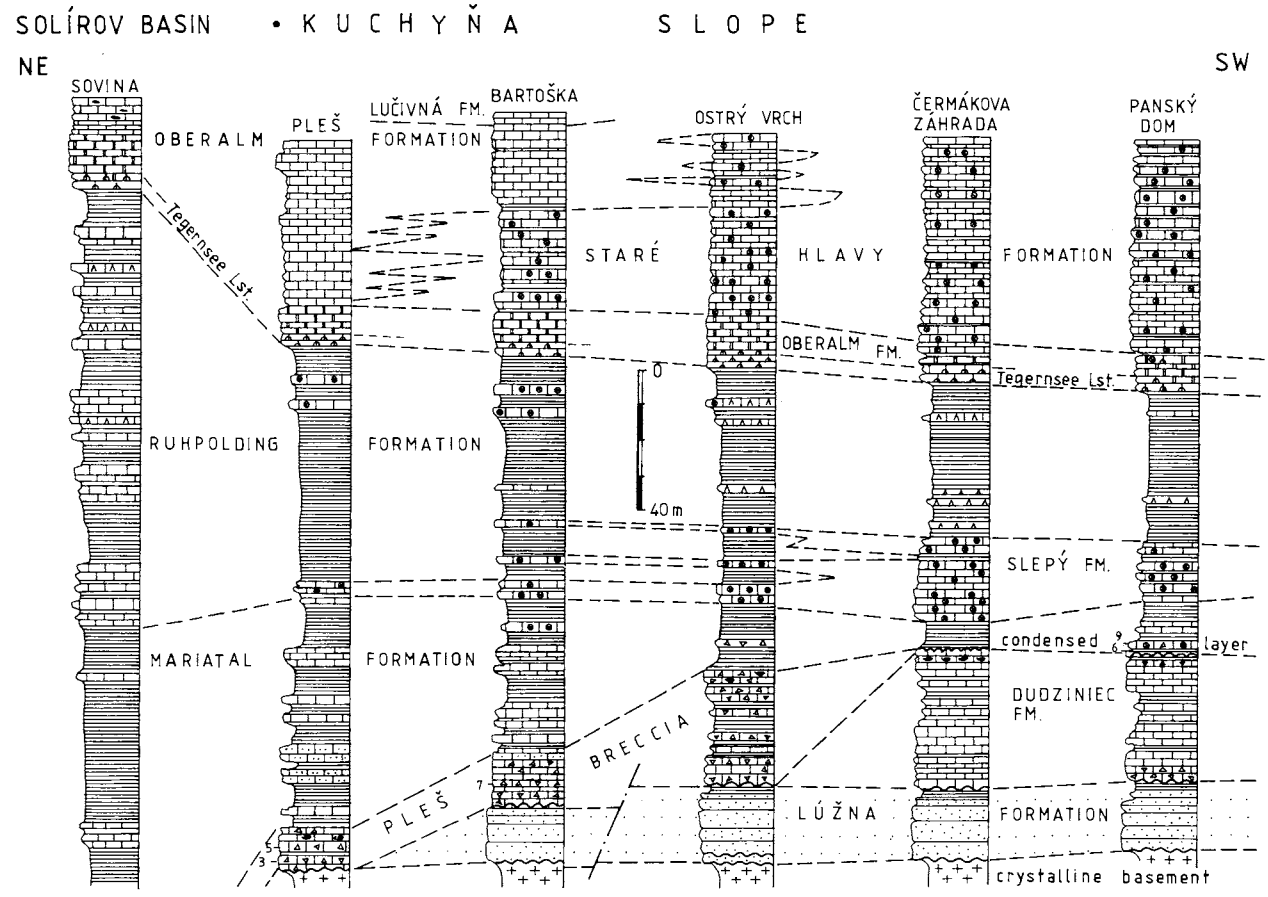


Fig. 3. Lithostratigraphic correlation of sections in the Mesozoic formations of the Kuchyňa and Solírov Units.

of a shale (?Šuňava) Formation and of the Gutenstein Dolomite are locally preserved. On Kukla hill, in the Orešany Unit, these reach a thickness of up to 50 m.

The Lower Jurassic sequence is preserved in the eastern part of the Kuchyňa Unit (Fig. 3), where the **Dudziniec Formation** occurs with a thickness of up to 20 m. It is composed of: 1 - coarsely crystalline limestones, with abundant clasts of metavolcanics; 2 - grey sandy and detritic limestones, which also fill dykes in the crystalline basement (in the western part of the Kuchyňa Unit); 3 - brecciated limestones, mainly composed of clasts of dolomite, dolomitic limestones, laminated Gutenstein limestones; 4 - thick to very thin bedded dark grey micritic and 5 - bioclastic limestones with brachiopods and bivalves (in the eastern part of the Kuchyňa Unit and in the Orešany Unit).

The sequence is terminated by a condensed layer, composed of fragments of crinoidal bioclastic limestones, fragments of phosphatized rocks, slates, cemented by ferruginous matrix, which contains many fragments of belemnites and fish teeth (eastern part of the Kuchyňa Unit). We assume that in the direction to the basin centre this layer passes into the **Pleš Breccia,** with a maximum thickness of up to 15 metres, composed of clasts of Triassic and Liassic carbonates, Lower Triassic quartzites and fragments of crystalline slates. At the top, these breccias pass into black grey marlstones, with thin graded layers of black marly and detrital limestones, equivalent to the Mariatal Formation.

The **Ruhpolding Formation**, with a thickness of 45 - 120 m, is composed of siliceous shales to bedded cherts. It laterally passes into calciturbidites of the **Slepý Formation**, deposited along the slope of the basin. The calciturbidite beds are graded crinoidal limestones with nodules of dark grey cherts. The maximum thickness of the Slepý Formation is 25 metres.

A formation of nodular- and indistinctly nodular limestones, with a thickness of several metres, equivalent to the **Tegernsee Formation,** represents the Upper Jurassic. Up-section, it changes to thin bedded, light grey to creamy grey micritic limestones with cherts (**Oberalm Formation).** Locally, these contain layers of thin limestone breccias, recalling the **Nozdrovice Breccia (Michalík** et al. 1993). In the eastern part of the Kuchyňa Unit (Fig. 3), they reach a thickness of perhaps 10 metres, and represent only the Tithonian and earliest Berriasian, but 40 - 70 m thick sequence in the western part of the Kuchyňa Unit and in the Solírov Unit represent the Tithonian to Valanginian. Bioclastic and micritic limestones with relatively well preserved remnants of crinoids, belemnites and aptychi (**Staré Hlavy Formation**, Michalík et al., 1993) are the lateral equivalent of the Lower Cretaceous part of the Oberalm Formation. The Staré Hlavy Formation, with a thickness of up to 50 m, probably represents a proximal facies of calciturbites, which are known as Barmstein Limestone in the basinal Oberalm sequence (Flügel & Fenninger 1966). Abundant intercalations of graded allodapic limestones, which may be equivalent to the calciturbidites mentioned, also occur in the Orešany Succession (Plašienka et al. 1989).

The **Lučivná Formation**, with a thickness of up to 100 metres, composed of thin- to thick bedded grey cherty limestones occurs in the western part of the Kuchyňa Unit and in the Solírov and Orešany Units. In the last two successions, it is laterally replaced by a calciturbidite facies now called the **Solírov Formation** (Jablonský et al. 1993)

Black marlstones equivalent to the **Párnica Formation** occur above the Lučivná Formation. They contain sparse intercalations and occasional lenses of thin bedded, black grey bioclastic limestones, with rare small clasts of Lower Cretaceous limestones. Locally, they also contain small bodies of hyaloclastic basic volcanics (Hovorka & Spišiak 1988). The formation, representing probably the Aptian to Lower Albian, is about 100 metres thick.

The youngest Cretaceous formation of the Kuchyňa Unit is composed of dark grey marly shales with occasional thin intercalations of black grey shaly limestones with Late Albian microfauna. Borza (1979, 1984) described similar intercalations of calcisphaerulid limestones from the **Butkov Formation** of the Manín Unit. An equivalent shaly formation in the Orešany and Solírov Units contains intercalations of sandy and fine grained conglomerates, more similar to those of the **Poruba Formation**.

Lithostratigraphy and microfacies

The Dudziniec Formation *(Lefeld et al. 1985)*

In the Kuchyňa Unit (Fig. 3), brecciated limestones lie at the base of the Lower Jurassic sequence. The majority of the clasts are dolosparite or dolomicrite without fossils, dark micritic and biomicrosparitic limestone with occasional fragments of crinoids and ostracods. In the overlying rocks, thin bedded, laminated, slightly marly biomicrites (wackestones, Pl. I, 1 - 5) occur, with fragments of bivalves, ostracods, crinoids, sponge spicules, lithistid sponges, gastropods, spines of sea urchins, bryozoans, and brachiopods. The association of the foraminifers *Neoangulodiscus leischneri* Kristan-Tollmann, *Lenticulina* ex gr. *varians* (Bornemann), *Glomospira* cf. *simplex* Harlton, *Dentalina* ? *pseudomonile* Terquem, *Vidalina* cf. *asymmetrica* Xiao - Qiao, *Vidalina martana* Farinacci, *Planiinvoluta* cf. *deflexa* Leischner, *Planiinvoluta* sp., *Glomospirella reacta* (Eicher), *Ammodiscus* cf. *planus* (Mueller), *Tolypammina* aff. *gregaria* (Wendt) suggests a Pliensbachian age. Thick bedded biomicrosparitic wackestones contain globular cherts (Mišík 1985). Shells of Pliensbachian to Domerian brachiopods and bivalves (Fig. 4; Pl. III) are present in the upper part of the formation. The limestones contain an admixture of clastic quartz, muscovite flakes and frequently pyrite. They are locally silicified and penetrated by irregular microstylolites.

Brown-grey thin bedded marly limestones with small clasts, and intercalations of clayey limestone with oblique lamination represent this formation in the Kadlubek Succession.

Adnet Formation *(Hauer 1853)*

Red brown, brecciated to nodular biomicrosparitic wackestones to packstones with rare intercalations of laminated micritic mudstones and with abundant crinoid detritus, ostracods, bivalves, gastropods, sponge spicules and fragments of foraminifers (*Lenticulina* sp., *Nodosaria* sp., *Dentalina* sp., *Marginulina* sp.), occur in the Kadlubek Succession above the Dudziniec Formation. They contain very small grains of clastic quartz and glauconite. The middle part of the formation is significantly condensed, in some sections (Fig. 2) it is represented only by a red condensed layer of Fe-Mn hydroxides with clasts of phosphatised limestones and of the Middle Triassic vermicular limestones. The latter show indications of tsunamite- and tempestitite structure, similar to those found in the Vysoká Limestone (Michalík et al. 1992). The thickness of the formation rarely reaches a few metres. The ammonite fauna (Kullmanová 1965) points to a Toarcian age for the formation.

Pleš Breccia *(new term)*

Type locality : Pleš Hill near Pernek, south-west slope.

Equivalent profiles : Devín Castle Rock, Bartoška Hill above the Švancpošská Valley near Kuchyňa, below Ostrý Hill, Panský Dom-1.

Thickness : *From several decimetres to several tens of metres.*

Lithology : The breccia is composed of clasts of Middle Triassic dolomicrosparites and dolosparites, microsparitic mudstones without fossils (which in places are either laminated, or bear pseudomorphoses of evaporite minerals), of micritic wackestones with fragments of ostracods and crinoids, and of pseudooosparitic wackestones with cherty sphaeroliths. In the section below Ostrý Hill (Fig. 3), clasts, up to 40 cm in diameter, of Middle Triassic quartzites and of slates derived from the crystalline basement are frequent. Clasts of Liassic biomicritic or microsparitic wackestones to packestones, with bivalve shells and foraminifers are rarer (Pl. I, 6 - 8). Microsparitic to pseudosparitic mudstones to wackestones with crinoid ossicles, juvenile- and adult bivalves, sponge spicules, phosphatised clasts with spicules of tetractinellid sponges, spines of sea urchins and foraminifers (*Trocholina* sp.) are derived from Liassic rocks. Fragments of biomicritic wackestones with juvenile bivalves and fragments of haematitic micritic mudstones with quartz silt are rarer.

In the eastern part of the Kuchyňa Succession, a condensed, 50 cm thick layer formed by clasts of crinoidal biosparrudites, slates, vein quartz, all embedded in a haematite enriched matrix, occurs in an analogous stratigraphic position. It contains a large quantity of belemnite rostra fragments, fish teeth, foraminifers (*Planiinvoluta* sp.) and zoospores of *Globochaete tatrica* Radwanski.

Age: Toarcian - Aalenian.

Range: Devín and Kuchyňa Units.

Environment: Slope facies bordering an eroded submarine high with condensed sediments of Toarcian age.

Mariatal Formation *(Hauer 1872)*

A formation of black shales with sporadic limestone intercalations, identical with the Mariatal Formation of the Borinka Succession occurs in the Kuchyňa, Solírov and Devín Units. The organic matter is concentrated in discontinuous laminae and lenses. Biomicritic to biomicrosparitic wackestones to packestones contain graded biodetritus, consisting of the crinoid columnalia, sponge spicules, fragments of bryozoa, bivalves and foraminifers, together with grains of quartz and muscovite flakes. Diagenetic framboidal pyrite with pressure solution rims is abundant. It also frequently impregnates organic fragments, and emphasizes stylolites. The maximum thickness of the formation is 120 m, in comparison with 500 m in the Borinka Succession. Its age, based on the ammonite collection of Schaffer (1899), is Toarcian to earliest Middle Jurassic, which well coincides with the time of the "falciferum anoxic event" of Jenkyns (1985).

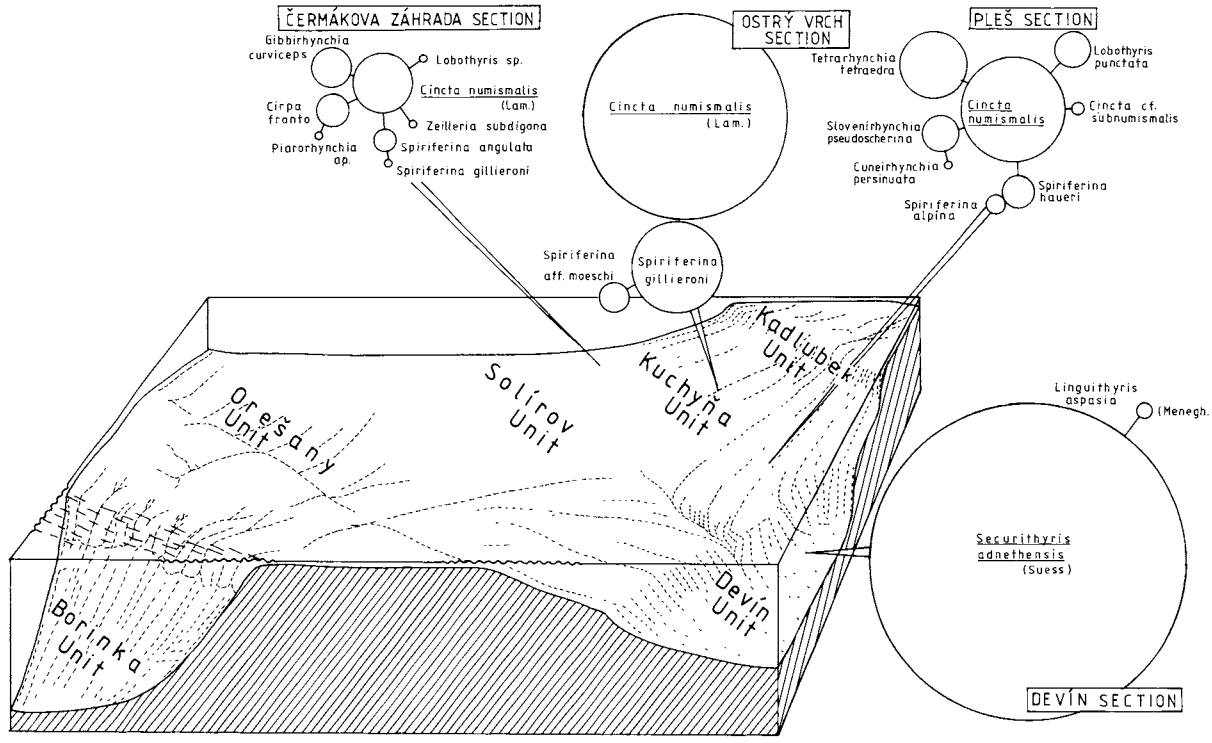


Fig. 4. Paleogeographical model of the Lower Jurassic sedimentation in the Tatric Units in the area of the Malé Karpaty Mts., with location and composition of brachiopod faunas.

Ruhpolding Formation *(Trauth 1950)*

A formation of dark grey siliceous shales with siliceous, chert-bearing limestone and bedded chert intercalations occurs in the Kuchyňa, Solírov, Orešany and Devín Units. It is usually composed of microsparitic mudstones, significantly silicified, containing globular to elliptical cross-sections of radiolarians, and also occasionally belemnite rostra, crinoid ossicles, and foraminifers (*Nodosaria* sp., *Textularia* sp.). The formation reaches a thickness of 50 - 300 m and represents most of the Middle Jurassic. In the centre of the basinal areas, the stratigraphic range of the formation could be wider, as indicated by possible Late Jurassic bryozoans collected in its uppermost part in the Borinka Unit (Taylor, Zagoršek, pers. comm.).

Slepý Formation *(Plašienka et al. 1991)*

Biomicrosparitic to biopseudosparitic, in places pelmicrosparitic wackestones and packestones, containing nodules of dark chert form a calciturbidite complex interfingering with the middle part of the Middle Jurassic basinal Ruhpolding Formation. Crinoid ossicles dominate over sponge spicules and fragments of foraminifers. Detrital grains also including clasts of dark micrites and grains of terrigenous quartz, occurs in graded layers. The thickness of the formation is roughly 40 - 60 m, wedging out towards the basin.

Raptawicka Turnia Formation *(Lefeld et al. 1985)*

Dark grey massive pelmicritic, pelmicrosparitic to micro-oncosparitic wackestones and biomicritic packstones, occur in the Kadlubek Unit (Fig. 2) and the easternmost part of the Kuchyňa Unit (Michalík et al. 1993) (Pl. II, 1 - 2). In contrast to pellets, mostly recrystallized micro-oncoids enclose globochaetes, ostracods, foraminifers, fragments of bivalves and crinoid columnalia. The packstones contain juvenile bivalve shells, fragments of aptychi, ostracods, foraminifers, crinoids, calcified radiolarians, globochaetes and occasional saccocomas. Graded layers of detritus, with microorganism tests, clastic quartz, mica, glauconite and chloritic slate fragments occur in places. The thickness of the formation is 10 - 17 metres; its age is Oxfordian to Kimmeridgian.

Tegernsee Formation *(Schafhäutl 1846)*

Red brown, pinkish to yellowish nodular biomicritic to biomicrosparitic wackestones to packstones occur in the Kadlubek Unit. Microfacies with juvenile bivalves and *Globochaete* and/or *Saccocoma & Globochaete* can be distinguished (Pl. II, 3 - 5). Further, shells of juvenile bivalves, crinoid ossicles, calcified radiolarians, fragments of ostracod tests, ramuli and secundibrachialia of planktonic crinoids, and abundant cross-sections of juvenile ammonites, are present. The nodular structure is less pronounced in the Kuchyňa and Solírov Units. Apart from the above mentioned microfossils, the biomicritic wackestones to packstones also contain *Parastomiosphaera malmica* (Borza), *Schizosphaerella minutissima* (Colom), *Carpistomiosphaera borzai* (Nagy), indicating Late Kimmeridgian to Early Tithonian age of this formation. It attains a thickness of 1 - 5 metres.

Oberalm Formation *(Lipold 1854)*

Thin bedded, light grey, grey brown, cherty biomicrites to biomicrosparites, with a calpionellid - globochaete microfacies, occur in the Kuchyňa and Solírov Units. The cherts form no-

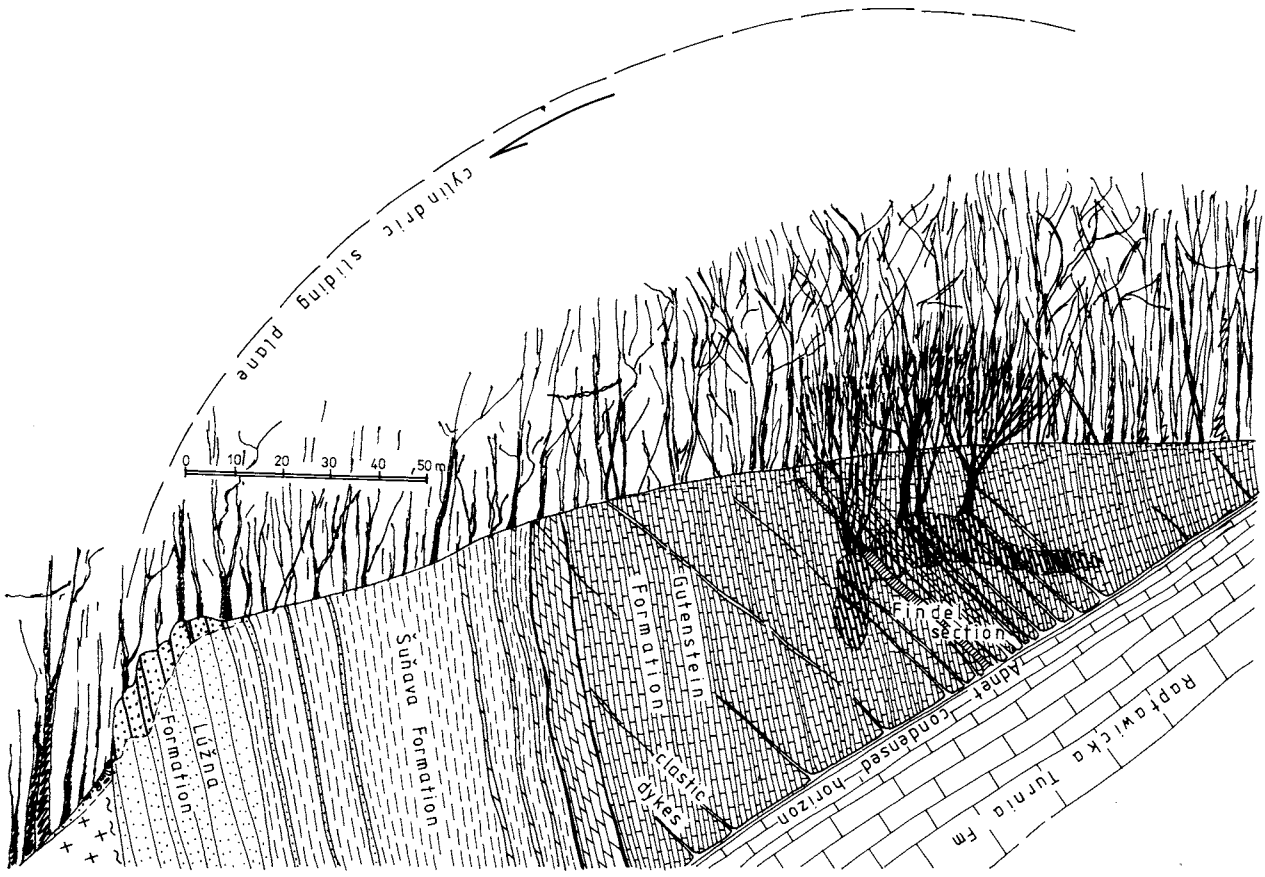


Fig. 5. Interpretational scheme of of the Kadlubek, Findel section.

dules, with diameters of about 10 cm, and in places are concentrated in stratiform layers. Occasionally, thin layers and laminae of coarser graded detritus composed mostly of crinoid ossicles, and some fragments of foraminifers (*Lenticulina* sp., *Dentalina* sp., *Textularia* sp.) and bryozoa (Barmstein Limestone) occur in the limestones. The wackestones contain fragments of crinoids, ostracods, ophiurids, bivalves, sponge spicules, calcified radiolaria, *Globochaete alpina* Lombard, *Crassicollaria parvula* Remane, *Tintinnopsella carpathica* (Murgeanu et Filipescu), *Calpionella alpina* Lorenz (Pl. II, 6), *C. elliptica* Cadisch, *Schizosphaerella minutissima* (Colom), *Calpionellopsis simplex* (Colom), *Calpionellopsis oblonga* Cadisch, *Gemeridella minuta* Borza et Mišík, *Calpionellites darderi* (Colom), indicating Berriasian - Valanginian age of the formation. Its thickness is around 35 metres.

Staré Hlavy Formation *(Michalík et al. 1993)*

Grey, heavy bedded organodetrital wackestones to packstones with expressivelly graded coarse detrital base. The formation, about 20 - 25 m thick contains abundant aptychi, crinoids, belemnites, brachiopod- and bivalve fragments. The microfacies of the limestones is calpionellid - globochaetid, calpionellid - radiolarian to radiolarian - calpionellid-sponge one. *Calpionella alpina* Lorenz, *C. elliptica* (Cadisch), *Tintinnopsella carpathica* (Murg. et Filip.), *T. remanei* Borza, fragments of *Laevaptychus* sp., foraminifers, bryozoans, crinoid ossicles, ostracods, sponge spicules and calcified radiolarians dominate in the association of Berriasian - Early Valanginian microfossils.

Nozdrovice Breccia *(Borza et al. 1980)*

Limestone breccia consisting of clasts (from microclasts up to several cm in diameter) of Tithonian and Lower Berriasian limestones. More rarely, also fragments of shales, volcanics, crystalline schists and quartz grains have been ascertained. The matrix of the breccia is formed by biomicrite. The thickness attains several dm to meters, exceptionally more than one hundred meters in local channel fillings. The breccia originated along synsedimentary fault scarps during Berriasian and Early Valanginian bottom relief denivelization.

Lučivná Formation *(Polák & Bujnovský 1979)*

Well bedded grey cherty biomicrite wackestones, bioturbated in the upper part of the sequence. The faunal spectrum is formed by belemnite rostra, irregular crinoids and aptychi. The microfossils are represented by last calpionellid *Tintinnopsella carpathica* (Murg. et Filip.), foraminifers *Hedbergella infracretacea* Glaessner, radiolarians *Acanthocircus dicranacanthos* (Squinabol), *Cecrops septemporatus* (Parona) and nannoplankton remnants, indicating Hauterivian to Barremian age.

Solírov Formation *(Jablonský et al. 1993)*

A complex of coarse detrital to brecciated limestones with marly intercalationshas been deposited by gravity flows originating on the slope of the adjoining swell. The thickness of this

sequence occurring in the Orešany- and Solírov Successions attains 30 - 60 m. The components of turbidite cycles consist of lithoclasts (quartzite blocks up to 2 m^3), fragments of fossils and dismicrite limestones. Pelagic intervals consist of argilaceous calcilutite with Barremian to Aptian microplankton (*Praecolomiella* sp., *Deflandronella* sp., *Stomiosphaera* cf *sphaerica* Bonet), planktic (*Caucasella hoterivica* (Subbotina), *Hedbergella trocoidea* (Gandolfi), *H. planispira* (Tappan), *Planomalina (Globigerinelloides) typica* (Gandolfi), *Clavihedbergella* aff. *cretacea* (Tappan)) and benthic foraminifers (*Falsurgonina* sp., *Cuneolina* sp., *Anomalina (Gavelinella) sigmoicostata* Dam., *Sabaudia* aff. *briacensis* Arnaud-Vanneau, *Belorussiella textulariodes* (Reuss), *Dorothia praeoxycona* Moullade, *Haplophragmoides* cf. *nonionina* (Reuss), *Gaudryina tuchaensis* Antonova).

Párnica Formation *(Hauer 1872)*

Several tens of meters of grey silky shining marlstones with limestone slump bodies and intercalations of black allodapic sandy organodetrital limestones and conglomerates. They contain Aptian macrofauna of ammonites, belemnites, oysters, brachiopods, crinoids and gastropods. Foraminiferal microfauna is represented by *Planomalina (P.) cheniourensis* (Sigal), *P. (Globigerinelloides) typica* (Gandolfi), *Biglobigerinella barri* Bolli, *Schackoina cabri* Sigal, *Hedbergella trocoidea* (Gandolfi); calpionellids by *Praecolomiella trejoi* Borza, *Praecolomiella boneti* Borza, *Parachitinoidella cuvilieri* Trejo, *Deflandronella veracruzana* (Trejo) and *Colomiella recta* Bonet. Nannoplankton remnants comprise forms of the *Chiastozygus litterarius* Zone.

Butkov Formation *(Kysela et al. 1982)*

Monotonous complex of pelagic dark blue-grey spotted marlstones with sole thin fine grained sandstone intercalations rich in glauconite and pyrite framboids. The marls contain rich association of nannofossils and planktonic foraminifers *Thalmanninella ticinensis ticinensis* (Gandolfi), *Dorothia oxycona* (Reuss), *Annomalina (Gavelinella) complanata* Reuss, *Planomalina (P.) buxtorfi* (Gandolfi) and *Hedbergella delrioensis* (Carsey) indicating Mid Albian to Mid Cenomanian age.

Poruba Formation *(Jablonský 1978)*

Flysch like sequence consisting of several hundred meters thick brown-grey marlstones alternating with argilaceous sandstones, with slumped limestone olistolithic bodies and polymict conglomerates. Bedding planes are often covered by plant detritus and by ichnofossils. The microfauna indicates Late Albian to Cenomanian age.

The benthic faunal assemblages

In its upper part, the Liassic Dudziniec Formation contains a dark grey, heavy bedded, finely organodetritic limestone, in which a relatively well preserved fauna of brachiopods and bivalves is found at two localities (Pleš, Čermákova Záhrada) (Pl. III).

Blocks of this limestone, coming from the Pleš breccia on the south - west slope of Pleš Hill near Pernek, yielded a fauna (100 individuals), composed of brachiopods (85 %) and bivalves (15 %):

Cincta numismalis (Lamarck)	31 %
Tetrarhynchia cf. *tetraedra* (Sowerby)	18 %
Lobothyris cf. *punctata* (Sowerby)	10 %
Spiriferina cf. *haueri* Suess	9 %
?Slovenirhynchia pseudoscherina (Böse)	8 %
Spiriferina alpina Oppel	5 %
Cincta cf. *subnumismalis* (Davidson)	3 %
Cuneirhynchia persinuata (Rau)	1 %
Eopecten tumidus (Zieten)	6 %
Oxytoma muensteri (Goldfuss)	5 %
Anomia cf. *pelea* d'Orbigny	3 %
?Lima sp.	1 %

A similar fauna with a less marked dominance of the species *Cincta numismalis* and other brachiopods (50 %) over bivalves (48 %) is found in the uppermost layer of the Dudziniec Formation on the southern slope of the Staré Hlavy Hill, above the meadow of Čermákova Záhrada in the Vývrat Valley, not far from the village of Kuchyňa (50 individuals):

Cincta numismalis (Lamarck)	16 %
Gibbirhynchia curviceps (Quenstedt)	12 %
Cirpa fronto (Quenstedt)	8 %
Spiriferina angulata Oppel	6 %
Zeilleria subdigona Oppel	2 %
Spiriferina gillieroni Haas	2 %
Lobothyris sp.	2 %
Piarorhynchia sp.	2 %
Bivalvia non ident.	18 %
Chlamys (Aequipecten) *thiollierei* (Martin)	12 %
Plagiostoma sp.	6 %
Anomia pelea d'Orbigny	4 %
Nucula sp.	4 %
Chlamys textoria (Schlotheim)	2 %
Chlamys sp.	2 %
Decapoda non ident.	2 %

Apart from the dominant species, both associations have a common significant representation of rhynchonellids and spiriferids. All the brachiopods were attached by a pedicle, while byssate and infaunal forms are most frequent among the bivalves. The composition of the associations points to a well aerated environment with moderate currents, able to carry small detrital particles, as well as the nutrient suspension. More abundant bivalves may reflect greater mobility of the sediment.

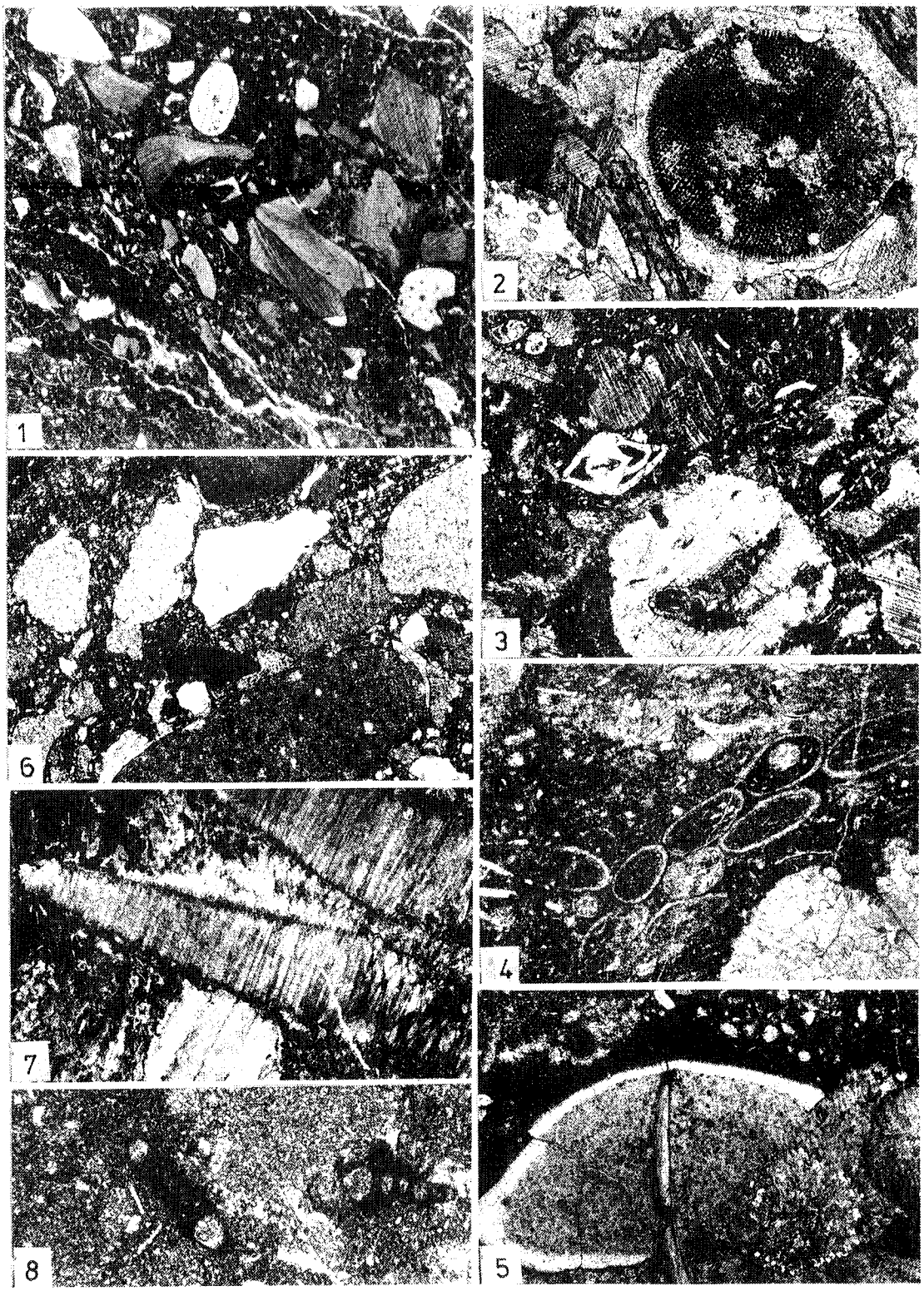
The third Liassic brachiopod locality in the Kuchyňa Unit is found on the south side of Ostrý Hill above the Modranská Valley near Kuchyňa. Recrystallized remnants of brachiopods (94 %) and bivalves occur here, in blocks of a dark brown grey limestone in the Pleš Breccia:

Cincta numismalis (Lamarck)	21 indiv.	58 %
Spiriferina gillieroni Haas	10 indiv.	28 %
Spiriferina cf. *moeschi* Haas	3 indiv.	8 %
Eopecten sp.	2 indiv.	6 %

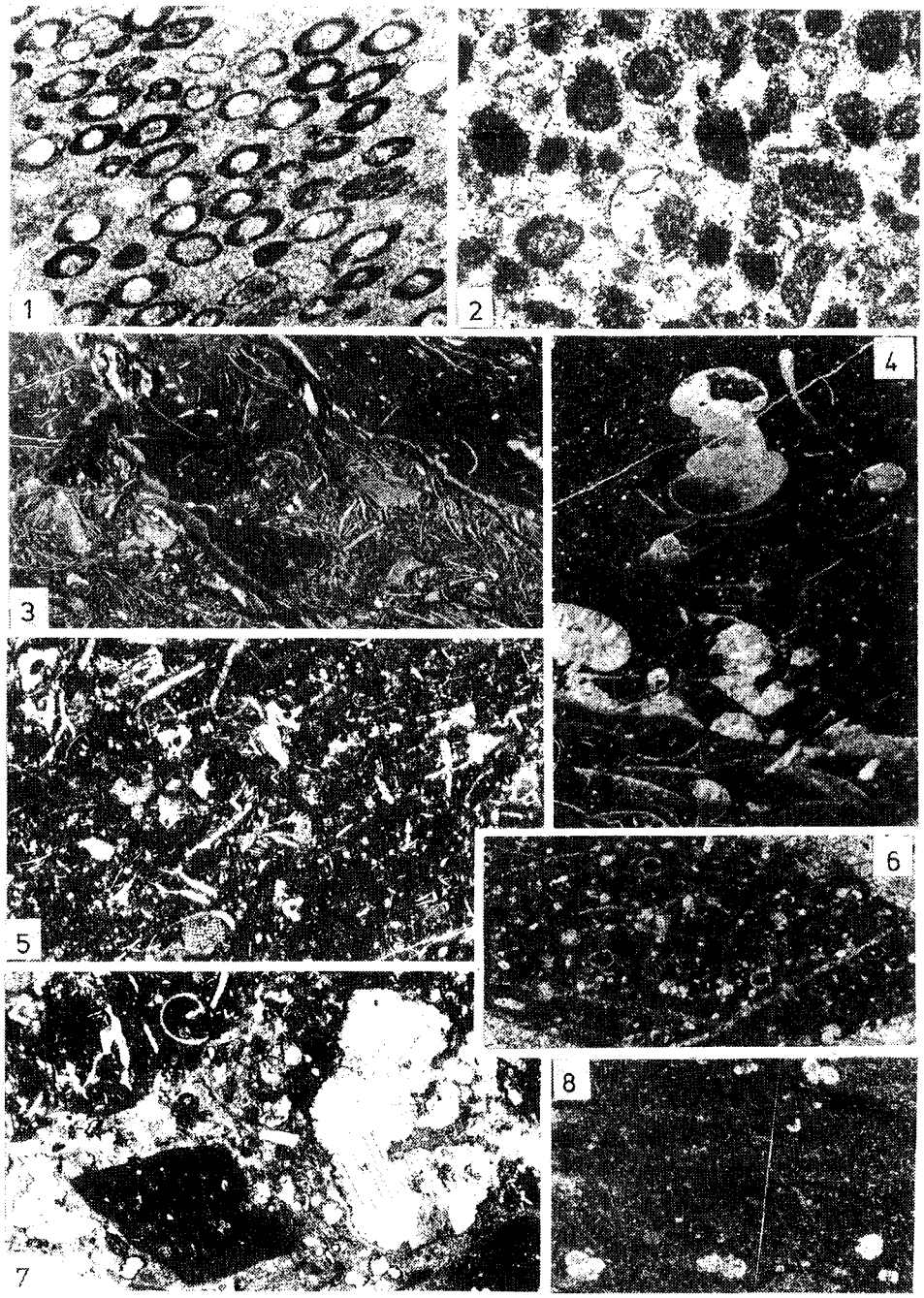
We also found a brachiopod fauna in blocks of a dark brown grey fine grained limestone in the Pleš Breccia, at the western foot of the Devín Castle Rock. It is composed exclusively of pygopid brachiopods (association of 84 individuals):

Securithyris adnethensis (Suess)	97.6 %
Linguithyris aspasia (Meneghini)	2.4 %

Brachiopods of this type were forms which achieved a very effective use of the nutrient suspension from slight currents. The



Figs. 1 - 5: Dudziniec Formation. 1 - Crinoidal wackestone. Kadlubek - above Zakopané section (Layer 5); x 9. **2** - Crinoid ossicles impregnated with Fe colloids and rimmed by mature syntaxial borders. Kadlubek - above Vodojem (layer 10); x 12. **3** - Crinoidal wackestone with fragments of foraminifers (*Lenticulina* sp.). Kadlubek - above Zakopané section (layer 13); x 9. **4** - Microbrecciated limestone with a colony of serpulid worm tubes, with sponge spicules, crinoid ossicles, and cavities filled by sparitic calcite. Block in the Pleš Breccia, Pleš near Pernek village (layer 5); x 12.5. **5** - Shells of bivalves and brachiopods in microbrecciated limestone with incipient silicification. Pleš near Pernek (layer 3); x 4.5.
Figs. 6 - 8: Pleš Breccia. 6 - Limestone breccia with clasts of Triassic dolomites, dolomitic limestones, pelmicrosparitic limestones, micrites without fossils, grains of clastic quartz and muskovite. Bartoška locality (layer 7); x 9. **7** - Limestone breccia with abundant fragments of belemnite rostra. Panský Dom-I (layer 9); x 4.5. **8** - Association of foraminifers *Vidalina mariana* Farinacci, in a microsparitic limestone. Clast in the Pleš Breccia. Panský Dom I (layer 6); x 104.



Figs. 1 - 2: Raptawicka Turnia Formation. 1 - Micro-oncosparitic limestone with ellipsoidal deformation of the micro-oncoid nodules. Kadlubek - Nad Zakopaným section (layer 6); x 9. 2 - Pelsparitic to pseudo-oolithic limestone. The original structure of the superficial ooids is mostly obliterated by recrystallization. Locally, a radial structure is preserved (arrow). Taricove Skalky section (layer 5); x 12.5. **Figs. 3 - 5: Tegernsee Formation** 3 - Pelagic bivalve - *Globochaete* microfacies of a microclastic limestone. The arrangement of the "filaments" was disturbed by the sliding of semi-plastic sediment. Kadlubek - above Vodojem section (layer 18); x 9. 4 - Nodular biomicritic packstone with abundant juvenile ammonites. Kadlubek - above Zakopané section (layer 11); x 4.5. 5 - Biomicritic wackestone with *Globochaete - Saccocoma* microfacies. Kadlubek, Egreš section (layer 12); x 12.5. **Fig. 6: Oberalm Formation.** Biomicrosparitic silicified wackestone with cross sections of *Calpionella alpina* Lorenz. Kadlubek, above Zakopané locality (layer 20); x 60. **Figs. 7 - 8: Filling of neptunic dykes.** 7 - Microclastic marly limestone, with a very impure sparitic matrix and clasts containing *Saccocoma,* calpionellids and upper Albian foraminifers. This limestone fills dykes in the Upper Jurassic limestones in the Kadlubek, Egreš section (layer 11); x 9. 8 - Planktonic hedbergelid foraminifers in a biomicrosparitic wackestones. Kadlubek, loose blocks (from ? neptunian dyke fillings) in eluvium above the Zakopané section. 45x.

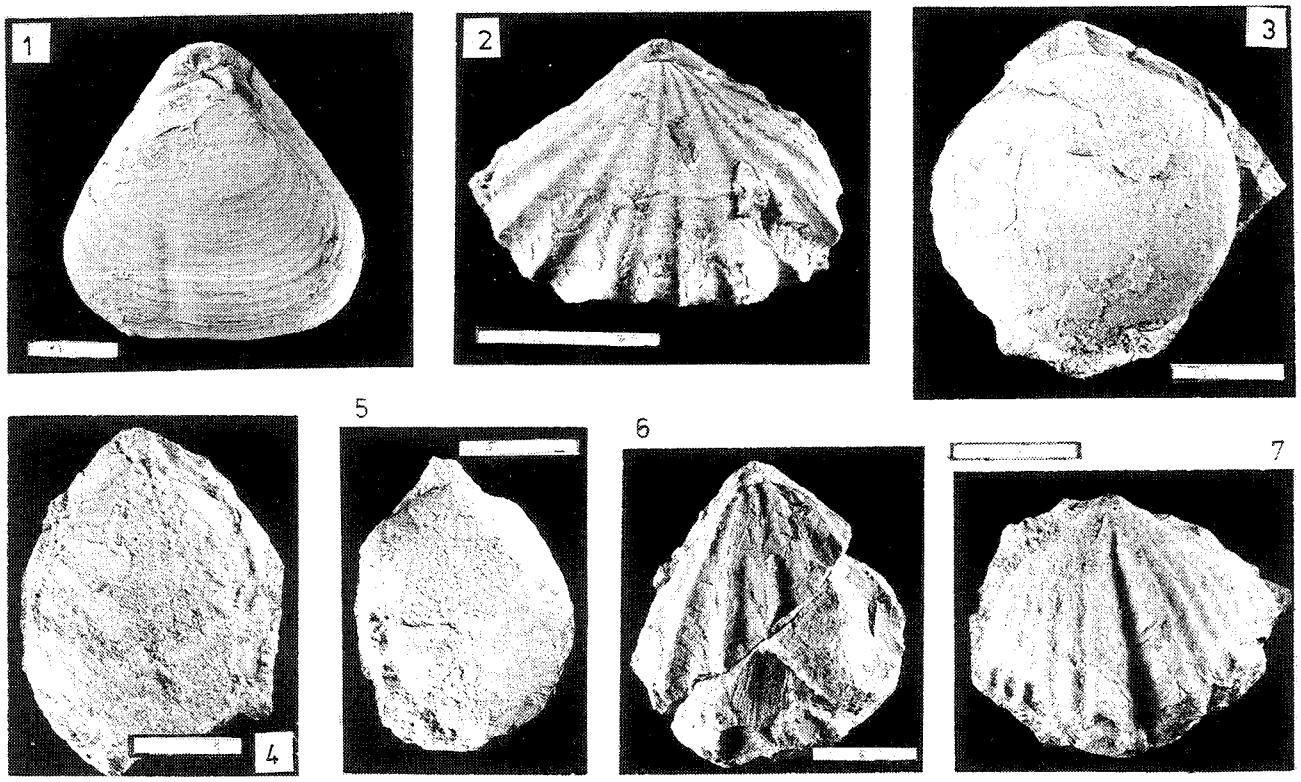


Plate III: Upper Liassic brachiopods from the Dudziniec Formation.
Fig. 1 - *Securithyris adnethensis* (Suess), Devín Castle Rock, blocks in the Pleš Breccia. Fig. 2 - *Cirpa fronto* (Quenstedt), Čermákova Záhrada Hill in the Vývrat Valley near Kuchyňa. Fig. 3 - *Cincta numismalis* (Lamarck), Čermákova Záhrada Hill. Fig. 4 - *Lobothyris* cf. *punctata* (Sowerby), Pleš Hill near Pernek. Fig. 5 - *Lobothyris* cf. *punctata* (Sow.), Pleš near Pernek. Fig. 6 - *?Slovenirhynchia pseudoscherina* (Böse), Pleš. Fig. 7 - *Spiriferina gillieroni* Haas, Ostrý Hill near Kuchyňa, from block in the Pleš Breccia.

monotypic composition of the association also points to extreme environmental conditions, which did not allow the development of a diversified community. The environment of this fauna was probably the inadequately aerated bottom of a local depression, which was hardly reached by any current carrying suspension.

The brachiopod associations from the Kuchyňa Succession are comparable to the association described by Siblík (1964) from the Belanská Valley in the Veľká Fatra Mts. (Michalík 1987). Although *Lobothyris punctata* is dominant in this assemblage, *Cincta numismalis, Cirpa fronto* and spiriferids are associated with it. Such an association apparently reflects an environment with constant moderate currents, but without turbulence (below storm wave base).

No equivalent of the association from Devín Castle Rock has been described from the Tatric of the Western Carpathians. The Pliensbachian pygopid *Securithyris* occurs more frequently in the central part of the Mediterranean Tethys (Vörös 1983). The trend to monotypic assemblage may also be observed in other associations, for example from the locality Krzyż Pola from the Kościeliska Valley in the Polish High Tatras (Horwitz & Rabowski 1922), but with a species composition closer to the association from the Kuchyňa Unit of the Malé Karpaty Mts. The spiriferids (*S. gillieroni* Haas - 55 %, *S. moeschi* Haas - 37 %) dominate over rhynchonelid brachiopods (*Cuneirhynchia persinuata* (Rau) - 1 %) and the associated bivalves. The dominance of spiriferids points to an environment below the wave base, influenced by a moderate, constant, one-directional current.

Summary of paleotectonic evolution

Complex evaluation of six detailed sections in the threshold-like Kadlubek Succession yielded new data concerning the Jurassic and Lower Cretaceous sedimentology, biostratigraphy and paleogeography of the Tatric part of the Malé Karpaty Mts. These data allow us to summarize the main evolutionary stages of the sedimentary area in following points:

1 - At the end of the Triassic period, the area of the Tatric of the Malé Karpaty Mts. was affected by the Early Cimmerian emersion, during which the Triassic sediments were locally eroded.

2 - During the Liassic sedimentary megacycle the Borinka half-graben formed on the northern margin of the Tatric. Olistostromes (Prepadlé Formation), followed by Lotharingian to Pliensbachian flysch (Korenec Formation) were deposited here. At the same time, Liassic breccias (containing a quantity of clasts of Triassic carbonates and fragments of crystalline rocks) and neritic carbonates, comparable to the Dudziniec Formation of the Tatric of the High Tatra Mts., were deposited in the Kuchyňa - Solírov Basin. The association of brachiopods and bivalves from the Kuchyňa Unit points to a well aerated neritic environment without turbulence (Fig. 4). However the association of brachiopods from the Devín Unit, already indicates an environment of an isolated depression at this time. On the Kadlubek High, this sequence is capped by a formation of red nodular limestones with an Ammonitico Rosso facies (the Adnet Formation), ending with ferromanganiferous condensed horizon.

3 - The Middle Jurassic sedimentary megacycle began with a significant Pleš Breccia erosional event, during which the older sedimentary cover was mostly removed. In places, the erosion reached even the crystalline basement. A tensional episode in the Penninic rift zone, which caused this event, was accompanied by the origin of a series of listric faults on the neighbour Tatric slope. Detachment faulting, gliding and tilting of rotated blocks along these faults, oriented towards the centre of the rift zone to the north, is indicated by a system of neptunic dykes penetrating Mesozoic carbonates and crystalline in the basement. These phenomena, known from another passive continental margin sections (Gibbs 1984; Lister et al. 1986, etc.), are well documented in the Findel section (Fig. 5).

4 - The post-rift Middle Jurassic succession consists of deep sea black shales (Mariatal Formation) and eupelagic siliceous shales (Ruhpolding Formation), with calciturbidites (Slepý Formation). In the area of deeper marine high, the Raptawicka Turnia Formation was sedimented.

5 - After the "Middle Jurassic collapse", a partial compensation of relief followed, indicated by the Tegernsee Formation of red nodular limestones.

6 - The Oberalm Formation with its calciturbiditic Barmstein Beds documents Upper Jurassic basinal sedimentation. The Lower Cretaceous basins were filled by the Lučivná Formation and by calciturbidites of the Staré Hlavy and Solírov Formations. New generation of neptunic dykes, the youngest of which are of Albian age, points to continuing extensional movements.

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