22nd IAS Meeting of Sedimentology - Opatija 2003

Field Trip Guidebook

Evolution of Depositional Environments from the Palaeozoic to the Quaternary in the Karst Dinarides and the Rannonian Basin

FIELD TRIP P7

Permian and Lower Triassic Facies of Velebit Mt. and the Gorski Kotar Region (NW Part of External Dinarides)

Leaders:

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Permian and Lower Triassic Facies of Velebit Mt. and the Gorski Kotar Region (NW Part of External Dinarides)

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Introduction

The geotectonic unit of the External Dinarides covers the western, southwestern and southern part of the Republic of Croatia. It is characterised by the south-west vergent fold-thrust belt formed along the eastern margin of the Adriatic carbonate platform since the late Cretaceous (HERAK, 1986). The predominant strike of the External Dinarides structures is NW-SE and the unit therefore extends into the neighbouring countries - Slovenia, Bosnia and Herzegovina and Montenegro. This is a recent karst area where the Palaeozoic and Lower Triassic rocks crop out through the karstified Mesozoic carbonates along the principle strike of the structures.

Outcrops of the Carboniferous, Permian and Lower Triassic rocks will be examined at locations in the mountain region of Gorski Kotar and in the vicinity of Brusane at Mt. Velebit (Fig. 1). These areas were explored palaeontologically and stratigraphically by SALOPEK (1942, 1949a, b, 1960), KOCHANSKY-DEVIDE (1965, 1970, 1973, 1979) and MILANOVIC (1982). The investigations of Salopek were the first, where various facies were delimited, described and mapped in the aforementioned area. Based on the fossil determinations, superposition and similarities with the locus typicus in the Southern Alps and Sicily, Salopek was also able to elucidate the stratigraphic determination of the Palaeozoic facies of the Gorski Kotar and Mt. Velebit.

Recent investigations, especially in the field of sedimentology, revised the known chronostratigraphic determination. Some sedimentological and stratigraphic problems still remain unsolved and can therefore be discussed during this excursion.

Visiting four localities in Gorski Kotar we will try to present a tentative interpretation of sedimentary processes and environment of the clastic Permian and Lower Triassic facies and this is also an opportunity to discuss the stratigraphic problem. At the localities on Velebit Mt. we will see Carboniferous(?) facies as well as Middle and Upper Permian platform carbonates which are missing in the Gorski Kotar reaion.

1st day - Gorski Kotar region

Geological setting

Gorski Kotar is located in the NW part of the External Dinarides between the well known Palaeozoic sediment succession at Velebit Mountain (KOCHANSKY-DEVIDE, 1979) and the Palaeozoic rocks of the External Dinarides in Slovenia (RAMOVŠ et al., 1987; ALJINOVIĆ & SREMAC, 1997). Palaeozoic rocks appear at the surface only in the zones of the main deep faults in the central part of Gorski Kotar (vicinity of **Mrzla Vodica)** in the northern (vicinity of **Gerovo** and **Tršće)** and northeastern parts (vicinity of **Brod na Kupi)** (Fig. la). They are in fault contacts with younger Triassic and Jurassic sedimentary rocks.

The Palaeozoic sedimentary complex is mostly composed of Lower? and Middle Permian elastics (SALOPEK, 1960; KOCHANSKY-DEVIDE, 1973)-Fig. 2. In the central part, an isolated occurrence of Carboniferous Triticites sandstones was discovered and these were determined (by SALOPEK 1949a) to be of Uralian age. The contact between these sandstones and the Permian clastic sediments remains unknown. The Clastic Permian sedimentary complex consists, according to SALOPEK (1949a, b, 1960) RAFFAELLI & ŠĆAVNIČAR (1968) and ALJINOVIĆ (1997), of distinctive lithotypes: **orthoquarzitic** and **petromictic conglomerates, gravelly and coarse grained sandstones** and fine grained (mostly pelitic) sedimentary rocks among which **thin-bedded sandstone-shale intercalation** are dominant. Siliciclastic rocks usually lack fossils, therefore the stratigraphic position of the clastic Permian sedimentary complex in Gorski Kotar has been the subject of many discussions and interpretations. A tentative chronostratigraphic correlation according to different authors has been given in Fig. 2 as well as comparison with the adjacent well known Permian succession at Velebit Mt. and in the Slovenian part of the External Dinarides.

In the central part of Gorski Kotar (in the vicinity of Mrzla Vodica) fossiliferous rocks are intercalated in a clastic sedimentary sequence. Thin-bedded calclithites and thick-bedded calcirudites appear intercalated in black

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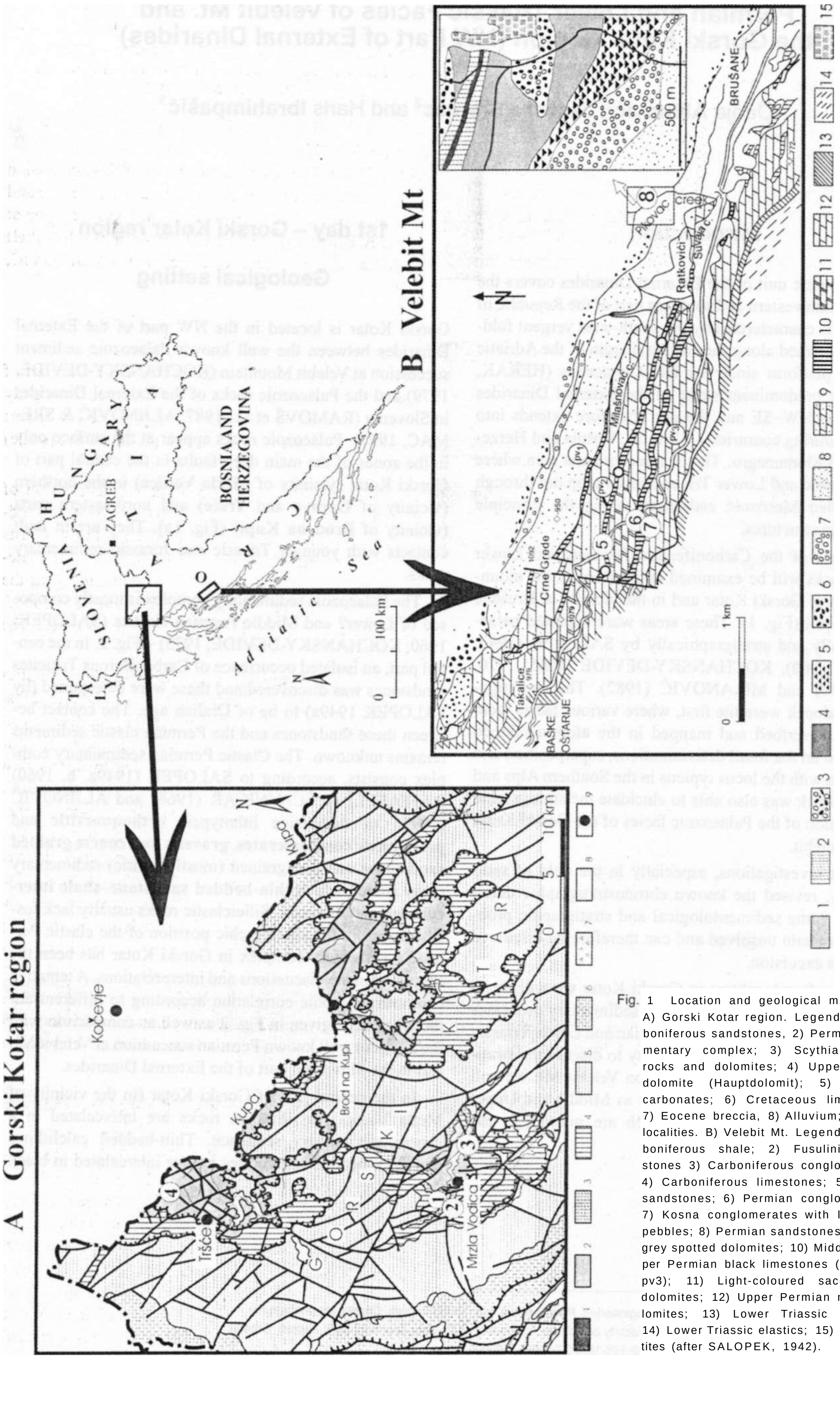

Fig. 1 Location and geological map of the A) Gorski Kotar region. Legend: 1) Carboniferous sandstones, 2) Permian sedimentary complex; 3) Scythian clastic rocks and dolomites; 4) Upper Trassic dolomite (Hauptdolomit); 5) Jurassic carbonates; 6) Cretaceous limestones; 7) Eocene breccia, 8) Alluvium; 9) Main localities. B) Velebit Mt. Legend: 1) Carboniferous shale; 2) Fusulinid sandstones 3) Carboniferous conglomerates; 4) Carboniferous limestones; 5) Pyrite-sandstones; 6) Permian conglomerates; 7) Kosna conglomerates with limestone pebbles; 8) Permian sandstones; 9) Dark grey spotted dolomites; 10) Middle to Upper Permian black limestones (pv1 pv2, pv3); 11) Light-coloured saccharoidal dolomites; 12) Upper Permian marly dolomites; 13) Lower Triassic dolomite; 14) Lower Triassic elastics; 15) pyroclastites (after SALOPEK, 1942).

shales. The fossiliferous rocks alternate vertically with orthoquartzitic and petromictic conglomerates forming fining upward sequences. In petromictic conglomerate clasts and blocks of fossiliferous limestones occur.

Compared to the central part, there are certain differences in lithology, morphology of sedimentary bodies and their structural position in the northern and northeastern part of Gorski Kotar. The facies assemblage still consists of quartz rich conglomerates, quartzitic sandstones and thin-bedded sandstone-shale intercalations but fossiliferous calclithites are completely absent. Nevertheless, SALOPEK (1949b, 1961) reported that a scarce ammonite fauna was found in shales, assuming a marine sedimentary environment coeval with the clastic fossiliferous sequence of the central part.

As the whole Gorski Kotar area is soil and vegetation covered and chronostratigraphic and lithostratigraphic markers are missing, correlation between successions from different localities is only possible according to similarities in depositidnal processes and palaeoenvironment. Ammonites found in black shale intercalations (SALOPEK, 1949a, b; 1961) assume a marine depositional environment, and imply a connection with the open, unrestricted sea. The abundant plant detritus occasionally appearing in sandstones indicates proximity to the uplifted land mass. Vast quantities of well rounded coarse grained material also imply denudation of the uplifted terrain and abrasion due to traction transport possibly related to alluvial fans. Thus, according to the assumption of intensive tectonic activity in the Early and Middle Permian (GRUBIĆ, 1980), and keeping in mind that black shales contain marine fauna, fan-delta depositional systems are a possible and the expected environment. It was assumed that a fan delta complex fringed edges of the uplifted terrain that resulted in accumulation of vast quantities of coarse grained material that intercalate with fine grained debris (ALJINOVIĆ, 1997). An assumption has been made that the sedimentological differences in central and north, northeastern parts were caused by variation in basin floor morphology formed due to tectonic instability, (mainly faulting). The subsiding trends were different in discrete parts of the study area and the steep or flat palaeorelief influenced the depositional processes. Faulting was probably related to synorogenic phases.

Some new and unpublished data however, suggest a completely different interpretation is possible and this will be discussed during the field trip.

The Upper Permian carbonate sediments were not found in the Gorski Kotar area, and this explains the hiatus of unknown duration as interpreted by ALJINOVIĆ & SREMAC (1997) - Fig. 2. The beginning of the Early Triassic transgression is marked by the predominantly carbonate shallow marine sedimentation with favourable conditions for ooid formation. The late diagenetic processes caused by the Middle Triassic magmatic event (ALJINOVIĆ et al., 2000) resulted in pyrite and barite mineralization of the Permian conglomerates and sandstones and of the basal layers of the Lower Triassic oolitic rocks.

Central part of Gorski Kotar

Stop 1: Kosmacev Brijeg old quarry - Permian clastic facies association with fossiliferous rock intercalations

In an abandoned quarry - Kosmacev Brijeg near Mrzla Vodica, a 6 m thick succession of Permian clastic rocks occurs (Fig. 3). The main characteristic of this succession is the appearance of fossiliferous rocks among the fine and coarse grained clastic facies association. The succession at Kosmacev Brijeg shows some elements of **prodelta-shelf** and **delta slope** sediment association (ALJINOVIC, 1997).

Coarse grained facies consist of calcirudites and gravelly mudstones.

Calcirudites occur as lentoid beds in the lower part of the succession (Fig. 3) and are characterised by tightly packed partly rounded limestone clasts in the lower part of the beds and a gradual increase of pelitic matrix (shale) upwards.

Gravelly mudstones contain a chaotic distribution of poorly sorted mostly limestone and lesser amounts of sandstone and quartz clasts scattered in shale - Fig 4. Clasts range from granule to boulder size. Granule size material usually forms contorted, slump-like structures. In the muddy matrix abundant crinoid ossicles have been found. In the limestone clasts calcitic veins can be observed. The veins are restricted only to clasts.

Facies interpretation: The sediment characteristics suggest deposition due to emplacement of mud rich delta-' slope derived debris flows that prograde to a deeper part of the basin. Increasing mud-rich matrix in the calcirudite was interpreted as textural inversion due to debris flow interaction with background mud (shale) of heterolithic facies (LARSEN & STEEL, 1978). Gravelly mudstones show the characteristics of typical subaqueous cohesive debris flows. Carbonate debris has been partly derived through destruction of a preexisting carbonate-shelf platform (that shows signs of complete lithification) and was mixed with extrabasinal material in relation to the early progradational phases of the fan-delta systems. Limestone clasts show signs of complete lithification before they were resedimented.

The coarse grained facies association was interpreted as a fan-delta slope facies. which advanced into deeper parts of the depositional basin.

Heterolithic facies consists of thin-bedded sandstone-shale intercalations and sheet-like calclithites - Fig. 3.

Thin-bedded sandstone-shale intercalations are represented by the even alternation of sandstone and shale beds a few cms in thickness. Sandstone interbeds are not always tabular but can be rather uneven and lentoid in shape. Their lower bedding planes are usually sharp or show load-cast structures. Sandstone interbeds consist of parallel lamination in their lower division with transitioning upward tendencies to faint current ripple-cross lamination. On the upper bedding planes of sandstone intercalations symmetric

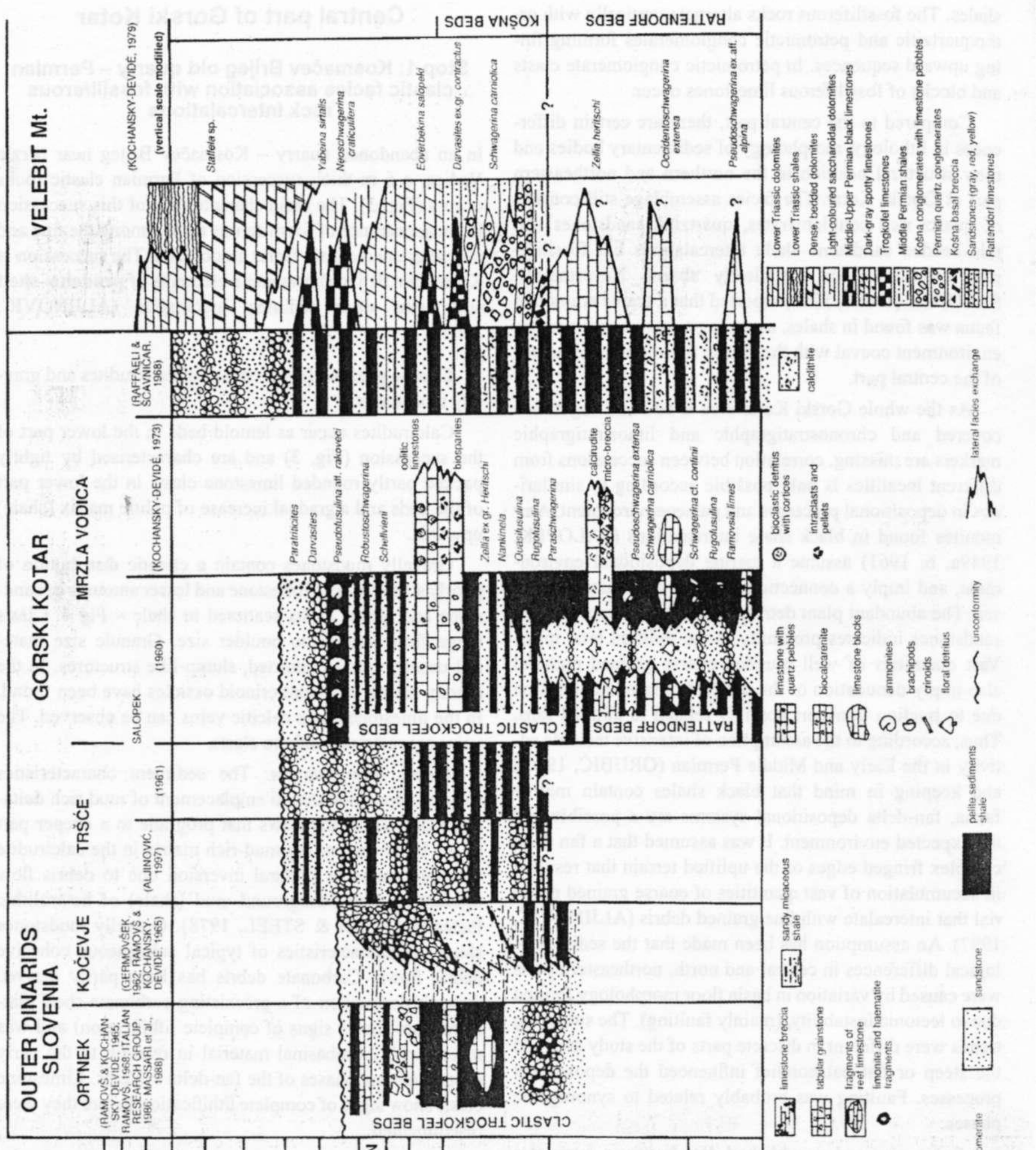

Fig 2 Schematic stratigraphic column through the Permian and Scythian sediments in Gorski Kotar and Velebit Mt. and correlation with the Slovenian part of the External Dinarides. Vertical scale after ITALIAN RESEARCH GROUP (1986). CASSINIS et al. (1988) and MASSARI et al. (1988).

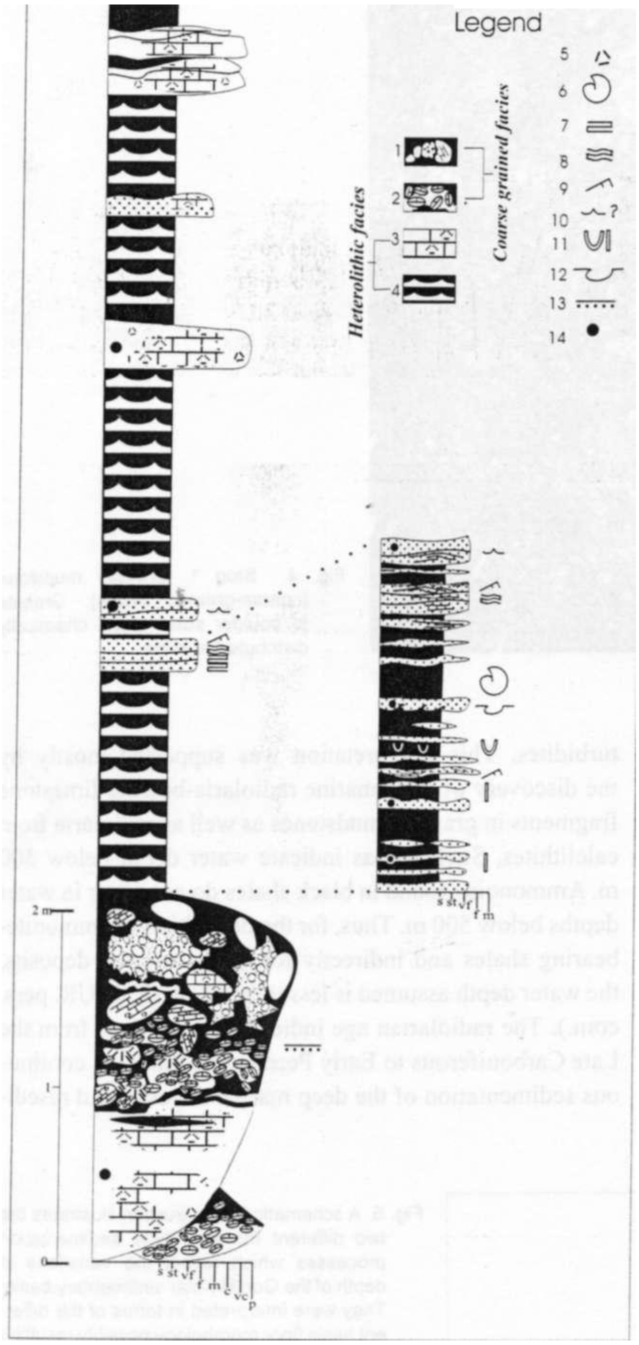

Fig 3 Stop 1. Fan-delta facies association at the Kosmacev brijeg section. Legend: 1) gravelly mudstone; 2) calcirudite; 3) calclithite; 4) sandstone shale intercalation; 5) skeletal detritus; 6) ammonoids; 7) parallel lamination; 8) wavy lamination; 9) ripple-cross lamination; 10) symetrical ripples; 11) ichnofossils; 12) load casts; 13) inverse grading; 14) position of samples.

ripples are preserved. Sandstone interbeds are very fine to fine grained. The boundary from sandstone to shale interbeds is transitional. Sandstones are determined as quartz or lithic graywackes with a calcitic or Fe-calcitic and sericite matrix. In lithic graywackes a significant amount of limestone clasts occur. In shale interbeds crinoid and ammonite fragments can be observed. Large amounts of an organic substance and pyrite present in shales, gives the sediments a dark colour. In the shales slanted "U" shaped burrows occur.

Sheet-like calclithites appear as massive 15-25 cm thick beds (Fig. 3), primarily composed of poorly rounded fragments of micritic or biomicritic limestones and older sandstones. Less abundant are poorly preserved bioclastic detritus. Some quartz grains are also apparent. Detrital fragments have pyritic or organic rich cortices.

Facies interpretation: The appearance of marine fossils in the shales link this facies to a marine environment. Considering that this facies exchanges vertically with the conglomerates of coarse grained delta slope facies, it was interpreted as a prodelta-shelf facies (ALJINOVIC, 1997).

Sandstone intercalations were deposited during periods of a sudden influx of sand. Parallel lamination that passes upwards to current ripple-cross lamination emphasises bedload transport and can be explained by deposition due to decelerating unidirectional currents. The sediment association described is inferred to have been deposited from short lived, sandy currents. The fining upwards sequence reflects the declining energy of episodic currents after which suspension settling of fines began. These mechanisms distributed sand over a wide area as a thin bedded cover, sometimes in a ""starved" condition (lentoid beds can be explained as ripple-thick sandstone beds). Activity of dwelling organisms was connected to periods of slow suspension sedimentation.

Thicker massive calclithites were interpreted as deposition from occasional sandy debris flows or high-density turbidity currents (JELASKA & PROHIC, 1982) which carry material offshore and deposit it in a distant area. Nevertheless the sandstone-shale couplets, previously described, can also be considered (partly) as Tb,c,d turbiditic intervals.

General characteristic of the Kosmacev Brijeg sedimentary succession: The Variscan orogenic phase reached its climax during Middle Westphalian times and was followed by faulting, which resulted in the formation of discrete sedimentary basins (KRAINER, 1993). Following this conception Permian clastic rocks seen at Kosmacev Brijeg have been interpreted as deltaic marine deposits of Early to Middle Permian age linked to the tectonic instability. Vast quantities of coarse grained material were derived mostly from the uplifted metamorphic source terrains. Thus fan-delta sedimentation was proposed for the Kosmacev Brijeg sedimentary succession.

Characteristics of calcirudite and gravelly mudstones suggest deposition from debris flows the evolution of which almost certainly requires a steep slope. The channel like morphology of conglomerate bodies emplaced in black shales found in the vicinity of Kosmacev Brijeg permits the assumption of chutes formed at the steep fan-delta slope. The deposition of coarse material was probably restricted to chutes, and scarps formed due to sliding while the fine grained facies association was considered as background sediment deposited alongside the chutes and on the flattened delta toe. These sediments suggest deposition below wave base. The slump-like contortions in the gravelly mudstones indicates steep palaeorelief and the succession can be interpreted as a slope type delta of ETHRIDGE & WESCOTT (1984) - mark A at Fig. 5. As in all slope type

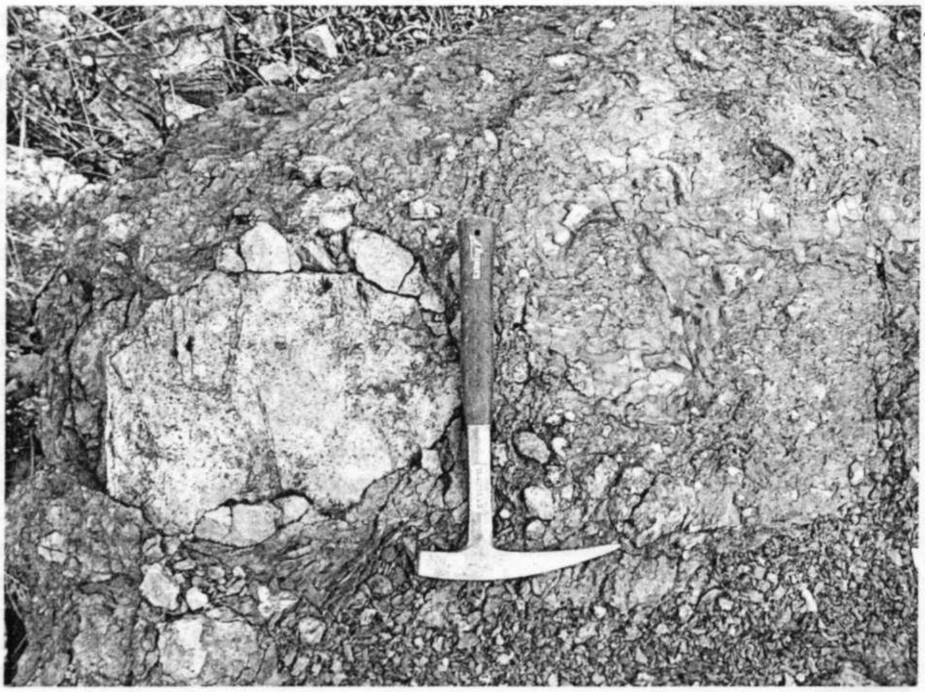

Fig. 4 Stop 1. Gravelly mudstone (coarse-grained facies). Granule to boulder sized clasts chaotically distributed in shale.

fan-deltas the shelf is narrow or missing. The carbonate fragments were interpreted as cannibalised parts of the marginal, shallow, recently uplifted shelf deposits.

Although the basin was primarily considered as a foredeep basin, related to the orogenic activity, there is a possibility that deposition took place in an active arc-trench related system, possibly a forearc basin. Thus, the chaotic distribution of clasts and blocks in a mud matrix (gravelly mudstone) can be considered as detritus derived from the front of the thrust forming accretionary wedge. The heterolithic fades can be thus considered as deposits of the distal turbidites. This interpretation was supported mostly by the discovery of deep marine radiolaria-bearing limestone fragments in gravelly mudstones as well as radiolaria from calclithites. Such faunas indicate water depth below 500 m. Ammonoids found in black shales do not occur in water depths below 500 m. Thus, for the deposition of ammonite-bearing shales and indirectly for the associated deposits, the water depth assumed is less then 500 m (KOZUR. pers. com.). The radiolarian age indicates a time span from the Late Carboniferous to Early Permian and favours continuous sedimentation of the deep marine deposits and resedi-

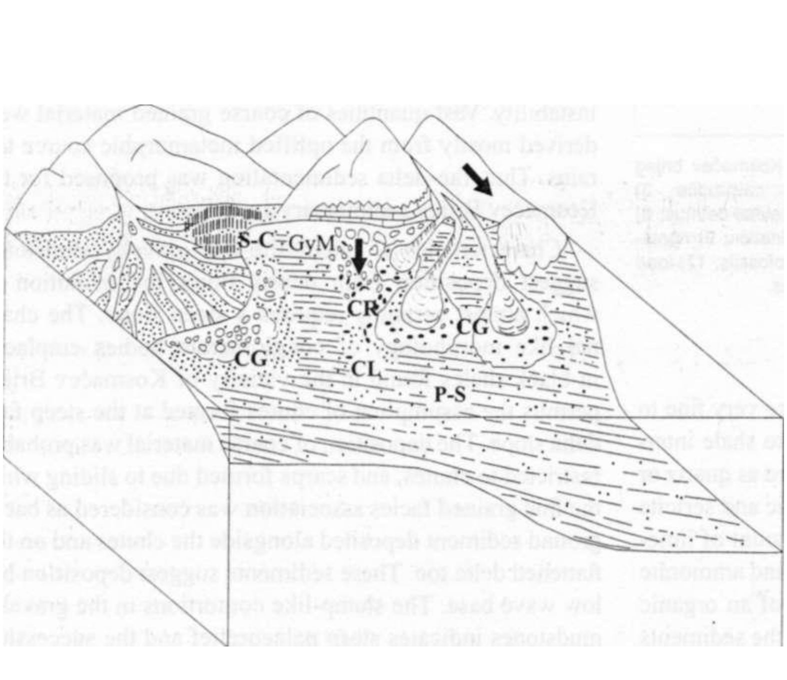

Fig. 5 A schematic reconstruction illustrates the two different fan-delta type sedimentation processes which reflect the variations in depth of the Gorski Kotar sedimentary basin. They were interpreted in terms of the different basin floor morphology possibly resulting from variable subsidence due to sub-basinal faulting in a teotonically active area. A) Sedimentation processes in the central part were determined by a steep delta slope (slope type delta of ETHRIDGE & WESCOTT, 1984). Sliding as well as the formation of chutes were noticed. The following facies and rock types were recognised: coarse grained facies (CG). calclithite (CL). calcirudite (CR), gravelly mudstones (GyM). B) In the northern and north-eastern part, sedimentation was determined by low inclined relief. The delta type corresponds to the shelf type delta of ETHRIDGE & WESCOTT (1984). Several facies associations were recognised: coarse grained (channel mouth derived) facies (CG) and subaerial or coastal facies (S-C). Shales and sandstone-shale intercalations, interpreted as prodelta-shelf facies (P-S) have similar characteristics in the central and N-NE part and were interpreted as "background" sediment deposited over the entire area, connecting the two fan delta types.

mentation possibly due to processes related to thrusting in an accretionary wedge (KOZUR, pers. com.).

Stratigraphic constraints: In 1973 KOCHANSKY-DEVIDE interpreted the coarse-grained clastic sediments near Mrzla Vodica as being the consequence of redepositon and unstable environmental conditions linked with tectonic activity. The Trogkofel age of the sediments has been proven with index species of *Pseudofusulina* and *Robustoschwagerina.* MILANOVIC (1982) described in detail the determined microfauna and suggested the post-Kasimovian age for these sediments. The work of SREMAC & ALJINOVIC (1997), embraced several fossiliferous rock types (calclithites, carbonate breccia and limestone clasts in conglomerates) from the vicinity of Mrzla Vodica, and resulted in 72 taxa being determined, with a predomination of foraminifers (32) and calcareous algae (20 taxa including 15 dasycladaceans). The age of the determined fossils varies from the Lower Carboniferous (Visean) through the Upper Carboniferous (Moscovian, Kasimovian, Gzhelian), to the Lower Permian (Asselian). Fossils younger than Lower Permian have not been collected. According to the fossil content, the similarity with the Rattendorf beds can be inferred (SREMAC & ALJINOVIC, 1997). As the fossiliferous fragments have been considered as resedimented detritus, a Middle Permian age was proposed.

Ammonites found in black shales {*Bamyaniceras* sp.) indicate a Roadian age for the discussed sequence (determination and age assignment Dr. sc. LEONOVA, Moscow, pers. com.).

Stop 2: Opaljenac old quarry - siliciclastic Middle Permian association with barite-pyrite ore mineralisation

The cross-section will be observed along the face of the abandoned barite pit at Opaljenac hill. In a vertical sequence, these sediments overlie the Permian elastics intercalated with fossiliferous limestones described at Stop 1 and are interpreted as being of Middle Permian age. The sequence is composed of (1) conglomerates, (2) sandstones and (3) pelitic sediments.

The conglomerates are composed of very well sorted quartz detritus having dimensions of granule and rarely pebble sized particles with a sandy matrix. Within the sandy matrix pyrite and barite crystals can be found. The graded as well as clast-supported or matrix-supported conglomerates of massive structure predominate. Layers are tabular and extensive in the direction of the strike. The uppermost parts of the sequence are characterised by the occurrence of "porous" conglomerates with a proportion of pebbles dissolved so that only the clast molds remain. Their immediate cover, the apical part of the sequence, is composed of fine-grained conglomerates wherein limonite crusts can be observed, forming an almost regular grid. Another characteristic observed in the conglomerates is the precipitation of barite along the joints or veinlets.

The sandstones consist of well-sorted quartz and lithic detritus of medium- to coarse-grain size and of the dolomite cement. They usually have a massive structure, with

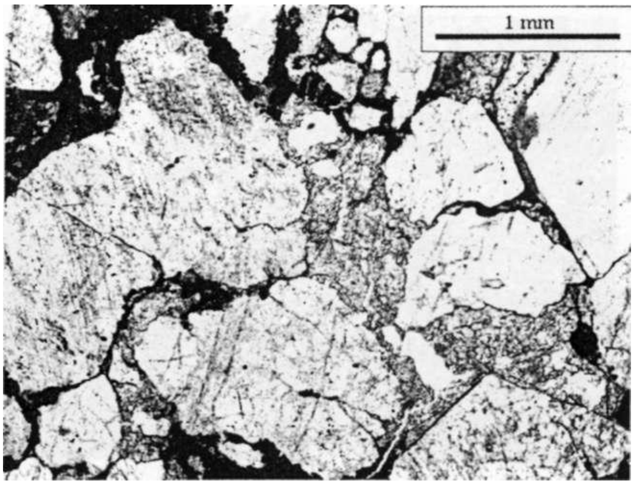

Fig 6 Stop 2. Permian sandstone from Opaljenac quarry with barite-pyrite mineralization in the intergranular pores.

the exception of the uppermost part of the sequence where thinner sandstone layers with normal gradation appear. As shown in Fig. 6, barite and pyrite were occasionally precipitated in the intergranular space. The pelitic sediments are represented by siltstones. The cm-size quartz nodules can be found in thicker siltstone layers.

General characteristics of the Opaljenac sedimentary succession: Based on determined characteristics, the facies of this succession cannot be interpreted unambiguously. It can only be concluded that, apart from the barite and pyrite mineralisation, the defined types of conglomerates and sandstones do not significantly differ from the characteristics of similar sediments analysed at the cross-sections in the northern part of the Gorski Kotar (Stop 4 of the field trip). The normal gradation signals deposition by decelerating turbulent currents. Based on the similarity with the facies association that was more extensively investigated in the northern part of Gorski Kotar, the fan delta depositional environment can be interpreted. The gravel material is well sorted, which means that grain-size separation took place in the course of lengthy transport, most probably connected with the alluvial fan.

The barite and pyrite mineralisation, as well as the "grid" of limonitic crusts are the diagenetic products formed by the circulation of solutions through the porous sediments. These processes (diagenesis and circulation of pore solutions) can also be connected with the dissolution of some pebbles (probably the carbonate ones) that left the clast molds.

Stop 3: Locality Homer - Lower Triassic dolomite with barite mineralisation

The carbonate and carbonate-siliciclastic Lower Triassic sediments of Gorski Kotar are best represented by outcrops in the old barite pits in the area of the Homer hamlet west of Lokve and in the area of the Školski Brijeg near Mrzla Vodica (Fig. 1). In a transgressive sequence, the Palaeozoic sediments are overlain by the basal dolomitised oolitic facies. Cross stratification stems from the migration of the

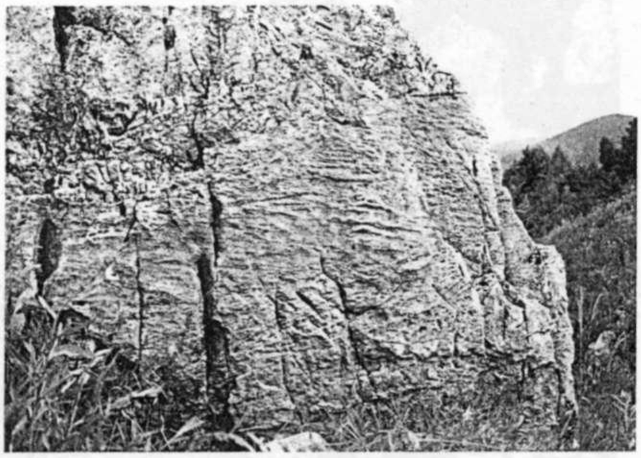

Fig 7 Stop 3. Lower Triassic dolomitised oolitic facies. Tabular and trough cross-bedding (2D and 3D dunes) formed in oolitic sand bars.

2D and 3D dunes (Fig. 7). The thicker sets of the oolitic sand were interpreted as being deposited by tidal currents exaggerated during storms, while the thinner planar and trough cosets are interpreted as the result of post-storm reworking of sediments by tidal currents. During diagenesis, the oolitic sands were exposed to late-diagenetic dolomitisation[4].

The oolitic sands exhibit the morphology and position of barrier bars located between the open sea and the lagoon. The lagoon behind the barrier, was characterised by deposition of mostly carbonate muds, occasionally with varying proportions of siliciclastic terrigenous detritus. These sediments are described as the lagoonal facies. They are characterised by thin to medium-bedded (2-30 cm) dolomicrites with interbeds of sandy dolomites and/or calcarenaceous sandstones. In the marginal parts of the lagoons, the carbonate muds have been subjected to early diagenetic dolomitisation.

General characteristics of the Homer sedimentary succession: In the vertical section at Homer a 7-10 m thick dolomitised oolitic facies. interpreted as a barrier bar, is overlain by a lagoonal facies. Such sequences are interpreted by some authors as representing progradation of the barrier bar complex, but we think that this was not the case with the above denned facies. Namely, the sequences of identical succession, oolitic bar covered by lagoonal sediments can also be formed by sudden transgression i.e. by the "in-place drowning" mechanism as denned by REINSON (1984) and described by FRIEDMAN & SANDERS (1978). In the case of gradual transgression, the barrier bars can be partly eroded so that the sandy detritus of the bar actually progrades seaward. But, when sudden transgression occurs, as is supposed in this case, the erosion of the bar no longer continues, as well as the progradation. and bars are covered with sediments of the wider lagoon as long as the coast line '"jumps" landward. There a new barrier can be built.

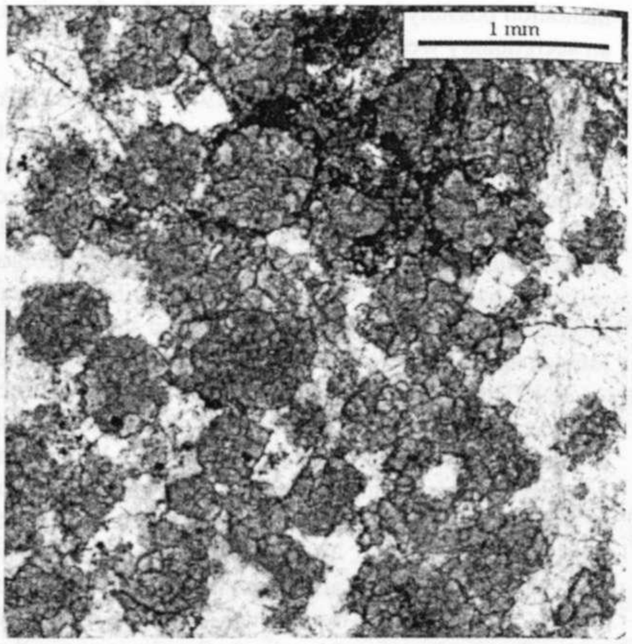

Fig. 8 Photomicrograph of Lower Triassic dolomitised oolitic facies with relict ooid detritus. Note barite mineralisation (white).

Further Lower Triassic transgressive tendencies resulted in formation of an extensive shallow sea.

Barite and pyrite mineralisation: Mineralisation is confined to the basal, (metre-scale) interval of the macrocrystalline cross-stratified dolomite with relics of ooid detritus (dolomitised oolitic facies). The mineral paragenesis consists predominantly of barite and pyrite. with occurrences of quartz, magnetite, haematite, sphalerite, cerusite. witherite, gypsum and manganese and titanium oxides.

Barite appears in the host dolomite as irregular impregnations, in lenses, nests, along the irregular system of veins, veinlets and in the stylolites. The irregular precipitation is the most frequent form of barite occurrence. Dolomite rocks affected by barite mineralisation are characterised by their anhedral and subhedral macrocrystalline structure. The primary limestone components of these rocks are almost completely destroyed by dolomitisation. apart from the "ghosts" of the primary ooids that can usually be observed in the dolomite (Fig. 8). The precipitation of barite is in the form of irregular impregnation, replacing the dolomite, as a poikilitic cement of the ooids (Fig. 8) or along certain directions in rocks that usually coincide with foresets in the dolomitised ooid facies (Fig. 9). The barite mineralisation along foresets is usually associated with quartz precipitation. The more weather-resistant minerals - barite and quartz clearly protrude along the foresets, which makes the staicture highly observable, while it is actually almost unobservable at a fresh cut. Furthermore, barite is also found in the form of cm-sized concave-convex lenses. Such lentoid occurrences along some lamina causes the wavy deformation of laminae above and below the lenses. Sometimes, barite crystals a few mm in size can

Op éd.: *A different interpretation of the barite bearing dolomites sedimentary facies and genesis of the mineralization is presented at Stop 4 of the field trip A3 - PALINKAS & BOROJEVIC-SOSTARIC (this Vol.).*

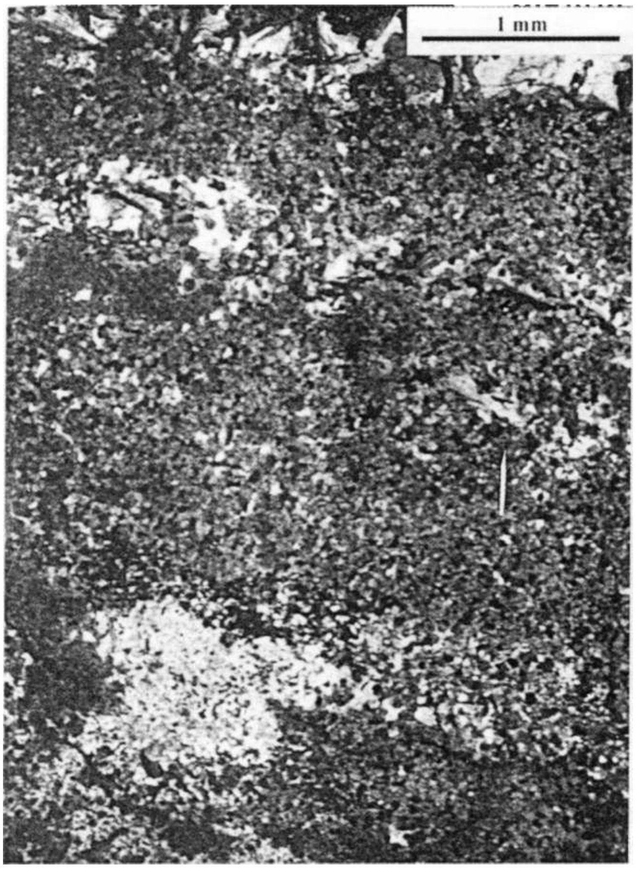

Fig 9 Preferred distribution of barite crystals (light grey) along cross laminae in dolomitised oolitic facies; photomicrograph, crossed nicols.

precipitate in cavities (nests), where they grow towards the centre like the drusy cement. In these nests, platy barite crystals several mm in size were observed. Veins are a few metres long and 2-5 cm wide. Several systems of veins and veinlets with either irregular or plan parallel surfaces were observed in the dolomites. Iron minerals also appear in the mineral paragenesis. Pyrite is usually altered at the surface due to weathering conditions. Stylolites are filled with barite, pyrite and iron oxides formed by weathering.

The veins, veinlets. lenses, nests, crusts and stylolites with barite, quartz and iron sulphides and oxides and with associated minerals, both within the Triassic and underlying Palaeozoic sediments, indicate a late diagenetic origin, i.e. post formation of the joint systems which enabled the circulation of solutions from which the barite, quartz, iron minerals and the rest of accessory minerals were crystallised. Analysing the characteristics of the dolomite replaced with barite and the linear precipitation of the barite crystals along the inclined strata or lamina in the dolomites, ALJINOVIC et al. (2000) concluded that the ore-formation and dolomitisation had been connected with several late-diagenetic phases and with circulation of the pore solutions along the joints and through the porous granular sedimentary rocks - Permian clastic sediments and Lower Triassic ooid grainstones. The mineralisation was, at least partly, in connection with the processes that dolomitised the primary limestones in the late phase of diagenesis at high temperature. The non-planar anhedral dolomite types, suggest the dolomitisation at high temperatures (GREGG & SIBLEY, 1984). Although the high-temperature conditions usually imply greater burial depths, the upward circulation of hydrothermal fluids through the joint systems, larger fractures or faults can be supposed. This suggests that there was circulation of the hot pore solutions influenced by an increase in geothermal gradient (KUPECZ & LAND, 1991) and this could have been caused by Middle Triassic volcanism which also formed the andésite at the nearby Fuzinski Benkovac.

The possible presence of witherite can be explained by the metasomatic influence of the secondary-hydrothermal solutions on the dolomite and by the secondary mobilisation of barium that is in accordance with previous investigations (SIFTAR, 1978).

Since the mineralisation of barite, pyrite and other described minerals is connected with the late diagenetic phase, the barite deposits are considered as epigenetic.

There is also a different interpretation for the origin of barite mineralization. PALLNKAS et al. (1993) reported a barite and pyrite ore mineral association exclusively. According to the same authors barite and pyrite ore mineralization is a stratabound ore deposit conformably situated at the Permian-Triassic boundary formed by early diagenetic, bacteriogenic sulphate reduction in a peritidal muddy environment, in a sabkha-like conditions. The early diagenetic model is supported by analysis of the sedimentary facies, trace element geochemistry and sulphur isotope distribution noticed along the two vertical profiles. More information about this interpretation can be obtained in this fieldtrip guidebook - field trip A3, Stop 4 (PALINKAS & BOROJEVIC-SOSTARIC, this Vol.).

Northern part of the Gorski Kotar region

Stop 4: Čabar succession - Permian siliciclastic deposits

This stop represents the Permian, dominantly siliciclastic facies association which is characteristic for the northern part of the Gorski Kotar. It is supposed that clastic sedimentary rocks as in the Čabar succession overlie the Permian succession seen at Stop 1. Orthoquarzitic conglomerates and quartz rich sandstones appear intercalated with thin-bedded sandstones and shales. Sediment types appearing in the Čabar succession were also found in other Permian outcrops in the N-NE part of Gorski Kotar. The interpretation of their depositional environment and facies was based on the comprehensive study of many localities, most of which are located in a rough area of mountain creeks and were, thus, inaccessible for this field trip. In shale ("schist") intercalations SALOPEK (1949b, 1961) found ammonites and crinoid fragments. These facts determine the depositional environment as marine and it was interpreted as fan-delta type deposits (ALJINOVIC, 1997).

The section, observed at the roadcut near Čabar, consists of fining-upward, metre scale cycles. In each cycle thick-bedded **coarse grained facies** (sandstones/conglomerates) that occur in the lower parts of the cycles, represent chan-

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Fig 10 Stop 4. Čabar section. Fining upward cycles consisting of thick bedded sandstone or conglomerate layers in the lower part (light grey) and thin-bedded sandstone–shale intercalations of prodelta–shelf facies (dark grey) in the upper part of each cycle.

nel mouth-derived deposits, while the **heterolithic facies** (thin-bedded sandstone-shale intercalations) in the upper parts of the cycles represent **the prodelta-shelf association** (Fig. 10). It must be emphasized that the following facies interpretation was made according to a combination of criteria: facies own characteristics, character of associated deposits and the broader structural context.

Several structural sandstone/conglomerate types occurring in the lower part of each cycle were defined as **coarse grained facies.**

Coarse grained facies: Thick-bedded **massive or normally graded sandstones** vary from medium to very coarse grained types. Outsized flattened shale clasts appear incorporated in the upper portion of beds. Tabular sandstone bodies have very sharp lower bedding planes but no obvious signs of erosion, rather some loading irregularities occur. The upper bedding planes sometimes show a convex surface. Lentoid (channel-like) beds incorporated in prodelta-shelf fines are also present. The thickness of bed varies from 0.2 to over 2 m. Sandstones are mostly quartz or lithic grayvvackes.

Gravelly sandstones are characterised by two distinctive lithotypes:

(a) *Massive gravelly sandstones* where gravels are scattered homogeneously in a sandy matrix. Layers are 0.15 to 0.3 m thick and usually show lentoid shapes.

(b) *Trough cross bedded gravelly sandstones* consist mainly of sand, but gravel sized clasts accumulated at the bottom of shallow troughs - Fig 11. Sporadically, gravel clasts that delineate troughs are not clearly visible. Instead, lentoid gravel marked forms or random accumulations of gravels can be observed.

Massive clast supported conglomerates consist of well sorted and well rounded pebbles. The thickness of bed-- varies from 0.7 to 1.5 in. **Massive matrix supported conglomerates** occur very rarely. The matrix is dominantly sandy but clayey matrix also occurs. In **normally graded conglomerates** the lower division of graded beds consists of clast supported gravels or pebbles with a sandy matrix. The thickness of beds varies from 0.5 to 3.3 m. As the clast sizes decrease upwards the amount of sand matrix increases which resulted in a continuous transition from the clast supported (lower) to matrix supported (upper) part of the bed or to a sandy upper division. Usually approximately 50% of graded beds consist in their upper parts of parallel laminated or massive sandstones. Other matrix supported varieties show only the upward decrease in gravel size. **Inversely graded conglomerates** show a sandy base (a few cm thick) which passes upwards to clast supported pebbles at the top. **Inversely-to-normally graded conglomerates** have a pebble clast-supported fabric only in their middle part. In the lower and upper parts they are matrix supported or sandy. Outsized flattened clasts of shale very often occur in all conglomerate types.

Comprehensive studies on some other localities in the vicinity indicate that the **tabular cross-bedded** and **trough cross-bedded conglomerates** are also present.

Facies interpretation: The **coarse grained facies** is generally recognised as **channel mouth-derived deposits.** No single described sandstone/conglomerate type permits recognition of the depositional setting, but as an assemblage it can be interpreted as a channel mouth deposit, due to the intercalation of beds generated by both traction and gravity-flow processes possibly representing the exchange of basin processes with fluvially constructed phases. The characteristic of coarse grained lithotypes suggest deposition of vast quantities of coarse material in a period of abrupt input. The massive to normally graded sandstones may represent channel mouth derived material that was deposited as a low-density turbidite flow. A sudden input of sand indicates flood events. These flash flows act as

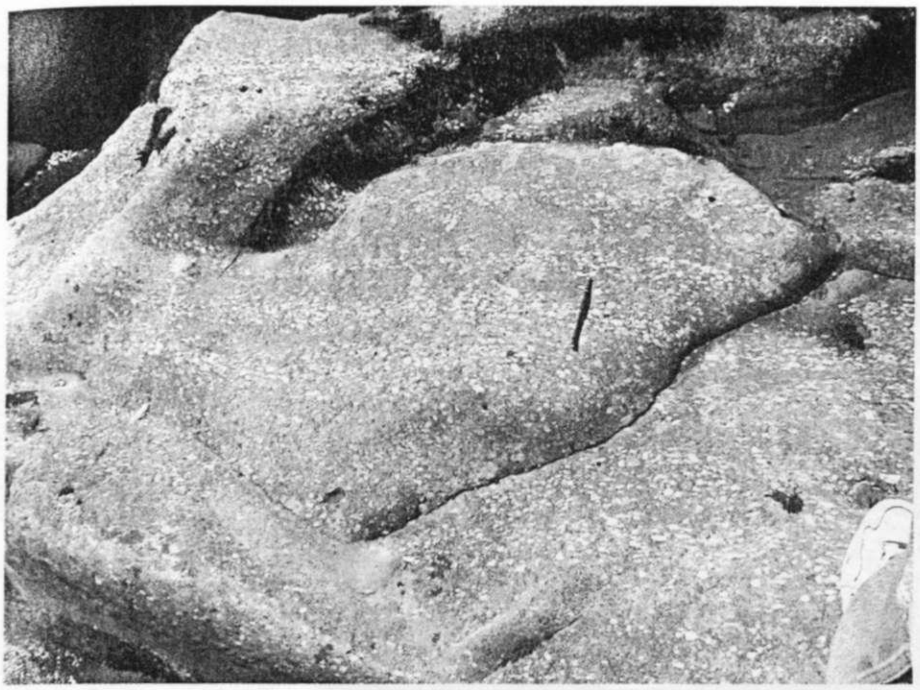


Fig 11 Stop 4. Trough cross-bedded gravelly sandstones.

unchannelized jets at the mouth of high discharge distributory channels. The absence of traction and wave generated structures excludes reworking by shallow marine currents and waves.

All described conglomerate types are interpreted as being deposited from debris flows or high-density turbidity flows (LOWE, 1982; NEMEC & STEEL, 1984).

Lack of internal stratification, the non erosive basal contacts, inverse grading, disorganised fabrics and outsized flattened clasts favour deposition from debris flows where shearing was restricted to the lower part of the flow. The ungraded massive bed types could represent debris flows which experienced minimum shearing probably only along the base. The appearance of debris flows suggests the relatively rapid accumulation of material and relative quiescence of the depositional environment. Debris flows were generated at the channel mouth or along the mouth bar descent as described by KLEINSPEHN et al. (1984) and MARZO & ANADÓN (1988). Debris flows can change to high-density turbidity flows where the steep slopes of mouth bars advanced to the basin (LOWE, 1982; NEMEC & STEEL. 1984). Though, deposition of normally graded conglomerate types was interpreted as high density turbidity currents. Inversely to normally graded lithotype as well as the transition from normally graded conglomerates to parallel laminated sandstones can be explained by deposition from primary debris flows which transform into liquefied high-density turbidity flows.

Structures like planar and trough cross bedding, indicative of tractional transport could be explained by deposition from near shore unidirectional currents and suggest reworked channel mouth derived material or they could represent linguoid or straight crested channel bars in fluvially constructed periods of fan-delta development.

Interstratification of debris flow or turbidity flow deposits with sediments generated by bedload traction currents could be the criterion that permits interpretation of mouth bar facies (KLEINSPEHN et al., 1984).

Heterolithic facies consists of thin-bedded sandstone-shale intercalations and occasionally decimetre thick sandstone beds with plane parallel lamination. Among sandstone-shale intercalations several lithotypes were distinguished: (a) In *parallel laminated shale lithotype* shale appears to be dominant, while silty/sandy material occurs as rare distinct cm thick beds or mm thick laminae - Fig. 12. (b) *Ripple-cross laminated lithotype* consists of the even alternation of sandstone and shale beds a few cm thick (Fig. 13). The proportion of sandstone and shale beds are equal. Their lower bedding planes are usually sharp. They consist of small scale ripple lamination where the dominant current ripple cross lamination is present in the lower part of the beds and passes upwards to wave ripple cross lamination. Some typical characteristics of wave origin such as offshooting and swollen upbuilding have been noticed. Upper parts of the sandstone intercalation are intensively bioturbated. (c) *Flaser lithotype* consists mainly of fine to middle grained sandstones with the thickness ranging from a few to several decimetres. They show internal ripple cross lamination. In the lower divisions of sandstone interbeds unidirectional current ripple cross lamination can be observed that passes upwards to wave-knitted lamination. Sandstone interbeds have sharp, very often erosional surfaces. The appearance of shale in this facies is restricted to rare thick lamina intercalations or thinner lamina shale drapes in ripple troughs, (d) *Plane stratified sandstones* consist of fine to medium grained sandstones with an average thickness of about 0.25 m. The lower bedding plane is sharp, slightly erosive. Very often these beds have sinusoidal ripples on the upper bedding plane. Faint ripple cross lamination can also be noticed, (e) *Micaceous sandstone beds containing plant detritus* are very often intercalated in this facies assemblage. The

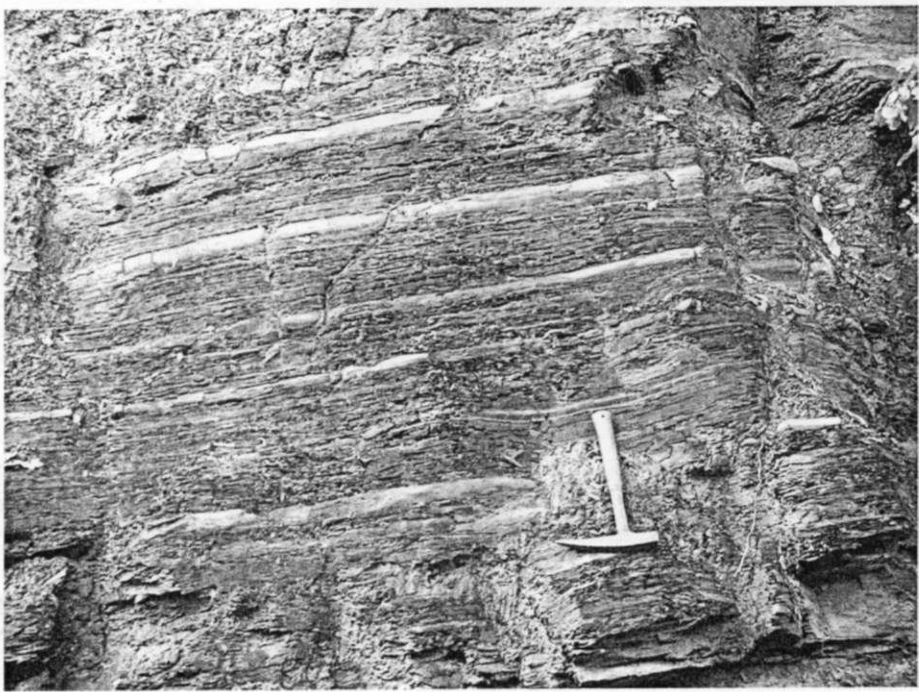


Fig 12 Stop 4. The parallel laminated shale lithotype consists of black shale as a dominant rock type while silty/sandy material appears as rare distinct lamina or thin beds.

abundant fairly well preserved plant stems or scattered plant detritus accumulate sporadically as decimetrer thick deformed or lensoid shaped layers.

Facies interpretation: The sharp and often erosive lower bedding planes of sandstone beds prove the abrupt commencement of deposition. Several groups of structures such as current ripples and erosive bases found in sandstones indicate that unidirectional currents were important as a sand transporting agent. However, wave ripple cross lamination and wave ripples found on top of some sandstone beds suggest that wave activity was an important mechanism in the redeposition of sandy material. Some types of structures resulted from the interplay of unidirectional and bedload transport and wave postdepositional reworking. Fine pelitic particles settled from suspension in quiescent periods that postdate sand deposition. Intense biogenic activity (bioturbation) appeared during the slow deposition of fines. The input of sand was possible during intense floods. *Plane parallel-stratified sandstones* show the characteristic of sediment deposited under the upper flow regime. Erosional lower bed surfaces also indicate that the sediment was derived by strong and erosive unidirectional currents, but after the material was deposited, the top of beds were reworked by waves (symmetrical wave ripples). Sheet like units of plane-stratified sand may be interpreted as sandy tongues of the mouth bar toe zone or as storm deposits.

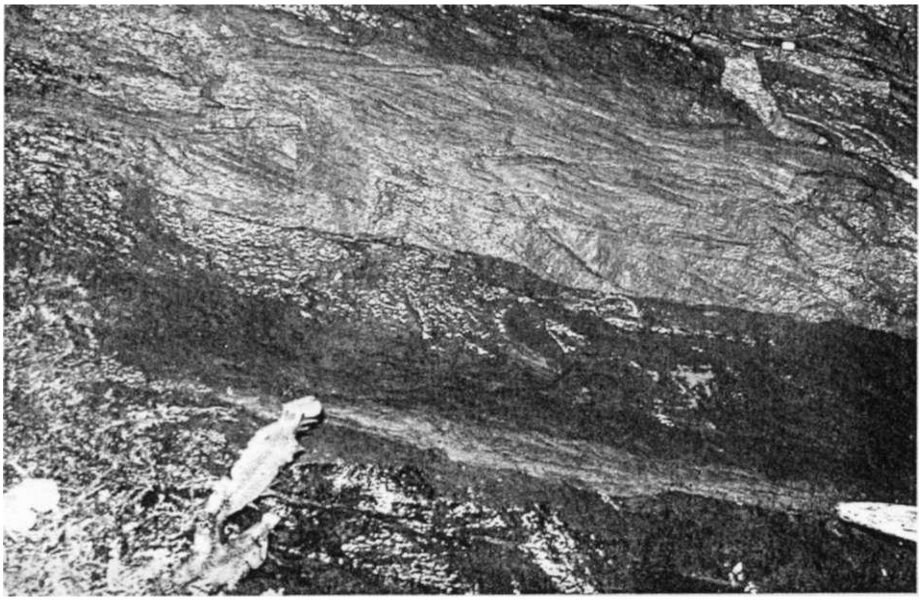


Fig. 13 Stop 4. The ripple-cross laminated lithotype consists of even alternation of ripple cross laminated sandstone interbeds (cm thick) and black bioturbated shales. Peak of the hammer for scale = 2 5 cm.

From the lateral persistence of sandstone-shale interbeds without any significant changes in bed thickness it is apparent that they were deposited on the flattened relief of the sedimentary basin which allows the interpretation as a prodelta-shelf facies. The prodelta-shelf sediment assemblage is thought to have accumulated in areas beyond and laterally equivalent to the active fan delta distributories. Some facies were surely restricted to the **subaerial or coastal** parts of the fan delta. The micaceous sandstones with abundant plant detritus represent the accumulation of plants in the most shallow, isolated parts of the depositional environment, possibly swamps. The area landward of the barrier spit can be assumed, close to the areas where the plants had grown.

General characteristics of the Cabar sedimentary succession: The sediments described at the Cabar cross-section represent the characteristics of deposition in the northern and northeastern part of the Gorski Kotar (marked as B in Fig. 5). Deposition took place in a shallow and flattened part of the basin where the coarse-grained elastics reflect the deposition of channel mouth derived material deposited partly as mouth bars, while the fine grained heterolithic facies, highly influenced by waves, is interpreted as a prodelta-shelf facies. Facies characteristics indicate the shelf fan-delta type as defined by ETHRIDGE & WESCOTT (1984). Vertical alternation of mouth bar and prodelta-shelf facies can be explained as the result of sea level oscillation within the overall subsiding trend but also as lateral shifting of temporarily active distributories. According to the low palaeorelief assumed, a slight sea level oscillation would have caused significant lateral facies changes.

The central, northern and northeastern part can be interpreted as a fan delta complex connected with the heterolithic finegrained facies (interpreted as prodelta-shelf), which assumes the Gorski Kotar region as a single depositional area, but with different basin floor morphology - Fig 5. Depositional mechanisms were different at the steep delta slope - the "slope-type delta" (central part) related to the flattened part of the basin where the "shelf-type delta" characteristics were observed (in the northern and north-eastern part) - Fig 5. In the supposed setting of active tectonism it is also possible to presume the palaeomorphological differences were caused by variations in the rate of subsidence accelerated by faulting in the central part of the basin.

Stratigraphic constraints: Although all the described facies were interpreted as contemporaneous, the question still remains whether some are relatively younger than others. This implies only minor differences in the relative ages of the rocks; it does not alter the previously determination of a Middle Permian age for the sediments. There is a possibility that the sediments with characteristics of deposition on a steep delta slope are relatively older sediments that were deposited immediately after the formation of steep faults in the initial phase of tectonic activity in either the Lower or early Middle Permian. Extensive weathering of the uplifted terrain and basin infilling result in the levelling of the depositional area and shaping of the mild palaeorelief. Therefore it is possible to assume that the sediments in the northern and northeastern part of the Gorski Kotar are relatively younger, and that they reflect deposition on a low inclined delta slope that formed after the depositional basin was partly filled and the steep relief modified. However, the absence of autochtonous fossils in the rocks, and the lack of their precise chronostratigraphic determination makes this only an assumption.

Following another possible conception, the whole Permian sequence in the Gorski Kotar region can be interpreted as the upward transition from the long lasting (Late Carboniferous - Middle Permian) deep water conditions, seen in the central part, to the shallow marine and coastal depositional conditions, seen in the northern part. This can possibly indicate a shallowing upward forearc sequence at the northern margin of the Palaeotetys which disappeared in the Late Permian (KOZUR, pers. com.).

2nd day-Velebit Mt.

Geological setting

The Upper Palaeozoic tectonic belt of Mt. Velebit and Lika represents the best known and the most completely developed Palaeozoic area in Croatia, showing a partial analogy with the Carnian Alps.

The lowermost portion of **Carboniferous** deposits of Moscovian-Kashirian age is present only in Lika but not in the area of this field trip. Kasimovian sedimentary rocks contain the first fusulinid taxa with keriothecal walls, together with calcareous algae (KOCHANSKY-DEVIDE, 1970). Gzhelian beds at Velebit Mt. are often compared with the Auernig beds of the Carnian Alps. Numerous remnants of foraminifera, brachiopods and bivalves have been found in these sediments. This horizon is well exposed at Pikovac creek valley (Stop 8). Different types of sediments can be distinguished:

(1) Argillaceous shales with brachiopods, crinoids, trilobites, bivalves and gastropods. The list of determined Pennsylvanian macrofossils from these sediments is extremely large. Numerous species of bivalves (including the genera *Lima, Pterinea, Aviculopecten, Streblopteria, Carbonarca, Schizodus, Modiola, Lucina* and several other taxa were described by RUKAVINA (1973). Among the gastropods, the most abundant are prosobranchs from the families *Naticopsidae, Bellerophontidae, Subulitidae, Murchisoniidae, Zygopleuridae* and *Pleurotomaridae.* More than thirty taxa were determined (BALAZ, 1981). Bryozoans (predominantly *Fenestella, Septopora* and *Polypora)* and scarce trilobites of the genus *Pseudophillipsia* also occur in these sediments. Particularly numerous and diverse brachiopods were studied by SIMIC (1935), productoids and spiriferids predominate. Some of the most important genera are *Linoproductus, Chaoiella, Productus, Productus, Marginijera, Neospirifer, Spirifer, Choristites* and *Martinia.* Chonetids are also numerous and diverse, as well as *Streptorhvnchus* and *Derbya.*

Crinoid stems were also found in these sediments. Local findings of the land flora indicate the vicinity of the shoreline. Almost thirty species of pteridosperms, equisetaceans, lycopodiaceans and cordaitaceans were described from this area. Some of the common genera are *Sphenopteris, Crossotheca, Pecopteris, Asterotheca, Alethopteris, Callipteridium, Odontopteris, Linopteris, Taeniopteris, Catamites, Sphenophyllum, Lepidodendron* and *Cordaites.*

(2) Fusulinid sandstones with fusulinids, crinoids and small brachiopods are developed in the wider area. Fine-grained greenish-grey sandstones with small fossils, and medium-grained, brownish-yellow weathered sandstones with fusulinids, brachiopods, bivalves and crinoids can be distinguished. The brachiopod species *Chaoiella grunewaldti* KROTOV is extremely abundant in these sediments.

(3) Limestones interbedded with argillaceous shales, with a predominance of *Anthracoporella spectabilis* productoid and spiriferid brachiopods are rather common in the sediment succession, while bivalves, molluscs, cephalopods and corals occur sporadically. Crinoid remnants predominate at several localities, aiding the production of carbonate sediments. Small fusulinids also occur in these sediments.

(4) Quartz-conglomerates commonly contain pebble sized clasts. They gradually pass into sandstones. Marine sediments predominate over sporadic intercalations of continental origin. The same type of sedimentation was prolonged into the Lower Permian.

A schematic column of the Permian rocks is shown in Fig. 2: the Lower Permian '"Rattendorf' limestones, although scarce, can be divided into three horizons on the basis of fusulinid foraminifera. The microfossil assemblage indicates a Sakmarian age for these sediments.

The Kosna beds (clastic equivalents of the Trogkofel limestone) are developed in a much broader area. Colourful conglomerates with limestone pebbles, fine/grained quartz conglomerates, red, yellow or grey pyritic sandstones and, very seldom, limestones with *Da)-vasites, Pseudoschwagerina* and calcareous algae can be distinguished. Typical Kosna conglomerates with clasts of Middle Carboniferous, Upper Carboniferous and Sakmarian limestones, outcrop at Kosna voda spring, NW from Brusane and in Pikovac creek valley - Stop 8.

Middle and Upper Permian sediments represent a continuous series of dolomites and limestones, that concordantly overlie the red Kosna sandstones. A gradual transition from the red sandstone into the black limestone of the zone *Eoverbeekina salopeki* can be observed at Paripov jarak, west from Brusane village (near Stop 5). Limestones contain large gastropods: *Platystoma, Bellerophon,* cephalopods *(Orthoceras)* and a typical microfauna *(Eoverbeekina, Sphaerulina, Staffella).* Limestones are overlain with an approximately 300 m thick sequence of grey "spotted" dolomites. White spots are recrystallized fossils, predominantly *Mizzia,* accompanied by *Eoverbeekina, Staffella, Neo.se/nvagerina, Waagenophyllum, Bellerophon, Pleurotomaria, Orthoceras* and *Edmondia.* Middle limestone zone - Zone *Neoschwagerina craticulifera* (Stop 5), is extremely rich in macrofossils. Numerous brachiopods (45 taxa), predominantly spiriferids, enteletids, productoids, oldhaminoids, including several endemic species; the aberrant bivalve *Tanchintongia,* calcisponges, bryozoans and gastropods have been collected from the area of Brusane and Baske Ostarije (Fig. 1). Foraminifers *(Neoschwagerina, Dunbarula, Nankinella, Schubertella, Glomospira, Globivalvulina* etc.) and calcareous algae *(Mizzia, Vermiporella, Gymnocodium, Permocalcnlus* and many other taxa) are extremely abundant (KOCHANSKY-DEVIDE, 1965; KOCHANSKY-DEVIDE et al., 1982; SREMAC, 1986, 1991).

The middle and the uppermost limestone zones are separated, or, at some places, replaced with light grey crystallime dolomite ("Schwagerina-dolomite" sensu SALOPEK, 1942) with *Mizzia, Likanella, Salopekiella, Goniolinopsis, Neoschwagerina, Kahlerina, Dunbarula* and gastropods. Fauna from the lowermost limestone zone also occurs sporadically *(Staffella, Eoverbeekina).* At some localities, sedimentation of so-called "transitional dolomites" (sensu SALOPEK, 1942) with poorly preserved fossil assemblage, had already begun in this period.

The uppermost limestone zone was named after the dominant fusulinid species - Zone *Yabeina syrtalis* (Stop 6), Although, *Yabeina* also occurs in the middle limestone horizon, but not in such numbers. Differences in the microfossil assemblages are not very distinct from the middle limestone zone, but some new macrofossils occur in the Yabeina-zone, such as brachiopods *(Derbya, Streptorhynchus, Orthotetes)* and gastropods *(TemnocheHus)* (SALOPEK, 1942; KOCHANSKY-DEVIDE, 1965). In its lower portion predominantly gymnocodiaceans have been found (RAMOVS & KOCHANSKY-DEVIDE, 1981). A lack of index species in the uppermost dolomite beds leave the problem of the Permian-Triassic boundary open. Dense "transitional" dolomites (sensu Salopek) are well bedded and rather poor in microfossils. In the lower portion predominantly gymnocodiaceans have been found, the uppermost portion contains small foraminifers, with a predominance of Earlandiacea.

Stop 5: Paripov jarak - Middle Permian patch-reef limestones *(Neoschwagerina craticulifera zone)*

In the area of Brusane and Baske Ostarije villages, in the central part of the Velebit Mt., three distinctly separated zones of black limestones can be clearly distinguished within the light grey dolomites of Middle and Upper Permian age (Figs, lb & 2). These limestones are characterized by numerous well-preserved micro- and macrofossils, thus enabling the precise stratigraphic division.

The zone named after the large fusulinid *Neoschwagerina craticulifera* (Middle Permian) is up to 30 m wide, and ca. 8. km long. During the detailed research numerous macrofossils and microfossils (175 taxa in total) were determined and fossil communities were studied (SREMAC. 1986, 1991).

A shallow platform environment with calcareous algae, large benthic foraminifera, and, at some places, numerous macrofossils (bryozoans, brachiopods, corals, bivalves) was widely spread in this area during the Murghabian (Fig. 14a). Almost thirty taxa of dasycladaceans and gymnocodiaceans were determined - *Mizzia, Vermiporella, Gymnocodium* and *Permocalculus* were the most abundant (Fig. 14b, c, d, e). Cyanobacterial crusts'were extremely important in the formation of mounds and patch-reefs. Foraminifera are the most diverse, with almost 50 taxa. Large fusulinids *(Neoschwagerina, Nankinella)* are often associated with calcareous algae, and/or with other fossils. Small foraminifera were sometimes part of these diverse communities, but sometimes formed their own assemblages *(Globivalvulina, Glomospira* and some other taxa). *Tubiphytes* was widespread in this area, supporting the consolidation of the sediment (Fig. 14c). Calcisponges (eg. *Sinocoelia, Imilce)* played the most important role in the formation of patch-reefs. Large brachiopods inhabited reef cavities *(Martinia, Enteietes),* lived on muddy substrate anchored with spines (e.g. *Ramovsia* and many small productids) or even formed biostromes by cementing themselves on the sea floor or on each other *(Leptodus, Keyseriingina).* They were the most diverse and abundant large marine invertebrates in this area. Bafflestones with *Waagenophyllum* can also be found at some places. Molluscs, though represented with 28 taxa, were less important. Large, aberrant *Tanchintongia* is an exception, forming lumachells at several localities. Small sized gastropods and cephalopods were found only sporadically. Bryozoans, predominantly fenestellids, played an important role in the formation of mounds and reefs. Fragments of echinoderms (radiolae, columnalia) can be found in bioclastic sediments.

Among the boundstones with an autochtonous community the bryozoan-calcisponge-cyanobacterial bioherm is the most interesting phenomenon. Large fenestellids were the first to colonize the substrate. Smaller bryozoans and calcisponges attached themselves to their fans, and were altogether overgrown with cyanobacterial crusts (Fig. 140- In later phases, the reef framework was almost solely composed of calcisponges (Fig.l4g). Reef cavities were inhabited with other benthic organisms. Brachiopods *Martinia velebitica* SREMAC and *Enteietes salopeki* SREMAC were the most abundant within the reef framework. At least three times the reef was buried in carbonate mud or fine grained bioclastic detritus of reef origin, and the recolonization had to start from the beginning. Three main cycles of reef formation have been observed (SREMAC, 1991; MARJANAC & SREMAC, 2000). Bioclastic sediments with redeposited microfossils (foraminifera, calcareous algae, fragments of *Tanchintongia)* can be found around the patch-reef.

Some shallow parts of the platform emerged from time to time; according to the oscillation of the sea-level there is no evidence of continental or pelagic Murghabian sediments in the vicinity. Therefore the position and distance of the Murghabian land cannot be proved.

In most of the neighbouring regions, the Middle Permian is represented by clastic Groden deposits, which are overlain by the Upper Permian Bellerophon limestone. The area of Velebit Mt. differs from other known Permian localities in the long-lasting carbonate sedimentation and peculiar macrofauna, and it is very dificult to make any conclusion on its regional position.

Stop 6: Road cut near Brusane - - the Upper Permian peritidal carbonates *(Yabeina syrtalis* zone)

Stop 6 is a continuous section of shallow water peritidal carbonates that continuously overlie the patch-reef limestones of Stop 5. According to previous studies (KOCHANSKY-DEVIDE, 1979; SREMAC, 1991; TISLJAR et al., 1991) the section represents the Upper Permian *Yabeina syrtalis* zone as shown in Fig. 15a). Along the approximately 200 m thick succession several facies types can be distinguished.

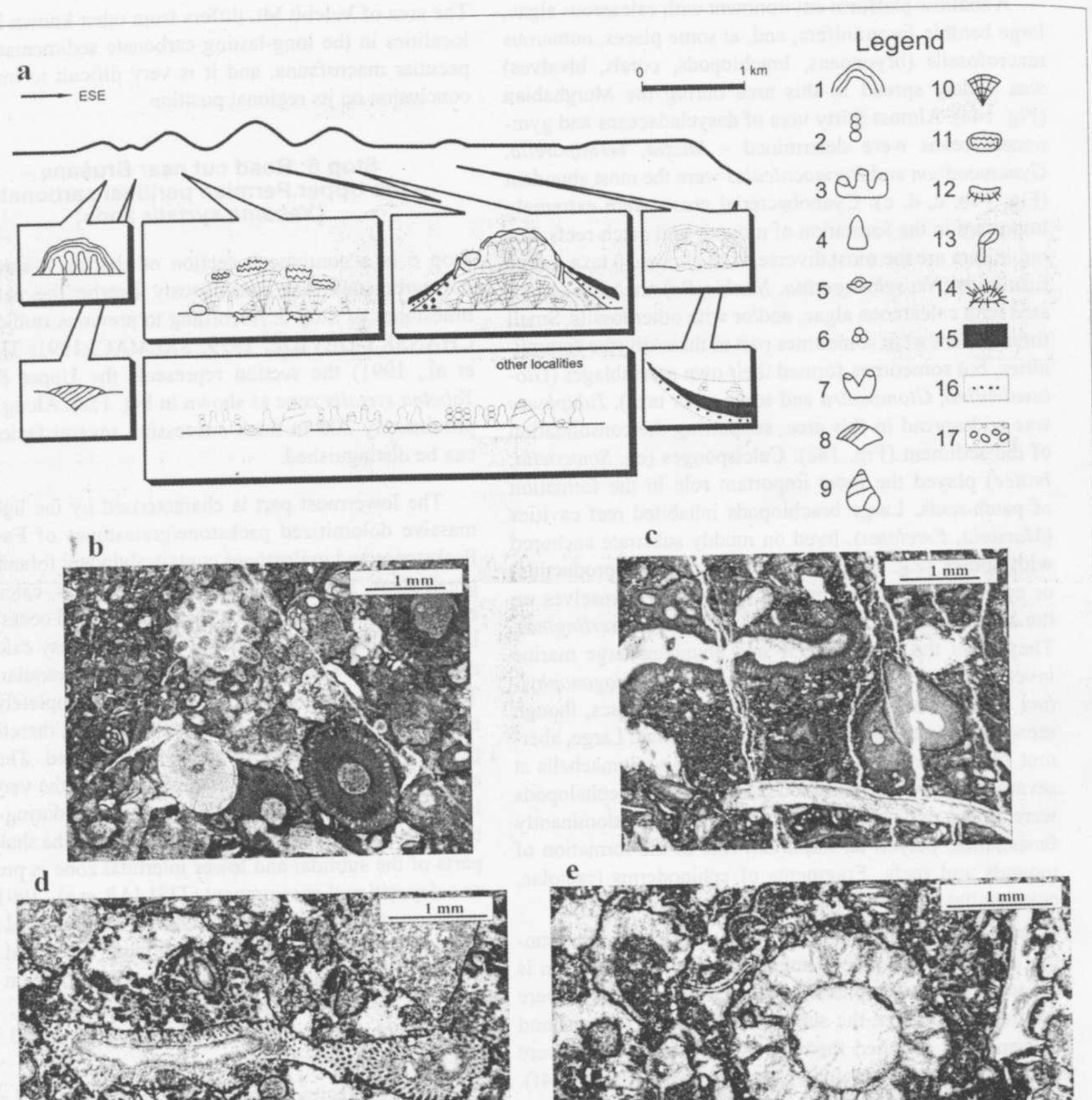
The lowermost part is characterised by the light grey massive dolomitized packstone'grainstones of Facies A. Packstones and grainstones contain abundant foraminifera, green algae, bioclasts of echinoderms, corals, calcisponges, gastropods, brachiopods (Fig. 15b, c), and occasionally large cortoids (micritic bioclasts) occur. Drusy calcite cement or micrite matrix is found in the intergranular pores. The rocks in this part of the section are completely dolomitized in the manner of mimic replacement; therefore the primary rocks remain structurally unchanged. The presence of vugs filled with crystal silt indicate the very shallow environment and occasional emersion during which the vugs occurred by dissolution processes. The shallowest parts of the subtidal and lower intertidal zone is proposed as a depositional environment (TISLJAR et al, 1991). The macrocrystalline dolomite structures were noticed in addition to the macrocrystalline dolomite types and partly dolomitized limestones. Early stage dolomitization of the platform limestones is suggested (TISLJAR et al, 1991), but the late diagenetic phase with mimic replaced fossils can also be assumed .

Rocks of Facies A contain the following fossil assemblage: foraminifera *(Hemigorius* and *Globivalvitlina* are the most abundant), calcareous algae *(Permocalculciihis),* encruster *(Tubiphytes)* and macro fossil fragments of gastropods (abundant), bivalves, brachiopods and echinoids.

Facies B is represented by the early diagenetic supratidal dolomites that overlie Facies A. It consists of a 30 m thick sequence of wavy laminated cryptalgal (stromatolitic) dolomites and dolomicrites that are light to dark grey (TISLJAR et al., 1991) in colour. This facies is divided into three parts.

The lower part of Facies B consists of dolomicrites and the occasional appearance of undulous cryptalgal laminae or thin cryptalgal beds. In the dolomicrites debris of thin-shelled bivalves and microgastropods are present. Irregular fenestrae, green algae, as well as moulds of shells appear. There are also solution vugs filled with internal sediments in their lower part and dolomite drusy cement in their upper part (geopetal structures).

In the middle part the thin cryptalgal dolomitised (stromatolite) beds/laminae occur (Fig. 15c). containing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in places dolointrasparite laminae, and rarely dolomicrite laminae with a clotted micrite structure. Desiccation and shrinkage cracks interrupt the continuity of laminae and thin-bedded edgewise breccia occur occasionally. The breccia consists of platy cryptalgal or micritic fragments which accumulate forming beds a few centimetres thick. Fragments were formed due to desiccation or shrinking of the cryptalgal or micritic rocks. Approching the top of this part, the quantity of stromatolitic laminae decreases, while the quantity of cryptocrystalline dolomites (dolomicrites and dolopelsparites) increases.

The upper part of the Facies B is an approximately 16.5 m thick interval of dark grey laminated cryptocrystalline dolomites. Laminae are 2-10 mm thick, and are composed of dolopelmicrite, dolointrasparite, dolopelsparite, dolomicrite, and occasionally stromatolite. Towards the uppermost part of this interval the colour of the dolomicrites darkens to black; the dark colour probably originated from organic matter and the presence of fine-grained pyrite suggests the activity of sulphate reducing bacteria (TISLJAR et al, 1991).

In contrast to Facies A, the fossil assemblage no longer contains large fusulinids, but numerous taxa of small foraminifera *(Globivakulina* and *Glomospira)* occur instead as well as ostracods.

The textural and structural characteristics of facies B, in particular the stromatolite laminae with desiccation cracks, the fenestral fabrics, the isolated edgewise breccia, and the degree of dolomite crystallinity (0.01 mm), suggest supratidal early-diagenetic dolomitization, possibly in sabkha like conditions (TISLJAR et al., 1991).

Facies C consists mostly of limestones although the dolomites are still present. The rhythmic alternation of organically rich mudstones and bioclastic-intraclastic packstone or floatstones occur. Metre scale coarsening upward cycles containing mudstones in the lower part and packstone/grainstones in the upper part can be observed.

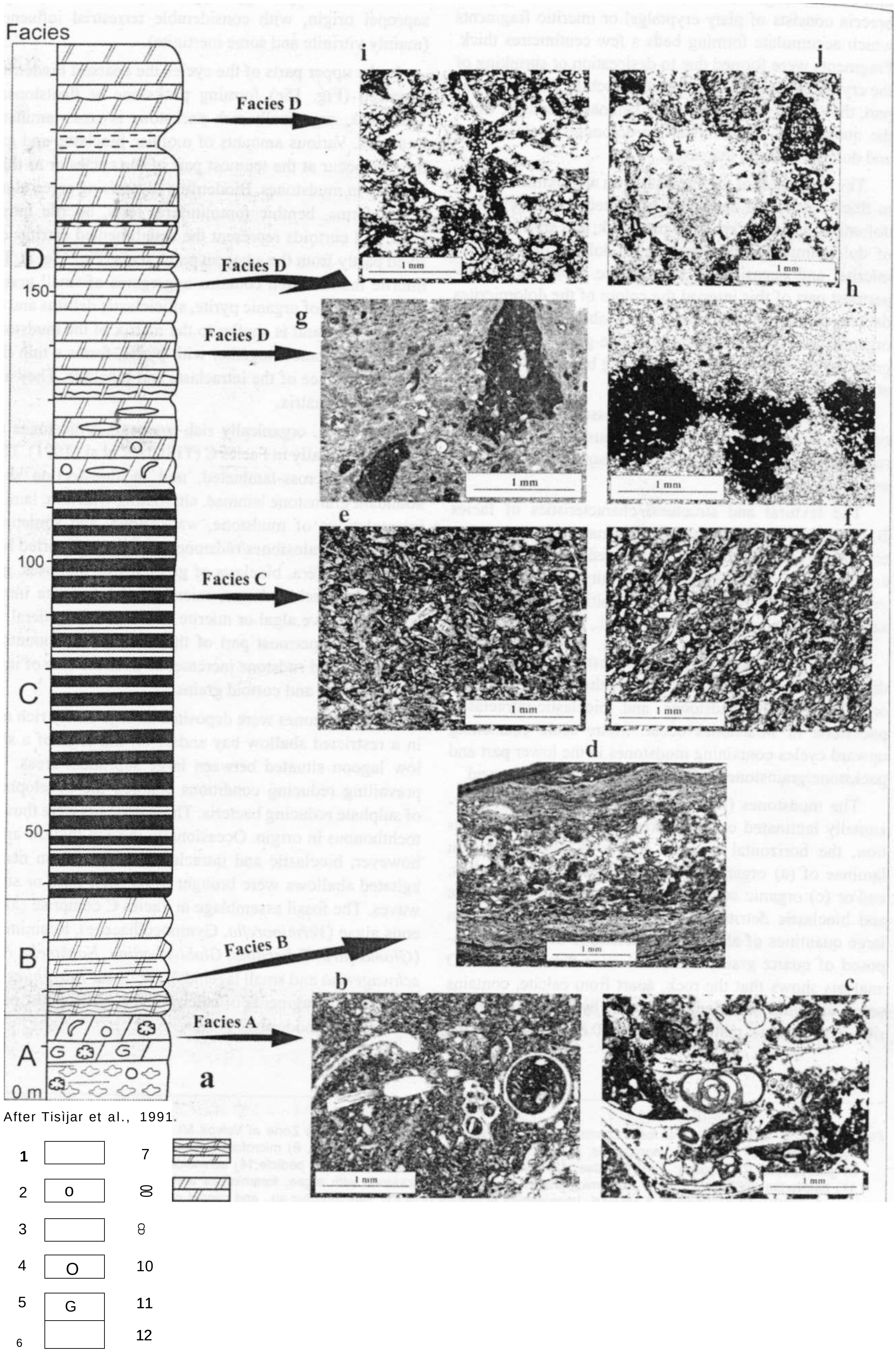
The mudstones (lowermost cycles' portion) are horizontally laminated or show extreme fissility. In thin-section, the horizontal laminae appear as alternating thin laminae of (a) organically rich micrites, (b) biomicrites, and/or (c) organic substance with or without siliciclastic and bioclastic detritus. Some bioclastic laminae contain large quantities of algae. The siliciclastic detritus is composed of quartz grains and small mica flakes. The XRD analysis shows that the rock, apart from calcite, contains small amounts of dolomite, quartz, hydromica, and pyrite. The organic matter content is 0.88% C_{org}, and the microscopic analysis shows that it is strongly thermally altered (%R_c = 2.43 ±0.26), corresponding to the dry gas formation stage, i.e. metagenesis (TISLJAR et al, 1991). The maceral morphology suggests a predominantly algal-sapropel origin, with considerable terrestrial influences (mainly vitrinite and some inertinite).

In the upper parts of the cycles the coarsest biodetritus appeared (Fig. 15e) forming packstone or floatstones . The black, organically rich packstone is cross-laminated in places. Various amounts of mollusc bioclasts, and gastropods occur at the topmost part of the cycles or as thick laminae in mudstones. Biodetritus comprising green algae, echinoderms, benthic foraminiferal tests, micrite intraclasts, and cortoids represent the resedimented detritus derived partly from the adjacent patch reefs (Fig. 15e, f). The micrite matrix often contains aggregates of small grains, impregnation of organic pyrite, siliciclastic detritus and organic matter, and is similar to the matrix of the mudstone. Organic substance, together with pyrite, forms a thin film over the surface of the intraclasts and bioclasts. They also occur in the matrix.

The black, organically rich grainstones/rudstones appear occasionally in Facies C (TISLJAR et al, 1991). They are usually cross-laminated, and in thin-section show abundant grainstone laminae, alternating with thin, laminal intercalations of mudstone, wackestone, and sometimes packstone. Grainstones/rudstones contain well-sorted benthic foraminifera, bioclasts of green algae, molluscs, gastropods and echinoderms; micrite and biomicrite intraclasts often have algal or micrite envelopes. In general, towards the uppermost part of this facies, the amounts of grainstone and rudstone increase, as does the size of intraclast, bioclast and cortoid grains.

The mudstones were deposited as organically rich mud in a restricted shallow bay and/or on the edge of a shallow lagoon situated between large supratidal areas. The prevailing reducing conditions enabled the development of sulphate reducing bacteria. These deposits were thus autochthonous in origin. Occasionally in such shallow areas, however, bioclastic and intraclastic detritus from nearby agitated shallows were brought in by high tides or storm waves. The fossil assemblage in Facies C comprise calcareous algae *{Vermiporella,* Gymnocodiaceae). foraminifera *{Glomospira, Tuberitina, Globivalvulina, Nankinela, Neoschwagerina* and small lagenids), encruster *Tubyphiies* and macrofossil fragments of calcisponges, gastropods, ostracods and echinoderms.

Fig. 14 Stop 5. a) Distribution of fossil communities in the *Neoschwagerina craticulifera* Zone at Velebit Mt. (Brusane Region). Legend: 1) cyanobacteria; 2) Mizzia; 3) Vermiporella; 4) gymnocodiaceae; 5) macroforaminifera, 6) microforaminifera; 7) porifera; 8) Tanchintongia; 9) gastropoda; 10) bryozoa; 11) lyttoniidae; 12) productoidea; 13) brachiopods with pedic!e;14) echinoideae 15) shale; 16) calcarenite; 17) calcirudite (SREMAC, 1991). Photomicrographs: b) bioclastic packstone with algae, foraminifera and macrofossil fragments *(Mizzia cornuta* KOCHANSKY-DEVIDE & HERAK, *Vermiporella nipponica* (ENDO), *Hemigordius* sp., and crinoid ossicles); c) bioclastic packstone with *Vermiporella longipora* PRATURLON & *Tublphytes obscurus* MASLOV; d) packstone with *Gymnocodium Bellerophontls* ROTHPLETZ; e) packstone with *Mizzia velebitana* SCHUBERT, *M. cornuta* KOCHANSKY-DEVIDE & HERAK, and small foraminifera; f) bryozoan-calcisponge-cyanobacterial framestone; sample was taken from the base of the reef. In the lower part of the photograph generations of overgrowth can be observed. Smaller bryozoans and calcisponges (2) attached themselves to large fenestelids (1) and then were all overgrown together with cyanobacterial crusts (3); peel 6x4 cm; g) plate-like calcisponges growing on each other; peel 6x4 cm.



After Tisijar et al., 1991.

Stop 7: Road cut near Brusane - the Upper Permian thick-bedded tabular dolomites (transition to Lower Triassic deposits)

These tabular like thick bedded dolomites ("transitional dolomites") continuously overlie limestones of Facies C from the former stop (facies D of TI$LJAR et al, 1991). The transition from limestones to dolomites is rather abrupt. In the uppermost part of the section nodular dolostones and thin grey shale intercalations appear.

Within the 85 m thick section tabular like layers or faintly laminated dolomites can be seen. The thickness of layers varies from 0.5 to 1.5 m. Bedding plains are sharp, usually flat, sporadically wavy. In thin section two stages of dolomitization can be seen: the dolomicritic structure of possible early diagenetic peritidal origin (TISLJAR et al., 1991), as seen in Fig. 15g, and subhedral macrocrystalline dolomite of late diagenetic origin (Fig. 15h). Late diagenetic dolomitization partially destroyed the primary structure of the rock. According to the preserved relics, the primary rock resembles the bioclastic limestones of Facies C at Stop 6. A rather poor fossil assemblage was preserved - most of the skeletons were dolomitized as well as the matrix of the rock (Fig. 15i, j). In the uppermost part of the section geopetal crystal silt fils the algal vugs.

The laminated dolomite types represent the alternation of laminae with dolomicrite structure and laminae with preserved intraclastic detritus. The nodular like dolomite has a homogeneous dolomicritic structure including isometric pyrite crystals.

Shales contain microcrystallinic carbonates (dolomite, calcite) and siliciclastic detritus composed of quartz, hydromica, chlorite, Fe-oxide and hydroxide.

According to the microcrystalline structure, intraclast remnants, and geopetal crystal silt, a supratidal early diagenetic origin in a regressive cycle was proposed (TISLJAR et al., 1991). Nevertheless, late diagenetic dolomitization appears to be the dominant phase during which the primary structure was mainly destroyed. Insertion of finegrained siliciclastic detritus into early-diagenetic dolomites is a common phenomenon in the Upper Periman rocks. In this area, this might be a sign of the imminent shift of a shallow peritidal sedimentation area to the terrestrial, dominantly siliciclastic realm. Although the change of composition appeared in the uppermost part of the section, the fossil assemblage is still typical for the Upper Permian. Microfossil communities from thick-bedded tabular dolomites are characterized by a decreased number of calcareous algae, as well as large fusulinid foraminifera. On the other hand, globivalvulines, lagenids, miliolids and palaeotextulariaceans took advantage, and become dominant constituents of the communities. The uppermost part of the section contains small foraminifera, with a predominance of Earlandiacea, typical for stressed environments (IBRAHIMPASIC & SREMAC, 2002). The lack of index species in the uppermost dolomite beds leaves the problem of the Permian-Triassic boundary open.

Although relatively poorly preserved, several fossil genera can be obtained: foraminifera *(Agathammina, Glomospira, Globivalvulina, Endothyra,* Earlandiidae, *Hemigordius, Nankinella, Schubertella,* Palaeotextulariidae), algae *(Anhtracoporella, Connexia, Deckerella, Epimastoporella, Gyroporella,Mizzia,Permocalcidus, Vermiporella,* Gymnocodiaceae) and skeletal fragments of macrofossils.

Stop 8: Carboniferous sediments in the Pikovac creek valley

In the valley of the Pikovac creek, north of Brusane, there is a cross-section that according to SALOPEK (1942) represents one of the best-developed successions of the Upper Carboniferous clastic sediments in this part of Croatia. In the creek gully, the Middle Permian clastic sediments can be observed, including characteristic Kosna conglomerates, named after the nearby type locality Kosna Voda. The facies as described by Salopek are shown in the detailed geological map (Fig. lb).

The oldest rocks exposed in the valley of the Pikovac creek are the elastics and carbonates for which the age of the Auernig layers (Carboniferous) was supposed. The characteristic facies observed are the black silty shales, limestones, fusulinid sandstones, conglomerates and limestone breccias.

The age of the succession was defined by the fossil content of the packstone and grainstone limestones intercalated with shale. Apart from the autochtonous skeletal detritus, these limestones contain ooid detritus as well. The most important findings in these layers comprise algae -*Anthracoporella spectabilis* PIA, foraminifera - *Ozawainella sp., Boultonia sp.,* brachiopods of the productidae group - *Martinia sp., Phillipsia sp.,* as well as small dielasmae *(D. plica* Kut. sp., SALOPEK, 1942). Based on this fossil community, Salopek expressed doubt on the Upper Carboniferous age of the limestones and interstratified clastic rocks. The excursion authors share the opinion that, on the basis of the determined fossil community (calcareous algae - *Anchicodium, Eugonophyllum, Anthracoporella, Epimastoporella. Velebitella, Gymnocodiaceae;* foraminifera - *Tuberitina, Tetrataxis, Endothyra, Schubertella, Bradynia. Triticites. Rugosofusulina;* macrofossil fragments of calcisponges, gastropods, ostracods, bryozoans, brachiopods. crynoids)

Fig. 15 Stops 6 & 7: *Yabeina syrtalis* zone & "transitional" dolomites, a) section at the road cut near Brusane (geological column after TISLJAR et al.. 1991). Legend: 1) echinoderms; 2) fusulinids; 3) corals: 4) algae, 5) gastropods; 6) bivalves; 7) early-diagenetic stromatolitic dolomites; 8) early-diagenetic dolomites; 9) late-diagenetic dolomites; 10)shale; 11) packstone-mudstone alternation; 12) nodular like dolomite. Photomicrographs of Facies A: b) fragments of brachiopods and gastropods in mud matrix; c) grainstone with foraminifera and brachiopod fragments; Facies B: d) stromatolites with doloíntrasparite laminae; Facies C: e) packstone with small foraminifera *(Geinitzma pastcarbonica* SPANDEL): f) laminated packstone with small foraminifera *(Hemigordius)* and algal fragments; Facies D: g) cyanobacterial oncoids in dolomicrite; h) anhedral macrocrystalline dolomite structure with diagenetic pyrite crystals (black); i) partially dolomitized matrix in bioclastic packstone: j) *Mizzia velebitana* SCHUBERT and *Gymnocodium* sp. *Mizzia* is recrystallized and dolomitized.

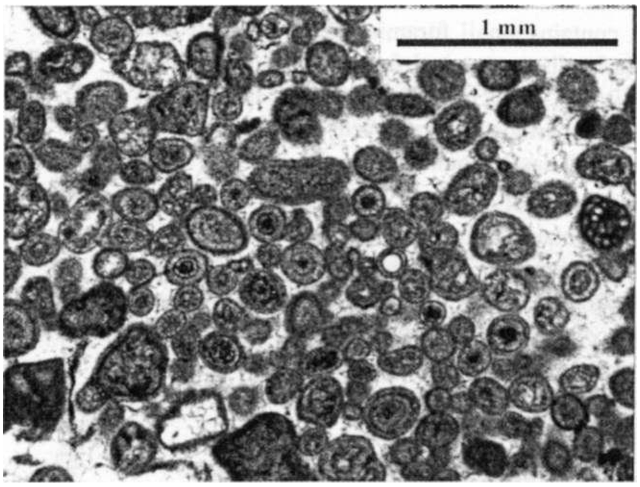


Fig. 16 Stop 8. Upper Carboniferous? - Lower Permian? ooid grainstone.

the fossil assemblage resembles that for the Rattendorf beds (the lower megacycle of the post-Variscan sediments of the Carnic Alps; KRAINER, 1993).

In the Pikovac creek valley, limestones occur at several horizons. The thickness of limestone intervals does not exceed 10 metres. Between these limestones the black shales crop out. Limestones are either bioclastic packstones or ooid to bioclastic grainstones (Fig. 16). The grainstone types contain well-preserved ooid and skeletal detritus, and they are considered to represent the autochtonous rocks. Large limestone lenses within the shale could be interpreted as olistolithes rather than the autochtonous deposits.

In the black shales, except for the pelitic siliciclastic detritus, there are laminae and interlayers of sandstone and micaceous sandstone. The bedding planes are full of fossils: brachiopods, bryozoans, gastropods, crynoids, corals and molluscs. In the micaceous sandstone interbeds plant remains occur *(Alethopteris, Annularia, Acitheca, Asterotheca, Odontopteris, Callipteridium, Catamites, Cordaites* - SALOPEK, 1942).

The shales occasionally contain thin interbeds of calcareous limestones - calclithites, wherein well-preserved fusulinids of the genus *Triticites sp.* can usually be found.

Several horizons of conglomerates and sandstones crop out in the valley of the Pikovac creek and are interlayered with shales. According to their mineral composition, the conglomerates are of oligomyctic and petromyctic types. The black coloured varieties enriched in pyrite and organic matter also occur. Some conglomerate types contain well-rounded pebbles of black chert. The variety of calcareous conglomerate is characterised by domination of the poorly-rounded clasts of irregular shape, of more than 5 cm diameter.

In the conglomerate layers, clast- and matrix-supported massive conglomerates were identified, either of bimodal or polymodal composition. The polymodal varieties are extremely rare. Graded and inversely graded conglomerates are also present. In the graded types, the transition from the clast-supported (close to the base of layers) into the matrix-supported structural type (in the uppermost part of the lavers) can be observed. Within the inversely graded layers, the gradual coarsening upward of clast-supported pebbles is observed at first and then again normal gradation and a transition into the more fine-grained clast-supported topmost part. The layers of both normally and inversely graded sandstones have a thickness ranging from a few to a maximum of seven metres. The bedding surfaces are sharp and usually planar.

The sandstone layers are most frequently tabular and show massive structure. Sometimes they exhibit parallel or ripple cross lamination. Thin granular interbeds also occur, usually depicting the bottoms of shallow channels, or show-chaotic distribution of granules within the predominantly sandy material. The micrographic characteristics of sandstones define them as lithic greywackes. Apart from quartz grains that dominate their composition, there are fragments of chert, quartzites, low grade metamorphic rocks and recrystallised volcanic rocks. Also, rare feldspar grains are identified (mostly plagioclase). The cement is quartz-sericite. Occasionally, the pores are filled with sparry calcite cement as well as with large pyrite crystals, resulting in the green colour of the rock.

The complete succession of limestone intercalations within shales with marine fauna confines the deposit to the marine realm. The intimately associated sandstones containing well preserved plant detritus indicate that land masses were probably adjacent to the depositonal environment. Very fine grained rippled sandstones commonly intercalated in shales represent the sudden influx of sand material to the region where normally suspension settling of fines occurerd. These are attributed to periods of flooding. The association of black shales with black carbonates suggest deposition in the restricted area beside the active siliciclastic distribution where limestones were deposited. The grainstones containing ooid detritus represent autochtonous shallow marine limestone types. The calcareous sandstone types rich in black calcite matrix and abundant bioclasts can be interpreted as resedimented rocks. Calcareous detritus came from the shallow parts of the nearshore environment where limestone sedimentation occured.

The conglomerate/sandstone facies association observed in the Pikovac creek can be produced by both traction and mass flow processes in the area of an activ e delta front or at the channel mouth. The abundance of traction current structures (granule to pebble clasts line shallow troughs, parallel and ripple laminated sands) can be interpreted as a channel mouth bar complex. The inverse graded and massive conglomerate types interpreted as mass flow deposits may be the product of oversteepening and failure on the slope of a mouth bar. The normally graded conglomerates were probably the product of a turbidity current generated from liquefied debris flows.

The micaceous sandstones with abundant plant detritus represent the shallowest parts of the depositional environment and probably the quiet, protected parts of the environment. The area landward of the coastline and possibly mouth bar or barrier spit can be assumed.

In the part of the Pikovac creek the Middle Permian Kosna type conglomerates can also be observed (fig. I 7). The Kosna conglomerate succession consists of pebble size

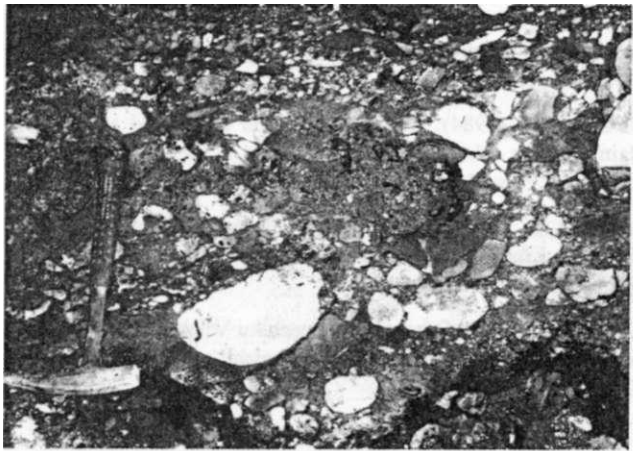


Fig. 17 Stop 8. Permian Košna conglomerate.

oligomyctic quartz rich conglomerate types that intercalate with limestone, rich, mostly cobble sized (4-250 mm) conglomerates (KOCHANSKY-DEVIDE et al., 1982). The quartz conglomerates sporadically interfinger with red sandstones. The matrix content is very low. Typical Kosna conglomerates are composed of poorly sorted limestone clasts with some pebbles of quartz, chert and sandstones. The limestone clasts contain Middle and Upper Carboniferous and Lower Permian microfossils. The structure of typical Kosna conglomerates is polymodal, massive and/or graded.

The origin of Kosna-type conglomerates still remains poorly understood and will be the task for further investigations and discussions.

References

ALJINOVIC, D. (1997): Late Palaeozoic and Early Scythian clastic fades.- Unpubl. PhD Thesis, University of Zagreb, 163 p.

ALJINOVIC. D. & SREMAC, J. (1997): The Middle and Upper Permian deposits in Gorski Kotar: facts and misconceptions.- Geol. Croat., 50/2, 231-242, Zagreb.

ALJINOVIC. D.. SLOVENEC, D.. DURN. G., SLAVKOVIC, R. MIKO. S & KOLARIC, D. (2000): Mineral occurrences in Palaeozoic clastic and Lower Triassic carbonate rocks in Gorski Kotar (Croatia).- In: VLAHOVIC. I. & BIONDIC. R. (eds.): 2nd Croatian Congress, Cavtat-Dubrovnik. Proceedings. 59-64, Institute of Geology. Zagreb.

BALAZ. E. (1981): Carboniferous gastropods of Lika and Velebit.- Paleont. JugosL, 26, 1-23, Zagreb.

CASSINIS. G., MASSARI, F., NERI, C. & VENTURINI, C. (1988): The continental Permian in the Southern Alps (Italy). A review.- Z. Geol. Vv'iss. 16. 11-26., Berlin.

ETHRIDGE. D.G. & WESCOTT. W.A. (1984): Tectonic setting recognition and hydrocarbon reservoir potential of fan delta deposits. In: KOSTER. E.H. & STEEL. R.J (eds.): Sedimen-(ology of Gravels and Conglomerates - Me. Can. Soc. Petrol. Geol.. 10. 217-235.

FRIEDMAN. CM. & SANDERS, J.E. (1978): Principles of Sedimentology. John Wiley & Sons. New York. 769 p.

GREGG, J.M. & SIBLEY D.F. (1984): Epigenetic dolomitization and the origin of xenotopic dolomite texture - Jour. Sed. Petrology, 54, 908-931.

GRUBIĆ, A. (1980): Early Middle Permian break in the geotectonic evolution of Yugoslav Dinarides.- In: Metalogenesis of Uranium, 26th Inter. Geol. Cong, in Paris, sect. 13.2.2., Geoinstitut, Beograd, 203-214.

HERAK, M. (1986): Anew concept of geotectonics of the Dinarides-Acta Geol., 16/1, 1—42, Zagreb.

IBRAHIMPAŠIĆ, H. & SREMAC, J. (2002): End Permian regresión - evidence from meiobenthic fossil communities from the Velebit Mt. (SW Croatia).- In: YANKO-HOMBACH, V. (ed.): The Third International Congress "Environmental Micropaleontology, Microbiology and Meiobenthology" EMMM 2002, Abstracts, 101-103, Vienna.

ITALIAN RESEARCH GROUP (1986): Field Conference on Permian and Permian-Triassic boundary in the South-Alpine segment of the Western Tethys- IGCP Proj. No 203, Excursion Field Guidebook. Societa Geológica Italiana, Commerciale Pavese, Pavia, 158 p.

JELASKA, V. & PROHIĆ, E. (1982): Facijelne karakteristike permskog fliša područja Mrzle Vodice (Gorski kotar, Hrvatska).- Jubilarni kongres geologa Jugoslavije, Zbornik radova, 1, 473-481, Budva.

KLEINSPEHN, K.L., STEEL, R.J., JOHANNESSEN, E. & NETLAND, A. (1984): Conglomeratic fan delta sequences. Late Carboniferous - Early Permian, western Spitsbergen.- Can. Soc. Petrol. Geol, Mem., 10, 279-294.

KOCHANSKY-DEVIDÉ, V. (1965): Karbonske i permske fuzulinidne foraminifere Velebita i Like. Srednji i.gornji perm (Die fusuliniden Foraminiferen aus dem Karbon und Perm im Velebit und in der Lika (Kroatien) Mittleres und Oberes Perm).-Acta geol., 5, 101-137, Zagreb.

KOCHANSKY-DEVIDE, V. (1970): Die Kalkalgen des Karbons vom Velebit-Gebirge (Moskovien und Kassimovien).- Palaeont. Jugosl, 10, 1-32, Zagreb.

KOCHANSKY-DEVIDE. V. (1973): Trogkofelske naslage u Hrvatskoj.- Geol. vjesnik, 26, 41-51, Zagreb.

KOCHANSKY-DEVIDÉ, V. (1979): Excursion D, Brušane, Velebit Mt. - Permian - 16th European Micropaleontological colloquium, 163-170, Ljubljana.

KOCHANSKY-DEVIDÉ, V. SREMAC. J., JELASKA, V. & PALČIĆ, I. (1982): Gornji paleozoik Velebita. IGCP-Projekt br. 5, Jugoslavenska radna grupa terenski sastanak 1982 (Field meeting 1982), Velebit Mt- Fieldtrip guidebook. 16-41. Zagreb

KRAINER, K. (1993): Late- and Post-Variscan Sediments of the Eastern and Southern Alps - In: RAUMER von J.F. & NEUBAUER, F. (eds.): Pre-Mesozoic Geology in the Alps. Springer-Verlag. Berlin, Heidelberg. 537-549.

KUPECZ, J.A. & LAND, L.S. (1991): Progressive recrystalization and stabilization of early-state dolomite: Lower Ordovician Ellenburger Group, west Texas.- In: PURSER, B.H., TUCKER. M.E. & ZENGER. D.H. (eds): Dolomites: A Volume in Honour of Dolomieu. Spec. Publ. Int. Ass. Sedimentol.. 21. 255-279.

LARSEN. V. & STEEL, R.J. (1978): The sedimentary history of a debris-flow dominated Devonian alluvial fan - study ot textural inversion.- Sedimentology. 25, 37-59.

LOWE, D.R. (1982): Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents - Jour. Sed. Petrology, 52, 279-297.

MARJANAC, T. & SREMAC, J. (2000): Middle Permian calcispongal cement reef on the Velebit ML- In: PAMIC, J. & TOMLJENOVIC, B. (eds.): PANCARDI 2000. Dubrovnik, Croatia, 1-3.10.2000. Fieldtrip guidebook. Vijesti Hrv. geol. drustva, 37/2, 135-138, Zagreb.

MARZO, M. & ANADON, P. (1988): Anatomy of a conglomeratic fan-delta complex: the Eocene Montserrat conglomerate, Ebro Basin, Northern Spain - In: NEMEC, W. & STEEL R.J. (eds.): Fan deltas: Sedimentology and Tectonic Settings. Blackie & Son, Glasgow and London, 318-340.

MASSARI, F., CONTI, M.A., FONTANA, D,. HELMOLD, K., MARIOTTI, N., NERI, C, NICOSIA, U., ORI, G.G. PASINI, M. & PITTAU, P. (1988): The Val Gardena Sandstone and Bellerophon Formation in the Bletterbach Gorge (Alto Adige, Italy): biostratigraphy and sedimentology- Mem. Sci. Geol., 40, 229-273.

MILANOVIC, M. (1982): Carboniferous microfossil associations from Gorski kotar, Hrvatsko zagorje and Banija.- Palaeont. Jugosl., 28, 1-34, Zagreb.

NEMEC, W. & STEEL, R.J. (1984): Alluvial and coastal conglomerates: their significant features and some comments on gravelly mass-flow deposits - In: KOSTER, E.H. & STEEL, R.J. (eds.): Sedimentology of Gravels and Conglomerates. Can. Soc. Petrol. Geol., Mem., 10, 1-31.

PALINKAS, L.A., PEZDlC, J. & SINKOVEC, B. (1993): The Lokve Barite Deposit, Croatia: an example of early diagenetic sedimentary ore deposits - Geol. Croatica, 46/1, 97-106, Zagreb.

PALINKAS, L.A. & BOROJEVIC-SOSTAR1C, S. (this Vol.): Stratabound Barite Deposit, Sabkha Depositional Environment, Permian-Triassic Boundary (Lokve Locality in the Gorski Kotar, Central Croatia).- In: VLAHOVIC, I. & TISLJAR. J. (eds.): Evolution of Depositional Environments from the Palaeozoic to the Quaternary in the Karst Dinarides and the Pannonian Basin. 22nd IAS Meeting of Sedimentology. Opatija - September 17-19, 2003, Field Trip Guidebook, 133-141, Zagreb.

RAFFAELLL P. & SCAVNlCAR, B. (1968): Naslagc gornjega paleozoika Like i Gorskog kotara - 1. kol. geol. Dinaridov, 1. 21-27, Ljubljana.

RAMOVS. A. & KOCHANSKY-DEVIDE, V. (1965): Razvoj mlajsega paleozoika v okolici Ortneka na Dolenjskem-Razprave VIII, Ljubljana, 98 p.

RAMOVS, A. & KOCHANSKY-DEVIDE, V. (1981): Permian-Triassic boundary at Brusane village in Velebit Mi. - Geologija, 24.2. 327-330, Ljubljana.

RAMOVS, A.. SREMAC. J. & KULENOVIC. E. (1987): Results of biostratigraphical investigations in western Yugoslav Paleozoic - IGCP Project No.5.- In: FLTJGEL, H.W., SASSI, F.P. & GRECULA, P. (eds.): Pre-Variscan and Variscan Events in the Alpine-MediterranieanJMountain Belts. Mineralia Slovaca Monography, 397-406.

REINSON, G.E. (1984): Barrier island and associated strand plain systems- In: WALKER, K.R. (ed.): Facies Models. Ainsworth Press. Limited, Kitchner, Ohio, 119-207.

RUKAVINA, D. (1973): Prilog poznavanju gornjopaleozojskih školjkaša Like i sjeveroistočnog podnožja Velebita.- Geol. vjesnik, 26, 319-323, Zagreb.

SALOPEK, M. (1942): O gornjem paleozoiku Velebita u okolini Brušana i Baških Oštarija - Rad Hrv. akad. znan. i umjetn., 274, 218-282, Zagreb.

SALOPEK, M. (1949a): Gornji paleozoik u okolini Mrzle Vodice u Gorskom kotaru.- Ljetopis JAZU, 55 (1946-1948), 175-184, Zagreb.

SALOPEK, M. (1949b): O gornjem paleozoiku u okolini Gerova i Tršća u Gorskom kotaru - Ljetopis JAZU, 55 (1946-1948), 193-198, Zargeb.

SALOPEK, M. (1960): O gornjem paleozoiku u okolici Mrzle Vodice i Crnoga Luga-Acta geol., 2, 121-132, Zagreb.

SALOPEK, M. (1961): Geološki odnosi paleozojskog prodora okoline Smrečja, Tršća i Čabra u Gorskom kotaru.- Acta geol., 3, 243-249, Zagreb

SIMIĆ, V. (1935): Oberkarbonische Versteinerungen von Lika in Kroatien- Vesnik geol. lnst. Kralj Jugoslavije, 4/1 (1934), 141-145, Beograd.

SREMAC, J. (1986): Middle Permian brachiopods from the Velebit Mts. (Croatia, Yugoslavia).- Palaeont. Jugosl., 35, 1-43, Zagreb.

SREMAC, J. (1991): Zone Neoschwagerina craticulifera in the Middle Velebit Mt. (Croatia, Yugoslavia).- Geologija. 34, 7-55, Ljubljana.

SREMAC, J. & ALJINOVIĆ, D. (1997): Upper Paleozoic fossils from clastic sediments in Gorski Kotar.- Geol. Croat., 50/2, 187-199, Zagreb.

ŠIFTAR, D. (1978): Bakteriogeno otopljeni barit kao mogući izvor sekundarno mobiliziranog barija - Geol. vjesnik, 30/2, 359-362, Zagreb.

TIŠLJAR. J., VLAHOVIĆ, I., SREMAC, J., VELIĆ, I„ VESELI. V. & STANKOVIĆ, D. (1991): Excursion A - Velebit Mt.. Permian-Jurassic- In: VELIĆ, I. & VLAHOVIĆ, I: Some Aspects of the Shallow Water Sedimentation on the Adriatic Carbonate Platform (Permian to Eocene). Excursion Guidebook of the Second International Symposium on the Adriatic Carbonate Platform, Zadar, May 1991. 1-50, Institute of Geology, Zagreb.