THE SECOND INTERNATIONAL SYMPOSIUM
ON THE ADRIATIC CARBONATE PLATFORM

RELATIONS WITH ADJACENT REGIONS

ZADAR, MAY 12th to 18th, 1991

SOME ASPECTS OF THE SHALLOW WATER SEDIMENTATION ON THE ADRIATIC CARBONATE PLATFORM (PERMIAN TO EOCENE)

EXCURSION GUIDE-BOOK

INSTITU)F GEOLOGY
ZAGREB, 199L

EXCURSION A - VELEBIT MT.
PERMIAN - JURASSIC

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1. Introduction

Velebit is the largest mountain in Croatia, (2270 square kilometers) and the longest in the Dinaride range (about 150 km). Situated as a ridge between the Adriatic coast and the interior of Croatia, it combines elements characteristic of both Mediterranean and Alpine environments. Velebit contains both alpine summits and wooded continental slopes, and has a mixed mediterranian-alpine flora and fauna, as well as many endemic species. It has long been recognized and protected because of its beauty and unique environments, dating to before World War II with the protection of Štirovača forest. Velebit is protected by the Yugoslav government as a nature reserve, and by UNESCO as part of the International Network of Biosphere Reserves. Some parts are under special protection, including : Tulove Grede (geological/geographical reserve), Velika and Mala Paklenica (national park), Hajdučki and Rožanski Kukovi (strictly protected nature reserves), and Modrić Dolac (botanical garden).

From a geological perspective, Velebit may be considered Nature's grand geological museum, for it features many characteristics of the Dinaride karst, from limestone scarps to karst poljes. Classic carbonate developments are known from the Carboniferous, the Permian, and the Triassic eras, and include various foraminifera (fusulinids) and limestone algae. The Jurassic deposits of Velebit are of the classical type of Dinaride Jurassic, of which excursion members will become acquainted with the Lias phase.

Our Velebit excursion will include shallow-water Upper Permian, Triassic and Jurassic deposits, as well as the Tertiary Jelar breccias. Each stop will be at a small profile where the basic litho- and biofacial characteristics of the sediments, as well as the products of various shallow-water surroundings, can be examined .

Summary of excursion stops:

Stop1: Calcispongite patch reef, Middle Permian (zone *Neoschwagerina craticulifera*).

Stop 2: Peritidal carbonate sediments, Upper Permian (zone *Yabeina syrtalis)*.

Stop **3:** Shallow-water carbonate sedimentation, and continental sediments on the border between the Middle and Upper Triassic.

Stop 4: Shallow-water carbonate sedimentation and biostratigraphic zoning in the Lower and Middle Lias.

Stop 5: Coquina tempestites in the Middle Lias, and bioturbated limestones in the Upper Lias.

Stop 6: The contact of shallow-water carbonate Malmian and Oligocene Jelar breccias.

2. An Outline of Velebit's Geological History from the Carboniferous to the Cretaceous

Sediments from the Upper Paleozoic to Triassic and Jurassic can be assigned to three major sedimentary cycles, each separated by a terrestrial phase: 1) Middle Carboniferous-Middle Permian; 2) Middle Permian - Middle Triassic and **3)** Upper Triassic - Jurassic and Cretaceous (Fig. 1).

The Middle Carboniferous-Middle Permian cycle is represented here mainly by clastics, alternations of sandstone with quartz conglomerate and shallow-water limestone intercalations. The maturation of the Variscan consolidation is evidenced by a developed relief and important terrestrial influences. This cycle ends in the Permian with the full formation of the mainland (Saalian events) and red clastic (Grodner) sedimentation.

The Upper Permian was a period of typical shallow-water sedimentation with carbonates prevailing (excursion stops 1 and 2). Rare clastic intercalations of primarily terrestrial origin suggest a dominant mainland influence. During the Upper Permian the limestone and dolomite sedimentation occurred mainly in the shallow-subtidal and intertidal areas. In the Lower Triassic, sandy dolomites, limestones, and mica sandstones were deposited; during the Middle Triassic these were replaced by algal Diplopora limestones distinctive of reef and back reef shallows. The second large cycle was brought to a close, at the end of the Ladinian, by rifting with basalt magmatite intercalations, followed by the formation of mainland, karst, and red continental clastics sedimentation.

The third cycle begins with the Carnian transgression (conglomerates, shale, and mudstone alternation), which is followed by the Norian-Rhaetian peritidal alternation of early and late diagenetic dolomites (Principal dolomite or Hauptdolomit - excursion stop 3). This is the beginning of the distinctive oceanisation of the carbonate platform at Velebit and its surroundings, which lasts until the end of the Cretaceous. A record of this phenomena, which is typical of shallow-water surroundings during the Jurassic in Velebit and elsewhere on the Adriatic platform, may be seen in most of the Lias profile (excursion stops 4 and 5).

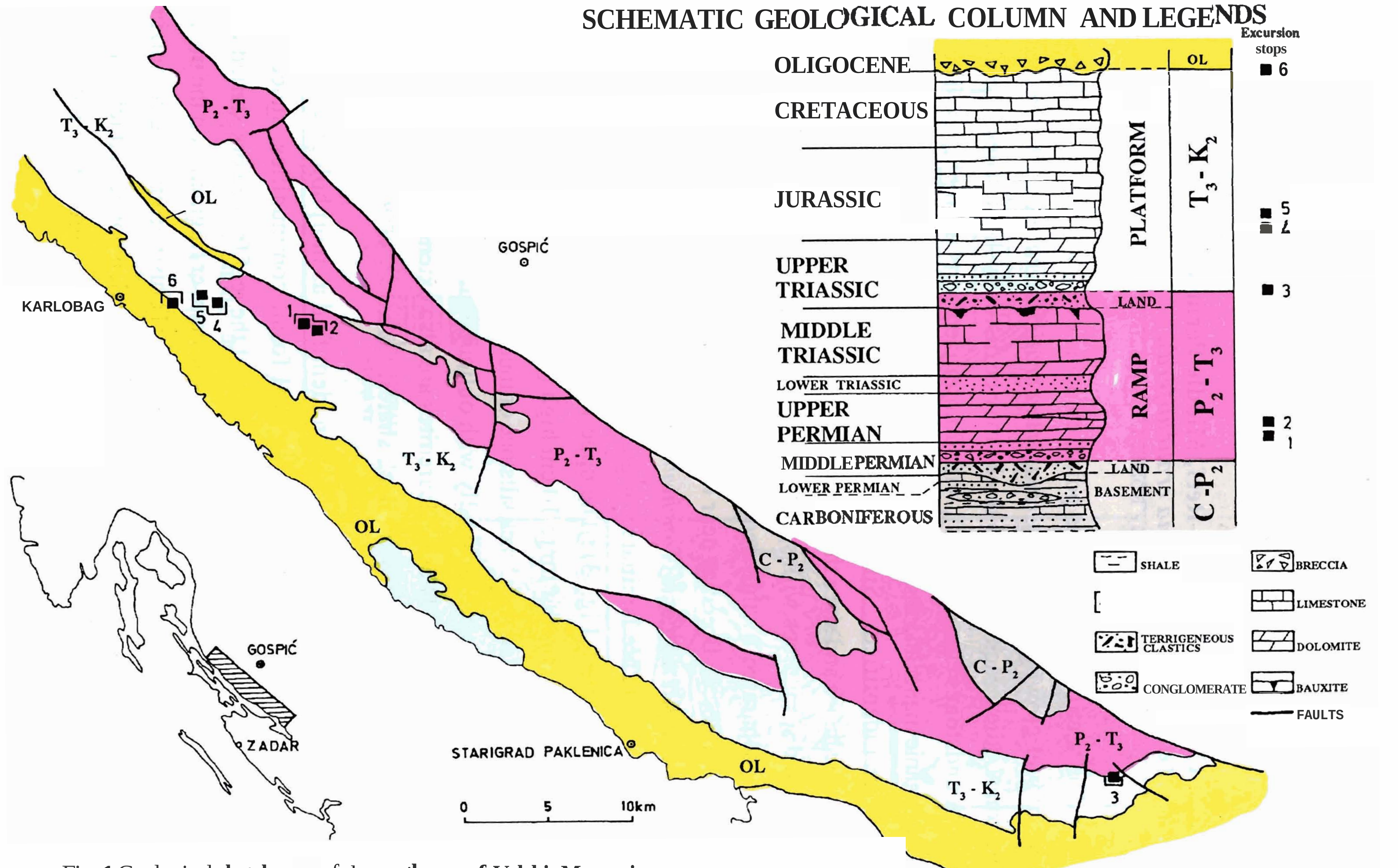

Fig. 1 Geological **sketch-map** of the **south part of Velebit Mountain.**

3. Description of Stops

STOP 1: Calcispongite Patch-Reef, Middle Permian (zone *Neoschwagerina craticulifera*).

Location: Gospić-Karlobag Road ca. 3.5 km SE from Oštarije

The section visible at this point, contains evidence of at least three episodes of reef growth in the Neoschwagerina craticulifera zone. Three massive limestone bodies, each 1.2 to 4 m thick, may be distinguished. These are bluish-black boundstones (framestones), with dolomitized parts of light gray. They are rich in organic matter and fossils, with up to eighty-five taxa of micro and macrofossils having been identified. Situated within the limestones are numerous cavities of different shapes and sizes that are filled with brownish-gray laminated siltstone (Fig. 2c) and sometimes with sparite. The boundstones are partly superimposed and partly separated by thin bedded calcarenites, shales, and thin channelized breccia (Fig. 2b,c). Breccias near the upper bed surface contain limestone and large bivalve shell fragments (Tanchintongia *ogulineci* Kochansky-Devidé). Some of these sediments are laminated or graded, and some are completely unsorted (tempestites) (Plate I, Fig. **3)** . The uppermost surface of the limestone body is convex with marked relief up to 10 cm high (branches of encrusting biota) and the interspaces are filled with black siltstone or mud. Limestone bodies are separated by graded calcarenites, occasionally with oblique lamination, and contain fine-grained skeletal debris. These calcarenites are also extended laterally from the reef units and are overlaid with black shales.

These limestone bodies have been identified as morphological and ecological reef units according to their typical fossil communities, succession, morphology and inner structure. Construction of the reef framework started with the colonization of large fenestellid bryozoans on coarser fragments on the muddy substrate, and the formation of thick cyanobacterial crusts around the colonizing organisms (Fig. 2a,b). Next, other bryozoans and calcisponges attached themselves to the existing bryozoan fans. In later phases of growth, the dominant reef builders were sponges :

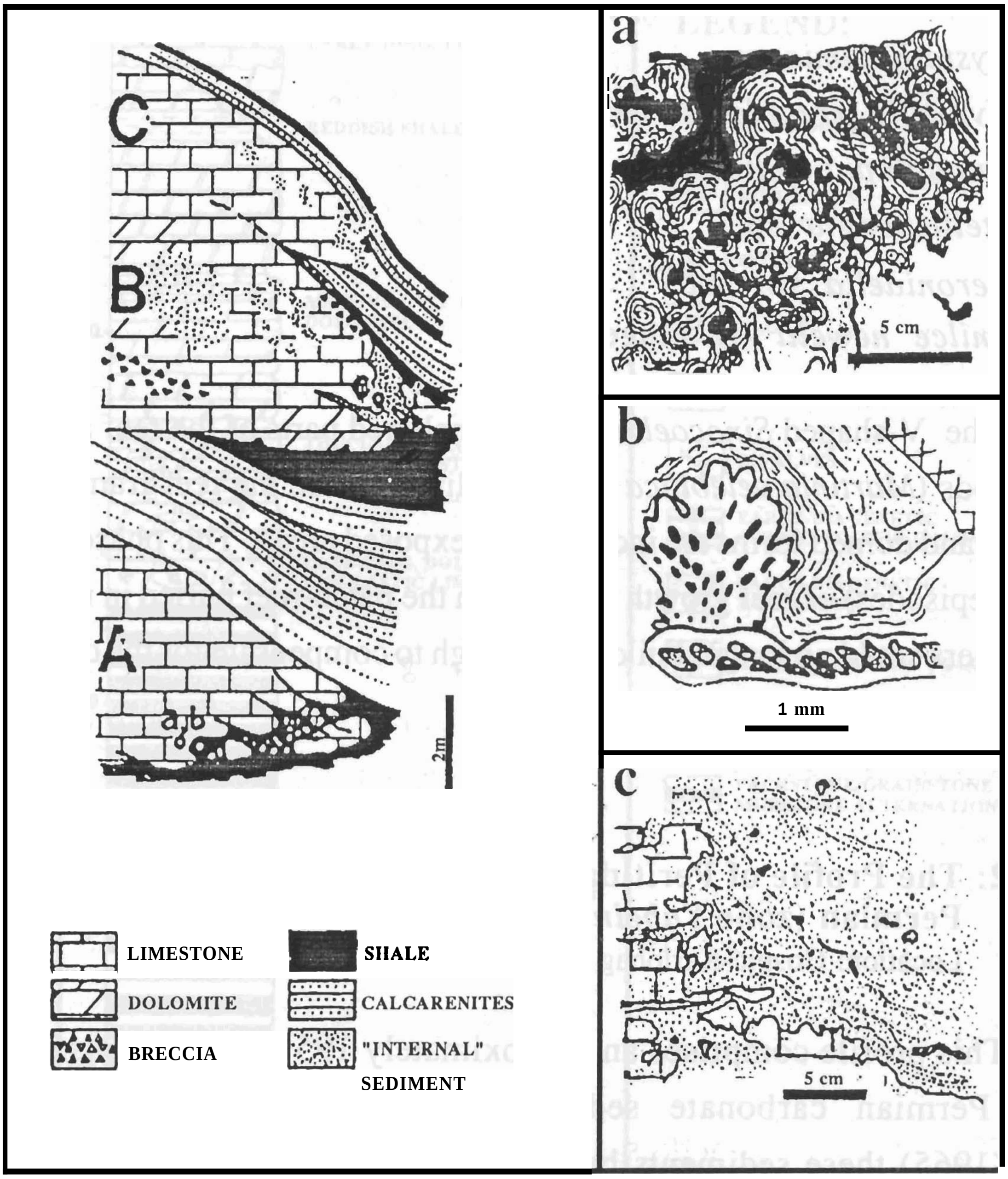

Fig. 2 Section through the reef complex with three reef units (A, B, C)

a,b - details from the base of the reef complex. Fenestellide bryozoans and calcisponges coated by cyanobacterial crusts.

c - intrareefal cavity filled with siltstone. Microfossils are arranged in laminae.

(Partly after Marjanac and Sremac, 1988)

Colospongia cf. *dubia* Laube,
Waagenella sp.,
Polycistocoelia sp.,
Sinocoelia lepida Zhang et Fan,
Cystothalamia sp.,
Uvanella irregularis Ott,
Guadalupia cyllindrica Girty,
Stellispongia sp.
Peronidella sp. and
Imilce newelli H. Flügel.

The V-shaped *Sinocoelia* lived in sheltered parts of the reef and numerous brachiopods (*Martinia velebitica* Sremac) lived inside the reef framework, while plate-like and domed forms are indicative of exposed areas. This phase (encompassing three episodes) of reef growth ended with the patch-reef buried in mud, since the reef dwellers could no longer build fast enough to compensate for the deposition rate of fine grained sediments.

STOP 2: The Profile of Peritidal Carbonate Sediments of the Upper Permian (zone *Yabeina syrtalis*).

Location: Gospić-Karlobag Road c. 3,5 km SE from Oštarije.

This profile comprises an approximately 195 m continuous sequence of Upper Permian carbonate sediments (Fig. 3). According to Kochansky-Devidé(1965) these sediments belong to the Upper Permian *Yabenia syrtalis* zone. Four characteristic facies have been identified on the basis of sediment deposition. These are: 1) **facies A,** dolomitized fusuline grainstones-packstones; 2) **facies** B, early diagenetic supratidal dolomites; 3) **facies C,** black, organically rich mudstones that rhythmically alternate with bioclastic packstones/grainstones; 4) **facies** D, supratidal early diagenetic dolomites with shale intercalations.

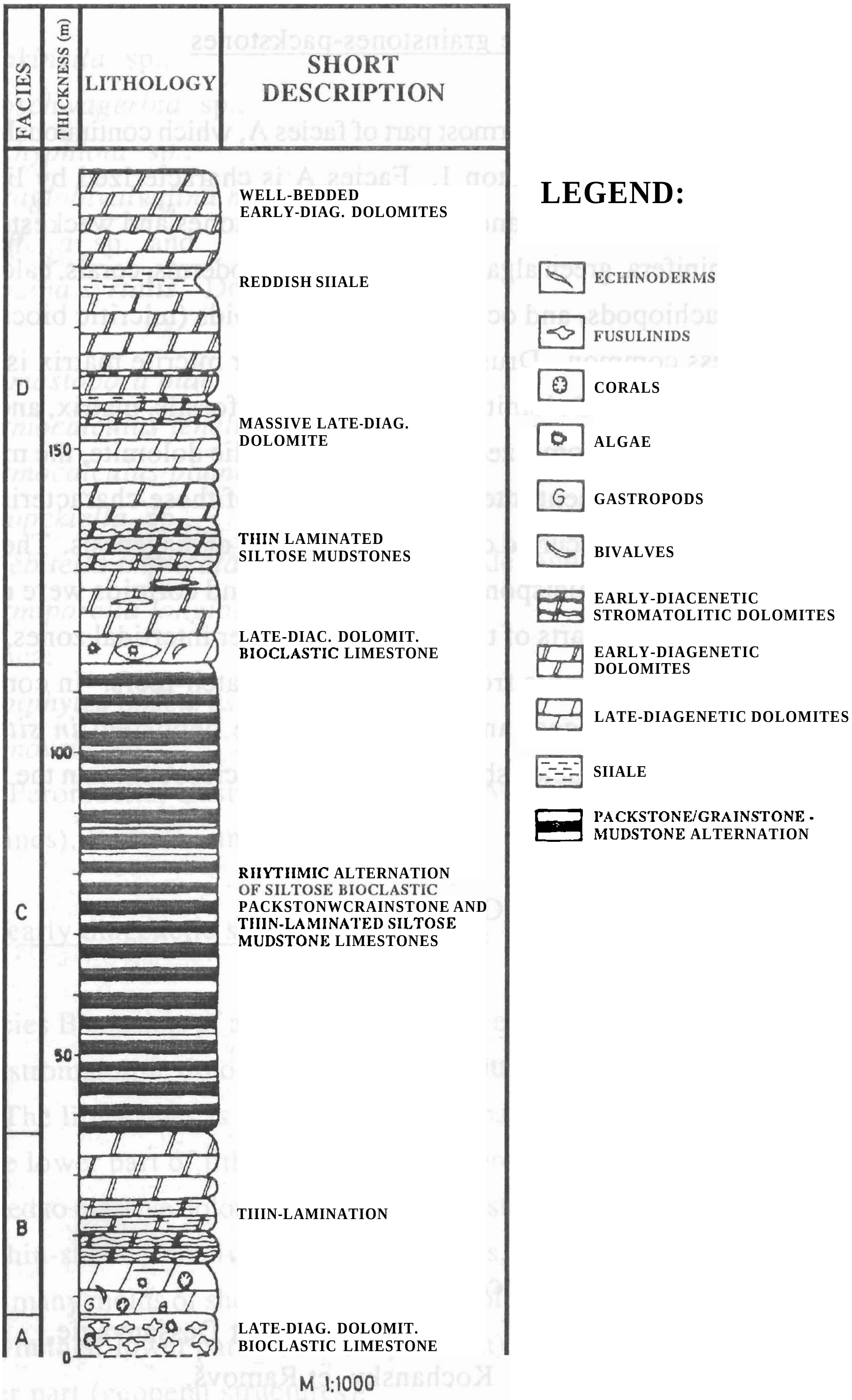

Fig. 3 Permian section on the Gospid-Karlobag Road.

Facies A: dolomitized fusuline grainstones-packstones

Stop 2 begins at the uppermost part of facies A, which continuously overlies the patch-reef limestones of Stop 1. Facies **A** is characterized by light gray, massive dolomitic grainstone and packstone. Packstones and wackestones with abundant foraminifera, green algae, bioclasts of echinoderms, corals, calcispongia, gastropods, brachiopods, and occasional large cortoids (micritic bioclasts) and oncoids, are 'less common. Drusy calcite cement or micrite matrix is found in the intergranular pores. Dolomitization affected the fossils, matrix, and cement. The fossils have been dolomitized into cryptocrystallic dolomite, the matrix into dolomicrite, and the cement into dolosparite. All of these characteristics suggest that dolornitization occurred during an early phase of diagenesis. The bioclasts of coral, echinoderms, calcisponges, brachiopods, and cortoids were not indigenous to the shallowest parts of the subtidal and lower intertidal zones, but were carried into them by currents from shallows with patch-reefs. In contrast, the benthic foraminifera, algae, and gastropods were deposited *in situ* in the shallow-subtidal and restricted shallows. Rocks of facies A contain the following fossil assemblage:

Foraminifera:

Agathammina pusilla Geinitz,
Agathammina sp.,
Bradyna sp.,
Climacammina sp. div.,
Chusenella sp.,
Endothyra sp.,
Eotuberitina sp.,
Geintzina sp.,
Globivalvulina vonderschmitti Reichel,
Ichtyolaria latilimbata S. dPPe Civrieux et Dessauvagie,
Kahlerina pachytheca Kochansky et Ramovš,
Langella sp.,
Nankinella waageni (Schwager),

Nankinella sp.,
Neoschwagerina sp.,
Pachyphloia sp.,
Paraglobivalvulina mira Reitlinger,
Staffella sp. and
Yabeina syrtalis Douville.

Algae:

Epimastopora piae Bilgutay,
Permocalculus tenellus (Pia),
Permocalculus plumosus Elliott,
Salopekiella sp.,
Velebitella triplicata Kochansky-Devidé and
Vermiporella longipora Praturlon.

Problematica:

Tubiphytes obscurus Maslov and
Ramovsia sp.

The rest: Peronidella, Gastropoda, Bryozoa, "Magnella" (brachiopods with spines), Radiolae and Ostracoda.

Facies B: early diagenetic supratidal dolomites

Facies B consists of a 30 m thick sequence of cryptocrystalline and wavy laminated stromatolitic dolomites, which are light to dark gray and thick-bedded (Fig. 3). The lithofacies is divided into three parts.

The lower part of lithofacies B is an approximately 8.5 m thick layer of thick-bedded to massive dolomicrites or cryptocrystalline dolomites. These contain debris of thin-shelled bivalves, microgastropods, irregular fenestrae, and green algae with many molds of shell. There are also solutional vugs filled with internal sediments in their lower part (vadose crystal silt) and dolomite drusy cement in their upper part (geopetal structures).

The middle part is an approximately 5 m thick layer of stromatolite dolomites with fenestral fabrics that contain rare tepee structures and thin-bedded edgewise breccia. Visible in thin-sections of the stromatolite dolomites, desiccation and shrinkage cracks interrupt the continuity of laminae. The laminae are cryptalgal, dolopelsparite, and rarely dolomicrite with a clotted micrite structure. As one moves towards the top of this part, the quantity of stromatolitic laminae decreases, while the quantity of cryptocrystallic dolomites (dolomicrites and dolopelsparites) increases.

The upper part of facies B is an approximately 16.5 m thick layer of dark gray laminated cryptocrystallic dolomites. Laminae are 2-10 mm thick, and are composed of dolopelmicrite, dolointrasparite, dolopelsparite, dolomicrite, and occasionally stromatolite. Towards the uppermost part of this layer, the color of the dolomicrites darkens to black; the dark color probably came from organic matter and the presence of small-grained pyrite suggests the activities of sulphate reducing bacteria.

In summary, 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 in diameter), suggest a supratidal early-diagenetic dolomitization, probably in sabkha-like conditions.

In contrast to facies A, the fossil assemblage no longer contains large fusulinids, but instead contains numerous taxa of small foraminifera. The following taxa were identified:

Foraminifera:

Endothyra sp.,
Eotuberitina reitlingerae Mikluho-Maklay,
Geinitzina uralicea Mikluho-Maklay,
Globivalvulina graeca Reichel,
Globivalvulina vonderschmitti Reichel,
Glomospira sp.,
Hemigordius sp.div.,
Ichthyolaria latilimbata S.de Civrieux and Dessauvagie,

Langella sp.,
Nodosaria longissima Suleimanov,
Pachyphloia sp.,
Pachysphaerina pachysphaerica (Pronina),
Paleonubecularia sp. and
Paraglobivalvulina mira Reitlinger.

Algae:

Permocalculus sp.,
Microalgae and
Calcisphaerae.

The rest :

Tubiphytes carinthaicus Fliigel, Spiculae, Ostracoda and Brachiopoda.

Facies C: black, organically rich mudstones and bioclastic packstones/grainstones

Facies C (Fig. 3) consists of a 79 m thick sequence of rhythmically alternating organically rich mudstones (0.2-2.8 m thick), and organically rich bioclastic-intraclastic packstone/floatstones or grainstone/rudstones (0.1-0.5 m thick).

The mudstones are horizontally laminated, and due to compaction and tectonics sometimes look like fissibile shales.In thin-sections, the horizontal laminae appear as alternating thin laminae of a) organically rich micrites, b) biomicrite, and c) organic substances with or without siliclastic and bioclastic detritus. Some bioclastic laminae contain large quantities of small biodetritus and rounded calcisphere and/or algae with a central cavity filled with sparry calcite surrounded by a micrite wall. Apart from the organically rich carbonate mud, these limestones contain the following: siliclastic detritus with grain dimensions up to 30 microns (in concentrations of 5-20%), micrograins with aggregates of organic pyrite caused by sulphate reducing bacteria, and well-dispersed organic matter. The siliclastic detritus, according to the microscopic analysis, is composed of quartz grains and small mica flakes, while the RTG analysis shows that the rock, apart from calcite, contains small amounts of dolomite, quartz, hydromica, and pyrite.Organic matter is abundant in the rock (0.88 % Corg), and the microscopic analysis shows that it is strongly thermically altered (% Ro=2.43+-0.26), corresponding to the dry gas formation stage, i.e. metagenesis. The maceral morphology suggests a predominantly algal-sapropel origin, with considerable terrestrial influences (mainly vitrinite and some intertinite). Some particles appear pyrobitumenous (D. Španić, analysis).

The black, organically rich packstone/floatstone is cross-laminated in places. The relative amounts of mollusc bioclasts, gastropods, green algae, occasional echinoderms, benthic foraminifera tests, micrite intraclasts, cortoids, and algal oncoids vary from layer to layer. The micrite matrix often contains aggregates of small grains, impregnations of organic pyrite, siliclastic detritus, and organic matter, and is similar to the matrix of the mudstone.

The black, organically rich grainstones/rudstones are usually cross-laminated, and in thin-sections show abundant grainstone laminae, alternating with thin, lamina1 intercalations of mudstone, wackestone, and sometimes packstone. Grainstones/rudstones contain well-sorted benthic foraminifera, bioclasts of green algae, molluscs, gastropods, echinoderms, micrite and biomicrite intraclasts, rare cortoids, algal oncoids, and spores (calcispheres?). The larger intraclasts often have algal or micrite envelopes. Organic substance, together with pyrite, form a thin film over the surface of the intraclasts and bioclasts. They also occur in the matrix, and sporadically as pigment in the sparry calcite cement. The siliclastic detritus content is significantly lower than in the mudstones, wackestones, and packstones. In general, as one approaches 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 muds in a restricted shallow bay and/or on the edge of a shallow lagoon situated between large supratidal areas. The prevailing reduction 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. These formed, with or without carbonate mud, cross-laminated packstones/floatstones or grainstones/rudstones. These tempestite deposits, therefore, were allochtonous in origin.

The fossil assemblage in facies C is similar, but less taxonomically diverse than that in facies B. In grainstones larger foraminifera are sometimes found along with the smaller forms. The following taxa were identified:

Foraminifera:

Agathammina pusilla Geinitz,
Calcitornella sp.,
Dunbarula? sp.,
Eotuberitina sp.,
Hemigordius ovatus Grozdilova,
Hemigordius sp.div.,
Kamurana sp.,
Nankinella sp.,
Nodosaria longissima Suleimanov,
Neoendothyra parva (Lange),
Paleonubecularia sp. and
Tuberitina sp.

Algae:

Vermiporella nipponica (Endo),
Small algae (undefined) and
Gymnocodiceae (fragments).

Problematics:

Aeolisaccus sp.,
Calcisphaerae,
Ramovsia sp.,
Tubiphytes obscurus Maslov.

The rest :

Ostracoda, Spiculae, Radiolae, Gastropoda,' Bryozoa and Faecal pellets.

Facies D: supratidal early diagenetic dolomites with shale intercalations

Sediments in facies D are 85 m thiek (Fig.3), and are identical to the supratidal early-diagenetic dolomites of facies B, except for sporadically occurring thin, reddish-brown or gray shale intercalations in the uppermost part. These shales contain microcrystallic carbonates (dolomite, calcite) and siliclastic detritus composed of quartz, hydromica, chlorite, Fe-oxide, and hydroxide.

In the Upper Permian regressive sedimentation cycle, the insertion of fine-grained sediments into early-diagenetic dolomites is a common phenomenon. In this area, this signals the imminent arrival of the shoreline, and a shift in sedimentation to terrestrial, siliciclastic detritus. The fossil assemblage from facies D is relatively poor and composed of:

Foraminifera:

Globivalvulina sp.,
Glomospira sp.,
Hemigordius sp. and
Nankinella sp.

Algae:

Mizzia sp.

The rest :

Faecal pellets.

STOP 3 : Shallow Marine Limestones and Continental Sediments from the Middle to Upper Triassic Border.

Location: Vrace bauxite deposits, 4.5 km SSW from Gračac - Lika.

During the Triassic epoch in the Lika region, several phases of emersion and transgression occurred on the carbonate platform. The emersion phase at the end of the Ladinian was most strongly expressed in the Vrace area (Fig. 4). During continental phase, there was strong erosion and karstic phenomena developed on the Middle Triassic limestones.

At the initial stage of the marine transgression, clastic rocks were deposited in the lower parts of the paleorelief, and as it progressed, carbonate sediments were deposited over the entire region . By the beginning of the Upper Triassic, the transgression covered all of Lika.