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LOFER CYCLOTHEMS FROM THE LOWER KRKA LIMESTONES

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Riassunto. Ciclotemi completi di tipo Lofer sono stati trovati per la prima volta nel Liassico inferiore delle Dinaridi esterne della Slovenia. La successione del Liassico inferiore, vicino al villaggio di Krka, è composta di calcari di bassa profondità, cioè da subtidale, intertidale e sopratidale. La successione è caratterizzata da predominio di carbonati di colore grigio scuro, tra i quali prevalgono micriti, biomicriti, oomicriti e oncomicriti. La caratteristica dei calcari di Krka è la sedimentazione ritmica ben sviluppata. I cicli sono composti da tre elementi, come nei ciclotemi della località tipica di Loferer Steinberge.

Abstract. The complete Lofer cyclothems were for the first time found in the Lower Liassic from the Slovenia part of Outer Dinarides. The Lower Liassic sequence at Krka composed of shallow water lagoonal limestones was formed in subtidal, intertidal and supratidal environment. The sequence is characterized by predominantly dark gray carbonate sediments among which micritic, biomicritic, oomicritic and oncomicritic limestones prevail. The main characteristic of Krka limestones is the well-developed rhythmic sedimentation. The cycles are composed of three members, such as cyclothems in the type-locality Loferer Steinberge.

Introduction.

The most part of the Lofer cyclothem data from the Lower Liassic beds south and southeast of Krka (Fig. 1) were obtained by detailed geological mapping for the "Thematic Geological Map of Slovenia" at a scale of 1:50.000. The purpose of this paper is to describe the Lower Liassic Lofer cyclothems, to discuss their environmental, paleogeographic and tectonic significance, and to underline that Lofer cyclothems appear also in sediments of different age from that of the classic Lofer facies.

This study is based on field investigations and numerous hand specimens as well as thin sections. Carbonate rocks are classified using the Folk (1959), Dunham (1962) and Gerdes & Krumbein (1987) classifications.

The Lower Liassic microfauna and microflora were determined by Rajka Radoicic from the Geological Survey Beograd.

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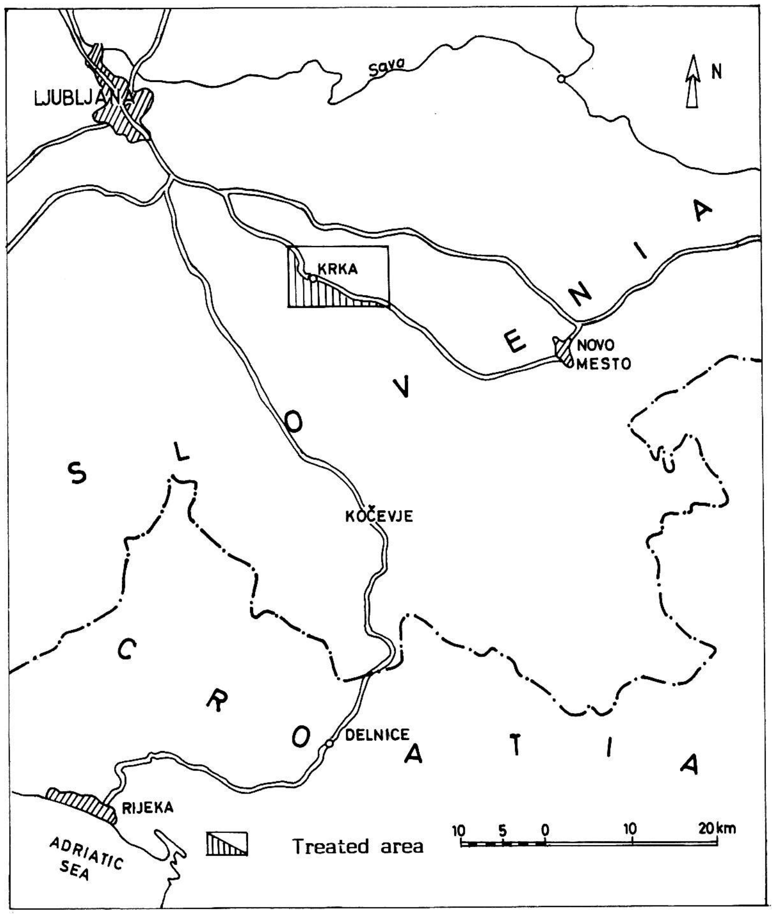

Fig. 1 - Location sketch map.

History.

Lofer cyclothems have so far been observed almost exclusively in the Upper Triassic Dachstein Limestone and Hauptdolomit. Cyclothems were first recognized in the Dachstein formation by Sander (1936) in the Loferer Steinberge near Lofer. The most complete description of the Lofer facies was made by Fischer (1964). Zankl (1967, 1969, 1971) established four depositional environments in the Norian-Rhaetian Dachstein Limestone of the Northern Limestone Alps. The Upper Triassic rhythmic sedimentation was investigated and described by Bosellini (1967) (Dolomiti and Prealpi Venete), Carannante (1971) (Monti di Venafro), Castellarin & Sartori (1973) (Trento), Catalano et al. (1974) (Capo Rama, Sicilia), Hardie et al. (1986) (Northern Italy), Bosellini & Hardie (1988) (Alpi Venete) and Burchell et al. (1990) (Southern Alps). The rhythmic sedimentation of the Upper Triassic subtidal, intertidal and supratidal calcareous sediments of the Outer Dinarides, which is well correlative with Dachstein limestones and dolomitic limestones of Northern and Southern Limestone Alps, have also been investigated in Slovenia, Croatia and Yugoslavia. These problems were dealt with by: Ogorelec & Premru (1975) (Sava folds), Pantic-Prodanovic (1975) (Tara), Dimitrijevic et al. (1981, 1982) (Zlatibor), Ogorelec (1984, 1988) (Julian Alps, Kanin, Trnovo forest), Ramovs (1986) (Julian Alps), Nastic & Zupancic (1986) (Jelovo mountain), Cadjenovic (1986, 1988) (Montenegrin Hinterland), Savic et al. (1986) (Gorski kotar), and Dozet (1989, 1990) (Kocevje area). Wilson (1975) used the term "Lofer cyclothem" for all cyclothems regardless their age. Tisljar (1978 a, b) discussed the Upper Jurassic and Cretaceous rhythmic succession from Istria and Dubrovnik. The Jurassic beds between Zagradec and Randol were described by Sribar (1966). Strohmenger and Dozet (1991) studied the stratigraphy, facies developments and geochemistry of Jurassic calcareous rocks in Suha Krajina.

Stratigraphic Position, Fossils and Age.

An about 250 m thick belt of Lower Liassic limestones between Krka and Zagradec was denominated (Dozet, 1989) "Krka limestones". The Krka limestone sequence with Lofer cyclic sedimentation lies concordantly between Upper Triassic Hauptdolomit (Fig. 2) and Middle Liassic beds with lithiotids. The uppermost part of Upper Triassic beds consists of an alternation of light gray micritic fine-grained laminated and stromatolitic dolomite showing the typical Lofer development.

The stratigraphic position of the Krka limestones points to their Lower Liassic age. The age is also confirmed by the fossils: *Palaeodasycladus mediterraneus* Pia, *P. elongatus* Praturlon, *Palaeodasycladus* sp., *Linoporella lucasi* Cros & Lemoine, *Thaumatoporella parvovesiculifera* (Raineri), *Favreina salevensis* Paréjas, *Gyroporella* sp., *Textulariidae*, *Verneuilinidae* and *Codiacea*. Besides microfauna and microflora, megalodontids and gastropods also appear in the considered Lower Liassic beds.

Lower Liassic Lofer Cyclothems and Facies.

Fisher's main conclusions (1964) in the region of Salzburg were that the typical cyclothem consists of 1) a disconformity at the base, 2) basal argillaceous member (red or green) which was commonly restricted to solution of desiccation cavities in the underlying rock, 3) an intertidal member containing biolaminated and other sediments showing a variety of shrinkage features attributed to desiccation, and 4) a subtidal massive limestone member with varied biota.

The Lower Liassic sequence from the area shows the same or very similar features which Sander (1936), Fischer (1964) and others observed in the northern Limestone Alps. The main characteristic of the limestone sequence is the rhythmic alternation of supratidal, intertidal and subtidal layers.

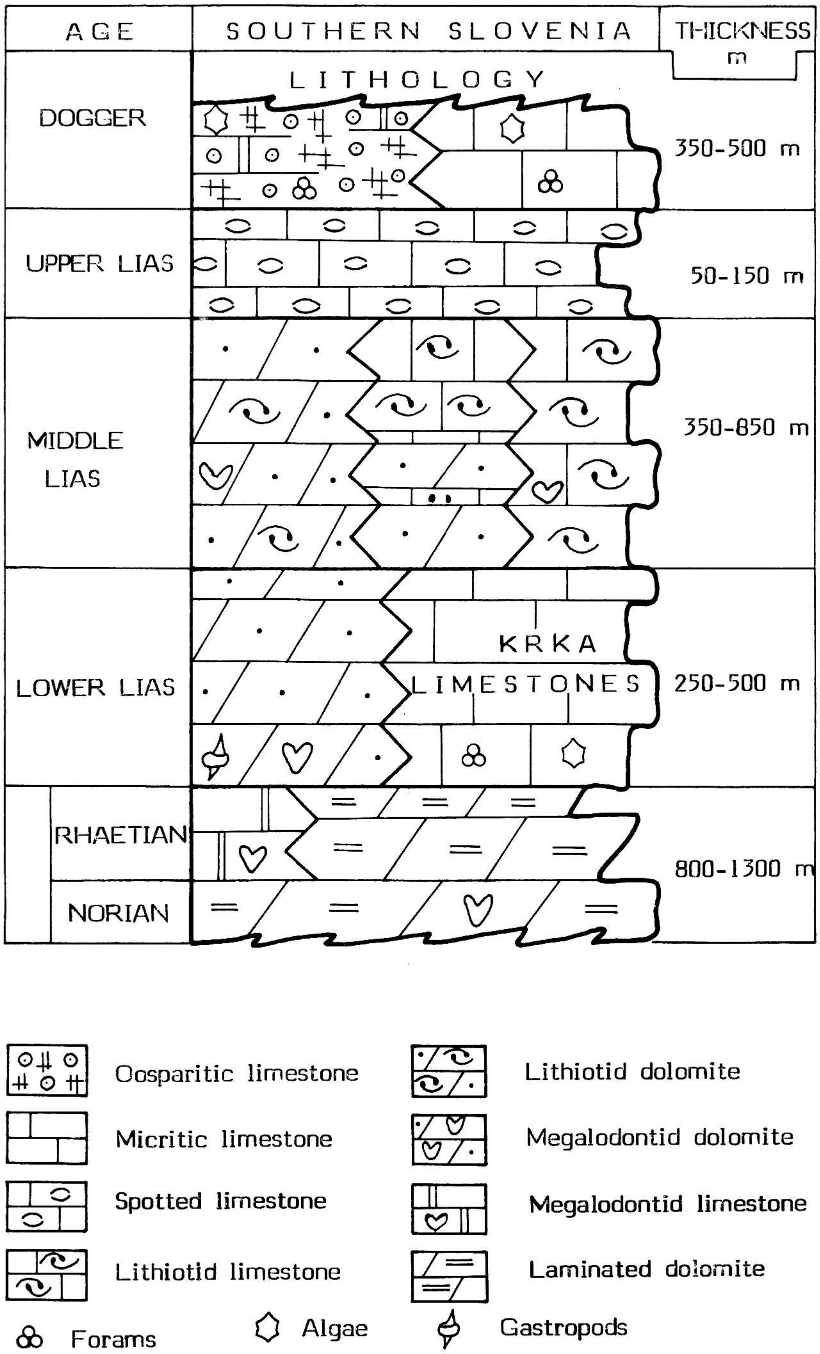

Fig. 2 - Facies distribution.

The complete Lofer cyclothem in the Lower Liassic Krka limestones (Fig. 3) consists of (top to bottom):

- subtidal member C, predominantly micritic limestone;
- interdital member B, fenestral limestones, biolaminated and laminated limestones, intraformational breccias and conglomerates;
- supratidal member A, red and/or green residual sediments;
- disconformity.

Disconformity.

The complete Lower Liassic cyclothem is limited by erosional surfaces. It may observed on the upper surface of the member C, which is mostly represented by micritic and biomicritic limestones with numerous solution cavities.

The erosional surface is more or less clearly expressed in relief, and mostly undulated or irregular. The signs of paleokarstification, mud cracks, solution cavities and rare minor neptunian dikes filled with red and greenish gray residual sediments are observed on it.

Supratidal Member A.

The supratidal member of the Lower Liassic Lofer cyclothem occurs in the form of: 1) fillings of shoaly mud cracks, solution and desiccation forms, 2) tiny superficial coatings, 3) breccias and conglomerates and 4) red dolomitized detritic limestones. No continuous horizon filled with sediments of the supratidal member has been found so far.

The member A is usually preserved in the form od reddish, yellowish gray, greenish and bluish gray marly-clayey-limonitic deposits, which filled tiny desiccation and other cracks and irregular shoaly solution forms. These sediments represent residual rest of chemical, mechanical and physical weathering of mostly carbonate rocks.

Fine paleokarstification forms filled with orange, yellowish orange, pink and pinkish red marly-clayey-limonitic material are also observed. The layer with these fillings is up to 10 cm thick. In other places the cavities are filled with orange, green, and greenish gray very fine-grained material. The thickness of the horizon with these fillings is up to 10 cm. In some places the member A is represented by some millimeter to at most 1 cm thick yellowish and/or greenish gray to bluish gray marly-clayey-limonitic coating. In the basal part of the Lower Liassic cyclothem here and there thin lenses of a homogeneous breccia occur. Poorly sorted 0.5 to 7 cm thick fragments of pale pink and pinkish red limestones are cemented with brick red marly-clayey-limonitic matrix. The thickness of the breccia is 2 to 10 cm, exceptionally up to 15 cm. On some locations, the basal member of the Lofer cyclothem is represented by a layer from 2 to 5 cm thick, composed of orange, brick red and bluish gray mud particles cemented with calcite and clayey groundmass.

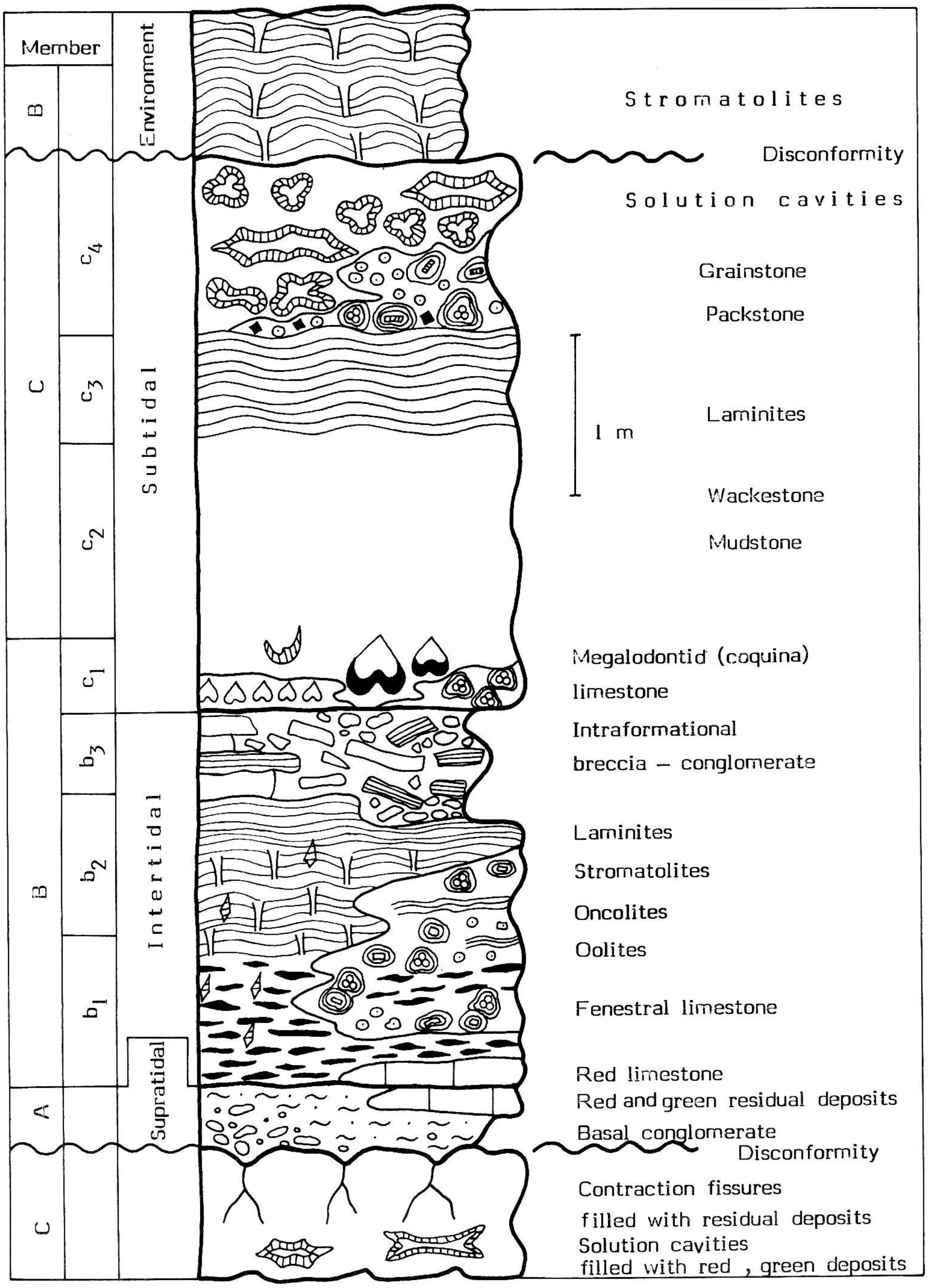

Fig. 3 - Idealized Lofer cyclothem in the "Krka limestones" (Southern Slovenia).

The member A is frequently represented by a horizon of a thickness from 5-20 cm, of red, pinkish red, platy, here and there laminated respectively banded dolomitized detritic limestone. The limestone contains a lot of fine-grained detritic quartz, appearing also in sand lenses. From the structural point of view there are micritic, siltic and sandy laminae. Solution cavities filled with calcite, mud cracks and micro-tepee structures were also noticed in the rock. These characteristics show that the banded red limestone was formed in a supratidal and in a shallow intertidal environment.

Intertidal Member B.

Fischer (1964) distinguished in this member loferites and intertidal sediments. In the Lower Liassic cyclothem, among intertidal sediments occur fenestral limestones, biolaminated limestones (stromatolites, stromatoloid limestones, oolites, oncolites), laminated limestones, as well as intraformational breccias and conglomerates. Among these sediments intraformational breccias and conglomerates prevail. In the sediments of the member B there are quite frequent shrinkage pores, mud cracks, and solution cavities. The encountered sediments contain rare fauna and flora remnants.

Fenestral Limestones.

In the Lower Liassic cyclothems at Krka, fenestral limestones are relatively frequent, but their thickness is small. Micritic, pelmicritic, oncobiopelmicritic and intrapelmicritic loferites occur. Especially frequent are birdseye limestones. Fenestral limestones appear in the basal part of the member B. Their most frequent thickness is 10 to 25 cm, reaching very rarely 0.5 m.

Micritic loferites are the most frequent sediments with shrinkage pores. They are composed of grayish black and black stratified (20 to 35 cm) micritic limestones which contain some tenth mm to 2 mm large pores subparallel or parallel to stratification. In some places 3 mm and larger (up to 5 mm) irregular cavities and fillings with somewhat limonitized clayey micrite are observed. Geopetally filled fenestrae are also found. Their lower part is filled with micrite, pelmicrite or calcitic silt and the upper part is filled with sparry calcite. Fenestrae at right angle to the stratification are very rare. Sometimes they are arranged without order to all sides in the rock. In fenestral limestones also 7 cm large irregular solution cavities could be found, usually filled with sparry calcite cement. Sometimes we observe up to 1 mm thick calcite sheet cracks. We may also notice orange brown stylolites parallel to stratification. Micritic limestone is gray, grayish black and black. Layers are 20 to 25 cm thick. Bedding planes are flat, irregular and sometimes little limonitized. In the grayish fenestral limestone even 15 mm x 2 mm large solution cavities filled with drusy calcite are found.

Pellet loferites usually occur in laminated limestones, but they also form their proper layers. There are well sorted (10 to 40 microns) and poorly sorted (grain size frequently more than 40 microns) pellets. The most part of the well sorted grains is probably of fecal origin. The colour of the pellets is brownish gray indicating organic origin.

Intrapelmicritic loferites appear either in laminated limestones or independently. They are composed of carbonate mud, 0.5 to 1 mm large grayish black micritic intraclasts with impregnated organic matter, brownish gray homogeneous 10 to 50 microns large pellets, and 0.5 to 1.5 mm large oval and irregular pores mostly filled with sparry calcite.

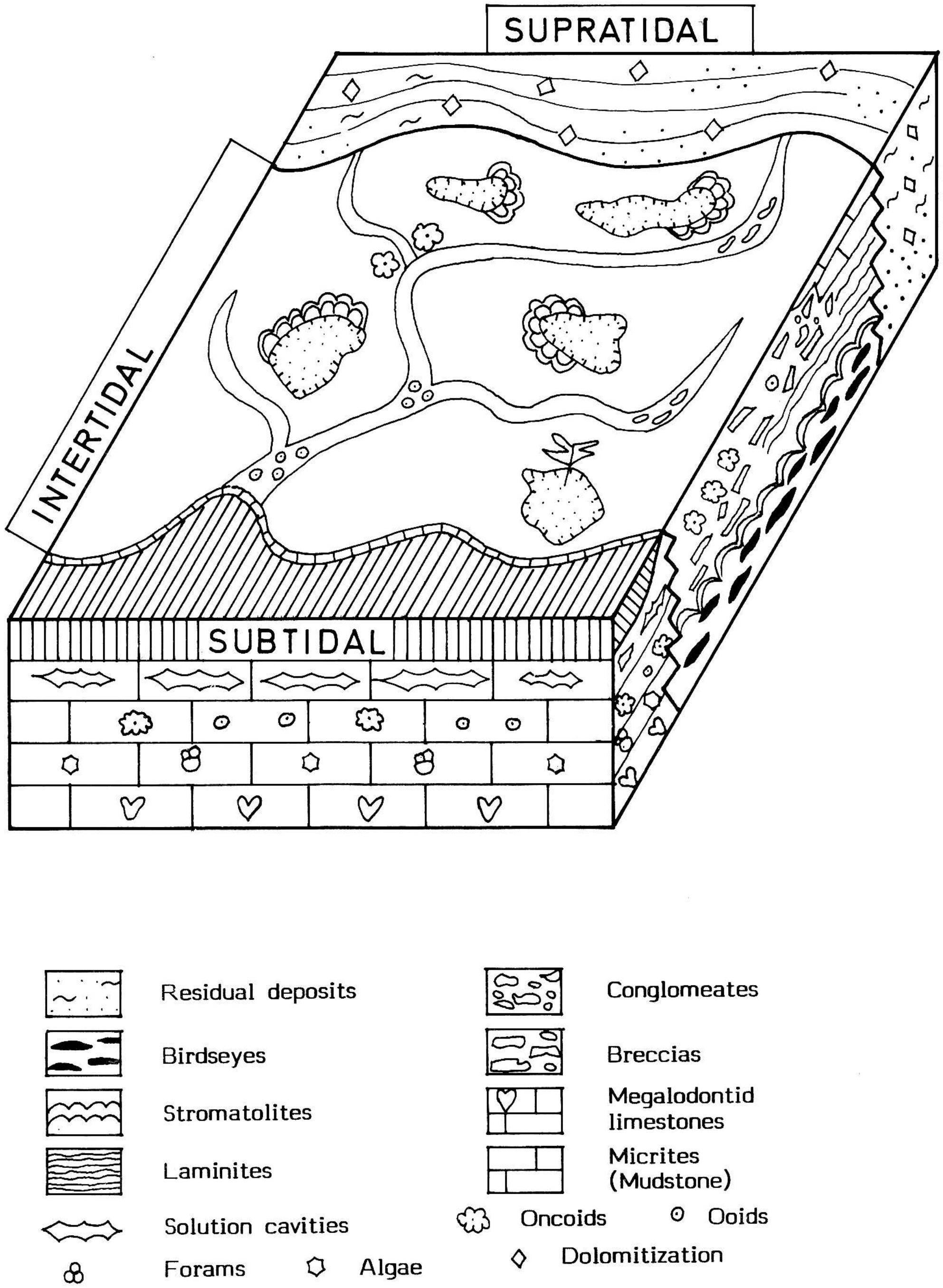

Fig. 4 - Lower Liassic sedimentary environments.

Birdseye limestones are relatively frequent in the Lower Liassic cyclothems. With the term "birdseye", Ham (1952) named some millimeter, large, oval, round and irregular calcite fillings in the limestones of the Mclish formation. Folk (1959) designated similar sediments as dismicrites. With the term "dismicrite" we could designate brownish gray and pink brownish gray limestones with numerous oval, lenticular and irregular cavities of up to 1 cm in size, filled with radiaxial cement. In the Lower Liassic Krka limestone, the birdseye limestones are black, as well as micritic, pelmicritic and pelmicrosparitic with several mm large cavities filled with fine-, medium-, and coarse-grained (predominant) sparry calcite. Pores predominantly originated from desiccation of sediments.

White calcite eyes are mostly arranged parallel with stratification. Fenestrae at right angle to stratification are very rare. Frequent are geopetal filling of cavities with calcitic silt (vadose silt: Dunham, 1969).. In some places, in the lower part of the cavities, micrite and in the upper part sparry calcite could be observed. More rare are cases with grayish black micrite below, calcitic silt in the middle, and fine-grained white calcite above. Still more rare are pores with dark gray micrite in the lower part and light gray calcitic silt in the upper part of cavities. In one of the larger pores light brownish fibrous calcite A and white coarse-grained calcite B are seen. Among fossils only rare ostracods are present in the examined sediments. Sedimentary structures indicate intertidal and supratidal environment.

Biolaminated Limestones.

Above the fenestral limestones there is a 35 to 60 cm thick horizon of biolaminated limestones among which stromatolitic and stromatoloid limestones prevail.

Stromatolitic (bindstone) limestones are light gray, very light gray to almost white and pale pink gray. The stromatolitic horizon is usually up to 35 cm thick, in rare cases even up to 60 cm. Stromatolitic limestones appear in 20 to 35 cm thick layers with undulated and irregular bedding planes. They are composed of laminae (LLH-C, Logan et al., 1964) several mm thick which are in several places interrupted and ruptured, as well as of 0.2 to 1 cm large and some mm thick predominantly irregular oblong fenestrae. Two types of laminae are observed:

1) laminae composed of light gray carbonate mud, and
2) laminae composed of transparent sparry calcite.

The latter correspond to Fischer's (1964) sheet cracks. Minor fenestrae are filled with fine-crystalline and medium-crystalline sparry calcite. In some places geopetally filled fenestrae are noticed: in the lower part of fenestrae micrite or pelmicrite, and in the upper part sparry calcite are found. Also other filling combinations are noticed: micrite - coarse grained calcite, calcitic silt - sparry calcite, only sparry calcite, only vadose silt. Stromatolitic laminae are often cut with mud cracks which are some mm long and more or less at right angle to laminae. Along some cracks the rupturing and removal of laminae occured providing in this way the material for supratidal homogeneous intraformational breccia which is often an equivalent of stromatolitic limestones. The internal structures are also destroyed by birdseyes, microtepees and bioturbation. In the stromatolitic limestone here and there minor oblong (0.5 cm x 4 cm) solution cavities filled with A and B cements or only with early diagenetic B cement are observed.

Stromatolitic limestone was formed in intertidal and periodically in supratidal environment. Very interesting is also stromatolitic limestone with ostracods. Ostracod shells are filled with calcitic silt. In the shells numerous geopetal fillings with calcitic silt below and fine-grained sparry calcite above are visible. Larger pores in the rock are filled with coarse-grained sparry calcite. Fossil contents consist of numerous ostracods, rare mollusc (gastropod) fragments, blue-green Algae and very rare *Favreina salevensis* Paréjas.

Over the stromatolitic loferites lie *stromatoloid limestones*. They are composed of laminae 1 to 2 mm thick and shrinkage pores. The most frequent are limestones with two types of laminae. Some consist of light gray little transparent micrite, pelmicrite and pelsparite, others are composed of round and oval cavities filled with sparry calcite. Occur also numerous irregular sparitic fillings subparallel and parallel to stratification: some pores are geopetally filled with dark micrite and sparry calcite.

Stromatoloid limestones are almost always more or less dolomitized so that light gray dolomitic and dark gray calcareous laminae alternate. Some layers show flat and/or undulated bedding planes without

LLH-C forms. Besides birdseyes also mud cracks appear in some places. The rock was formed in low-energy lagoon or intertidal and shallow subtidal environment, respectively.

Laminated Limestones.

Lamination among limestones is chiefly represented in the form of alternation of the different coloured micrites. The colour differentiation is the consequence of different contents of mostly clayey and organic matter and trace elements, especially iron and manganese. Limestones with increased contents of clay are darker. On the other hand, the limestones with organic admixture are brownish. Elements such as iron and manganese, contribute for the most part to red and pinkish variability of the rocks.

By banded (laminae wider than 1 cm) limestones an alternation of different textural and structural types of limestones of some cm to some dm thickness are mostly noticed. Coarse-grained laminated and banded limestones were formed in an intertidal environment. Fine-grained laminites were formed most probably in a shallow subtidal environment.

Intraformational Breccias and Conglomerates.

Intraformational breccias and conglomerates form the uppermost part of the member B. As to their composition, they are:

1) light gray homogeneous stromatolitic breccia-conglomerate passing to a loferitic breccia,

2) black homogeneous breccia,

3) many-coloured heterogeneous calcareous breccia-conglomerate,

4) mud pebble conglomerate.

The thickness of the breccia-conglomerate horizon varies from 20 to 35 cm. These sediments usually contain only scarce fauna and flora remains.

Stromatolitic breccia-conglomerate and loferitic breccia. The composition and textural, as well as structural characteristics of the stromatolitic breccia-conglomerate indicate their supratidal and intertidal formation. The rock is composed of ruptured and removed oblong fragments of 1 to 1.5 cm x 3 to 10 cm in size and of very light gray to white stromatolitic limestones. The fragments are oriented parallel or subparallel to the bedding planes, but very often they are chaotically arranged. The degree of roundness of fragments varies: in places prevail poorly rounded and in other cases medium-rounded fragments. The micritic and silty groundmass has the same composition as the fragments, but it is, due to clayey admixture, in some spots medium dark gray or dark olive gray. Here and there the supratidal and intertidal breccia-conglomerate also includes numerous shrinkage pores of different shapes and sizes. It passes into breccia that Fischer (1964) designated as loferitic breccia or conglomerate respectively. The larger pores are geopetally filled with dolomitized micrite and intramicrite as well as fine-grained sparry calcite. In some places geopetal fillings consist of calcitic silt in the lower part and of sparry calcite in the upper part. Some larger pores are exclusively filled with coarse-grained calcite.

Black calcareous homogenous breccia is composed of oblong poorly rounded fragments of black micrite bound with grundmass of the same composition as fragments. The solution cavities in the rock are filled with red and orange, more or less limonitized carbonate mud. The calcareous breccia was formed in supratidal and intertidal environments by desiccation of carbonate mud and rupturing along the cracks under the influence of waves and currents.

Heterogeneous calcareous breccia-conglomerate. Several types of this rock have been found.

The first is composed of poorly and moderately rounded fragments of 5 to 25 cm size of grayish black, dark gray medium and pinkish gray poorly stratified (3 to 50 cm) micritic limestone and calcite cement. The rock is compact and the groundmass is subordinate. The bedding planes are irregular.

The second type differs for the color of the fragments, among which medium gray and gray prevail.

In spots a breccia composed of fragments of stromatolitic, dismicritic and biomicritic limestones is observed. There is a little groundmass, and it is calcitic. In the fragment filaments of blue-green Algae, rare ostracods, gastropods and other molluscs are visible.

Mud pebble conglomerate appears in lenses of 20 to 30 cm thickness as the final horizon of the member B. It is a mixture of orange, orange gray and pink reddish gray carbonate mud in primary plastic condition. This sediment originated in intertidal environment by erosion of carbonate mud in tidal channels.

Subtidal Member C.

The most expressive member of Fischer's (1964) ideal Lofer cyclothem is the member of megalodontid limestones. Beside megalodontid biomicrite which is poorly developed in the Lower Liassic Lofer cyclothems from the Krka area there are many other structural types, such as micritic, biomicritic (Algae, forams), oomicritic, oncomicritic, intrasparitic, biointrasparitic, sparitic as well as laminated and banded ones.

The most abundant facies of the member C in Krka limestones are *micrites*. There are grayish black, dark gray, medium gray, and light gray bedded (40-100 cm) micritic limestones with flat and irregular bedding planes and clear contacts. Biogenic components are rare. In spots they contain individual shells and rare mollusc fragments or even individual megalodontid sections, rare ostracods and irregular forms of algal origin. On some locations traces of bioturbation and gentle lamination are noticed. The described sediments originated in shallow lagoons.

Micrite with red calcareous nodules. In medium gray, gray and dark gray stratified limestone appear 10 to 12 cm large nodules of red limestone. Contacts between red nodules and rock are sharp, the contact surface is smooth and gently undulated. The nodules consist of pale brick red micrite passing to yellowish and orange one. Somewhere the rock is pinkish. It is quite possible that the nodule-like forms were in fact filled later with marly-clayey-limonitic substance. The other possibility is that coherent pebbles of intertidal red marly-clayey-limonitic mud were rolled into the still unconsolidated carbonate mud of the subtidal environment.

Micrites with solution cavities. In the upper part of the member C in Krka limestones appears a horizon of grayish black, dark gray poorly bedded micritic limestones of a thickness of 0.5 m to 1 m, including numerous solution cavities. Solution cavities, representing 50% of the bulk, are mainly irregular, intermixed, forming variegated micritic rock. The above quoted features are more than 0.5 cm in diameter, irregular, usually more or less oblong. The walls are covered with brownish gray early diagenetic radial fibrous calcite cement (A cement): on the other hand, their inside is filled with mostly red or white interior sediment. In the Krka limestones the solution cavities are parallel to stratification, but for the most part they are inclined. Generally speaking, their texture is varied. The size varies from 0.5 to 40 cm, but mostly between 2 and 5 cm. They commonly have a trefoil shape, and they are rarely round or oval. Very rare are narrow (0.5 cm) and long (20 to 30 cm) solution cavites.

Inside, they are filled in several different ways:

1) with radial fibrous calcite A and younger drusy calcite cement (cement B) where crystal size increases from pore walls to center of cavities. 2) With fibrous calcite A, cement B, and grayish red, brick red or pink limonitic substance in the central part. 3) With fibrous calcite A, cement B, and black micrite in the

middle. 4) With fibrous calcite A and pinkish micrite. 5) With fibrous calcite A and black micrite in the middle. 6) With fibrous calcite A and olive gray clayey micrite. 7) Only with fibrous calcite A. Here and there geopetal fillings in solution cavities are observed. There is usually white grained calcite below and red carbonate mud or clayey-limonitic substance above. Fauna and flora are very rare. Only rare fragments of molluscs, microfauna and ostracods occur.

The horizon with solution cavities was formed most probably in a shallow subtidal environment by periodical intertidal conditions.

Megalodontid limestone of coquina type is rare and poorly developed in the Lower Liassic Lofer cyclothems. This is dark gray and grayish black biomicrite with small (1 to 2.5 cm) recrystallized undeterminable megalodontid sections. Megalodontid limestones overlie concordantly the loferites of the member B. The horizon with megalodontids is about 50 cm thick. Beside megalodontids there are also rare algal and foram remnants, fragments of molluscs, rare pellets, oncoids and ooids.

Medium gray *intrasparite (grainstone)* is chiefly composed of intraclasts, ooids pellets, and coarse-grained sparry calcite. Poorly rounded intraclasts of a size 0.1 to 3 cm are algal, oomicritic, oopelmicritic, pelsparitic, oopelsparitic, biomicritic, pelmicritic, and pelsparitic. Ooids have concentric structure. Bioclasts of blue-green Algae and rare textulariids occur in the rock.

Biointrasparite (grainstone) is composed of bioclasts, ooids, intraclasts, pellets and sparry calcite. Intraclasts from 0.1 to 1.5 cm belong to oomicrite, biopelmicrite, micrite, biooopelmicrite, oopelsparite, pelmicrosparite and pelooointrasparite. Ooids are 0.05 to 0.15 cm thick with micritic, sparitic, microsparitic, biomicritic and biooointrasparitic core. Among fossils forams, dasycladacean fragments and other remains are observed. The groundmass is often pelmicritic, and rarely micritic. Described ooids have a concentric structure. They are cemented with coarse-, medium-, and fine-crystalline sparry calcite. Among fossils occur also sections of Algae *Palaeodasycladus mediterraneus*, dasycladaceans, gastropods, molluscs, forams (*Trochamminidae*, *Verneuilinidae*, *Textulariidae*) and codiaceans. A specimen of *Favreina salevensis* Paréjas was also observed. Characteristic for the fossil content is the absence of echinoderms and rare forams. The biointrasparite often passes into oosparite, oopelsparite, oopelmicrite, biooopelmicrite and biooopelsparite and was most probably deposited in tidal channels and shallow subtidal with a rather high energy index. Among diagenetic changes micritization and recrystallization are present. Here and there micritic envelopes are observed. Intraclasts are from 0.1 to 1.5 cm large, angular to poorly rounded, poorly sorted, micritic, biomicritic, oomicritic and dismicritic. They often contain pellets which are of fecal (round, well sorted) and algal origin (irregular shape, poorly sorted): other grains probably belong to small micritized ooids.

Intraoobiosparite (grainstone) is composed of more or less rounded intraclasts, radial to concentric ooids, bioclasts and sparry calcite. Among bioclasts occur algal (dasycladacean, codiacean) fragments which are sometimes encrusted, fragments of echinoderms, encrusted mollusc fragments and benthic forams. Among structures cross-lamination and gradation frequently occur. The limestone was formed in a shallow marine high-energy environment with constant waving (shoals).

Medium gray coarse-grained *oosparite (grainstone)* often passes to biooointrasparite and oointrapelsparite. It is composed of ooids and groundmass. Ooids are from 0.05 to 0.15 cm and have concentric structure. They are usually more or less micritized. The core is microsparitic, sparitic, a fragment of mollusc or dolomitic crystal. For the most part only the exterior envelope is visible, others are micritized. Among the poor fossil material, the Alga *Palaeodasycladus mediterraneus*, dasycladacean sections, gastropods, mollusc fragments and rare forams occur. Rare poorly rounded intraclasts of size from 0.1 to 0.8 cm are micritic, oomicritic, biomicritic and biopelmicritic.

Gray *biooosparite (grainstone)* is medium-grained, medium sorted and has a homogeneous structure. It is composed of ooids, fossils and sparry calcite. Ooids of a size of 0.1 to 0.3 cm have a concentric structure and small number of visible envelopes. Some of them are washed out and filled with cement. The core is micritic, or of gastropod fragments and dolomite crystals. Many ooids are completely micritized. The limestone also includes rare pellets. Among fossils gastropods and numerous echinoderms appear. The groundmass is fine-grained, sometimes of coarse-grained sparry calcite. There is also radiaxial cement. The sediment was deposited in tidal channels in the intertidal area.

Oomicrite (wackestone) passes to biointrapelmicrite and biooncopelmicrite. The rock is composed of ooids, oncoids, fossils, pellets and groundmass. Ooids of 0,025 to 0.075 cm of size have concentric structure. The core is micritic, microsparitic and sometimes of a mollusc fragment. Among diagenetic changes recrystallization and micritization are frequent. Dasycladaceans, molluscs and codiaceans occur among fossils. Forams are very rare (*Trochamminidae*). Ooids have concentric structure. They are poorly sorted with micritic and microsparitic core. Sometimes micritic and pelmicritic intraclasts from 0.1 to 1.5 cm across as well as Alga *Palaeodasycladus mediterraneus* are found in the rock.

Medium gray *oncomicrite and oncopelmicrite* are composed of ooids, oncoids, fossils, pellets and groundmass. Among fossils forams (*Verneuilinidae*, *Textulariidae*, *Trochamminidae*) and sections of Alga *Palaeodasycladus mediterraneus* occur. The size of oncoids is 0.7 to 1 cm. The described sediment was formed in subtidal environment.

Grayish black *laminated limestone*. Up to 0.1 cm thick dark gray, grayish black and very light gray micritic, biointrapelsparitic, intrapelsparitic, pelmicritic, pelmicrosparitic and dismicritic laminae alternate. Pores and cement consist of fine-grained sparry calcite. Intraclasts are micritic. The rock contains remains of blue-green Algae, ostracods, textulariids, and other forams, as well as rare mollusc remnants.

Dark gray and grayish black *pelmicrite* and *pelsparite (grainstone)* are composed of pellets and micritic or sparitic groundmass. Pellets are poorly sorted and chiefly belong to algal pelloids (Flügel, 1982). There are also well sorted small fecal pellets, ooids (frequently micritized), rare encrusted intraclasts, rare foram remains, algal remnants (codiaceans, blue-green Algae), gastropods and other molluscs as well as sections of Alga *Palaeodasycladus mediterraneus*. The above enumerated characteristics indicate lower energy environment.

Light gray *pelmicritic, pelmicrosparitic and pelsparitic limestone with solution cavities (wackestone)*. Pellets are well sorted and mostly of fecal origin. Solution cavities are filled with brownish gray fibrous calcite with only a very little white mosaic medium-grained sparry calcite in the central part. In some places they are filled with coarse-crystalline sparry calcite.

Biopelmicrite (wackestone) is composed of fossils, pellets and micritic groundmass. An alternation of finer and coarser fragments causes gentle lamination, here and there. In some place bioturbation, geopetal filling of pores with calcitic silt and even mud cracks in the rock are noticed. The limestone was deposited in shallow lagoon or subtidal environment, respectively at periodically intertidal conditions.

Conclusions.

The Lower Liassic beds from the Krka area were deposited under similar conditions as the Dachstein Limestone and the Main Dolomite (Hauptdolomit) in Northern and Southern Limestone Alps, as well as the Upper Triassic calcareous beds on the Julian and Dinaric carbonate platform. These formations are characterized by typical Lofer rhythmic sedimentation: all three members of Fischer's ideal Lofer cyclothem are more or less developed. In the member A of the Lower Liassic Lofer cyclothem at Krka red and green residual deposits originated from land were sedimented. In other places a basal conglomerate was deposited. The sediments of the member B are intertidal, deposited predominantly in a moderate and higher energy environment. In member C prevail microfacies of low-energy environment. A special characteristics of the member C of the Krka Lower Liassic sedimentation is poorly developed megalodontid horizon, a relative frequency of oolitic, oncolitic as well as biosparitic limestones, and clearly developed uppermost horizon of micrite with solution cavities. Generally speaking, Lower Liassic cyclothems are well developed. The member A is relatively frequent. All three horizons, i.e. bee fenestral, stromatolitic and conglomeratic horizons of the member B, are clearly developed and equally frequent. The sediments of the member C prevail in view of frequency and with regard to the thickness. Finally, the Lofer sedimentation in the Krka area very probably took place in the lowermost part of the Middle Liassic too.

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PLATE 1

Fig. 1 - Intertidal sediments (b_2). Stromatolitic limestone (bindstone). Krka Valley, Lower Liassic; 6x.
Fig. 2 - intertidal sediments (b_3). Loferitic breccia-conglomerate. Krka Valley, Lower Liassic; 25 x.

PLATE 2

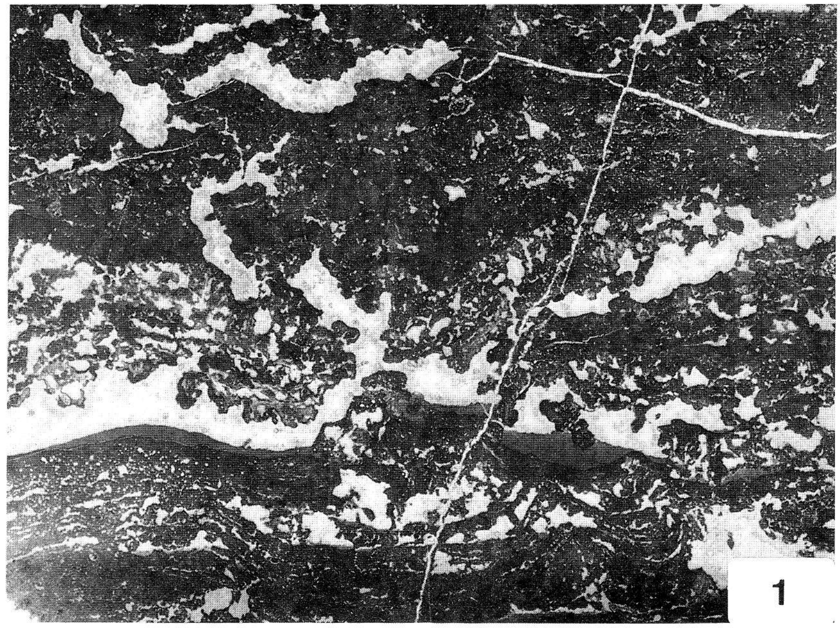
Fig. 1 - Intertidal sediments (b_1). Birdseye limestone (dismicrite). Krka Valley, Lower Liassic; 8 x.
Fig. 2 - Intertidal sediments (b_1). Birdseye limestone (dismicrite). Krka Valley, Lower Liassic; 8x.
Fig. 3 - Intertidal sediments (b_1). Fenestral limestone. Krka Valley, Lower Liassic; 8 x.
Fig. 4 - Intertidal sediments (b_1). Homogeneous loferite. Krka Valley, Lower Liassic; 25 x.
Fig. 5 - Intertidal sediments (b_3). Intraformational breccia. Krka Valley, Lower Liassic; 6x.
Fig. 6 - Subtidal sediments (c_4). Biointrasparitic limestone (grainstone). Krka Valley, Lower Liassic; 6 x.
Fig. 7 - Subtidal sediments (c_3). Laminated limestone. Krka Valley, Lower Liassic; 7 x.
Fig. 8 - Subtidal sediments (c_3). Laminated limestone. Krka Valley, Lower Liassic; 7 x.

PLATE 3

Fig. 1 - Subtidal sediments (c_1). Biopelmicritic limestone containing gastropod fragments (wackestone). Krka Valley, Lower Liassic; 6 x.
Fig. 2 - Subtidal sediments (c_1). Biointrapelmicritic limestone containing molluscan fragments (packstone). Krka Valley, Lower Liassic; 6 x.
Fig. 3 - Subtidal sediments (c_4). Biointrasparitic limestone. Krka Valley, Lower Liassic; 25 x.
Fig. 4 - Subtidal sediments (c_4). Biointrapelsparitic limestone (grainstone). Krka Valley, Lower Liassic; 5 x.
Fig. 5 - Subtidal sediments (c_4). Biointrasparitic limestone (grainstone) with *Palaeodasycladus mediterraneus* Pia. Krka Valley, Lower Liassic; 35 x.
Fig. 6 - Subtidal sediments (c_4). Bioooointrasparitic limestone (grainstone) with molluscan and algal fragments and *Palaeodasycladus mediterraneus* Pia. Krka Valley, Lower Liassic; 7 x.
Fig. 7 - Subtidal sediments (c_4). *Thaumatoporella parvovesiculifera* (Raineri). Krka Valley, Lower Liassic; 35 x.
Fig. 8 - Subtidal sediments (c_4). Biointraoopelsparitic limestone (grainstone). Krka Valley, Lower Liassic; 7 x.

PLATE 4

Fig. 1 - Subtidal sediments (c_4). Bioooointrapelsparitic limestone (packstone). Krka Valley, Lower Liassic; 7 x.
Fig. 2 - Subtidal sediments (c_4). Fine-grained bioosparitic limestone (grainstone). Krka Valley, Lower Liassic; 8 x.
Fig. 3 - Subtidal sediments (c_4). Biointrasparitic limestone (grainstone). Accumulation of molluscan fragments. Krka Valley, Lower Liassic; 6 x.
Fig. 4 - Subtidal sediments (c_4). Bioooointrapelsparitic limestone (grainstone). Krka Valley, Lower Liassic; 7 x.
Fig. 5 - Subtidal sediments (c_4). Micritic limestone with solution cavities. Krka Valley, Lower Liassic; 5 x.
Fig. 6 - Subtidal sediments (c_4). Micritic and microsparitic limestone with solution cavities. Krka Valley, Lower Liassic; 5 x.
Fig. 7 - Subtidal sediments (c_4). Pelmicritic and pelsparitic limestone with solution cavities. Krka Valley, Lower Liassic; 25 x.
Fig. 8 - Subtidal sediments (c_4). Pelmicritic and pelsparitic limestone with solution cavities. Krka Valley, Lower Liassic; 35 x.



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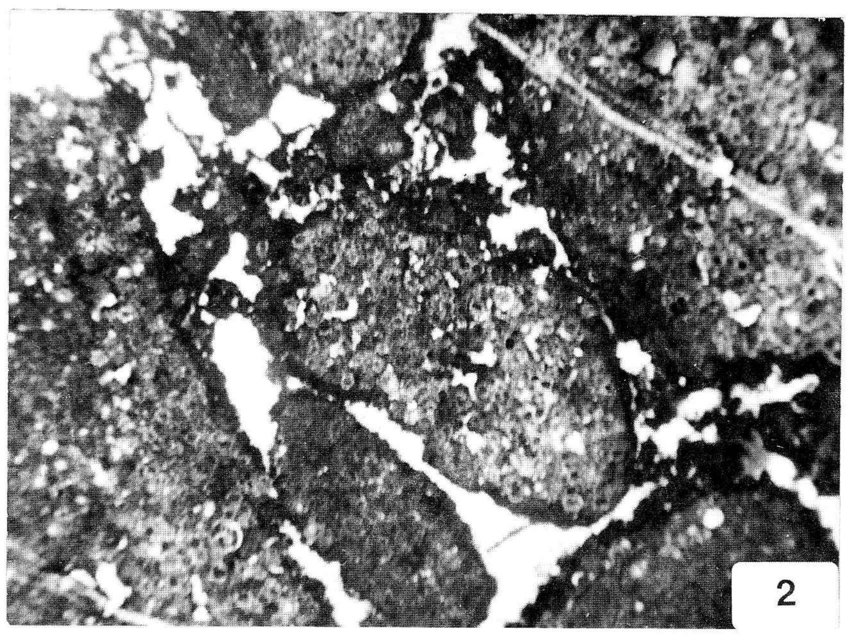

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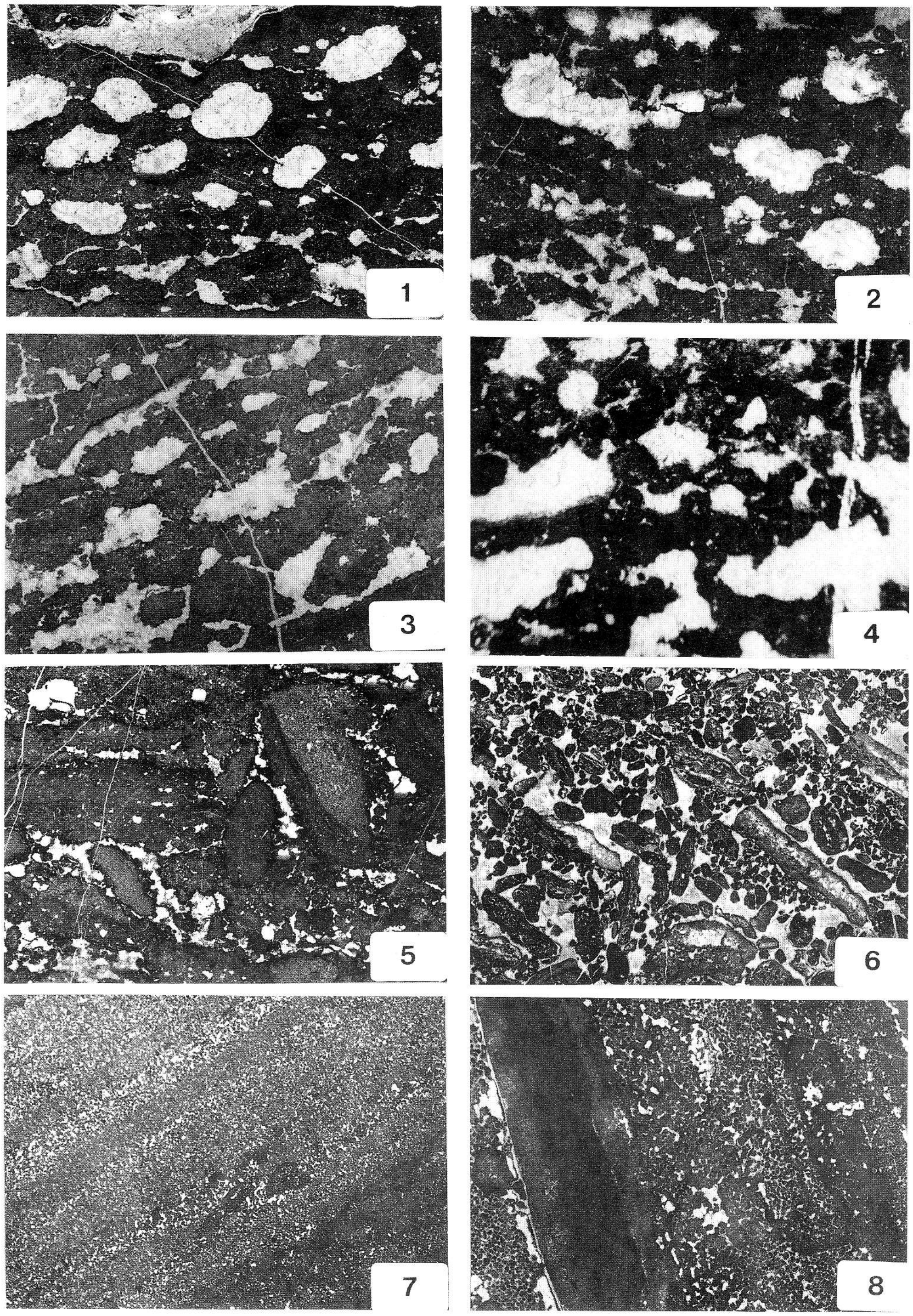

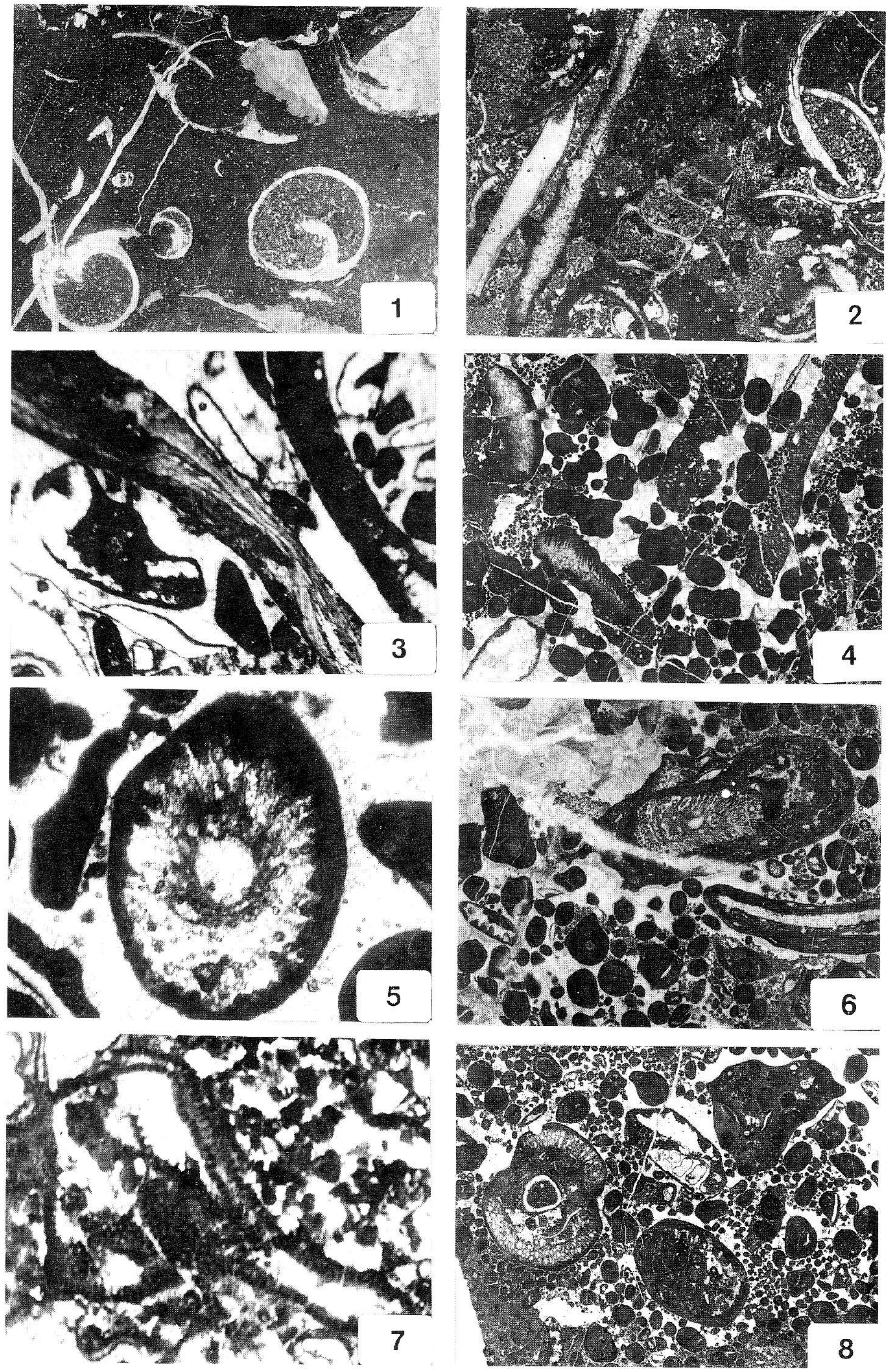
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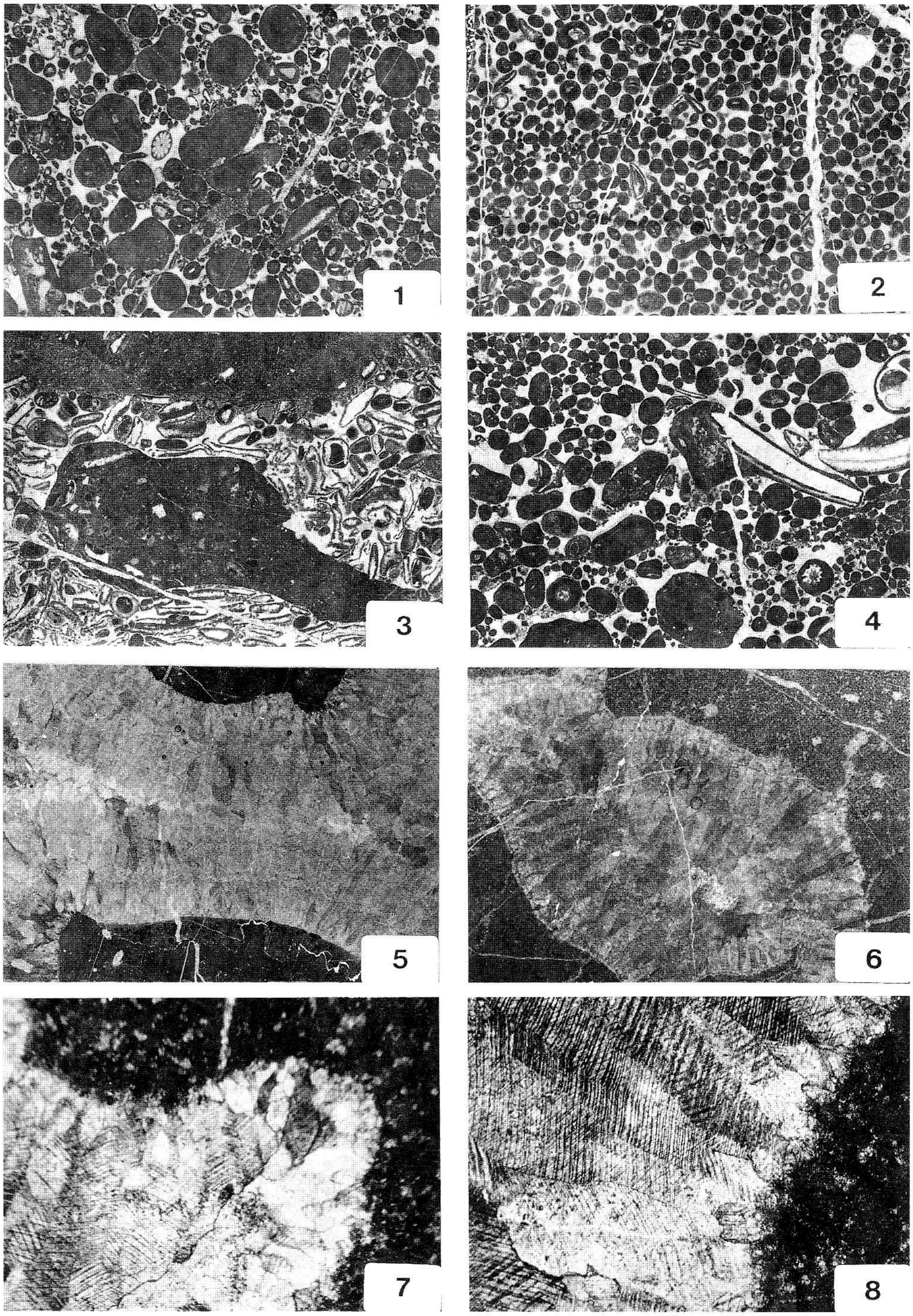
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