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BARITE-BEARING STROMATOLITES AT THE PERMIAN-TRIASSIC BOUNDARY IN GORSKI KOTAR (CROATIA, YUGOSLAVIA)

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ABSTRACT

Barite-bearing dolomites in Gorski Kotar are conformably situated above the Upper Paleozoic clastic sediments, rich in early diagenetic pyrite. Discovery of cryptalgal fabrics in elastics and dolomites, together with other sedimentary features supports their affiliation to a tidal flat facies. The geological development at the locality Mrzle Vodice shows some elements of Sabkha environment.

SAŽETAK

Baritonosni dolomiti u Gorskom Kotaru konkordantno su položeni na gornjopaleozojskim klastičnim sedimentima, bogatim na ranbdijagenetskom piritu. Otkriće kriptoalgalnih struktura u klastitima i dolomitima, zajedno s ostalim sedimentnim karakteristikama podržava tvrdnju da se radi o facijesu plimskih zaravni. Geološki razvoj u Mrzlim Vodicama sadrži neke elemente Sabkha sedimentne sredine.

KEY WORDS: *Stromatolites, Barite, Paleoenvironment, Permian/Triassic Boundary.*

INTRODUCTION

This paper deals with different barite-bearing stromatolitic morphotypes near Lokve village in Gorski Kotar, Croatia. Their discovery and description is a contribution to the paleoenvironmental analysis and lends support to the early diagenetic ore forming model as well. The dilemma of continuous or discontinuous sedimentation at the elastics-carbonates contact is resolved, but its stratigraphic position is still in question and may be in the Upper Permian or in the Lower Triassic.

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GEOLOGICAL SETTING AND STRATIGRAPHIC POSITION

Middle and Upper Permian sediments in Gorski Kotar are characterized by shales, sandstones and conglomerates deposited in the shallow Dinaric sea. The sedimentary basins were filled by persistently maturing elastics as disintegration products of progressive cordillera denudation. Obliteration of low relief led to formation of extensive low-lying coastal areas, which, together with a warm-arid climate, initiated carbonate and evaporite deposition in adjacent lagoons and sabkhas.

The basal dolomites (formerly aragonitic mud) at the Permian-Triassic boundary in Gorski Kotar are characterized by typical peritidal sedimentary features like oolitization, cross-, oblique- and parallel laminations, ripple-marks, intraformational slumping, desiccation cracks, presence of bioherms and biostromes, etc. (SĆAVNIČAR & ŠUŠNJARA, 1967; BABIĆ, 1968; ŠĆAVNIČAR, 1973; ČERINA, 1968; PALINKAŠ & ŠINKOVEC, 1986a; 1986b).

Stratabound and at places even stratiform barke mineralization is conformably situated on the elastics-carbonates contact, but predominantly in carbonate rocks. On the basis of ore sedimentary structures PALINKAŠ & ŠINKOVEC, 1986a; 1986b proposed an early diagenetic ore forming model, related to tidal flat facies and evaporative dolomitization.

The age of basal barite-bearing dolomites and nature of the elastics-carbonate contact, whether continuous or discontinuous, has been the subject of much dispute.

SALOPEK 1961, considered the basal dolomites to be of the Upper Triassic age.

Detailed investigation of the dolomites and the overlying clastic sediments performed by ŠĆAVNIČAR & ŠUŠNJARA (1967) and ŠĆAVNIČAR (1973), confirmed the significant similarity of accessory mineral association with the underlying Upper Paleozoic clastic rocks. Index fossils *(Anodontophora fassaensis* WISSM., *Pseudomonotis* cf. *inaequicostata* BENECKE) in the same dolomite overlying the clastic proved their Lower Triassic affiliation as shown by the same authors, but the age of the basal dolomites is still in question.

According to ŠUŠNJARA & ŠINKOVEC (1973), the barite bearing dolomites belong to a transitional zone between the Permian and the Lower Triassic. They were deposited in very shallow, partly or completely landlocked basins during regressive conditions.

The narrow range of $\delta^{34}S$ values indicates a homogeneous marine source of barite sulphur, probably of the Triassic age (SIFTAR, 1981).

According to SAVIĆ *et alii* (1982) the basal dolomites with barites are Upper Triassic in age, while the minor occurrences in limonites and beneath them belong to the Middle Permian.

FACIES CHARACTERISTICS AND STROMATOLITE MORPHOTYPES

In this paper, the authors would like to produce a sedimentary model by presenting some new observations on the nature of barite-bearing bioherms and biostromes. On the other hand the description of the two given stratigraphic columns (fig. 5, 6) might be an additional moment in making a desicion on whether continuous or discontinuous sedimentation occured at the transition between the Upper Permian and Lower Triassic in Gorski Kotar.

The schematic column at the locality Homer (fig. 5) represents a characteristic stratigraphic sequence at Lokve village. Underlying rocks are the Permian elastics. This is a subparallel alternation of shales and sandstones on a cm-scale. The rocks are dark, almost black, often with macroflora remnants. The coarser members are pervaded by pyritic cement, whereas big euhedral pyrite crystals are situated at the boundary fine-coarse grained elastics, but submerged and oriented into the fine-grained member, formerly an organic-rich mud. The quantity of pyrite amounts to a few percents but increases significantly on approaching the elastics-carbonates boundary (few tens and, at places almost a hundred percent). In the uppermost part of the elastics the first scattered masses of barite appear. The boundary is sharp and topped by barite-bearing dolomites.

The bioherms distinctly emerge as prominent masses surrounded by laminated dolomites, rich in different high energy water structures. At the lowermost part of the basal dolomite (in laminated and biohermal lithotypes) a nodular, pyritic, barite ore occurs with characteristic chicken-wire structures. The dolomitic part of the bioherm is dissolved on the outcropping surfaces by weathering processes and the stromatolitic fabric is clearly demarcated by chemically resistant barite. Thin section and acetate peel examinations have not revealed any conspicuous internal structure, since severe recrystallization during dolomitization and baritization destroyed it, although barite patches possess a kind of sponge-like porosity (few hundred μm). Crudely developed barite lamination and coarse fenestrae suggest an intertidal stromatolitic fabric formed from pustular mat (PLAYFORD & COCKBAIN, 1976) in fairly agitated water of an unprotected environment.

Discrete stromatolitic morphotypes have been observed at Školski brijeg (fig. 1). The stromatolitic series starts with low relief species having almost biostromal characteristics (fig. 2, point A). Coarse fenestrae, caviting, crude lamination and low relief indicate sublittoral, but lower energy water. The conditions were gradually changing in-

Fig. 1 - The contact of elastics and catbonates at Skolski brijeg with discrete columnar stromatolites. The discovery site is shown by the circle.

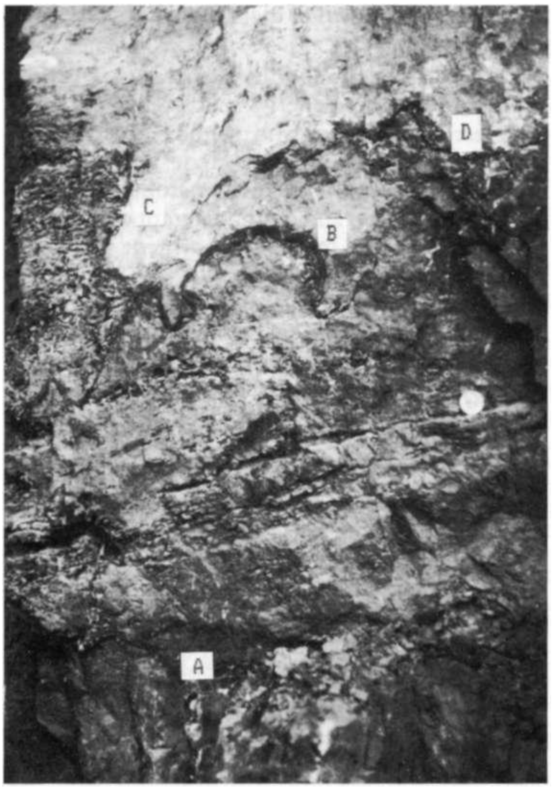

Fig. 2 - The Skolski brijeg locality, different stromatolitic morphotypes:

A - Low relief biostromal formation with pyrite crust.

B - Discrete columnar stromatolite with prevailing conical and domal forms. The outer crust is made of app. 5 cm thick pyrite at the clown of the column.

C - Club shaped columnar stromatolite with the missing pyrite crest and crudely developed baritic, fenestral fabric.

D - Ridge-and-rill stromatolites formed in lowered water energy.

to a more agitated water environment, causing formation of columnar stromatolites of different shape. Conical and domal forms prevail (fig. 2, point B). The outer surface of the stromatolites is covered by a pyritic crust, which is approximately 5 cm thick at the crest of columns. This is a former soft, colloform mat, ideal food for desulfurizing anaerobic bacteria, which digested it during later anoxic conditions, likely after burial. The burial must have been fast, perhaps even torrential, since algal growth was stopped instantaneously, and organic matter preserved from disintegration in otherwise oxidizing water conditions.

DILL *et alii* (1986) reported a "24-hour-covering" of a 40 cm tall columnar stromatolite by megaripple in a current-swept channel between Exuma Island on the eastern Bahama Bank.

On the left side of fig. 2, at point C, one may observe a 0.5 m tall, club-shaped column with coarse, irregular fenestrae, formed from pustular mat. The pyrite crown is missing, since mucilage, or organic layer was destroyed during emergence and subaerial exposure, a common case of the disintegration process on living stromatolites in the upper intertidal zone.

The uppermost pyritic, irregular layer (fig. 2, point D) is a cros-section through a ridge-and-rill, pseudocolumnar stromatolite, shaped by wave action and tidal scouring in sublittoral, but again lower energy water.

The situation at Mrzle Vodice is markedly different in some very important details. The Permian elastics are red with green and gray intercalations, here named "Groeden equivalent" (fig. 6). A layer of gray siltstones and sandstones, rich in pyritic cement surmounts "the red clastic series". This uppermost gray clastic member differs from its equivalent at the locality Homer only in a higher contribution of sandy fraction and greater quantity of pyritic cement.

The gray, pyritic, clastic layer, several meters thick, preceding the carbonate deposition, is present at all mentioned localities and is of great importance for elucidating the dilemma of continuous or discontinuous sedimentation, which will be discussed later.

The upper surface of the elastics is impregnated by a large quantity of pyrite, which converted

Fig. 3 - The Mrzle Vodice locality. Flat-laminated barite stromatolites with scallop fabric due to desiccation process in the uppet intertidal.

into thick masses of gossan limonite. A careful examination revealed a conspicious, tiny lamination with sparse barite fenestrae. In still preserved parts of the limonitic lamellae one may observe a pyritic precursor. This is very probably a former organic-rich, stromatolitic layer, pyritized completely during early diagenesis. It carpeted muddy shoals with stagnant, hypersaline water, as deduced by the absence of trapped detrital particles and grazing metazoans.

Fine, undulate lamination on the mm-scale, at the contact of the elastics and carbonates, changes to sligthly coarser baritic in the overlying dolomites, with the first appearance of domal forms, laterally passing into the flat laminated fabric (fig. 4). The change in the fabric type from fine, undulatory, laminated, formed in the lower intertidal, protected environment, into coarser, pseudocolumnar, shows an increase in water energy.

Stromatolitic bioherms with scallop fabric succeeding upwards, are upper intertidal formations, and curling up of algal mats is due to dessication processes (fig. 3).

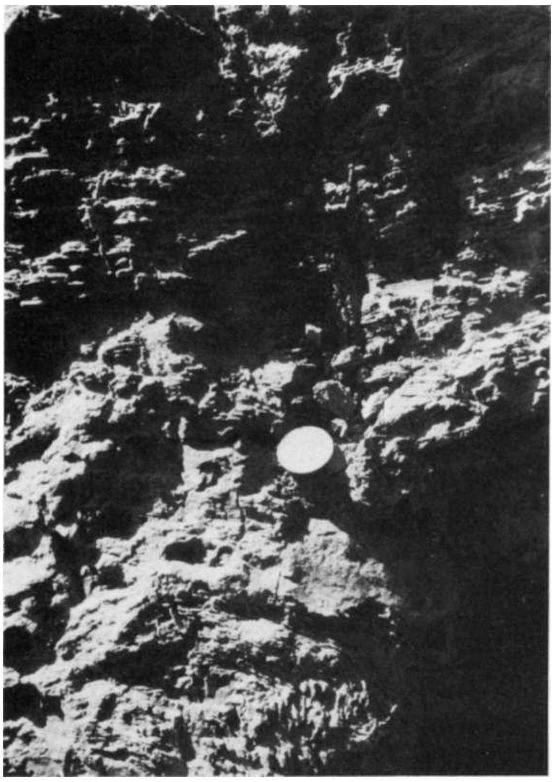

Fig. 4 - The Mrzle Vodice locality. Pseudocolumnar baritic sttomatolites with undulatory-laminated fabric, laterally passing into flat-laminated ones fotmed in low energy water, protected environment (muddy embayment).

Comparing the localities, there is an obvious difference in water energy. Skolski brijeg might be refered to as a headland, while Homer belongs more to a bight coastal type. Mrzle Vodice with fine, laminated organic-rich stromatolites (transformed into pyrite) and without trapped particles might have been a muddy embayment with sabkha environment characteristics.

A pyritized clastic layer, several meters thick, is present at all localities. It undoubtedly proves a continuous sedimentation of elastics-dolomites, since pyritic elastics would have otherwise undergone a severe oxidizing weathering during dry land conditions.

Transition "red-grey" rocks at Mrzle Vodice might be a trangressive contact (hiatus) in deposition of the Permian elastics. The low relief with subaerial exposure of dry-land heights (red sediments) was submerged probably during some later transgression. There may be a gap in clastic sedimentation but certainly not at the elastics-dolomites contact.

CONCLUSION

The barite-bearing stromatolites in Gorski Kotar near Lokve village, regarding their morphogenetic characteristics, may be grouped into the three distinctive types:

- Školski brijeg domed bioherms with discrete columnar stromatolites were mostly formed in high energy water, changing temporarily into less agitated, affecting columnar shape. Club-shaped, domal, cylindrical stromatolites changed into ridge-and-rill structures in this way.

- The Homer locality is characterized by undefined biohermal formations surrounded by laminated dolomites (cross-, oblique-, and parallel lamination). Non-columnar stromatolites with crude-flat laminated fabric and coarse fenestrae, with still unexplained sponge-like porosity in barite patches, are a sublitoral to lower intertidal formation, growing in fairly agitated water.

- Mrzle Vodice is distinguished by large quantity of pyritic-limonitic gossan, whose internal structure is minutely laminated, undulatory pyrite-limonite (former organic-rich algal mat) with sparse fenestrae. Trapped particles are almost absent. Other morphotypes are also flat-laminated with some pseduo-columnar varieties. Scallop fabric is a sign of desiccation in the upper interti-

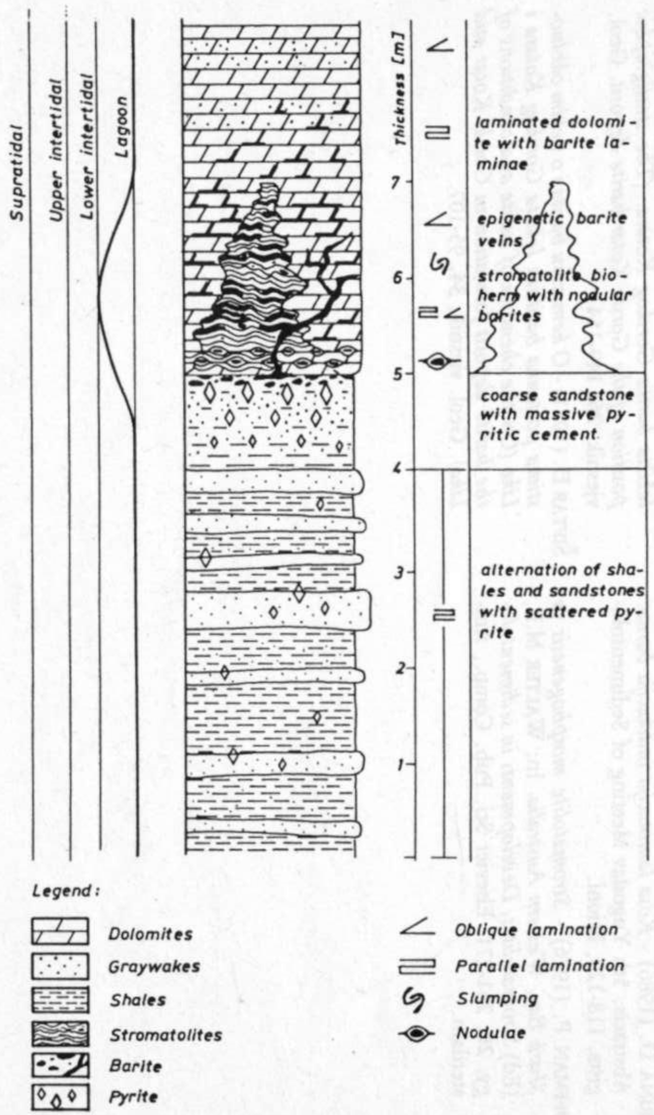

Fig. 5 - Schematic column at the Homer locality.

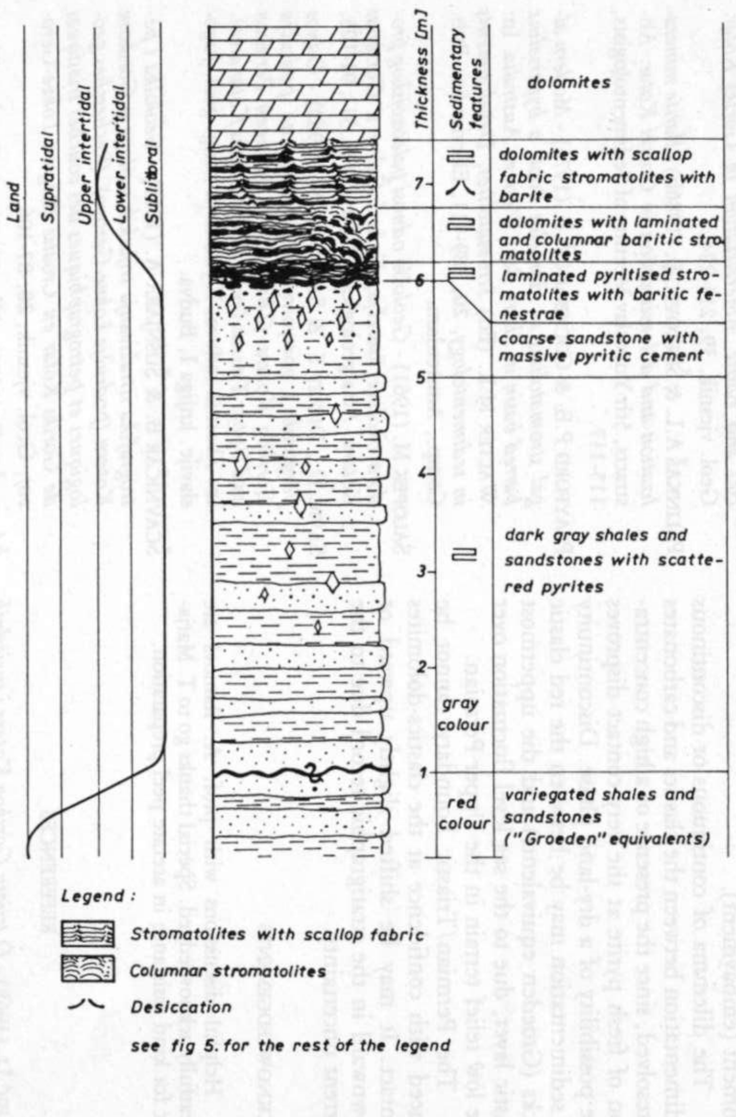

Fig. 6 - Schematic column at the Mrzle Vodice locality.

dal. This was a protected, low water energy environment (embayment).

The dilemma of continuous or discontinous sedimentation between the elastics and carbonates is resolved, since the presence of a high concentration of fresh pyrite at the very contact disproves the possibility of a dry-land phase. Discontinuity in sedimentation may be between the red clastic rocks (Groeden equivalents) and the uppermost clastic layer, due to the sea level fluctuation over the low relief terrain in the Upper Permian.

The Permian/Triassic boundary cannot be placed with confidence at the elastics-dolomites contact. It may be shifted slightly upward or downward in the stratigraphic record due to the current uncertainty.

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