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Late Malm carbonate breccias at Korinj and their significance for eustacy and tectonics (Central Slovenia)

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Abstract

On the Dinaric carbonate platform along the margin of the Upper Malmian shelf carbonate breccias were formed. The most typical, various and extended breccias outcrop at Korinj in the Suha Krajina area. The breccias are composed of various, more or less angular limestone and dolomite fragments, and of calcitic and dolomitic cement. The study shows that breccias from different stratigraphic levels were formed in different ways and environments.

Generally, the sedimentary succession consists of limestones, dolomites and carbonate breccias. The sedimentary structures of the succession indicate high energy shallow-water environment. Determined microfauna and flora of the succession prove the Upper Malmian age of the studied sediments.

The shallow-water deposition, the breccias, and the subaerial exposures, evidenced by bauxite at some places in the Suha Krajina area, are considered to be connected with eustatic sea-level variations as well as synsedimentary fracturing and block-faulting.

Introduction

Detailed geological investigations have been carried out in the section Krka-Mali Korinj in the Suha Krajina area about 35 km SSE from Ljubljana (Fig. 1.). In this section a complete succession of the Jurassic beds is exposed including the contacts between the Upper Triassic and Lower Liassic as well as the Upper Malm and the Lower Cretaceous.

In the Malmian sedimentary succession at Korinj numerous breccias lenses and irregular bodies have been found. The breccias outcrop in localities Kamni vrh, Ograja, Šataja and Ciganov vrh. They are underlain by various types of tidal bar oolitic limestones and are conformably overlain by Tintinnina-Clypeina limestones. Genetically different breccias were formed in different time intervals of the Malm period and are present

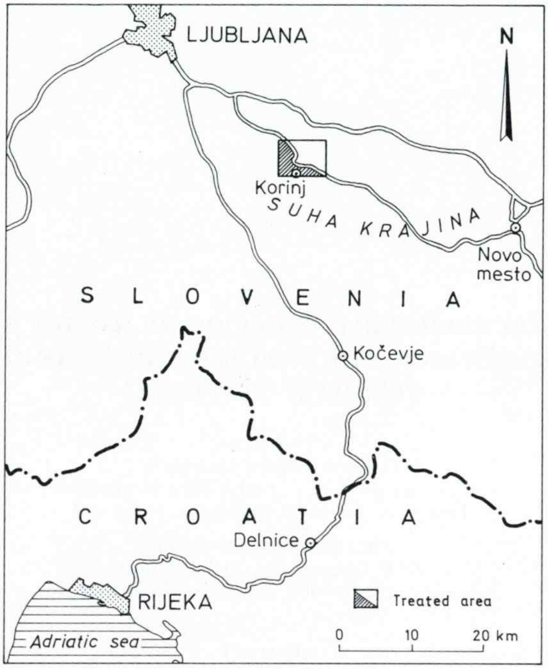

Fig. 1. Location sketch map

in different stratigraphic levels of the Malmian succession at Korinj. In order to ascertain the composition, genesis and age of the breccias and their geologic significance we have attempted to examine the exposures of breccia more exactly. Further on, we wanted to establish if and how the brecciation was connected with the sea-level variations and tectonics. We believed that the study of the breccias was of great importance not only for the explanation of the sedimentation but also for better interpretation of Malmian eustacy, paleogeography and tectonics. The carbonate rocks are classified using Folk's (1959) practical petrographic classification of limestones and Dunham's (1962) classification of carbonate rocks according to depositional texture. The microfossils are determined by Rajka Radoičič and the senior author.

Previous investigations

Šribar (1966) described the Jurassic sediments between Zagradec and Randol in the Suha Krajina area. On the bassis of microfossils and the stratigraphic position she divided the Jurassic succession into the Lower and Middle Liassic, Upper Liassic-Dogger, Lower Malm, and Upper Malm.

In a comparatively small region of southern Slovenia Turnšek (1969) distinguished three types of Hydrozoan fauna formed during the Lower Malmian that are connected with three separated areas. These are the hydrozoan Cladocoropsis in the southern faunistic area, the parastromatoporidian Hydrozoa, corals and Chaetetidae in the central faunistic area, and the actinostromaridian Hydrozoa in the northern faunistic area.

Buser (1979) studied the general geology on the sheet Ribnica 1:100000 and divided the Jurassic succession in the lower (Oxfordian and Lower Kimmeridgian) and upper part (Upper Kimmeridgian and Tithonian).

In his dissertation Strohmenger (1988) discussed microfacies and diagenetic development of the Jurassic carbonate rocks from the section Kompolje-Ogorelec at the Mala gora mountain and the section Krka–Mali Korinj in the Suha Krajina area.

Strohmenger and Dozet (1991) studied the stratigraphy, facies developments and geochemistry of the Jurassic carbonate rocks in Suha Krajina. The field studies showed that at least the uppermost part of Dogger was not deposited.

Strohmenger et al. (1991) compared the Upper Jurassic stratigraphy and the facies development of the Dinaric carbonate platform of Slovenia with the Jurassic carbonate platform of southern Jura (southeastern France). The Malm discontinuity is interpreted as representing a large-scale sequence boundary, probably of type 1, (black pebble conglomerate: France; reef breccia: Switzerland; Karst breccia: Slovenia).

Dozet (1993) detected the complete Lofer cyclothems in the Lower Liassic beds from the Slovenian part of the Outer Dinarides.

General geology of the area

Shallow-water carbonate rocks of Jurassic age are well exposed in southern Suha Krajina area with an average thickness of about 1500 metres. The Lower Liassic beds from the Suha Krajina area were deposited under similar conditions as the Dachstein Limestone and the Main Dolomite (Haptdolomit) in Northern and Southern Limestone Alps, as well as the Upper Triassic carbonate rocks on the Julian and Dinaric carbonate platforms. These formations are characterized by typical Lofer rhythmic sedimentation (Dozet, 1993). The brownish limestones of the Lower Liassic contain algae *Palaeodasycladus mediterraneus* Pia and *Palaeodasycladus elongatus* Praturlon. The Middle Liassic succession consists of lithiotid limestones, Orbitopsella intrasparitic limestones and oolitic limestones passing continuously upwards into the Upper Liassic spotted limestones. The Dogger beds are exclusively developed as ooid grainstones which laterally can also be somewhat dolomitized. The uppermost beds of the ooid grainstones are rich in the foraminifer *Dictyoconus cayeuxi* Lukas. The determined fauna and flora showed that at least the uppermost part of Dogger was not deposited in the studied area (Strohmenger, 1988). To ooid grainstones with hydrozoans, corals and Chaetetidae was attributed the Lower Malmian age (Turnšek, 1969; Buser, 1979). Finally, the Upper Malmian succession is composed of Clypeina and Tintinnina limestones and dolomites intercalated with carbonate breccias.

The carbonate breccias mainly occur in the Upper part of the Malmian succession. The terrain at Korinj exibits quite well exposures of the breccias. The breccias occupy a relatively large area between Kamni vrh and Ciganov vrh. They start at the road level at 600 metres and finish at Ciganov vrh at the level of 670 metres.

The uppermost part of the Upper Malmian sedimentation is characterized by rhythmic sedimentation of micritic, light gray laminated limestones and dolomites.

From the paleogeographical point of view the investigated area belongs to the Outer Dinarides. The unit of the Outer Dinarides was originally a relatively large and morphologically poorly differentiated area of predominantly shallow-water carbonate deposits ranging from subtidal to supratidal environment. Carbonate rocks were continuously deposited there from the Upper Triassic to the Upper Cretaceous. The platform consisted of a very thick carbonate succession with an average thickness of about 4000 to 5000 metres. Later, the Outer Dinarides underwent a differentiation due to the formation of the Slovene trench, and the originally uniform area was dissected into two minor platforms, the Julian and the Dinaric one (Buser, 1989). The examined breccias belong to the Dinaric platform sedimentary succession.

Korinj carbonate breccias

At Korinj in the Suha Krajina area several horizons of carbonate breccias within Malmian carbonate rocks occur, consisting of fragments varying in dimensions from pieces of half a metre in length to the smallest of microscopic dimensions. All these breccias, composed of more or less angular limestone and/or dolomite fragments enclosed in calcitic and dolomitic cement, are nominated with Korinj carbonate breccias. The cement surrounding these constituents consists of very fine crystals that appear as a brown matrix surrounding the differently colored breccia fragments. Despite the similarity, there is a considerable difference between the breccia and the cement with respect to megascopic appereance, microfauna content and especially genesis. Breccias occur first of all in dolomites and subordinately in limestones and are certainly wedging out.

With respect to genesis polymict subaerial karst breccia, talus breccia, submarine talus breccia, mud pebble conglomerate-breccia and tidal flat breccia occur in the area treated.

Polymict karst breccia

At Kamni vrh breccias of polymict composition, which are attributed to the karst breccias, are intercalated within ooid grainstones. They contain typical clasts of the Malmian ooid grainstones and/or oncoid-peloid packstones as well as wackstones whose fossil content (*Clypeina jurassica* Favre, *Clypeina* cf. *maslovi* Praturlon, *Salpingoporella annulata* Carozzi and *Campbelliella milesi milesi* Radoičić) clearly identifies them to be of the Upper Malmian age. The breccias and adjacent limestone beds are often heavily dolomitized. The polymict composition of the breccias (clasts of different composition and stratigraphic levels), age as well as their confined occurrence as lenticular intercalations within the Lower Malm strata allow the conclusion that they represent true karst breccias. Consequently, they are interpreted to be the lateral equivalents to the bauxite horizon, which is often intercalated between the Lower and Upper Malmian beds in the Dinarides (Strohmenger, 1988), and is also present nearby the investigated carbonate succession.

Mudstone breccia-conglomerate

At the northern foot of the hillock Šataja a several metres thick lense of predominantly platy to stratified (5–50 cm) breccia-conglomerate occurs. It contains brownish gray, angular to moderately rounded mudstone clasts with a diameter of 2–4 centimetres embedded in greenish gray and yellowish gray clayey and limonitic matrix. This sediment probably originated due to dessication. Irregular and mud-cracked polygons have been broken into angular fragments which have then been eroded from the mud-cracked layer of sediment, more or less rounded by transportation and deposited with muddy sediment. The treated carbonate rock is often somewhat nodular. The mudstone clasts contain scarse microfauna and flora such as remains of ostracods, molluscs, foraminifers and algae, possibly Characea and tintinnids. The stratigraphic position of the mudstone breccia-conglomerate and microfossils indicate the Malmian age.

Tidal flat breccia

The next and by origin similar type of Korinj breccias is composed of angular and subangular fragments of dark gray and grayish black micrite and stromatolite. The size of unsorted fragments embedded in mud is 0.5 cm to 5 cm. Fragmentation of the newly formed sediment was obviously caused by shoaling and temporary withdrawal of water, followed by desiccation and mud-cracking. Mud-cracking and clasts overgrown with stromatolite laminae prove that the clasts are essentially contemporaneous in origin with matrix and sedimentation. The composition and textural as well as structural characteristics of the breccia indicate its intertidal and supratidal formation.

Talus breccias

On the northern slope of the hillock Šataja an about 20 metres thick belt of preponderantly massive to poorly stratified unsorted to poorly sorted carbonate breccias of rather heterogeneous composition is exposed. Limestone, limestone-dolomitic and dolomitic breccias occur there. The composition of the breccias change in lateral and vertical direction. Regarding the structure, the breccias are fine-grained, medium-grained and rarely coarsegrained. The size of angular, subangular and rarely rounded fragments ranges from 0.5 cm to 100 cm. The groundmass is calcitic, dolomitic and very rarely somewhat sandy.

Dolomitic breccia is usually fine-grained and composed of angular to poorly rounded fragments of brownish gray, brownish black and very light gray fine-grained and medium grained bituminous dolomite. The cement is dolomitic and calcitic.

Limestone-dolomitic breccia is predominantly fine-grained and medium-grained and has a heterogeneous composition. Within the breccia very light gray to black micritic limestone fragments prevail; also light gray to grayish black, fine grained limestones as well as light to dark gray fragments of fine-grained and medium-grained dolomite occur. Dolomite fragments are 3–10 cm in size, and the limestone ones 0.5 to 30 cm. The cement of the breccia is calcitic and dolomitic.

The most frequent and variegated is the **limestone breccia**. In spots, light gray to dark medium gray oosparite, intraoosparite or biointrasparite fragments prevail in the breccia. At other places fragments of white to black micritic limestones prevail. Various fine-grained limestone fragments also appear in the breccia. The fragments of stromatolitic limestone are very rare. At places the limestone breccia contains rounded fragments passing thus into a conglomerate. Fragments of intrasparite, intramicrite and biosparite are also seen in the breccia. The most frequent fossils are foraminifera and algae:

Foraminifera: *Alzonella cuvillieri* Bernier et Neumann, *Nautiloculina oolithica* Mohler, *Pfenderella arabica* Redmond, *Protopeneroplis striata* Weynschenk, *Pseudocyclammina lituus* (Yokoyama), *Trocholina alpina* (Leupold), *Trocholina elongata* (Leupold), *Valvulina lugelni* Septfontaine, *Kurnubia* sp., *Pfenderina* sp., *Trocholina* sp., Verneuilinidae, Textulariidae, Trochaminidae.

Algae: *Actinoporella podolica* Alth, Cyanophycea, Codiacea, Blue-green algae.

In spots, sponge (*Cladocoropsis mirabilis* Felix), gastropods and other molluscs occur. According to fossils, the fragments can be attributed to the Malmian.

The main characteristics of the described breccias are angular to subangular carbonate clasts of uniform or polymict composition, very dense packing of clasts, poor to very poor sorting without grading or bedding, sand-sized to boulder sized blocks, grain-supported rubbles, and up to 20m thick lenticular units of breccias. This speaks in favour of hypothesis that the breccias were formed by the accumulation and consolidation of rock fragments derived from a cliff, i.e. a high very steep to overhanging face of rock rising above the shore, usually produced by faulting and erosion. The talus has been chiefly formed by gravitational falling of loose fragments and their accumulation and consolidation at the foot of the described escarpment or steep wall.

Talus breccias in relation to submarine faulting

Some Upper Malmian talus breccias may have been formed in relation to synsedimentary submarine block-faulting. Namely, series of lenses of breccias not strictly contemporaneous occur in the Upper Malmian succession at Korinj. The size of the blocks varies greatly from place to place. Near the faults, deposits show no trace of bedding but not far away from the fault the breccia grades rather abruptly into finer material and intertongues with bedded fine-grained breccia. The fact that the sedimentary successions in the vicinity of the breccias are not quite conformable, and the boundaries between breccias and other sediments are in greater part not clearly defined indicates that the formation of breccias at Korinj is related to tectonics.

Very typical for the area between the localities Kamni vrh and Ciganov vrh is a heterogeneous **limestone-dolomitic breccia**. In the composition of the breccia dolomite and rarely limestone fragments prevail. The talus sediment is composed of medium-gray, heavily dolomitized biosparitic limestone with alga *Clypeina jurassica* Favre, and fragments (0.5cm–3cm) of white to grayish black Upper Malmian micrites, biomicrites, very light gray and light gray coarse-grained dolomite (Upper Malm), dark brownish gray bituminous dolomite, as well as white and very light gray stromatolitic dolomite.

In the heterogeneous **limestone breccia** fragments and boulders (up to 120cm in size) of white to dark gray micritic limestones prevail. From the chronostratigraphic point of view the following fragments are very interesting and important: Clypeina biomicrite, Tintinnina biomicrite, Clypeina-Tintinnina biomicrite and Favreina biointrasparrudite. Two types of Favreina limestone are present; dark brownish gray and very light gray one. Beside the enumerated limestone fragments intramicritic, intrasparruditic, stromatolitic, fenestral, biointrasparitic and pseudooosparitic ones also occur.

The fragments of the breccia contain relatively rich microfauna and flora:

Foraminifera: *Trocholina alpina* (Leupold), *Trocholina elongata* (Leupold), *Kurnubia* sp.

A l g a e: *Bacinella irregularis* Radoičić, *Clypeina jurassica* Favre, *Thaumatoporella parvovesiculifera* (Raineri).
S p o n g e: *Cladocoropsis mirabilis* Felix.
A b e r r a n t t i n t i n n i n s: *Campbelliella milesi milesi* Radoičić
as well as: *Favreina salevensis* Paréjas, gastropods and other molluscs.

Fossils and age of breccias

Fossils have not been found in the groundmass of the breccias so far. Consequently, we can describe biofacies and age of the breccias only on the basis of the fossil association from the fragments. As we have seen the fauna and flora from the breccia fragments consist of foraminifera, algae, hydrozoans, corals, gastropods and other molluscs, ostracods echinoderms and abberant tintinnins.

F o r a m i n i f e r a: *Alzonella cuvillieri* Bernier et Neumann, *Nautiloculina oolithica* Mohler, *Pfenderina arabica* Redmond, *Protopeneroplis striata* Weynschenk, *Pseudocyclammina lituus* (Yokoyama), *Trocholina alpina* (Leupold), *Trocholina elongata* (Leupold), *Valvulina lugelni* Septfontaine, *Kurnubia* sp., *Pfenderina* sp., *Trocholina* sp., Textulariidae, Trochaminidae, Verneuilinidae.
A l g a e: *Actinoporella podolica* Alth, *Bacinella irregularis* Radoičić, *Salpingoporella annulata* Carozzi, *Thaumatoporella parvovesiculifera* (Raineri), Codiacea, Cyanophycea, Blue green algae.
S p o n g e: *Cladocoropsis mirabilis* Felix.
C o r a l s: *Stylosmilia* sp.
A b e r r a n t t i n t i n n i n s: *Campbelliella milesi milesi* Radoičić.
F a v r e i n a: *Favreina salevensis* Paréjas
as well as: Ostracods, gastropods and other molluscs, Echinodermata.

The described biofacies of the greater part of the breccias can be referred to the *Clypinea jurassica* cenozone (R a d o i č i ć, 1966; D o z e t, 1990). The association of the breccia fragments with *Clypeina jurassica* and *Campbelliella milesi* Radoičić favours the interpretation that the prevalent part of described breccias is the Upper Malmian in age. Generally, judging from the age of the constituent breccia fragments and their stratigraphical position the treated breccias are deemed to be Malmian in age.

The role of eustacy and tectonics in the formation of the breccias

The geologic investigations in the Suha Krajina area, performed in the last years showed that the Malmian sedimentation was provoked and controlled by sea-level variations as well as fault and block tectonic activity.

Tectonic movements in the area investigated were reflexive consequences of the Alpine tectonic cycles. Jurassic movements did not have any particular influence on the tectonic structure of this part of Slovenia, but they had a very strong influence on the sedimentation during that time (D o z e t, 1989). We may state that in the study area no orogenic movements in the Jurassic period occurred since no folding can be found there, nor are there any traces of thrusting or nappe tectonic movements, volcanism or metasomatic changes of sedimentary rocks.

There are nowhere any greater tectonic discordant contacts. Further on, in the area investigated no thicker coarse-grained basal transgressive formations can be found, so that we may be correct in affirming that the continuity of sedimentation had only been disturbed by periodical interruptions as a reflection of weaker or stronger epeirogenic movements of the carbonate platform. These periodical movements created the paleogeography in the Jurassic period. They also affected the differentiation of the carbonate platform and thus had a considerable influence on sedimentation. We came to conclusion that epeirogenic movements alone could not cause all changes of the Malmian sedimentation in the Suha Krajina area. From our point of view the fault tectonic activity played an essential role in the formation of Korinj breccias and bauxites. During the Kimmeridgian the subsidence of the Dinaric carbonate platform stopped and intensified positive epeirogenic movements began that caused locally an emergence of the area. Malmian bauxites on the Dinaric platform proved that such emersions occurred. On the other hand, the absence of bauxite deposits at some places suggests that the emersion was only local phenomenon, and that the degree of subaerial exposures in Outer Dinarides was not everywhere the same.

On the Dinaric platform, the Malmian emersion phase had a different character. It was generally relatively short, but at some places, allowing for shorter and longer interruptions, it lasted through the greater part of the Upper Malm because of the late Kimmerian movements (Dozet et al., 1993).

Regional geology, sedimentological data, vertical and lateral developments and extent, variation of facies, the thickness of individual lithostratigraphic units, usually nondefined lithologic boundaries with other sediments and extremely poorly sorted carbonate rock indicate a close relationship between breccias and synsedimentary block faulting of different scale and extent. However, negative forms i.e. relatively narrow and shallow basins made possible the origin of submarine talus breccias. While the unconsolidated sediment was still in the environment of deposition it was decomposed by gravity-induced movements, displaced from scarps and accumulated in negative forms at the base of scarps.

Conclusions

The breccias that appear in numerous stratigraphic levels of the Malmian sedimentary succession at Korinj in the Suha Krajina area (central Slovenia) have been named the Korinj carbonate breccias.

Five genetically different breccias have been distinguished. The polymict karst breccias are interpreted to be the lateral equivalent of the Lower Malmian-Upper Malmian bauxite horizon. The formation of karst paleorelief was favoured by tectonics. Mudstone breccia-conglomerate originated by dessication. Textural and structural characteristics of some breccias indicate their intertidal and supratidal formations (tidal flat breccia). Dolomitic, limestone-dolomitic and limestone talus breccias were formed by the accumulation and consolidation of talus at the base of coastal cliffs. Some talus breccias have been formed in relation to submarine synsedimentary faulting.

The Korinj carbonate breccias are predominantly of the Upper Malmian age. The biofacies can be referred to the *Clypeina jurassica* cenozone.

The genesis of the Korinj breccias is various but our main concept is that they are chiefly related to eustacy, sea-level changes, as well as local and regional synsedimentary tectonics.

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