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Ambrus Beds – Important Key for Interpretation of Neocomian Paleogeography, Sea-Level Changes, Depositional Setting and Tectonics in Suha Krajina Area (Slovenia)

Ambruške plasti in njihov pomen za interpretacijo neokomskih paleogeografskih, evstatičnih in tektonskih razmer na območju Suhe krajine (Slovenija)

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Abstract

The lower part of the Lower Cretaceous stratigraphic sequence at Ambrus, composed of limestones, dolomitic limestones, dolomites, intertidal breccias and overlying heterogeneous carbonate breccias is described in this paper. On the basis of stratigraphic order, fossil contents as well as the well-determined fossiliferous underlying Upper Malm and overlying Barremian carbonate sediments, the formation denominated the Ambrus beds was ascribed to the Neocomian. Fenestral limestones, laminated limestones and dolomites containing stromatolites, mudcracks and numerous erosion and oxidation surfaces are interpreted as tidal storm deposits. The shallow water sediments, the breccias and the subaerial exposures, evidenced by relatively common karstification phenomena, are considered to be connected with eustatic sea-level variations and epeirogenetic movements. The lithology and areal distribution of these deposits indicate a sedimentation in a relatively symmetric, rather shallow lagoon. The breccias composed of various poorly sorted angular and subangular limestone and dolomite fragments, as well as of calcitic and dolomitic cement, have been attributed to tidal and cliff breccias. The majority of the breccia fragments indicate a pretty shallow water and subaerial sedimentation conditions.

Kratka vsebina

Najnižji del spodnjekrednega sedimentnega zaporedja pri Ambrusu sestavljajo apnenci, dolomitizirani apnenci, dolomiti in heterogene karbonatne breče. Glede na statigrafsko lego, fosile in s fosili dobro dokazane spodaj ležeče zgornjemalmske plasti ter zgoraj ležeče barremijske sedimente, smo formacijo, ki smo jo poimenovali Ambruške plasti, uvrstili v Neokom. Fenestralni in laminirani apnen-

ci in dolomiti s stromatoliti, izsušitvenimi porami ter številnimi erozijskimi in oksidacijskimi površinami so nastali v plimskem območju. Nastanek plitvovodnih karbonatnih sedimentov, breč in nadplimskih tvorb s številnimi pojavi zakrasovanja povezujemo z evstatičnimi in epirogenetskimi premikanji. Litološka sestava in razširjenost teh sedimentov na površini kažeta na sedimentacijo v plitvi laguni. Breče, ki so sestavljene iz različnih slabo sortiranih oglatih do slabo zaobljenih apnenčevih in dolomitnih drobcev, vezanih s kalcitnim in dolomitnim cementom, smo uvrstili med plimske breče in breče strmih obrežij (cliff). Drobci kamnin v brečah kažejo na plitvovodne in nadplimske pogoje sedimentacije.

Introduction

The purpose of this preliminary work is to describe the carbonate formation, denominated the Ambrus beds that builds up the small hills Kamni vrh, Stražarjev vrh and Mali vrh at Ambrus. The most part of the data from the study area were obtained by detailed geological mapping for the Geological map of Slovenia on the scale of 1:50.000. This study is based on field mapping data and thin-section analysis. Facies characteristics of the Ambrus sedimentation have been considered, with the

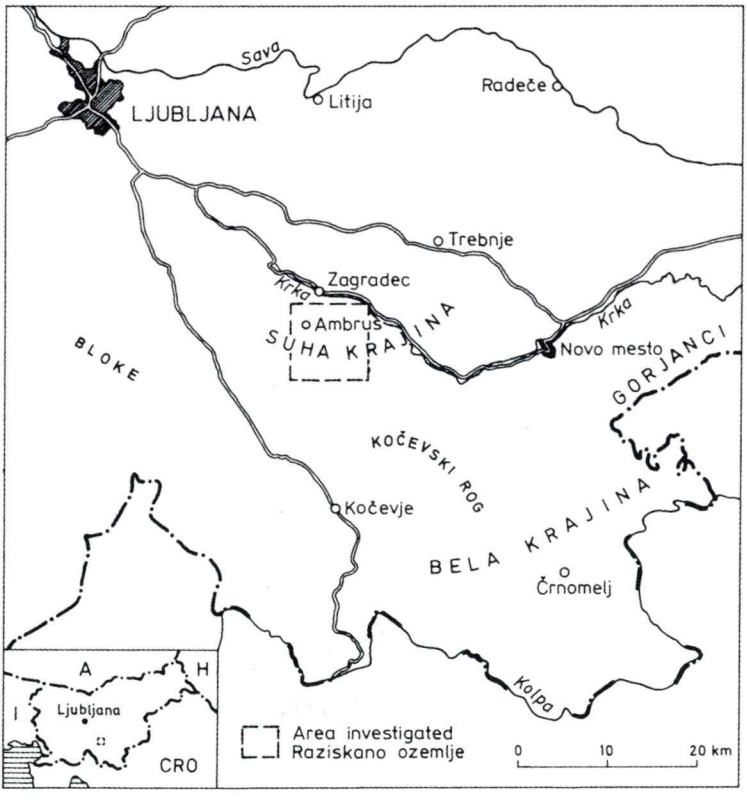

Fig. 1. Location sketch map of investigated area
Sl. 1. Položajna karta raziskanega ozemlja

purpose to explain the geological events of the Suha Krajina area (Fig. 1). In order to ascertain the geologic significance of the discontinuous breccia body, we have attempted to date the breccia exposures along the road that leads to Kamni vrh, and to reconstruct its shape, size, composition, depositional conditions and environment. In addition to this, we wanted to find out, whether the brecciation phenomenon was related to tectonic activity. The study of the Ambrus formation has a great importance not only for the stratigraphy of the study area, but also for better explanation of the Lower Cretaceous paleogeography. On the other hand, the breccias provide an important key to the depositional setting during the Neocomian. An attention is given to the Ambrus breccia constituents, differentiating fragment and cement types, as well as to the underlying and overlying sedimentary successions, providing in this way a more general information on the brecciation process and evolution. As a matter of fact, the carbonate breccias reflect a specific and relatively longstanding phase in the geologic history of the considered area.

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 textures. The present work has been performed with support of the IGGG-Geological survey of Ljubljana.

Previous Work

Šribar (1966) described the Jurassic sedimentary rocks between Zagradec and Randol in the Suha Krajina area. On the basis of microfossils and the stratigraphic position she divided the Jurassic stratigraphic sequence into the Lower and Middle Liassic, the Upper Liassic–Dogger, the Lower Malm and the Upper Malm. After styding all the aspects of the occurrences of abberant tintinnids she found (1979) that abberant tintinnids from the Dinarides of the South Slovenia do not indicate the Valanginian stage. She attributed the transitional beds between Jurassic and the Lower Cretaceous to Berriasian.

Buser (1979) mapped the Ribnica Map sheet area and divided the Upper Malm carbonate rocks of the area into the lower (Oxfordian and Lower Kimmeridgian) and upper part (Upper Kimmeridgian and Tithonian). The author subdivided the Lower Cretaceous beds into the following units: Valanginian, Hauterivian+Barremian, Aptian+Albian+ +Cenomanian.

According to Buser (1989) 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.

Savić and Dozet (1985) described the general geology of the Delnice Map sheet area dividing the Lower Cretaceous succession as follows: Berriasian, Valanginian, Hauterivian, Barremian, Lower Aptian, Upper Aptian, Lower Albian and Upper Albian. To the Neocomian they attributed the limestone-dolomite-chert breccia.

Dozet (1990) subdivided the Jurassic stratigraphic sequence of the Kočevje and Gorski Kotar area into 5 cenozones and 3 subzones by algae, foraminifera and pelecypods. Furthermore, 5 cenozones and 3 subzones are recognized in the Lower Cretaceous sequence by algae and foraminifera.

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.

Stratigraphic Position

The Neocomian Ambrus beds can be followed in a some kilometres wide area north of Ambrus. The treated beds are about 250 metres thick. They lie between the Upper Malm and the Upper Barremian beds.

The underlying strata

The strata occurring immediately bellow the Ambrus beds are composed of micritic, biomicritic, biointrasparitic, oncolitic and stromatolitic limestones, as well as early and late diagenetic dolomites and carbonate breccias that reflect the shallow subtidal, intertidal and supratidal cycles. The carbonate rocks enumerated above are more or less recrystallized and dolomitized. According to the texture they mostly belong to calcirudites and calcarenites. The Malm beds of the Suha Krajina area contain coated grains of algal origin that were formed in periodically and intermediately agitated water in a shallow subtidal environment. Some data suggest that a part of oncolites were deposited in a water of greater turbulence (Dozet, 1995b). The Upper Malm succession is composed predominantly of *Clypeina* and *Tintinnina* limestones and dolomites intercalated with carbonate breccias. Sedimentological features within the majority of limestones and dolomites point at shallow-subtidal, intertidal and supratidal depositional settings. The carbonate breccias prevalently occur in the uppermost part of the Malm stratigraphic sequence.

Occurring in numerous stratigraphic levels of the Malm sedimentary succession at Korinj, the breccias have been named the Korinj breccias (Dozet & Strohmenger, 1996). Five genetically different breccias have been distinguished. The polymict karst breccia is interpreted to be the lateral equivalent of the Lower Malm/Upper Malm bauxite horizon (Strohmenger, 1988). Emplacement of carbonate breccia into the Malm sedimentary succession is a characteristic feature in certain places of the Outer Dinarides region, the Logatec plateau and especially in the Suha Krajina area (Dozet, 1995a). Mudstone breccia-conglomerate originated by desiccation. Textural and structural characteristics of some breccias indicate their intertidal and supratidal formation (tidal breccias). Dolomitic, limestone-dolomitic and limestone talus breccias were formed by accumulation and consolidation of talus at the base of coastal cliffs. Some talus breccias have been formed in relation to submarine synsedimentary faulting.

The uppermost part of the Malm sedimentation is characterized by rhythmic sedimentation of light gray, micritic and laminated limestones and dolomites. The stratigraphic sequence described above belongs biostratigraphically to the Upper Malm *Clypeina jurassica* cenozone (Dozet, 1994, 1996).

The overlying strata

The strata which overlie the Ambrus breccias and which consist of platy and stratified (5 – 45 cm) limestones, dolomitic limestones and dolomites, sporadically intercalated with thin layers of small-scale intraformational carbonate breccias, belong to the Barremian. The limestones include fine, medium and thick-bedded, gray, dark gray and black, more or less bituminous micrites, pelmicrites, bioin-

trasparites, biosparites and stromatolites. Among biomicrites and biosparites predominate the foraminiferal and algal ones. The main constituents of the foraminiferal limestones are benthic foraminifera, miliolids and algae Dasycladaceae. Rhythmic sedimentation of limestones can be often seen in this interval of the Lower Cretaceous stratigraphic sequence. Rhythms of pelsparite-stromatolite are very common and typical. Also characteristic is a rhythmic alternation of early diagenetic and late diagenetic dolomites. From the biostratigraphical point of view the described succession of limestones and dolomites belongs to the *Salpingoporella muehlbergii* (Lorenz) cenozone (Šribar, 1979). The gradational contact of the breccia and overlying strata is characterized by a development of alternations of up to 0.35 metres thick, light-brown coloured dolomites and equally thick, dark gray mudstones, locally with bird's-eyes. The dolomite beds decrease in thickness from bottom to top. In fact, these dolomite beds are chiefly composed of coarse-grained structureless and finer-grained stromatolitic dolomites. The stromatolites within breccia testify to high-intertidal and supratidal conditions. Above this alternating succession the unit is mainly composed of mudstones. On the basis of field and sediment-petrographical data the overlying carbonate strata (Barremian) are interpreted to be chiefly originated in a shallow lagoon.

The Ambrus Beds
Berriasian

The lower part of the Ambrus sedimentary succession consists of limestones, dolomitic limestones, dolomites, dedolomites and tidal carbonate breccias. Limestones are commonly more or less early and late-diagenetically dolomitized. Consequently, all transitional types between limestone and dolomite can be observed in the Ambrus stratigraphic sequence. Limestones were formed in shallow marine environments, namely: lagoon, subtidal, intertidal and back reef. According to the structure and the texture the limestones belong to micrites, dismicrites, as well as stromatolitic and intraclastic limestones. Most typical and important are *Favreina* and *Salpingoporella* limestones. The limestones are commonly more or less karstified and contain at some places residual materials. Erosive, rarely stylolitic contacts and surfaces can be found, too. Further on, the lower part of the Ambrus stratigraphic sequence which chronostratigraphically belongs to Berriasian consists of alternating late diagenetic, early diagenetic, structureless and stromatolitic dolomites, as well as dedolomites. Early diagenetic dolomite is light gray to white, stratified (30-80 cm), fine-grained, cryptocrystalline to microcrystalline, laminated and stromatolitic, containing ostracods, rare gastropods, oncoids, shrinkage pores, fecal pellets and bird's-eyes. Late diagenetic dolomite is chiefly dark gray to brownish gray, coarse-grained (saccharoidal), internally structureless, occurring in lenticular or irregular bodies. Small-scale brecciation and the limestone breccia become apparent at the Lower Malm/Lower Cretaceous contact and within the beds at the base. According to its origin it belongs to the tidal type of breccias. The strata occurring immediately bellow the breccias reflect shallow intertidal and supratidal cycles. Tidal breccias, originated due to desiccation, are overlain by fenestral and laminated limestones of predominantly algal origin, and karstified limestones with residual materials. Stromatolitic dolomites, locally characterized by gastropod remains, are sometimes intercalated within structureless dolomites. At the top of the described sedimentary succes-

sion white and dark gray mudstones occur. An increase in bed thickness towards the upper contact is present. The mudstones above the Lower Berriasian stratigraphic sequence represent a short transgressive trend. At the top of the transgressive strata mudstones with bird's-eyes and stromatolites occur.

Neocomian (Valanginian to Lower Barremian)
Ambrus Breccias
General description of breccias

The Neocomian heterogeneous carbonate breccias come to light in the Kamni vrh-Stražarjev vrh-Mali vrh area at Ambrus. They build the upper part of the Ambrus beds with an average thickness of 150 metres. The Ambrus breccias (Fig. 2) are prevalently massive. In the lower part of the breccias an unclear stratification can be seen. Better stratified are breccias from the upper part of the Neocomian lithologic column. The size of limestone and dolomite fragments varies considerably. In the lower part of the breccia unit the fragments are on an average 3 cm to 6 cm and in the upper one from 0.5 cm to 3.5 cm in size. The fragments are bound together by calcitic and dolomitic cement and some clayey matrix. Since some carbonate fragments contain the Malm microfossils and due to the Barremian dasycladaceans in the overlying strata, the breccias chronostratigraphically correspond to Neocomian. In spots in the upper part of the breccia column a thick-bedded, white biomicrite and biopelmicrite with algae *Clypeina? solkani* occur, which confirms the Neocomian age of the breccias. According to the composition and sedimentological properties of the breccias we can conclude that after the Upper Malm important paleogeographic and depositional changes took place. These changes are supposed to be a consequence of epeirogenetic, eustatic and tectonic movements which caused the differentiation of up to this time relatively uniform environment. These movements caused faulting, uplifting, vertical displacements, local dry land and, accordingly, new paleogeographic disposition between the land and the sea. On the basis of morphological characteristics, the size, the shape, the poor sorting of breccia constituents, and with regard to the type of cement, we come to conclusion that during the deposition of the breccias there were great differences with respect to the base level of erosion.

The section Brezovšče-Kamni vrh at Ambrus was investigated in the field, however, the description of the breccias given here is based on numerous outcrops in the entire study area. About 30 thin sections from the type locality section and 20 thin sections from other outcrops were studied under the petrographic microscope. The maximum thickness of the breccias at the type locality on Kamni vrh at Ambrus is 150 m, but elsewhere it can be extremely reduced. The contact with the underlying Berriasian rocks is pretty sharp and it is about parallel to bedding. The contact of the breccias with the overlying Barremian limestones and dolomites is in some places sharp, but locally a gradual transition of the breccias into the overlying carbonate succession can be seen. The dark gray to black heterogeneous carbonate breccias consist of fragments varying in dimensions from pieces of almost half a metre in length to the smallest ones of microscopic dimensions. On the basis of the fragment size the breccias can be divided in two parts: the coarse-grained (5-55 cm) lower part and the finer-grained (0.5-3.0 cm) upper one. The Ambrus breccias are mostly massive carbonate sediments. However, the upper part of the breccia complex is often more or less clearly stratified. Moreover, carefull examination of the fragment

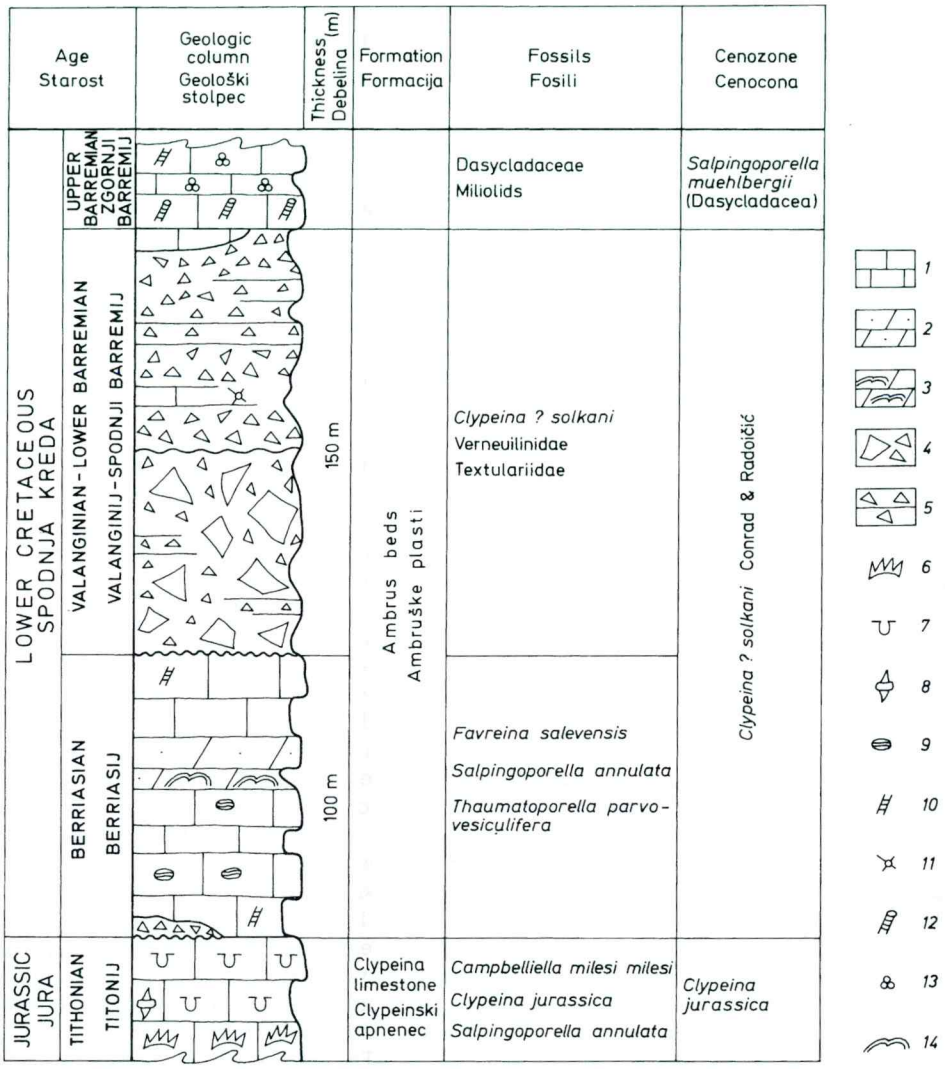

Fig. 2. Geologic column of the Ambrus beds in the Suha Krajina area
1 Bedded limestone; *2* Bedded coarse-grained dolomite; *3* Stromatolitic dolomite; *4* Massive breccia; *5* Bedded breccia; *6 Clypeina jurassica* Favre; *7* Aberrant tintinnids; *8* Gastropods; *9* Favreinas; *10* Algae (generally); *11 Clypeina Ž solkani* Conrad & Radoičić; *12* Dasycladaceae; *13* Benthic foraminifers; *14* Stromatolites

Sl. 2. Geološki stolpec Ambruških plasti na območju Suhe krajine
1 Plastnati apnenec; *2* Plastnati debelozrnati dolomit; *3* Stromatolitni dolomit; *4* Masivna breča; *5* Plastnata breča; *6 Clypeina jurassica* Favre; *7* Velike tintinine; *8* Polži; *9* Favreine; *10* Alge (splošno); *11 Clypeina ? solkani* Conrad & Radoičić; *12* Dazikladaceje; *13* Bentonske foraminifere; *14* Stromatoliti

lithology show that many of the larger displaced fragments still maintain a relative orientation approximately parallel to the stratification giving the breccias of the lower part an apparent stratification, too. On the other hand lenses of very light gray to white, thick-bedded *Clypeina? solkani* limestone can be observed in the upper part of the Lower Cretaceous brecciated lithologic interval.

Petrography of the breccia fragments

The Ambrus breccias are composed of limestone, dolomite and silica fragments. The fragments are rather variable from millimetre to half a metre-sized. Larger fragments occur more frequently in the lower part of the breccia. Angular and subangular fragments are the main constituents of the breccias. Some fragments, especially from the lower part of the breccia interval, contain calcite and/or dolomite veins. Normally, the breccias have a heterogeneous and rather chaotic fabric. Namely, the breccia which is locally associated with tectonics, consists of a mixture of large and small blocks of irregular shape and different age and very fine-grained, tightly packed material accumulated in a state of total disorder. It is oligomictic with dolomite fragments as the most abundant rock type.

Limestones fragments are common in the upper part of the breccia complex. The predominant limestone type of fragments is white lime mudstone containing small algae and ostracods. Other mudstone fragments contain rare mollusc remains. The mudstones are interpreted as lower intertidal to shallow subtidal muds. The existence of broken ostracods suggests that some of these bioclasts were redeposited. Algal laminated mudstone fragments, consisting mainly of dense accumulation of pellets, are also common. The algal laminated mudstone is interpreted as having been deposited in the intertidal zone or possibly in a shallow subtidal environment. Limestone fragments are usually subordinate constituents of the Ambrus breccias, but in spots they become even predominant. The limestone fragments of the Ambrus breccias belong to the following structural and textural types: black, greyish black, dark gray, dark brownish gray, brownish gray, gray, moderate gray, light gray and white micrites, biomicrites, biopelmicrites, biosparites, biointrasparites, intramicrites, intrasparites, intrasparrudites, as well as grained, stromatolitic, fenestral and dolomitic limestones.

Dolomite fragments are predominant (60-85 %) particles in the Ambrus breccias. Three dolomite types are present in the fragments, namely: brownish gray, dark brownish gray and grayish black dolomicrite, dolosparite and stromatolitic dolomite. Gray dolomicrite was recognized in the lower breccia unit: The dark brown idiotopic dolosparite fragments predominate in the lower breccia unit. Dolomite in crystalline form almost always occurs together with calcitized and dolomitized mudstones or is interbedded with grainy limestones. It consists of subhedral to euhedral dolomite crystals. This dolomite rarely retains original sedimentary textures. In outcrop it is often intensively altered by surface weathering. Fragments composed solely of stromatolitic dolomite also exist. These dolomites normally retain original sedimentary textures. Here and there gastropod sections, ostracod shells, as well as fecal pellets and algal skeletons can be observed in the stromatolitic dolomite. All three dolomite types constitute continuous beds in the lower part of the Ambrus beds, i.e. in the sedimentary succession immediately underlying the cliff breccias, as well as the dolomites in the Upper Malm dolomite-limestone succession.

Silica fragments occur only sporadically in the studied breccia. They are present exclusively in the middle part of the upper breccia unit and belong to chert. The silica fragments are usually more than 5 centimetres in size.

Breccia cement and matrix

The cement in Ambrus breccias belongs to fine-grained calcite, dolomite, rarely matrix. In spots, coarser sparry crystals originated as a result of crystallization of fine-grained miciritic carbonate can be observed. Occasionally, only coarsely crystalline calcite (sparry calcite) cement fills the space among fragments. Since the matrix itself is often brecciated, it clearly postdates the lithification of the microsparitic matrix. As already said, the two breccia units were differentiated on the basis of the grain size and the material filling the interstices among grains. In the lower breccia unit the sparry calcite cement is preceded by a finelly crystalline calcite. Moreover, the clayey fine-grained interstitial material contains individual clasts and dolomite crystals. The dolomite crystals commonly are abraded and/or broken, being in any case formed before brecciation. Some smaller mudstone fragments, incorporated in the mud, are completely recrystallized. Larger cavities may be partly sediment-filled or in part spar-filled which created geopetal fabrics. In fact, the sediment forms the floor, and the sparry calcite the upper part of the cavity.

Genesis

The Ambrus beds represent an important key to the depositional setting during Neocomian time intervals as well as to major tectonic events in the Suha Krajina area. The occurrence of stromatolites, mud-cracks, erosion surfaces, karstification phenomena, accumulations of insoluble residue, breccias, rhythmical alternations of highly dolomitized and laminated lime mud in the lower part of the Ambrus beds, lead us to conclusion that the finely stratified dolomites are supratidal deposits. The lack of fossils as well as the structural characteristics suggest current-agitated conditions. Furthermore, fine stratification of the intertidal and supratidal mud deposits is performed by storms that transport and deposit marine sediment into the intertidal and supratidal setting. It should be noted that the fragmentation of the newly formed sediment occurred at shoaling and temporary withdrawal of water by dessication and mud-cracking. Irregular dried-out and mud-cracked polygons have been broken into angular fragments, being later deposited and lithified together with remained lime mud. The lithologic composition, the scarity of fauna as well as textural and structural characteristics of the breccias indicate their intertidal and supratidal formation. The main characteristics of the cliff breccias are angular to subangular carbonate clasts of uniform or polymict composition, a very dense packing of clasts, a very poor sorting without grading or bedding, and different-sized fragments. It should be emphasized that this all speaks in favour of hypothesis that the breccias were formed by accumulation and consolidation of rock fragments derived from cliffs i.e., a high, very steep to overhanging face of rocks rising above the shore, usually produced by physical disintegration, chemical decomposition, 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 escarpments or steep walls.

Fossils and Age

The lower part of the Ambrus beds contains numerous *Favreina salevensis* Paréjas which are almost always rock-forming, further on *Salpingoporella annulata* Carozzi, *Thaumatoporella parvovesiculifera* (Raineri), Verneuilinidae and Textulariidae. Fossils have not been found in the matrix of the breccias so far. Consequently, we can describe biofacies and define the age of the Ambrus breccias on the basis of the fossil association from the rock fragments. The biofacies can be referred to the *Clypeina? solkani* Conrad & Radoičić zone, which is typical for the carbonate platform shallow marine environment of the Neocomian age. Considering the constituent breccia fragments, their fossil contents, the stratigraphic position as well as the underlying and overlying fossiliferous carbonate sediments the breccias are of Valanginian, Hauterivian and very probably of the Lower Barremian age.

During the Neocomian the restricted lagoon was developed in the study area. Detrital influx within the area studied was insignificant, suggesting that the surrounding dry land was built of carbonate rocks. The lithologic composition, structural and textural characteristics of the sediments suggest that these sediments were formed in a shallow-marine setting. The stratification of breccias is poor, what is comprehensible, since strata in these depositional conditions could not be formed.

Paleogeographic Interpretation

According to the composition and sedimentological properties of the breccias, we can conclude that after the deposition of the Upper Malm beds important paleogeographic and depositional changes took place. The quoted changes, which are supposed to be the consequence of epeirogenetic, eustatic and tectonic movements, caused the differentiation of up to this time relatively uniform environment. These movements and forces caused faulting, uplifting, vertical displacements, local dry land and, accordingly, new paleogeographic disposition of the land and the sea.

On the Jurassic/Lower Cretaceous boundary some parts of the Suha Krajina area were subjected to tectonic movements as a consequence of the Late Kimmerian orogenetic phase (Dozet, 1989), resulting in an uplifting and rupturing of individual parts of the bottom of the sea. The new formed land gave the material for origin of the heterogeneous limestone-dolomite sedimentary breccias. A new paleogeographic picture between the land an the sea developed. The Neocomian carbonate breccias that originated predominantly in shore regions are genetically closely related to the mentioned paleogeographic changes.

On the basis of morphological characteristics, the size, the shape, the poor sorting of breccia constituents, and with regard to the type of cement, we come to conclusion that during the deposition of the breccias, there were great differences with reference to base level of erosion. The coast region was characterized by steep, often vertical and even overhanging cliffs and with a strong water dynamics, but the transport was very short. With regard to the composition of the coarse-grained carbonate rocks it is evident that then being land, as source area of rock material, was composed exclusively of carbonate rocks. At new conditions of sedimentation carbonate breccias were formed.

Depositional environment of the Berriasian beds (Lower Ambrus Beds)

A poor faunal diversity i.e., a low number and a low quantity of species, as well as stromatolites, bird's-eyes, numerous local erosion surfaces, common occurrences of marine and meteoric cements, dolomitization, common occurrences of karstified carbonate rocks, clearly indicates shallow subtidal to intertidal and even shortstanding periodical supratidal setting during Berriasian as well as Valanginian, Hauterivian and very probably the Lower Barremian.

Deposition of the brecciated rocks (Ambrus breccias)

The brecciated Neocomian carbonate succession at Ambrus was deposited in a very shallow restricted lagoonal setting. The predominance of the shallow intertidal to supratidal carbonate fragments i.e., dolomites, algal laminates and mudstones with bird's-eyes within the breccia indicates an overall restricted shallow lagoonal setting. Bellow the breccia in the Ambrus-Kamni vrh type section the petrographic evidence suggests that the restricted lagoon periodically changed into dry land.

The first small brecciation could have resulted from small-scale periodic seasonal dessication under evaporative conditions. The lower breccia part underwent two major phases of forming. The first probably occurred soon after deposition during a short period of emergence. The existence of an emergence period between the lower and upper breccia part is resumed from the observation that the mud matrix is absent in the upper breccia part. The carbonate groundmass material may originate from unlithified mud, occurring at the top of the lower breccia unit, or may relate to mud infiltration at the initial stages of sedimentation of the upper breccia unit. After the emergence period sedimentation resumed with deposition of mudstones. The dolomite beds become less prevalent through time and finally disappeared.

Characteristic appearances within the breccia such as veined fragments, re-brecciated breccia fragments and the presence of two groundmass generations (microcrystalline and sparry calcite cement) exhibit at least two phases of formation of breccia. Initial formation of breccia occurred soon after deposition during a short period of emergence. During this stage the original carbonate beds locally became veined and fractured. Carbonate mud infiltrated into interstices between the fragments. Finally, the breccia fragments were cemented by sparry calcite.

Conclusions

During the Upper Triassic, Jurassic and Cretaceous periods the study area was a part of the Dinaric Carbonate Platform.

As far as tectonics is concerned, in the Jurassic and the Lower Cretaceous periods the Dinaric Carbonate Platform was not subjected to any stronger tectonic movements (Savić, 1973; Buser, 1979, 1980, 1989; Dozet, 1989, 1994). Consequently, in the Upper Malm and the Lower Cretaceous a relatively continuous sedimentation occurred, interrupted with periodical, short-lived local interruptions, as a consequence of intensified epeirogenetic movements of the Carbonate Platform. These movements caused periodical land forms especially at the time between the Lower and the Upper Malm as well as between the Upper Malm and Neocomian.

The Malm and the Berriasian sedimentation was, generally speaking, a result of three different modes of sediment forming: 1) – land setting, 2) – changeable shallow marine and subaerial setting and 3) – shallow marine setting.

The beds between fossiliferous underlying Upper Malm *Tintinnina* and *Clypeina* limestones and overlying Barremian Dasycladacea limestones at Ambrus have been named the Ambrus beds.

The lower part of the Ambrus beds, belonging to Berriasian, is interpreted as a shallow water deposition with considerable degree of subaerial exposures. The predominance of laminites, mudstones with birdseyes and shallow intertidal to supratidal carbonate fragments indicates that the treated sequence was originally formed in a shallow restricted lagoonal setting.

The upper part of the Ambrus beds is occupied by heterogeneous carbonate breccias.

In the breccia interval the heterogeneous dolomite breccias are predominant, the limestone-dolomite breccias are less extended, whereas pure limestone breccias are rare.

Chronostratigraphically, the Ambrus-breccias are of Valanginian, Hauterivian, and probably of the Lower Barremian age, since in their composition the fragments of dark gray to black carbonate fragments, being common in Barremian, are predominant.

From the biostratigraphic point of view the Ambrus beds are included in the *Clypeina? solkani* Conrad & Radoičić zone (Neocomian).

It seams acceptable to conclude that the Neocomian heterogeneous breccias discussed above, composed of the Upper Berriasian, Valanginian, Hauterivian and very probably the Lower Barremian fragments, could not be exposed by erosion alone. The reason can be found in the increasingly more intensive movements of the sedimentary basis from the Berriasian to the Upper Barremian.

Interruption in the stratigraphic record without larger angular discordance testifies to the statement that from the Upper Malm, Berriasian respectively, to the Upper Barremain predominantly epeirogenetic movements with local disturbances existed, contributing to the origin of the Ambrus breccias.

Finally, our main concept is, the heterogeneous Ambrus breccias with limestone and dolomite constituents are products of intensified epeirogenetic and tidal movements, eustatic sea-level changes, erosion as well as local synsedimentary tectonics.

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