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Facies of the Cretaceous (Berriasian) Deposits from the River Belbek Area (Southwestern Crimea)

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Summary

A section of Berriasian deposits from the River Belbek area (Southwestern Crimea) containing coral-algal bioherms is described. A detailed lithological and palaeontological description of one of these bioherms is given. Lithological features of Berriasian carbonate rocks are discussed, microfacies analysis of these rocks with there palaeontological remains are carried out. The history of the Berriasian development of the territory will be reconstructed.

Introduction

Berriasian marine deposits are widespread in southwestern Crimea. They are represented by terrigenous to marine carbonate rocks containing coral-algal bioherms. Ammonites are of great importance for the stratigraphy of the deposits, however, the palaeontological characteristics of stratigraphic units established in the section are still controversially discussed. Carbonate deposits of the Berriasian age are up to now poorly studied and reported. Coral-rudist biogenic buildups of this age are very rare, they have been described e.g. in France (MASSE & PHILIP, 1981).

Berriasian terrigenous deposits have been studied in detail by DRUSHCHITS & YANIN (1958), GORBATSHIK et al. (1975), KRAVTSOV & SHALIMOV (1978), BOGDANOVA et al. (1981), MAZAROVICH et al. (1989). The Berriasian biogenic buildups are exposed in the Second Range of the Crimea Mts. and are arranged in a narrow west-east stretching band extending from Balaklava to Mezhgorye (KUZMICHEVA & SHALYA, 1962). A great contribution to the knowledge about this area was provided by the 4th Outdoor Paleoecological Session in 1966. The participants of this session E.I. KUZMICHEVA and R.F. GEKKER have described bioherms near Mazanka, Solovyevka and Mezhgorye (GEKKER & NEGODAEV-NIKONOV, 1966). Afterwards Kuzmicheva continued the study of the systematic composition of Early Cretaceous scleractinians of the Mountain Crimea and their facial peculiarities (KUZMICHEVA, 1966, 1972, 1985). ARKADIEV (1989-96) has described in detail the main stratigraphic sections of the Berriasian deposits in the River Belbek basin and studied their palaeontological characteristics. BUGROVA has studied Berriasian bioherms and their corals. One of the places where the Berriasian bioherms are widespread is the area of Mts. Polus and Voskhod (Fig. 1).

The material is stored in the Museum of the Saint Petersburg State Mining Institute (collection number 308). Fossils have been determined by the following palaeontologists: Berriasian and Late Albian bivalves and Berriasian ammonites: T.N. BOGDANOVA; Late Albian ammonites: A. A. ATABEKIAN; belemnites: G. Ya KRYMGOLTZ; brachiopods: S.V. Lobacheva; echinoids: N.A: Tur; crinoids: V.G. KLIKUSHIN; scleractinians: I. Yu. BUGROVA; foraminifers and algae: M.B. PREOBRAZHENSKY and E.M. BUGROVA. Petrographic studies and photomicrographs of thin sections have been made by K.N. MAZURKEVICH and V.V. ARKADIEV.

Lithology and Stratigraphy

As a result of the study, a new stratigraphic scheme of the Lower Cretaceous deposits of the south-west Crimea has been carried out (ARKADIEV & BOGDANOVA, 1997) and the presence of the Berriasian, Valanginian, Hauterivian and Albian sediments in the section has been confirmed by palaeontogical data.

Berriasian deposits overlie the Lower Jurassic sediments with a sharp structural unconformity (Fig. 2). The base of the section, is formed by reddish gray and brown polymictic conglomerates consisting of poorly- to medium-rounded, non-sorted pebbles, cobbles and, in places, boulders embedded in an argillaceous matrix. Quartz, dark-coloured sandstones and siltstones prevail as clasts. Fossils are very rare: bivalves (*Myophorella loewinson-lessingi* (Renng.) have been found by KRAVTSOV & SHALIMOV (1978). Arkadiev has found the coral *Axosmilia kobyi* (Ang. d'Oss.) in the matrix of the conglomerates. The foraminifer

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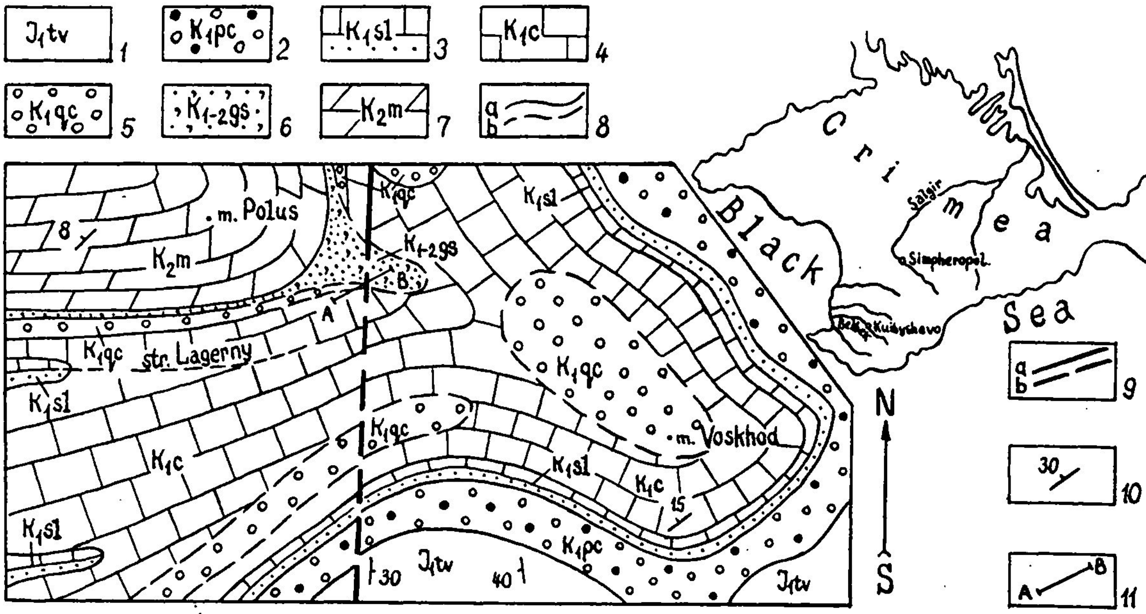


Fig. 1. Sketch map of Crimea (scale 1: 3 900 000 and geological map of the Mts.' Polus-Voskhod area (scale 1: 13 000).
1 - Lower Jurassic, Tavric series, 2 - polymictic conglomerates; 3 - interbedding sandstones and limestones; 4 - carbonate strata, 5 - quartzose conglomerates; 6 - glaucontitic sandstones; 7 - marls; 8 - geological boundaries: a - authentic, b - supposed; 10 - dip of beds; 11 - line of the profile

Hoeglundina caracolla caracolla (Roemer) was found near Golubinka (Mazarovich & Mileev, 1989). The bivalves can be found in the interval from the Berriasian up to the Valanginian, corals - from the Late Jurassic (Oxfordian) until the Early Cretaceous (Albian), foraminifers - from the Berriasian up to the Hauterivian. The conglomerates have been assigned to the Berriasian because of their stratigraphic position under strata with typical Berriasian fossils.

Above the conglomerates , the following units have been recognized: (1) interbedding sandstones, calcareous sandstones and limestones; (2) carbonate strata; (3) quartzose conglomerates.

(1) The first of them are represented by grey and greenish-gray fine-grained sandstones, gray calcareous sandstones and gray detrital and oncoid limestones. In the surroundings of Solnechnoselye (section of Mt. Voskhod), a considerable component of the unit is a sandy oncoid limestone. Fossils are diverse and abundant: *Dalmasiceras* ex gr. *crassicostatum* (Djan.), *D.* sp., *Lytoceras honnorati* d'Orbigny, *L. liebigi* Oppel, *Haploceras* ex gr. *elimatum* (Oppel), *Ptychophylloceras ptychoicum* (Quenst.), *P.* cf. *inordinatum* (Toucas), *Malbosiceras* ex gr. *paramimounum* (Maz.), *M.* ex gr. *malbosi* (Pict.), *Euthymiceras* sp., *Neocosmoceras* sp., *Himalayites* sp., *Mazenoticeras* sp., *Tauricoceras* sp., *Protetragonites tauricus* Kulj.-Vor., *Spiticeras orientale* Kil., S. *multiforme* Djan. The complex of the characteristic ammonite genera (*Dalmasiceras, Malbosiceras, Euthymiceras, Neocosmoceras, Mazenoticeras* and *Himalayites*) characterizes the Berriasian age of the deposits and allows a correlation with the stratotype section of South-East France (Le Hegarat, 1973). The section covers the upper part of the *occitanica*-zone (*privasensis*- and *dalmasi*-subzones) and the lower part of the *boissieri*-zone (*paramimounum*-subzone) of the Berriasian. The term "Strata with *Dalmasiceras* and *Euthymiceras*" is used for the SW Crimea area (Bogdanova et al., 1981). The thickness of interbedding sandstones, calcareous sandstones and limestones varies between 15 m and 30 m.

(2) The overlying carbonate strata have been subdivided into three members (from bottom to top): (a) oncoid limestones, (b) bioclastic limestones and (c) biohermal limestones. The most complete sections of the carbonate strata are exposed on the southern slope of Mt. Voskhod near Solnechnoselye (Figs. 1 and 2) and in the Kabaniy ravine.

Oncoid limestones are grainstones, gray and yellowish gray in colour, massive or laminated and consist of oncoids (80%), quartz grains (5%) and calcite cement (15%). Oncoids are 0.5-1 mm up to 1.5-2 cm in diameter, round or irregular in shape and have been formed around quartz grains and bioclasts. The limestones contain noncoated fragments of bryozoans, oysters, gastropods and foraminifers and coated fragments of oysters, echinoids, bryozoans and corals. This member is 15-20 m thick.

Bioclastic limestones are packstones, light gray in colour, consisting of fragments of thick-shelled bivalves and brachiopods, crinoids, corals, bryozoans and algae. Grains are bioclasts (90-95%), quartz (up to 5%), oncoids (less than 1%). The cement consists of slightly ferruginous calcite. This member is 30-35 m thick.

The member of biohermal limestones usually includes relatively small bioherms (up to 3 - 5 m high and 4 m wide, rarely more). Bioherms are formed by hermatypic corals and algae. Intermound areas are filled with bioclastic grainstones and packstones containg fragments of corals, bivalve and brachiopod shells, crinoid stems and echinoid spines.

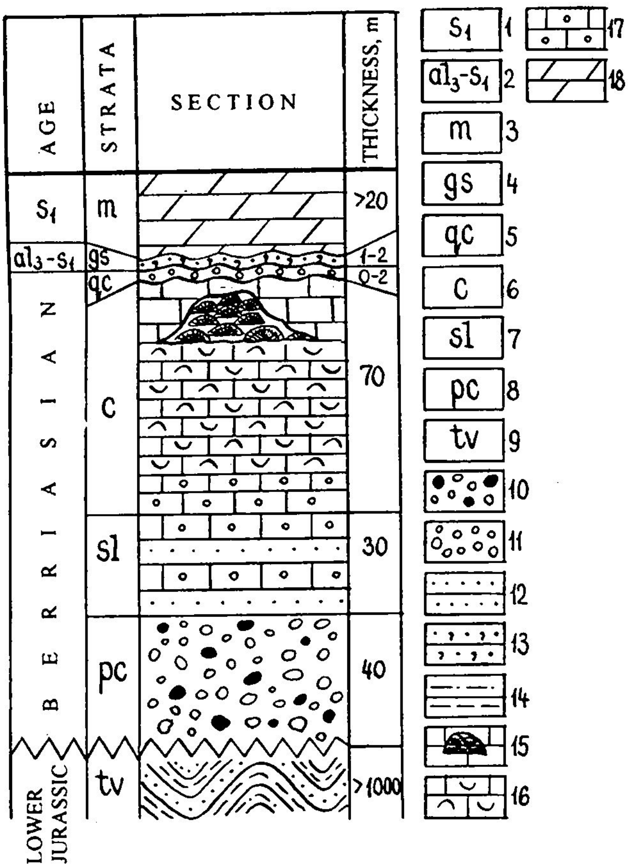


Fig. 2. Stratigraphic section of Lower Cretaceous deposits of the Mts. Polus-Voskhod area (based on the authors' data). 1 - Lower Cenomanian; 2 - Upper Albian - Lower Cenomanian; 3 - strata of marls; 4 - strata of glauconitic sandstones; 5 - strata of quartzose conglomerates; 6 - carbonate strata; 7 - strata of interbedding sandstones and limestones; 8 - strata of polymictic conglomerates; 9 - Tavric series; 10 - polymictic conglomerates; 11 - quartzose conglomerates; 12 - sandstones; 13 - glauconitic sandstones; 14 - siltstones and mudstones; 15 - biohermal limestones; 16 - bioclastic limestones; 17 - oncoid limestones; 18 - marls.

One of the largest and well exposed bioherms (called "Ulianovsky bioherm") (Fig. 3) is situated on the right bank of the River Belbek, 1.5 km upstream from Kuibyshevo, near the mouth of the Ulianovsky ravine.

This bioherm is a mound-shaped exceptionally large buildup. In the outcrop the bioherm is oriented 290° NW. The basement and the host rocks of the buildup are light gray packstones, the lower contact of the bioherm is not exposed. The top of the bioherm is overlain by a gravelstone lens and a relatively thin (2 m) bed of arenaceous limestones which are replaced upwards by detrital limestones. The western contact of the bioherm exhibits the onlapping host rocks. The eastern side of the bioherm has a more intricate, winding contact (not in the sketch!). Here, the surface of the buildup is truncated, cavernous, covered with numerous pockets. Near this contact, the sand content in the biohermal limestones increases and a breccia occurs along the contact. The framework of the bioherm consists of a light gray, very solid, massive limestone (framestone). It is formed by colonial corals and the problematic algae (*Lithocodium*). Two types of scleractinian colonies have been distinguished: (a) massive platy forms of the thamnasteroid and meandroid morphs up to 10-15 cm (rarely 30-40 cm) in diameter and 5-10 cm in height; (b) phaceloid and ramose colonies up to 80 cm in diameter at their bases and 100 cm high. Ramose colonies are inclined at 80° north-eastward. All scleractinians are heavily recristallized. The massive forms belong to the *Microsolenidae* and *Lathomeandriidae*, ramose forms to *Thamnaraea mammelonata* Turnsek, phaceloid forms to *Dermosmilia cretacica* Turnsek and *Placophyllia grata* Bugrova. The space between colonies of corals and algae is filled with an argillaceous wackestone and packstone rich in fossils: (a) small complete shells of brachiopods: *Weberithyris moisseevi* (Weber), *Zeillerina baksanensis* Smirnova, *Terebrataliopsis quadrata* Smirnova, *Septaliphoria* cf. *guerassimovi* Moiseev; (b) fragments of crinoid stems: *Heberticrinus heberti* (de Loriol in Pictet), (c) spines of echinoids: *"Cidaris" maresi* (Cotteau), (d) small solitary corals, and non-determinable bivalves. Brachiopods are most abundant and high-diverse among the reef-inhabiting organisms. Most of the fossils have been found in the central (78%) and western (16%) parts of the bioherm. The number of the reef-dwelling organisms is extremely low near the eastern contact. Some crustaceans, bryozoans, sponges and foraminifers have been found.

The thickness of the member of biohermal limestones is 15 m.

In addition the fauna of the carbonate strata includes many corals (*Cyathophora almae* Kusm., *Dimorphocoenia alpina* (Koby), *Stylosmilia alpina* Koby, *Stylina regularis* From., *Thecosmilia tobleri* Koby, *Heliocoenia variablis* Etallon, *Dimorphastraea fungiomorpha* Kusm., *Dimorpharaea burulchiensis* Kusm.), fragments of bivalves (*Rastellum* sp.) and foraminifers (*Charentia* cf. *cuvillieri* Neumann, *Ammobaculites* sp., *Trocholina* sp.).

No ammonites have been found in the carbonate strata. Representatives of the foraminifers' genera *Charentia* and *Trocholina* are known from the Berriasian deposits of the Northern Caucasus and Crimea (Benenson, 1985). Other species determined are either local (brachiopods, crinoids) or have wide sratigraphic distribution. The corals are known from the Oxfordian up to the Albian. The carbonate strata have been conventionally assigned by the authors to the Berriasian. The carbonate strata are up to 70 m thick. (3) The carbonate strata of the River Belbek basin are overlain by quartzose conglomerates. These consist mainly of rounded quartz pebbles and cobbles cemented by ferruginous carbonate. The thickness of conglomerates varies from 0 to 70 m. In the section of Mt. Voskhod it does not exceed 2 m. No fossils have been found here, the conglomerate strata have been assigned to the Berriasian, according to their stratigraphic positon below deposits containing Early Valanginian ammonites (Arkadiev & Bogdanova, 1997). In the section of Mt. Voskhod, Valanginian, Hauterivian, Barremian and Aptian deposits

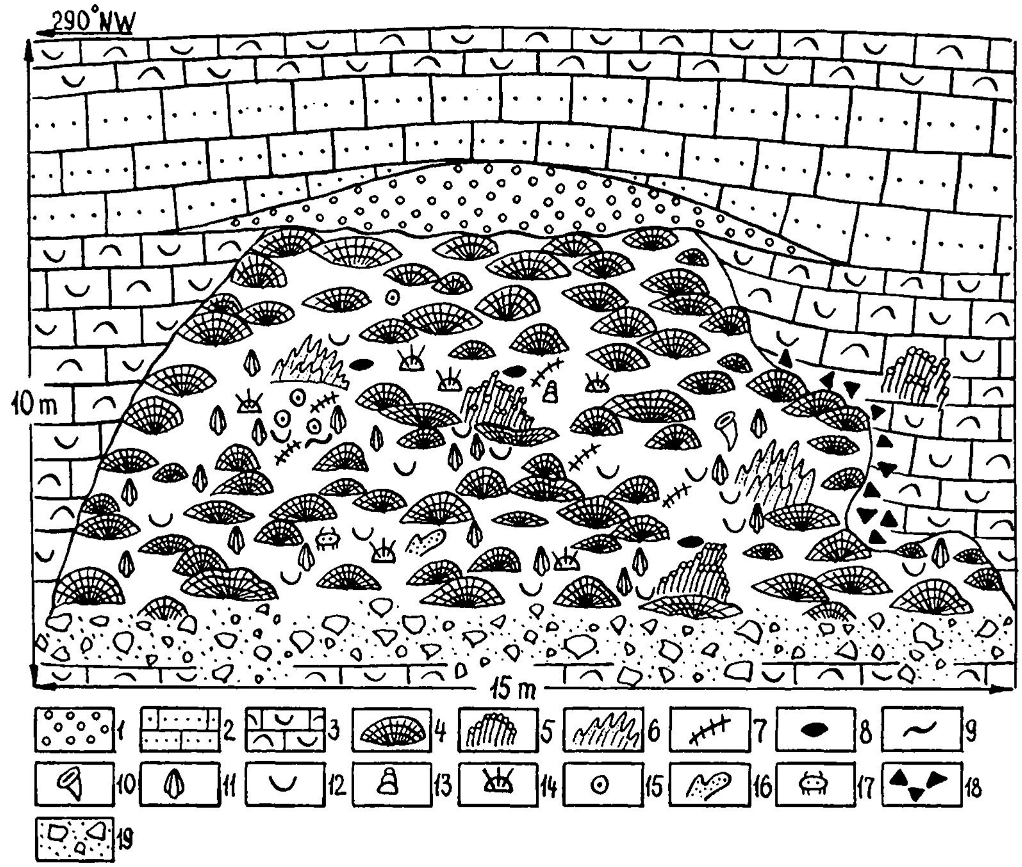


Fig. 3. Schematic field sketch of the Ulianovsky bioherm. 1 - quartzose gravelstones; 2 - arenaceous limestones; 3 - bioclastic limestones; 4 - massive scleractinian colonies; 5, 6 - ramose scleractinian colonies of various shapes; 7 -algae; 8 - foraminifers; 9 - worms; 10 - sponges; 11 - brachiopods; 12 - bivalves; 13 - gastropods; 14 - echinoids; 15 - crinoids; 16 - bryozoans; 17 - crustaceans; 18 - brecchia; 19 - talus.

are lacking, and the eroded surface of the quartzose conglomerates is discontinously overlain by Upper Albian-Lower Cenomanian glauconitic sandstones (Fig. 2)

In the River Belbek basin, this unit is represented by green and light green, fine-to-medium-grained calcareous glauconitic sandstones, containing magnetite grains. The sandstones transgressively overlap Lower Cretaceous rocks of varying age. In some places the sandstones include lenses of dark gray solid limestones containing abundant shells of *Aucellina gryphaeoides* (Sow.). In addition the following fossils have been recognized: ammonites: *Anapuzosia naidini* Marc., *Puzosia mayoriana* (d'Orb.), *Desmoceras inane* (Stol.), *D. latidorsatum* (Mich.), *Mortoniceras rostratum* (J. Sow.), *M.* cf. *perinflatum* (Spath), *Hamites virgulatus* Brong., *Anisoceras perarmatum* Pict. et Camp., *Ostlingoceras puzosianum* (d'Orb.), *Mariella crassituberculata* Spath, *M. bergeri* (Brong.), *Lechites moreti* Breistr. and belemnites: *Neochibolites ultimus* (d'Orb.).

The fauna, especially the ammonites, indicates a Late Albian age (*Stoliczkaia dispar* zone) of the sandstones. Kravtsov & Shalimov (1978), however, have assigned the upper part of this unit to the Lower Cenomanian. The thickness of the glauconitic sandstones varies from 1.5 to 10 m. Up the section, they are unconformably overlain by gray and dark gray marls and light gray argillaceous limestones containing Early Cenomanian ammonites *Mantelliceras picteti* Hyatt (Arkadiev & Bogdanova, 1997).

Facies of the carbonate strata

Modern erosional processes formed a gully in the saddle between Mts. Polus ans Voskhod, in which the top of the carbonate strata is exposed. The gully is 120 m long and oriented almost parallel to the strike of rocks (70° NE). The modern erosional processes expose an unconformity. In some parts of the gully, contacts between the carbonate strata and the overlying Berriasian quartzose conglomerates, and the Upper Albian-Lower Cenomanian glauconitic sandstones are visible. In the gully, the carbonate strata are represented by light gray solid bioclastic limestones. The top of the limestones is very cavernous, covered with numerous funnels, furrows and fissures.

At the point 6B-1 of the studied profile, the bioclastic limestones (packstones, wackestones and framestones) contain many quartz grains, lithoclasts and separate massive scleractinian colonies in living position. From this point Bugrova has determined *Actinastraea* sp., *Stylina* sp., *Stylosmillia* sp., *Calamophylliopsis* (?) sp. Thin sections show that quartz is represented by small (0.05-0.8 mm) angular and semi-angular isometric grains. Lithoclasts occur, consisting mainly of bioclastic limestones. *Lithocodium* and sponges, usually encrusting the colonies of scleractinians, rudists, echinoids and foraminifers occur. Complete bivalve shells, half-filled with carbonate material and skeletal detritus, have been found in some thin sections (Plate 6/5. Rare boring traces (triangular and pearshaped holes 0.15-0.25 mm deep) can be observed.

At the point 6B-2 of the studied profile (Fig. 4), this

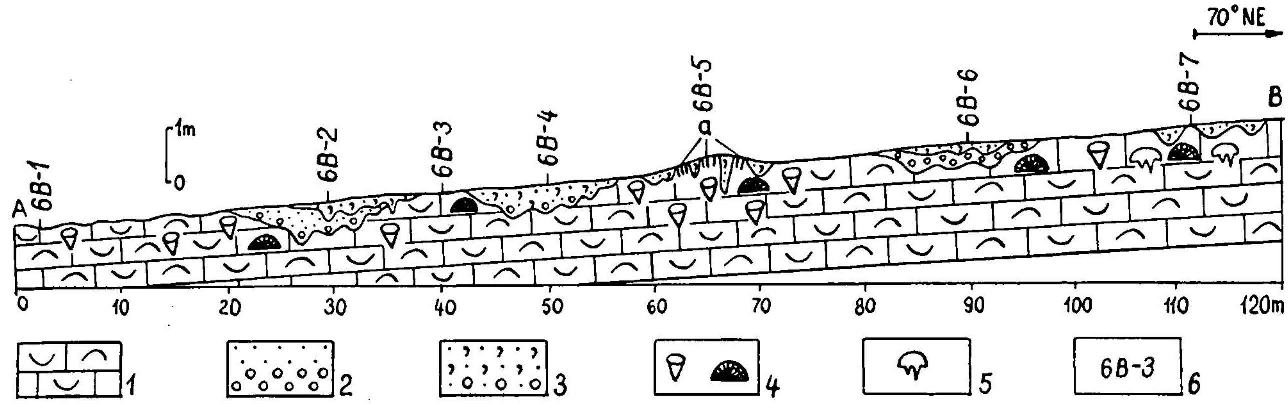


Fig. 4. Section through the Berriasian and Upper Albian deposits of the Mts. PolusVoskhod area (along the Line AB shown on the geological map, fig. 1). South-west Crimea, river Belbek. 1 - bioclastic limestones (Berriasian); 2 - quartzose conglomerates and sandstones (Berriasian); 3 - glauconitic sandstones with quartz pebbles (Upper Albian- Cenomanian); 4 - scleractinian remains; 5 - bivalves (rudist) remains; 6 - numbers of observation points, a-boring traces.

bioclastic coral-bearing limestone is in some places covered by a sandstone unit. Numerous deep (up to 5-10cm) flutes, funnels and furrows occur on the top of the limestones. They are filled with brown and yellowish brown coarse-grained, wavy and cross-laminated calcareous sandstone containing rare quartz pebbles and a great proportion of magnetite grains concentrated parallel to the lamination (Pl. 6/6). The laminae are 3-5 mm thick. The sandstone is up to 0.5 m thick, polymictic, has a fine-to medium-grained psammitic texture and a ferruginous carbonate cement. The grains are quartz and magnetite. Quartz grains are 0.05 to 0.5, rarely up to 1 mm in diameter, isometric in shape, angular to semi-angular. Quartz pebbles (ø 1 to 2 cm) are present in the upper part of the bed. Magnetite grains (ø 0.05 to 0.25, rarely up to 0.4 mm) are isometric (occasionally elongate), semi-rounded, sometimes semi-angular. Some layers in the lower part of the sandstones contain up to 50% magnetite; its amount decreases towards the top until it completely disappears. The sandstones contains glauconite grains (greenish brown to dark green, isometric in shape, rounded, 0.1 to 0.2, rarely up to 0.25 mm). The glauconite content increases from bottom to top of the sandstones. The uppermost beds contain up to 3 % glauconite. The sandstones yield a great amount of small bioclasts of various organisms: bivalves, echinoids, crinoids, brachiopods and algae.

The sandstones and limestones are cut by vertical or steeply dipping fissures, with sharp winding edges and filled with overlying glauconitic gravelstones, containing quartz pebbles. The depth of the fissures reaches 30-50 cm. The sandstone has a medium-grained psammitic texture and is carbonate cemented. The clasts are represented by limestone, calcareous sandstone, quartz and potassium feldspar. The limestone clasts are large (ø up to 1 cm), angular and contain echinoids and foraminifera. Quartz grains are 0.5 to 4.0 mm in diameter, semi-angular and have mosaic internal structure. Quartz pebbles up to 1-3 cm in diameter are rare. Glauconite grains are dark green, sometimes brownish green, 0.1 to 0.3 mm in diameter, well-rounded.

A contact between the glauconitic sandstones and the underlying rocks can been observed at the point 6B-4 (Fig. 4). Here, glauconitic sandstones unconformably overlie bioclastic framestones, filling numerous flutes, furrows and wedge-shaped fissures up to 10-20 cm in depth. Massive coral colonies, encrusted by questionable algae and microbes, fragments of bivalves and the foraminifers (*Gaudryina* sp.) have been found in these limestones.

At the point 6B-5 of the studies section (Fig. 4), the limestones form a small (0.5 m high) scarp in the gully. The limestones are bioclastic, massive, sometimes cross-laminated and can be described as wackestones. The lamination is marked by quartz grains (0.05 to 0.3 mm). Some parts of limestone contain massive colonies of scleractinians (*Microphyllia*?). Fragments of this coral, bivalves, brachiopods, echinoid spines, coral-encrusting algae and planktonic foraminifers have been recognized in thin sections .

All the surface of the limestone at the point 6B-5 is covered by various types of fissures and holes (Fig. 5, Pl. 6/1-4):

Type 1. Large zigzag and winding, sharp-edged fissures 2-3 to 4-6 cm wide. They are wedge-shaped and penetrate the limestones from the top till the depth of 0.5 m and more. These fissures form irregular polygons on the top surface, reminding of desiccation fissures.

Type 2. Horizontal or slightly inclined furrows on the surface of the limestones, 2-5 mm wide, 1-3 mm deep, 1-4 cm long, with almost flat or slightly concave bottom, straight or slightly curved. In some samples these furrows cut through the skeletons of colonial scleractinians oriented normally to the surface of the limestone. The fissures of the type 1 cross the furrows of type 2.

Type 3. Vertical, inclined or curved cylindric holes, 1 to 3 mm in diameter (prevail), up to 5 mm, and generally up to 5 mm (rarely more) in depth from the top of the limestone. The densitiy of these holes is 40-50 by 10 square centimetre of the surface, it increases on some parts of the surface. The holes are observed inside the furrows of type 1 and the fissures of type 2.

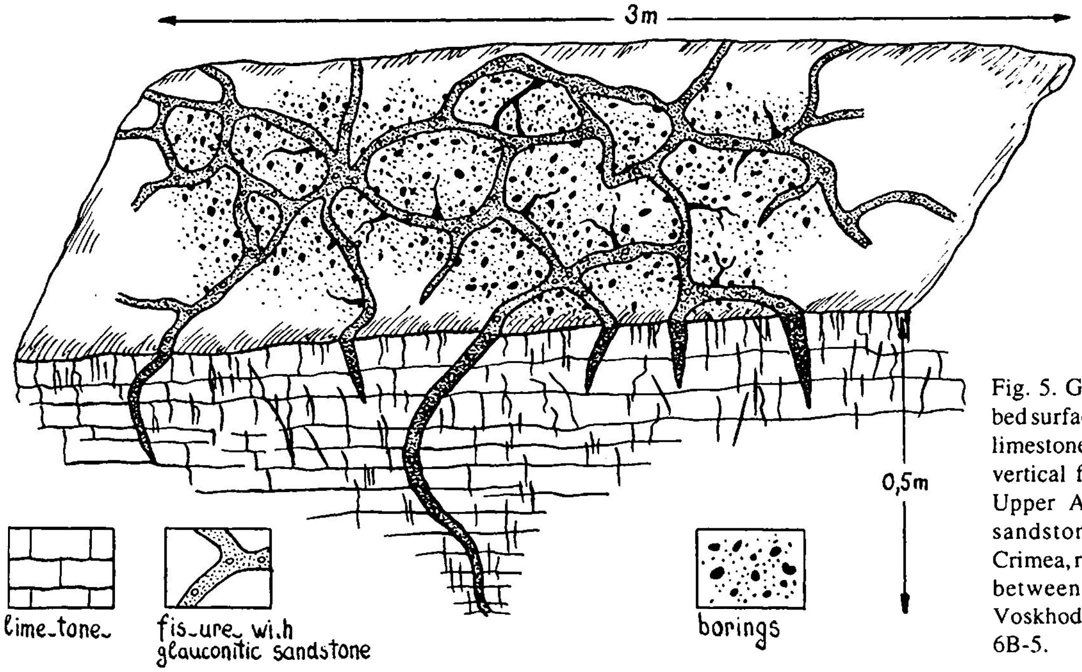


Fig. 5. General view of the bed surface of the Berriasian limestones with borings and vertical fissures filled with Upper Albian glauconitic sandstones. South-west Crimea, river Belbek, saddle between Mts. Polus and Voskhod, observation point 6B-5.

All three types are filled with glauconitic sandstone containing quartz pebbles. In the large fissures of type 1, angular and semi-angular and even semi-rounded quartz pebbles reach 2-2.5 cm in diameter. Small quartz grains are seen inside almost all holes of type 3.

At the point 6B-6 (Fig. 4), a quartzose conglomerate with pebbles of quartz, limestone, sandstone and rounded fragments of colonial corals occurs. The wackestone clasts contain ooids and remains of echinoderms, bivalves, foraminifers (*Rotalia*), serpulids and corals (*Stylinina*). The carbonate matrix of the conglomerate contains debris of echinoderms, bivlaves and foraminifers. On the surface of the conglomerate bed, numerous hollows, filled with glauconitic sandstone occur. The thickness of the residual conglomerate bed does not exceed 30 cm.

At the point 6B-7 (Fig. 4), the top of light gray solid massive bioclastic limestones is exposed. The limestones contain corals *Calamophylliopsis* cf. *compressa* (d'Orbigny), *Stylina* sp. and a great amount of large, up to 20 cm in diameter, thick-walled shells of rudists. The surface of the limestone is irregular, with numerous furrows filled with glauconitic sandstone.

Sedimentary environments

The Berriasian deposits of the River Belbek area have been formed during a single transgression-regression cycle.

The beginning stage of this cycle is characterized by deposition of the polymictic conglomerates in a nearshore shallow-marine (littoral), probably deltaic environment. The clastic material has been derived from land which was intensively eroded (Odesskiy, 1969).

Later, the interbedding sandstones and limestones have been deposited during an evolving transgression, the source land had undergone considerable planation.

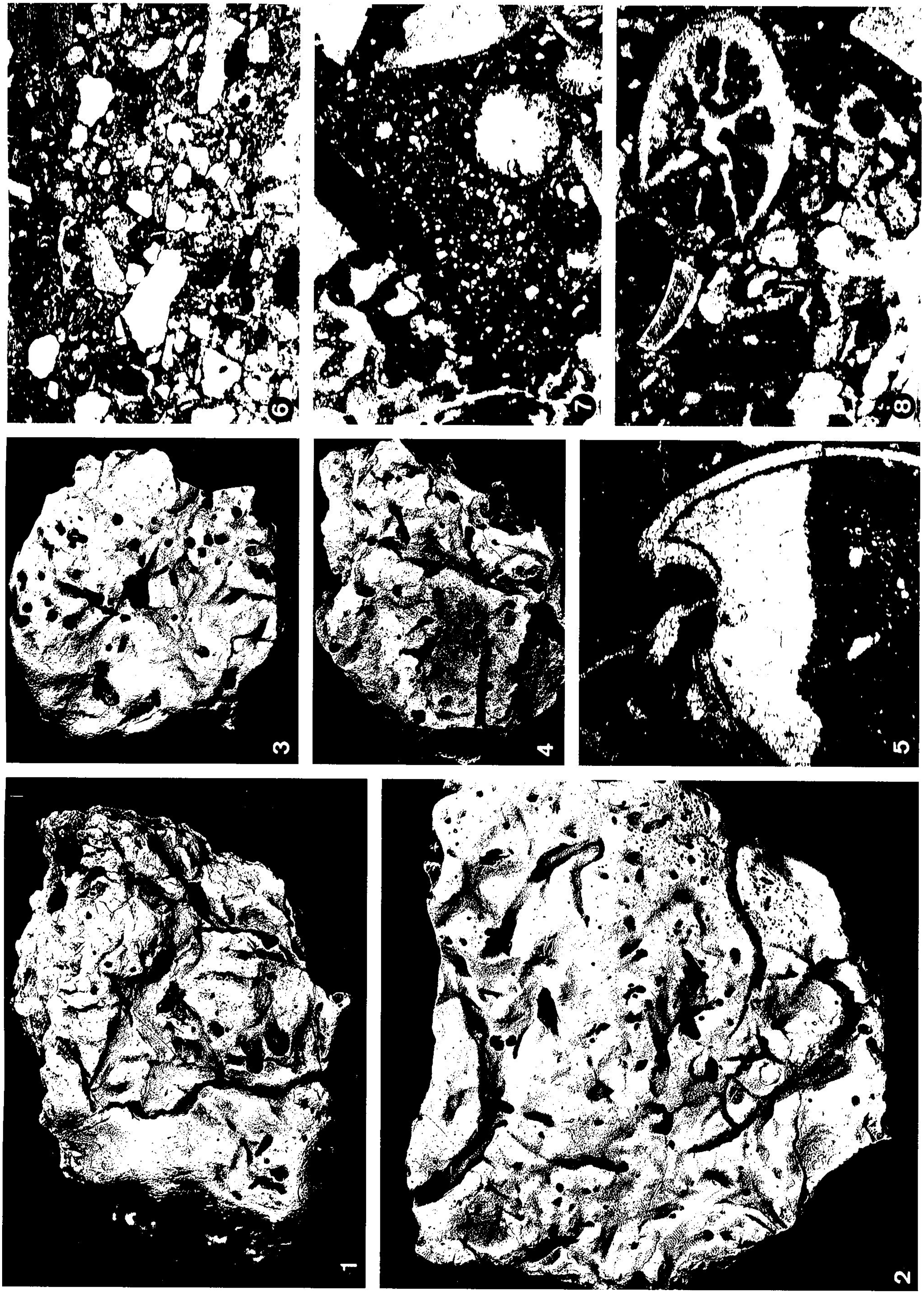
During the next stage, the overlying reefal carbonate sediments have been deposited as a part of an evolving reef system (Wilson, 1980). The oncoid limestones are deposits of a distal reef area, the bioclastic limestones are deposits of a near-reef position and the biohermal limestones have been formed at the reef margin. Descriptions of Berriasian carbonate facies are rare in literature.

During the formation of the reef system the area situated near the shore was covered by a warm, normal saline sea which allowed the growth of coral-algal bioherms.

Plate 6 Samples from south-western Crimea, river Belbek, saddle between Mts. Polus and Voskhod.

Figs. 1-4. Limestone beds with surfaces cut by fissures and bored by *Polychaeta.* Fig. 1: sample 2/308; Fig. 2: sample 1/308; Fig. 3: sample 5/308; Fig. 4: sample 4/308. Point 6B-5, top of the Berriasian carbonate strata. Figs. 1-4: x 1.0.

Figs. 5-8. Thin sections of Berriasian rocks. Fig. 5: complete bivalve shell, half-filled with fine carbonate sediment. Sample 28/308. Observation point 6B-1, the Berriasian carbonate strata;
Fig. 6: polymictic calcareous sandstone. Large angular and semi-angular quartz grains, semi-angular magnetite grains and debris of bivalves and foraminifers. Sample 19/308. Observation point 6B-2, strata of quartzose conglomerates;
Fig.7: fragment of scleractinian colony with a cavity filled with carbonate sediment, containing broken echinoid spines and fine quartz grains. Sample 28/308. Point 6B-1, Berriasian carbonate strata;
Fig. 8: bioclastic limestone (wackestone). Sample 27/308. Point 6B-3, Berriasian carbonate strata. Figs. 5-8: x 15.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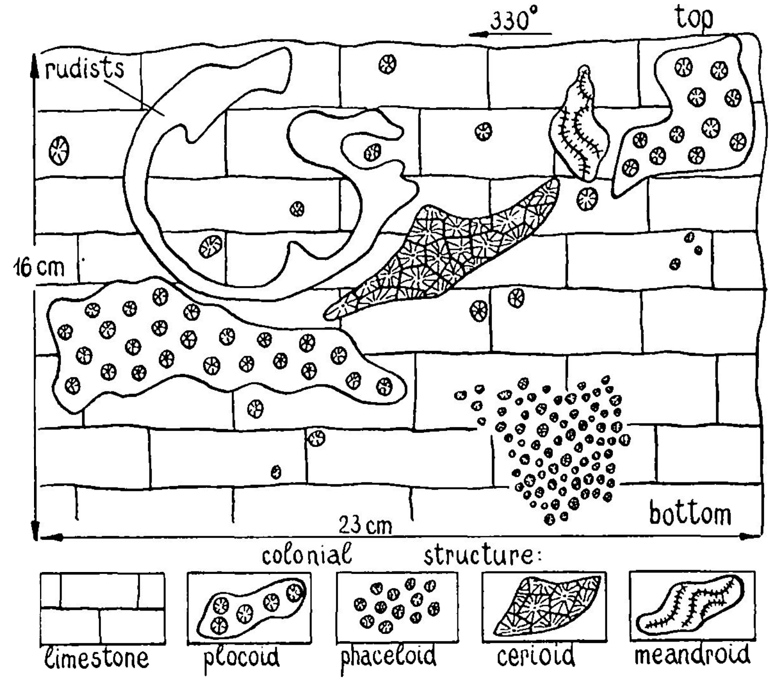

Fig. 6. Bioclastic limestone with rudists and scleractinians. South-west Crimea, river Belbek, saddle between Mts. Polus and Voskhod, observation point 6B-7, vertical section of limestone bed.

The bioherms formed highs on the sea floor, the intermound areas were filled with carbonate mud containing fragments of the benthic fauna. Main contributors to the formation of the bioherms were scleractinians and encrusting algae. Small platy colonies prevail among the massive corals of the bioherms indicating somewhat muddy water and even usually rapidly growing porous colonies do not reach large dimensions. Only porous ramose and phaceloid forms were able to overcome the rapid burrying in mud and grew about 100 cm high. Hydrodynamic activity was high, judging from the presence of colonies with compact and strong skeletons (*Montlivaltiidae, Stylinidae, Actinastraeidae* etc.) and by the abundance of bioclastic debris. Ramose colonies of the towards NE inclined Ulianovsky bioherm can be explained by a currents containing food particles from this direction.

The bioherms contain a fauna of brachiopods, echinoids, crinoids, encrusting algae, sponges, bivalves (lithophags and rudists), polychaete worms. The latter most likely have formed the furrows of the type 2. Polychaetes belong to the main "eroders" of coral reefs (Gekker & Ushakov, 1962; Gekker, 1983; Warme, 1975). The steady supply of terrigenous material (quartz) caused conditions of a rather surpressed growth of the bioherms. Quartz was transported from the nearby land by local streams, judging by a low degree of roundness (angular to semi-angular) and poor sorting of the grains.

An abrupt increase of terrigenous material in carbonate sediments, directly overlying the bioherms (e.g. in the Ulianovsky bioherm and the bioherms on Mt. Rifovaya), obviously caused by a general rise of the region, had led to a poor development and finally to a destruction of the biogenic buildups.

Deposition of quartzose gravel in nearshore, probably deltaic, environment occurred in the next stage (Odesskiy, 1969, Dorofeeva, 1981). The steady uplift of the block of Mts. Polus and Voskhod caused an abrupt decrease in thickness of the quartzose conglomerates here and their unconformable contact with the carbonate strata. Other blocks of the territory obviously underwent downward movements, which caused increased thickness of conglomerates. The strata of quartzose conglomerates are very variable in type. At point 6B-2, conglomerates are replaced by calcareous sandstones. The presence of cross lamination, marked by quartz and magnetite grains, suggests the deposition on a highly mobile nearshore shallow-marine or deltaic environment. This suggestion is supported by the presence of glauconite in upper layers of sandstones. Terrigenous material was derived from land by local streams, judging by its non-homogenous sorting and poor roundness. The abundance of quartz grains and pebbles in limestones and sandstones indicates a probably flat topography of erosional area with chemical weathering.

The next uplift of the territory had led to a total or partial erosion of the quartzose conglomerates in the area of Mts. Polus and Voskhod. Carbonate deposits rose above the sea level and underwent weathering. Narrow, winding and deep fissures on the surface of limestones were formed on cemented sediments (Shrock, 1950; Vassoyevich et al., 1983).

At the end of Berriasian, the transgression brought the surface of the limestones again below the sea level. Strong bottom currents prevented sedimentation, so the surface of the limestones became a hardground, on which only a few organisms were able to settle, especially lithophags. The borings of type 3, most likely by worms are characterized by their cylindric shapes, small diameters and depths. Borings of lithophages bivalves described by B.T. Yanin (1978) from Lower Cretaceous deposits of the Crimea are usually larger (0.5-2 cm in diameter) and have pear-like shapes.

For some time during the Berriasian a subaerial firm surface existed, which became drowned but remained near the shoreline. Similar hardground environments have been observed by GEKKER (1960, 1983) and GEKKER & USPENSKAYA (1966).

The break in sedimentation from the deposition of Berriasian carbonate sediments until the deposition of the Late Albian glauconitic sandstones includes the Valanginian, Hauterivian, Barremian, Aptian, Early and Middle Albian, a time span of about 35 ma. The beginning sedimentation during the late Albian, resulting from a sinking of the area, had led to filling of all depressions of the surface of the Berriasian rocks, with glauconitic sands rich in quartz grains and pebbles. The sands deposited in turbulent water, so that many holes in the surface of the limestones were deepened and enlarged.

Conclusions

The observations broaden our ideas of the development of the SE Crimea during the pre-late Albian. A warm shallow sea of the Berriasian was characterized by the widespread formation of small coral-algal bioherm buildups. An uneven uplift of the territory during the pre-Late Albian had disturbed the stability of this basin, and caused its block development and an increased supply of terrigenous material. This, together with the sea level changes, had led to the destruction of the buildups. During the pre-Late Albian time, the area of Mts. Polus and Voskhod fell dry or nearly dry indicated by the development of hardgrounds. At this moment, it represented an example of the hardground environment, where strong bottom currents prevented sedimentation and where only a few groups of organisms were able to settle. Further paleoenvironmental studies in neighbouring areas are necessary to determinate the character and position of the shoreline of the ancient basin more exactly.

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