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The Structure and Formation Conditions of the Bedenekir Formation Deposits (Thithonian Stage) of Mountainous Crimea

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Abstract—The composition and origin of the Bedenekir Formation deposits of Mountainous Crimea are detailed on the basis of our work results and analysis of both published and unpublished data.

Keywords: Mesozoic, Tithonian stage, stratigraphy, Mountainous Crimea

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INTRODUCTION

Despite the long history of geological research (since the 18th century) and abundance of the data on structure, composition, age, and formation conditions of the Tithonian deposits in Mountainous (Gorny) Crimea, a commonly accepted idea of their characteristics and genesis has not been developed as yet. This is caused by disturbance of primary spatial relationships between strata by tectonic dislocation and, in some places, by the scarcity of paleontological remains which would help to determine a more accurate age and sedimentation conditions of these deposits. The last point is extremely important in terms of specifying the scheme of formations of Mountainous Crimea (in particular, stratigraphic positions and extents of identified formations).

MATERIALS AND METHODS

The methods were (1) collection, analysis, and systematization of stock, archive, and published data; (2) field works; (3) laboratory studies; and (4) office works.

Collection, analysis, and systematization of published and published data involved the analysis of the work results of the previous researchers.

In the framework of the field observations, 22 observation points were described at Babugan-Yaila, coupled with measurements of occurrence elements and samples collection. Nanoplanktonic composition was analyzed in eight samples collected at the Mt. North Demerdzhi from coeval deposits. Field observations were carried out by E.A. Bakai, A.V. Sergienko, T.A. Konovalova, and others under the leadership of R.R. Gabdullin and with technical support provided by N.V. Badulina.

The laboratory studies included petrographic examinations of 18 thin sections, microfaunal analysis of nanoplankton from 8 samples of coeval deposits of the Mt. North Demerdzhi, measurement of insoluble residue concentration, and determination of the composition of rock-forming minerals in 22 samples of carbonate rocks by the gas-volumetric method.

Thin sections were prepared and described at the Department of Geology, Moscow State University (MSU). Petrographic examination of rocks in thin sections was carried out by E.V Karpova and M.A. Varzanova (MSU) using the standard technique (Frolov, 1992). Dissolution of carbonate rocks in acetic acid to determine the insoluble residue concentration was carried out by M.A. Varzanova (Department of Geology MSU) using the standard technique (Dmitrieva et al., 1969).

The gas-volumetric method involved measuring the carbonate contents in rocks; the carbonates were calcite ($CaCO_3$), dolomite ($CaCO_3 \cdot MgCO_3$), soda (Na_2CO_3), potash (K_2CO_3), siderite ($FeCO_3$), and others. During the determination of carbonate content, all calculations were divided to the $CaCO_3$ mass, because calcite is the most common in rocks and is the most plentiful among the mentioned carbonates.

Among the methods of determination of the carbonate content when analyzing samples, the most commonly used method is the gas-volumetric method; this is based on chemical decomposition of carbonates exposed to hydrochloric acid and measurement of the carbon dioxide volume yielded from the following chemical reactions:

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2,$$

$$CaMg(CO_3)_2 + 4HCl$$
$$= CaCl_2 + MgCl_2 + 2H_2O + 2CO_2.$$

A Karbonatometr KM-04 instrument was utilized to determine calcite and dolomite contents separately. The carbonate measuring instrument works as follows. A powdered rock sample (the grain size is 0.1 mm or less) up to 1000 mg in weight is placed in the portable glass of a reaction chamber, which is closed with a tightly fitting lid; the rock is then dissolved (1 : 6 ratio). Hydrochloric acid is supplied to it with a piston feeder. When the solution is injected, the air in the chamber compresses, leading to a rapid pressure change by approximately 0.17 kg/cm^2) and the measurement automatically starts with the running of driver of the magnetic mixer.

During mixing, due to interaction between carbonate substances and hydrochloric acid, carbon dioxide releases increasing pressure in the reaction chamber by a value that is proportional to the volume of released gas. Excessive pressure is measured by a sensor and displayed on the digital panel of the control unit and on a PC monitor. The difference in the reaction rate between HCl—pure calcite and HCl—calcite-dolomite mixture in a sample allows us to automatically determine the content of carbonate components in a sample from the measured values of pressure. Temperature control enables one to introduce corrections to temperature-related pressure changes to the processing software. The analyst was E.A. Bakai (MSU); the technical support was provided by M.A. Varzanova (MSU).

Nanoplankton specimens were prepared from an unworked rock using the standard technique (Bown and Young, 1998): powdered rock was put on a glass and spread in a drop of spirit until a homogeneous distribution occurred over the glass surface; Norland Optical Adhesive 60 was then used to fix the covering glass. After the drying of specimens, they were examined on an Olympus BX-41 microprobe. The analyst was E.A. Shcherbinina (Geological Institute of the Russian Academy of Sciences, Moscow).

At the office work stage, R.R. Gabdullin and N.V. Badulina (MSU) reviewed the stone-material collections in the studied area (State Geological Map of Ukraine, sheets L-36-XXIX, L-37-XXXV (Fikolina et al., 2008), and L-36-XXXIV (Chaykovskyy et al., 2006); Geological Map of USSR, sheet L-36-XXX (Bobylev and Balakina, 1973)), interpolated the results of analytical studies, and performed the comprehensive interpretation of geologic and lithological-chemical data.

CHARACTERISTICS OF DEPOSITS

The Bedenekir (Bedenekyr) Formation is exposed on the plateau and along the northern slopes of the Ai-Petri yaila, Dolgorukovskaya yaila, and Karabi-yaila. This formation was distinguished by V.F. Pchelintsev in 1962. The stratotype of this formation is the Mt. Bedenekir section in the western Ai-Petri yaila. Deposits of this formation are presented by interleaving gray and yellow limestones with interbeds of marls, siltstones, and clays, making the section of a cyclic structure (Anfimova, 2015; Fikolina et al., 2008). Bed cyclicity is well outlined by the weathering profile. The Bedenekir Formation conformably rests on rocks of the Yalta Formation (Lower and Middle Tithonian) or, in some places, rests unconformably on the eroded surface of the Yaila Formation (northern slope of the Main Range). Within the limits of the Ai-Petri yaila, Dolgorukovskaya yaila, and Karabi-yaila they form a plateau; on their northern slopes they are unconformably superimposed by the Lower Cretaceous rock complex (Anfimova, 2015; Fikolina et al., 2008).

According to our observations, dipping azimuths are 253—300° (usually approximately 260—270°) and the dipping angles are 45—84° (usually approximately 40—50°) (Table 1). Rocks of the Bedenekir Formation are tectonically dislocated in places, which is indicated by the change in bedding elements (dipping angle and azimuth) and cracking that occurs here. Untypical bedding elements are characterized by dipping azimuths of 37—45° (usually approximately 40°) and dipping angles of 21—30° (usually approximately 22—25°) (Table 1).

In the lower part of the stratotypical section on the Ai-Petri Plateau, detrital organic and pelitomorphic limestones (individual layers can be up to 15—20 m thick) with subordinated interbeds of marls (up to 1 m) and siltstones (0.2 m) dominate. In the upper part of the section, the thickness (and fraction) of marl and siltstone layers increase up to 3 and 0.6 m, respectively. Deposits of this formation demonstrate facial variability: e.g., on the northern slope of the Main Range, at Mt. Basman-Kermen, the predominantly carbonate sequence represented by fine-grained pelitomorphic detrital (sometimes brecciated) limestone sometimes contain beds of such terrigenous rocks as sandstones, conglomerates, and clays. Thicknesses of fine-grained dark gray polymictic sandstones and conglomerates

Table 1. The comparative characteristics of bedding elements of the Bedenekir Formation rocks

Sampling point	Dip azimuth, deg	Dip angle, deg	Parameters of cracking
3000	300	56	Mutually perpendicular cracks Az = 220, Dip = 90 and Az = 295, Dip = 4
3001	296	52	–
3002	290	45	–
3003	286	50	–
3004	301	48	System of cracks, Az = 286, Dip = 6
3005	40	25	–
3006	289	47	–
3007	275	42	–
3008	280	48	–
3009	44	22	System of cracks, Az = 256, Dip = 92
3010	290	50	–
3011	284	46	–
3012	43	21	–
3013	290	51	–
3014	38	22	–
3015	45	30	–
3016	37	24	–
3017	283	84	System of cracks, Az = 283, Dip = 84
3018	253	45	System of cracks, Az = 274, Dip = 92
3019	270	60	Mutually perpendicular cracks Az = 220, Dip = 91 and Az = 295, Dip = 5
3020	261	48	–
3021	254	57	–
3022	260	63	–
3023	261	60	–
3024	270	62	System of cracks, Az = 264, Dip = 78

Boldface italics denote the values that differ from the main data massif and correspond to dislocation zones. Az in the rightmost column means dip azimuth; Dip, dip angle.

(consisting mostly of carbonate rock fragments) are up to 4.5 and up to 10 m, respectively, while that of clays is no more than 1 m. The thickness of the entire formation in the stratotypical section is 100.8 m (Fikolina et al., 2008).

We believe that this formation corresponds to the largest part of stratum VI (Upper Tithonian) in the section of Mt. North Demerdzhi (Rud'ko, 2014). The thickness of this formation is highly variable: 200–250 m in the Grand Canyon area; 400–450 m at Mt. Bedenekir, and 100–150 m at Mt. Basman-Kermen, and reaches the maximum of 500–800 m in Karabi-yaila (Fikolina et al., 2008). Thus, the thickness ranges from 100 to 800 m.

The cyclicity of layers is usually expressed in interlaving pelitomorphic and/or oranogenic–detrital and brecciated limestones with subordinated interbeds of sand-grained limestones and marls (or such terrigenous rocks as sandstones, clays and conglomerates) or by interbedding of rocks that contain relatively more and less carbonates. The structure of the formation contains signs of eustatic sea-level changes, namely, third-order shallowing cycles (Rud'ko, 2014).

In the stratotypical section of the formation the fossils are represented by the brachiopods *Itieria rugifera* Zitt., *Ravillieria tilhaviensis* (Suess.), *Postepithyria biceidensis* (Zlusehn.), and others; the corals *Cryptocoenia hexapetalia* Dampell, *Thamnasteria globosa* (Og.), *Th. ruchini* Kr., *Th. subgregorti* Kr., and others; and the gastropods *Ptygmatis longa* Pčel., *P. caucava* Pčel., *Nerinea urcugteusis* Pčel. (Fikolina et al., 2008). At Mt. Basman-Kermen the corals *Stylina parvipora* (Ogilvie.) have been found; on the northern slope of Karabi-yaila, ammonites *Thysanolytoceras* aff. *liebigi* (Opp.), *T. sutile* (Opp.), *Berriassella callisto* (Orb.), *B. chaperi* Pict., *Malbosiceras malbasi* (Pict.), and *Haploceras carachtheis* Zeusch. occur; in the section of Dolgorukovskaya yaila (Mt. Kol-Bair), the gastropods *Arahimedea oblonga* Pchel. and *Nerinea jeacjuni* Ram., ammonites *Protetragonites guadrisulatus* (d'Orb.), and

Table 2. The geochemical characteristics of the Bedenekir Formation deposits, after (Rud'ko, 2014)

S.a.*, %	Mg, %	Mn, μg/g	Fe, μg/g	Sr, μg/g	Mg/Ca	Mn/Sr	Fe/Sr	$^{87}Sr/^{86}Sr^2$
8.7	0.4	280	2770	563	0.011	0.50	4.9	0.70729

* Silicoclastic admixture.

others were found. Thus, rocks comprising this formation contain species generally characteristic of the Late Tithonian (*Virgatosphinctes transitorius* zone) (Fikolina et al., 2008); thus, the age of the formation was assumed to be Late Tithonian.

In aerial and satellite images, the areas where this formation is exposed are light gray in tone. Layer cyclicity is seen from the remote sensing data. Rocks of the Bedenekir Formation represented by carbonates host limestones of industrial value; for example, the large Mramornoe deposit is located here.

The areas where this formation is presented correspond to low values of magnetic field anomalies and to high values of the gravity field.

Metamorphic alterations have not been revealed by either our works or by previous researchers. Metasomatic alterations are represented by dolomitization of limestones. Radiologic ages of the rocks from this formation are not available.

According to previous studies (Fikolina et al., 2008), the following lithologic types (lithotypes) can be distinguished among rocks of the formation:

(1) pelitomorphic limestones composed of fine-grained calcite;

(2) organogenic-detrital limestones composed predominantly of calcitated shells and their fragments, cemented by micritic calcite;

(3) brecciated limestones and limestone breccias consisting of fragmented organogenic and pelitomorphic limestones (the fragments are 0.1 to 3–10 cm in size) cemented by clay-carbonate material;

(4) sandy–silty limestones containing up to 30% silty–psammitic material (up to 99% composed of quartz; the rest is feldspar);

(5) carbonate–chlorite–hydromica marl with a significant admixture of quartz;

(6) quartz sandstones and siltstones with clayey–carbonate cement, enriched in coalified vegetation remains (Fikolina et al., 2008).

These lithologic units from rocks of the formation were revealed during field studies. In addition, we have distinguished a new lithotype represented by dolomite. Dolomitization of limestones was noted in field reports and was verified later during later laboratory studies by the gas-volumetric method (indirectly, by the insoluble-residue method) and during petrographic examination of thin sections.

The comprehensive geochemical characteristics are available for one specimen of pelitomorphic limestone (Rud'ko, 2014), which was collected at Mt. North Demerdzhi (Table 2). We can see that these limestones referred to lithotype 1 are characterized by a low fraction of a silicoclastic admixture (8.7%) or so-called insoluble residue.

RESULTS AND DISCUSSION

Summarizing the analysis of literature sources, we can note the generally good degree of knowledge about these deposits, as well as the satisfactory correlation between our data and the results of previous studies. We have obtained new data to supplement the existing knowledge about the rock compositions in the formation.

Microfaunal Analysis

At least 15–20 samples for each specimen were examined to reveal lime nanoplankton remains; however, none were found. The complete absence of nanoplankton (even of a bad degree of preservation) in marine sediments, which formed under conditions a priori favorable for nanoplanktonic organisms, probably indicates unfavorable conditions of nanoplankton deposition rather than recrystallization of deposits (even in this case, undeterminable coccoliths of species that are most resistant to recrystallization often remain in the deposits); thus, the basin was not only a shallow one, but also had a high hydrodynamic activity that impeded precipitation of fine particles (of nanoplankton size).

Insoluble Residue Measurement and Determination of Rock-Forming Minerals for Carbonate Rocks (Gas-Volumetric Method)

We can note the good correlation between the results obtained by two different methods (Table 3). The minimum and maximum values of the contents of different components are similar, suggesting that, from a methodological point of view, either method can be utilized in practice, although the gas-volumetric method is considerably more exact and informative. The data generally correlate well with the field macroscopic descriptions (Table 4) and the data of previous researchers. In particular, we found the lithotypes that were identified previously (Table 4). The dolomite content in the studied samples is remarkably low (no more than 4.5%), which is also supported by microfaunal studies (see above).

Table 3. Comparison between component determination results by the gas-volumetric and insoluble-residue methods in the Bedenekir Formation deposits

Method	Components	Content, %		
		maximal	average	minimal
Gas-volumetric	Calcite	100 (samp. nos. 3009, 3010, 3013)	66.6	0 (samp. nos. 3001, 3002)
	Dolomite	40 (samp. no. 3001)	2.7	0 (samp. nos. 3000, 3007, 3008, 3009, 3010, 3011, 3013, 3014, 3018–3022)
	Insoluble residue	95.5 (samp. no. 3002)	25.7	0 (samp. nos. 3003, 3005, 3006, 3009, 3010, 3013)
Insoluble residue	Carbonate	100 (samp. nos. 3006, 3009, 3010, 3013)	65.6	0 (samp. no. 3002)
	Insoluble residue	100 (samp. no. 3002)	25.7	0 (samp. nos. 3006, 3009, 3010, 3013)

Table 4. The compositions of the Bedenekir Formation rocks from the gas-volumetric method (a), insoluble-residue method (b), petrographic study of thin sections (c)

Samp. nos.	Lithology (based on microscopic description)	Lithotype, after (Fikolina et al., 2008)	Calcite, %			Dolomite, %		Insoluble residue, %		
			a	b	c	a	c	a	b	c
3000	Dolomitized limestone	1	95.4	94	40	0	0	4.6	6	60
3001	Cyanobacterial-algae dolomite	7*	0	2.5	5	40	50	60	97.5	45
3002	Dolomitized limestone	7*	0	0	10	4.5	35	95.5	100	55
3003	Dolomitized limestone	2	96.9	95.2	20	3.1	5	0	4.8	75
3004	Organogenic limestone	2	–	97.3	40	–	–	–	2.7	60
3005	Organogenic limestone	2	94.8	96.2	30	5.2	0	0	3.8	70
3006	Organogenic limestone	2	99.2	100	50	0.8	1	0	0	49
3007	Dolomitized limestone	1	77.2	65.5	25	0	10	22.8	34.5	65
3008	Organogenic limestone	2	98.4	97.5	40	0	0	1.6	2.5	60
3009	Organogenic limestone	2	100	100	35	0	1	0	0	60
3010	Limestone	1	100	100	40	0	0	0	0	60
3011	Dolomitized limestone	1	96.5	94.2	40	0	20	3.5	5.8	40
3013	Limestone	1	100	100	40	0	1	0	0	60
3014	Dolomitized limestone	1	97.1	95.5	30	0	10	2.9	4.5	60
3017	Dolomitized limestone	1	88.4	75.5	20	0	15	11.6	24.5	65
3018	Sandstone	6	39.9	30.1	20	0	5	60.1	69.9	75
3019	Sandstone	6	40.1	21.2	15	0	10	59.9	78.8	75
3020	Sandstone	6	30.3	25.1	20	0	5	69.7	74.9	75
3021	Sandstone	6	35.6	17.2	15	0	5	64.6	82.8	80
3022	Sandstone	6	42.1	5.1	25	0	5	57.9	94.9	70

* Identified for the first time.

Petrographic Study

The petrographic study of these rock samples (performed by E.V. Karpova and M.A. Varzanova, MSU) revealed the following lithotypes: dolomites (type 7), limestones of different structural types (1 and 2) possessing different degrees of dolomitization, and sandstones (type 6). Below is the brief overview of the obtained and systematized data. Thin-section images are shown in Fig. 1.

Spherically aggregated dolomite (thin section no. 3001) composed of cyanobacteria and algae (with fragments of stromatolite structures), completely micritic in places, with calcite filling (fine- and small- up to coarse-crystalline in size) of cavities and second-

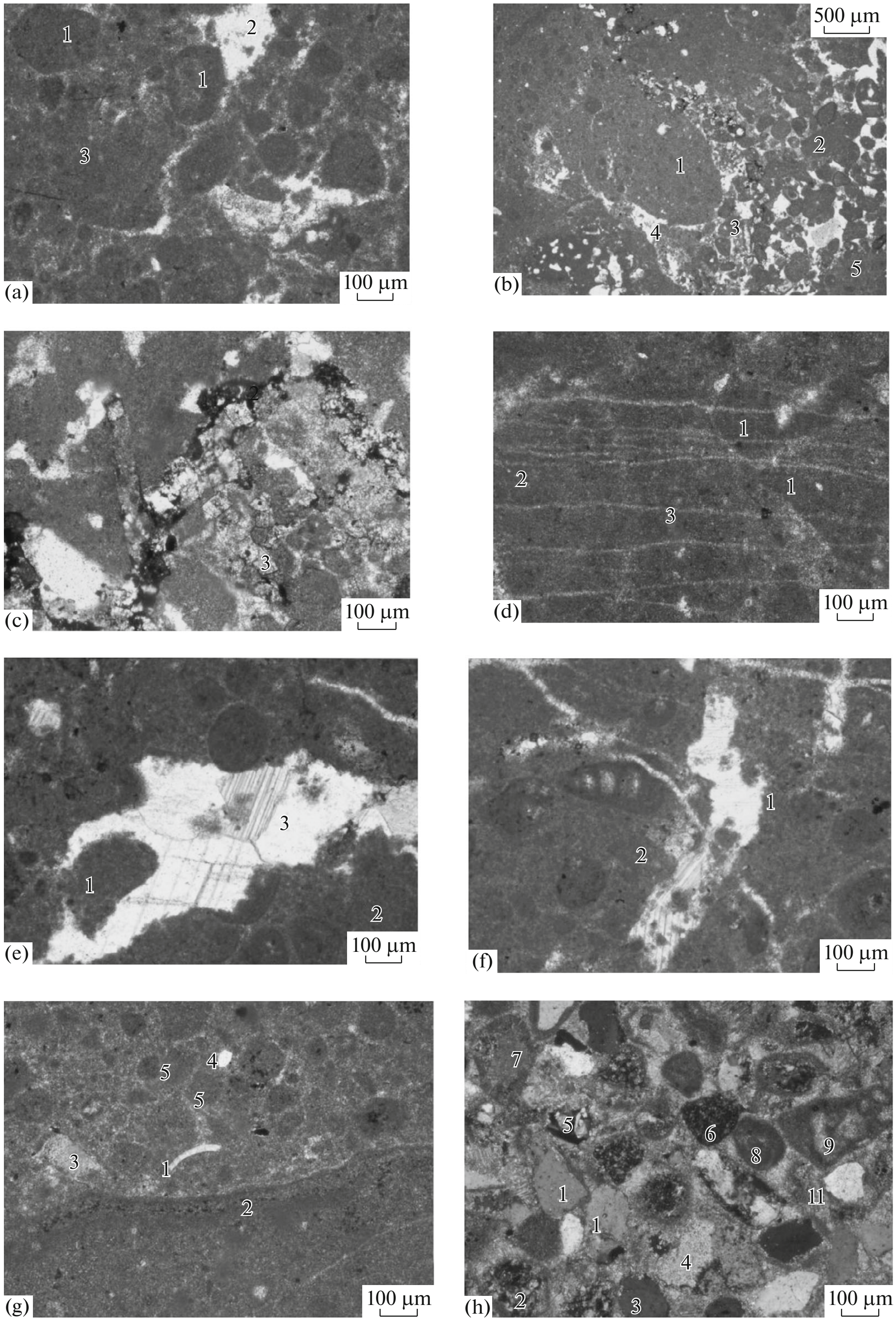

Fig. 1. Thin sections and the respective arbitrary notes (numerals in circles). (a) Thin section no. 3001: 1, spherical aggregates; 2, leached cavities filled by calcite and/or dolomite; 3, zones of solid micritic groundmass. (b) Thin section no. 3003: 1, gravel-size fragment, 2, sand-size fragment, 3, spherical aggregates, 4, crystalline calcite in the interpore space, 5, crinoids fragment. (c) Thin section no. 3003: 1, solid micritic groundmass; 2, microstylolite suture; 3, dolomite crystals covered by organic matter. (d) Thin section no. 3004: 1, spherical aggregates; 2, solid micritic groundmass; 3, cracking. (e) Thin section no. 3006: 1, spherical aggregate; 2, solid micritic groundmass; 3, cavities filled by microcrystalline calcite. (f) Thin section no. 3006: 1, foraminifera shell in cyanobacterial-algae film; 2, solid micritic groundmass. (g) Thin section no. 3007: 1, ostracods shell fragment; 2, algae crust; 3, crinoids fragment; 4, quartz fragment; 5, spherical aggregates. (h) Thin section no. 3018: 1, quartz grains; 2, flint; 3, siltstone fragment; 4, granitoids fragment; 5, plagioclase; 6, effusive rock fragment; 7, solid micritic groundmass; 8, cyanobacterial-algae lump; 9, faunal remains; 10, cyanobacterial-algae film covering the fragments; 11, pore calcite.

ary microcracks, unlayered; the amount of calcareous material is less than 5%. (Note that the rock description in the thin section does not correspond to the result of chemical analysis, which can probably be explained by the finely dispersed clayey admixture, which looks like carbonate matter and appears to dominates in the rock, comprising as much as approximately 60% of it.) The rock consists of micritic lumps and clods, with (or without) zones of clear microcrystalline texture inside them, with unclear washed contours that often merge with the abundant zones of through micritic dolomite. Cyanobacterial-algaic assemblages are represented by small crusts, fine channels, and thalluses consisting of individual filaments and their aggregations. Thalluses are mostly spherical or tubular in shape, rarely dendritic. Rare zones with laminite-banded texture are observed, as well as singular quartz grains of small-to-fine grain sand size and singular foraminifera shells with micritized walls. These rocks form under the conditions of a closed platform (along the belts of Wilson's standard facies), in the sites with a low-level hydrodynamic regime. Dolomitization of primary deposited calcareous material occurred almost syngenetically owing to bacterial-algae communities that produced a special geochemical environment promoting the deposition of magnesian compounds. Note that this lithotype has not been previously reported in deposits of this formation (Fikolina et al., 2008).

Dolomite-containing (10–15%) limestone, type 1 after (Fikolina et al., 2008) (thin section no. 3007). Spherically aggregated (micrities lumps and clods of 0.03 to 0.5 mm in size) and completely micritic zones occur, along with singular micritized foraminifera shells, with cavities and secondary cracks being filled with clearly crystalline calcite. Rocks are nonlayered. There are microstylolitic sutures marked by organic matter, with an amplitude of up to 2 mm. Dolomitization (10–15%) occurs both in micritic zones, where it appears in the form of a fine-grained mass that syngenetically replaces calcite, and in stylolitic zones, where it occurs as singular idiomorphic monocrystals of fine sand grain size and their clusters formed at the catagenetic stage. Dolomites are also seen in filling of the cavities. The sedimentation conditions remain the same.

Limestone, type 2 after (Fikolina et al., 2008) (thin sections nos. 3003, 3004, and 3006). Limestones in thin sections are detrital, intraclastic, ranging from mid-to-large sand to small and large gravel in grain size, moderately sorted, and nonlayered. The texture of fragments and filling between them is spherically aggregated, sometimes solid micritic. Spherical aggregates are represented by spherical and elliptic micritic lumps and clods of 0.05 to 0.4 mm in size, with eroded contours, which often merge with the solid micritic groundmass. Apart from spherical aggregates and the micritic groundmass, the interstitial space contains cyanobacterial-algae fragments and singular micritized foraminifera shells, as well as fragments of skeletons belonged to crinoids and osctracods. All these elements are cemented by fine-to-small calcite or dolomitized clearly microcrystalline lime mass. The rock contains microstyllolite sutures marked by organic matter, with the amplitude of up to 3 mm, to which secondary dolomite monocrystals (<5%) of fine-grained size coincide, with organic matter smeared on crystal faces. The rock is partitioned by a system of mutually intercepting secondary cracks in various directions, filled with clearly microcrystalline calcite. The genesis of this lithotype, given the generally similar sedimentation environment, demonstrates signs of an intensified hydrodynamic regime, which led to disintegration of semisolidified silt and deposition of its fragments without any significant transportation.

Fine-to-small grained sandstone, type 6 (thin section no. 3018), well sorted, nonlayered, mesomictic, consisting of angular-semirounded grains of quartz (60%) and feldspar (15%), lithoclasts (15%) (quartzites, effusive rocks, siltstones, and flints) with admixture of calcite spherical aggregates (10%), singular shell fragments, and algae thalluses. Many rock components are covered by bacterial micritic film. Fine crystalline calcite cement (15–20%) fills the pores. The rock formed under the conditions of a shallow marine basin with the predominance of the wave effect.

FORMATION CONDITIONS

The fossil complex includes foraminifera, corals, mollusks, brachiopods, and crinoids. It characterizes a shallow marine basin of normal salinity, several tens of meters depth, with water temperature higher than 20°C (according to the presence of corals) and intensive hydrodynamics (a zone of high wave energy). This is also verified by the microfaunal analysis and partially by petrographic studies of thin sections. In particular, the latter has allowed us to distinguish and characterize the zones with various hydrodynamic conditions of shallow marine environment: (1) conditions of intensive wave energy (sandstones, lithotype 6); (2) a carbonate platform with generally quiet (but periodically intensified, with washing of bottom sediments) hydrodynamic regime (detrital limestone); (3) a carbonate platform in the sites with a quiet hydrodynamic regime (micritic dolomitized limestone and cyanobacterial-algae dolomite). The settings mentioned above indicate eustatic sea level variations. In particular, thin sections contain both relatively deep water species (such as crinoids and foraminifera) and those from relatively shallow habitats (cyanobacteria (stromatolites) and osctracods). The outcrop exhibits an elementary bed-wise cylicity represented by alternation of rocks with higher and lower carbonate contents.

According to the earlier data (Rud'ko, 2014), the eustatic cycles of the second and third orders were revealed in this section and the sedimentation rate for this formation was defined (on the basis of limestones from Demerdzhi Plateau) at 0.23–0.28 m/1000 years.

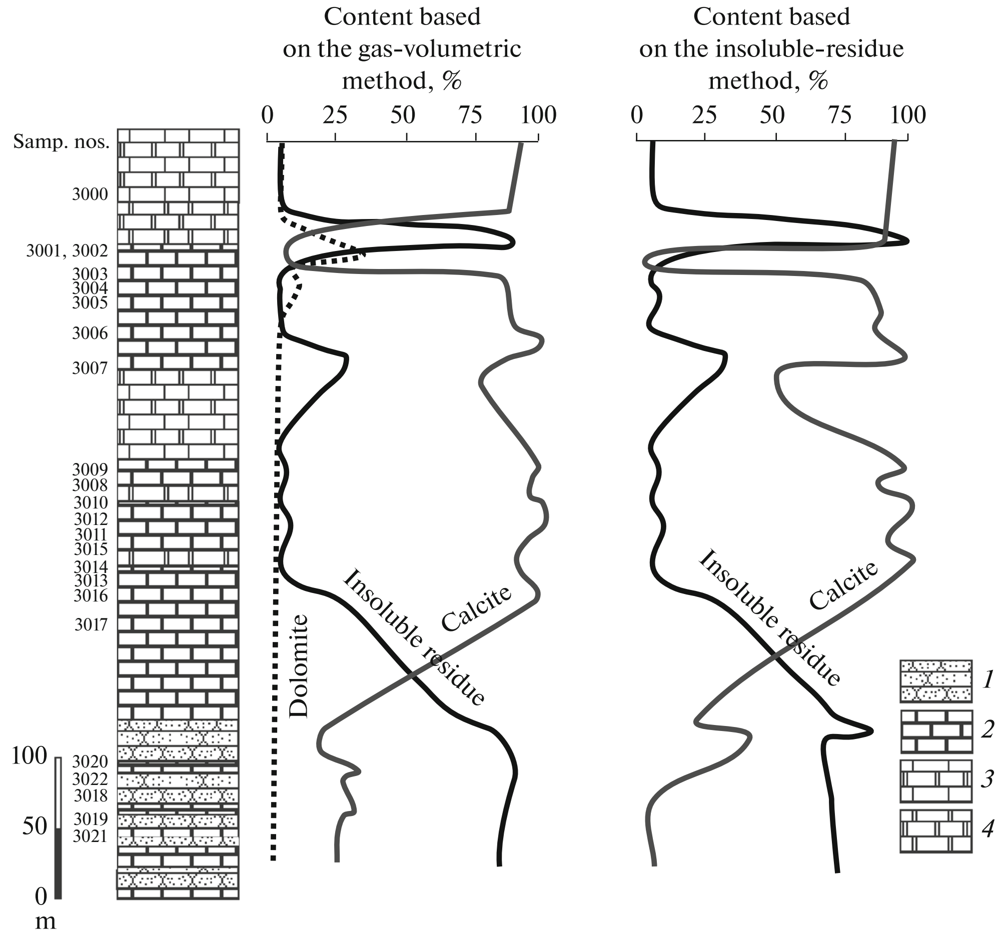

Fig. 2. The distributions of contents of calcite, dolomite, and insoluble residue in the Bedenekir Formation deposits from Babugan-Yaila: *1*, sandstones; *2*, limestones; *3*, alternation of limestones and dolomites; *4*, dolomites.

Apart from very shallow water conditions, the presence of osctracods may indicate variations in salinity (freshening or salinization). In most cases (but only if they are quite abundant in rock), they characterize a brackish basin with salinity of 0.5–15‰. The presence of dolomitized limestones and dolomites might indicate a higher salinity; however, examination of thin sections suggested that dolomitization was related to the change in the chemical composition of the environment by bacteria (syngenetic factor) and to the later filling of caverns and crack vicinities (catagenetic factor).

The studied 532-m thick section interval does not cover the entire visible thickness of the Bedenekir Formation outcrops in Babugan-yaila; nevertheless, we can note that the obtained values of formation thickness are, in our opinion, overestimated because of the presence of at least four tectonic dislocations (of layer-wise detachment or thrust types) in the site where samples 3005, 3009, 3012, and 3014–3016 were collected. In other words, we can suppose that the same fragment (or different fragments) of the formation may repeat at least four times. According to our estimates, the studied fragment of the formation section was initially approximately 130–150 m thick. However, determination of the more exact value of the initial thickness requires special study.

In this respect, it would be incorrect to reconstruct the geological history for the entire time when this formation was deposited. Nevertheless, the change in lithology of rocks was noted, as well as variations in a number of studied parameters along the section. The lower part of the section (samples 3021, 3019, 3018, 3022, and 3020), represented by a 125-m thickness of interleaving sandstones and limestones, corresponds to a transgression setting (transgression systems tract). The middle part (samples 3017–3006), which is characterized by interleaving of limestones and marls and is 266 m thick, corresponds to the high-stand position and stable water level in the basin (the first half of the highstand tract). The upper part, which is composed of interleaving dolomites, dolomitized limestones, and limestones (samples 3005–3000) and is 141 m thick, corresponds to the regression setting of a shallowing basin (the second half of the highstand tract).

The fluctuation cycles of calcite content and insoluble residue were revealed from gas-volumetric data and by the insoluble-residue method (Fig. 2); they can be largely explained by eustatic variations.

The geological history of the studied region, according to (Rud'ko, 2014), can be subdivided into the following stages. The time interval from the Kimmeridgian to the early Tithonian, preceded the deposition of the Bedenekir Formation (the time when the Yalta Formation deposited), was marked by the "formation of a large carbonate platform in the form of a step-wise ramp" under the conditions of "rapid downwarping of the basin and general transgression" (hereinafter in this paragraph, the quotes are from (Rud'ko, 2014)). Then, since the Late Tithonian until the Berriassian, under the conditions of "alternating-sign tectonic movements and relative regression" in the Late Tithonian (the time when the Bedenekir Formation deposited), "the platform changed its configuration (from step-wise to framed) and Gilbert-type deltas formed" (Gilbert-type deltas are those with frontal parts of noticeably sloped (up to 35°) to form clearly expressed clinoform bodies). As well, "deep water parts of the basin shallowed and breccias formed on the background of partial platform destruction at the peak of regression."

CONCLUSIONS

As a result of our study of the Bedenekir Formation section fragment, the characteristics of this formation have been determined and new data has been added. The new data correlate with the previous results. Six lithotypes that characterize the formation deposits are joined by a seventh one represented by dolomite. Laboratory studies verified dolomitization of limestones, which was revealed during the field works. The nature of dolomitization has been determined to be syngenetic and catagenetic. Analysis of the distribution of bedding elements within stratigraphic units has shown the tectonic dislocation of the sequence. Dislocation zones do not correlate to dolomitization of rocks.

New data on cyanobacterial communities, ostracods, and crinoids have been added to the data on the paleontological characteristics of the formation. The settings with different hydrodynamic energies have been distinguished (a zone of intensive wave energy; a carbonate platform with a generally low (but periodically intensified) hydrodynamic regime, with washing of bottom sediments during the intensified period; and a carbonate platform of a low hydrodynamic regime). In the studied section, eustatic variations have been found and system tracts have been distinguished. Eustatic variations were largely determined by the tectonic factor.

In the beginning of the Bedenekir time (early Tithonian), a carbonate platform of a step-wise ramp shape existed in the studied area; in the Late Tithonian the basin configuration changed to a framed platform; finally, at the end of Bedenekir time (the end of the Tithonian) a Gilbert-type delta formed.

The paleogeographic settings at which the formation rocks deposited were generally characterized by normal salinity (sometimes with variations toward an increase of seawater salinity), a warm water temperature (above 20°C), and generally intensive hydrodynamic conditions (sometimes less intensive).

In terms of the methods that were used, the results of the gas-volumetric and insoluble-residue methods demonstrated a good correlation. As well, examination of thin sections allowed us to provide new details to the results obtained by other methods and add new data to them.

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