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Radiolaria, Planktonic Foraminifera, and Stratigraphy of Turonian–Lower Coniacian in the Biyuk-Karasu Section, Crimea

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Abstract—The first data on the distribution of Radiolaria and planktonic Foraminifera in the section at Biyuk-Karasu River in central part of the Crimean Mountains, are presented. Based on the study of radiolarian findings, the upper Cretaceous deposits of Biyuk-Karasu section are subdivided into the following biostratigraphic units: Alievium superbum–Phaseliforma turovi (middle Turonian), Dactylodiscus longispinus–Patulibracchium (?) quadroastrum (upper Turonian), and Orbiculiforma quadrata–Patellula sp. B (Turonian–Coniacian boundary deposits). The stratigraphic interval of Alievium superbum–Phaseliforma turovi has been previously characterized by the complex of Alievium superbum–Phaseliforma sp. A (middle Turonian, Mt. Chuku section, SW of the Crimean Mountains, and middle Turonian, Mt. Ak, central part of the Crimean Mountains). Based on the study of Foraminifera findings, the following biostratigraphic subdivisions were identified: Whiteinella paradubia (lower–lower part of the middle Turonian), Marginotruncana pseudolinneiana (uppermost middle Turonian), and Marginotruncana coronata (upper Turonian). The complex of beds with *Marginotruncana pseudolinneiana* and *Marginotruncana coronata* are comparable to the deposits of zones of same name in the Crimean–Caucasian region.

Keywords: Crimea, stratigraphy, Turonian, Coniacian, Radiolaria, Foraminifera

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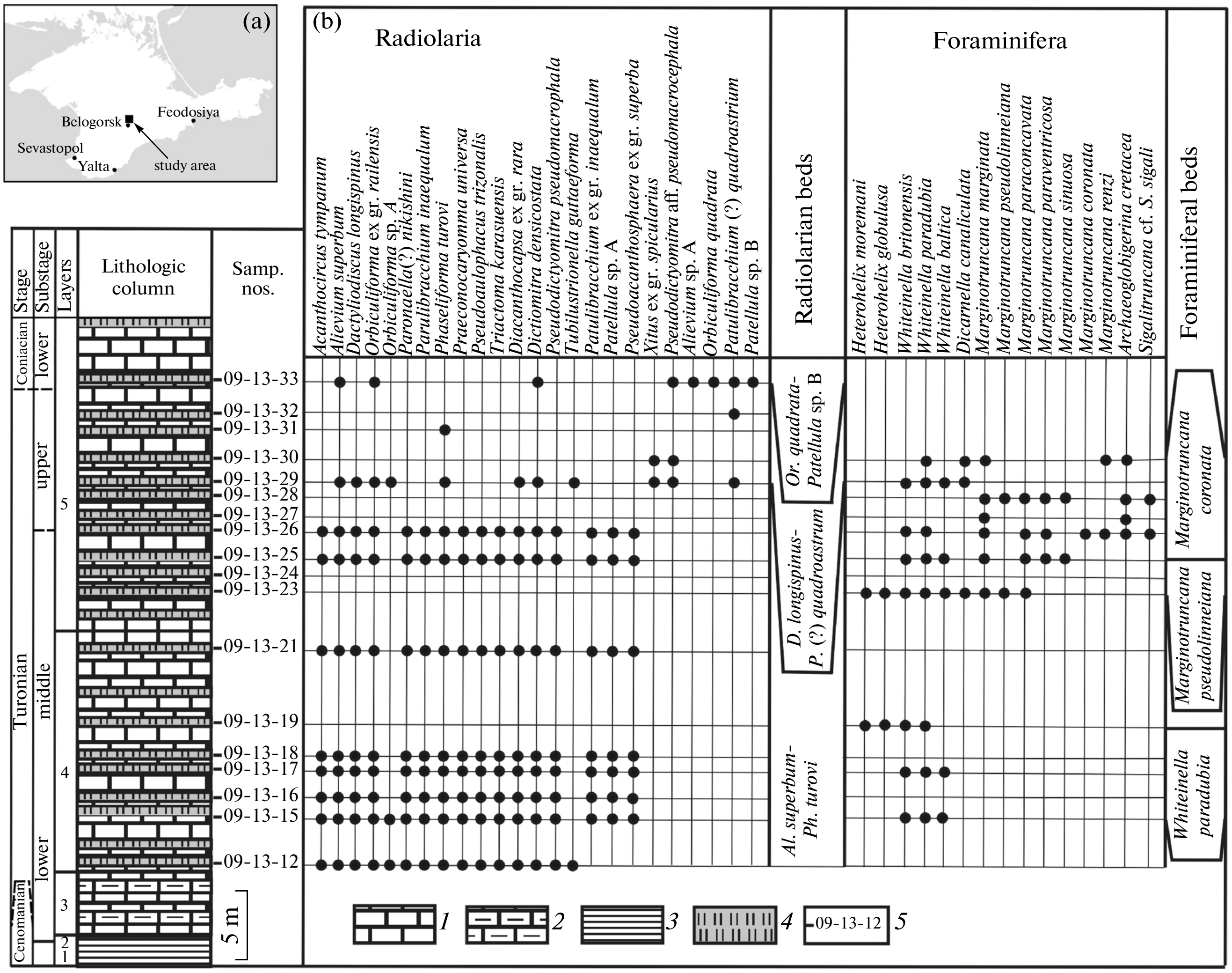
INTRODUCTION

Upper Cretaceous Radiolaria of Crimean Mountains have been actively studied during the recent decade (Bragina, 2013, 2014; Bragina and Bragin, 2007). The results of this study demonstrate that this group can be successfully used for subdivision of Cretaceous deposits of Crimean Mountains in the stratigraphic interval of the lower Cenomanian–upper Santonian (Bragina, 2009a; Korchagin, Bragina, and Bragin, 2012). Based on Radiolaria studies, the position of the Cenomanian–Turonian boundary at the Sel'-Bukhra section has been specified (Bragina, 2011). We emphasize that Radiolaria-based subdivision for some stratigraphic sections in Crimea, e.g., for the upper Santonian, is higher than that based on orthostratigraphic groups (Korchagin et al., 2012). In order to use the high stratigraphic potential of this group, the complex study of Crimean Mountains sections based on Radiolaria and planktonic Foraminifera is necessary to carry out. The detailed sampling of the upper Cretaceous sections in Crimean Mountains for Foraminifera and Radiolaria has been carried out only at the Ak-Kaya section (central Crimean Mountains) (Korchagin et al., 2012). These studies are of special interest, because they provide an opportunity to study radiolarians and foraminifers from the same samples.

Further study in this field implies sampling of the microfauna from the Turonian–lower Coniacian part of the section on the right bank of Biyuk-Karasu River. At present, the Radiolaria are reported for the middle Turonian–lower Coniacian deposits of Mt. Chuku (SW of the Crimean Mountains) and for the lower–middle Turonian deposits of Mt. Ak (central Crimean Mountains) (Bragina, 2013). Thus, analysis of the microfaunal distribution in the deposits at Biyuk-Karasu River has broad promise in the sense of the correlation between coeval deposits in the SW and central part of the Crimean Mountains.

THE HISTORY OF INVESTIGATIONS IN THE STUDY AREA

Based on geological mapping results, Turonian deposits in the territory of the Crimean Mountains are the most widespread in its SW part and in the vicinity of the town of Belogorsk (central part of the Crimen Mountains) (Fig. 1). Subdivision of the upper Cretaceous deposits of Crimen Mountains has been made based on inoceramus and ammonites (Alekseev, 1989; Kopaevich and Walaszczyk, 1990), and also planktonic and benthic Foraminifera (Maslakova, 1978; Astakhova et al., 1984; Kopaevich and Kuzmicheva, 2002; Kopaevich, 2009). In Crimean Mountains,



Study area location within Crimean Mountains (a) and stratigraphic distribution of characteristic radiolarians and planktonic foraminifers species in the Biyuk-Karasu section (b): (*1*) limestones; (*2*) chalky limestones; (*3*) clays; (*4*) flint interbeds; (*5*) findings of radiolarians and planktonic foraminifers.

Turonian deposits are subdivided into lower and upper (Alekseev, 1989).

Lower Turonian deposits are represented by gray and pale gray marls connected via gradual transitions with upper Cenomanian rocks. Marls in the upper part of the lower Turonian deposits contain flint nodules and flint lens-shaped interbeds. A lower Turonian age of the host deposits is verified by the findings of *Mytiloides labiatus* Schloth. The Upper Turonian deposits are represented chiefly by limestones that contain findings of *Inoceramus lamarcki* Park. and *Cataceramus schloehbachi* (Boehm) (Alekseev, 1989).

N.I. Maslakova proposed the following zonation of the Turonian–Coniacian deposits: a Helvetoglobotruncana helvetica Zone for the lower Turonian; a Globotruncana lapparenti Zone for the upper Turonian; and a Globotruncana angusticarinata Zone for lower Coniacian (Maslakova, 1978). However, the systematics of planktonic Foraminifera has been substantially changed since that study, therefore, the species described by N.I. Maslakova must be revised (Korchagin, 1982; Caron, 1985; Korchagin, 2001). With respect to this, the specified zonation scheme was proposed in 2009 for upper Cretaceous deposits of the Crimean–Caucasian region, based on the planktonic foraminifers (Kopaevich, 2009).

In according with the most recent ideas, the Turonian stage in the standard scale is subdivided into three substages, viz., lower, middle, and upper ones (Robaszynski et al., 1990; Gradstein et al., 2004). According to the standart zonation of the Turonian, which is based on the planktonic Foraminifera of the Globotruncanidae family, the following zones are distinguished: Whiteinella archaeocretacea (lower part of the lower Turonian); Helvetoglobotruncana helvetica (upper part of the lower Turonian–lower part of the middle Turonian); Marginotruncana schneegani (lower part of the middle Turonian); and the lower part of the Concavatotruncana concavata (upper part of the middle Turonian–upper Turonian) (Gradstein et al., 2004). Thus, the boundaries of the Turonian and Coniacian are located within the Concavatotruncana concavata Zone.

When subdividing the upper Cretaceous deposits based on Radiolaria, the scheme that is most often used is the scheme that was developed on the basis of sections studied in California (Pessagno, 1976); however, subzones of this scheme are usually not traced beyond California. With respect to this, the Radiolaria-based zonal scheme for the upper Cretaceous needs to be specified and described. Hence, the study of upper Cretaceous sections, which was characterized on the basis of orthostratigraphic groups (in addition to radiolarians), is of special interest.

MATERIALS AND METHODS

This work is based on the data collected by N.Yu. Bragin. Radiolaria and planktonic Foraminifera were studied by L.G. Bragina and L.F. Kopaevich, respectively. The samples of siliceous rocks were treated with 5–10% HF using the standard method. From the resulting sediment from a series of samples, the radiolaria and foraminifera shells of satisfactory and good preservation were selected. Shells were imaged by N.V. Gor'kova using a Tescan-2300 scanning electron microprobe with the subsequent digital processing at the Geological Institute of the Russian Academy of Sciences.

STRATIGRAPHIC DATA

The studied section of the upper Cenomanian–Turonian is located on the right bank of the Biyuk-Karasy River, north of the town of Belogorsk (Fig. 1a). The distributions of and appearances of the most characteristic radiolarian species are given in Figs. 1–4; those for planktonic foraminifers are shown in the Figs. 1, 5–7. Below, the brief description of the Biyuk-Karasy section (45°04′20.4″ N, 34°37′18.7″ E) is given, as well as the distribution of planktonic foraminifers and radiolarians in it (Fig. 1b).

Layer 1. White chalky limestones. The visible thickness is 0.5 m.

Layer 2. Greenish gray plastic thin-slabby (bentonite?) clays, with interbeds of (i) black bituminous slabby clays containing carbon-bearing detritus and (ii) pale-yellowish gray highly-argillaceous marls possessing the finest millimeter lamination and having fish scales on bedding planes. In the upper part of the layer, the interbed of yellowish-brown ferruginous aleurites and yellowish gray aleuritic marls is located. The visible thickness of the entire layer is 1.5 m.

Layer 3. Interbedding of white indistinctly laminated dense limestones and pale gray thin-slabby marls (the latter contain ferruginous burrows). Rare interbeds of dark gray clays and yellowish gray aleuritic marls. The thickness is 4–5 m.

Layer 4. White chalky, slabby and thick-slabby limestones with interbeds of opoka-like flints with silicified central parts of interbeds up to dark gray compact flint. Small intraformation folds (probably related to submarine sliding) are developed; rare thin interbeds of dark gray clay, some flint interbeds are breccia-like in texture (rewashing due to submarine sliding).

At 1 m above the base of the layer (samp. 09-13-12), the radiolarian complex contains *Acaeniotyle diaphorogona* Foreman, *A. macrospina* (Squinabol), *A. umbilicata* (Rust), *Acanthocircus tympanum* O'Dogherty, *Alievium sculptus* (Squinabol), *Al. superbum* (Squinabol), *Archaeocenosphaera* (?) *mellifera* O'Dogherty, *Becus regius* O'Dogherty, *Cavaspongia antelopensis* Pessagno, *C. californiaensis* Pessagno, *C. euganea* (Squinabol), *C. robusta* Bragina, *C. tricornis* O'Dogherty, "*Cenosphaera*" *boria* Pessagno, *Crucella cachensis* Pessagno, *Cr. latum* (Lipman), *Cr. messinae* Pessagno, *Dactyliodiscus longispinus* (Squinabol), *Dactylioshpaera* ex gr. *silviae* Squinabol, *Halesium diacanthum* (Squinabol), *H. sexangulum* Pessagno, *Hexapyramis* (?) *perforatum* Bragina, *Orbiculiforma maxima* Pessagno, *O. maxima* Pessagno sensu O'Dogherty, *O.* ex gr. *railensis* Pessagno, *Orbiculiforma* sp. A, *Paronaella* (?) *nikishini* Bragina, *P. spica* Bragina, *Patellula cognata* O'Dogherty, *P. verteroensis* Pessagno, *Patulibracchium inaequalum* Pessagno, *P.* ex. gr. *inaequalum* Pessagno, *P. woodlandensis* Pessagno, *Pessagnobrachia irregularis* (Squinabol), *P. fabianii* (Squinabol), *Phaseliforma inflata* Bragina, *Ph. turovi* Bragina, *Praeconocaryomma californiaensis* Pessagno, *Pr. lipmanae* Pessagno, *Pr. universa* Pessagno, *Pseudoacanthosphaera galeata* O'Dogherty, *Ps. superba* (Squinabol), *Pseudoaulophacus praeflorensis* Pessagno, *Ps. trizonalis* Bragina, *Pyramispongia glascockensis* Pessagno, *Quadrigastrum insulsum* O'Dogherty, *Savaryella novalensis* (Squinabol), *S. spinosa* O'Dogherty, *Staurosphaeretta euganea* (Squinabol), *St. wisniowskii* (Squinabol), *Triactoma karasuensis* Bragina, *Afens liriodes* Riedel et Sanfilippo, *Amphipyndax stocki* (Campbell et Clark), *Cryptamphorella conara* (Foreman), *Diacanthocapsa aksuderensis* Bragina, *D. ancus* (Foreman), *D. antiqua* (Squinabol), *D. fossilis* (Squinabol), *D.* ex gr. *rara* (Squinabol), *Dyctiomitra densicostata* Pessagno, *Distylocapsa veneta* (Squinabol), *Pseudodictyomitra pseudomacrocephala* (Squinabol), *Rhopalosyringium euganeum* (Squinabol), *Squinabollum fossile* (Squinabol), *Strichomitra communis* Squinabol, *S. insignis* (Squinabol), *S. magna* Squinabol, *Torculum coronatum* (Squinabol), *Tubilustrionella guttaeforma* (Bragina), and *Xitus asymbatos* (Foreman).

At 4 m above the base of the layer (samp. 09-13-15), the radiolarian complex from the lower part of layer 4 continues, but new species appear: *Pseudoacanthosphaera* ex gr. *superba* (Squinabol) and *Patellula* sp. A. Planktonic foraminifers are also found here: a speci-

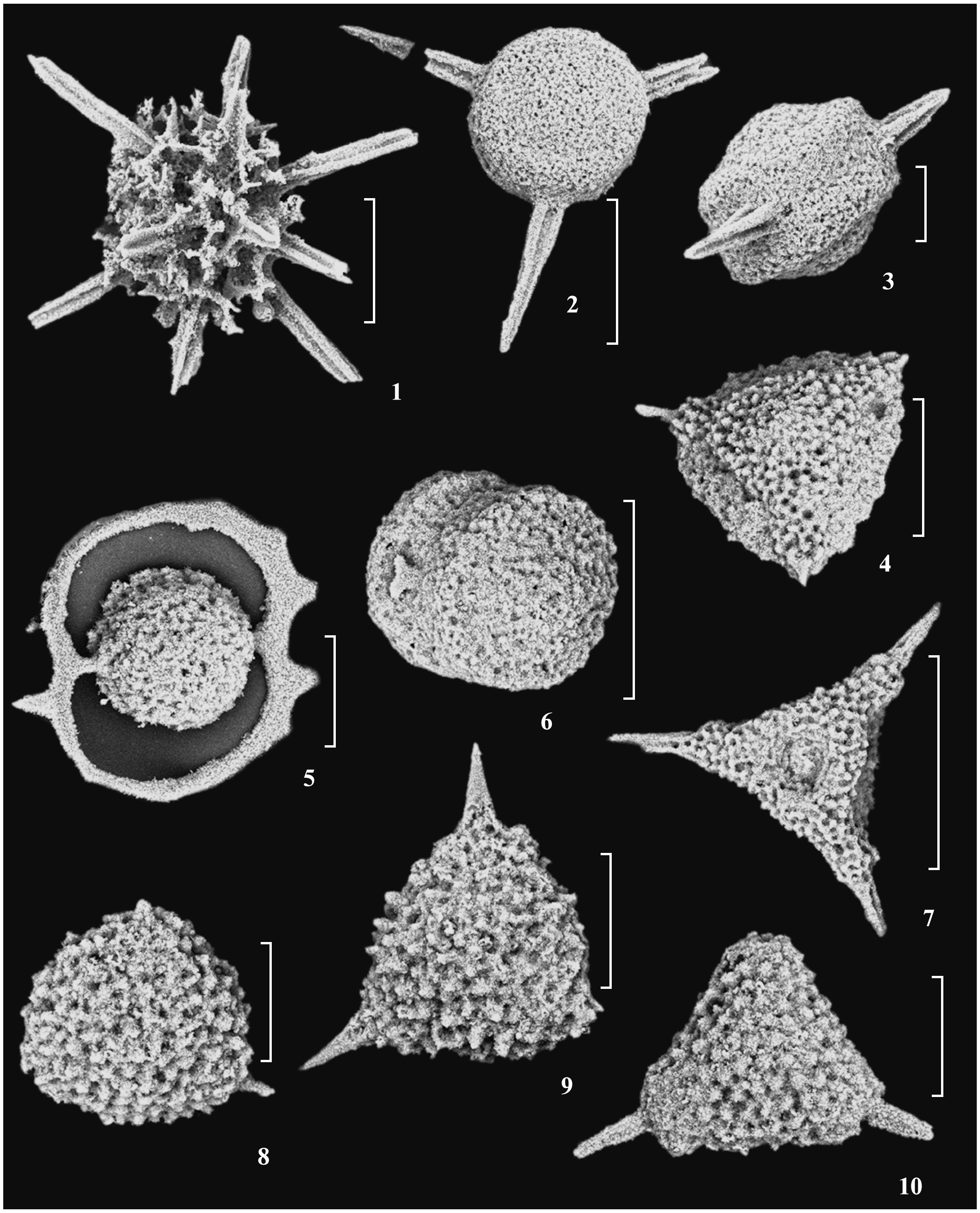


Plate 1. Radiolaria from middle Turonian–lower Coniacian deposits of the Biyuk-Karasu section, central part of the Crimean Mountains. The scale bar length is 200 μm for 1–3, and 7; 100 μm for 4–6 and 8–10. 1, *Pseudoacanthophaera* ex gr. *superba* (Squinabol) (samp. 09-13-15); 2 and 3, *Triactoma karasuensis* Bragina (samp. 09-13-15); 4 and 7, *Pseudoaulophacus trizonalis* Bragina (samp. 09-13-18 for 4 and 09-13-12 for 7); 5 and 6, *Acanthocircus tympanum* O'Dogherty (samp. 09-13-18; 6 is the specimen showing cylindrical cortical shell); 8 and 9, *Alievium superbum* (Squinabol) (samp. 09-13-33); 10, *Alievium* sp. A (samp. 09-13-33).

men of *Guembelitria* cf. *cenomana* (Keller), as well as *Whiteinella baltica* Duglas et Rankin, *Whiteinella brittonensis* (Loeblich et Tappan), *Whiteinella paradubia* (Sigal), and *Whiteinella* sp. with an anomalous structure of the last coil.

At 5, 7, and 8 m above the base of the layer (samp. 09-13-16, 09-13-17, and 09-13-18 respectively), the radiolarian complex from the lower part of layer 4 continues. Small juvenile shells of nonkeeled planktonic foraminifers are also found in these samples.

At 10 m above the base of the layer (samp. 09-13-19), planktonic foraminifers *Guembelitria* cf. *cenomana* (Keller), *Heterohelix globulosa* (Ehrenberg), and *H. moremani* (Cushman) are found, as well as singular shells of non-keeled trochoid planktonic foraminifers with bad preservation.

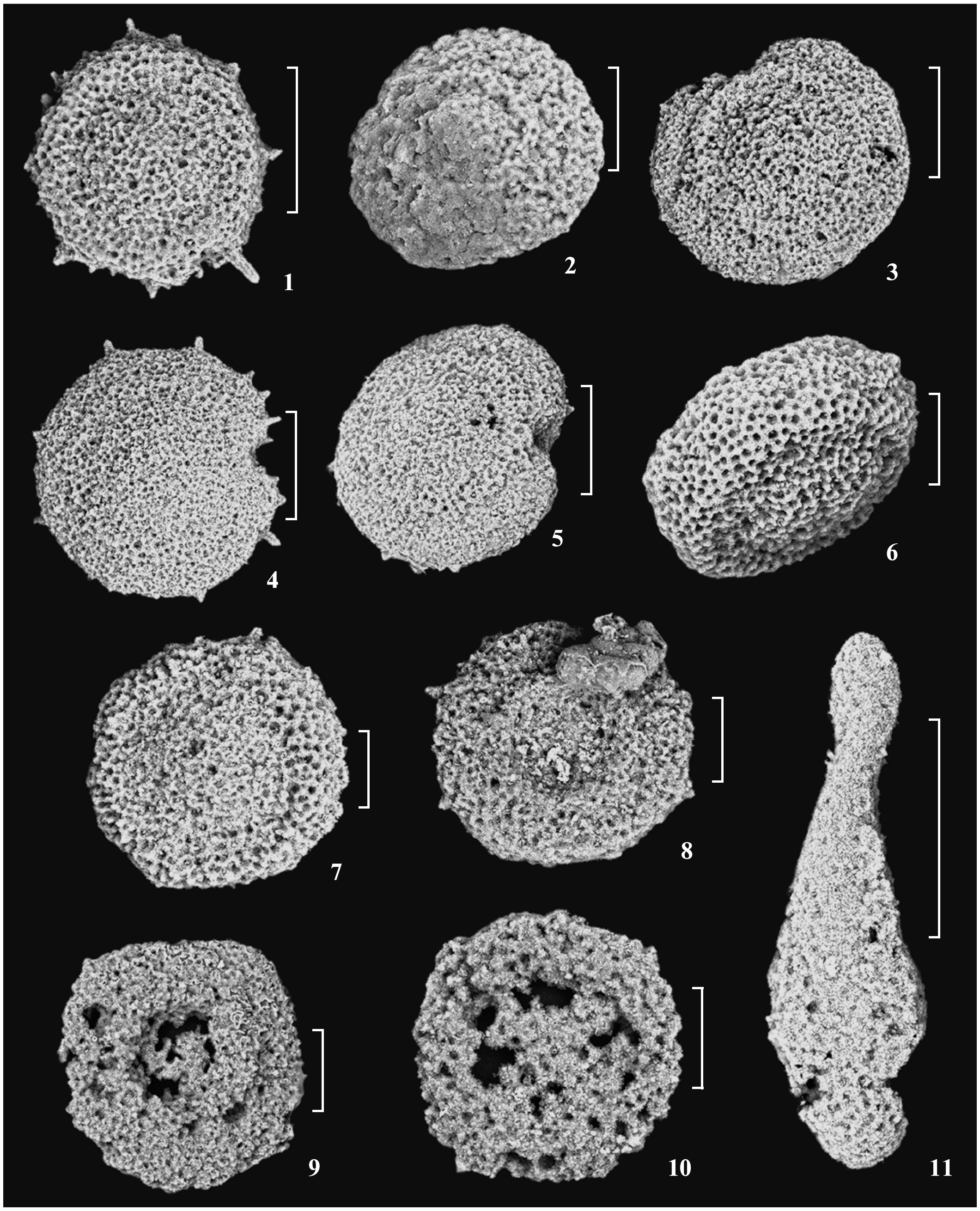


Plate 2. Radiolaria from middle Turonian–lower Coniacian deposits of the Biyuk-Karasu section, central part of the Crimean Mountains. The scale bar length is 200 μm for 1, 3–5, and 11; 100 μm for 2 and 6–10: 1, 6, and 7, *Orbiculiforma* sp. A (samp. 09-13-12 for 1, 09-13-15 for 6, and 09-13-29 for 7); 2, *Patellula* sp. B (samp. 09-13-33); 3–5, *Patellula* sp. A (samp. 09-13-18 for 4, 09-13-15 for 4 and 5); 8, *Orbiculiforma* ex. gr. *railensis* Pessagno (samp. 09-13-33); 9 and 10, *Orbiculiforma quadrata* Pessagno (samp. 09-13-33); 11, *Phaseliforma turovi* Bragina (samp. 09-13-12).

At 15 m above the base of the layer (samp. 09-13-21), the radiolarian complex from the lower part of layer 4 continues. The thickness of the entire layer 4 is 15–17 m.

Layer 5. White chalky massive and thin-slabby limestones, with large contractions of black and dark gray flints, rare interbeds of gray clays, and flint interbeds.

At 2 m above the base of the layer (samp. 09-13-23), the following planktonic foraminifers are found: *Dicarinella canaliculata* (Reuss), *D. imbricata* (Mornod), *Heterohelix globulosa* (Ehrenberg), *H. moremani* (Cushman), *Marginotruncana marginata* (Reuss), *M. paraconcavata* (Porthault), *M. paraventricosa* (Hofker), *M. pseudolinneiana* (Pessagno), *Whiteinella brittonensis* (Loeblich et Tappan), *W. paradubia* (Sigal), and *Whiteinella* sp.

At 5 m above the base of the layer (samp. 09-13-25), the radiolarian complex of the layer 4 continues. As

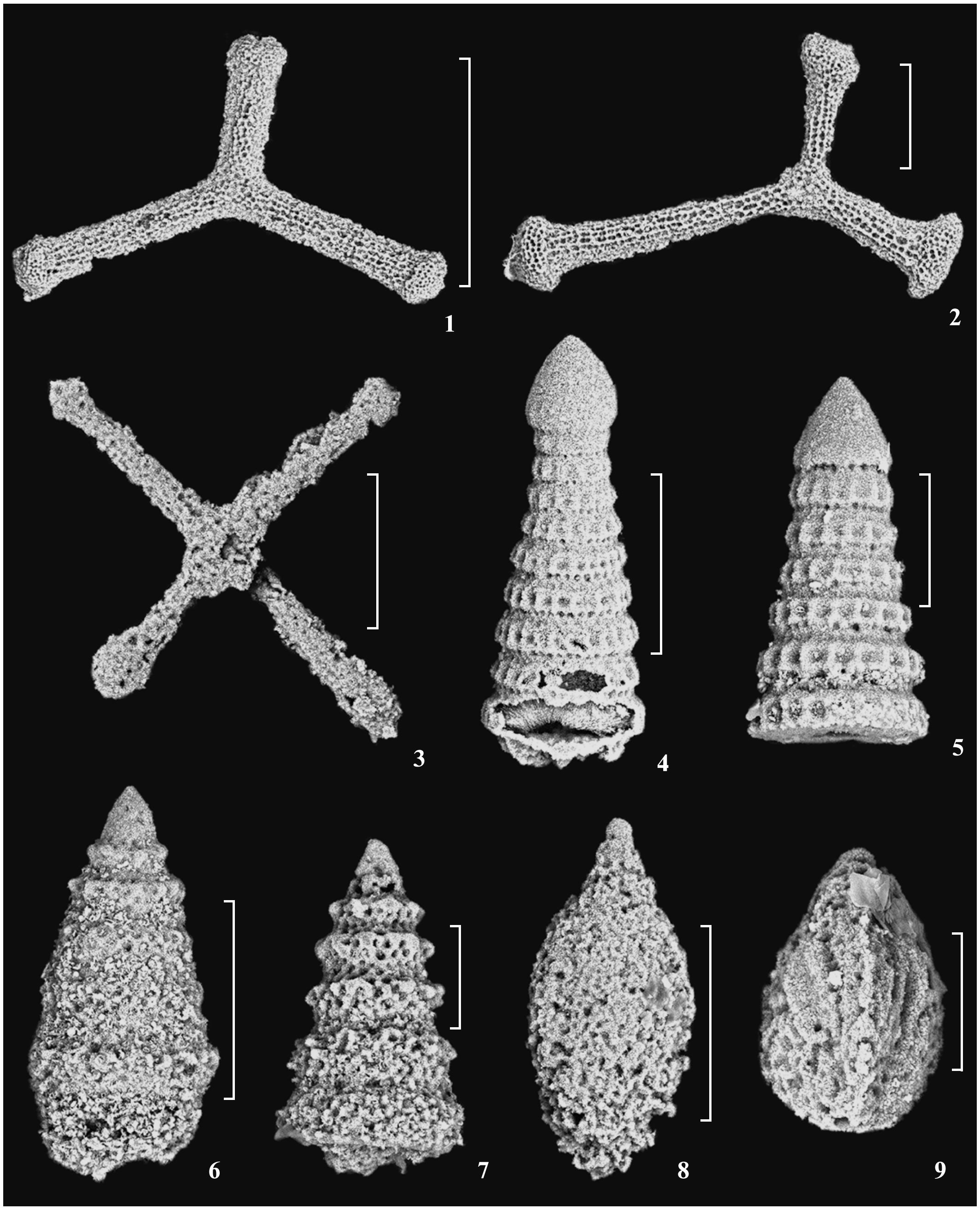


Plate 3. Radiolaria from middle Turonian–lower Coniacian deposits of the Biyuk-Karasu section, central part of the Crimean Mountains. The scale bar length is 500 μm for 1; 200 μm for 2–4 and 6–8; 100 μm for 5 and 7; 50 μm for 9: 1, *Patulibracchium inaequalum* Pessagno (samp. 09-13-17); 2, *Patulibracchium* ex gr. *inaequalum* Pessagno (samp. 09-13-15); 3, *Patulibracchium* (?) *quadroastrum* Bragina (samp. 09-13-33); 4, *Pseudodictyomitra pseudomacrocephala* (Squinabol) (samp. 09-13-17); 5, *Pseudodictyomitra* aff. *pseudomacrocephala* (Squinabol) (samp. 09-13-29); 6 and 7, *Xitus* ex gr. *spicularius* (Aliev) (samp. 09-13-29); 8, *Tubilustrionella guttaeforma* (Bragina) (samp. 09-13-17); 9, *Diacanthocapsa* ex gr. *rara* (Squinabol) (samp. 09-13-12).

well, planktonic foraminifers found here are *Marginotruncana marginata* (Reuss), *M. paraventricosa* (Hofker), *M. paraconcavata* (Porthault), and the species of Whiteinella genus from the previous samples.

At 7 m above the base of the layer (samp. 09-13-26), the radiolarian complex of the layer 4 continues. As well, planktonic foraminifers found here are *Archaeoglobigerina cretacea* (d'Orbigny), *Marginotruncana coronata* (Bolli), *M.* aff. *coronata* (Bolli), *M. marginata* (Reuss), *M. paraventricosa* (Hofker), *M. renzi* (Gandolfi), *Sigalitruncana* cf. *sigali* (Reichel), and *Whiteinella* spp.

At 8 m above the base of the layer (samp. 09-13-27), rare shells of planktonic foraminifers *Archaeoglobiger-*

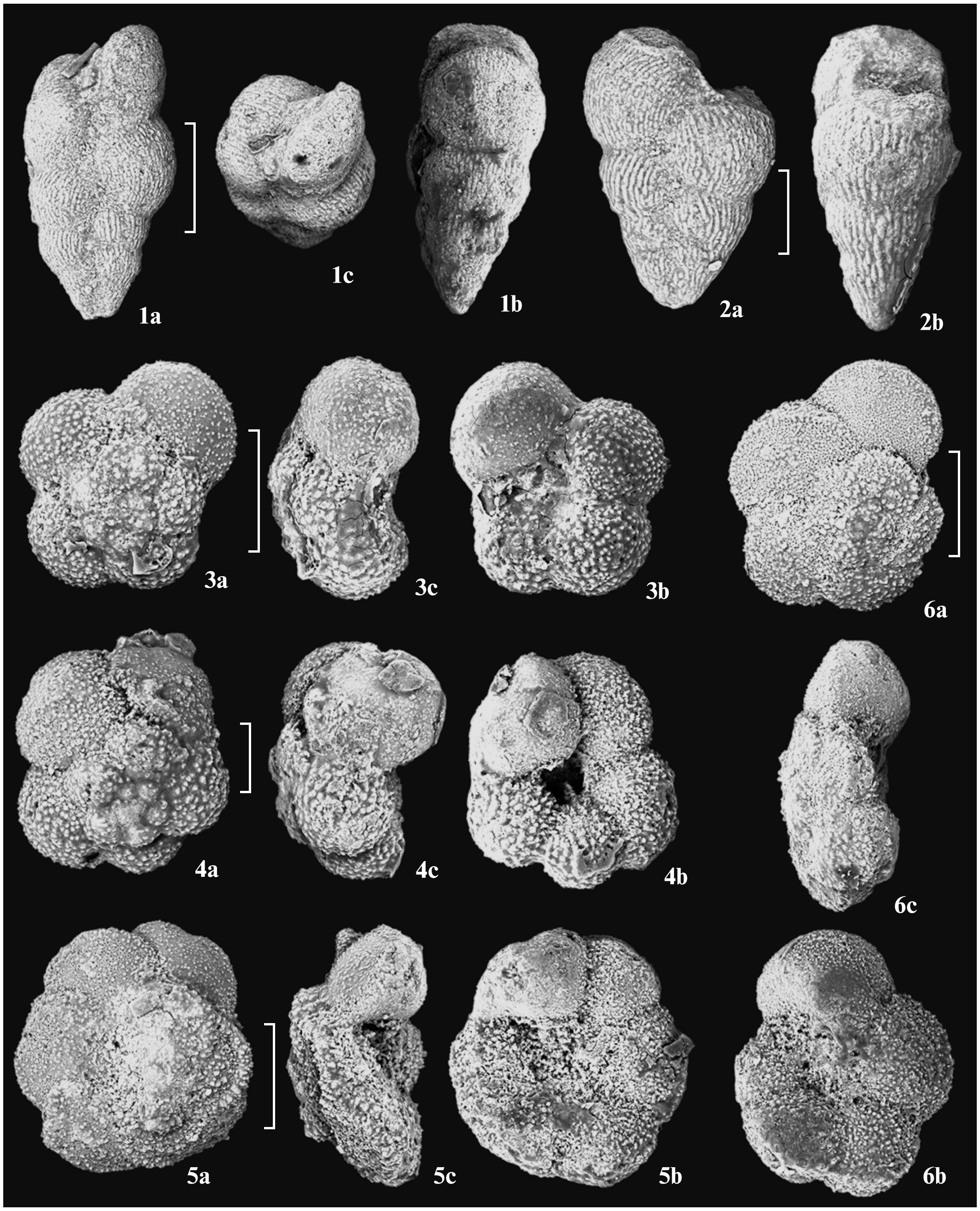


Plate 4. Turonian Foraminifera from the Biyuk-Karasu section, central part of the Crimean Mountains: a, dorsal view; b, umbilical view; c, peripheral view. The scale bar length is 200 μm. 1a–c, *Heterohelix moremani* (Cushman) (samp. 09-13-19); 2a–b, *Heterohelix globulosa* (Ehrenberg) (samp. 09-13-23); 3a–c, *Whiteinella brittonensis* (Loeblich et Tappan) (samp. 09-13-23); 4a–c, *Whiteinella paradubia* (Sigal) (samp. 09-13-23); 5a–c, *Marginotruncana paraventricosa* (Hofker) (samp. 09-13-29); 6a–c, *Dicarinella canaliculata* (Reuss) (samp. 09-13-25).

ina cretacea (d'Orbigny) and *Marginotruncana marginata* (Reuss) are found.

At 9.5 m above the base of the layer (samp. 09-13-28), the planktonic foraminifers *Archaeoglobigerina cretacea* (d'Orbigny), *Marginotruncana marginata* (Reuss), *M. paraventricosa* (Hofker), *M. pseudolinneiana* (Gandolfi), *M. sinuosa* Porthaut, *Sigalitruncana* cf. *sigali* (Reichel), and *Whiteinella* spp. are found.

At 10.5 m above the base of the layer (samp. 09-13-29), the identified radiolarian complex includes *Alevium superbum* (Squinabol), *Archaeocenosphaera* (?) *mellifera* O'Dogherty, *Crucella cachenis* Pessagno, *Cr. latum* (Lipman), *Cr. messinae* Pessagno, *Dactyliodiscus longispinus* (Squinabol), *Halesium diacanthum* (Squinabol), *H. sexangulum* Pessagno, *Hexapyramis* (?) *perforatum* Bragina, *Orbiculiforma maxima* Pessagno,

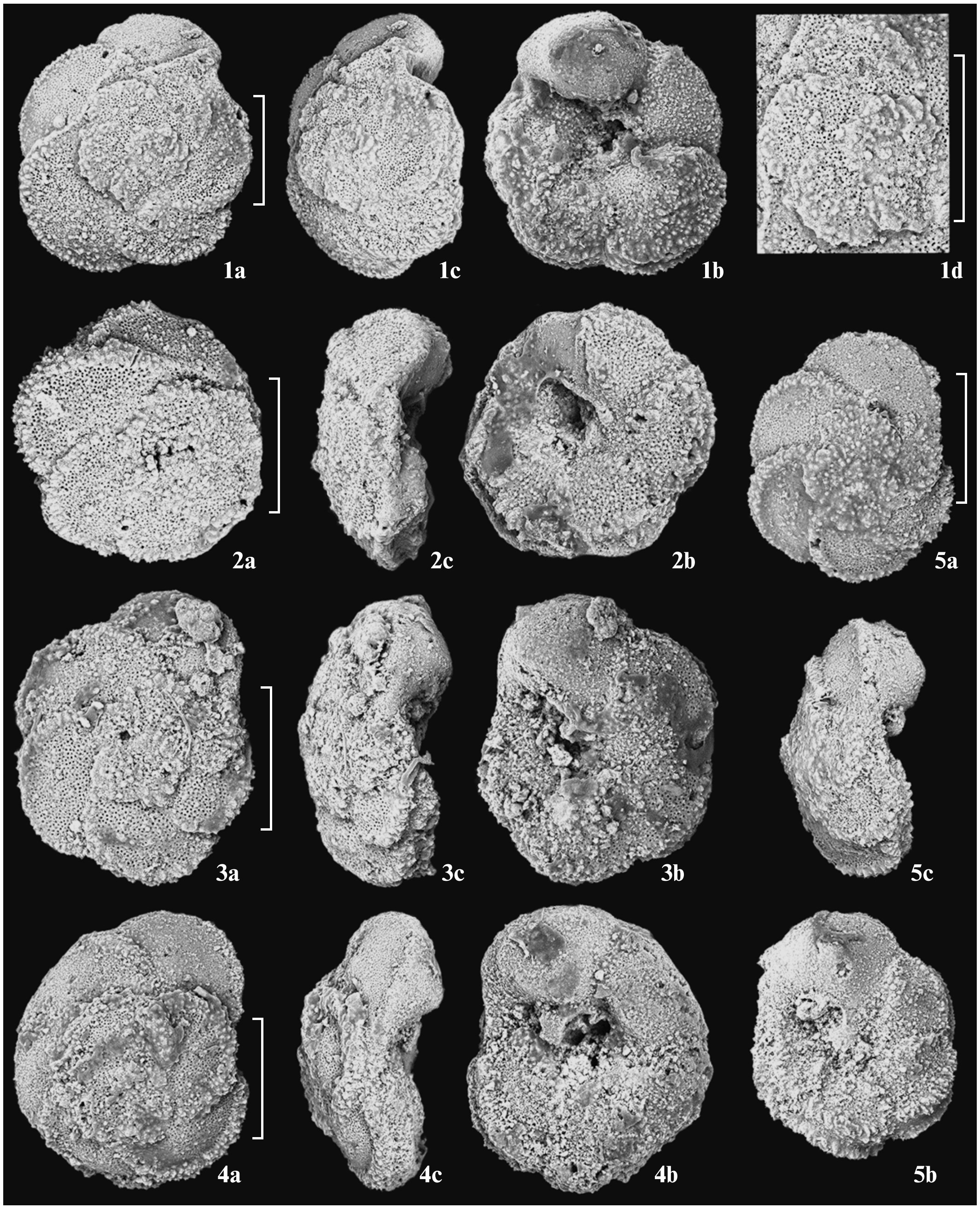


Plate 5. Turonian Foraminifera from the Biyuk-Karasu section, central part of the Crimean Mountains: a, dorsal view; b, umbilical view; c, peripheral view. The scale bar length is 200 μm. 1a–c and 2a–c, *Marginotruncana sinuosa* (Porthault) (samp. 09-13-25 for 1; 1d is the enlarged dorsal view at ×300; samp. 09-13-28 is for 2); 3a–c, *Marginotruncana renzi* (Gandolfi) (samp. 09-13-26); 4a–c, *Marginotruncana coronata* (Bolli) (samp. 09-13-26); 5a–c, *Marginotruncana pseudolinneiana* (Gandolfi) (samp. 09-13-23).

O. maxima Pessagno sensu O'Dogherty, *O.* ex gr. *railensis* Pessagno, *O.* sp. A, *Patellula verteroensis* Pessagno, *Patulibracchium* (?) *quadroastrum* Bragina, *Pessagnobrachia fabianii* (Squinabol), *Phaseliforma turovi* Bragina, *Diacanthocapsa* ex gr. *elongata* Bragina, *D.* ex gr. *rara* (Squinabol), *Dictyomitra densicostata* Pessagno, *Pseudodictyomitra* aff. *pseudomacrocephala* (Squinabol), *Turbilustrionella guttaeforma* (Bragina), *Xitus asymbatos* (Forman), and *X.* ex gr. *spicularius* (Aliev). Single specimens of planktonic foraminifers with bad preservation are also found here: *Dicarinella canaliculata* (Reuss), *Marginotruncana* sp., *Whiteinella baltica* Duglas et Rankin, *W. brittonensis* (Loeblich et Tappan), *W. paradubia* (Sigal), and *Whiteinella* sp.

At 12 m above the base of the layer (samp. 09-13-30), the Radiolaria are *Orbiculiforma maxima* Pessagno, *O. maxima* Pessagno sensu O'Dogherty, *O.* ex gr. *railensis* Pessagno, *O.* sp. A, *Patellula verteroensis* Pessagno,

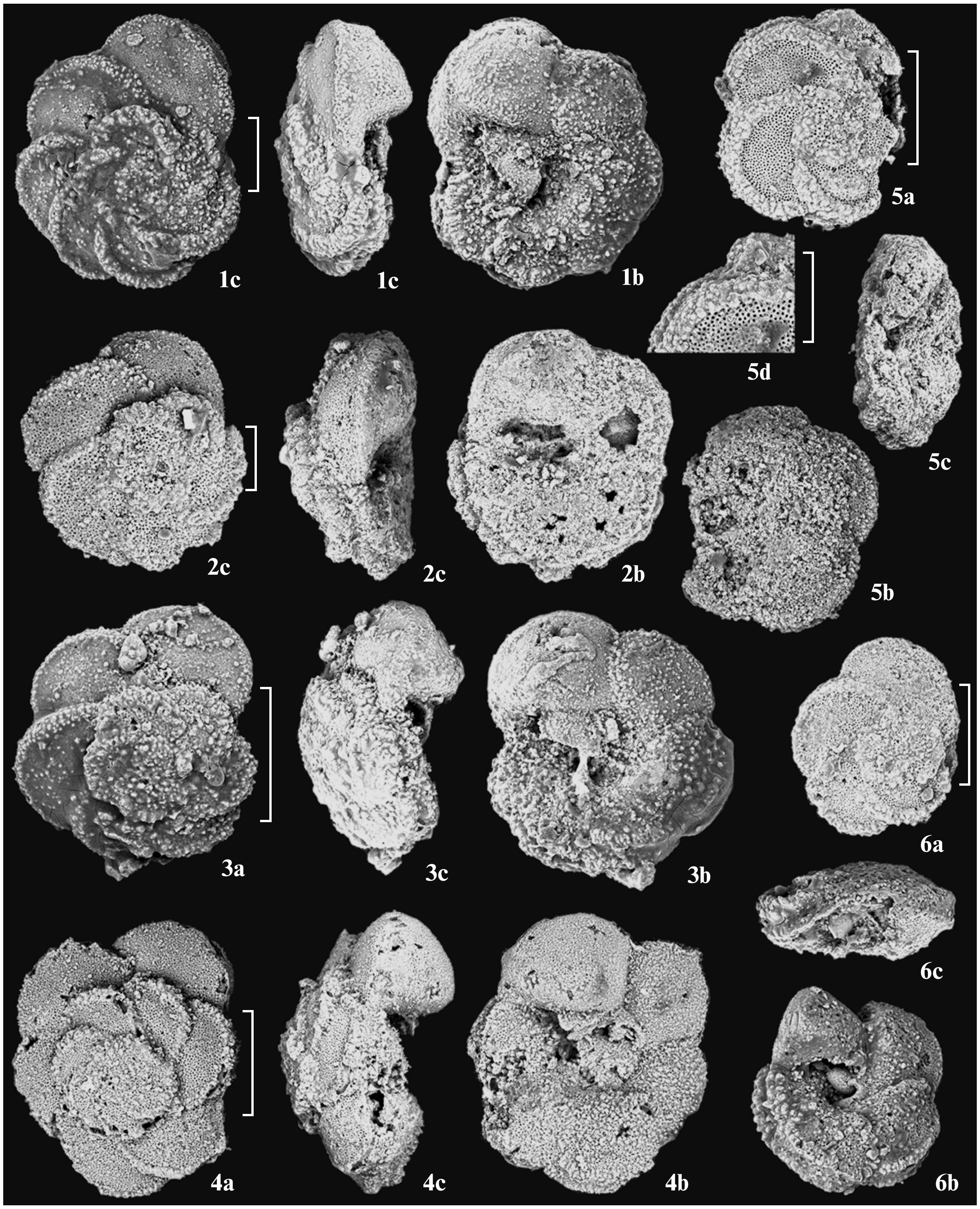


Plate 6. Turonian Foraminifera from the Biyuk-Karasu section, central part of the Crimean Mountains: a, dorsal view; b, umbilical view; c, peripheral view. The scale bar length is 200 μm. 1a–c and 3a–c, *Marginotruncana marginata* (samp. 09-13-26 for 1; 09-13-28 for 3); 2a–c and 6a–c, *Marginotruncana sinuosa* Porthault (samp. 09-13-28); 4a–c, *Marginotruncana paraventricosa* (Hofker) (samp. 09-13-25); 5a–c, *Marginotruncana paraconcavata* (Hofker), 5d is the enlarged dorsal view at ×300 (samp. 09-13-28).

Pseudodictyomitra aff. *pseudomacrocephala* (Squinabol), *Xitus* ex gr. *spicularius* (Aliev); the planktonic foraminifers from here are *Archaeoglobigerina cretacea* (d'Orbigny), *Dicarinella canaliculata* (Reuss), *Marginotruncana marginata* (Reuss), *M. renzi* (Gandolfi), *Whiteinella paradubia* (Sigal), and *Whiteinella* sp.

At 14 m above the base of the layer (samp. 09-13-31), radiolarians *Orbiculiforma maxima* Pessagno, *O. maxima* Pessagno sensu O'Dogherty, *O.* ex gr. *railensis* Pessagno, *O.* sp. A, *Phaseforma turovi* Bragina, and *Novixitus* sp. are present.

At 15 m above the base of the layer (samp. 09-13-32), the Radiolaria are *Orbiculiforma* ex gr. *railensis* Pessagno, *O.* sp. A, *Patulibracchium* (?) *quadroastrum* Bragina, and *Xitus asymbatos* (Foreman).

At 18 m above the base of the layer (samp. 09-13-33), the identified radiolarian complex includes: *Acaeniotyle diaphorogona* Foreman, *Acanthocircus* cf. *tympanum*

O'Dogherty, *Alevium murphyi* Pessagno, *Al., superbum* (Squinabol), *Al.* cf. *murphyi* Pessagno, *Al. sculptus* (Squinabol), *Al.* sp. A, *Archaeocenosphaera* (?) *mellifera* O'Dogherty, *Archaeospongoprunum* cf. *bipatritium* Pessagno, *Al. triplum* Pessagno, *Cavaspongia antelopensis* Pessagno, *C. californiaensis* Pessagno, *C. euganea* (Squinabol), *Crucella aster* (Lipman), *Cr. cachensis* Pessagno, *Cr. latum* (Lipman), *Cr. messinae* Pessagno, *Halesium quadratum* Pessagno, *H. sexangulum* Pessagno, *Hexapyramis* (?) *perforatum* Bragina, *Orbiculiforma quadrata* Pessagno, *O.* cf. *maxima* Pessagno, *O.* cf. *monticelloensis* Pessagno, *O.* ex gr. *railensis* Pessagno, *O.* ex gr. *quadrata* Pessagno, *O.* sp. A, *Paronaella solanoensis* Pessagno, *Patellula verteroensis* Pessagno, *P.* sp. B, *Patulibracchium inaequalum* Pessagno, *P.* (?) *quadroastrum* Bragina, *Dictyomitra densicostata* Pessagno, *Pseudodictyomitra* aff. *pseudomacrocephala* (Squinabol), *Vistylaria* sp., and *Xitus asymbatos* (Forman). The visible thickness of the entire layer 5 is 22 m.

ANALYSIS OF RADIOLARIAN COMPLEXES

Alevium superbum–Phaseliforma turovi Beds

Beds are distinguished on the basis of joint findings of index species, as well as *Orbiculiforma* sp. A, *Patellula* sp. A, *Paronaella* (?) *nikishini*, *Pseudoaulophacus trizonalis*, and *Triactoma karasuensis* (Fig. 1b). Initially, the complex was named Alievium superbum–Phaseliforma sp. A and identified in the middle Turonian part of the Mt. Ak section (central Crimean Mountains) (Bragina 2009b, 2013). At present, one of the initial index species (*Phaseliforma* sp. A) is described as a new one, viz., *Phaseliforma turovi* Bragina, thus allowing the name of the complex to be changed (Bragina, 2014). In the interval of Alevium superbum–Phaseliforma sp. A distribution, we distinguished the beds with Al. superbum–Ph. turovi.

The complex characterizing the Al. superbum–Ph. turovi interval (samp. 09-13-12 to 09-12-26) is of good preservation and is represented by two thirds of the species that are widespread in both the upper and middle Turonian deposits of Crimean Mountains. Almost all the mentioned species are characteristic of the lower part of the Alevium superbum Zone (lower Turonian) in sections located in Italy (O'Dogherty, 1994).

In the microfossil complex of Al. superbum–Ph. turovi interval, special attention should be paid to taxa that are widespread in the Mt. Ak section starting from the middle Turonian, e.g., *Orbiculiforma* sp. A, *Patellula* sp. A, *Paronaella* (?) *nikishini* Bragina, *Phaseliforma turovi* Bragina, *Pseudoaulophacus trizonalis* Bragina, and *Triactoma karasuensis* Bragina (Bragina, 2014). These species have not been found in the older deposits of the Mt. Ak section and in beds with Pr. universa–D. densicostata (upper part of lower Turonian–middle Turonian in the sections of SW Crimean Mountains). This suggests location of the Alevium superbum–Phaseliforma turovi Zone within middle Turonian.

Dactylodiscus longispinus–Patulibracchium (?) quadroastrum Beds

These beds are distinguished on the basis of joint findings of index species, as well as *Pseudodictyomitra pseudomacrocephala* (Fig. 1b). The complex that characterizes the D. longispinus–P. (?) quadroastrum interval (samp. 09-13-29 to 09-13-32) is of satisfactory preservation and includes 21 species.

In the Mt. Chuku section, SW mountainous Crimea, the Trochodiscus maximus–Multastrum robustum beds, encompassing the upper part of middle Turonian and also upper Turonian (without the uppermost part), were distinguished within the limits of the *M. labiatus* and *I. lamarcki* zones (Alekseev, 1989; Bragina, 2009a). The D. longispinus–P. (?) quadroastrum and T. maximus–M. robustum beds contain the following common species: *Acaeniotyle diaphorogona* Foreman, *A. macrospina* (Squinabol), *Alevium sculptus* (Squinabol), *Archaeocenosphaera* (?) *mellifera* O'Dogherty, *Crucella cachensis* Pessagno, *Praeconocaryomma lipmanae* Pessagno, *P. universa* Pessagno, *Pseudoacanthosphaera galeata* O'Dogherty, *Quadrigastrum insulsum* O'Dogherty, *S. wisniowskii* (Squinabol), *Afens liriodes* Riedel et Sanfilippo, *Amphipyndax stocki* (Campbell et Clark), *Diacanthocapsa antiqua* (Squinabol), and *Xitus asymbatos* (Forman); note that all of these species are typical for the Turonian. However, the D. longispinus–P. (?) quadroastrum beds do not contain *T. maximus* and *M. robustum* species. The *P.* (?) *quadroastrum* species has been described for the first time in the upper Turonian deposits of the Naiba reference section in South Sakhalin and found in the Mt. Chuku section in the upper part of T. maximus–M. robustum beds (Bragina, 2009a). Based on the joint presence of *D. longispinus* (no higher than upper Turonian) and *P.*(?) *quadroastrum* (no lower than the upper Turonian), as well as on the position within the section, we can suggest that the D. longispinus–P. (?) quadroastrum beds belong to the upper Turonian.

Orbiculiforma quadrata–Patellula sp. B Beds

These beds are distinguished on the basis of joint findings of index species (Fig. 1b). The complex that characterizes the Orbiculiforma quadrata–Patellula sp. B interval (samp. 09-13-33) has satisfactory preservation and includes 34 species, with the dominance of forms that have dense and hard skeletons. Of a special interest is the presence of *Orbiculiforma quadrata* Pessagno (in Californian sections it is found only starting from the lower Coniacian) and *Archaeospongoprunum* cf. *bipatritium* Pessagno (the most characteristic representative in the Coniacian and Santonian deposits of California) species in this complex (Pessagno, 1976). *Vistylaria* sp. and *Alievium* sp. are also present in the complex. A taxa that has not been found in the lower-lying deposits, *Vistylaria* sp. is likely a predecessor form of *Vistylaria magna* Gorka species, which are typical for the Santonian and Campanian (Korchagin, Bragina, and Bragin, 2012). *Alievium* sp. is the transitional form between *Al. superbum* (Squinabol) and *Al. praegallowayi* (White). The latter species, an index of the Zone of the same name in the Coniacian in California, is absent in the studied complex (Pessagno, 1976). Thus, the joint presence of *P.* (?) *quadroastrum* (upper Turonian), *O. quadrata* (Coniacian–Santonian), and the first representatives of the *Vistylaria* Gorka genus, as well as the absence of *Al. praegallowayi*, can indicate the boundary of the Turonian–Coniacian age of the host deposits. Hence, the interval of Orbiculiforma quadrata–Patellula sp. B beds should be estimated within the uppermost Turonian–lower Coniacian.

ANALYSIS OF FORAMINIFERAL COMPLEXES

Whiteinella paradubia Beds

As distinguished on the basis of index species, these beds include the lower (without the lowermost) part of the radiolarian-based Alevium superbum–Phaseliforma turovi beds (see above) (Fig. 1b). The complex that characterizes the Whiteinella paradubia interval (samp. 09-13-15 to 09-13-19) is of good preservation and is represented by five species. Representatives of the *Whiteinella* Genus appear as early as Cenomanian deposits and can be found up to the Santonian. The only relic of Cenomanian deposits is the rare presence of shells of *Guembelitria* cf. *cenomania* (Keller). However, the preferrably Turonian age of this interval is implied from the absence of *Thalamanninella* and *Rotalipora* genus representatives, which are typical for Cenomanian deposits of Crimean Mountains. The complex does not contain *Dicarinella hagni* Scheibnerova, *D. elata* (Lamolda), and *Praegobotruncana oravensis* Scheibnerova species that are typical of the lower Turonian (Kopaevich, 2009). The joint presence of *Heterohelix moremani* (Cushman) and *H. globulosa* (Ehrenberg) indicates an age not older than the early Turonian. Thus, the time interval of these beds can be suggested within lower to preferably middle Turonian.

Marginotruncana pseudolinneiana Beds

Distinguished on the basis of index species, these beds include the upper (without the uppermost) part of the radiolarian-based Alevium superbum–Phaseliforma turovi beds (see above) (Fig. 1b). The complex that characterizes the Marginotruncana pseudolinneiana interval (samp. 09-13-23 to 09-13-25) is of good preservation and is represented by 11 species, with the dominance of *M. marginata* (Reuss) among them. The complex is generally characterized by double-keel representatives of *Marginotruncana* genus; in the Biyuk-Karasu section such species as *M. pseudolinneiana* Pessagno, *M. marginata* (Reuss), and *M. sinuosa* Porthault can be found. In the deposits of the NE Caucasus, *M. sinuosa* is found starting from the upper Turonian (at its bipartition). In Poland and Germany, *M. sinuosa* appears in the upper part of the upper Turonian at its tripartition (Tur et al., 2001; Walaszczyk et al., 2010). The composition of the planktonic foraminiferal complex is comparable to that of the M. pseudolinneiana Zone of the Crimean–Caucasian Region; the age of M. pseudolinneiana Zone is middle Turonian (Kopaevich, 2009).

Marginotruncana coronata Beds

As distinguished on the basis of index species, these beds include the uppermost part of the radiolarian-based Alevium superbum–Phaseliforma turovi beds (see above) (Fig. 1b). The complex that characterizes the Marginotruncana coronata interval (samp. 09-13-26 to 09-13-30) is of good preservation and is represented by 12 species. At the bases of beds, such species as *Archaeoglobigerina cretacea* (d'Orbigny), *Marginotruncana coronata* (Bolli), *M. renzi* (Gandolfi), and *Sigalitruncana* cf. *sigali* (Reichel) appear. The first occurrence of *M. renzi* (Gandolfi) is at the lower Coniacian deposits of the East European Craton (Walaszczyk et al., 2010). However, sections in Germany and Poland contain this species in their Turonian intervals (Walaszczyk et al., 2010). The discussed beds with *M. coronata* are comparable to the deposits of the Marginotruncana coronata Zone that encompasses the interval from the upper Turonian to lower Coniacian (Kopaevich, 2009). In the Dubivtsy section in Western Ukraine, the Marginotruncana coronata Zone is referred to the upper Turonian (Dubicka and Peryt, 2012).

RESULTS AND DISCUSSION

The studied interval of the Biyuk-Karasu section has been dated based on Radiolaria at the middle Turonian–early Coniacian. The presence of lower Coniacian deposits is supposed from findings of the first representatives of *Vistylaria* genus and *Obiculiforma quadrata* as well. Unfortunately, the complex does not contain *Al. praegallowayi*, the index species of the Coniacian in California, while the characteristic species *Archaeospongoprunum bipatritium* is defined only in the open nomenclature.

The study showed the insignificant difference in interpretation of the age of host deposits based on planktonic Foraminifera and Radiolaria in the lower part of the section, e.g., the deposits of beds with Al. superbum–Ph. turovi are referred to the middle Turonian, based on the presence of certain species including *Paronaella* (?) *nikishini* Bragina, *Phaseliforma turovi* Bragina, *Pseudoaulophacus trizonalis* Bragina, and *Triactoma karasuensis* Bragina. However, foraminifera-based dating (beds containing W. paradubia) of the same part of the section suggest the location on the timescale at the lower Turonian, preferably, the lower part of the middle Turonian. This discrepancy is caused by insufficient investigation and validation of the zonal scales of planktonic Foraminifera and Radiolaria.

According to the modern planktonic Foraminifera biostratigraphy, the Turonian–Coniacian boundary lies within the Concavatotruncana concavata Zone (Robaszynski et al., 1990; Walaszczyk et al., 2010). This species is not present in the studied samples; however, the joint presence of the Whiteinella Genus and various double-keel Marginotruncana forms indicates the lower Turonian–early Coniacian age of the host deposits. The composition of the planktonic Foraminifera complex from the Biyuk-Karasu section allows us to refer this complex to a moderate or transitional climate province (Caron, 1985). Compared to the typically Tethyan complexes, they are much less variable, contain rare single-keel Sigalitruncana with bad preservation, and contain no umbilical-convex Concavatotruncana.

CONCLUSIONS

(1) During study of the Turonian–Coniacian deposits in the Biyuk-Karasu section, multiple levels that contain both Radiolaria and planktonic Foraminifera have been identified for the first time. The utilized method of Radiolaria and planktonic Foraminifera extraction from hard rocks allowed us to identify the levels that contain both microfossil groups. Complex application of methods of extraction from hard and soft rocks would allow the optimal results to be obtained and the correlations between the thus-found stratigraphic units to be specified.

(2) The deposits of the Biyuk-Karasu section have been subdivided for the first time, based on Radiolaria, into the following beds: Al. superbum–Ph. turovi (middle Turonian), D. longispinus–P. (?) quadroastrum (upper Turonian), and Orbiculiforma quadrata–Patellula sp. B (Turonian–Coniacian boundary deposits).

(3) On the basis of the Foraminifera study, the following beds were identified: Whiteinella paradubia (lower–lower part of the middle Turonian), Marginotruncana pseudolinneiana (uppermost middle Turonian), and Marginotruncana coronata (upper Turonian). The complex of beds with Marginotruncana pseudolinneiana is comparable to that of the same name in the Crimean–Caucasian Region. The beds with Marginotruncana coronata are comparable to the M. coronata Zone.

(4) Further study of the section in central Crimean Mountains would give broad perspectives for both intraregional and interregional correlations on both groups, and the first steps on this path have already been taken.

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