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Problems of Geocosmos—2018

Proceedings of the XII International Conference and School

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Saint Petersburg State University
St. Petersburg, Russia

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Saint Petersburg State University
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Andrey V. Divin
Saint Petersburg State University
St. Petersburg, Russia

Alexander K. Saraev
Saint Petersburg State University
St. Petersburg, Russia

Nadezhda V. Zolotova
Saint Petersburg State University
St. Petersburg, Russia

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Magnetostratigraphy and Biostratigraphy of the Valanginian in the Crimean Mountains

V. A. Grishchenko, A. G. Manikin, Yu. N. Savelieva and A. A. Feodorova

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Keywords Berriasian · Valanginian · Crimean Mountains · Magnetostratigraphy · Biostratigraphy · Geomagnetic polarity · Magnetic chrons · Foraminifers · Ostracods

1 Introduction

Sediments of Berriasian and Valanginian age are widespread on the territory of the Crimean peninsula. The most complete sections of the Valanginian stage, in terms of sedimentation continuity, are found in East Crimea. However, the complete absence of index fauna (ammonites), insufficient resolution ability of micropaleontologic methods and intensive deformations of an unclear nature (syn- or post-sedimentation) prevent their detailed subdivision, substantiation of their exact stratigraphic age and the determining the Berriasian-Valanginian boundary position. Despite all above difficulties, in the last few years a reliable magnetostratigraphy has been established

V. A. Grishchenko (✉) · A. G. Manikin
Saratov State University, Astrakhanskaya Str., 83, Saratov 410012, Russia
e-mail: grishenko-vladimir@bk.ru

Yu. N. Savelieva · A. A. Feodorova
AO "Geologorazvedka", Fayansovaya Str. 20/10, Saint-Petersburg 192019, Russia

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Part II
Paleomagnetism, Rock Magnetism and Geomagnetism

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e-mail: grishenko-vladimir@bk.ru

Yu. N. Savelieva · A. A. Feodorova
AO "Geologorazvedka", Fayansovaya Str. 20/10, Saint-Petersburg 192019, Russia

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for the Berriasian-Valanginian boundary interval in the section Zavodskaya balka (Feodosia) [8] and the synsedimantary age of deformations in sediments has been substantiated [17]. Studies of two remaining Valanginian sections (Sultanovka Village and Koklyuk Mountain) in Feodosia region are now in progress.

Southwest Crimea is the only region of the peninsula, where the Valanginian age of sediments is substantiated by ammonite fauna. However, this does not remove the difficulties related to the definition of the Berriasian-Valanginian boundary in Crimea. This problem has exacerbated after the decision to transfer the T. otopeta zone/subzone, previously traditionally identified with the base of the Valanginian (e.g., [11]), to the Berriasian as an upper subzone of the S. boissieri zone (e.g., [1, 21]). The lower Valanginian substage in Southwest Crimea is severely condensed, so that the maximum thickness of the correspondent coarse-grained sandstones does not exceed 9 m, but the upper substage is represented by a thick (~45 m) series of alternating clay and sandstone. The detailed microfaunistic characteristic of the Valanginian in Southwest Crimea has been missing until present.

The above difficulties hamper the correlation of Valanginian sections across the Crimean Mountains, and their comparison with the key sections in Mediterranean. To overcome them, it is necessary to employ multiple methods, preferably those based on features having a global distribution all over the world. One of such methods is magnetostratigraphy, based on the registration of reversals of the Earth's magnetic field that are global by their nature. The magnetostratigraphic data are invaluable for distant correlations since the magnetic chrons boundaries serve as an isochronous marker, allowing, in combination with paleontological data, to precisely compare detailed scales of different regions. Obtaining the magnetic polarity characteristics of the Berriasian-Valanginian boundary interval in the Crimean Mountains would thus give a possibility for an isochronous correlation of Crimean sections with the coeval sections in other regions that are already characterized paleomagnetically.

In the framework of the project aimed on compiling a composite magnetostratigraphic section of the Valanginian in the Crimean Mountains we studied 9 sections expected to contain the Berriasian-Valanginian boundary interval, 3 sections in East Crimea (Zavodskaya balka, Koklyuk, Sultanovka) and 6 sections in Southwest Crimea (Dlinnaya, Sheludivaya, Patil-1, Patil-2, Selbukhra, Bolshoy Kermen) (Fig. 1). Paleomagnetism of Valanginian rocks of condensed sections in Southwestern Crimea was studied for the first time.

A key section of the upper Valanginian, the Rezanaya Mountain near the Verkhorechye Village of Bakhchisaray district has been paleomagnetically studied earlier [45]. However, bearing in mind a possibility of using a 2G Enterprises cryogenic magnetometer for magnetization measurements, in 2016–2018 we have conducted a detailed field and laboratory study of this section.

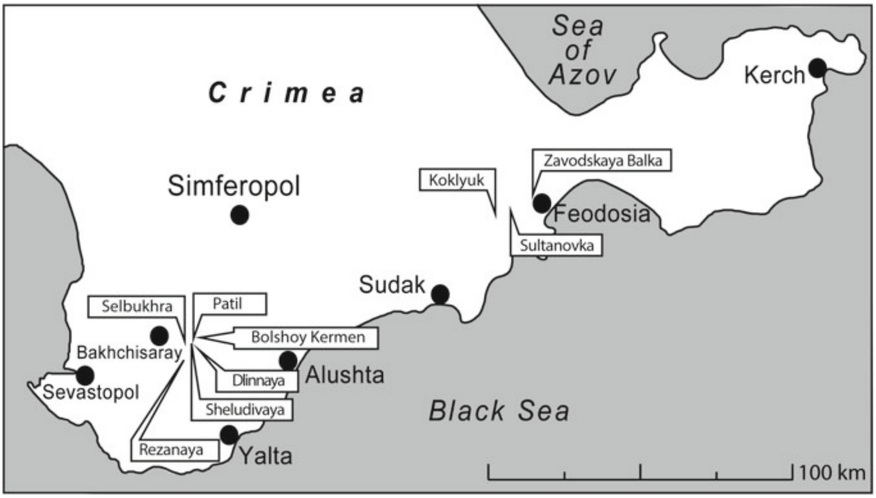

Fig. 1 Location of the studied sections

2 Characteristics of Sections

2.1 East Crimea

In East Crimea, within the Berriasian-Valanginian boundary sediments the Sultanovskaya formation and Nanikovskaya series are recognized (e.g., [9]). Sultanovskaya formation is composed of gray carbonate clay with rare thin layers of marl and limestone. Nanikovskaya series, according to our data, overlies concordantly the Sultanovskaya formation and is composed of similar clays with thin layers of siderite; however it is impossible to trace exactly the boundary between the two.

The Zavodskaya balka section is exposed by a clay extraction quarry in the northern outskirts of Feodosia. The results of complex paleontological and paleomagnetic studies of the Berriasian at Zavodskaya balka were published previously [4, 7, 20]. In 2015 sediments composing the Berriasian-Valanginian boundary interval (outcrop 3058, coordinates: 45°01′49.1″ N, 35°20′59.5″ E) were sampled. The Koklyuk section (outcrop 3030: 45°00′08.5″ N, 35°12′27.5″ E, and outcrop 3060: 45°00′08.6″ N, 35°12′31.3″ E) is situated near the Nanikovo Village in a ravine on the slope of Koklyuk Mountain. The Sultanovka section (outcrop 2926: 45°00′09.9″ N, 35°17′38.2″ E) is situated near the Sultanovka Village in the apex of Sultanovskaya syncline. All the studied sections are characterized by micropaleontological and ammonite data [8].

2.2 Southwestern Crimea

The lithological column of the Berriasian-Valanginian boundary interval in Southwestern Crimea is represented by an alternation of solid and loose calcareous dolomitic sandstones of shallow, shoal genesis. The sections are condensed and a large number of stratigraphic hiatuses are found [12].

All sections were sampled in natural outcrops at mountains Dlinnaya (outcrop 3065: 44°45′32.9″ N, 34°00′9.4″ E), Sheludivaya (outcrop 3107: 44°45′28.2″ N, 33°59′55.7″ E), Patil (Patil-1 (outcrop 3133): 44°45′51.4″ N, 33°59′46.7″ E; Patil-2 (outcrop 3139): 44°45′51.4″ N, 33°59′48.7″ E), Bolshoy Kermen (outcrop 3135: 44°46′22.3″ N, 34°00′54.8″ E), Selbukhra (outcrop 3134: 44°43′54.6″ N, 33°59′33.5″ E). All studied sections are characterized by the records of ammonites, belemnites and bivalves [12].

The Rezanaya section (outcrop 3106: 44°42′7.9″ N, 33°59′9″ E), situated near the Verkhorechye Village is the most complete key section of the upper Valanginian in the Crimean Mountains [12].

In the description of the section, made by E. Yu. Baraboshkin [12], five lithologic slices were detected. The first one, situated at the base of the section consists of "pudding" conglomerates and gravelstone. In the lower 1.5 m of the slice, the *T. otopeta* zone was recognized. Higher in the section an interval corresponding to the *Thurmanniceras pertransiens* zone follows. The sediments of the first slice are related to the Karatlykhskaya formation [46]. Overlying four slices in general are represented by alternation of clay with solid and loose sandstones of Rezanskaya formation [46]. The records of the species *Neohoploceras submartini* (Mallada) correspond to the second and third slices, which were assigned to the upper Valanginian. In the lower part of the fourth slice, the *Himantoceras trinodosum* zone is recognized, but most of the slice in terms of ammonite zonation is related to the *Teschenites callidiscus* zone of the upper Valanginian. The complex of fauna found in the fifth slice is interpreted as late Valanginian [12].

3 Methods

Oriented samples were collected from a total 363 stratigraphic levels in 10 sections described above. Sampling was conducted by two different methods: (1) using a mining pick (sections Zavodskaya balka, Koklyuk, Sultanovka, Dlinnaya and the Rezanaya Mountain); (2) using a specialized portable drill (model Pomeroy EZ core D261-C) with a diamond crown, made of non-magnetic metal (model Pomeroy BSS-1E Drill Bit), with the diameter of 1 in. (sections Sheludivaya, Patil-1, Patil-2, Selbukhra, Bolshoy Kermen and the Rezanaya Mountain). For the orientation of a drilled cylinder an orientation device (model OR-2) with an attached magnetic compass (model "Brunton Pocket Transit"). Sampling intervals were chosen in accordance with the thickness of studied section and varied between a minimum of

14 ccm for the condensed sections and 50–90 ccm for 'normal' sections. To exclude possible misinterpretations and errors in assimilating data obtained by different methods, sampling was carried out in bed-by-bed manner simultaneously with geological description and paleontological analysis. For further laboratory studies each sample, depending on the way of sampling, was sawn to the specimens of cubic (8 cm) or cylinder (10 cm) shape. The total quantity of oriented specimens was 1089.

In order to estimate the suitability of rocks for the paleomagnetic analysis and to obtain a supplementary geological information, each sample was explored for a number of petromagnetic characteristics. These included of magnetic susceptibility (K) and anisotropy of magnetic susceptibility (AMS), magnetic susceptibility after heating a specimen to 500 °C (Kt), natural remanent magnetization ($\mathbf{J_n}$), saturation remanent magnetization ($\mathbf{J_{rs}}$), coercivity of remanence ($\mathbf{H_{cr}}$). Out of these, parameters such as ratio $K/\mathbf{J_{rs}}$, increment of magnetic susceptibility after the heating of specimens up to 500 °C $dK = Kt - K$ and the Koenigsberger ratio Q were calculated. Rock magnetic experiments also included thermomagnetic analysis (TMA) carried out using a TAF-2 magnetic balance (Orion Ltd., Russia), and measurements of temperature dependences of magnetic susceptibility using an MFK1-FA kappabridge with an attached CS3 furnace (AGICO, Czech Republic).

Paleomagnetic studies were conducted using standard methods [29, 34] and consisted of consequential temperature demagnetization up to 350–500 °C with 50 °C increment or alternating field demagnetization up to 50–100 mT with 2–5 mT increment. Measurements of natural remanent magnetization were conducted using a spin-magnetometer JR6 (AGICO, Czech Republic) in the Petrophysics laboratory of SSU (Saratov) and a cryogenic magnetometer (2G Enterprises, US) in paleomagnetic laboratory (Institute of Physics of the Earth of the Russian Academy of Sciences, Moscow). To detect possible phase transformations of magnetic minerals during temperature demagnetization, after each heating step a magnetic susceptibility (K) of the sample has been measured using an MFK-1FB kappabridge.

The standard field tests [27, 28] and also a set of indirect characteristics (directions of different polarity are regularly grouped throughout the section, making large N- or R-magnetozones; polarity sign is indifferent to lithological composition; paleomagnetic structures of the examined sections conform to each other) [19] were used to verify the ancient nature of magnetization.

The samples for micropalaeontological studies were processed with the standard extraction technique for foraminifera and ostracods. The palynological samples were processed with the use of standard HF/HCl acid preparation method. The foraminifers were identified by A. Feodorova, ostracods by Y. Savelieva. Foraminifers and partially ostracods were photographed under a binocular microscope LOMO MCP-1 (Geologorazvedka); the rest of the ostracods were photographed on a scanning microscope JEOL-JSM-6390 LA (Botanical Institute and Palaeontological Institute, Russian Academy of Science). Foraminifer and ostracod collections are kept at the Petroleum Geology Department of the AO "Geologorazvedka", Saint-Petersburg, Russia.

4 Results

4.1 Micropaleontologic Data

Micropaleontologic data on the Berriasian-Valanginian boundary sections of East Crimea were published previously by V. V. Arkadiev and co-workers (e.g., [6–8, 35, 36, 37]). In the sections of Southwest Crimea the foraminifers and ostracods were studied in four sections, namely Patil-1, Patil-2, Dlinnaya and Rezanaya. In the powders that were investigated, we found: teeth, megaspores, fragments of echinoderms, belemnites, staghorns, shelly detritus, ichtyo detritus, blackened phytodetritus. The major part of samples contain medium- and coarse grained quartz, foraminifers and the fragments of echinoderms.

Foramnifers were found in all samples. In general they are represented by primitive forms, and also simple Haplophragmiidae, Trochammina and Lenticulina of different integrity degree. In two samples collected from the Rezanaya section, numerous Rotaliida, Ataxophragmiidae and singular planktonic forms were found.

Four assemblages of foraminifers were established.

The complex of "primitive" foraminifers, a typical "beach—shoal" complex, is represented by primitive forms (Hippocrepininae, Saccamminidae and Hormosinidae), simple Haplophragmiidae and singular Trochammina—agglutinated benthos foraminifers with coarse- and medium grained agglutinate. The presence of the species *Ammobaculites subasper* Bulynnikova, *Bulbobaculites inconstans* Bartenstein et Brand and *Trochammina* ex gr. *neocomiana* Mjatliuk (Patil-1 section; sample 3133/1) points at the early Cretaceous (Berriasian-Hauterivian) age of host rocks (Fig. 2). On the Dlinnaya Mountain (sample 3065/1), the age of stratigraphic level with *Reophax adaptatus* Dain, *Kutsevella* cf. *praegoodlandensis* (Bulynnikova), and *Haplophragmium* ex gr. *aequale* Roemer is assumed as Tithonian—lower Valanginian.

In the sections Patil-2, Dlinnaya and Rezanaya, the fossil complex with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *Aequale* is established (Figs. 2, 3 and 4; Plates 1, 2). The particularity of this complex is the presence of rolled and split exemplars of secreting benthos characteristic for upper sublittoral inhabit, on the back of typical "shoreface" agglutinate forms with coarse- medium-grained agglutinate. The following forms are also identified here till the species rank: *Reophax* ex gr. *metensis* Franke, *Kutsevella* cf. *praegoodlandensis* (Bulynnikova), *Ammobaculites subasper* Bulynnikova, *Bulbobaculites inconstans* Bartenstein et Brand, *Haplophragmium monstratus* (Dain), *H.* ex gr. *aequale* Roemer, *Flabellammina* ex gr. *lidiae* Mjatliuk, *F. jurassica* Mjatliuk, *Triplasia emslandensis* Brat. et Brand, *Trochammina* ex gr. *neocomiana* Mjatliuk, *Verneuilinoides neocomiensis* (Mjatliuk), *Lenticulina macra* Gorbatchik, *L. espitaliei* Dieni et Massari, *L. insignita* Mjatliuk, *L.* aff. *akmetchetica* Mjatliuk, *L. andromede* Espitalie et Sigal, *L. nimbifera* Espitalie et Sigal, *L. nodosa* (Reuss), *Trocholina* cf. *alpine* (Leupold). These species are characteristic for the stratigraphic interval from the Tithonian to the Berriasian or from the Berriasian to the Hauterivian.

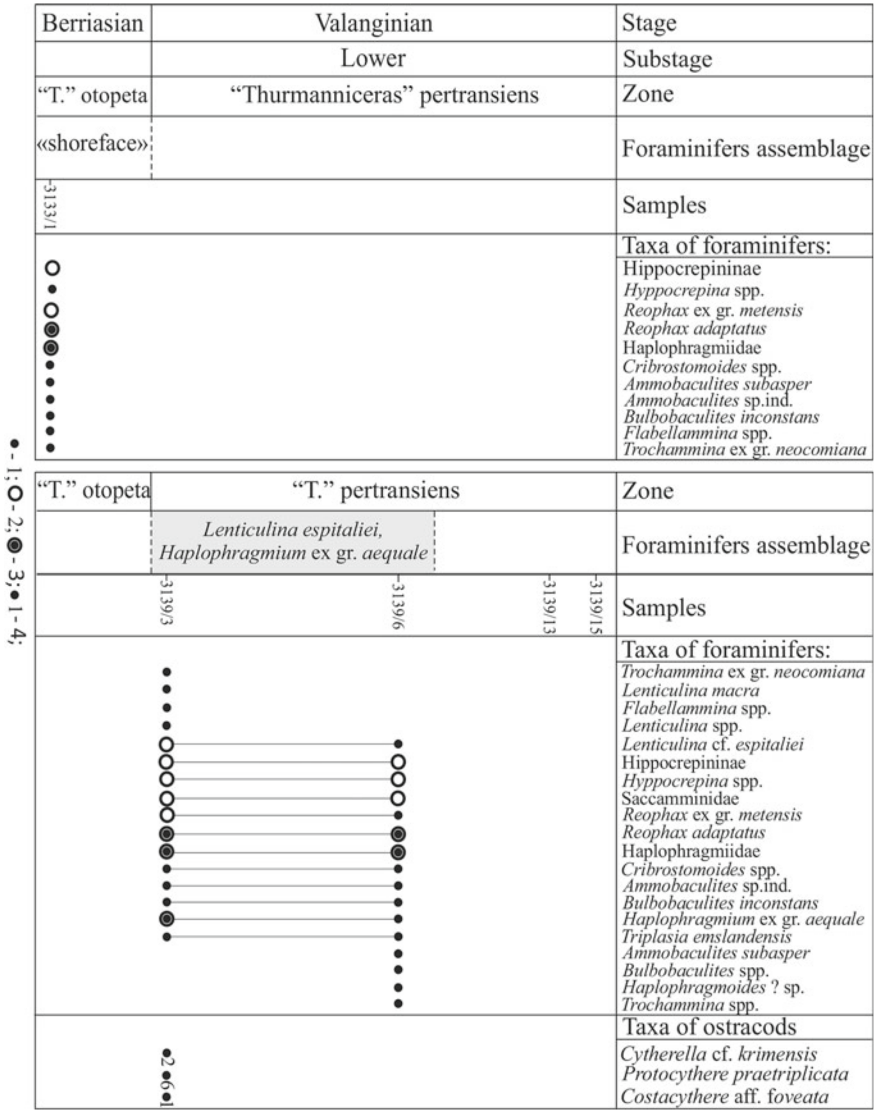

Fig. 2 Distribution of foraminifers and ostracods in outcrops Patil-3133 and Patil-3139 (Southwest Crimea). *Legend 1* 1–10; *2* 10–20; *3* 20–50—quantity of specimens in a sample; *4* occurrence and quantity of ostracods

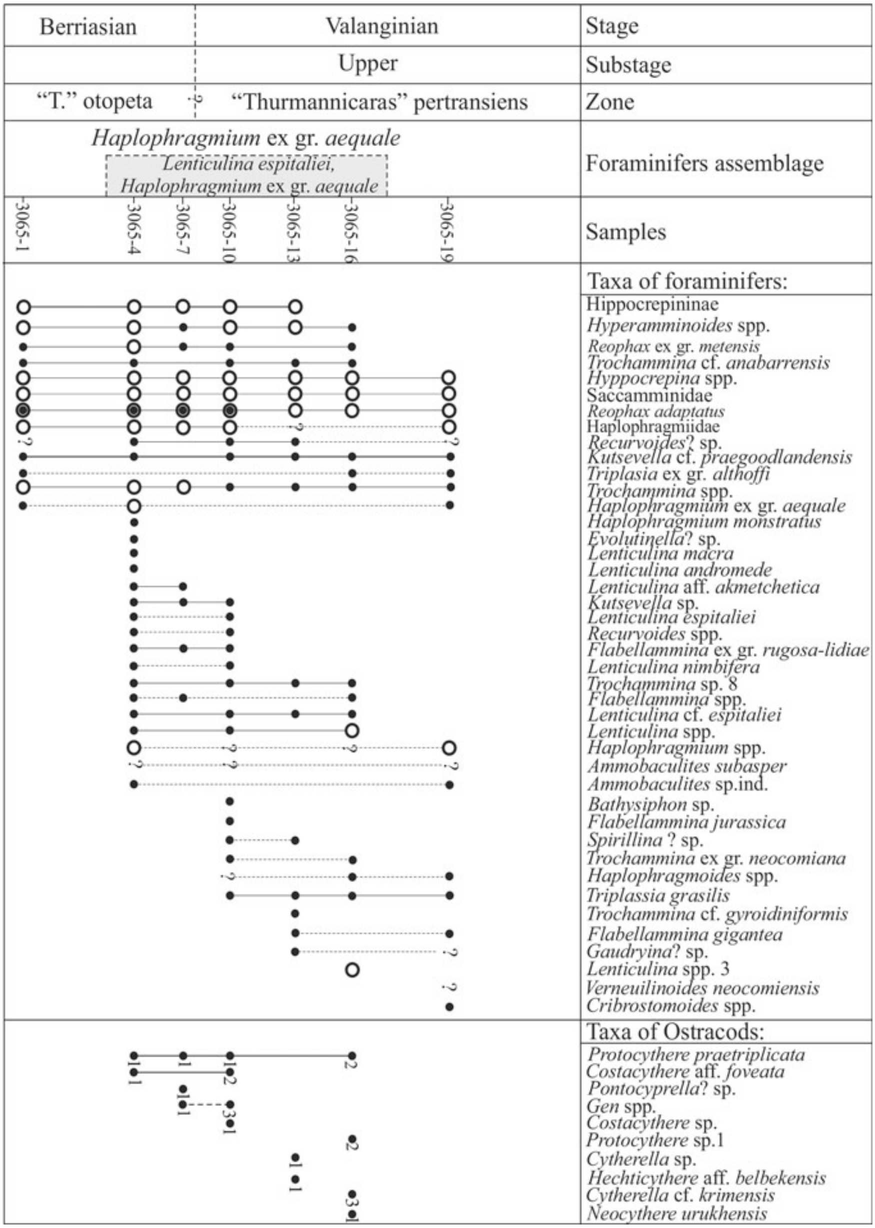

Fig. 3 Distribution of foraminifers and ostracods in the outcrop Dlinnaya-3065 (Southwest Crimea). Notation as in Fig. 2

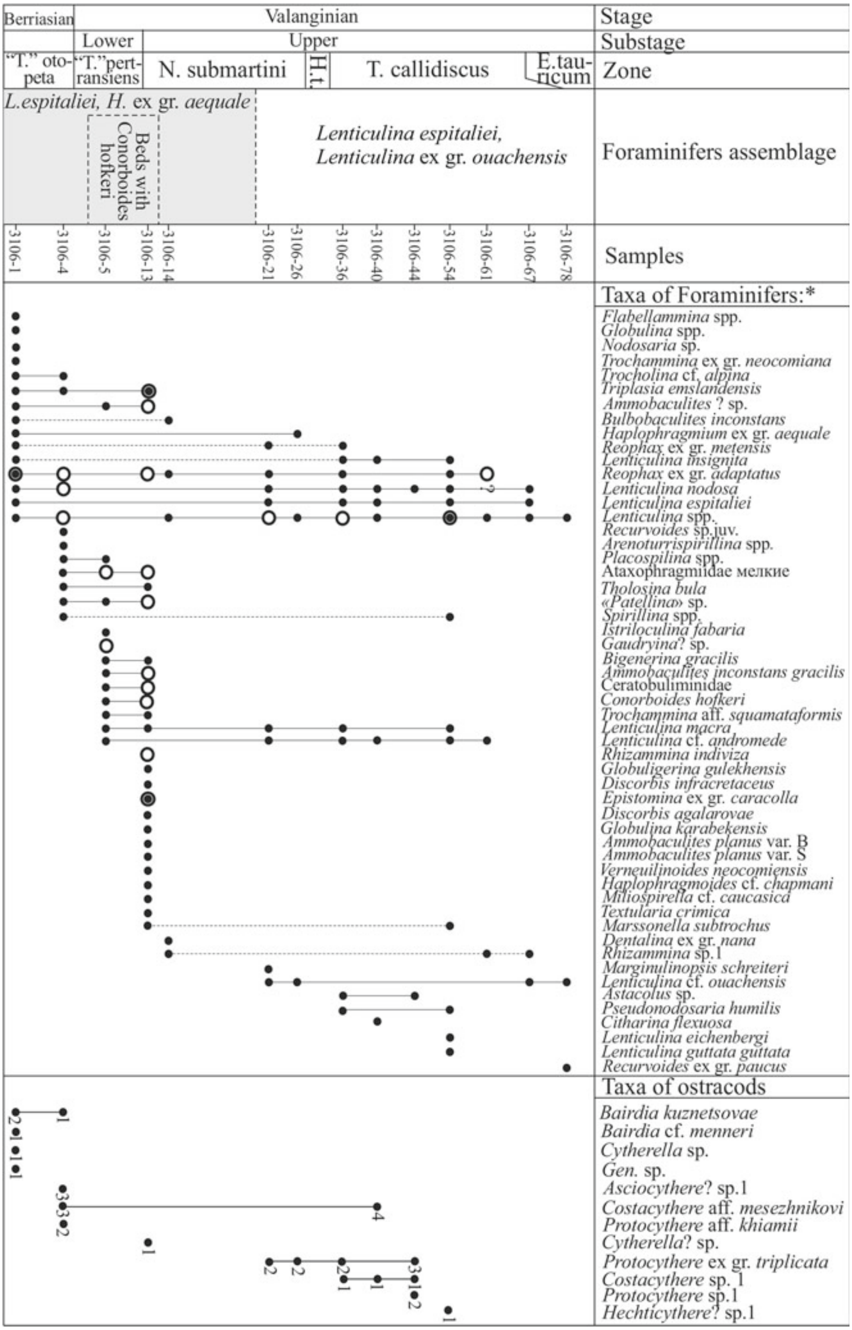

Fig. 4 Distribution of foraminifers and ostracods in the outcrop Rezanaya-3106 (Southwest Crimea). Numerous primitive forms Hippocrepininae, Saccamminidae and Hormosinidae found throughout the section are not shown in the figure. Notation as in Fig. 2

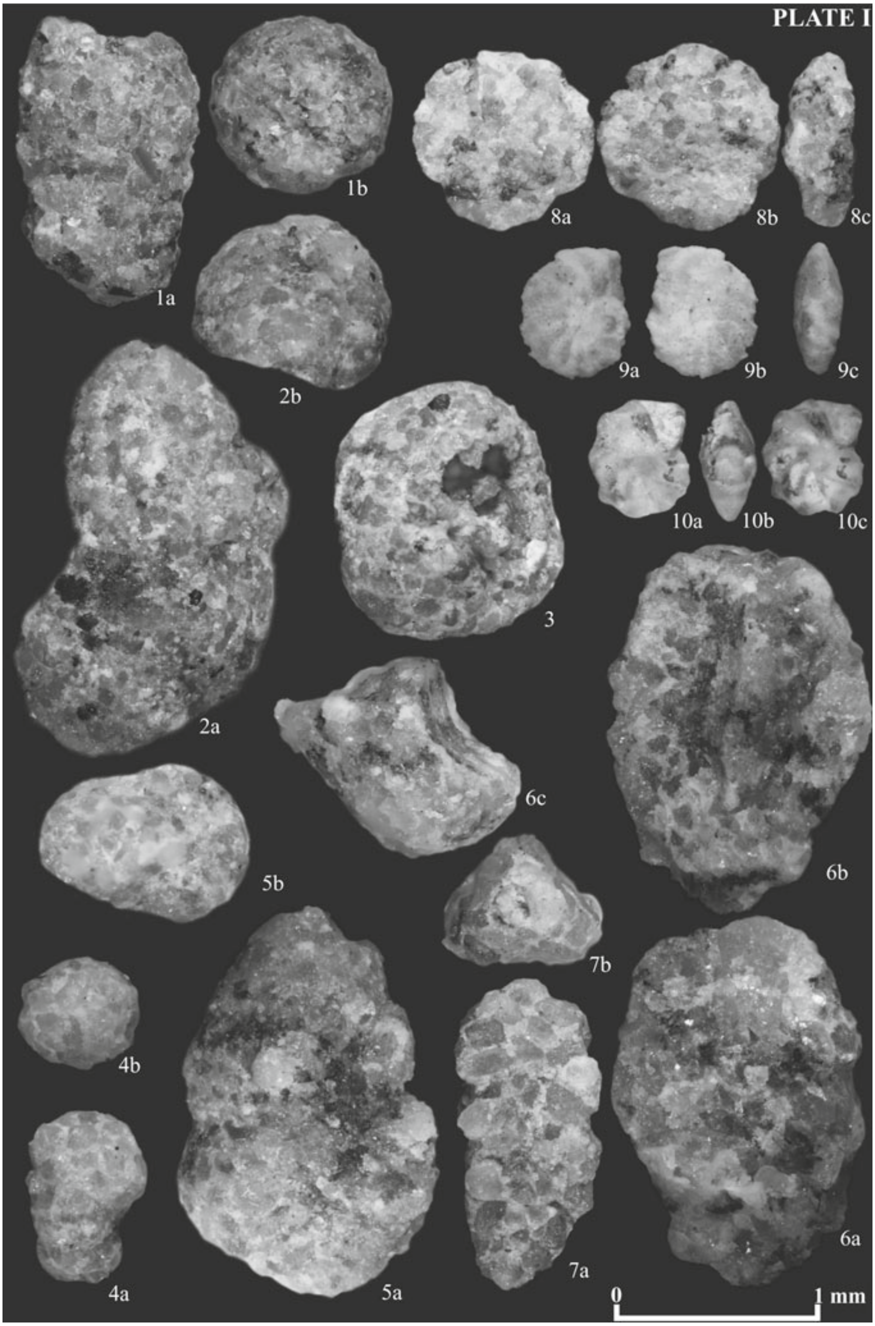
PLATE I
1a
1b
2a
2b
3
4a
4b
5a
5b
6a
6b
6c
7a
7b
8a
8b
8c
9a
9b
9c
10a
10b
10c
0
1 mm

◀**Plate 1** Foraminifers. Assemblage with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *Aequale* Magnification X40. **1–4** *Haplophragmium* ex gr. *aequale* (Römer), **a** lateral view, **b** apertural view. Patil-2, sample № 3, Subzone Otopeta, Berriasian, **1a** lateral view, **1b** apertural view. **5** *Haplophragmium monstratus* (Dain), **5a** lateral view, **5b** apertural view. Patil section № 3139, sample № 3, Subzone Otopeta, Berriasian. **6** *Triplasia emslandensis* Brat. et Brand, **6a**, **b** lateral view, **6c** apertural view, Rezanaya section № 3106, sample № 4, Subzone Otopeta, Berriasian. **7** *Triplasia elegans* (Mjatluk), **7a** lateral view, **7b** apertural view, Dlinnaya section № 3065, sample № 4, Subzone Otopeta, Berriasian. **8** *Trochammina* ex gr. *neocomiana* Mjatliuk, **8a** dorsal view, **8b** ventral view, **8c** frontal view, Patil section № 3139, sample № 3, Subzone Otopeta, Berriasian. **9** *Lenticulina* cf. *espitaliei* Dieni et Massari, **9a**, **b** lateral view, **9c** frontal view. Patil section № 3139, sample № 3, Subzone Otopeta, Berriasian. **10** *Lenticulina nodosa* (Reuss), **10a** lateral view, **10b** frontal view, **10c** lateral view in water, Patil section № 3139, sample № 3, Subzone Otopeta, Berriasian

In the Rezanaya section, a complex with *Conorboides* cf. *hofkeri* (samples 3106/5 and 3106/13) was found (Fig. 4). In sample 3106/5, the complex is poor and represented by a small group of species: *Placopsilina neocomina* Bart et Brand., *Tholosina bula* (Brady), *Ammobaculites gracilis* Bartenstein et Brand, *Bulbabaculites inconstans* Bartenstein et Brand; downtrodden *Bigenerina gracilis* Antonova, *Istriloculina fabaria* Mats. et Temirb., *Trochammina* aff. *squamataformis* Kaptarenko, *Lenticulina macra* Gorbatchik, *L.* cf. *andromede* Espitalie et Sigal, *Conorboides* cf. *hofkeri* (Bartenstein and Brand); it also contains numerous dwarf forms of several Ataxophragmiidae species.

In sample 3106/13, a complex with *Conorboides* cf. *hofkeri* is more complete and variegated: besides the species listed above here there are *Rhizammina indiviza* Brady, *Haplophragmoides chapmani* Crespin, *Ammobaculites planus* Belousova, *Verneuilinoides neocomiensis* (Mjatliuk), *Marssonella* (*Dorothia*) *subtrochus* (Bartenstein), *Textularia crimica* (Gorbatchik), *Miliospirella* cf. *caucasica* Antonova, *Globulina karabekensis* Mjatluk, *Hoeglundina* ex gr. *caracolla* (Roemer), *Discorbis agalarovae* Antonova, *D. infracretaceus* Schokhina, and also the planktonic *Globuligerina gulekhensis* Gorbatchik et Poroshina. The relatively deep-water forms of Rotaliida dominate here.

The most numerous species of lower Cretaceous is *Hoeglundina* (*Epistomina*) *caracolla* (Roemer). The species *Conorboides hofkeri* (Bartenstein and Brand) is known from the lower part of the Berriasian to the Valanginian, indicating the Conorboides hofkeri—Conorbina heteromorpha zone comparable with the interval of ammonite zones from the top of the T. occitanica (D. dalmasi subzone) to the S. boissieri [24]. The species *Discorbis agalarovae* Antonova is known from the upper Tithonian—lower Valanginian, and *D. infracretaceus* Schokhina—from the topmost Tithonian-Berriasian.

The planktonic species *Globuligerina gulekhensis* Gorbatchik et Poroshinais is known from the Berriasian and Valanginian, however, in Crimea this species is characteristic for the upper Valanginian [24].

It is important to note that all the secretory forms are "sideriated", and agglutinate forms have different degree of integrity with different "types" of wall: in such manner *Ammobaculites planus* Belousova is represented by exemplars with an agglutinate

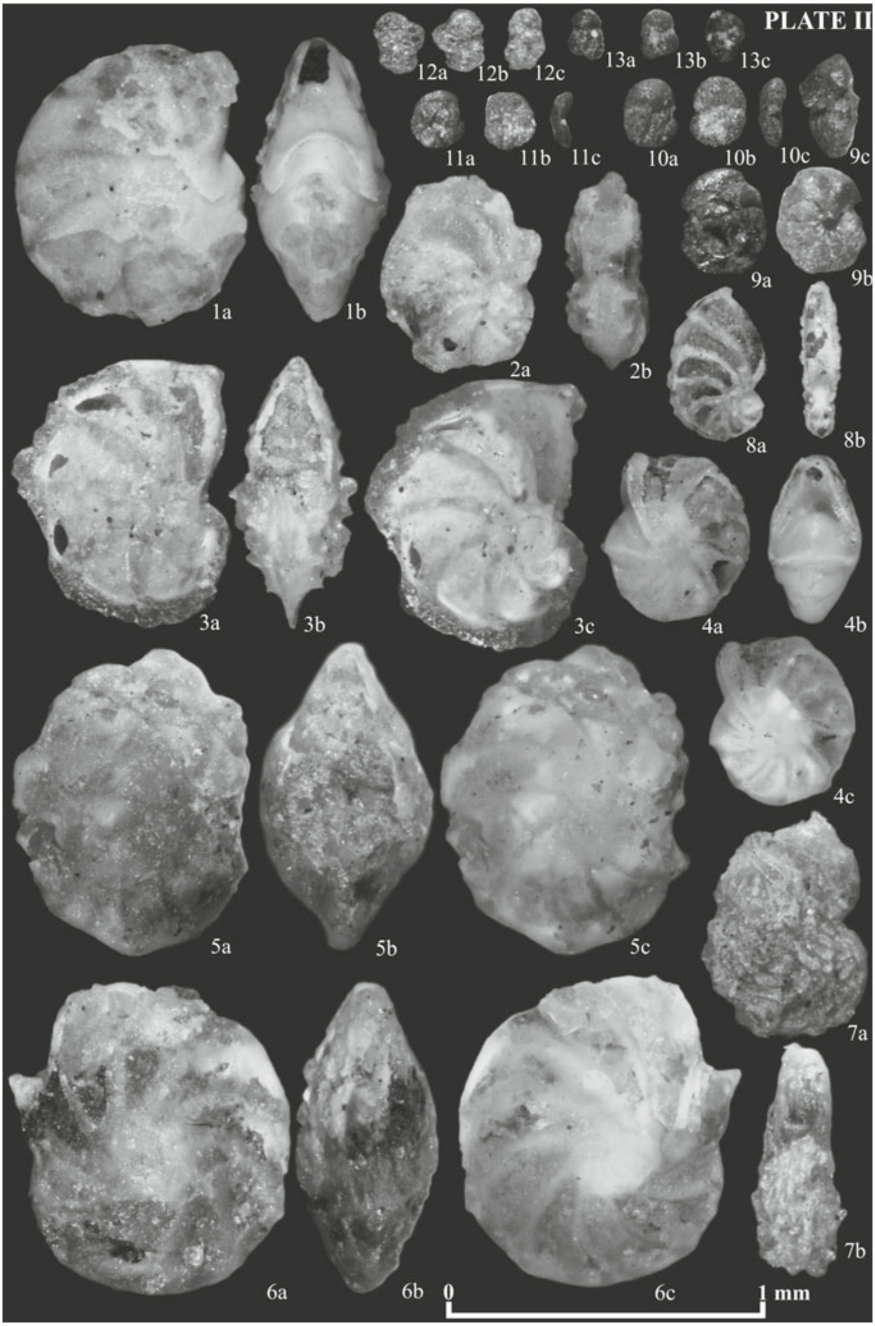
PLATE II
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3b
3c
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5a
5b
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7a
7b
6a
6b
6c
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◂**Plate 2** Foraminifers. Assemblage with *Lenticulina espitaliei*, *Lenticulina* cf. *ouachensis*, Magnification X60. **1** *Lenticulina* cf. *ouachensis* Sigal, **1a** lateral view, **1b** frontal view, Rezanaya section № 3106, sample № 54, Zone T. callidiscus, Valanginian. **2** 3106_54, 2 *Lenticulina guttata* (Ten Dam), **2a** lateral view, **2b** frontal view, Rezanaya section № 3106, sample № 54, Sone T. callidiscus, Valanginian. **3** *Lenticulina eichenbergi* Bartenstein et Brand, **3a** lateral view, **3b** frontal view, **3c** lateral view in water, Rezanaya section № 3106, sample № 54, Zone T. callidiscus, Valanginian. **4** *Lenticulina nodosa* (Reuss), **4a** lateral view, **4b** frontal view, **4c** lateral view in water, Rezanaya section № 3106, sample № 54, Zone T. callidicus, Valanginian. **5** *Lenticulina espitaliei* Dieni et Massari, **5a** lateral view, **5b** frontal view, **5c** lateral view in water, Rezanaya section № 3106, sample № 21, Zone N. submartini, Valanginian. **6** *Lenticulina* cf. *andromede* Espitalie et Sigal, **6a** lateral view, **6b** frontal view, **6c** lateral view in water, Rezanaya section № 3106, sample № 54, Zone T. callidiscus, Valanginian. **7** *Marginulinopsis schreiteri* (Echrenberg), **7a** lateral view, **7b** frontal view, Rezanaya section № 3106, sample № 21, Zone N. submartini, Valanginian. **8** *Citharina flexuosa* (sp. D Espitalie et Sigal, 1963), **8a** lateral view, **8b** frontal view, Rezanaya section № 3106, sample № 54, Zone T. callidiscus, Valanginian. Assemblage with *Conorboides* cf. *hofkeri* Magnification X60. **9** *Hoeglundina* ex gr. *caracolla* (Roemer), **a** dorsal view, **b** ventral view, **c** peripheral view, Rezanaya section № 3106, sample № 13, Zone N. submartini, Valanginian. **10**, **11** *Conorboides* cf. *hofkeri* (Bartenstein and Brand), **a** dorsal view, **b** ventral view, **c** peripheral view, Rezanaya section № 3106, sample № 13, Zone N. submartini, Valanginian. **12**, **13** *Conoglobuligerina gulekhensis* (Gorbatchik et Poroshina), **a** spire view, **b** umbonal view, **c** peripheral view, Rezanaya section № 3106, sample № 13, Zone N. submartini, Valanginian

of quartz grains of small and medium size (*A. planus* var. B, characteristic for the shallow marine facies) and exemplars with a cryptocrystalline wall (*A. planus* var. S, characteristic for the moderate-marine conditions).

Bearing in mind dominating of characteristic species of the complex belonging to the Conorboides hofkeri—Conorbina heteromorpha zone [24] and the layers with Conorboides hofkeri [8, 35] comparable with the upper part of the Subthurmannia boissieri ammonite zone (Berriasella picteti (upper part) to Thurmanniceras alpillensis subzones), the host sediments may be dated as late Berriasian. However, considering the difference in common habit and the degree of integrity of associations of littoral and upper/middle sublittoral zone, this complex probably should be viewed as re-sedimented into the above described complex with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *aequale*.

In the Rezanaya section, a complex with *Lenticulina espitaliei*, *Lenticulina* cf. *ouachensis* was established (Fig. 4). In this complex, despite the sedimentation in littoral zone (shoreface and ebb-tide conditions), there is a large quantity of secretory foraminifers, characteristic for the upper sublittoral inhabit. The representatives of *Lenticulina* become more various, but *Haplophragmium* ex gr. *aequale*, represented by a large quantity of exemplars in the underlying sediments, was not found in this complex.

The following taxa are also recorded till the species rank: *Reophax adaptatus* Dain, *R.* ex gr. *metensis* Franke, *Recurvoides* ex gr. *paucus* Dubrovskaja, *Flabellammina* ex gr. *rugosa-lidiae* Mjatliuk, *Marssonella* cf. *subtrochus* (Bartenstein), *Dentalina* ex gr. *nana* Reuss, *Marginulinopsis schreiteri* (Echrenberg), *Citharina flexuosa* (var. D, Espitalie et Sigal, 1963), *Pseudonodosaria humilis* (Echrenberg), *Lenticulina eichenbergi* Bartenstein et Brand, *L.* cf. *andromede* Espitalie et Sigal, *L.* cf. *ouachensis* Espitalie et Sigal, *L. macra* Gorbatchik, *L. insignita* Mjatliuk, *L. nodosa* (Reuss), *L. espitaliei* Dieni et Massari, *L. g. guttata* (Dam). The most part of species appear in the upper part of the Berriasian and are characteristic for the Valanginian or the Valanginian-Hauterivian. Similar increasing of diversity of nodozariides is characteristic for the terminal Berriasian—lower Valanginian of East Crimea [6–8, 24, 36].

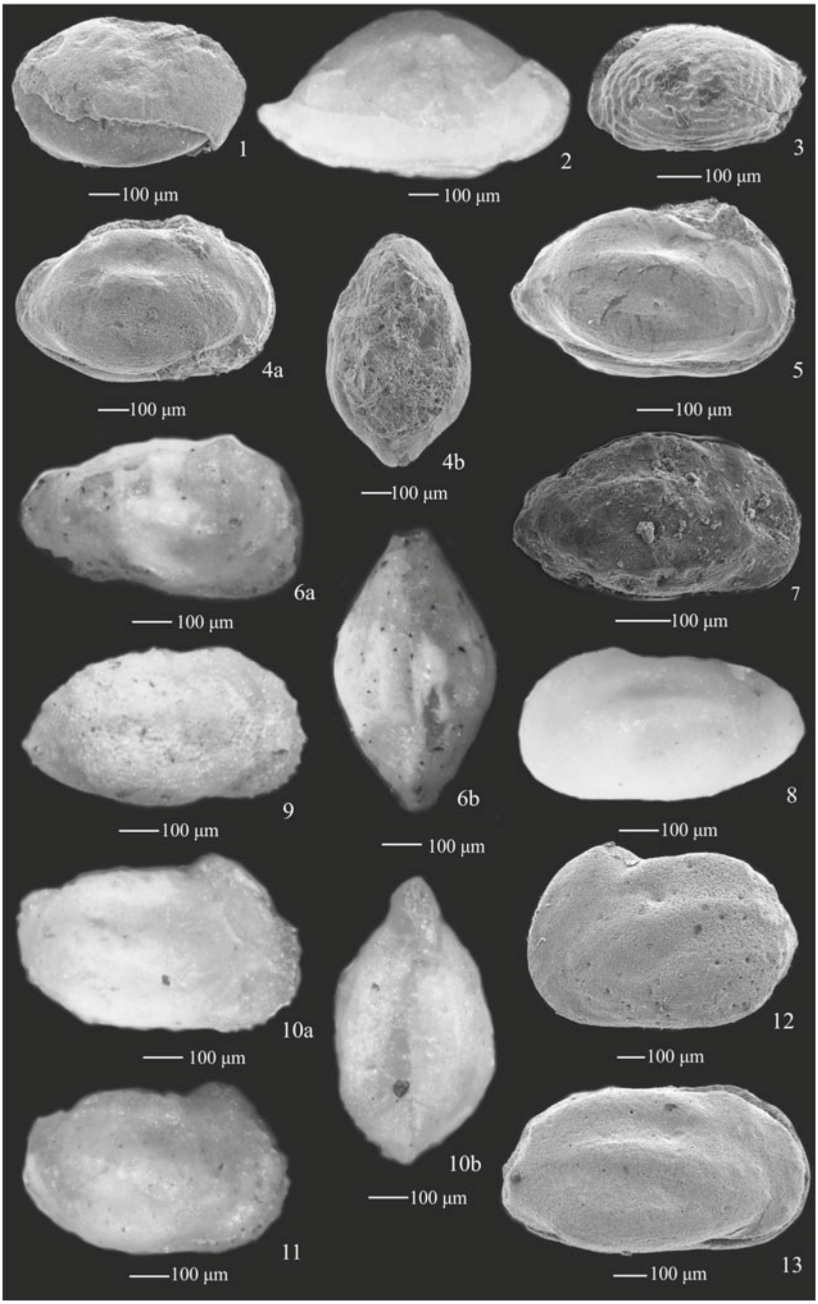
Thus, despite the absence of short-lived characteristically Valanginian foraminifera species, this taxonomic composition indicates, with a high degree of confidence, the Valanginian age of the enclosing sediments.

Ostracods were found in three sections, namely Patil-2, Dlinnaya and Rezanaya, but they are not present in every sample. In total, 17 species belonging to 8 genera were found, the shells are mostly thick-walled, and the condition is satisfactory (Figs. 2, 3 and 4; Plate 3). Limited deep-water representatives of the genus *Bairdia* and singular *Pontocyprella* were found. Such assemblage is characteristic for the most shallow areas of sublittoral with an active hydrodynamic regime.

The most important stratigraphic meaning is borne by the representatives of the family *Protocytheridae* (*Protocythere*, *Costacythere*, *Hechticythere*) [32]. The species *Protocythere praetriplicata* Bartenstein et Brand is known from the upper part of the Berriasian on the Northern Caucasus (Urukh section) and from the Berriasian-Valanginian of Mangyshlak, Germany, France and Algeria [3, 10, 13, 22]. This species is an index of cognominal zone, determined in the middle part of the Berriasian of Central Asia [2]. It also composes the complex with *Palaeocytheridea fistulosa*, *Pal. bassovi*, determined in the upper part of the lower Valanginian of the Boyarka river in northern Siberia [25]. It composes the complex with *P. hannoverana*, *P. praetriplicata* of the lower Valanginian on Kolguev Island in the Barents Sea as well [23]. The close form, *Protocythere* ex gr. *triplicata* (Roemer), was found in the upper part of the Rezanaya section (complex of foraminifers with *Lenticulina espitaliei—L.* cf. *ouachensis*). The species *P. Triplicata* is one of the most widespread species, which is known from the Valanginian to the lower Barremian in central Asia [2], Precaspian [26], England [30, 39], Germany [14, 43] and France [10]. In Southwest Crimea, this species was recorded from the Hauterivian–Barremian at Verkhorechye [38]. It also has a status of an index species of cognominal zone, which was established in Central Asia in the range from the upper part of the upper Valanginian to the lower Hauterivian [2]. In the Hauterivian of Kolguev Island, a complex with *Protocythere triplicata*, *Eucythere neocomiana* has been found [23].

In the studied samples, *Costacythere* aff. *foveata* Tesakova et Rachenskaya, *C.* aff. *khiamii* Tes. et Rach., *Hechticythere* aff. *belbekensis* Tes. et Rach. were also found. Enumerated taxa are close forms of the species earlier known from the Berriasian sediments of the Crimean Mountains [5, 6, 8, 41]. We found *Costacythere* aff. *mesezhnikovi* Neale et Kolpenskaya, earlier reported from the middle and upper parts of the Berriasian of the Northern Caucasus (Urukh section), and *Hechticythere* aff. *belbekensis* Tes. et Rach., which is known from the upper part of the Berriasian of the same region and section [22]. The species *Cytherella krimensis* Neale is widespread in the Tithonian-Berriasian of the Crimean Mountains and in the middle and upper parts of the Berriasian in the Northern Caucasus (Urukh section, S. occitanica zone

PLATE III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◀**Plate 3** Ostracods. **1** *Cytherella* cf *krimensis* (Neale, 1966), Dlinaya, sample 3065-16, carapace, left lateral view. **2** *Bairdia kuznetsovae* Tesakova et Rachenskaya, 1996, Rezanaya, sample 3106-4, carapace, right lateral view. **3** *Neocythere urukhensis* Neale et Koppenskaya, 2000, Dlinaya, sample 3065/16; left valve, lateral view. **4** *Protocythere praetriplicata* Bartenstein et Brand, 1959, Patily, sample 3139/3, carapace: **4a** right lateral view; **4b** dorsal view. **5** *Protocythere praetriplicata* Bartenstein et Brand, 1959, Dlinaya, sample 3065/16, carapace, right lateral view. **6** *Protocythere* ex gr. *triplicata* (Roemer, 1840), Rezanaya-3106, sample 3106-21, carapace: **6a** right lateral view; **6b** dorsal view. **7** *Protocythere* ex gr. *triplicata* (Roemer, 1840), Kermen, sample 3, carapace, right lateral view. **8** *Protocythere* sp. 1, "Dlinaya", sample 3065/16, left valve, lateral view. **9** *Costacythere khiamii* Tesakova et Rachenskaia, 1996, Rezanaya, sample 3106-4, right valve, lateral view. **10**, **11** *Costacythere* aff. *mesezhnikovi* Neale et Kolpenskaya, 2000, Rezanaya, sample 3106-40, **10a** carapace, right lateral view; **10b** carapace, ventral view; **11** carapace, right lateral view. **12** *Costacythere* aff. *foveata* Tesakova et Rachenskaia, 1996, Patily, sample 3139/3, left valve, lateral view. **13** *Hechticythere* aff. *belbekensis* Tesakova et Rachenskaya, 1996, Dlinaya, sample 3065/13; carapace, right lateral view

(D. tauricum subzone) and S. boissieri zone) [5, 6, 22, 31]. The species *Neocythere urukhensis* Neale et Kolp. (= *Macrodentina melnikovae* Tes.) was earlier found in the upper part of the Berriasian in Central Crimea and the Northern Caucasus (Urukh section) [22, 42]. The species *Bairdia kuznetsovae* Tes. et Rach. is known from the Berriasian of Central and East Crimea; and species *B. menneri* Tes. et Rach. from the middle and upper parts of the Berriasian in the Crimean Mountains [5, 35, 42].

4.2 Magnetostratigraphy

Magnetite as a main carrier of $\mathbf{J_n}$ in rocks in East and Southwest Crimea was established earlier in the sections Zavodskaya balka, Dlinnaya and Sheludivaya [4, 7, 16]. Comparable results of magneto-mineralogical analysis were obtained for sections Patil-1, 2, Bolshoy Kermen, Selbukhra and Rezanaya. Fe_3O_4 is detected by the fall of magnetization on the TMA curves around 570–580 °C (Fig. 5a, c, d). The presence of a magnetically soft phase is confirmed by isothermal remanence acquisition curves (Fig. 5b). In several samples the presence of hydrous ferric oxides was established inferred from a characteristic fold on the graphs of TMA second derivative between 100 and 200 °C and a steady growth of isothermal remanence up to 700 mT (Fig. 5e, f). In a petromagnetic regard, all studied sections are well differentiated allowing to further subdivide the series into petromagnetic intervals [8, 15].

4.2.1 East Crimea

The total of 392 oriented samples, collected from 196 stratigraphic levels were studied.

The major amount of data has come from the magnetostratigraphic study of the Zavodskaya balka section. In the lower part of the section, two isolated groups of

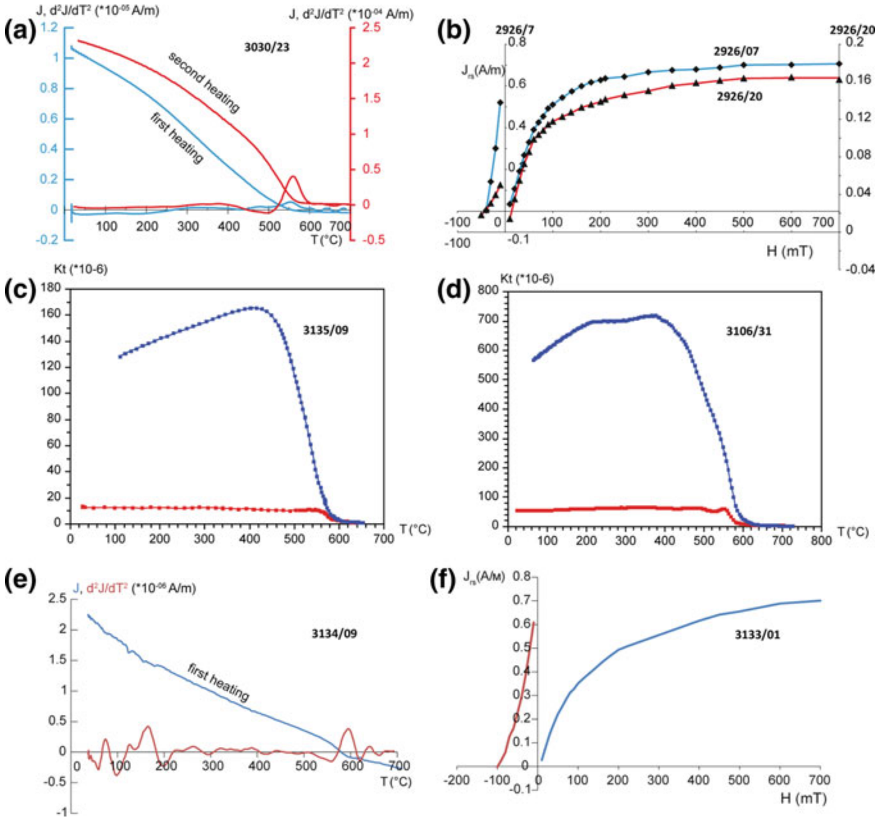


Fig. 5 Results of magnetomineralogical examinations: **a**, **e**—DTMA results; **b**, **f**—isothermal remanence acquisition curves; **c**, **d**—dependence of magnetic susceptibility on temperature

$\mathbf{J_n}$ directions appear to be present: in the N–NW quarter of lower hemisphere and in the SE sector of upper hemisphere, corresponding to the epochs of normal (N) and reverse (R) polarity of geomagnetic field, respectively. In the upper part of the section many paleomagnetic directions have an anomalous character (for example, negative inclination with northern declination) not allowing to determine the sign of polarity even hypothetically [8]. Further studies have detected the significant correlation (on the significance level $p = 0.001$) between the distribution of short axes of the ellipsoid of anisotropy of magnetic susceptibility (K3) and paleomagnetic directions of ChRM component. We attempted to use the anisotropy of magnetic susceptibility for correcting paleomagnetic data, and achieved a considerable improvement of paleomagnetic data in the upper part of the Zavodskaya balka section [17].

The Koklyuk section is characterized by a similar to that in Zavodskaya balka character of K3 (AMS) and $\mathbf{J_n}$ vectors distribution which are significantly correlated appears at the 95% level, and is likely caused by the same factors. In this section intensive landslide deformations are visible in the marl layers at the base of the

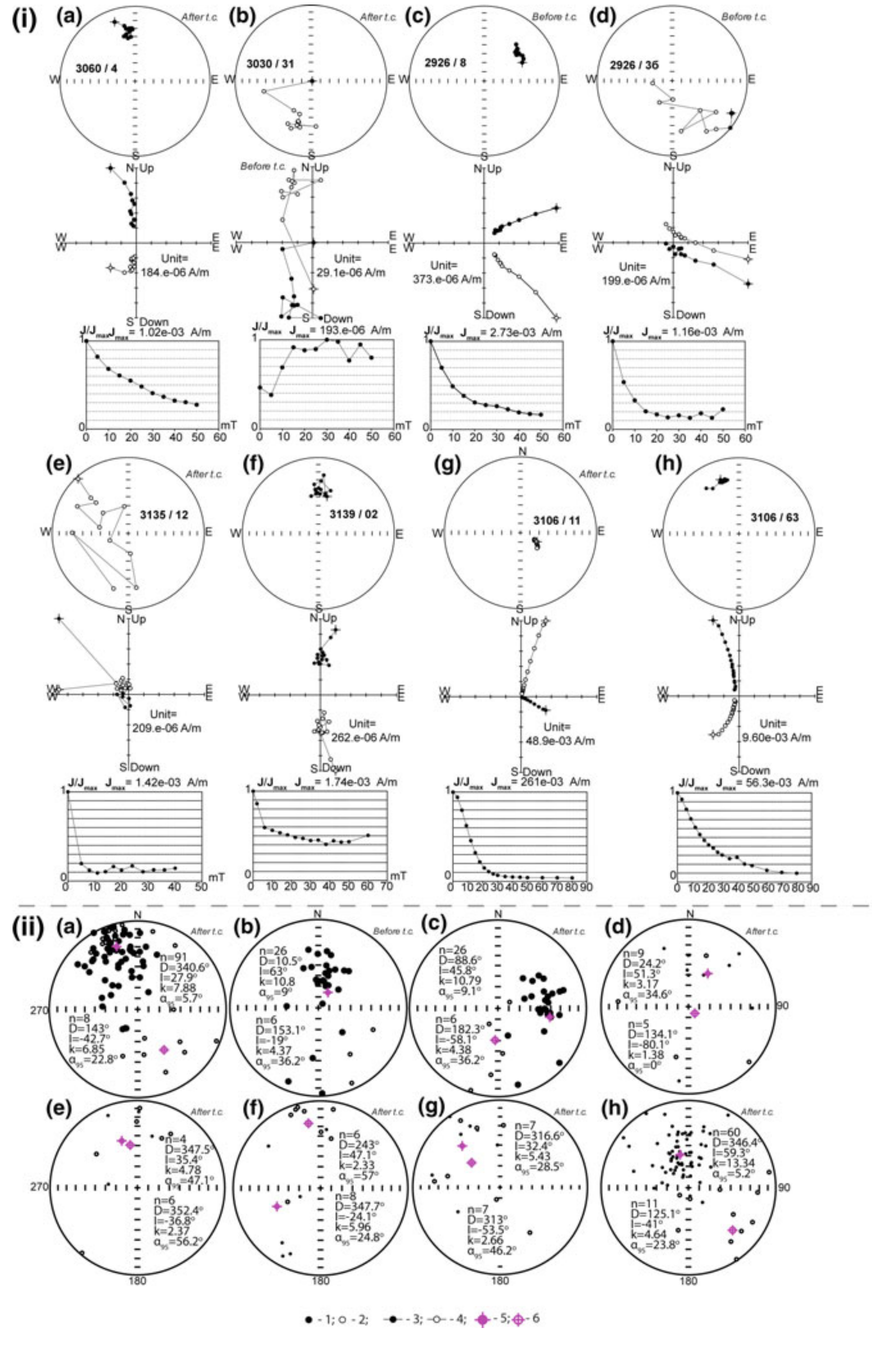
3030 outcrop. So we have used the same approach as for the Zavodskaya balka section for the magnetic polarity interpretation of the data from the Koklyuk section as well. Only a few samples (<7% of the total collection) failed to yield a stable $\mathbf{J_n}$ component characterized by maximum angle deviation (MAD) <15°. In general, Zijderveld diagram analysis reveals a two-component structure of $\mathbf{J_n}$ comprising a low-coercitivity component demagnetized in 5–25 mT field and a high-coercitivity component retained until 30–60 mT (Fig. 6 Ia, b, IIa). The results of component analysis for both thermal and AF demagnetization of Zavodskaya balka and Koklyuk samples generally show a good convergence thus raising the confidence to the quality of paleomagnetic determinations.

The result of the reversal test [28] for the Koklyuk section is negative ($A = 20.5°$; $A_c = 20.1°$). Fold test [27] results in this section are either inconclusive or indicate the presence of a post-folding component.

However, the negative reversal test per se does not contradict to the hypothesis of an ancient magnetization age, because it may be explained by viscous-plastic deformations in clay that are impossible to take into account properly. These deformations introduce distortions to the paleomagnetic directions. In our opinion, the important factor that designates the results of fold test is the ability of ferromagnetic grains to follow the direction of geomagnetic field during a synfolding deformation. Small particles may continue to be oriented along the field direction in a semifluid sediment while large particles are not. The degree of the sediment lithification, in turn, depends on a number of factors, e.g. carbonate content, organic matter content, degree of bioturbation etc. The described scenario may result in a situation when every sample will carry pre-, syn-, and post-folding components of $\mathbf{J_n}$ in variable proportion, which would be nearly impossible to resolve by demagnetization since their stability is expected to be quite similar.

In the Sultanovka section, it is impossible to determine a polarity sign in the ancient coordinate system. Directions of stable magnetization components show a more regular distribution in the present-day coordinate system than in the ancient one. The same is true for the projections of AMS ellipsoid axes: in the present-day coordinates they group into two clusters with average directions close to magnetization directions expected for normal and reverse polarity, respectively (Fig. 6 Ic, d, IIb, c). Similar behavior has been observed previously in other Crimean sections [17]. The fold test [27] clearly argues for the postfolding age of the magnetization at Sultanovka, but the presence of magnetozones with different polarity does not conform to a hypothesis of rocks remagnetization after their lithification. However, this contradiction may be erased considering a synsedimentational age of the syncline and magnetization acquisition in sediments dewatered after the fold development, simultaneously with the magnetic fabric. Therefore, we believe possible to use the directions of magnetization in geographic coordinate system to determine the polarity sign in this section.

The data thus acquired satisfy a number of indicators of primary magnetization [19, 40, 44]: (1) intervals of different polarity sign consistently group along the section, forming large N- and R-magnetozones; (2) the polarity sign does not depend on the lithological composition, because magnetozones of different polarity


(i)
(a) After t.c. 3060 / 4
Unit= 184.e-06 A/m
J/J_{max} J_{max} = 1.02e-03 A/m
(b) After t.c. 3030 / 31
Before t.c.
Unit= 29.1e-06 A/m
J/J_{max} J_{max} = 193.e-06 A/m
(c) Before t.c. 2926 / 8
Unit= 373.e-06 A/m
J/J_{max} J_{max} = 2.73e-03 A/m
(d) Before t.c. 2926 / 36
Unit= 199.e-06 A/m
J/J_{max} J_{max} = 1.16e-03 A/m
(e) After t.c. 3135 / 12
Unit= 209.e-06 A/m
J/J_{max} J_{max} = 1.42e-03 A/m
(f) 3139 / 02
Unit= 262.e-06 A/m
J/J_{max} J_{max} = 1.74e-03 A/m
(g) After t.c. 3106 / 11
Unit= 48.9e-03 A/m
J/J_{max} J_{max} = 261e-03 A/m
(h) 3106 / 63
Unit= 9.60e-03 A/m
J/J_{max} J_{max} = 56.3e-03 A/m
(ii)
(a) After t.c. n=91 D=340.6° I=27.9° k=7.88 α_{95}=5.7°
n=8 D=143° I=-42.7° k=6.85 α_{95}=22.8°
(b) Before t.c. n=26 D=10.5° I=63° k=10.8 α_{95}=9°
n=6 D=153.1° I=-19° k=4.37 α_{95}=36.2°
(c) After t.c. n=26 D=88.6° I=45.8° k=10.79 α_{95}=9.1°
n=6 D=182.3° I=-58.1° k=4.38 α_{95}=36.2°
(d) After t.c. n=9 D=24.2° I=51.3° k=3.17 α_{95}=34.6°
n=5 D=134.1° I=-80.1° k=1.38 α_{95}=0°
(e) After t.c. n=4 D=347.5° I=35.4° k=4.78 α_{95}=47.1°
n=6 D=352.4° I=-36.8° k=2.37 α_{95}=56.2°
(f) After t.c. n=6 D=243° I=47.1° k=2.33 α_{95}=57°
n=8 D=347.7° I=-24.1° k=5.96 α_{95}=24.8°
(g) After t.c. n=7 D=316.6° I=32.4° k=5.43 α_{95}=28.5°
n=7 D=313° I=-53.5° k=2.66 α_{95}=46.2°
(h) After t.c. n=60 D=346.4° I=59.3° k=13.34 α_{95}=5.2°
n=11 D=125.1° I=-41° k=4.64 α_{95}=23.8°
- 1; - 2; - 3; - 4; - 5; - 6

◀**Fig. 6** Component analyses results (**I**) for the Koklyuk (**a**, **b**), Sultanovka (**c**, **d**), Bolshoy Kermen (**e**), Patil-2 (**f**) and Rezanaya (**g**, **h**) sections (from top to bottom: stereographic projections of $\mathbf{J_n}$ changes in the course of demagnetization, Zijderveld diagrams, demagnetizations graphs) and Stereoprojections of the $\mathbf{J_n}$ stable components (**II**): **a** Koklyuk; **b**, **c** Sultanovka; **d** Bolshoy Kermen; **e**, **f** Patil-1 and 2; **g** Selbuhra; **h** Rezanaya. *Legend* 1, 2—on the lower and the upper semispheres respectively; 3, 4—on the horizontal and the vertical planes respectively; 5, 6—average direction of the $\mathbf{J_n}$ stable components

are established within monotonous clay series; (3) paleomagnetic structure of the studied sections shows many common features (Fig. 7).

Consequently, the whole assemblage of obtained data does not support a remagnetization hypothesis, but rather suggests that magnetization have been formed in a partially lithified sediment during the synsedimentational deformations [17]. For this reason, we consider possible to use the obtained data for magnetostratigraphic reconstructions despite the problematic paleomagnetic results.

The final composite paleomagnetic column constructed for East Crimea of contains 3 subzones of reverse, 2 subzones of normal and 1 subzone of mostly anomalous polarity (Fig. 7).

4.2.2 Southwest Crimea

In the paleomagnetic regard, the rocks of condensed sections at mountains Patil, Bolshoy Kermen and Selbukhra are analogues to Dlinnaya and Sheludivaya sections [16]. Most part of the studied samples were stable in paleomagnetic regard. They are characterized by two $\mathbf{J_n}$ components: soft (demagnetized between 0 and 24–32 mT) and hard (demagnetized above 24–32 mT) (Fig. 6 Ie–h). The second component is characteristic in some cases but it remains uncompletely demagnetized in many samples.

The results of group statistics on the established characteristic components have revealed that all studied sections are characterized by poor interbed grouping and shallow inclinations of paleomagnetic vectors (Fig. 6 IId–g) probably related to their coarse-grained composition originating from a shallow-water genesis and to presence of stratigraphic breaks. The standard tests used to substantiate the ancient age of magnetization, reversal test and fold test, either yielded a negative result (reversal test), or were impossible to apply because of too small variation of layers bedding elements. Despite all these factors, using several circumstantial attributes, employed while substantiating the ancient age of $\mathbf{J_n}$ in the magnetostratigraphic studies [19] it is possible to substantiate the primary nature of magnetization.

1. The established directions, corresponding to normal or reverse polarity, group in the sections consistently (Fig. 8).
2. The polarity sign does not depend on the lithological composition of studied rocks (Fig. 8).

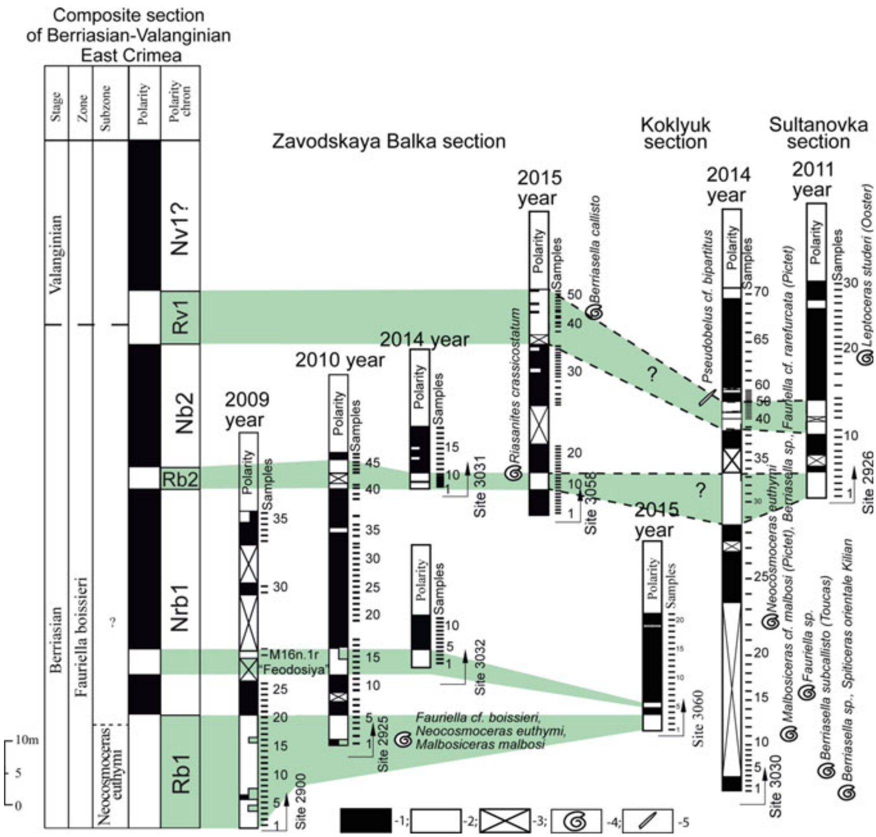


Fig. 7 Magnetostratigraphic correlation of the Berriasian-Valanginian boundary interval in the East Crimea. *Legend* 1, 2—normal and reverse geomagnetic polarity, respectively (in half of the column thickness—tentative determination of the polarity sign); 3—no paleomagnetic data available; 4, 5—finds of ammonites and belemnites

3. The main carrier of magnetization in the section is probably detrital magnetite, which is detected by low fields of magnetic saturation, DTMA data (Fig. 5). Note that formation of secondary magnetite in the shallow-water, oxic environment appears rather unlikely.
4. The large variance of paleomagnetic vectors, typical for rudaceous sediments.
5. Comparability of obtained paleomagnetic results with paleontological data and known data on the regime of geomagnetic field in the Valanginian [33].

In this way, the obtained data reveal that paleomagnetic columns of all studied sections (Dlinnaya, Sheludivaya, Patil, Bolshoy Kermen, Selbukhra) are compatible and can be viewed as an alternation of seven subzones (intervals) of different sign (Rb2, Nb2, Rv1, Nv1, Rv2, Nrv, Rnv1). Magnetostratigraphic data on each single section may reasonably cast doubt, because of numerous anomalous paleomagnetic

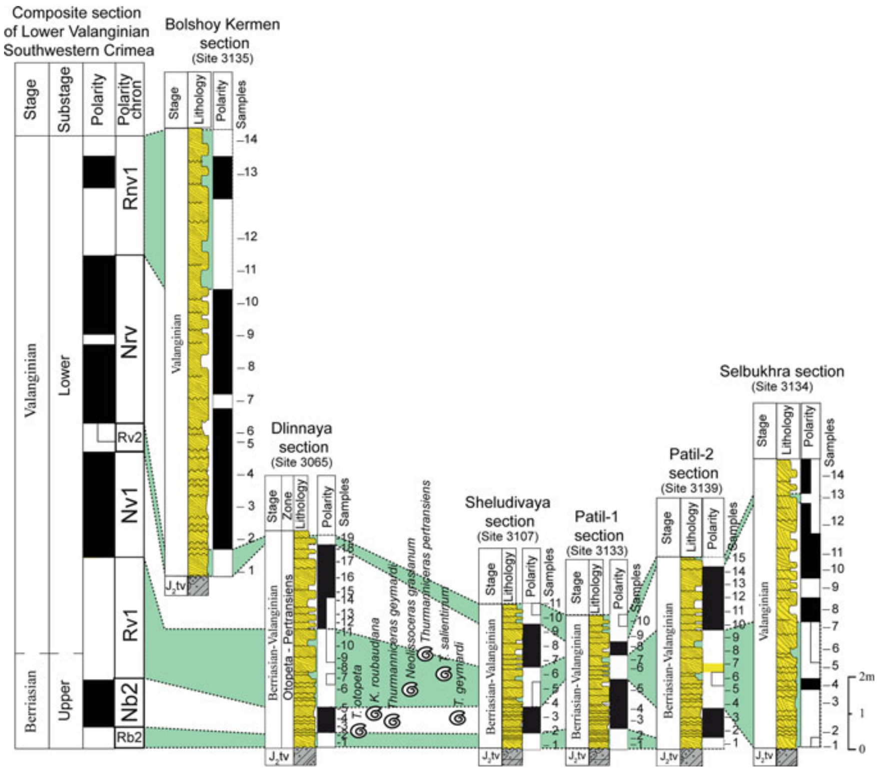


Fig. 8 Magnetostratigraphic correlation of the lower Valanginian in the Southwestern Crimea. See Fig. 7 for the legend

directions and abundant sedimentation breaks. However, the similar paleomagnetic structure can be traced in as many as 5 sections giving some confidence to the obtained data (Fig. 8).

4.2.3 The Rezanaya Mountain Section

The reference section of the Upper Valanginian in Southwest Crimea, located near the town of Rezanaya, apprears more favorable in the paleomagnetic sense.

The analysis of Zijderveld diagrams has shown that the major part of Valanginian samples from the Rezanaya section are characterized by two-component $\mathbf{J_n}$ vectors, with low coercivity (low-temperature) component probably of viscous origin demagnetized at 18–25 mT (200–350 °C), and high coercivity (high-temperature) extending up to 80–100 mT or 550 °C (Fig. 6 Ig, h). Interbed grouping is rather poor, and large number of anomalous directions are observed; data from 12 stratigraphic levels were excluded from further consideration. Still, the remaining data appear suitable for magnetic polarity determination and magnetostratigraphic analysis (Fig. 6 IIh).

Paleomagnetic column of the upper Valanginian substage in the Rezanaya section is subdivided into seven subzones (Fig. 9). Four are characterized by exclusively normal polarity (Nv, the probable analogue of the upper part of magnetozone Nrv from the rest of Southwest Crimea, Nv2, Nv3 and Nv4), and three subzones show mainly reverse polarity (Rnv1, Rnv2, Rnv3).

5 Discussion

5.1 East Crimea

In East Crimea, the reliable magnetostratigraphic characteristic for the Berriasian-Valanginian boundary interval is obtained for the Zavodskaya balka section [8]. Micropaleontologic exploration of the section revealed here the layers containing Lingulina trilobitomorpha, Haplophragmoides vonontianus. The range of detected micropaleontologic layers is comparable with the range of ammonite zones T. Otopeta—S. Verrucosum (upper Berriasian—Valanginian) [36]. The find of Berriasian ammonite Berriassella callisto [8] within the magnetozone of reverse polarity makes it possible to correlate the latter with the chron M14r (Fig. 7). In the similar way, biostratigraphic data allow to correlate a rather complex paleomagnetic zonality of the Zavodskaya balka section with magnetic chrons M16, M15 and M14. Considering an extreme rarity of the ammonite findings in the Berriasian-Valanginian boundary interval, the base of M14r chron should be used in East Crimea as a criteria for substantiating the base of the Valanginian by analogy with the Geomagnetic Polarity Timescale (Fig. 9). In general, the base of the Valanginian may be traced in the Koklyuk and Sultanovka sections because there seems to be possible to establish the succession of magnetic chrons M16, M15 and M14 in both sections, despite a poor quality of paleomagnetic data.

5.2 Southwest Crimea

Micropaleontologic studies of the Dlinnaya, Patil-1, 2 and Rezanaya sections have detected the presence of foraminifers complex with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *aequale*; *Conorboides* cf. *hofkeri*; *Lenticulina espitaliei*, *Lenticulina* ex gr. *ouachensis*, implying the Berriasian-Valanginian or Valanginian age of the host sediments. The most part of recognized ostracod species are known from Berriasian sediments of Crimea and the Caucasus, but they are identified by us in the open nomenclature; perhaps they are descendant forms (Berriasian forms may be their ancestors) and are on the same evolutionary line of development.

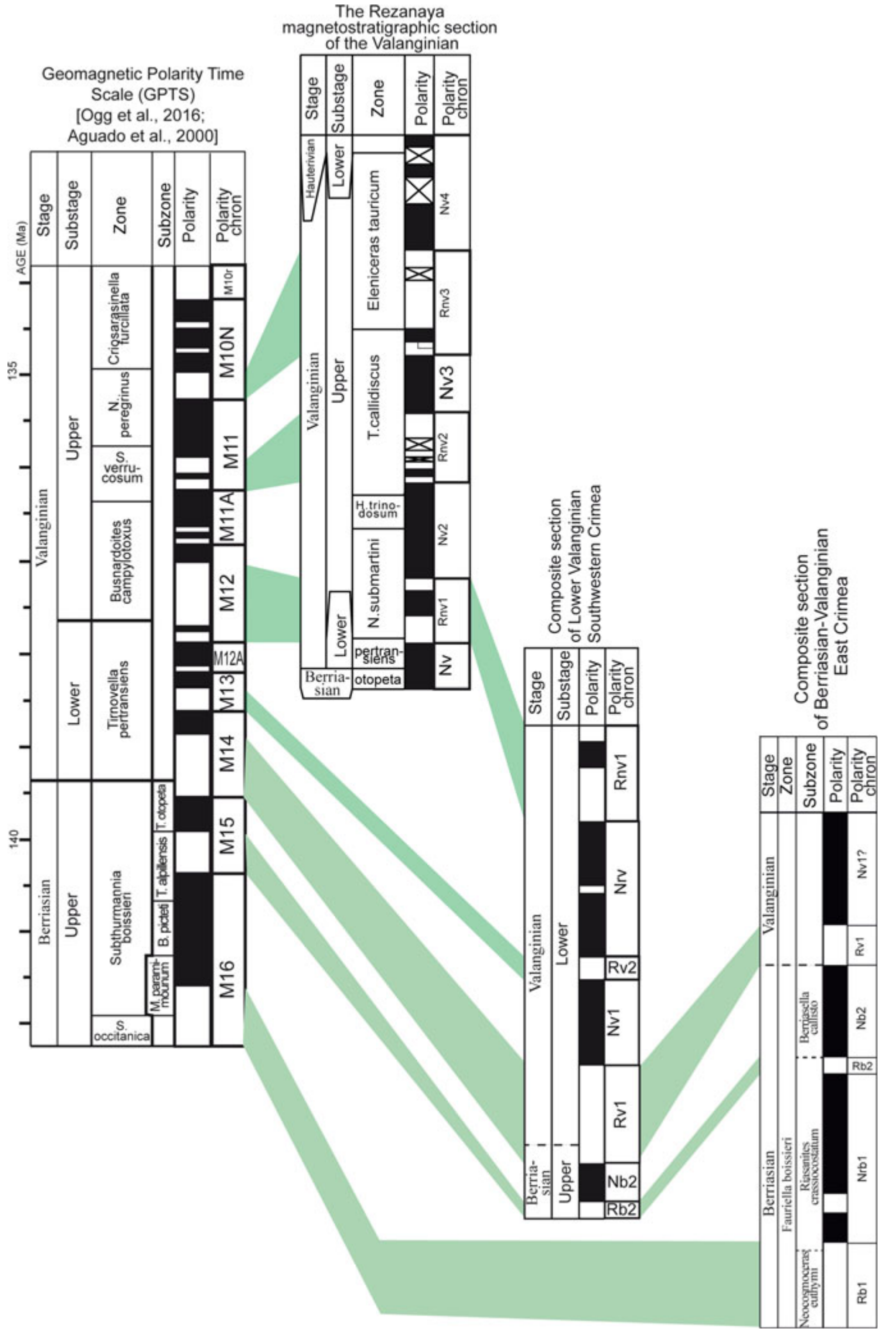


Fig. 9 General magnetostratigraphic scheme of the Valanginian in the Crimean Mountains

The cooccurrence of Berriasian-Valanginian species *Protocythere praetriplicata* and Valanginian-Barremian species *P. Triplicata* is noted for the Valanginian [2, 10]. In the upper part of the Rezanaya section, a transitional form *P.* ex gr. *Triplicata* was found. It is important to note that the representatives of *P. Triplicata* were found in the Hauterivian-Barremian of the Rezanaya section [38], that also does not contradict the hypothesis about the Valanginian age of the studied strata. In such manner, considering the available paleontologic and paleomagnetic data, established in the sections Dlinnaya, Sheludivaya, Patil-1, 2, Selbukhra and Bolshoi Kermen, the analogues of chrons M15—M12 may be identified in the composite magnetostratigraphic section of the Berriasian-Valanginian transition in the Crimean Mountains (Fig. 9).

The results of magnetostratigraphic data on the Rezanaya section contradict the biostratigraphic data on ammonites [12, 33]. The detected zone of mostly reverse polarity Rnv2, located within T. callidiscus zone, matches with magnetic chron M11r which is considered coeval with the ammonite zone S. verrucosum. However, considering $\delta^{13}C$ isotope data obtained from the Rezanaya section [18, 45] where isotope peak occurs within the ammonite zone T. callidiscus and $\delta^{13}C$ isotope data on the sections of Northern Mediterranean [18] where a similar peak is detected in the lower part of the ammonite zone N. Peregrinus, it is important to note a good correlation obtained with non-biostratigraphic methods. Assuming the proposed correlation, the overlying zone of mostly reverse polarity (Rnv3) is to be correlated with magnetic chron M10N, and the underlying subzone Rnv1 with magnetic chron M12. In this way, the analysis of obtained data allows to establish the following chrons: M12, M11A, M11, M10N in the section of mtn. Rezanaya (Fig. 9).

6 Conclusions

The microfaunistic analysis conducted for four sections of Southwestern Crimea allowed:

1. To establish four foraminiferal assemblages: "shorefase" complex with *Haplophragmium* ex gr. *Aequale* (middle Tithonian—lower Valanginian); complex with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *Aequale* (uppermost Berriasian—lower Valanginian); resedimented (?) complex with *Conorboides* cf. *Hofkeri* (uppermost Berriasian); complex with *Lenticulina espitaliei*, *Lenticulina* cf. *ouachensis* (Valanginian);
2. To trace the complex with *Lenticulina espitaliei*, *Haplophragmium* ex gr. *Aequale* in three sections;
3. To compare the complex with *Lenticulina espitaliei*, *Lenticulina* cf. *ouachensis*, established in the Rezanaya section in Southwestern Crimea, with the upper part of the Zavodskaya balka section and the middle-upper parts of the Koklyuk section of East Crimea using several common species;

4. The most part of the studied species of ostracods is known from the Berriasian of Crimea and the Caucasus, but they are reported mainly in open nomenclature. In the upper part of the Rezanaya section (complex with *Lenticulina espitaliei*, *Lenticulina* cf. *ouachensis*), an intermediate form between the species *Protocythere praetriplicata* (Berriasian—Valanginian) and *P. triplicata* (Valanginian—Barremian) was found, namely *P.* ex gr. *triplicata*. This form most likely indicates the Valanginian stage.

The paleomagnetic analysis allowed:

1. In the Zavodskaya Balka section, the Upper Berriasian biostratigraphic subdivisions have been for the first time recognized in a continuous succession: the Euthymi, Crassicostatum and Callisto subzones and magnetic chron analogues from M16n to M14r (Fig. 9).
2. Established in the sections Dlinnaya, Sheludivaya, Patil-1, 2, Selbukhra and Bolshoi Kermen, the analogues of chrons M15—M12 may be identified in the composite magnetostratigraphic section of the Berriasian-Valanginian transition in the Crimean Mountains (Fig. 9).
3. To establish next following chrons: M12, M11A, M11, M10N in the section of mtn. Rezanaya (Fig. 9).

By the results of correlation, the following conclusions were obtained:

1. A composite magnetostratigraphic section of the Valanginian for the Crimean Mountains was constructed and correlated with Geomagnetic Polarity Timescale (Fig. 9).
2. The sections located in East Crimea represent the fullest stratigraphic succession of the Berriasian-Valanginian boundary interval in the Crimean Mountains. In these sections, the presence of an age analogues of the T. otopeta zone has been substantiated and the base of the Valanginian stage has been traced by the analogy with West European sections, using the base of the M14r magnetic chron as a tie-point.
3. In Southwest Crimea the analogues of the majority of Valanginian magnetic chrons were detected. Despite a hypothetical character of the identification of the lower Valanginian magnetozones and their comparison with chrons M15-M12A, the obtained data allow to provide a detailed correlation of condensed lower Valanginian sections in Southwest Crimea.

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