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Developments in the Cretaceous Stratigraphy of Crimea. Part 1. Introduction and the Lower Cretaceous

E. Yu. Baraboshkin[a, g, *], **V. V. Arkadiev**[b], **A. Yu. Guzhikov**[c], **Yu. N. Savelieva**[d], **O. V. Shurekova**[e], **E. S. Platonov**[f], **and M. A. Ustinova**[g]

[a] *Geological Faculty, Moscow State University, Moscow, 119234 Russia*
[b] *Institute of Earth Sciences, Saint Petersburg State University, St. Petersburg, 199034 Russia*
[c] *Geological Faculty, Saratov State University, Saratov, 410012 Russia*
[d] *All-Russian Research Geological Oil Institute, Aprelevka Branch, Moskow Region, Aprelevka Town, 143360 Russia*
[e] *Department of Stratigraphy and Paleontology, Russian Geological Research Institute, St. Petersburg, 199106 Russia*
[f] *All-Russian Research Geological Oil Institute, Saint Petersburg Branch, St. Petersburg, 192019 Russia*
[g] *Department of Stratigraphy, Geological Institute of the Russian Academy of Sciences, Moscow, 119017 Russia*
**e-mail: EJBaraboshkin@mail.ru*

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Abstract—This paper summarizes the state of knowledge of the Cretaceous stratigraphy of the Mountainous Crimea and selected biostratigraphic groups and magnetostratigraphy. The first part of the paper discusses the Early Cretaceous, its stratigraphy, selected fossil groups and magnetostratigraphy of the Mountainous Crimea. The data on the figured reference sections were updated in terms of biostratigraphic zonation. Selected fossil groups represented in the paper include ammonites, organic-walled dinoflagellate cysts, ostracods, calpionellids and nannoplankton. The description of each group contains an information on the main publications, types of biostratigraphic units and their distribution, fossil assemplages, images of the most important fossils, and brief discussion on the correlation. Some of the ammonite index fossils are figured for the first time. The magnetostratigraphy summarizes latest data published mostly in Russian for the whole Early Cretaceous succession of the Mountainous Crimea.

Keywords: Early Cretaceous, ammonites, organic-walled dinoflagellate cysts, ostracods, nannoplankton, calpionellids, magnetostratigraphy

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INTRODUCTION

The Crimean Peninsula has a complicated geological structure, studied by many generations of geologists, but still causing controversy. The northern part of the peninsula is the Plain Crimea belonging to the Hercynian Scythian Platform. It is framed by the late Kimmerian folded structure of the Crimean Mountains in the south. The basement of the Plain Crimea is totally covered by Mesozoic–Cainozoic deposits thickening in the south-west in the Indol–Kuban Foredeep Basin (Fig. 1).

Cretaceous deposits are exposed in the Second Range of the Mountainous Crimea, and in the First Range (also known as the Main Range or the Yaila Plateau), they fill ancient depressions and grabens.

The rocks later referred to the Cretaceous were mentioned in the publications of P. Pallas, V. Zuev, and K. Gablitz in 18th century, but the first descriptions of the sections with the recognition of their Cretaceous age were given by Dubois de Montpéreux (1843–1845). Publications of E. Eichwald (1865–1868), W.H. Baily (1858), G.D. Romanovsky (1867), N.A. Golovkinsky (1890), A.A. Shtukenberg (1873) and R.A. Prendel (1876) made the basement of the Cretaceous geology of Crimea, but they focused on the general geological structure. Later the stratigraphy of the Lower Cretaceous of Crimea was discussed in the fundamental papers of N.I. Karakasch (1907), G.F. Weber (Weber and Malicheff, 1923), A.S. Moiseev, V.F. Pchelintzev, V.M. Muratov, M.S. Eristavi, V.V. Drushchits, T.N. Gorbachik, D.P. Naidin, N.I. Maslkova, I.A. Mikhailova, N.I. Lysenko, B.T. Yanin and others. The results of the stratigraphical and palaeontological study were published in "Atlas of the Upper Cretaceous fauna of the North Caucasus and Crimea" (Moskvin, 1959), "Atlas of the Lower Cretaceous fauna of the North Caucasus and the Crimea" (Drushchits, 1960), "Geology of the USSR" (Muratov, 1969), "Geology of the Shelf of the Ukrainian SSR" (Shnyukov, 1984), "Stratigraphy of the USSR. Cretaceous System" (Moskvin, 1986–1987),

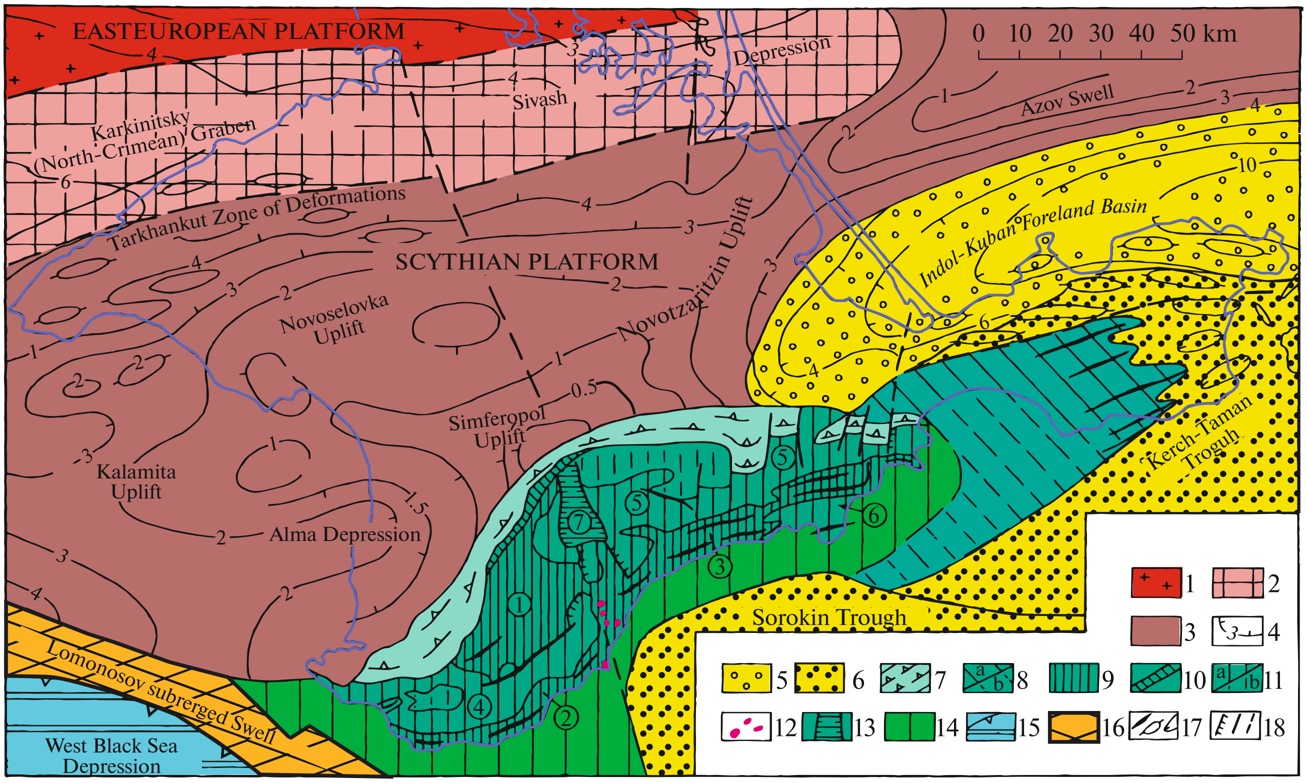


Fig. 1. Scheme of the tectonic structure of the Crimean Peninsula (Baraboshkin, 2016, after Milanovsky, 1996; Nikishin et al., 2015, with changes). (1) East European Platform; (2, 3) Plain Crimea structures: (2) North Crimean zone; (3) Scythian Platform; (4) stratoisohypses of the base of the Cretaceous-Cenozoic cover in zones 1–3, 5; Alpine Folded Belt: (5) Indol-Kuban Foredeep; (6) Kerch-Taman Trough, filled by N_1^2–N_2; (7, 8) folded structure of the Crimean Mountains: (7) northern monoclinal flank composed of K–Pg; (8) eastern pericline composed of Pg_3–N_1: (a) on the surface, (b) below the sea bottom; (9–13) the core of the folded structure: (9) anticlinoria, folded T_3–J_2, (10) Lozovskaya zone in the Kacha uplift, (11) troughs filled by J_3 (a) and K_1 (b), (12) intrusive bodies; (13) depressions filled by K_1al; (14) part of the core and the southern flank of the folded structure submerged in the Late Cenozoic; (15) Black Sea Depression; (16) Lomonosov submarine Massif; (17) linear and brachymorphic folds; (18) faults recognised and proposed. Numbers in circles are structural elements of the Crimean Mountains: uplifts: (1) Kacha; (2) South Coast; (3) Tuak Uplift with the Sudak-Karadag folded zone on its eastern margin; depressions: (4) SW Crimea, (5) Eastern Crimea, (6) Sudak, (7) Salgir.

"The Lower Cretaceous of the south of the USSR" (Benenson, 1985), "The Upper Cretaceous of the south of the USSR" (Aliev and Mirkamalov, 1986), and many scientific papers.

The present paper summarizes developments of the Cretaceous stratigraphy during the last 30–20 years. The most important Lower Cretaceous sections (Fig. 2) and selected fossil groups of macro- and microfossils are discussed in the first part of the paper. They are resulted in appearance of new detailed stratigraphic schemes of the Cretaceous rocks of the Mountainous Crimea. The current state of knowledge regarding some of these groups is presented here. The Berriasian ammonites (by V.V. Arkadiev), the Valanginian to Late Cretaceous ammonites (by E.Yu. Baraboshkin), and the Early Cretaceous ostracods (by Yu.N. Savelieva, organic-walled dinoflagellate cysts (by O.V. Shurekova), calpionellids (by E.S. Platonov), nannoplankton (by M.A. Ustinova) and others have also made significant contributions to the field. Several fossil groups are not included in this paper, but one can find additional information in the monographs on bivalves (Yanin, 1989, 2004, 2021), brachiopods (Smirnova, 1972), corals (Kuzmicheva, 1987), foraminifers (Gorbachik, 1986), crustaceans (Ilyin, 2005), radiolarians (Vishnevskaya, 2001; Bragina, 2016), and Cretaceous sharks (Trikolidi, 2014).

The investigation was completed by non-paleontological methods (magnetostratigraphy and stable isotopes), and an overview of Cretaceous magnetostratigraphy is presented by A.Yu. Guzhikov (Saratov). Stable isotopes data are not sufficient yet, but some of them were published by Gröcke et al. (2005) and Fisher et al. (2005). The U–Pb data were obtained from volcanic material originating from the town of Balaklava (Nikishin et al., 2013; Shnyukova, 2016).

The figured fossils are from the collections of CNIGR Museum (Chernyshev Central Research Geological Museum), St. Petersburg, Russia, the Earth Science Museum at Moscow State University, Moscow,

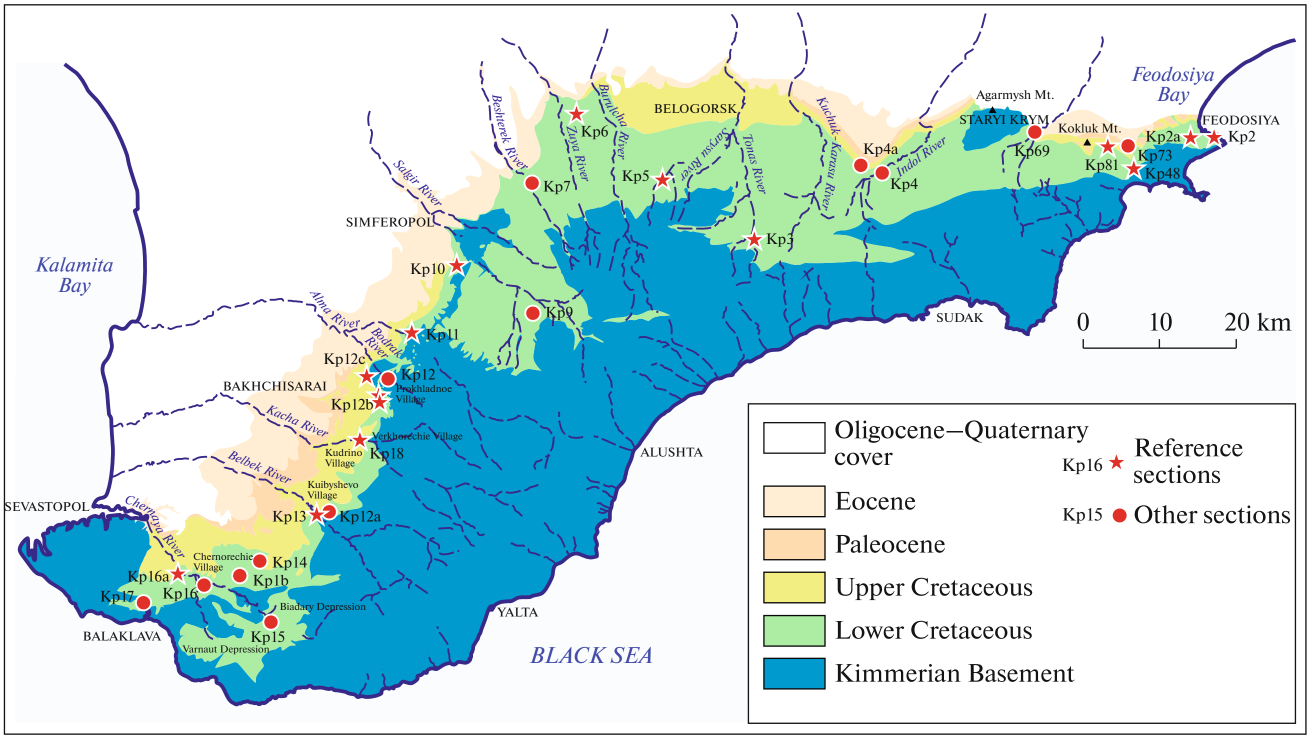


Fig. 2. Simplified scheme of the distribution of the Lower Cretaceous deposits in the Mountainous Crimea and main localities mentioned in the text. **Reference sections:** Kp2, Feodosiya City (Dvuyakornaya Bay, Feodosiya Cape, Saint Elias Cape); Kp2a, Zavodskaya Balka; Kp3, Tonas River (Krasnoselovka, Alekseevka villages, Kuchuk-Uzen creek); Kp5, Balki, Novoklenovo, Mezhgorie, Zelenogorskoe villages, Baksan Mountain, Enisaraj ravine, Sarysu River; Kp6, Krymskaya Roza Quarry (Kunich Mountain); Kp11, Partizanskoe village; Kp12, Prokhladnoe village (including Sheludivaya, Dlinnaya, Bolshoy Kermen Mountains); Kp12b, Selbukhra Mountain; Kp12c, Mender Mountain; Kp13, Kabanyi Log, Belbek River; Kp16a, Chernaya River, Chernorechie village; Kp18, Verkhorechie village (Rezanaya–Belaya Mountains); Kp48, Nanikovo and Sultanovka [Yuzhnoe] villages; Kp81, Koklyuk, Klement'eva, and Brodskaya Mountains. **Other sections**: Kp1b, Menester gully; Kp4, Kurskoe, Topolevka, Grushevka villages; Kp4a, Kubalach Mountain; Kp7, Mazanka–Litvinenkovo villages; Kp9, Mramornoe quarry and Taskor ravine, Chatyr-Dag Mountain; Kp10, Mar'ino quarry, Simferopol; Kp12a, Sbrosovyi Log, Sukhoi Log, Belbek River; Kp14, Ternovka village; Kp15, Baidary depression; Kp16, Gasforta Mountain; Kp69, town of Staryi Krym.

Russia (MSU), The Moscow State University Field Station in Crimea, Russia (FS MSU), and Museum of the Palaeontological Institute, Moscow, Russia (PIM), Museum of the University of National Mineral Resources (Mining University, Saint Petersburg) and the Paleontological Museum of Saint Petersburg State University.

THE LOWER CRETACEOUS SUCCESSION

The Lower Cretaceous of Crimea, in contrast to the uniform Upper Cretaceous, has a much more complex structure and diverse composition (Fig. 3).

The base of the Cretaceous System and the Berriasian Stage was accepted at the base of the Berriasella jacobi ammonite Zone. Berriasian deposits inherit the main features of the Tithonian. At this time, a distally steepened ramp developed in Crimea. The northwestern part of the ramp was shallow (Krajewski, 2010; Piskunov, 2013; Arkadiev et al., 2015a). The eastern part was submerged along a system of faults and was characterized by deep-sea sedimentation with the presence of debrites and calciturbidites (Guzhikov et al., 2012; Baraboshkin et al., 2022). The activity of the faults decreased during the Berriasian.

In the Plain Crimea and on the Kerch Peninsula, the Berriasian was discovered in boreholes only in the southeast, where it is composed of bioclastic limestones, marls, siltstones, sandstones and conglomerates up to 500–600 m thick (Krinichki and Tambovka villages) containing ammonites *Euthymiceras* sp., foraminifers *Melathrokerion spirialis* Gorb. and others (Drushchits, Gorbachik and Kamenetzky in Moskvin, 1986–1987).

Berriasian rocks are widely distributed within the Main and Second ranges of the Crimean Mountains. Their typical features are sharp facies variability, considerable differences in rock thickness, and incompleteness of geological sections. The latter is caused by sophisticated tectonics of the region.

Crimean Berriasian deposits have been studied by many geoscientists (Retowski, 1893; Drushchits and Yanin, 1959; Druschits, 1975; Bogdanova et al., 1981, 1999; Glushkov, 1997). Since 2001, the Berriasian of the Mountainous Crimea has been explored by a large team of Russian geoscientists. An integrated (biostra-

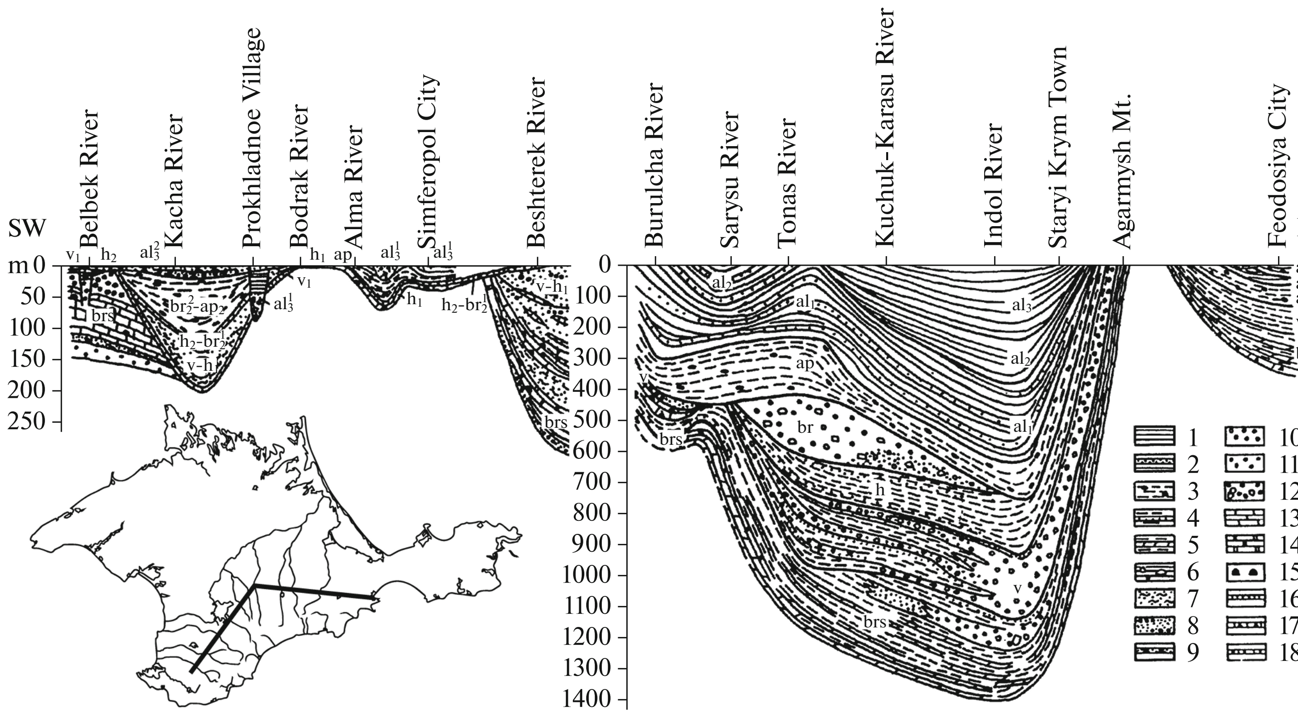


Fig. 3. Schematic geological profile of the Lower Cretaceous of the Mountainous Crimea (Baraboshkin, 2003, with changes). (1) Dark mudstones (K_1al); (2) alternation of mudstones and sandstones; (3) mudstones with ankerite concretions (K_1br–ap); (4) mudstones with sandstone beds (K_1brs, K_1v, K_1h); (5) alternation of mudstones and marls (K_1br$_1$); (6) mudstones with boulders (K_1al$_2^1$); (7) siltstones and sandstones (K_1brs–h$_1$); (8) alternation of soft and hard sandstones; (9) sandstones (K_1v–h); (10) quartz conglomerates (K_1brs$_2$); (11) polymictic conglomerates (K_1brs$_1$); (12) conglomerates (K_1brs–h); (13, 14) limestones (grain-packstones) (K_1brs$_{1-2}$); (15) coral-algal bioherms (K_1brs, K_1h$_1$); (16) cephalopod limestones (K_1h$_2$–br$_2$); (17) brecciated limestones (K_1brs$_1$); (18) "pudding" conglomerates and sandstones (K_1v). Note change in vertical scale.

tigraphic, magnetostratigraphic, and sedimentological) research of upper Tithonian–Berriasian sections was accomplished there. Over 30 sections have been studied in southwestern, central and eastern Crimea. As a consequence of biostratigraphic investigations, the Berriasian zonal scheme and the ages of formations assigned to the Berriasian Stage were updated (Bogdanova and Arkadiev, 1999, 2005; Arkadiev et al., 2000, 2006, 2008, 2010, 2012, 2015a, 2015b, 2017, 2018a, 2019; Arkadiev, 2007a, 2007b, 2020, 2022; Guzhikov et al., 2012; Platonov et al., 2014; Platonov, 2016; Savelieva et al., 2017; Baraboshkin et al., 2019; Table 1). A group of contemporary European scientists suggested their option of bio- and magnetostratigraphic stratifications of the Berriasian key section located in the vicinity of the city of Feodosiya in eastern Crimea (Bakhmutov et al., 2016, 2018).

In eastern Crimea (Fig. 2: Kp2) and the Tonas River basin (Fig. 2: Kp3), two formations were assigned to the Berriasian—the Dvuyakornaya and Sultanovka formations. The lower part of the Dvuyakornaya Formation section is characterized by upper Tithonian ammonites. Both sections are very similar in sedimentary style but significantly differ from central and southwestern Crimea sections (Arkadiev, 2007a; Baraboshkin et al., 2022).

The reference section of the Tithonian–Berriasian boundary interval (Dvuyakornaya Formation) is located near Feodosiya (Fig. 2: Kp2), in the Dvuyakornaya Bay, at Saint Elias Cape and Feodosiya Cape (Guzhikov et al., 2012; Arkadiev et al., 2018) (Figs. 4, 5). The upper Berriasian (Sultanovka Formation) and its assumed contact with the Valanginian are well studied and described at the Zavodskaya Balka quarry (Fig. 2: Kp2a) in the northern outskirts of Feodosiya (Baraboshkin et al., 2019), near the village of Nanikovo, on Koklyuk Mountain and near the village of Sultanovka (Fig. 2: Kp48). The Feodosiya section is currently one of the most extensively studied sections in the field. The biostratigraphic subdivision of the section was made on the basis of ammonites, foraminifers, ostracods, calpionellids, organic-walled dinoflagellate cysts, and calcareous nannoplankton, with detailed research of trace fossils and lithology. A magnetostratigraphic scheme was also created (Guzhikov et al., 2012; Arkadiev et al., 2018b, 2019).

The Dvuyakornaya Formation (400 m) is subdivided into two subformations. The lower subformation consists of channel and levee calciturbidites and pelagic mudstones with sideritic nodules (Guzhikov et al., 2012). The upper subformation consists mainly of pelagic mudstones and marls named "Feodosiya marls."

Table 1. Development of the zonal subdivision of the Berriasian of the Crimean Mountains

Ammonite standard zonation of the Berriasian for the West Mediterranean Province (Reboulet et al., 2018)		Crimean Mountains: Kvantaliani and Lysenko, 1979		Bogdanova et al., 1981	Glushkov, 1997		Arkadiev et al., 2012		Arkadiev et al., 2018b	
Tirnovella alpillensis	"Thurmanniceras" otopeta	?		?	?		Valanginian	Otopeta Zone		?
	Tirnovella alpillensis			Layer with Zeillerina baksanensis			Fauriella boissieri	?		
Fauriella boissieri	Berriasella picteti	Fauriella boissieri			Berriasella callisto			Beds with *Jabronella* cf *paquieri* and *Berriasella callisto*	Fauriella boissieri	Berriasella callisto
				?	Fauriella simplicicostata			?		?
				Bed with Symphythyris arguinensis				Beds with *Symphythyris arguinensis*		Riasanites crassicostatum
		Tauricoceras crassicostatum		Bed with Tauricoceras crassicostatum	Tauricoceras			Riasanites crassicostatum Subzone		
	Malbosiceras paramimounum	Euthymiceras euthymi		Bed with Euthymiceras and Neocosmoceras	Euthymiceras–Balkites			Neocosmoceras euthymi Subzone		Neocosmoceras euthymi
					Dalmasiceras khimchiachvili	?		?		?
Subthurmannia occitanica	Dalmasiceras dalmasi	Dalmasiceras dalmasi		Lenses Dalmasiceras crassicostatum			Tirnovella occitanica	Dalmasiceras tauricum Subzone	Tirnovella occitanica	Dalmasiceras tauricum
	Berriasella privasensis	Spiticeras spitiense		Layer with Malbosiceras (?) sp.		Berriasella privasensis		Beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*		Beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*
					Subalpinites remanei					
	Subthurmannia subalpina							?		?
Berriasella jacobi		Zone P. grandis–B. jacobi	Malbosiceras malbosi Subzone (?)		Malbosiceras nikolovi	Delphinella janus	Berriasella jacobi	Beds with *Malbosiceras chaperi*		Beds with Malbosiceras chaperi
			Pseudosbplanites euxinus Subzone	Pseudosubplanites ponticus–P. grandis				Pseudosubplanites grandis	Berriasella jacobi	Pseudosubplanites grandis
			Pseudosubplanites grandis Subzone		Pseudosubplanites subrichteri			Berriasella jacobi		Berriasella jacobi

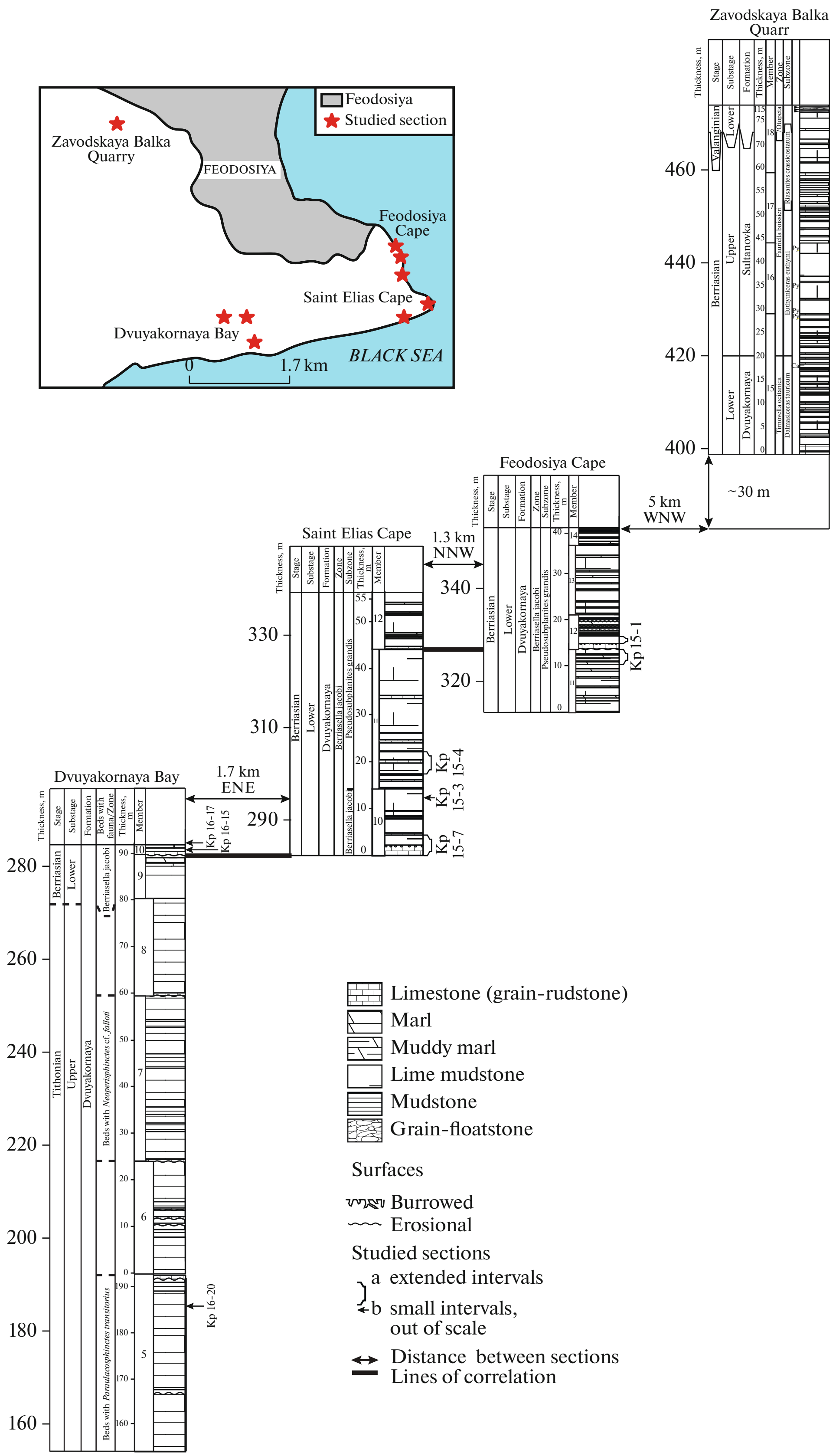


Fig. 4. Feodosiya (Saint Elias Cape, Dvuyakornaya Bay, Feodosiya Cape, Fig. 2: Kp2) and Zavodskaya Balka Quarry (Fig. 2: Kp2a) reference sections correlation (after Baraboshkin, 2017, with changes).

Fig. 5. Saint Elias Cape reference section (after Baraboshkin, 2016, with changes). Photo by E.Yu. Baraboshkin made in 2015.

The Sultanovka Formation (200 m) is represented by dark-grey carbonate mudstones with rare interbeds of sandstones and limestones, and marly concretions. Its contact with the Dvuyakornaya Formation remains known. The boundary with the overlying Nanikovo Formation is conformable.

The Berriasian of central and southwestern Crimea is defined by the Bechku and Kuchki formations with the exception of the section of the Belbek River. The upper part of the carbonate Bedenekyr Formation in central Crimea was also assigned to the Berriasian (Bogdanova et al., 1981; Arkadiev et al., 2015a). The Berriasian section of central Crimea was studied in the vicinity of Novoklenovo, Balki, and Mezhgorie villages (Fig. 2: Kp5). The section (600 m) consists of (from bottom to top) packstones and marls of the upper Bedenekyr Formation; siltstones and sandstones of the Bechku Formation; sponge packstones, clays, marls, siltstones and coral-algal reefal framestones of the Kuchki Formation. The Berriasian age of the upper part of the Kuchki Formation was confirmed by the unique find of the ammonite *Malbosiceras* cf. *malbosi* (Pict.) (Arkadiev, 2022).

The Belbek River reference Berriasian section is represented by (from bottom to top) (Arkadiev et al., 2012): Bechku Formation, Kuchki Formation, and Albat Member. Bechku Formation overlays the Belbek Member, which consists of polymictic conglomerates (40 m) with sandy-clayey matrix. It unconformably overlies the Early Jurassic Tauric Group and is uncomfortably covered by the Bechku Formation. Its provisional age is Late Jurassic (Drushchits, 1975; Baraboshkin, 2016). This member is limited to the Belbek River Basin.

The Albat Member consists of quartz conglomerates (70 m) with carbonate cement. The unit does not contain ammonites and its Berriasian age is also provisional (Baraboshkin, 2016). It occurs in the Belbek River Basin and in central Crimea.

The reference section of the Bechku and Kuchki formations of the Belbek River is located in the Kabanyi Log Ravine (Fig. 2: Kp13) and has been the subject of extensive study by numerous geologist (Bogdanova and Arkadiev, 1999; Yanin and Baraboshkin, 2000; Arkadiev et al., 2002, 2018b). The Bechku formation is represented by interbedded siltstones, sandstones and limestones. The Kuchki formation is composed of a "sponge horizon" at the bottom, siltstones in the middle part, and biohermic limestones at the top.

In the area of the Baidary depression (Fig. 2: Kp15), the lower Berriasian is composed of alternating siltstones, sandstones, and limestones (36 m) or limestones (45 m) with inclusions of gravelstones or conglomerates with dinocysts, ostracods and ammonites *Fauriella* sp., *Pseudosubplanites subrichteri* (Ret.), and

Berriasella subcallisto (Touc.) (Shurekova et al., 2022a). These rocks are overlain by sandstones (3–5 m) with lenses of bioclastic limestones with *Dalmasiceras crassicostatum* Djan. and *Dalmasiceras* sp. The upper Berriasian is represented by intercalation of siltstones, sandstones, and rare limestones (30–50 m thick). In the same area, there is also a "sponge horizon," the thickness of which does not exceed 20–25 m.

The **Valanginian** deposits are found to overlie a range of rock units of varying ages, and are represented by a wide variety of facies, which vary in thickness. In the southwest of the peninsula (Varnaut and Baidary depressions), lower Valanginian clays and sandstones (up to ≥300 m) overlie Tithonian and Berriasian rocks with erosion (Drushchits, 1960). Similar clays were found in the Gasfort quarry (Balaklava region, Fig. 2: Kp16). They contain pyritized ammonites of the early Valanginian Campylotoxia campylotoxa Zone: *Campylotoxia campylotoxa* (Uhl.) and *Phyllopachyceras*? sp. (Baraboshkin et al., 2002). The stratigraphy of these clays needs to be clarified, since a thin (0.15 m) condensed Fe-oolitic conglomerate of brown shallow-water limestones lies nearby in the Menester gully (Rodnoe village region, Fig. 2: Kp1b) on the upper Berriasian limestones. The conglomerate contains the early and late Valanginian *Thurmanniceras* sp., *Neohoploceras* sp. (N.I. Lysenko collection). The olive-gray clays with Valanginian–early Hauterivian *Didayilamellaptychus didayi* (Coq.) overlie this conglomerate.

More complete sections of the Valanginian were traced and described in terrigenous to carbonate-terrigenous facies from the Belbek river (Fig. 2: Kp12a) to the Bodrak river (Baraboshkin in Arkadiev and Bogdanova, 1997; Baraboshkin and Yanin, 1997; Baraboshkin and Mikhailova, 2000; Baraboshkin, 2016). The rocks (Rezanskaya Formation) can be attributed to the middle- to lower shoreface and shallow-marine deposits, the maximum thickness (about 50 m) and completeness of which are best represented in the section near Verkhorechie village (Fig. 2: Kp18; Figs. 6, 7). It is the reference section of the Valanginian of the Crimean Mountains (Figs. 5a, 5b), which original name was Biasala. It is the main section studied by Karakasch (1907).

To the northeast, in the Bodrak River Basin (near Prokhladnoe village and on the right bank of the Bodrak River (Fig. 2: Kp12)), the shallow-marine succession is replaced by upper shoreface cross-bedded sandy limestones and sandstones with early Valanginian ammonites *Thurmanniceras* spp., *Bodrakiceras inostranzewi* (Kar.) and *Karakaschiceras biassalense* (Kar.) (Baraboshkin and Yanin, 1997; Baraboshkin and Mikhailova, 2000; Baraboshkin, 2016). The top of the sections is truncated by the early Hauterivian coral reef and sandy shoreface facies.

Continental to marine terrigenous facies of the Valanginian (Mazanka Formation) are exposed in the region of Mazanka, Litvinenkovo and Zuya villages of

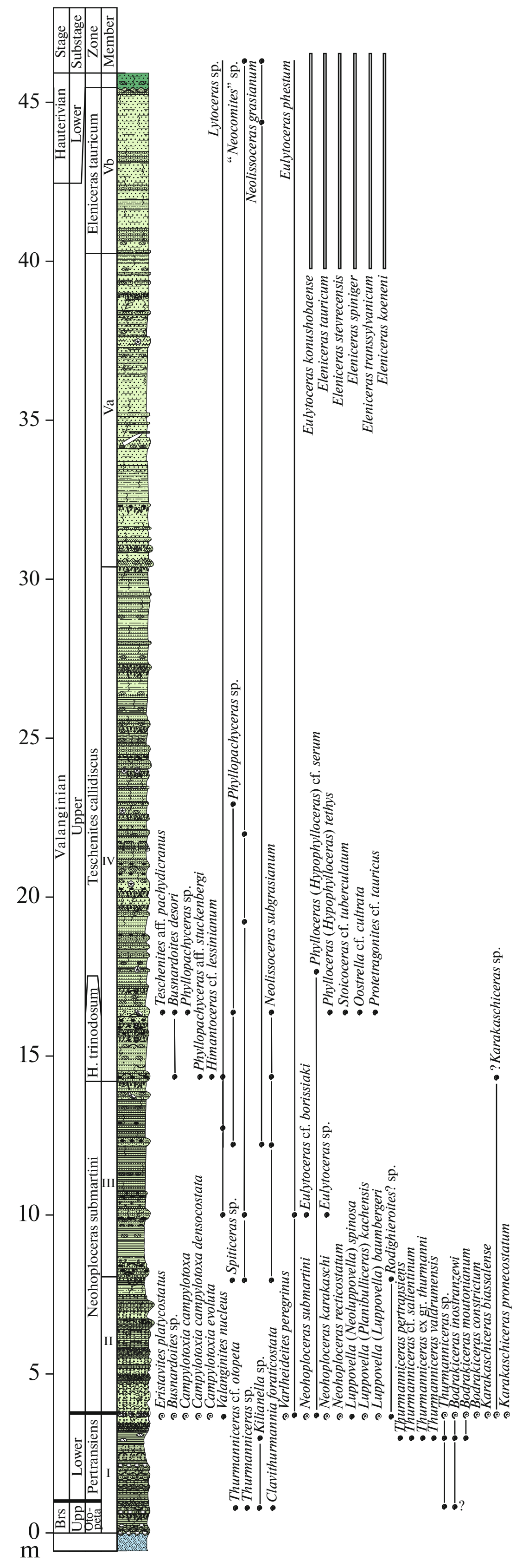


Fig. 6. Rezanaya Mountain reference section near Verkhorechie village (Fig. 2: Kp18) (after Baraboshkin and Yanin, 1997, with changes). Fore the legend see Fig. 9.

Fig. 7. Rezanaya Mountain reference section near Verkhorechie village. Photo by E.Yu. Baraboshkin made in 2017.

central Crimea (Fig. 2: Kp6-7). Valanginian ammonite *Neocomites (Neocomites) neocomiensis* (d'Orb.) was found in the sandy gravel shoreface facies in the top of the Krymskaya Roza quarry (Fig. 2: Kp6; Fig. 8), which is the reference section of the central Crimea Valanginian (see below). Previously this ammonite was determined as late Valanginian *Teschenites flucticulus* Thieul. (Baraboshkin and Yanin, 1997; Baraboshkin, 2016). The re-examination of this rare ammonite finding yielded new insights. It was determined that the upper part of the Mazanka Formation is slightly older than previously thought, but the age of the lower part, represented by continental alluvial facies, remains uncertain. Nevertheless, the presence of early Valanginian deposits transgressively overlying the latest Berriasian indicates that the gap between them was very short.

The Mazanka Formation is interpreted as transgressive deltaic succession (Baraboshkin and Yanin, 1997; Baraboshkin, 2016) and localized only in central Crimea. The source of sediments was in the Plain (Steppe) Crimea, where thickness of the formation reaches 200–300 m, whereas in the Mountainous Crimea only 60–100 m. The origin of this delta is evidenced by sandy composition, the presence of well-washed proluvium, types and orientations of crossbedding (Baraboshkin, 2016), and the presence of marine facies of the Valanginian in the south. In the late Valanginian, the southern margin of the fen began to be flooded by the sea and was transformed into a fen-delta, which was completely submerged in the early Hauterivian, when the coastline of the basin advanced far into the Plain Crimea. An alternative interpretation of the Masanka Formation also exists (Dubkova et al., 2022).

In the northern slope of the Main Ridge, Valanginian deposits are developed in muddy shelf-type facies (Baraboshkin, 2016). They are present in the Varnaut and Baidary depressions, in the northern slope of Chatyr-Dag Mountain (Mramornoye village quarry, Fig. 2: Kp9) and Dolgorukov Yayla (Plateau), where Valanginian *Didayilamellaptychus didayi* (Coq.), *Neocomites neocomiensis* (d'Orb.) and *Duvalia dilatata* (Blainv.) are known (Lysenko and Vakhrushev, 1974 and the author's data).

In eastern Crimea, the Valanginian includes pelagic calcareous clays (more than 100 m) with *Duvalia conica* (Blainv.) and *Pseudobelus bipartitus* (Blainv.) (Muratov, 1937). In the section near Yuzhnoye village (Fig. 2: Kp48), these clays contain ammonites (Baraboshkin, 2016). In the Plain Crimea, presumably Valanginian deposits were discovered in wells near the villages of Tambovka, Krinichki, Saki and on the Kerch Peninsula in the area of the village of Moshkarevka (Benenson, 1985). They are closely related to the Berriasian succession and composed of silty clays

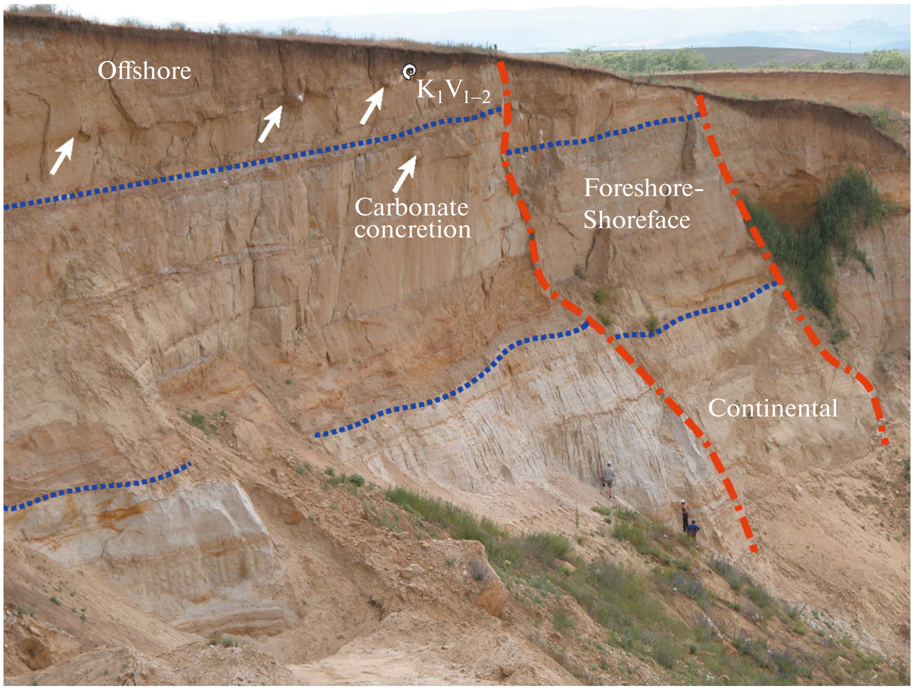


Fig. 8. Krymskaya Roza quarry Valanginian reference section (does not exist now). Dashed lines: red, normal faults; blue, approximate boundaries of environmental changes. Ammonite symbol marks the position of *Neocomites (Neocomites) neocomiensis* (d'Orb.) find (see Figs. 23r–23t). Photo by E.Yu. Baraboshkin made in 2003.

with layers of limestones, marls, sandstones, with siderite nodules.

The **early Hauterivian** succession resembles the Valanginian one. The substage is represented in shallow-marine to shoreface facies (50 m) of the Rezanskaya Formation in the reference section on the slope of Belaya Mountain (Figs. 9, 10) near Verkhorechie village (Fig. 2: Kp18). The important sequence boundary locates at the base of the Theodorites theodori Zone. This boundary reflects the strongest sea-level drop in the interval and the beginning of quick transgression and possibly coincides with Kha1 sequence (Gradstein et al., 2020). The boundary can be easily distinguished in the most of early Hauterivian sections of Crimea. Shallow-marine to near-shore terrigenous deposition took place in the north and north-west (Kacha–Bodrak–Alma–Salgir–Burulcha rivers). The thickness of the deposits does not exceed 100–200 m.

Specific facies of the lower Hauterivian are located in the interfluve of the Bodrak and Salgir rivers. They are represented by a thin (3–16 m) patch coral reef confined mainly to the solid substrate of the Jurassic basement and intrusions (Baraboshkin, 1997a, 2016). According to Kuzmicheva (1985), the reef is composed of scleractinian *Stylina*, *Ellipsocoenia*, *Eugyra*, *Thamnastraea*, *Actinastraea*, *Agathelia*, *Dimorphocoenia*, *Placocoenia*, *Cyathophora*, *Meandraraea*, *Montlivaultia*, *Diplocaenia*, and other corals. In addition, it contains numerous sponges, bivalves, gastropods, brachiopods and the extremely rare ammonite species *Leopoldia desmoceroides* (Kar.). The biotic assemblage indicates extreme shallow marine environments with active hydrodynamics. The extinction of the reef was due to the influx of terrigenous material and the formation of sandy shoreface facies of the Theodorites theodori Zone.

On the watershed of the Beshterek and Zuya rivers (Kunich Mountain, Fig. 2: Kp6) in central Crimea, the unit of sandstones, clays and sandy limestones (25–30 m) occurring above the Valanginian Mazanka Formation belongs to the lower Hauterivian. Baraboshkin (1997a, 1997b) found *Spitidiscus rotula inflatum* Thiel. in the middle part of this sequence, indicating the presence of analogues of the Nodosoplicatum zone. In addition, from the base of the section, *Acanthodiscus* sp., *Crioceratites* sp., and *Crioceratites nolani* (Kil.) were collected by N.I. Lysenko and determined by Baraboshkin. These finds indicate the presence of the lower part of the lower Hauterivian in the section.

Early Hauterivian muddy pelagic facies (tens of meters) were reported from the Mramornoe quarry on the Chatyr-Dag Mountain slope (Baraboshkin, 1997a; Fig. 2: Kp9), the Belbek River (Savelieva and Shurekova, 2014; Fig. 2: Kp12a), and the Feodosiya region (Baraboshkin et al., 2012). In other places, the Valanginian–Hauterivian transition and the early Hauterivian age of this muddy pelagic succession have to be studied in the future.

Hauterivian deposits transgressively overlie older rocks in the Plain Crimea. The thickness of the

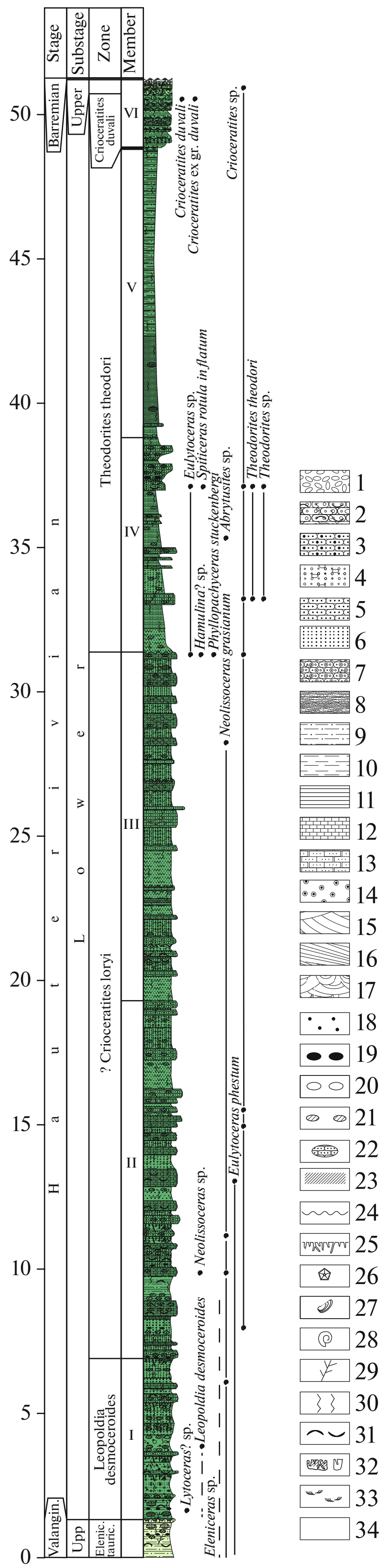


Fig. 9. Belaya Mountain reference section near Verkhorechie village, lower Hauterivian (Fig. 2: Kp18) (after Baraboshkin, 1997a, with changes).

Hauterivian reaches 400 m in the Indol trough (Benenson, 1985; Leshchukh, 1987).

Crimean paleogeography changed during the late Hauterivian. The marine basin underwent deepening, and a transgressive condensed section (up to 2 m) of "cephalopod limestones" formed in the modern western and central Mountainous Crimea (Baraboshkin, 1997a, 2016; Baraboshkin and Enson, 2003). These facies were replaced by thin (tens of meters) "aptych clays" with *Didayilamellaptychus angulicostatus* (Pict. et Lor.). These clays can be differentiated from Valanginian–? early Hauterivian clays only by fossil remains. This allows to assume that the Crimean Mountains were covered by the sea and could not be a source of clastic material, as is considered in several works (Kamenetsky, 1963; Gnidets, 1986; Gnidets et al., 2010; Dubkova et al., 2022).

"Cephalopod limestones" (Koyas-Dzhilga Formation) can be traced from the watershed of the Belbek River (Fig. 2: Kp12a) in the west to Ivanovka, Mazanka and Litvinenkovo villages (Fig. 2: Kp7) in the east. They overlie rocks of different ages (from the Triassic to the lower Hauterivian) and penetrated by wells on the Simferopol uplift (Benenson, 1985). The rocks are characterized by rich and diverse cephalopod-dominated assemblages of fossils, described by Karakasch (1907) in the Verkhorechie village reference section (Figs. 11, 12). The stratigraphic range of the condensed section covers the upper Hauterivian, lower Barremian, and the lower part of the upper Barremian (Baraboshkin, 1997a, 2016; Baraboshkin and Mikhailova, 2020). Among the numerous Tethyan forms in the upper part of the Hauterivian part of the section, there is a significant number of Boreal ammonites *Speetoniceras*, *Simbirskites*, *Milanowskia* and occasional Boreal inoceramids *Heteropteria*.

The shallow sea completely covered the Plain Crimea in the late Hauterivian. Sandstones and mudstones (20 to 200 m) with interlayers of bioclastic limestones were formed here (Gnidets et al., 2010), which yield a depleted foraminiferal assemblage. These predominantly upper Hauterivian deposits accumulated during the development of transgression, as evidenced by the find of ammonite *Crioceratites* ex gr. *duvalii* (Lev.) in Soldatovskaya-1 well (Leshchukh, 1987). In the Indol-Kuban trough, Hauterivian–lower Barremian deposits are composed of mudstones and sandstones with foraminiferal assemblage *Spiroplectammina magna* Ant. et Kal., *Planularia tricarinella* (Reuss.), *Gaudryina tuchaensis* Ant., *Neobulimina* aff. *media* Ant. (Nizhnegorsky well: Benenson, 1985).

Pelagic clays accumulated in the south of the Mountainous Crimea from latest Hauterivian until the late Aptian. The muddy succession with *Didayilamellaptychus angulicostatus* (Pict. et Lor.), overlying Tithonian limestones and Valanginian clays was recognized in the southwest (Gasfort Mountain: Fig. 2: 16). The early Aptian age of mudstones with olistostrome

Fig. 10. Belaya Mountain reference section near Verkhorechie village, Valanginian–Hauterivian boundary interval. Photo by E.Yu. Baraboshkin made in 2019.

horizons (Nikishin et al., 2015) was confirmed by nannoplankton and foraminifers (Shcherbinina and Loginov, 2012; Brovina, 2012) in the Balaklava quarries. Upper Hauterivian clays (20 m) unconformably overlie lower Valanginian deposits and contain aptychs *Didayilamellaptychus angulicostatus* (Pict. et Lor.), belemnites *Duvalia dilatata* (Blainv.) and microfossil assemblages (Baraboshkin, 1997a, 2016; Savelieva and Shurekova, 2014) in the Sbrosovyi Log, the Belbek River (Fig. 2: 12a).

The Barremian-Aptian reference sections were described in the basins of Kacha, Bodrak, Alma and Salgir rivers (Drushchits et al., 1981; Baraboshkin et al., 2004; Yampolskaya et al., 2006; Mikhailova and Baraboshkin, 2009; Shcherbinina and Loginov, 2012; Baraboshkin, 2016; Karpuk, 2016a). At present, the age of these deposits is based on ammonites, foraminifers, ostracods, nannoplankton, and paleomagnetic data. The whole succession is composed by greenish-gray and reddish clays of Biasala Formation (150–170 m in total) with siderite and ankerite layers and nodules. Each part of this succession is incomplete, is preserved locally in depressions and grabens and overlies rocks of different age. In the basins of the Kacha and Bodrak rivers (Fig. 2: Kp12b, Kp18), the upper Barremian–lower Aptian succession is best preserved (Fig. 13). The middle Aptian is represented in the Alma River section near Partizanskoe village (Fig. 2: Kp11) (Shcherbinina and Loginov, 2012), and the middle-upper Aptian is exposed in Ukrainka and Mar'ino villages near the city of Simferopol (Fig. 2: Kp10). Rare ammonite finds of *Colombiceras* sp., *Parahoplites multicostatus* (Sinz.), *Acanthohoplites* ex gr. *aschiltaensis* (Anth.) were reported from the Mar'ino quarry (Drushchits et al., 1981).

Valanginian to Aptian pelagic mudstones were described on the northern slope of Chatyr-Dag Mountain in the quarry near Mramornoe village (Lysenko and Vakhrushev, 1974; Baraboshkin, 1997a, 2016; Baraboshkin and Yanin, 1997; Fig. 2: Kp9). The thickness of Aptian mudstones in this region and in the Salgir River basin ("Salgir Depression") is estimated as 200–300 m (Bashilov, 1957).

The thickness of these clays rises to 450 m eastward in the direction of Karasevka village, where early Barremian ammonites were reported from red-colored limestiones: *Metahoplites ziczac* (Kar.), *Avramidiscus fallacior* (Coq.), and *Emericiceras emerici* (Lev.) (Moisseiev, 1937).

The Barremian–Aptian succession of central and eastern Crimea is also represented by clays. Their thickness decreases from 200 m on the Burulcha and Sarysu rivers to 30–50 m to Feodosiya. These clays contain belemnites *Neohibolites ewaldi* (Stromb.),

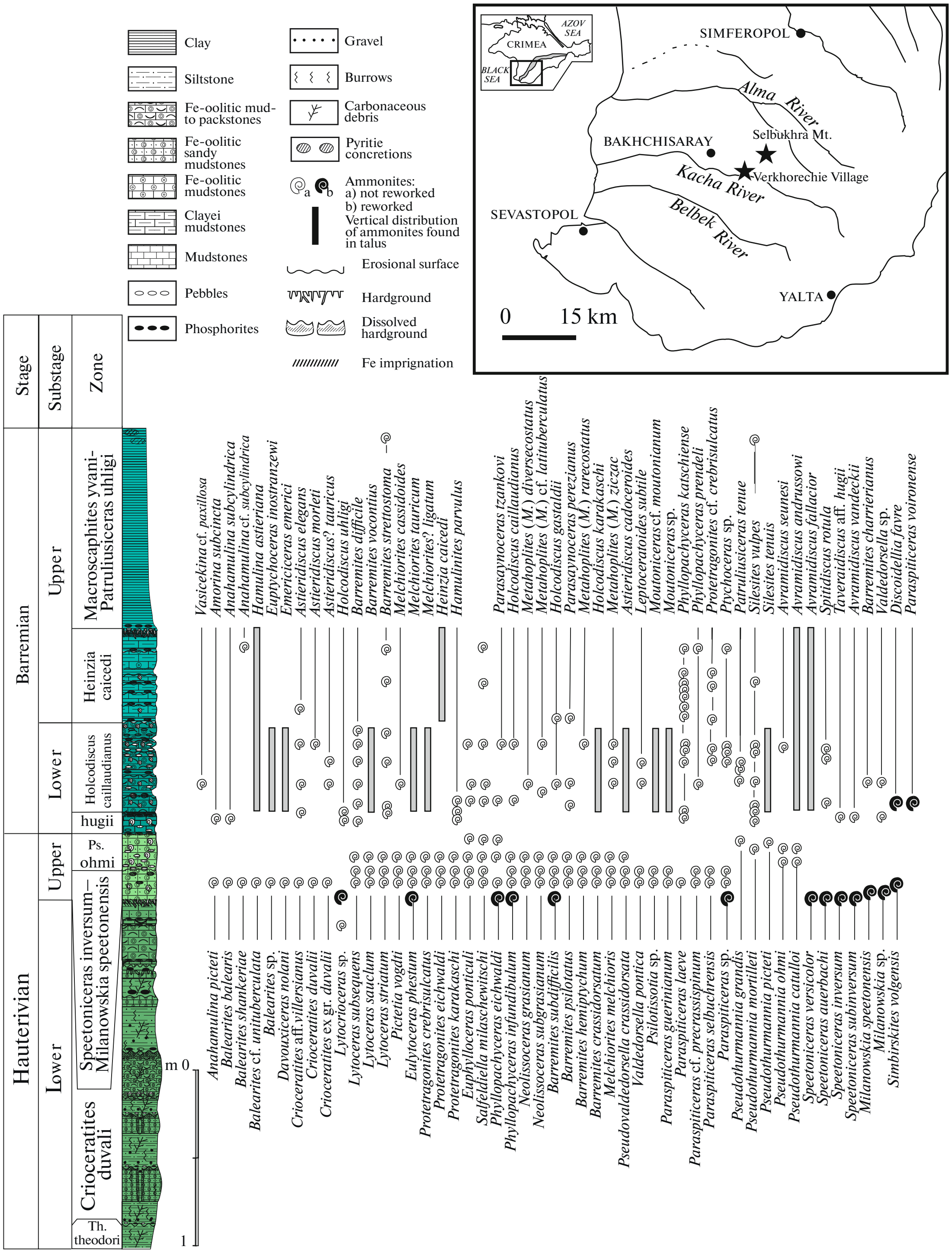


Fig. 11. Belaya Mountain reference section near Verkhorechie village, "Cephalopod limestones" (Fig. 2: Kp18) (after Baraboshkin and Mikhailova, 2020, with changes).

Mesohibolites uhligi (Schwetz.), *M. elegans* (Schwetz.), *M. minareticus* Krimh., rare ammonites and foraminifers (Drushchits and Gorbachik, 1959; Drushchits and Yanin, 1959). Integrated study of the Barremian-Aptian muddy succession (40–50 m) of the Feodosiya region (Zavodskaya Balka (Fig. 2: Kp2a) and Kokluk (Fig. 2: Kp81) sections) demonstrated evidence of OAE 1a in the section, but without black shales (Karpuk et al., 2018; Karpuk, 2023).

Barremian deposits of the Plain Crimea are represented by sandstones, gravelstones, conglomerates, and limestones at the base, and by clays in the upper part. The succession (65 m) of the central part of the

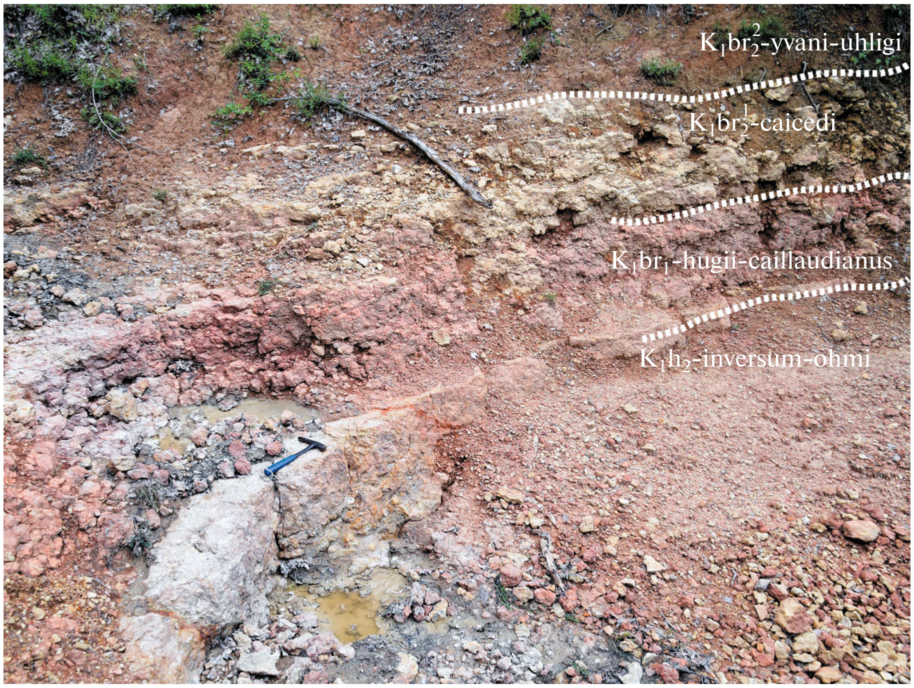


Fig. 12. Belaya Mountain reference section near Verkhorechie village, “Cephalopod limestones.” Photo by E.Yu. Baraboshkin made in 2019 (after Baraboshkin and Mikhailova, 2020, with changes).

Fig. 13. Belaya Mountain reference section near Verkhorechie village, Barremian–early Aptian mudstones. Photo by E.Yu. Baraboshkin made in 2019.

Plain Crimea (wells near Gvardeiskoye and Klepinino villages) overlies Paleozoic shales and contains Barremian ammonites *Barremites* cf. *difficilis* (d'Orb.), *Barremites* sp. and *Melchiorites* cf. *falloti* (Kil.) (Leshchukh, 1992).

The Barremian–Aptian succession of the eastern Plain Crimea consists of carbonate clays (50–100 m) with siderite concretions, sandstone and gravelstone layers and foraminiferal assemblage: *Lingulogavelinella barremiana* (Bett.), *Gaudryina* ex gr. *neocomica* Chal., *Vaginulina* cf. *duestensis* Bart. et Brand. In the east (Kerch Peninsula), the Barremian is not proven paleontologically. In the west (Tarkhankut Peninsula, the town of Evpatoria region), Barremian sandstones, siltstones, and mudstones (50–70 m) contain foraminifers *Palorbitolina tenticularis* (Blum.) (Bogaets, 1973).

The **lower Aptian** of the central Plain Crimea composes mainly of siltstones and sandy siltstones with ammonites *Deshayesites* cf. *dechyi* Papp, *Deshayesites* sp., and *Sinzovia sasonovae* Wright and a rich assemblage of bivalves (wells near Klepinino and Krasnogvardeiskoe; Leshchukh, 1992). In the east, Aptian clays and siltstones associate with siderite nodules and glauconite. They are characterized by early Aptian foraminifers *Hedbergella aptica* Agal., *Gyroidina nitida* Mor., *Gaudryina elongate* Tair., *Saracenaria spinosa* Eich. and others. In the north (Novoselovska uplift, Karkinit Graben and Azov Sea region), Aptian deposits are represented by siltstones and sandstones (70–200 m) with middle-upper Aptian ammonites *Colombiceras* cf. *subpeltoceroides* (Sinz.), *Nolaniceras nolani* (Seun.), *Acanthohoplites uhligi* (Anth.), *Hypacanthoplites jacobi* (Coll.), *H. nolaniformis* (Natz.), etc. (Leshchukh, 1987, 1992). The thickest Aptian succession (450–500 m) was documented in the Kerch Peninsula (Bogaets et al., 1983; Leshchukh, 1987, 1992).

It is noteworthy that the upper part of the Aptian and the basal Albian are absent in the Mountainous Crimea due to tectonic deformations (Drushchits, 1960; Nikishin et al., 2015; Baraboshkin, 2016), while in the Plain Crimea the Aptian–Albian transition is almost complete and biostratigraphically proven (Leshchukh, 1987, 1992).

The deformations are marked by the well-developed unconformity in the base of Albian and Upper Cretaceous deposits. Uppermost Aptian and lower Albian deposits are missing in the Mountainous Crimea because of the unconformity. Information about its presence around Simferopol (the village of Mar'ino: Drushchits, 1960) was not confirmed (Drushchits et al., 1981). The presence of lower Albian mudstones in the Feodosiya region (Drushchits and Gorbachik, 1959; Drushchits, 1960) was not confirmed (Baraboshkin, 2016). In opposite, the lower Albian is present in the Plain Crimea, where it was penetrated by wells. It consists of dark gray mudstones with siltstone layers (70–100 m). The age is supported by findings of *Leymeriella tardefurcata* (d'Orb.) and other fossils found in the well core in the northwest of the Plain Crimea (Tatyanovka and Voronki villages region; Leshchukh, 1992).

The oldest documented Albian deposits in the Mountainous Crimea are latest middle Albian. They are represented by fining upward transgressive gravelstones to sandstones near the town of Balaklava. The reference section is located near Chernorechie village (Fig. 2: Kp16a; Fig. 14), where Albian gravelstones overlie Tithonian to Berriasian surface bored by bivalves (Baraboshkin and Baraboshkin, 2014). The carbonate concretions in shallow-marine part of the succession contain rich ammonite assemblage (Baraboshkin, 2016, redetermined here): *Anahoplites daviesi* Spath, *Hamites (H.) maximus* (Sow.), *H.* sp., *Kossmatella agassiziana* (Pict.), *Kossmatella romana* Wied., *Puzosia (P.) mayoriana* (d'Orb.), *Desmoceras latidorsatum* Mich., *Phylloceras (Hypophylloceras) cypris cypris* Fall. et Term., numerous bivalves *Actinoceramus concentricus* (Park.), *Rutitrigonia taurica* Yanin, and others. Some of these ammonites were reported from sandstone blocks of the Albian olistostrome of Balaklava (Lysenko, 2003). Additional photos of ammonites from this region were published on the internet (https://www.ammonit.ru/text/2559.htm). The assemblage includes *Paranahoplites praecox* (Spath), *Proeuhoplites loricatus* (Spath), *Dipoloceras subdelaruei* (Spath), *Dipoloceras cornutum* (Pictet), *Anahoplites planus* (Mant.), *Hamites* spp., *Kossmatella* spp., and others, indicating the stratigraphic range from Paranahoplites intermedius Zone of middle Albian to the Dipoloceras cristatum Zone of upper Albian.

The only specimen of *Kossmatella* sp. from condensed "Shara limestone" (0.5–0.7 m) of the Bodrak River basin (Fig. 2: Kp12, Kp12c) was determined by Baraboshkin from the collection of Yanin. The limestone contains also finds of *Scaphites (Scaphites) simplex* (Juk.-Brown) (Marcinowski and Naidin, 1976) of the Mortoniceras inflatum Zone (Baraboshkin, 1997b). Taking in account ammonites from the Balaklava region, the age of "Shara limestone" could be older. The *Kossmatella–Epihoplites–Hysteroceras* assemblage of Hysteroceras orblgnyi and Hysteroceras varicosum zones is typical for the upper Albian Mangush Formation (Marcinowski and Naidin, 1976) exposed in the Prokhladnoe village region (Fig. 2: Kp12; Fig. 15) (Baraboshkin, 1997b). Shallow-marine to estuarine clays and sandstones of the Mangush Formation fill erosional depression that appeared after Aptian-Albian tectonic uplift (up to 400–800 m), which corresponds to early Albian rifting event (Gozhyk et al., 2006; Nikishin et al., 2008, 2015; Baraboshkin, 2016). These estuarine facies are traced eastward to Partizanskoe village, the Alma River (Fig. 2: Kp11).

The Middle Albian age was confirmed by ammonites and foraminifers in eastern Crimea (Drushchits and Gorbachik, 1959; Gorbachik, 1986). The muddy succession is exposed in the region from the town of

Fig. 14. Middle Albian reference section near Chernorechie village. Photo by E.Yu. Baraboshkin made in 2018.

Belogorsk (120–150 m) to Feodosiya City (70 m), interrupting around the town of Staryi Krym. Middle Albian clays disconformably overlie the lower Albian, with gravelstones, plant remains, belemnites *Neohibolites minimus* (List.), *Kossmatella* ex gr. *agassiziana* (Pict.), and foraminifera *Hedbergella planispira* (Tapp.) in the region of Kurskoye and Topolevka villages (Fig. 2: Kp4) (Drushchits and Gorbachik, 1959; Gorbachik, 1986).

The middle Albian of the Plain Crimea is composed of shallow-water silty mudstones with interlayers and lenses of andesite-dacitic volcanic and volcanogenic-detrital rocks in the upper part in the town of Evpatoria region. The thickness varies from 20 to 200 m, and in the Karkinit graben (volcanic section) it reaches 700 m (Leshchukh, 1987, 1992; Gnidets et al., 2010).

Upper Albian rhythmical tuffaceous sandstones are observed in the Kadykovskyi quarry on the outskirts of Balaklava (Fig. 2: Kp17; Fig. 16) in southwestern Crimea. The rocks erosionally overlie the Tithonian limestones and contain debrites with clastic material of various composition at the base (Lysenko, 2003, 2005). The source for "exotic" material was located several kilometers south of present-day Balaklava, possibly within the Lomonosov underwater massif (Shnyukov et al., 1997). The section of andesite-dacitic tuffaceous sandstones in the railway excavation on the northern outskirts of Balaklava does not contain macrofossils, and a late Albian age was obtained from zircons of tuffites (Nikishin et al., 2013; Shnyukova, 2016). Silty marls with early Cenomanian foraminifers truncate the top of this volcanoclastic unit (Nikishin et al., 2013).

In the Chernaya River basin, the upper Albian is represented by polymictic sandstones (45 m) with *Hysteroceras varicosum* (Sow.) and *Parahibolites pseudoduvaliia* (Sinz.) (Drushchits, 1960). They are overlain by quartz-glauconite sandstones (25–30 m) which contain *Mortoniceras (Durnovarites)* cf. *perinflatum* (Spath) near Ternovka village (Baraboshkin, 2016; Fig. 2: Kp14). The same sandstones (0–10 m) are exposed in the section along the Belbek River near Kuibyshevo village (Fig. 2: Kp12a). Their upper part is composed of glauconite sandstones (1–1.5 m). The section contains *Mortoniceras (M.)* cf. *rostratum* (Sow.), *M. (Durnovarites)* cf. *perinflatum* (Spath), *Anisoceras perarmatum* (Pict. et Camp.) and other ammonites (Arkadiev and Bogdanova, 1997). The shallow-marine quartz-glauconite sandstones are present in the Kacha River and Bodrak River basins, having thickness of 0–20 m. Quartz conglomerates (1–1.5 m) are locally developed in the base of sandstones, and lower Cenomanian tuffaceous greenish sandstones

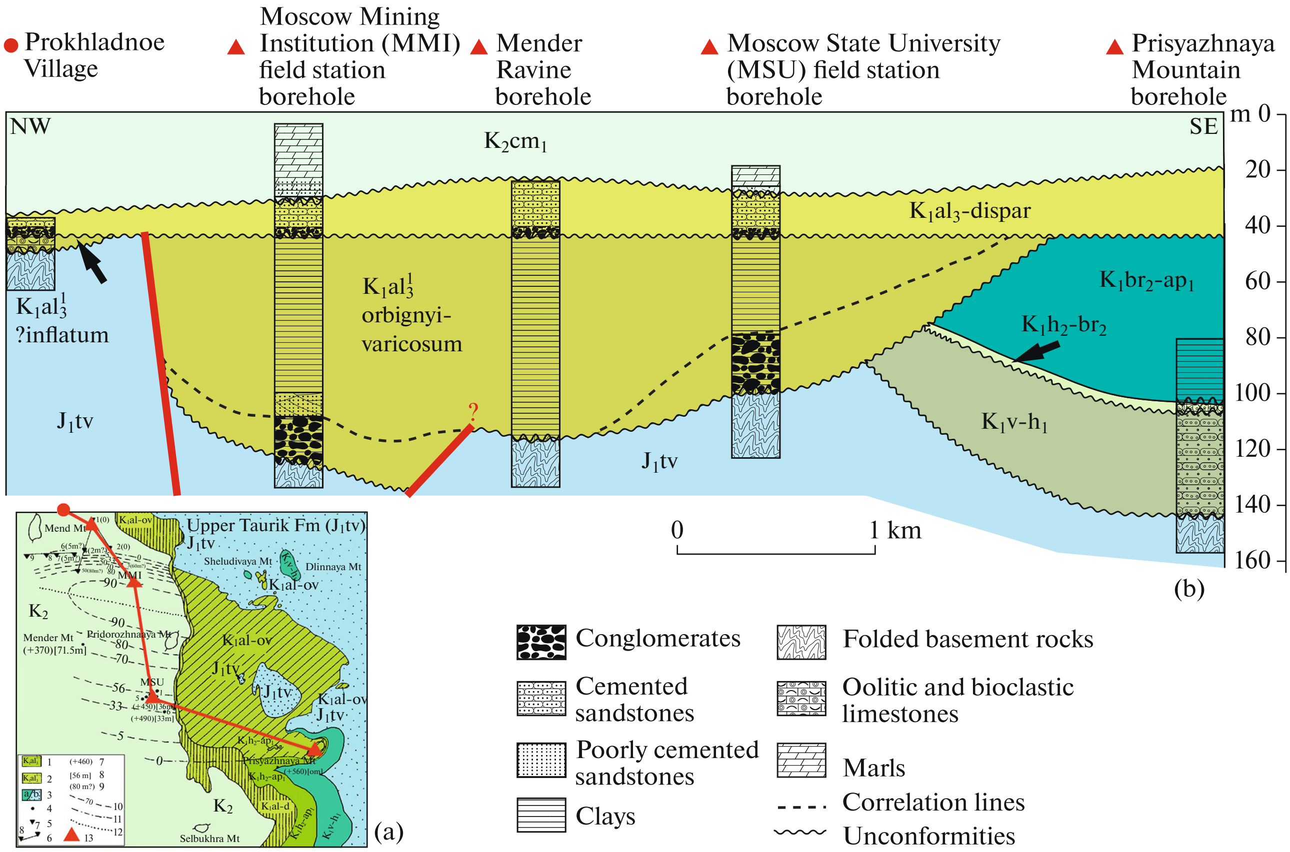


Fig. 15. The upper Albian Mangush Formation in the Prokhladnoe village region. (a) Scheme of the distribution (after Mazarovich and Mileev, 1989, with changes): (1a) Mangush Formation (Hysteroceras orbignyi–H. varicosum ammonite Zones): clays, sandstones and conglomerates; (1b) Shara limestones (Mortoniceras inflatum Zone); (2) Vysokiy Bugor Formation (Mortoniceras rostratum–perinflatum Zones): quartz-glauconite sandstones; (3a) Upper Cretaceous, (3b) Lower Jurassic Upper Tauric Formation; (4) wells; (5) Geoelectric points; (6) Geoelectric profiles; (7) absolute marks of wells in meters; (8, 9) thickness of the Mangush Formation according to drilling (8) and Geoelectric data (9); (10) isopachs of the Mangush Formation; (11) northern and southern sides and (12) the proposed axis of the Mangush erosional valley; (13) well points on the profile. Red line, the location of the profile in Fig. 15b; (b) schematic geological profile across the Mangush erosional valley.

(1–2 m) unconformably overlie the top of succession. Sandstones contain late Albian *Stoliczkaia (S.)* sp. and numerous *Aucellina gryphaeoides* (Sow.).

The reference section of the upper Albian of the Crimean Mountains is located in the vicinity of Prokhladnoe village (Fig. 2: Kp12; Marcinowski and Naidin, 1976; Yanin, 1976; Yanin and Vishnevsky in Mazarovich and Mileev, 1989; Baraboshkin, 1997b). Its lower part is represented by the Mangush Formation (0–70 m, see above, Fig. 15), which was drilled by wells. The basin was drilled in several places and studied by geophysical methods (Yanin, 1976); its sides are complicated by faults. The formation of the basin is undoubtedly associated with a significant uplift of the territory (up to 400–800 m; Nikishin et al., 2015) and the formation of an erosional relief. This episode corresponds to early-middle Albian rifting according to Gozhyk et al. (2006), Nikishin et al. (2008, 2015), and Baraboshkin (2016).

The middle part of the upper Albian of reference section in the Prokhladnoe village region consists of quartz-glauconite sandstones of the Vysokiy Bugor Formation (0–20 m) with ammonite assemblages of the Mortoniceras (M.) rostratum and M. (Durnovarites) perinflatum subzones (Marcinowski and Naidin, 1976; Baraboshkin, 1997a) with a disconformity surface in the top (Fig. 17). It is overlain by tuffaceous sandstones of Albian to early Cenomanian age (Baraboshkin, 1997b, 2016; Kopaevich and Khotylev, 2014; Baraboshkin et al., 2023c).

The Albian-Cenomanian tuffaceous unit can be traced from the Kacha River to Trudolyubovka village (Baraboshkin, 1997b; Marcinowski and Naidin, 1976; Gorbachik et al., 2000; Popov et al., 2016). The tuffite section has a small thickness (1.5 m) and complex structure with numerous discontinuities. It contains late Albian ammonites *Puzosia (P.) mayoriana* (d'Orb.), *Hamites* sp., *Stoliczkaia (S.) notha* (Seeley), *Mariella* cf. *lewesiensis* (Spath), *Lechites* cf. *gaudini* (Pict. et Camp.) (Marcinowski and Naidin, 1976; Baraboshkin, 1997b), as well as the foraminiferal assemblage of the Thalmanninella appenninica Zone

Fig. 16. Contact of the upper Albian volcanoclastic unit and Tithonian limestones. The arrows show the largest olistoliths. Kadykovsky quarry on the outskirts of town of Balaklava. Photo and interpretation by E.Yu. Baraboshkin, 2004.

(Nikishin et al., 2013; Kopaevich and Khotylev, 2014). An early Cenomanian foraminiferal assemblage with *Thalmanninella globotruncanoides* (Sigal) was found in tuffaceous sandstones of the base (Avenirova, 2023; Baraboshkin et al., 2023c) in the Selbukhra Mountain reference section. It covers erosional surface of the Albian quartz-glauconitic sandstones.

It is assumed that the source of tuffaceous Albian material of andesite-dacitic composition could be in the region of the Balaklava volcanic arc or the Karkinit graben (Nikishin et al., 2013), originating from different eruptive centers (Popov et al., 2016).

A similar tuffaceous stratum is also known in Kubalach Mountain (Fig. 2: Kp4a), in central Crimea, where its thickness reaches 30 m, and its age is substantiated by the findings of *Aucellina gryphaeoides* (Sow.), *Neohibolites ultimus* (d'Orb.) and foraminifers (Lebedinsky and Dobrovolskaya, 1961); to the east, however, it is not traceable.

The upper Albian deposits are exposed to the east, in the region of Ukrainka and Mar'ino villages (Fig. 2: Kp10) in the margin of the Salgir depression ("graben"), where they are composed of dark gray clays (0.7–10 m) with tuffaceous lamina and *Neohibolites* belemnites. The age is confirmed by late Albian planktonic foraminifers of the Hedbergella infracretacea and H. globigerinellinoides zones (Gorbachik, 1986), and by radiolarians (Gorbachik and Kazintsova, 1998; Bragina and Bragin, 2020). These deposits can be interpreted as shallow-marine, and the presence of well-preserved plant fragments (Stanislavsky and Kiselevich, 1986) implies a close land.

Further to the east, upper Albian deposits are traced in the basins of Mokryi Indol and Kuchuk-Karasu rivers and in Feodosiya City (0–250 m). They are composed of dark-gray clays with sand layers and lenses and rare carbonate concretions with *Aucellina gryphaeoides* (Sow.), *Actinoceramus sulcatus* (Park.), *A. concentricus* (Park.), *Neohibolites stylioides* Renng., *N. subtilis* (Krimh.), and others (Benenson, 1985).

The upper Albian is penetrated by numerous boreholes in the Plain Crimea. It is represented in the lower and middle parts by mudstones with siltstone, sand layers, as well as tuffs, tuffites with lapilli, andesitic and andesite-dacitic tuff lavas, and in the upper part by clayey marls. The thickness varies from a few

Fig. 17. Upper Albian reference section near Prokhladnoe village. Photo by E.Yu. Baraboshkin made in 2003.

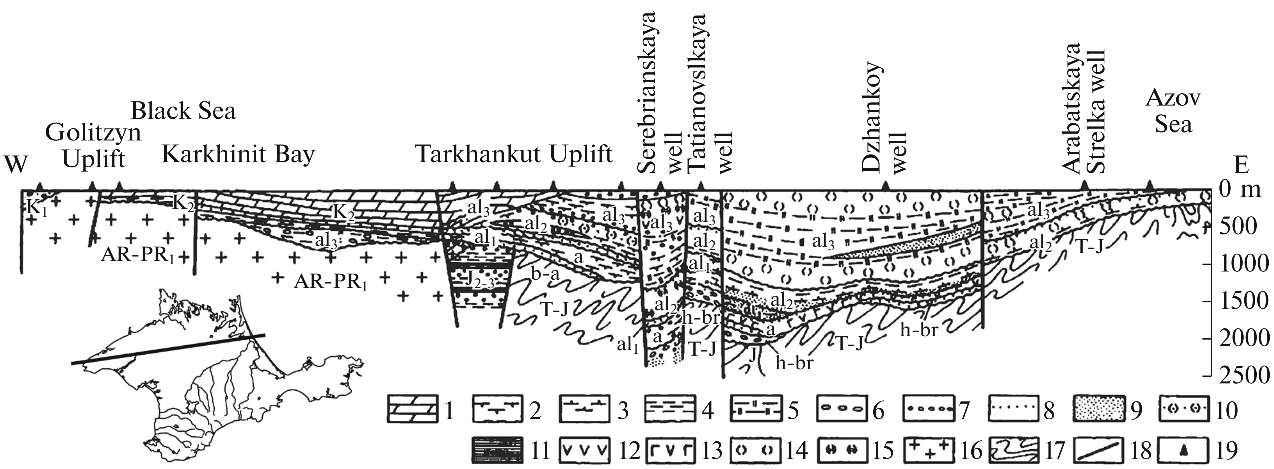


Fig. 18. Scheme of the structure of the Lower Cretaceous Profile through the Plain Crimea (Moskvin, 1986–1987, with changes by E.Yu. Baraboshkin). (1) Marls; (2–5) mudstones: calcareous (2), slightly calcareous (3), non-calcareous (4), siliceous (5); (6) conglomerates; (7) gravelstones; (8) sandstones; (9) siltstones; (10) volcanic sandstones; (11) shales; (12, 13) lavas: andesitic (12), dacite-andesitic (13); tuffs (14); tuffites (15); granites (16); folded shales (17); faults (18); wells (19).

hundred to 1200 m (Plakhotny et al., 1971; Leshchukh, 1992; Fig. 18). Thirteen volcanos were identified in the Karkinit graben according to Plakhotny et al. (1971), Gozhyk et al. (2006), and Gnidets et al. (2010). They are confined to the cross points of large faults. It is likely that eruptions occured in both submarine and air-exposed conditions as ash material is also present. The age of the volcanic activity varied from early Albian to Turonian (Gnidets et al., 2010).

The total thickness of Albian deposits in the Plain Crimea varies from 15–50 m in the Simferopol uplift to 1340 m at the Tarkhankut Peninsula, and up to 2300 m in the North Crimean trough (Moskvin, 1986–1987).

As can be seen, there were several periods of reorganization of geological history of Crimea during the Early Cretaceous. (1) End-Jurassic sedimentary conditions were preserved in the Berriasian, except for the northern regions bordering the Hercynian land of the Plain Crimea. (2) Minor deformations and short-term uplift occurred at the Berriasian–Valanginian boundary. They were accompanied by a change in sedimentation from predominantly carbonate to predominantly terrigenous deposits and ended with a new subsidence of the southern part of the Crimean Mountains. (3) The basin underwent a deepening process during the Valanginian–Aptian. The sea quickly spread into the Plain Crimea in the late Hauterivian–early Barremian, which led to the formation of "cephalopod limestones" condensed section in the Mountainous Crimea. (4) Deformations and a new uplift of the Crimean Mountains took place at the end of the Aptian–the beginning of the Albian. The sea again occupied a significant part of the Crimean Mountains during the middle-late Albian. Rifting accompanied by volcanism (Nikishin et al., 2015) developed at the same time in the Plain Crimea, on the Lomonosov Swell and, probably, on the site of the future Black Sea. Active subsidence of the Black Sea basin took place somewhat later, in the first half of the Late Cretaceous (Nikishin et al., 2015).

BIOSTRATIGRAPHY OF SELECTED FOSSIL GROUPS OF THE LOWER CRETACEOUS OF CRIMEA

Berriasian Ammonites

There were determined ammonite assemblages of all standard zones (Reboulet et al., 2018) in the Berriasian of the Mountainous Crimea: Jacobi, Occitanica and Boissieri. Their distribution in the Crimean sections is different. There are also local biostratigraphic units—"beds with ammonites" apart the standard zones (Arkadiev et al., 2018b) (Fig. 19, Table 1).

The **Jacobi Zone** in the Mountainous Crimea is subdivided into two subzones: Jacobi and Grandis. The **Jacobi Subzone** is characterized by the ammonite assemblage *Berriasella jacobi* Maz. (Figs. 20a–20c), *B. chomeracensis* (Touc.), *Berriasella* sp., *Fauriella* cf. *floquinensis* Le Hég., *Ptychophylloceras semisulcatum* (d'Orb.), and *Haploceras* sp. The ammonite *B. jacobi* is known from central Crimea and the Tonas River (Fig. 2: Kp3) sections, while *B. chomeracensis* was identified only in the Feodosiya section (Fig. 2: Kp2). The **Grandis Subzone** is characterized by *Pseudosubplanites grandis* (Maz.) (Figs. 20f–20h), *P. ponticus* (Ret.), *P. subrichteri* (Ret.), *P. lorioli* (Zit.), *P. combesi* Le Hég., *P. crymensis* Bog. et Ark., *P. fasciculatus* Bog. et Ark., *Delphinella subchaperi* (Ret.), *D. crimensis* (Burc.), *D. obtusenodosa* (Ret.), *D. tresannensis* Le Hég., *D. delphinensis* (Kil.), *D. janus* (Ret.), *D. pectinata* Ark. et Bog., *Berriasella berthei* (Touc.), *B. oppeli* (Kil.), *B. subcallisto* (Touc.), *B. paramacilenta* Maz., *Retowskiceras andrussowi* (Ret.), *R. retowskyi* Kvan., *Spiticeras orientale* (Kil.), *Negreliceras protium* (Ret.), *N. mirum* (Ret.), *N.* ex gr. *negreli* (Math.), *Ptychophylloceras semisulcatum* (d'Orb.), *Bochianites neocomiensis* (d'Orb.), *B. goubechensis* Man., and *B. crymensis* Ark. Both subzones were recognised in eastern Crimea, Tonas River basin, and central Crimea.

There are no completely exposed sections of the **Occitanica Zone** in Crimea. Its presence in the Feodosiya region was determined by Bogdanova (Bogdanova and Arkadiev, 1999) by ammonite specimens from the collection of Retowski (Retowski, 1893). The stratigraphic position of the ammonites assigned by Retowski to "Ammonites occitanicus" had been unknown over 100 years. Only in 2016 these ammonites were found in the Sultanovka Formation of the Zavodskaya Balka quarry (Baraboshkin et al., 2019). Crimean *Tirnovella occitanica* (Pict.) (Figs. 20d–20e) were assigned to *Pseudoneocomites retowskyi* (Saras. et Schönd.) by Frau et al. (2016). We suppose this opinion is erroneous (Baraboshkin et al., 2019), and two fragmented specimens figured by Frau et al. (2016) are insufficient to assign them to a certain species.

Poor exposure of the Occitanica sections does not allow to determine boundaries of its zonal subdivisions. The zone includes local biostratigraphic units: Beds with *Malbosiceras chaperi*, Beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*, and Dalmasiceras tauricum Subzone.

The **Beds with *Malbosiceras chaperi*** were proposed by Arkadiev and Bogdanova (Arkadiev et al., 2006) in central Crimea and contain ammonite assemblage: *Malbosiceras chaperi* (Pict.) (Fig. 21a) and *M. malbosi* (Pict.).

The **Beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*** were proposed by Arkadiev et al. (2006) in central Crimea and contain ammonite assemblage: *Tirnovella occitanica* (Pict.), *Retowskiceras retowskyi* Kvan. (Fig. 21b), and *Berriasella moesica* Nik. et Man.

The **Dalmasiceras tauricum Subzone** is distributed in the whole Mountainous Crimea. It was proposed by Arkadiev and Bogdanova (Arkadiev et al., 2008). The ammonite assemblage includes *Dalmasiceras tauricum* Bog. et Ark. (Figs. 21j–21l), *D. belbekense* Bog. et Ark., *D. subtoucasi* Bog. et Ark., *D.* ex gr. *punctatum* (Djan.), *Malbosiceras malbosi* (Pict.), *M. broussei* (Maz.), *M. pictetiforme* Tav., *Pomeliceras breveti* (Pom.), *P.* aff. *boisseti* Nik., *Fauriella* sp., *Subalpinites insolitus* Ark., *S. amplus* Ark., and *Spiticeras obliquelobatum* (Uhl.).

The **Fauriella boissieri Zone** includes the Neocosmoceras euthymi Subzone, the Riasanites crassicostatum Subzone, the Beds with *Symphythyris arguinensis*, and the Berriasella callisto Subzone (Arkadiev et al., 2015a; Baraboshkin et al., 2019). The **Neocosmoceras euthymi Subzone** is characterized by ammonites (Fig. 21): *Fauriella boissieri* (Pict.), *Neocos-*

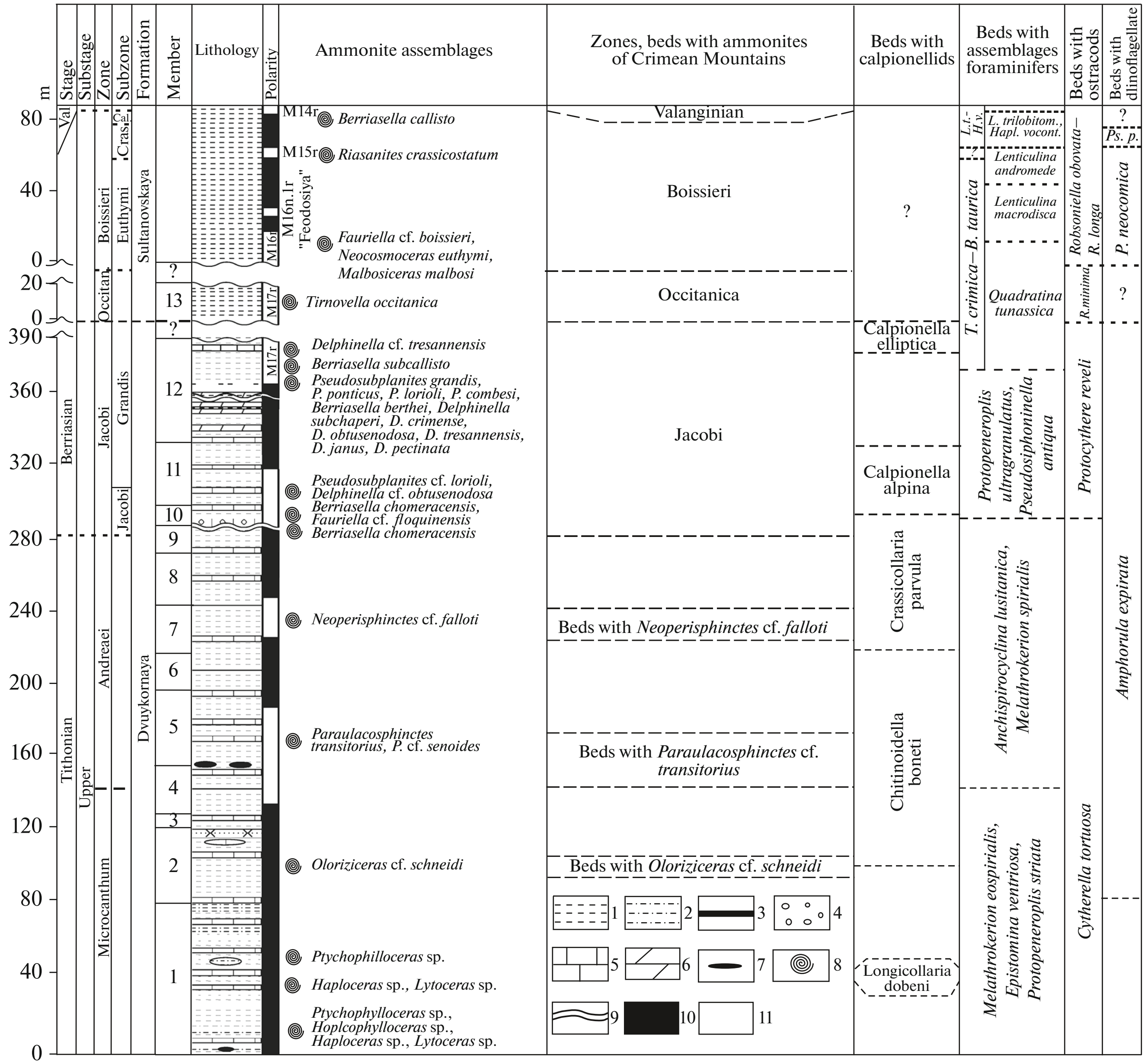
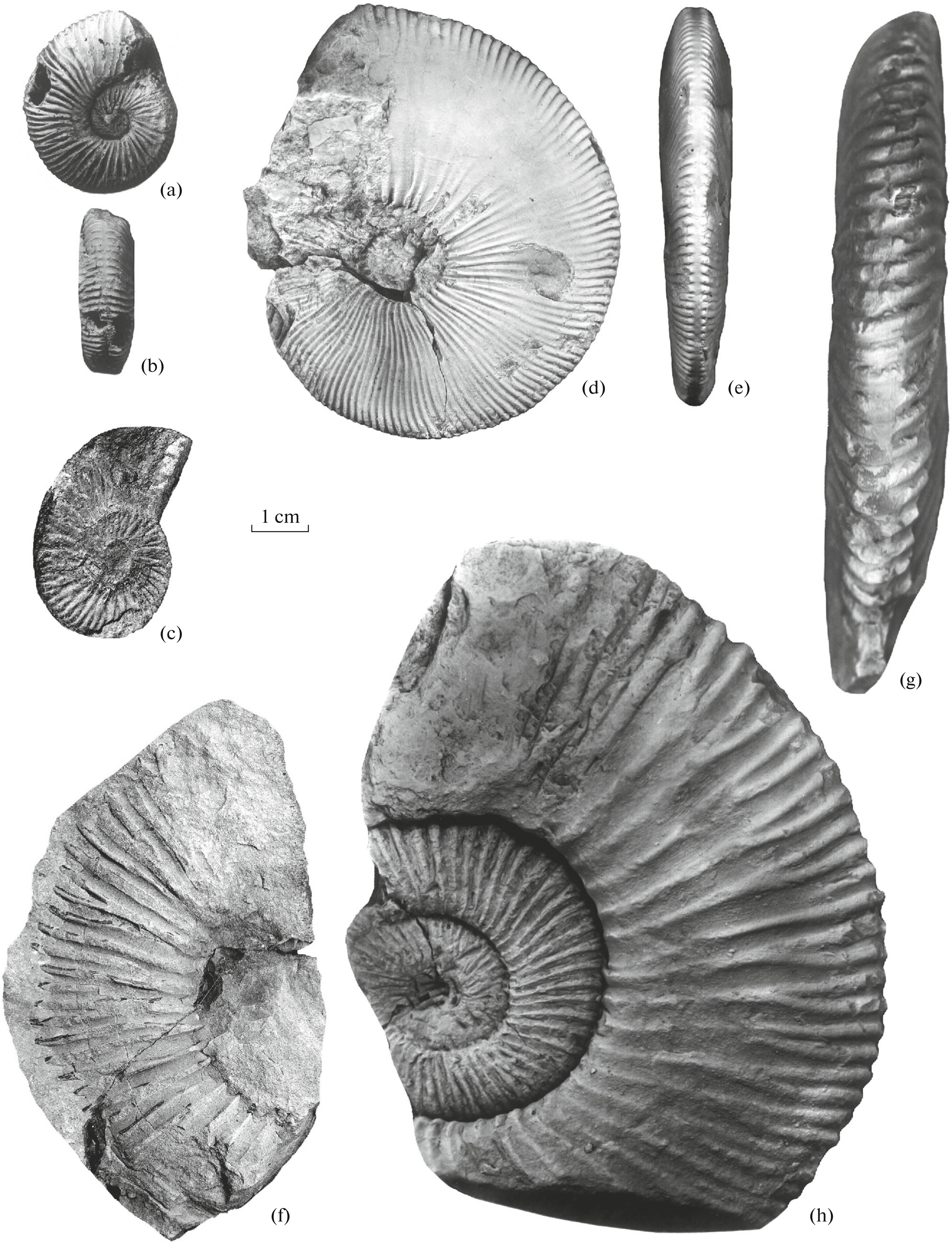


Fig. 19. Tithonian–Berriasian composite section of eastern Crimea and its biostratigraphic and magnetostratigraphic zonation (Arkadiev et al., 2019, with changes). (1) Clay, (2) siltstone, (3) calcareous sandstone, (4) conglomerate, (5) limestone, (6) marl, (7) siderite lenses, (8) ammonites, (9) not observed, (10–11) geomagnetic polarity: (10) normal, (11) reversal.

moceras euthymi (Pict.) (Figs. 21c–21i), *N.* cf. *transfigurabilis* (Bog.), *N. giganteus* Ark. et Bog., *N. minutus* Ark. et Bog., *Malbosiceras malbosi* (Pict.), *Pseudosubplanites jauberti* (Maz.), *Hegaratia balkensis* (Bog. et Kvan.), *H. taurica* (Bog. et Kvan.), *H. nerodenkoi* (Bog. et Kvan.), *H. bidichotoma* (Bog. et Kvan.), *Spiticeras multiforme* Djan., and *S. subspitiense* (Uhl.). The zone was recognized in the whole Mountainous Crimea.

Fig. 20. Berriasian ammonites. (a–c), *Berriasella jacobi* Maz.: (a, b), specimen 1/13098 in lateral and ventral views, Sary-Su River Basin; (c), specimen 4/378 in lateral view, Tonas River Basin, village of Krasnoselovka, Jacobi Zone; (d, e) *Tirnovella occitanica* (Pict.), specimen 41/10916 in ventral and lateral views, Feodosiya, Occitanica Zone; (f–h), *Pseudosubplanites grandis* (Maz.): (f) specimen 1/13139 in lateral view, Tonas River Basin, village of Krasnoselovka; (g, h), specimen 18/13077 in ventral and lateral views, Feodosiya, Saint Elias Cape, Jacobi Zone. Figured ammonites are stored at the CNIGR Museum (F.N. Chernyshev Central Research Geological Museum, Saint Petersburg) under registration numbers 10916, 13098, 13146 and 13209; in the Museum of the University of National Mineral Resources (Mining University, Saint Petersburg, No. 333), the Paleontological Museum of Saint Petersburg State University (No. 409).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The **Riasanites crassicostatum Subzone** was proposed by Arkadiev and Bogdanova (Arkadiev et al., 2008. The ammonite assemblage includes: *Fauriella simplicicostata* (Maz.), *Riasanites crassicostatum* (Kvan. et Lys.) (Figs. 22c–22d), *R. irregulatus* (Kvan. et Lys.), *R. tuberculatum* (Kvan. et Lys.), *R. petrovensis* (Kvan. et Lys.), *Hegaratia balkensis* (Bog. et Kvan.), *H. bidichotoma* (Bog. et Kvan.), *H. taurica* (Bog. et Kvan.), *H. nerodenkoi* (Bog. et Kvan.), and *Pomeliceras* (?) *funduklense* Lys. et Ark. The subzone was recognized in the Mountainous Crimea.

The **Beds with *Symphythyris arguinensis*** were proposed by Lobacheva and others (Bogdanova et al., 1981; Lobacheva, 1983) in central Crimea. A "sponge horizon" with numerous brachiopods *Symphythyris arguinensis* (Mois.) was distinguished in the upper part of the Crassicostatum Subzone section. In a "sponge-bed," Baraboshkin found *R. crassicostatum* (Kvan. et Lys.) (Arkadiev et al., 2015a; Baraboshkin, 2016).

The **Berriasella callisto Subzone** was initially determined as "Beds with *Jabronella* cf. *paquieri* and *Berriasella callisto*" in the Berriasian section of Tas-Kor Ravine and Chatyr-Dag Mountains (Arkadiev et al., 2006; Fig. 2: Kp9). Later it was proposed to distinguish the Berriasella callisto Subzone (Arkadiev et al., 2018b). The subzone was recognized in the Zavodskaya Balka section (Fig. 2: Kp2a: (Baraboshkin et al., 2019)). Its ammonite assemblage contains *Jabronella* cf. *paquieri* (Sim.), *Fauriella boissieri* (Pict.) (Figs. 22e–22f), *F. rarefurcata* (Pict.), *Fauriella* sp., *Tirnovella alpillensis* (Maz.), *Tirnovella* sp., *Berriasella callisto* (d'Orb.) (Figs. 22a–22b), *Berriasella* sp., and *Malbosiceras malbosi* (Pict.). Perhaps, *B. callisto* (d'Orb.) indicates presence of the Otopeta Subzone of the Alpillenisis Zone (Reboulet et al., 2018), as in the Spain it was assigned to the Otopeta Subzone (Tavera, 1985). The Berriasella callisto Subzone is distributed in southwestern (?), central and eastern Crimea.

Valanginian to Albian Ammonites

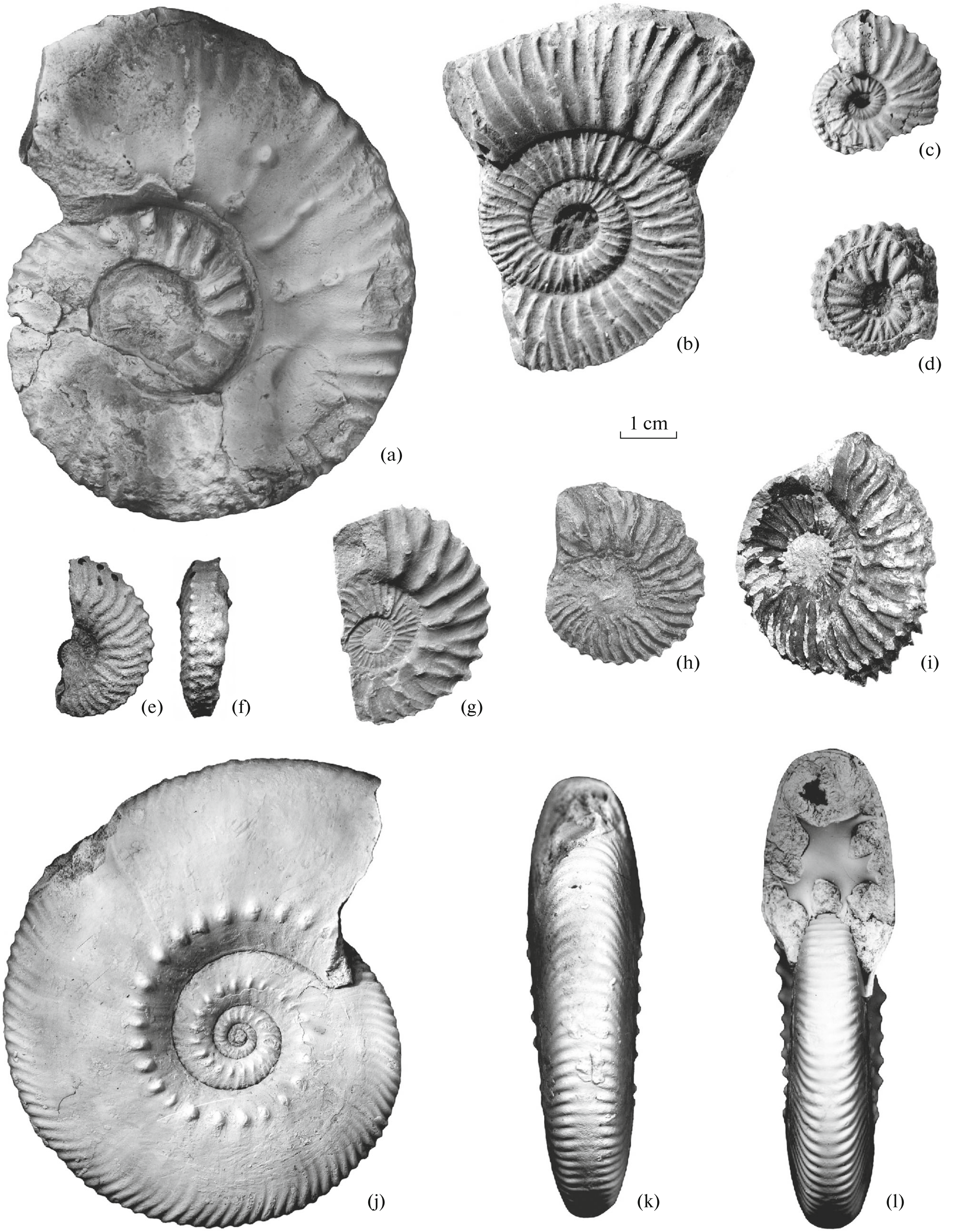
The stratigraphy and ammonites of the Valanginian-Albian deposits of Crimea were studied by many geologists and paleontologists: E. Eichwald, O. Retowski, N.I. Karakasch, K.K. Foght, V. Tsebrikov, A.A. Borisyak, A.D. Natsky, G.F. Weber, D.P. Stremoukhov, N.S. Kulzhinskaya-Voronets, M.V. Muratov, M.S. Eristavi, V.V. Drushchits, I.A. Mikhailova, G.K. Gorn, E.S. Chernova, D.P. Naidin, R.J. Leshchukh, N.I. Lysenko, I.V. Kvantaliani, M.V. Kakabadze, T.N. Bogdanova, R. Marcinowski, and others. They developed the basics of the Lower Cretaceous ammonite biostratigraphy, which outline is discussed below.

Generally, ammonites are quite rare fossils in the Valanginian-Albian succession exept condensed horizons at the base of the upper Valanginain and upper Hauterivian-lower upper Barremian "Cephalopod limestone." The base of the most ammonite zones briefly described below represents a level with abundant ammonite finds and very rare finds above it, till the next ammonite level.

The **Valanginian** deposits and ammonite faunas of Crimea were recognized by Karakasch (1889, 1907, etc.). According to Karakasch (1907), several levels of conglomerates and sandstones with "*Hoplites oxygonius, Ostrea rectangularis*" had Valanginian age (Table 2). A part of the grey sandstones above with "*Duvalia dilatata, Crioceras Duvali*" and other fossils were referred by him to the Hauterivian. Ammonites of the "*Hoplites Leopoldi*" group (recently identified as Valanginian *Bodrakiceras, Karakaschiceras, Neohoploceras* and Hauterivian *Leopoldia desmoceroides* (Kar.): Baraboshkin and Mikhailova, 2000) Karakasch referred to the Hauterivian, but noted that they occurred together with Valanginian ammonites (Karakasch, 1907, p. 416). In his final biostratigraphical scheme he excluded most of these ammonites because of uncertainties in their interpretation. The biostratigraphical scheme of Karakasch was accepted by Eristavi (1957) and Drushchits (1956, 1960) except for the Valanginian part. Drushchits assumed the Valanginian fauna was redeposited at the base of the Hauterivian. Most of the geologists who worked in this region followed Drushchits's scheme to define the stratigraphical range of rocks. The mistake arose from the incorrect determination of the ammonite genus "*Leopoldia*" that Drushchits supposed to be early Hauterivian. Valanginian deposits were defined on the base of belemnites, gastropods and rare ammonites found by Lysenko in southwestern and eastern Crimea and on the base of foraminifers determined by Gorbachik (Benenson, 1985).

First zonal scheme of the Valanginian of Crimea was renewed by Baraboshkin (Baraboshkin and Mikhailova, 1994) for the Verkhorechie (Rezanaya Mountain) section (Fig. 2: Kp18). This scheme was modified (Table 2) and published in the review of the Early Cretaceous zonation of southwestern Crimea

Fig. 21. Berriasian ammonites. (a) *Malbosiceras chaperi* (Pict.), specimen 20/13143 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, condensed horizon at the base of the Boissieri Zone; (b) *Retowskiceras retowskyi* Kvant., specimen 12/13209 in lateral view, Feodosiya, Zavodskaya Balka, Occitanica Zone, Beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*; (c–i), *Neocosmoceras euthymi* (Pict.): (c) specimen 2/12943 in lateral view, (d) specimen 1/12943 in lateral view, village of Balki, Boissieri Zone, Euthymi Subzone; (e, f) specimen 6/13175 in lateral and ventral views, village of Balki, Boissieri Zone, Euthymi Subzone; (g) specimen 12/409 in lateral view, village of Nanikovo, Koklyuk Mountain, Boissieri Zone, Euthymi Subzone; (h) specimen 9/13175 in lateral view, Tonas River Basin, Alekseevka village, Boissieri Zone, Euthymi Subzone; (i) specimen 80/13175 in lateral view, Feodosiya, Zavodskaya Balka, Boissieri Zone, Euthymi Subzone; (j–l) *Dalmasiceras tauricum* Bogd. et Ark. in lateral, ventral and oral views, specimen 4/333, Belbek River Basin, village of Kuibyshevo, Occitanica Zone, Tauricum Subzone.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(Baraboshkin, 1997a; Baraboshkin and Yanin, 1997) and ammonites (Baraboshkin and Mikhailova, 1994). The scheme is modified in this paper in connection with the additional data, revision of some ammonites and the changes of the West Mediterranean Province zonal Standard (Reboulet et al., 2018).

The zonal succession is based on the Rezanaya Mountain section in the vicinity of Verkhorechie village, Kacha River basin (Figs. 6, 7). It is the only known completest Valanginian section in the Mountainous Crimea characterized by ammonites and it is the main section studied by N.I. Karakasch, V.V. Drushchits, M.S. Eristavi, and others. The base of each zone was determined by appearance of zonal index, which is distributed in a narrow interval (except for the Eleniceras tauricum Zone).

Thurmanniceras otopeta Zone contains *Thurmanniceras otopeta* Thieul., *Thurmanniceras* sp., *Kilianella* sp., *Clavithurmannia foraticostata* Thieul., and ? *Bodrakiceras inostranzewi* (Kar.). After decision of the meeting of the "Kilian Group" in 2002 (Hoedemaeker et al., 2003), the zone was shifted into the Berriasian. The Otopeta Zone was confirmed only in the Verkhorechie section, but possibly it exists in the Belbek River section.

Thurmanniceras pertransiens Zone contains *Thurmanniceras pertransiens* (Sayn) (Figs. 23p, 23q), *T.* cf. *pertransiens* (Sayn), *Thurmanniceras* cf. *salientinum* (Sayn), *T.* ex gr. *thurmanni* (Pict. et Camp.), *T. valdrumensis* (Sayn), *Thurmanniceras* sp., and *Kilianella* sp. It was recognized in the Verkhorechie section (Fig. 2: Kp18), in a series of sections near Prokhladnoe village (Fig. 2: Kp12) and in the Belbek River basin (Fig. 2: Kp12a). The ammonite assemblage of the zone in the Sbrosovyi Log (Belbek River) section includes *Phylloceras (Hypophylloceras) ponticuli* (Rouss.), *Neolissoceras grasianum* (d'Orb.), *Olcostephanus (Olcostephanus)* cf. *globosus* Spath, *Thurmanniceras pertransiens* (Sayn) (Figs. 24g, 24h), *T.* cf. *valdrumensis* (Sayn), *T. salientinum* (Sayn), *Kilianella roubaudiana* (d'Orb.), *Pseudscanthodiscus crymicus* Bar., and *Belbekiceras belbekii* Bar. (Arkadiev and Bogdanova, 1997). There is a disconformity surface in the top of this zone.

Campylotoxia campylotoxa Zone was recognized in a highly condensed interval of the Verkhorechie reference section, where most of the ammonite finds are condensed and mixed with younger ammonites. It could be detected by the presence of *Campylotoxia campylotoxa* (Uhl.), *C. campylotoxa densocostata* Bar. et Mikh. and *C. evoluta* Bar. et Mikh. Other ammonites are *Phylloceras (Hypophylloceras)* cf. *serum* (v. Zlttel), *Eulytoceras phestum* (Math.), ? *Thurmanniceras* sp., *Bodrakiceras moutonianum* (d'Orb.), *B. inostranzewi* (Kar.) (Figs. 23n, 23o), *B. constrictum* Bar. et Mikh., *Bodrakiceras* sp., *Karakaschiceras biassalense* (Kar.), *Luppovella (Neoluppovella) spinosa* Bar. et Mikh., and *Eristavites platycostatus* (Sayn) (Figs. 23a, 24b). Obviously both Inostranzewi and Platycostatus subzones of the Standard scale (Reboulet et al., 2018) are condensed in the interval.

Neohoploceras submartini Zone was proposed as the basal upper Valanginian zone because representatives of *Saynoceras* were not found in Crimea. The zone contains *Varlheideites peregrinus* Raws. et Kemp. (Fig. 23i), *Busnardoites* sp., *Neohoploceras submartini* (Mallada) (Figs. 23d, 23e), *N. karakaschi* (Uhl.), *N. recticostatum* Bar. et Mikh., *Luppovella (Planibulliceras) kachensis* Bar. et Mikh., *L. (Luppovella) baumbergeri* (Spath), *Rodighieroites* (?) sp., *Neolissoceras subgrasianum* Drus., and *Valanginites nucleus* (Roem.). The presence of *Varlheideites peregrinus* indicates correlation of this zone with the Saynoceras verrucosum and "Neocomites" peregrinus zones of the Standard scale (Reboulet et al., 2018). Finds of *Neohoploceras submartini* (Mallada) are also reported from the Menester gully section (Fig. 2: Kp1b) (Baraboshkin and Yanin, 1997; Baraboshkin, 2016).

Himantoceras trinodosum Zone was replaced by the Niklesi and Furcillata subzones (Hoedemaeker et al., 2003). Both zonal indexes were not found in Crimea yet, so it is reasonable to leave the Trinodosum Zone in the scheme. Finds of *Himantoceras* are very rare in Crimea, but their position in the Verkhorechie section is well-documented (Baraboshkin and Yanin, 1997; Baraboshkin and Mikhailova, 2000). The zone contains *Eulytoceras* cf. *borissiaki* (Kulzh.-Vor.), *E.* cf. *phestum* (Math.), *Lytoceras* sp., *Himantoceras* cf. *lessinianum* Faraoni et al., *Himantoceras* sp., *Karakaschiceras* sp., *Teschenites* sp., *Neolissoceras grasianum* (d'Orb.), *N. subgrasianum* Drus., *Phyllopachyceras* aff. *stuckenbergi* (Kar.), and *Phyllopachyceras* sp.

Teschenites callidiscus Zone contains ammonite assemblage: *Stoicoceras tuberculatum* (Roman) (Fig. 23f), *Teschenites callidiscus* Thiel., *T. subpachydicranus* Reb., *Oostrella* cf. *cultrata* (d'Orb.), *Eulytoceras* sp., *Protetragonites* cf. *tauricus* (Kulzh.-Vor.), *Neolissoceras subgrasianum* Drus., *Phylloceras (Hypophylloceras) tethys* (d'Orb.), and *Phyllopachyceras* sp. This zone was recognized only in the Verkhorechie section. The presence of *Stoicoceras tuberculatum* gives a possibility of correlation of the Tethyan Callidiscus Zone and Tuberculatum Zone of northern Europe (Kemper et al., 1981).

Fig. 22. Berriasian ammonites. (a, b) *Berriasella callisto* (d'Orb.): (a) specimen 20/13098 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, Boissieri Zone; (b) specimen 11/409 in lateral view, Feodosiya, Zavodskaya Balka, Boissieri Zone, Callisto Subzone; (c, d) *Riasanites crassicostatum* (Kvant. et Lys.): (c) specimen 8/409; (d) specimen 9/409, all in lateral view, Feodosiya, Zavodskaya Balka, Boissieri Zone, Crassicostatum Subzone; (e, f) *Fauriella boissieri* (Pict.): (e) specimen 1/13146 in lateral view, Sary-Su River Basin, Boissieri Zone; (f) specimen 3/13146 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, Boissieri Zone.

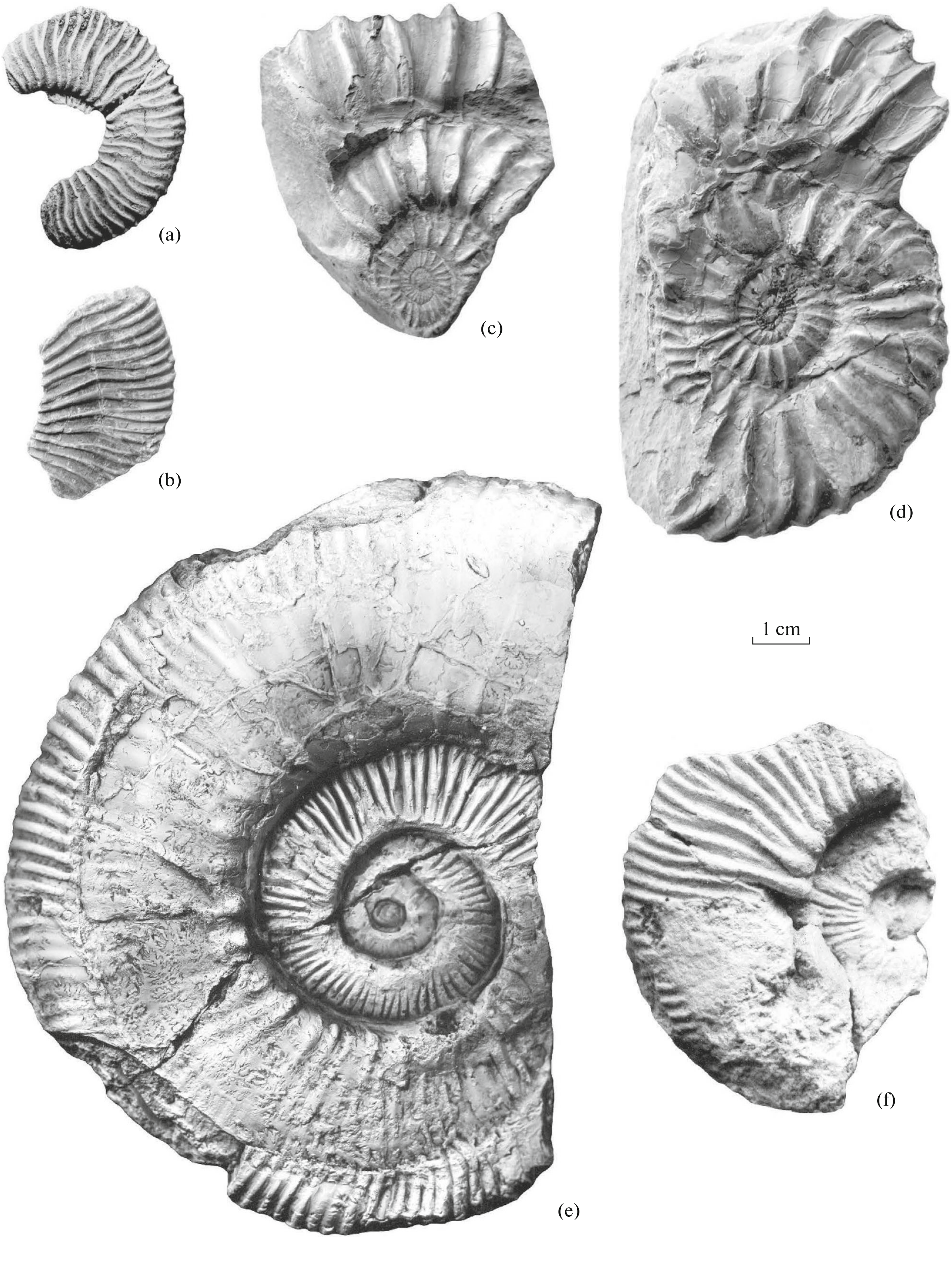
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Table 2. A review of the ammonite biostratigraphic subdivision of the Valanginian deposits of the Crimean Mountains

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<tr><th rowspan="2">Substage</th><th colspan="2">West Mediterranean Zonal Standard, Reboulet et al., 2018 (pars)</th><th rowspan="2">Stage</th><th>Crimean Mountains, Karakasch, 1907</th><th rowspan="2">Substage</th><th>Crimean Mountains, Eristavi, 1955</th><th rowspan="2">Substage</th><th>Mountain Crimea, Drushchits, 1960</th><th rowspan="2">Substage</th><th>Kacha-Bodrak Interfluve, Baraboshkin and Yanin, 1997</th><th colspan="2">Mountain Crimea, This paper</th></tr>
<tr><th colspan="2">Zone, Subzone</th><th></th><th>Zone</th><th>Zone</th><th>Zone</th><th colspan="2">Zone, Subzone</th></tr>
<tr><td>Lower Hauterivian</td><td colspan="2">Acanthodiscus radiatus</td><td>Hauterivian</td><td>Sandstones with Echin. cordiformis, Ost. Couloni, Duv. crimica</td><td>Hauterivian</td><td>Leopoldia leopoldi</td><td>Lower Hauterivian</td><td>Zones are not proposed Ammonites: Leopoldia leopoldi, Acanthodiscus karakaschi, Lyticoreras amblygonius, Olcostephanus astieri</td><td>Lower Hauterivian</td><td>Leopoldia leopoldina</td><td colspan="2">Leopoldia desmoceroides</td></tr>
<tr><td rowspan="7">Upper Valanginian</td><td rowspan="3">Criosarasinella furcillata</td><td rowspan="2">Teschenites callidiscus</td><td rowspan="12">Valanginian</td><td rowspan="12">Sandstones with Duv. crimica, N. pseudoelegans, Hopl. oxygonius, cf. heliacus, tauricus, Ast. Schapei, Cr. Kiliani, Hapl. Grasi, Rhynch. multiformis, Holect. Tacropygus, O. Couloni

Conglomerate with N. ps.-elegans, N. Malbosi, Hopl. longinodis, Arnoldi, pronecostatus, Karakaschi, Ast. spitiensis, nucleus, O. Couloni, O. rectangularis, tuberculifera</td><td rowspan="12">Middle–Upper Valanginian</td><td rowspan="12">Thurmanniceras thurmanni</td><td rowspan="7">Upper Valanginian</td><td rowspan="7">Zones are not proposed Cephalopod remains: Neocomites neocomiensis, Lamellaptychus didayi, Pseudobelus bipartitus, Conobelus conicus</td><td rowspan="7">Upper Valanginian</td><td>Elenic. tauricum</td><td colspan="2">Eleniceras tauricum</td></tr>
<tr><td>Teschenites callidiscus</td><td colspan="2">Teschenites callidiscus</td></tr>
<tr><td>Criosarasinella furcillata</td><td rowspan="2">Himantoceras trinodosum</td><td colspan="2" rowspan="2">Himantoceras trinodosum</td></tr>
<tr><td rowspan="2">Neocomites peregrinus</td><td>Olcostephanus (O.) nicklesi</td></tr>
<tr><td>N. peregrinus</td><td rowspan="3">Saynoceras verrucosum</td><td rowspan="3">Neohoploceras submartini</td><td>Varlheid. peregrinus</td></tr>
<tr><td rowspan="2">Saynoceras verrucosum</td><td>Karakaschiceras pronecostatum</td><td rowspan="2">?</td></tr>
<tr><td>Saynoceras verrucosum</td></tr>
<tr><td rowspan="5">Lower Valanginian</td><td rowspan="2">Karakaschiceras inostranzewi</td><td>platycostatus</td><td rowspan="5">Middle Valanginian</td><td rowspan="5">Zones are not proposed. Ammonites: Thurmanniceras thurmanni, Kilianella roubaudiana</td><td rowspan="6">Lower Valanginian</td><td rowspan="3">“Busnardoites” campylotoxus</td><td colspan="2" rowspan="3">Campylotoxia campylotoxa</td></tr>
<tr><td>inostranzewi</td></tr>
<tr><td>Neocomites neocomiensiformis</td><td rowspan="2"></td></tr>
<tr><td rowspan="2">“Thurmanniceras” pertransiens</td><td rowspan="2">Thurmannicreas pertransiens</td><td colspan="2" rowspan="2">Thurmannicreas pertransiens</td></tr>
<tr><td>Neocomites premolicus</td></tr>
<tr><td>Brs</td><td colspan="2">Thurmanniceras otopeta Berriasian</td><td></td><td>Berriasian</td><td>LV</td><td>Spiticeras negreli</td><td>LV</td><td>Zones are not proposed. Ammonites: Berriasella pontica, etc.</td><td>Kilianella otopeta</td><td colspan="2">Thurmanniceras otopeta</td></tr>
</table>

Brs, Berriasian, LV, Lower Valanginian.

Eleniceras tauricum Zone includes ammonite assemblage: *Eulytoceras konuschobaense* (Kulzh.-Vor.), *Eleniceras tauricum* (Eichw.), *E. nikolovi* Bresk., *E. stevrecense* Bresk., *E. spiniger* Koen., *E. transsylvanicum* (Jek.), *E. koeneni* (Kar.), and *Neolissoceras grasianum* (d'Orb.). The stratigraphic distribution of the zonal index passes into the basal Hauterivian. The top of the zone and the base of the Hauterivian are defined by the appearance of *Leopoldia desmoceroides* (Kar.). The Eleniceras tauricum Zone was traced in the interfluve of Kacha–Bodrak rivers.

The ammonite finds are very rare in the Valanginian muddy deeper-water facies of eastern and southern parts of the Mountainous Crimea, so it is not possible to trace zonal scheme there.

The Hauterivian. First Lower Cretaceous ammonite zonation of the Mountainous Crimea was proposed by Drushchits in 1953 in his PhD Thesis, which was published in 1956 (Drushchits, 1956). Following the ideas of Muratov, he thought that Valanginian deposits are missing in the Mountainous Crimea and proposed 3 ammonite zones in the Hauterivian: Bidichotomites bidichotomus, Leopoldia leopoldi, Crioceratites duvalii. Eristavi (1955, 1957) did not agree with this zonation and proposed ammonite zones typical for the Mediterranean region (Table 3). Eristavi recognized the Thurmanniceras thurmanni Zone in the "middle-upper Valanginian" (which is Valanginian now), but Valanginian deposits of Karakasch (1907) he included in the Hauterivian Leopoldia leopoldi Zone. Later Drushchits proposed a zonal scheme for the Crimea–Caucasus area ("South of the USSR": Drushchits and Mikhailova, 1966). It was modified, and the "Lythicoceras sp." or "Lyticoceras noricum–L. amblygonium" Zone was added below the Hauterivian Acanthodiscus radiatus–Leopoldia leopoldina Zone (Gorbachik et al., 1975).

This zonation was revised by Baraboshkin after recognition of the Valanginian succession (Baraboshkin and Mikhailova, 1994; Baraboshkin and Yanin, 1997; Table 3). The scheme was modified in 2008 (Baraboshkin, 2008), and in this paper it is modified again in relation with standard zonation (Reboulet et al., 2018).

Leopoldia desmoceroides Zone of the early Hauterivian was recognized in the interfluve of Kacha (Fig. 2: Kp18), Bodrak (Fig. 2: Kp12) and Alma rivers (Fig. 2: Kp11). The zone contains *Lytoceras*? sp., *Leopoldia desmoceroides* (Kar.), *L.* cf. *leopoldina* (d'Orb.), *Neolissoceras grasianum* (d'Orb.), and *Breistrofferella* sp. The only find of *Acanthodiscus* ex gr. *radiatus* (Brug.) from this interval was determined in the collection of Lysenko (Crimean Federal University). The specimen was found in a talus of Kunich Mountain (Fig. 2: Kp6) in central Crimea and was not published.

?Crioceratites loryi Zone was provisionally determined in the Verkhorechie section only. It has clear regressive trend and includes *Crioceratites* cf. *loryi* Sarkar, *Crioceratites* sp., *Davouxiceras nolani* (Kil.), *Neolissoceras grasianum* (d'Orb.), *Neolissoceras* sp., *Lytoceras*? sp., and *Eulytoceras phestum* (Math.).

Theodorites theodori Zone transgressively overlies older rocks and is recognized in a wider region from the Kacha River in the southwest to Kunich mountain in the northeast. The interval was originally referred to the Lyticoceras nodosoplicatum Zone due to affinity of larger fragments of *Theodorites* and *Lyticoceras*. Then it was established that *Theodorites* are heteromorph ammonites with unrolled second whorl (Baraboshkin and Mikhailova, 2006) and *Lyticoceras* are not represented in Crimea. The zone contains *Theodorites theodori* Bar. et Mikh., *T. drushitsi* Bar. et Mikh., *Crioceratites* sp., *Phyllopachyceras stuckenbergi* (Kar.), *Spiticeras rotula inflatum* Kil., *Abrytusites* sp., *Hamulina* sp., and *Eulytoceras* sp. In this list, *Spiticeras rotula inflatum* Kil. is distributed in the Lyticoceras nodosoplicatum Zone of Western Europe (Thieuloy, 1972), which confirms the correlation of the Theodori and Nodosoplicatum zones.

Crioceratites duvalii Zone was proposed by Drushchits for the Mountainous Crimea in his PhD Thesis (Eristavi, 1955; Drushchits, 1956). The zone was recognized by all biostratigraphers in southwestern Crimea and immediately precedes the "Cephalopod limestone" unit. The index species of this zone was also documented in the Plain Crimea by Leshchukh (1987, 1992). Kakabadze (1981) studied the Duvali Zone in the Verkhorechie section and figured some ammonites. The assemblage contains *Crioceratites duvalii* Lev., *C.* ex gr. *duvalii* Lev., *C.* aff. *duvalii* Lev., *C.* cf. *tenuicostatus* Thom., and *C.* sp.

Speetoniceras inversum Zone is highly condensed at the base of a brown layer (0.4 m) of the "Cephalopod limestone." The zone contains the Boreal ammonite assemblage of *Speetoniceras inversum* (M. Pavl.) (Figs. 24o, 24p), *S. auerbachi* (Eichw.), *S. subinversum* (M. Pavl.), and *S. versicolor* (Trautsch.) and others, which are difficult to separate from the younger fauna.

Milanowskia speetonensis Zone represents the middle part of the condensed brown limestone. The ammonite assemblage is highly diverse: *Milanowskia speetonensis* (Young et Bird), *M.* sp., *Lytoceras subsequens* Kar., *Phyllopachyceras infundibulum* (d'Orb.), *P. eichwaldi* (Kar.), *P. baborense* (Coq.), *Davouxiceras nolani* (Kil.), *C. tenuicoststus* Thom., *Criolytoceras* sp., *Paraspiticeras guerinianum* (d'Orb.), *Euphylloceras ponticuli* (Rouss.), *E. serum* (v. Zlttel), *Anahamulina picteti* (v. Eichw.), *Melchiorites haugi* (Kil.), *M. melchioris* (Tietze), *Valdedorsella renevieri* (Kar.), *Pseudovaldedorsella crassidorsata* (Kar.), *Discoidellia* aff. *couratieri* Vermeulen (Figs. 24l, 24m), etc. (Fig. 10). Finds of the genus *Paraspiticeras* from this zone were recently described by Baraboshkin and Mikhailova (2020).

Pseudothurmannia ohmi Zone was proposed instead of the Pseudothurmannia angulicostata Zone (Table 3) after comparison with standard zonation (Baraboshkin, 1997a, 1997b). Zonal indexes of all subzones (Reboulet et al., 2018) are also present in the condensed horizon and were recognized previously (Karakasch, 1907; Drushchits, 1960; Kakabadze, 1981): *Pseudothurmannia picteti* Sark., *P. catulloi* (Parona), *P. ohmi* (Win.), *P. mortilleti* (Sar. et Schönd.), and other ammonites (Fig. 11), including Boreal *Simbirskites volgensis* Glaz. (Figs. 24q, 24r). The zone is preserved in the interfluve of Kacha and Alma rivers and still not confirmed for the Plain Crimea.

Lower Barremian and lower upper Barremian deposits are condensed in the red- and white-colored "Cephalopod limestone," respectively. The upper part of the upper Barremian and the Aptian are represented by a thick muddy unit (Biasala Formation). Originally the "Pseudothurmannia angulicostata" Zone of the modern upper Hauterivian scale was included in the upper Barremian together with the Holcodiscus caillaudi Zone and Lytoceras taiganense Zone (Table 4). Later Eristavi (1955) replaced these zones by the Beds with *Holcodiscus caillaudianus* in the lower Barremian limestones and overlying Silesites seranonis mudstones. The first attempt to recognize standard zones was made by Baraboshkin (1997a). Barremian zonation is modified in the present paper according to standard zonation (Reboulet et al., 2018) and revision of some ammonites.

Taveraidiscus hugii Zone is about 10 cm thick in the Verkhorechie section, the only section where it was recognized. It contains *Phyllopachyceras katschiense* Drus., *Protetragonites* sp., *Hamulina*? sp., *Hamulinites parvulus* (Uhl.), *Barremites difficilis* (d'Orb.), *Taveraidiscus* aff. *hugii* (Oost.), *Spitidiscus vandeckii* (d'Orb.), *Spitidiscus* sp., *Asterodiscus*? sp., *Silesites* sp., and *Patruliusiceras* aff. *tenue* (Kar).

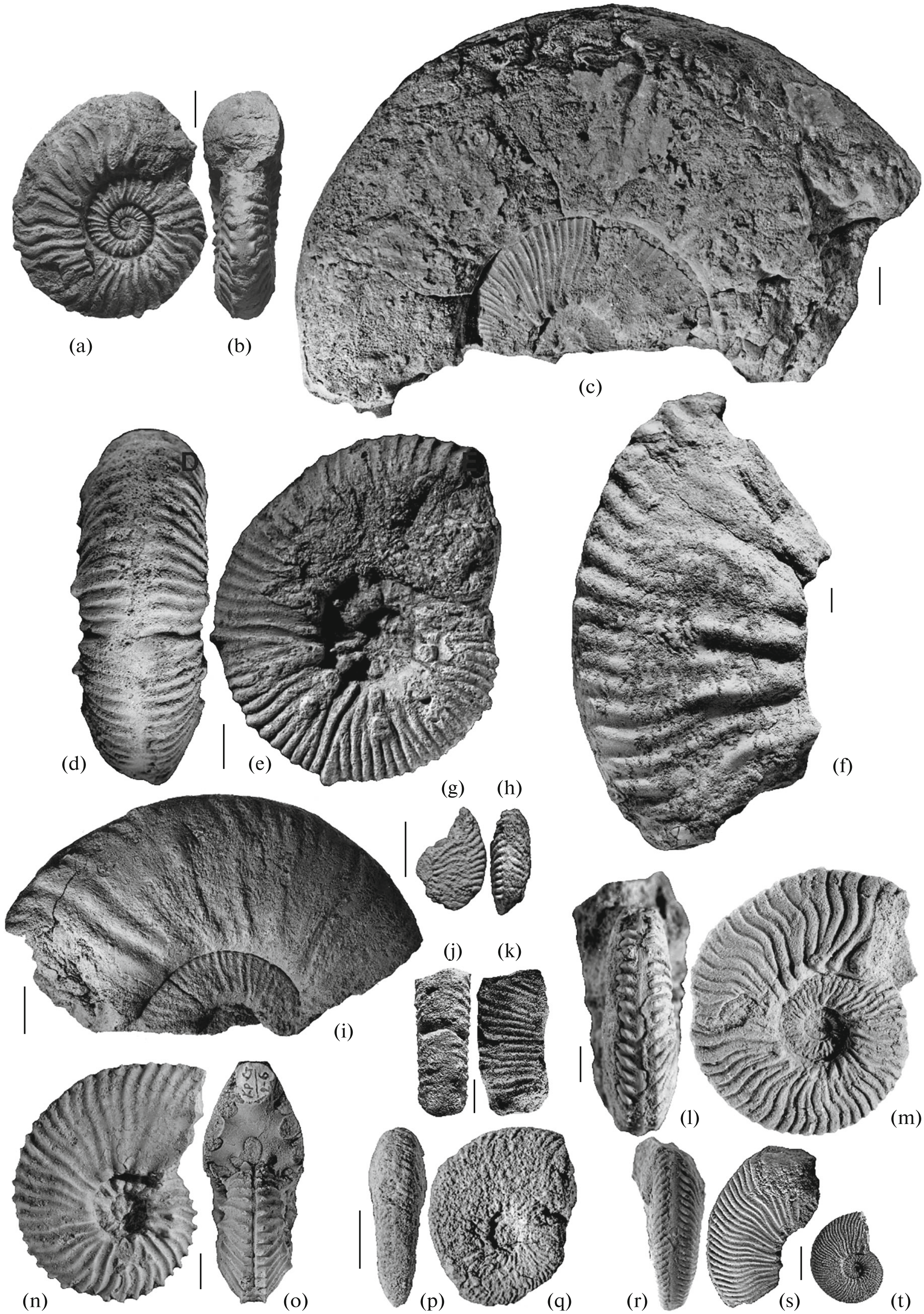
The presence of the **Niklesia pulchella Zone** is based on the single sample of the zonal index. Its zonal assemblage is not possible to determine.

Holcodiscus caillaudianus Zone was proposed by Eristavi (1955) for the Mountainous Crimea. The zonal assemblage includes *Phyllopachyceras katschiense* Drus., *P. infundibulum* (d'Orb.), *Holcodiscus caillaudianus* (d'Orb.), *H. uhligi* (Kar.), *Parasaynoceras tzankovi* (Avram), *Metahoplites (Metahoplites) diversecostatus* (Coq.), *M. (M.) diversicostatus latituberculatus* (Tzan. et Bres.), *M. (M.) rarecostatum* (Kar.), *M. (M.) ziczac* (Kar.), *Avramidiscus seunesi* (Kil.), *Silesites vulpes* (Math.), *Patruliusiceras tenue* (Kar.), *Barremites difficilis* (d'Orb.), *Barremitites* cf. *strettostoma* (Uhl.), *Abrytusites* spp., *Melchiorites* spp., *Valdedorsella* spp., *Anahamulina subcylindrica* (d'Orb.), *Vasicekina subcincta* (Uhl.), *Leptoceratoides subtilis* (Uhl.), etc. Many of the figured specimens have been redetermined by E. Avram, V. Tzankov, J. Vermeulen and other paleontologists during revision of Karakasch (1907) and Drushchits (1960) monographs. They did not cite *Holcodiscus caillaudianus* from there. Nevertheless, we think this important index ammonite is present in Crimea. The other important ammonite *Holcodiscus uhligi* was used by Vermeulen (Vermeulen et al., 2016) as a zonal index for the basal upper Barremian. It was described by Karakasch (1907) from the condensed lower Barremian red limestones. It is possible that this ammonite passes into the upper Barremian, but it needs a confirmation. Therefore, we replace the **Holcodiscus caillaudianus Zone** by the **Holcodiscus caillaudianus–H. uhligi Zone** in the present paper. It is not possible to differentiate this condensed interval into zones and subzones as in (Reboulet et al., 2018).

Heinzia caicedi Zone is a new name of the replacing **Heinzia provincialis Zone** proposed earlier (Baraboshkin, 1997a). It is based on a single specimen of the zonal index (Fig. 24n) from the condensed white limestones. *Heinzia caicedi* (Karst.) is distributed in the Coronites darsi Zone–Heinzia sayni Subzone passing through the lower/upper Barremian boundary (Vermeulen et al., 2016). The accompanied ammonite assemblage is like the previous.

The muddy Biasala Formation, which continue the succession, contains very rare ammonites of the late Barremian–middle Aptian age in the region of Verkhorechie village. *Lytoceras taiganense* (Kulzh.-Vor.), *Imerites giraudi* (Kil.), and *Silesites seranonis* (d'Orb.) were used as zonal indexes for the lower part of the succession (Table 4). *Imerites* is not found in Crimea. *Silesites seranonis* (d'Orb.) appears earlier in the succession, so it is not useful as the zonal index for the Biasala Formation. *"Lytoceras" taiganense* (Kulzh.-Vor.) has not clear systematic and stratigraphic position, so it needs to be revised. All these ammonites have problems, and the interval was indicated as the Beds with *Patruliusiceras*, the most common ammonite here (Baraboshkin, 1997b). Later this interval was referred to the **Patruliusiceras uhligi Zone** (Baraboshkin et al., 2004). It contains *Barremites* sp., *Phyl-*

Fig. 23. Selected Valanginian ammonites. (a, b) *Eristavites platycostatus* (Sayn), MSU 95/29; (c) *Eleniceras tauricum* (Eichwald), MSU 129/1; (d, e) *Neohoploceras submartini* (Mallada), MSU 1/93; (f) *Stoicoceras tuberculatum* (Roman), MSU 95/30; (g, h) *Thurmanniceras pertransiens* (Sayn), MSU 94/3; (i) *Varlheideites peregrinus* Raws. et Kemp., MSU 95/31; (j, k) *Himantoceras* cf. *lessinianum* (Far. et al.), MSU 95/20; (l, m) *Campylotoxia campylotoxa campylotoxa* (Uhl.), MSU 95/10; (n, o) *Bodrakiceras inostranzewi* (Kar.), MSU 95/3; (p, q) *Thurmanniceras pertransiens* (Sayn), MSU 95/32; (r–t) *Neocomites neocomiensis* (d'Orb.), MSU 95/33. Figures 23a, 23b, 23d–23f, 23i–23q are from Verkhorechie village, Rezanaya Mountain: Figs. 23a, 23b, 23d, 23e, 23i, from condensed horizon in the base of upper Valanginian Neohoploceras submartini Zone; Fig. 23f, from upper Valanginian Teschenites callidiscus Zone; Figs. 23j, 23k, from Himantoceras trinodosum Zone; Figs. 23p, 23q, from lower Valanginian Thurmanniceras pertransiens Zone. Figure 23c is from Observatory Plateau, upper Valanginian Eleniceras tauricum Zone. Figures 23g, 23h are from Sbrosovyi Log, Belbek River, lower Valanginian Thurmanniceras pertransiens Zone. Figures 23r–23t are from Krymskaya Roza Quarry, lower–basal upper Valanginian. Scale bars: 1 cm. Photos by E.Yu. Baraboshkin and G.P. Petukhova (MSU).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lopachyceras spp., *Macroscaphites* sp., *Patruliusiceras uhligi* Avram, *P.* aff. *sulcistriatum* (Kar.), *P. tenue* (Kar.), *Haplobrancoceras subquadratum* (Avram), and *Heteroceras*? sp. Drushchits (1956) reported the presence of *Silesites seranonis* (d'Orb.), *Costidiscus* sp., and *Colchidites* sp. from the lower part of the succession.

The Barremian ammonite assemblages of the Plain Crimea are very poor, but they were linked with standard ammonite zones used in the USSR by means of microfauna (Leshchukh, 1987, 1992).

The **Barremian–Aptian** boundary is not characterized by ammonites and was drown due to paleomagnetic data and microfossils (Baraboshkin et al., 2004; Brovina, 2017). The Aptian part of the Biasala Formation contains rare ammonites and numerous belemnites. The zonation was proposed by Drushchits, Mikhailova and Nerodenko (1981) on the base of ammonite finds in the interfluve of the Kacha–Salgir rivers (Fig. 2: Kp18, Kp10–12; Table 5). It was modified by Baraboshkin (2003) and Mikhailova and Baraboshkin (2009). These zones could be traced only in southwestern Crimea and their boundaries are provisional.

Aconeceras nisoides Zone proposed by Baraboshkin in 2001 for the Mountainous Crimea (Baraboshkin, 2003) is subdivided into the Deshayesites volgensis and Deshayesites deshayesi subzones. The **Deshayesites volgensis Subzone** contains *Paradeshayesites* aff. *callidiscus* (Casey) (Figs. 24a, 24b). The **Deshayesites deshayesi Subzone** was originally proposed as a zone for the Mountainous Crimea (Drushchits et al., 1981). It is characterized by the presence of *Deshayesites* ex gr. *deshayesi* (d'Orb.) (Figs. 24c, 24d), *D.* cf. *deshayesi* (d'Orb.), and *Cheloniceras* ex gr. *seminodosum* (Sinz.). Both subzones contain *Aconeceras nisoides* (Saras.) and numerous belemnites.

Aconeceras nisus Zone was proposed by Baraboshkin in 2001 for the Mountainous Crimea (Baraboshkin, 2003) instead of the Colombiceras crassicostatum Zone (Drushchits et al., 1981) because *Aconeceras nisus* (d'Orb.) is much more common in this interval. Additionally, the Nisus/Crassicostatum Zone contains *Colombiceras* sp., *Zurcherella* sp. indet., *Valdedorsella* aff. *akuschaense* (Anth.), and *Jauberticeras latericarinatum* (Anth.).

Parahoplites melchioris Zone proposed by Drushchits et al. (1981) does not supported by the zonal index, so it could be accepted with a question mark. However as in the North Caucasus and Caspian region, it could be subdivided into two subzones. The **Parahoplites multicostatus Subzone** (Baraboshkin, 2003) contains *Parahoplites* aff. *multicostatus* (Sinz.) and the **Acanthohoplites aschiltaensis Subzone** (Baraboshkin, 2003) is characterized by the presence of the zonal index. Some ammonites of wide strarigraphic range like *Pseudohaploceras matheroni* (d'Orb.) (Fig. 24f) are also present.

? Nolaniceras nolani Zone was proposed by Drushchits et al. (1981) on the base of findings of *Acanthohoplites trautscholdi* (Sim.).

The Aptian zonal ammonite record of the Plain Crimea is more complete than that of the Mountainous Crimea and is discussed by Leshchukh (1987, 1992).

The Aptian–Albian transition is marked by tectonic uplift and erosion (see above). The **lower Albian** is missing in the southwestern Crimea, but it was reported from the central and eastern Crimea (Drushchits, 1960; Benenson, 1985). Resent revision of the same sections demonstrates the presence of upper Aptian deposits (Karpuk et al., 2022). Ammonites *Leymeriella* sp. from these regions were not figured and not found in Drushchits's collection. Therefore, the presence of the **Leymetiella terdefurcata** ammonite Zone in the Mountainous Crimea is doubtful (Table 6).

Middle Albian was recognized only in the town of Balaklava region (this paper, see above). It starts from the **Paranahoplites intermedius Zone** which contains *Paranahoplites praecox* (Spath) and *Proeuhoplites loricatus* (Spath).

Anahoplites daviesi Zone (Baraboshkin, 2016 and this paper, see above) continues the succession. The ammonite assemblage includes *Anahoplites daviesi* Spath (Figs. 25e, 25m, 25n), *A. planus* (Mant.), *Hamites (H.) maximus* (Sow.) (Fig. 25s), *H.* sp., *Kossmatella romana* Wied. (Figs. 25p, 25q, 25r), *Puzosia (P.) mayoriana* (d'Orb.), *Desmoceras latidorsatum* Mich., and *Phylloceras (Hypophylloceras) cypris cypris* Fall. et Term. (Fig. 25t).

The generic attribution of the species *A. daviesi* Spath should be specially discussed, but we refer it to

Fig. 24. Selected Hauterivian–Aptian ammonites of southwestern Crimea. (a, b) *Paradeshayesites* aff. *callidiscus* (Casey), MSU 79/15; (c, d) *Deshayesites* ex gr. *deshayesi* (d'Orb.), MSU 79/12; collected by G.F. Weber; (e) *Pseudothurmannia catulloi* (Par.), MSU 101/24; (f) *Pseudohaploceras matheroni* (d'Orb.), MSU 79/16; (g, h) holotype of *Theodorites drushitsi* Bar. et Mikh., MSU 8/93; the restored photo combining photo of the inner whorl (from Baraboshkin and Mikhailova, 2006) and outer fragment of body chamber recently found in the collection; (i) *Pseudothurmannia ohmi* (Win.), MSU 101/25; (j) *Pseudothurmannia angulicostata* (d'Orb.), MSU 101/26; (k) *Crioceratites duvaliii* Lév., MSU 101/27; (l, m) *Discoidellia* aff. *couratieri* Verm., MSU 101/28; (n) *Heinzia caicedi* (Karst.), MSU 101/29; (o, p) *Speetoniceras inversum* (M. Pavl.), MSU 101/30; (q, r) *Simbirskites volgensis* Glaz., MSU 101/31. Figures 24a–24d are from Aptian, talus at the southern slope of Belaya Mountain near Verkhorechie village in southwestern Crimea. Figure 24f is from Partizanskoe village, Alma River, collected by B.A. Zaitsev (Taurida National University, Simferopol), 2015. Figures 24e, 24i–24k, 24n–24r are from upper Hauterivian–lower upper Barremian condensed section, southern slope of Belaya Mountain near Verkhorech'e village, E.Yu. Baraboshkin collection. Figures 24l, 24m are from upper Hauterivian–lower upper Barremian condensed section, southern slope of Selbukhra Mountain, collected by A.V. Areshin (Timiryazev Agricultural Academy). Photos by E.Yu. Baraboshkin and G.P. Petukhova (MSU).

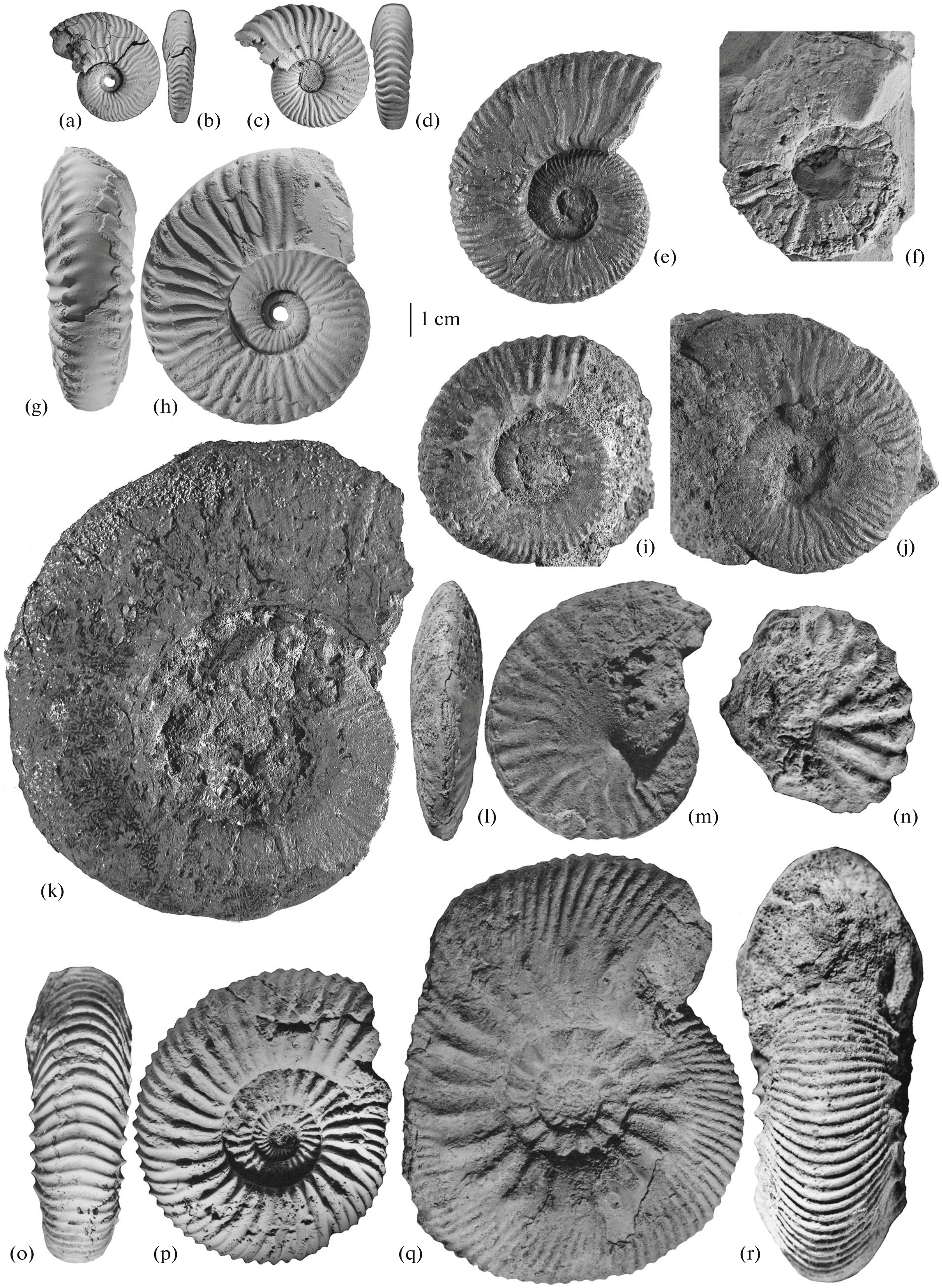
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Table 3. A review of the ammonite biostratigraphic subdivision of the Hauterivian deposits of the Crimean Mountains

<table>
<tr><th rowspan="2">Substage</th><th colspan="2">West Mediterranean Zonal Standard, Reboulet et al., 2018 (pars)</th><th rowspan="2">Stage</th><th>Mountain Crimea, Karakasch, 1907</th><th rowspan="2">Substage</th><th>Mountain Crimea, Eristavi, 1955</th><th rowspan="2">Substage</th><th>Mountain Crimea, Drushchits, 1956, 1960</th><th rowspan="2">Substage</th><th>Kacha-Bodrak Interfluve, Baraboshkin, 1997a</th><th rowspan="2">Substage</th><th colspan="2">Mountain Crimea, Baraboshkin, 2008 and this paper</th></tr>
<tr><th colspan="2">Zone, Subzone</th><th></th><th>Zone</th><th>Zone</th><th>Zone</th><th colspan="2">Zone, Subzone</th></tr>
<tr><td rowspan="5">Lower Barremian</td><td colspan="2">Moutoniceras moutonianum</td><td rowspan="5">Barremian</td><td rowspan="4">Limestones with Bel. minaret, Desm. difficile, Charrieri, strettostoma, etc.</td><td rowspan="11">Lower Barremian</td><td rowspan="4">Holcodiscus caillaudi</td><td rowspan="4">L. Barremian</td><td rowspan="4">Holcodiscus caillaudianus</td><td rowspan="5">Lower Barremian</td><td rowspan="3">Niklesia pulchella</td><td rowspan="5">Lower Barremian</td><td colspan="2" rowspan="4">Niklesia pulchella</td></tr>
<tr><td colspan="2">Kotetishvilia compressissima</td></tr>
<tr><td colspan="2">Nicklesia pulchella</td></tr>
<tr><td colspan="2">Kotetishvilia nicklesi</td><td>Missing?</td></tr>
<tr><td colspan="2">Taveraidiscus hugii</td><td rowspan="9">Limestones with Duv. dilatata, Ph. ponticuli, Dsm. subdifficile, hemiptychym, Lyt. auctum, Crioc. Duvali, angulicostatum</td><td rowspan="7">Pseudothurmannia angulicostata</td><td rowspan="7">Upper Hauterivian</td><td rowspan="7">Pseudothurmannia angulicostata</td><td>Spitidiscus hugii</td><td colspan="2">Taveraidiscus hugii</td></tr>
<tr><td rowspan="8">Upper Hauterivian</td><td rowspan="4">“Pseudo-thurmannia ohmi”</td><td>P. picteti</td><td rowspan="12">Hauterivian</td><td rowspan="8">Upper Hauterivian</td><td>Missing?</td><td rowspan="8">Upper Hauterivian</td><td rowspan="4">Pseudothur-mannia ohmi</td><td>P. picteti</td></tr>
<tr><td>P. catulloi</td><td rowspan="2">Pseudothurmannia angulicostata</td><td>P. catulloi</td></tr>
<tr><td rowspan="2">“P. ohmi”</td><td rowspan="2">P. ohmi</td></tr>
<tr><td>Craspedodiscus discofalcatus</td></tr>
<tr><td colspan="2">Balearites balearis</td><td>Milanowskia speetonensis</td><td colspan="2">Milanowskia speetonensis</td></tr>
<tr><td colspan="2" rowspan="2">Pseudospitidiscus ligatus</td><td>Speetoniceras inversum</td><td colspan="2">Speetoniceras inversum</td></tr>
<tr><td rowspan="2">U.Haut.</td><td rowspan="2">Crioceratites duvali</td><td rowspan="7">Lower Hauterivian</td><td rowspan="2">Crioceratites duvali</td><td rowspan="2">Crioceratites duvali</td><td colspan="2" rowspan="2">Crioceratites duvalii</td></tr>
<tr><td colspan="2">Subsaynella sayni</td></tr>
<tr><td rowspan="4">Lower Hauterivian</td><td colspan="2">Lyticoceras nodosoplicatum</td><td rowspan="4">Sandstones with Echin. cordiformis, Ost. Couloni, Duv. crimica</td><td rowspan="5">Lower Hauterivian</td><td rowspan="5">Leopoldia leopoldi</td><td rowspan="5">Leopoldia leopoldi
Bidichotomtes bidichotomus</td><td rowspan="4">Lower Hauterivian</td><td>Lyticoceras nodosoplicatum</td><td rowspan="4">Lower Hauterivian</td><td colspan="2">Theodorites theodori</td></tr>
<tr><td rowspan="2">Crioceratites loryi</td><td>Olcostephanus (J.) jeannoti</td><td rowspan="2">Crioceratites loryi</td><td colspan="2" rowspan="2">? Crioceratites loryi</td></tr>
<tr><td>Crioceratites loryi</td></tr>
<tr><td colspan="2">Acanthodiscus radiatus</td><td>Leopoldia leopoldina</td><td colspan="2">Leopoldia desmoceroides</td></tr>
<tr><td colspan="5">Valanginian</td><td colspan="5">Valanginian</td></tr>
</table>

Table 4. A review of the ammonite biostratigraphic subdivision of the Barremian deposits of the Crimean Mountains

<table>
<tr><th rowspan="2">Substage</th><th colspan="2">West Mediterranean Zonal Standard, Reboulet et al., 2018 (pars)</th><th rowspan="2">Stage</th><th>Mountain Crimea, Karakasch, 1907</th><th rowspan="2">Substage</th><th>Mountain Crimea, Eristavi, 1955</th><th rowspan="2">Substage</th><th>Mountain Crimea, Drushchits, 1960</th><th rowspan="2">Substage</th><th>Kacha-Bodrak Interfluve, Baraboshkin, 1997a</th><th>Mountain Crimea, Baraboshkin, 2008 and this paper</th></tr>
<tr><th colspan="2">Zone, Subzone</th><th></th><th>Zone</th><th>Zone</th><th>Zone, Beds with fauna</th><th>Zone, Subzone</th></tr>
<tr><td>L.A.</td><td colspan="2">Deshayesites oglanlensis</td><td rowspan="8">Aptian</td><td rowspan="8">Mudstones with Bel. semicanaliculatus</td><td>L.A.</td><td>Neohibolites ewaldisimilis</td><td>L.A.</td><td>Zones are not proposed</td><td>L.Apt.</td><td>Aconeceras nisoides</td><td>?</td></tr>
<tr><td rowspan="9">Upper Barremian</td><td rowspan="2">Martellites sarasini</td><td>Pseudocrioc. waagenoides</td><td rowspan="7">Upper Barremian</td><td rowspan="7">Lytoceras taiganense</td><td rowspan="7">Upper Barremian</td><td rowspan="7">Zones are not proposed. Ammonites: Heteroceras astieri, Costidiscus recticostatus, Silesites seranonis, Barremites strettostoma, B. subdifficilis</td><td rowspan="9">Upper Barremian</td><td rowspan="7">Beds with Patruliusiceras</td><td>?</td></tr>
<tr><td>Martellites sarasini</td><td rowspan="6">Patruliusiceras uhligi</td></tr>
<tr><td rowspan="2">Imerites giraudi</td><td>Heteroceras emerici</td></tr>
<tr><td>Imerites giraudi</td></tr>
<tr><td rowspan="3">Gerhardtia sartousiana</td><td>Hemihoplites feraudianus</td></tr>
<tr><td>Gerhardtia provincialis</td></tr>
<tr><td>Gerhardtia sartousiana</td></tr>
<tr><td rowspan="2">Toxancyloceras vandenheckii</td><td>Gassendic. alpinum</td><td rowspan="6">Barremian</td><td rowspan="6">Limestones with Bel. minaret, gladiiformis, Desm. difficile, Charrieri, strettostoma, cassidoides, Ph. Ponticuli, Ph. infundibulum, Costid. nodosostriatus, Macrosc. Yvani, Lyt. subsequens, Phestus, stephanense, etc.</td><td rowspan="8">Lower Barremian</td><td rowspan="6">Holcodiscus caillaudi</td><td rowspan="6">Lower Barremian</td><td rowspan="6">Holcodiscus caillaudianus</td><td rowspan="2">Heinzia provincialis</td><td rowspan="2">Heinzia caicedi</td></tr>
<tr><td>T. vandenh.</td></tr>
<tr><td rowspan="6">Lower Barremian</td><td colspan="2">Moutoniceras moutonianum</td><td rowspan="6">Lower Barremian</td><td rowspan="3">Holcodiscus caillaudianus</td><td rowspan="3">Holcodiscus caillaudianus–H. uhligi</td></tr>
<tr><td rowspan="2">Kotetishvilia compressissima</td><td>Holcodiscus caillaudianus</td></tr>
<tr><td>Holcodiscus fallax</td></tr>
<tr><td>Niklesia pulchella</td><td rowspan="2"></td><td>Niklesia pulchella</td><td>Niklesia pulchella</td></tr>
<tr><td>Kotetishvilia nicklesi</td><td rowspan="2">Hauterivian</td><td rowspan="2">Limestones with Duv. dilatata, Ph. ponticuli, Dsm. subdifficile, hemiptychym, Lyt. auctum, Crioc. Duvali, angulicostatum</td><td rowspan="2">Pseudothurmannia angulicostata</td><td rowspan="2">U. Hauteriv</td><td rowspan="2">Pseudothurmannia angulicostata</td><td rowspan="2">Avramidiscus hugii</td><td rowspan="2">Taveraidiscus hugii</td></tr>
<tr><td>Taveraidiscus hugii</td><td></td></tr>
</table>

Table 5. A review of the ammonite biostratigraphic subdivision of the Aptian deposits of the Crimean Mountains

Substage	West Mediterranean Zonal Standard, Reboulet et al., 2018 (pars)	Stage	Mountain Crimea, Karakasch, 1907	Substage	Mountain Crimea, Eristavi, 1955	Mountain Crimea, Drushchits, 1960	Substage	Mountain Crimea, Drushchits and Mikhailova, Nerodenko, 1981	Substage	Kacha-Bodrak Interfluve, Baraboshkin, 1997b	Mountain Crimea, Mikhailova and Baraboshkin, 2009 and this paper	
	Zone				Zone	Zone		Zone		Zone	Zone, Subzone	
L. Alb.	Leymeriella tardefurcata	Albian	Sandstones and limestones with *O. arduennensis*, *Plicatula inflata*	Lower Albian	Neohibolites wollemanni	Leymeriella tardefurcata	Not studied		L. Alb.	Missing	Not confirmed	
Upper Aptian	Hypacanthoplites jacobi	Aptian	Mudstones with *Bel. semicanaliculatus*			Hypacanthoplites jacobi (paleontologically not confirmed)	U. Apt.		U. Apt.		Missing	
	Acanthohoplites nolani					Acanthohoplites trautscholdi		Acanthohoplites nolani			? Nolaniceras nolani	
	Parahoplites melchioris			U. Aptian	Neohibolites inflexus and Puzosia emerici	Zones are not proposed. Cephalopods: *Neohibolites inflexus*, *N. aptiensis* *N. wollemani* *N. semicanaliculatus*, *Colomblceras* sp., *Epicheloniceras* sp.	Middle Aptian	Parahoplites melchioris	Mid. Aptian	Aconeceras nisum	? Parahoplites melchioris	Acanthohoplites aschiltaensis
												Parahoplites multicostatus
	Epicheloniceras martini							Colombiceras crassicostatum			Aconeceras nisus	Colombiceras crassicostatum
Lower Aptian	Dufrenoya furcata			Lower Aptian	Neohibolites ewaldissimilis	Zones are not proposed. Cephalopods: *Deshayesites deshayesi*, *Aconeceras trautscholdi*, *Mesohibolites elegans*, *M. moderatus*, *M. beskidensis*, *M. minareticus*	Lower Aptian	Deshayesites deshayesi	Lower Aptian	Deshayesites deshayesi	Aconeceras nisoides	?
	Deshayesites deshayesi											Deshayesites deshayesi
	Deshayesites forbesi									?		Deshayesites volgensis
	Deshayesites oglanlensis											?

Table 6. A review of the ammonite biostratigraphic subdivision of the Albian deposits of the Crimean Mountains

<table>
<tr><th rowspan="2">Substage</th><th colspan="2">West Mediterranean Zonal Standard, Reboulet et al., 2018 (pars)</th><th rowspan="2">Stage</th><th>Mountain Crimea, Karakasch, 1907</th><th rowspan="2">Substage</th><th>Mountain Crimea, Eristavi, 1955</th><th>Mountain Crimea, Drushchits, 1960</th><th rowspan="2">Substage</th><th colspan="2">Kacha-Bodrak Interfluve, Marcinowski and Naidin, 1976</th><th colspan="2">Kacha-Bodrak Interfluve, Baraboshkin, 1997a</th><th>Mountain Crimea, this paper</th></tr>
<tr><th colspan="2">Zone, Subzone</th><th></th><th>Zone</th><th>Zone</th><th colspan="2">Zone, Beds with fauna</th><th colspan="2">Zone, Subzone</th><th>Zone, Subzone</th></tr>
<tr><td rowspan="8">Upper Albian</td><td colspan="2">Arrhaphoceras briacense</td><td rowspan="14">Albian</td><td rowspan="14">Sandstones and limestones with O. arduennensis, Plicatula inflata</td><td rowspan="8">Upper Albian</td><td rowspan="8">Hysteroceras varricosum and Pervinquieria inflata</td><td rowspan="5">Pervinquieria inflata</td><td rowspan="8">Upper Albian</td><td colspan="2" rowspan="3">Beds with Stoliczkaia</td><td rowspan="3">Stoliczkaia dispar</td><td rowspan="2">Durnovarites perinflatum</td><td rowspan="2">Mortoniceras (Durnovarites) perinflatum</td></tr>
<tr><td colspan="2">Mortoniceras perinflatum</td></tr>
<tr><td colspan="2">Mortoniceras rostratum</td><td>Mortoniceras rostratum</td><td>Mortoniceras (Mortoniceras) rostratum</td></tr>
<tr><td colspan="2">Mortoniceras fallax</td><td colspan="2" rowspan="2">Beds with Mortoniceras</td><td colspan="2" rowspan="2">Mortoniceras (Mortoniceras) inflatum</td><td rowspan="2">Mortoniceras (Mortoniceras) inflatum</td></tr>
<tr><td colspan="2">Mortoniceras inflatum</td></tr>
<tr><td colspan="2" rowspan="2">Mortoniceras pricei</td><td rowspan="3">Hysteroceras orbignyi</td><td rowspan="2">Beds with Hysteroceras</td><td rowspan="2">Beds with Scaphites</td><td colspan="2">Hysteroceras varicosum</td><td>Hysteroceras varicosum</td></tr>
<tr><td colspan="2">Hysteroceras orbignyi</td><td>Hysteroceras orbignyi</td></tr>
<tr><td colspan="2">Dipoloceras cristatum</td><td colspan="2" rowspan="7">Missing</td><td colspan="2" rowspan="7">Missing</td><td>Dipoloceras cristatum</td></tr>
<tr><td rowspan="4">Middle Albian</td><td colspan="2">Euhoplites lautus</td><td rowspan="5">Middle Albian</td><td rowspan="5">Neohibolites minimus and Hoplites dentatus</td><td rowspan="4">Hoplites dentatus</td><td rowspan="5">Middle Albian</td><td>Anahoplites daviesi</td></tr>
<tr><td colspan="2">Euhoplites loricatus</td><td>Paranahoplites intermedius</td></tr>
<tr><td rowspan="2">Hoplites dentatus</td><td>Hoplites spathi</td><td rowspan="3">Missing</td></tr>
<tr><td>Lyelliceras lyelli</td></tr>
<tr><td rowspan="2">L. Albian</td><td colspan="2">Douvilleiceras mammillatum</td><td>Douvilleiceras mammillatum</td></tr>
<tr><td colspan="2">Leymeriella tardefurcata</td><td>L. Albian</td><td>Neohibolites wollemanni</td><td>Leymeriella tardefurcata</td><td>L. Albian</td><td>Leymeriella tardefurcata (not confirmed)</td></tr>
</table>

the genus *Anahoplites*, not to the *Neanahoplites* (Cooper, Owen, 2011). It should be noted that the types of *A. daviesi s.s.* and *A. ornatus* (originally *A. daviesi ornata* Spath) in the paper (Cooper, Owen, 2011) were mixed up: the holotype of *A. daviesi* (Spath, 1926, pl. XIV, Figs. 5a, 5b) is the neotype of *Neanahoplites ornatus* in (Cooper, Owen, 2011, Figs. 1k, 1l) and the holotype of *Anahoplites daviesi ornata* (Spath, 1926, pl. XIV, Figs. 5c, 5d) is the same (? or very close to) as the holotype of *Neanahoplites daviesi* (Cooper, Owen, 2011, Figs. 1m, 1n). According to Michael Cooper (personal communication, 20 and March 25, 2024), who asked me to display this information on such unfortunate misconception, it does not affect on the generic name *Neanahoplites* Cooper, Owen, 2011.

Dipoloceras cristatum Zone is in the base of the upper Albian (this paper, see above). It contains *Dipoloceras subdelaruei* (Spath), *D. cornutum* (Pictet) and *Anahoplites planus* (Mant.) and was recognized only in the town of Balaklava region.

Hysteroceras orbignyi Zone was proposed for the Mountainous Crimea by Drushchits in 1953 (Drushchits, 1956). These deposits fill local "ingressive" depression of estuarine type (see above) and has been studied by many geologists (Drushchits, 1956; Yanin, 1964, 1976; Muratov, 1969; etc.). The description of the ammonite assemblage of the "Beds with *Hysteroceras*" was published by Marcinowski and Naidin (1976). These beds are characterized by *Hysteroceras orbignyi* (Spath) (Fig. 25o), *H.* sp., *Hamites compressus* J. Sow., *H. attenuates* J. Sow., *Stomohamites virgulatus* (Brongn.), *Scaphites* (Scaphites) cf. *hugardianus* d'Orb., *Hamites (Lytohamites) similis* Casey, *Euhoplites inornatum* Spath, *Puzosia (Puzosia) mayoriana* (d'Orb.), *Epihoplites trifidus* Spath, and *Epihoplites* sp.

Hysteroceras varicosum Zone was distinguished by Baraboshkin (1997b) from the "Beds with *Hysteroceras*" (Marcinowski and Naidin, 1976). The zone includes *Hysteroceras varicosum* (J. de C. Sow.) (Figs. 25f, 25g), *H.* sp., *Epihoplites gibbosus* Spath, *E. denarius* J. de C. Sow., *E.* spp., *Metaclavites iphitus* (Spath), and *Kossmatella* sp.

The zonal index *Mortoniceras (Mortoniceras) fallax* (Breistr.) (Figs. 25 k, 25l) proposed instead of those for the Orbignyi–Varicosum zones (Kennedy et al., 2008) was found in these deposits in the Prokhladnoe village region. This is the only finding, whose exact location has not been documented, so there is no reason to change the name in the zonal scheme at the moment.

Mortoniceras (Mortoniceras) inflatum Zone was introduced in the Crimean geology by Drushchits in 1953 (Drushchits, 1956) as "Pervinquieria inflata Zone." The zone was described by Marcinowski and Naidin (1976) as "Beds with *Mortoniceras*." Baraboshkin (1997b) referred single sample of "*Mortoniceras (Mortoniceras) inflatum* (J. Sow.)" of Marcinowski and Naidin (1976) to *M. (M.) rostratum* (J. Sow.) and splited former the Inflatum Zone into the Rostratum and Perinflatum Subzones of the **Stoliczkaia dispar Zone**. The "Beds with *Scaphites*" of Marcinowski and Naidin (1976) were attributed to the **Mortoniceras (Mortoniceras) inflatum Zone** (Baraboshkin, 1997a). It has limited distribution in the Mountainous Crimea and is known as "Shara limestones" and contains *Scaphites (S.) simplex* Juk.-Brown., *S. (S.)* sp., and *Kossmatella (K.)* sp. Taking in account the Balaklava middle Albian–early late Albian ammonite assemblages, the age of "Shara limestones" may be older. The **Stoliczkaia dispar Zone** quartz-glauconitic sandstones were traced from the towm of Balaklava to the Bodrak River Basin of southwestern Crimea.

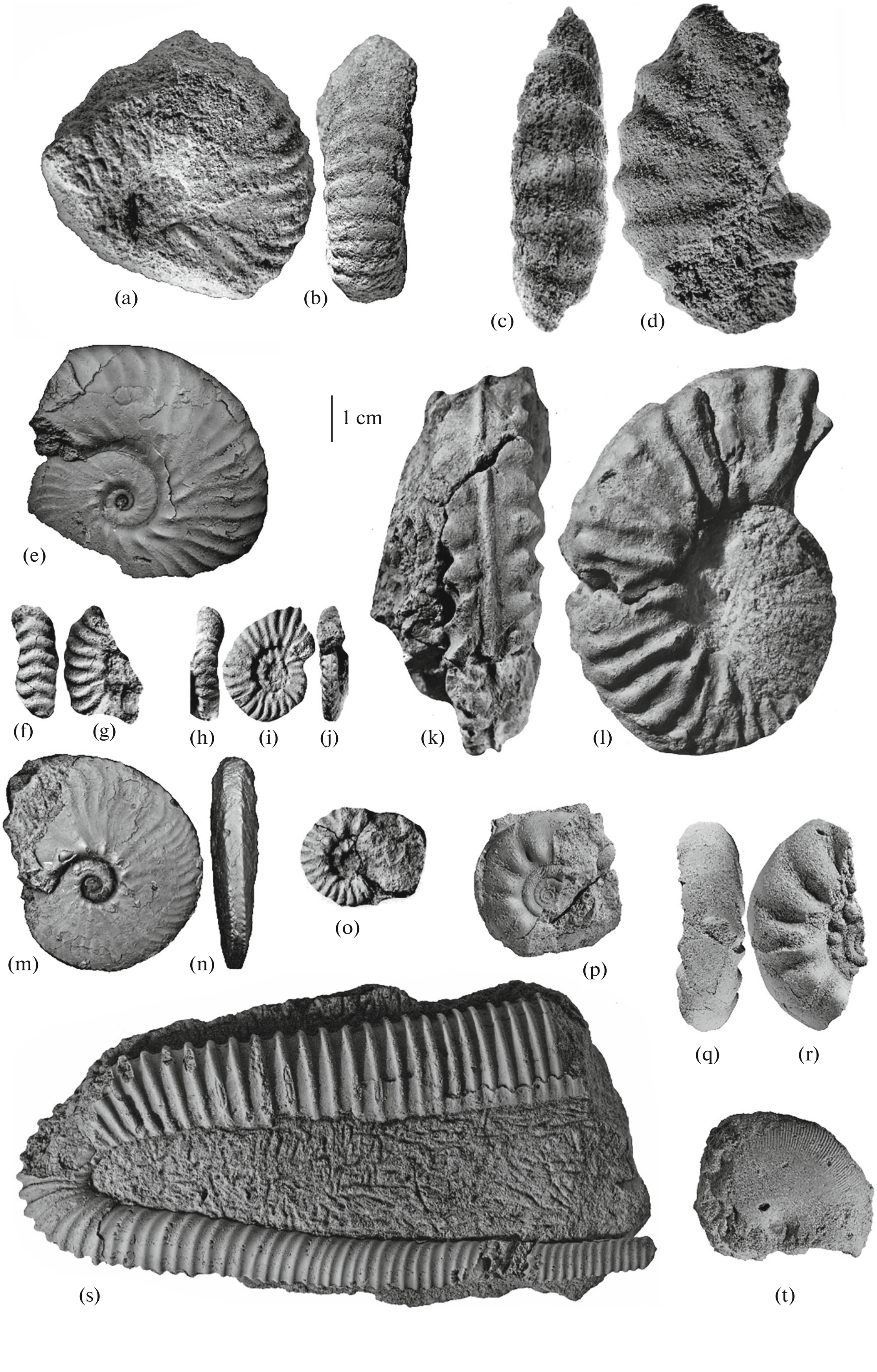
Mortoniceras (Mortoniceras) rostratum Zone is characterized by *Mortoniceras (M.) rostratum* (J. Sowerby), *M. (M.) stoliczkai* (Spath), *Stoliczkaia (Stoliczkaia) notha* (Seeley) (Fig. 25a), and *Puzosia* spp. (Baraboshkin, 1997b).

Mortoniceras (Durnovarites) perinflatum Zone contains *Mortoniceras (Durnovarites) perinflatum* (Pict. et Camp.), *M. (D.) postinflatum* Spath, *M. (D.) subquadratum* Spath, *M. (D.) vraconense* Renz, *Stoliczkaia (Stoliczkaia) clavigera* Neum. (Fig. 25b), *Callihoplites* sp., *Anisoceras perarmatum* (Pict. et Camp.), and *Lepthoplites* aff. *cantabrigiensis* Spath (Baraboshkin, 1997b).

The Albian succession of the Plain Crimea is more complete than that of the Mountainous Crimea and includes most of the standard ammonite zones (Leshchukh, 1987, 1992).

To resume, the state of knowledge of the Early Cretaceous ammonites is very irregular. Berriasian-

Fig. 25. Selected Albian ammonites. (a, b) *Stoliczkaia (Stoliczkaia) notha* (Seeley), MSU 156/8; (c, d) *Stoliczkaia (Stoliczkaia) clavigera* Neum., MSU 156/9; (e) *Anahoplites daviesi* Spath, MSU 156/2; (f, g) *Hysteroceras varicosum* (J. de C. Sow.), MSU 156/10; (h–j) *Hysteroceras binum* (J. Sow.), MSU 156/11; (k, l) *Mortoniceras (Mortoniceras) fallax* (Breistr.), MSU 156/12; (m, n) *Anahoplites daviesi* Spath, MSU 156/4; (o) *Hysteroceras orbignyi* Spath, MSU 156/13; (p, q, r) *Kossmatella romana* Wiedm.: (p) MSU 156/6, (q, r) MSU 156/7; (s) *Hamites (Hamites) maximus* J. Sow., MSU 156/1; (t) *Phylloceras (Hypophylloceras) cypris cypris* (Fal. et Term.), MSU 156/5. Figures 25a, 25b are from upper Albian, Mortoniceras rostratum Zone, Belaya Mountain near Verkhorechie village, V.V. Druschits collection. Figures 25c, 25d are from upper Albian, Mortoniceras perinflatum Zone, Mender ravine, near Prokhladnoe village, MSU student's collection. Figures 25f–25l, 25o are from upper Albian, Hysteroceras varicosum–Hysteroceras orbignyi zones, Mangush ravine, near Prokhladnoe village, MSU student's collection. Figures 25e, 25m–25n, 25s are from middle Albian, Anahoplites daviesi Zone, Old Psilerahsky Quarry (recultivated now), Balaklava Town, E.Yu. Baraboshkin's collection, 1997. Figures 25p, 25r, 25t are from middle Albian, Anahoplites daviesi Zone, Chernorechie village region, N.I. Lysenko's collection (Crimean Federal University, Simferopol). All samples were covered by NH_4Cl. Photos by E.Yu. Baraboshkin and G.P. Petukhova (MSU).


(a)
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Valanginian ammonites are studied much better than the others. Early Hauterivian and latest Barremian-Aptian ammonites are rather rare, especially ammonites from Biasala mudstones. They need additional collecting and redescription. Late Hauterivian and early late Barremian ammonites from condensed intervals are numerous but published in old monographs. Their taxonomy needs serious revision after publications of E. Avram, R. Busnardo, J. Vermeulen, V. Tzankov, Z. Vašiček and other ammonite specialists. Possibly additional cm-scale ammonite collecting will clarify the zonal to subzonal succession and give more detailed knowledge on the Tethyan-Boreal correlation as ammonites from different paleobiogeographic provinces are abundant in this interval. Albian ammonites also need a revision, and the ammonite succession of Balaklava needs special study.

Early Cretaceous Ostracods

The study of Crimean Lower Cretaceous ostracods started only in the second half of the 1960s. The monograph description of new species and assessment of their stratigraphic value were initially made by Neale (1966) who studied six samples from the central Crimea Berriasian. He distinguished 20 species, 9 of which he described as new, and 11 considered as indeterminable. Later Rachenskaya published several papers on ontogenesis, sexual dimorphism, morphology, and stratigraphic value of some of Berriasian and Valanginian ostracods. She identified 50 and described 28 species, but 19 new species have not been published (Rachenskaya, 1970). Berriasian ostracods from southwestern Crimea and central Crimea were studied by Tesakova. She identified about 30 species, 11 of which were new and 10 were indeterminable (Tesakova and Rachenskaya, 1996a, 1996b). The first information on the Barremian-Aptian ostracods (southwestern Crimea, Verkhorechie section, Fig. 2: Kp18) were described by Nemirovskaya (1972), who determined 25 taxa, but only five of species level.

Early Cretaceous ostracods from the different parts of Crimea were studied by Savelieva since 2001. Tesakova, Manushkina, and Karpuk joined to these investigations later (Karpuk, 2016a, 2016b, 2016c; Brovina et al., 2016; Arkadiev et al., 2018a, 2018b; Karpuk et al., 2018). The integrated study was focused on the upper Tithonian (Andreai and Microcantum Zones)–lower Berriasian (Jacobi Zone) sections (Arkadiev et al., 2018b), and included macrofossils (mostly ammonites), ostracods, forams, calpionellids, and palynology. Thirteen new species were identified from the new genera *Dorsocythere* Karpuk et Tes., *Pseudotethysia* Karpuk, *Protobrachycythere* Karpuk, and *Gibbosocythere* Karpuk, referred to families Loxoconchidae, Trachyleberididae, Cytheruridae, Protocytheridae, Paradoxostomatidae, and Mandocytheridae (Karpuk and Tesakova, 2013, 2014; Karpuk, 2016c; Karpuk et al., 2019). The research also covered some palaeoecological aspects discussing preferable life conditions for the new genera and ostracod assemblages typical for different marine bionomic zones (Tesakova and Savelieva, 2005; Savelieva, 2014, 2022; Karpuk, 2016a, 2023; etc.).

A part of assemblages comprises smooth-shelled forms: *Cytherella*, *Robsoniella*, *Bairdia*, *Paracypris*, and *Pontocyprella*. Many species belong to Cytherelloidea, especially at the top of the central Crimea Berriasian. Sculptured large-size ostracods are represented by the family Protocytheridae (Protocythere, Costacythere, Hechticythere, and Reticythere) and the small-size forms like *Eucytherura* belong to the family Cytheruridae (Fig. 26). The following succession of zones and subzones were recognized in the Early Cretaceous succession by ostracods (Table 7).

Protocythere revili Assemblage Zone (Berriasian, Jacobi Zone). Initially, Savelieva and Tesakova identified the Raymoorea peculiaris, Eucytherura ardescae,

Fig. 26. Selected Early Cretaceous Ostracods. (a) *Cytherella parallela* (Reuss), 10-1, carapace, left lateral view; SW Crimea; lower Hauterivian; Theodorites theodori Zone; (b) *Sigillium* sp. 1, 3061-8, carapace, right lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (c) *Robsoniella longa* Kuzn., 3030-28, carapace, right lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (d) *R. obovata* Kuzn., 3030-31, carapace, right lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (e) *R. minima* Kuzn., 183/13220, carapace, right lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (f) *Bairdia kuznetsovae* Tes. et Rach., 185/13220, carapace, right lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (g) *Paracypris* aff. *explorata* (Kuzn.), 11-3, carapace, right lateral view, SW Crimea, upper Hauterivian; (h) *Monoceratina bicuspidata* (Grund.), 15-2, right valve, lateral view, SW Crimea, Aptian; (i) *Hemicytherura moorei* Neale, Kp-11/9, carapace, left lateral view, eastern Crimea, upper Berriasian Occitanica Zone; (j) *Loxoella variealveolata* Kuzn., 210/13220, left valve, lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (k) *Macrodentina* sp. 1, 3059-28, left valve, lateral view, eastern Crimea, upper Berriasian Boissieri Zone; (l) *Protocythere revili* Donze, 220/13220, right valve, lateral view, eastern Crimea, lower Berriasian Jacobi Zone; (m) *P. praetriplicata* Bart. et Brand, 3065/16, carapace, right lateral view, SW Crimea, Dlinnaya Mountain, Valanginian; (n) *P.* ex gr. *triplicata* (Roem.), SW Crimea ("B. Kermen"), 3, carapace, right lateral view; (o) *P. triplicata* (Roem.), SW Crimea, 62-4, left valve, lateral view; (p) *Reticythere marfenini* (Tes. et Rach.), 221/13220, carapace, right lateral view, SW Crimea, upper Berriasian Occitanica Zone, Tauricum Subzone; (q) *Costacythere khiamii* Tes. et Rach., 238/13220, right valve, lateral view, central Crimea, upper Berriasian Occitanica Zone, Tauricum Subzone; (r) *Hechticythere belbekensis* Tes. et Rach., 225/13220, left lateral view, SW Crimea, upper Berriasian Occitanica Zone, Tauricum Subzone; (s) *C. drushchitzi* (Neale), 230/13220, right lateral view, male, central Crimea, upper Berriasian Boissieri Zone; (t) *C. drushchitzi* (Neale), 231/13220, left valve, lateral view, female, Central Crimea, upper Berriasian Boissieri Zone; (u) *Saxocythere omnivaga* Lyub., 328-P1-70, left valve, lateral view (in coll. M.S. Karpuk), SW Crimea. All collections are stored in the Federal Core Material Fund of All-Russian Research Geological Oil Institute, Aprelevka Branch, Moskow Region.

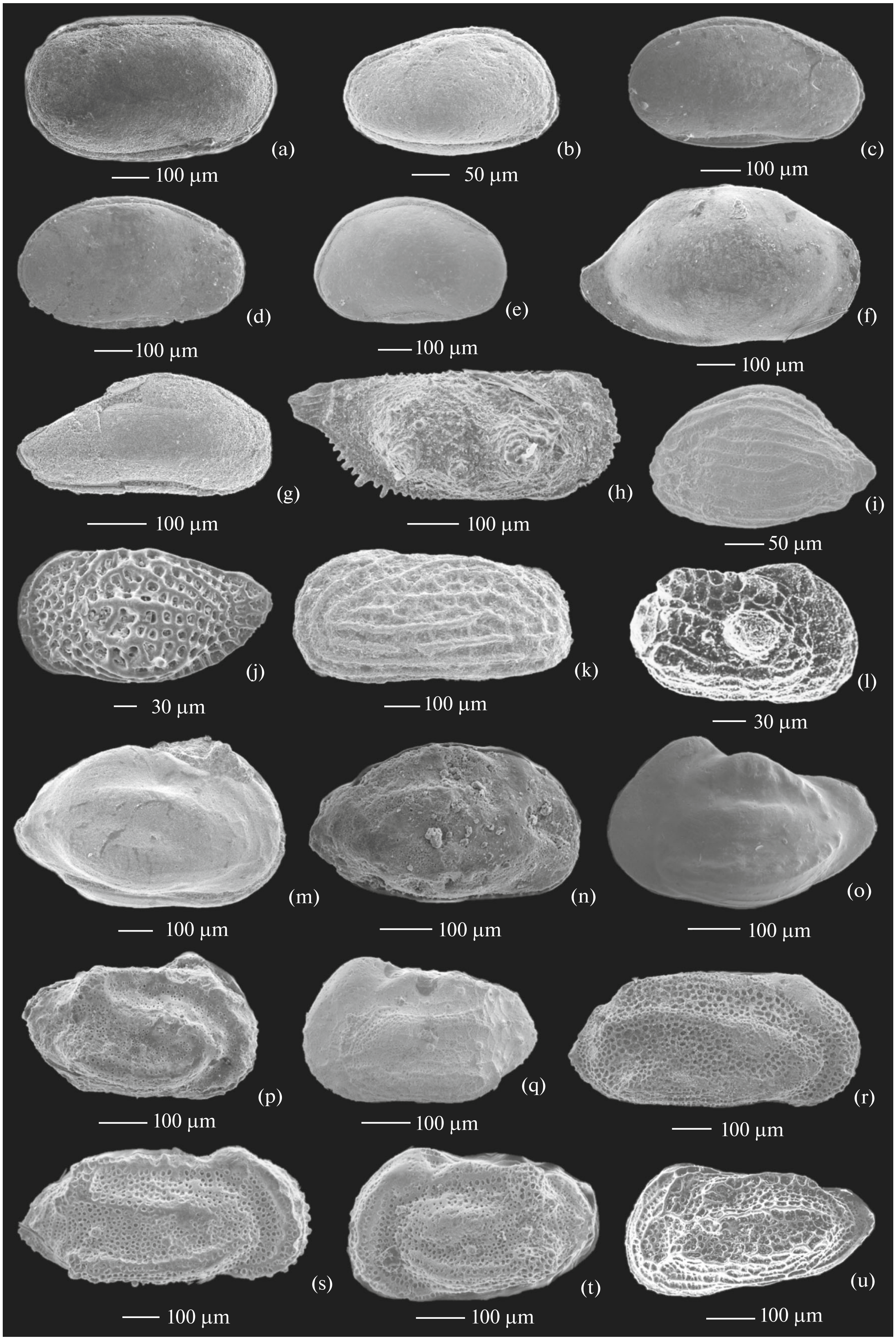
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Table 7. Lower Cretaceous ostracod biostratigraphy of the Crimean Mountains and its correlation with the Crimean and West-European ammonite zones

Stage	Series	Stage	Substage	Ammonite standart zonation of the Berriasian for the West Mediterranean Province (Reboulet et al., 2018)	CRIMEAN MOUNTAINS: Ammonite zones, subzones and beds with (Baraboshkin, this paper; Arkadiev et al., 2018)	CRIMEAN MOUNTAINS: Ostracods: Southwestern and Central Crimea (Savelieva, 2015; Brovina et al., 2016; Karpuk, 2016a, 2016b; Schurekova and Savelievs, 2016; 2022b; Grishchenko et al., 2020): zone/subzone/assemblage zone/assemblage	CRIMEAN MOUNTAINS: Ostracods: Eastern Crimea, Belogorsk area (Arkadiev et al., 2018b, 2021; Karpuk et al., 2018; Schurekova et al., 2022a): zone/assemblage zone
CRETACEOUS	LOWER	Albian	Upper	Arrhaphoceras briacense	Mortoniceras perinflatum	only Cytherella sp., Bairdia sp., B. cf. simplicatilis	
				Mortoniceras perinflatum			
				Mortoniceras rostratum	Mortoniceras rostratum		
				Mortoniceras fallax			
				Mortoniceras inflatum	Mortoniceras inflatum		
				Mortoniceras pricei	Hysteroceras orb.-varicos.		
				Dipoloceras cristatum	Dipoloceras cristatum		
			Mid.	Euhoplites lautus	Neanahoplites daviesi		
				Euhoplites loricatus	Paranahoplites intermedius		
				Hoplites dentatus	Missing		
			Low	Douvilleiceras mammilatum			
				Leymeriella tardefurcata	?? Leymeriella tardefurcata		
		Aptian	Upp	Hypacanthoplites jacobi	?	assemblage zone Cytherella	
				Acanthohoplites nolani	? Nolanicaras nolani	assemblage zone Dorsocythere stafeevi	
			Mid.	Parahoplites melchioris	? Parahoplites melchioris	zone Monoceratina bicuspidata; s/z M. bicuspidata, D. stafeevi	zone S. omnivaga
				Erichelonicerás martini	Aconeceras nisus	s/z Saxocythere omnivaga	zone M.bicuspidata,R.min.
			Lower	Dufrenoya furcata	Aconeceras nisoides: ?	subzone M. bicuspidata, Robsoniella minima	
				Deshayesites deshayesi	D. deshayesi		
				Deshayesites forbesi	D. volgensis	zone Robsoniella minima, Loxoella variealveolata; beds with *Cytheropteron tesakovae*	zone Robsoniella minima, Loxoella variealveolata
				Deshayesites oglanlensis	?		
		Barremian	Upper	Martellites sarasini	?		rare Robsoniella minima, Robsoniella? sp.
				Imerites giraudi	Patruliusiceras uhligi	zone Protocythere triplicata	
				Gerhardtia sartousiana	Heinzia caicedi		
				Taxancyloceras vandenheckii			
			Lower	Moutoniceras moutonianum	Holcodiscus caillaudianus–H. uhligi		
				Kotetishvilia compressissima			
				Kotetishvilia nicklesi	Nicklesia pulchella		
				Taveraidiscus hugii auctorum	Taveraidiscus hugii		
		Hauterivian	Upper	"Pseudothurmannia" ohmi	Pseudothurmannia ohmi; Craspedodiscus discofalcatus		
				Balearites balearis	Milanowskia speetonensis		
				Pseudospitidiscus ligatus	Speetoniceras inversum		
				Subsaynella sayni	Crioceratites duvali	assemblage zone Paracypris explorata	
			Lower	Lyticoceras nodosoplicatum	Theodorites theodori	assemblage zone Cytherella parallela	
				Crioceratites loryi	? Crioceratites loryi		
				Acanthodiscus radiatus	Leopoldia desmoceroides		
		Valanginian	Upper	Criosarasinella furcillata	Eleniceras tauricum; Teschenites callidiscus	assemblage Protocythere ex gr. praetriplicata, Costacythere sp.1	
				Vahrleideites peregrinus	Himantoceras trinodosum		
				Saynoceras verrucosum	Neohoploceras submartini		
			Lower	Karakaschiceras inostranzewi	Campylotoxia campylotoxa		
				Neocomites neocomiensiformis	Thurmanniceras pertransiens	assemblage Protocythere praetriplicata, Bairdia kuznetsovae	
				"Thurmanniceras" pertransiens			Robsoniella obovata, Robsoniella longa
		Berriasian	Upper	Thurmanniceras otopeta	Thurmanniceras otopeta		
				Subthurmannia boissieri: T. alpillensis	Fauriella boissieri: ?		Costacythere drushchitzi, Macrodentina sp.1
				Berriasella picteti	Berriasella callisto		
					?	Costacythere drushchitzi, Reticythere marfenini	
					R. crassicostatum		Robsoniella longa, Sigillium sp.1
				M. paramimounum	Neocosmoceras euthimi	assemb. R. marfenini, Bairdia sp.	
					?		
			Lower	Subthurmannia occitanica: D. dalmasi	Tirnovella occitanica: D. tauricum	Costacythere khiamii, Hechticythere belbekensis	?
				Berriasella privasensis	assemblage zone T.occitanica, R. retowskyi		Costacythere cf. khiamii, Bairdia sp.9
				S. subalpina	?		
					ass.zone with M. chaperi		
				Berriasella jacobi	B. jacobi: Ps. grandis	ass.zone C. cf. khiamii, Hemicytherura moorei	Protocythere revili
					B. jacobi		

and Protocythere revili Assemblage Zone (Arkadiev et al., 2006). Later Savelieva left only one index species as the most typical for this part of the section (Arkadiev et al., 2018b). The whole assemblage includes 92 species of 61 genera. The typical representatives of the assemblage are *Cytherella lubimovae* Neale, *Cytherelloidea flexuosa* Neale, *Eucytherura trinodosa* Pok., *Raymoorea peculiaris* (Donze), *Costacythere foveata* Tes. et Rach., *Protocythere revili* Donze (Fig. 26l), *Palaeocythereidella teres* Neale, *Clitro-*

cytheridea paralubrica Neale et Kolp., *Phodeucythere eucretacea* Neale et Kolp., and *Tethysia chabrensis* Donze. They are distributed in eastern Crimea (Saint Elias Cape, Fig. 2: Kp2) and the Tonas river basin (Krasnoselovka village, Fig. 2: Kp3).

Costacythere cf. khiamii, Hemicytherura moorei (Fig. 26i) **Assemblage Zone** (Berriasian, Jacobi Zone, Grandis Subzone) was described by Savelieva in southwestern Crimea (Shurekova et al., 2022b). Eighteen species of 14 genera have been identified, and the typical assemblage includes *Cytherella krimensis* Neale, *Bairdia* cf. *kuznetsovae* Tes. et Rach., *Eocytheropteron* sp. 1, *Neocythere dispar* Donze, and *Acrocythere alexandrae* Neale et Kolp. The zone was recognised in southwestern Crimea (Pavlovka village).

Costacythere khiamii, Hechticythere belbekensis Assemblage Zone (Berriasian, Occitanica Zone) was proposed by Savelieva in central Crimea (Arkadiev et al., 2012, 2018b). Seventy species referred to 30 genera were identified: *Cytherella lubimovae* Neale, *C. krimensis* Neale, *Costacythere khiamii* Tes. et Rach. (Fig. 26q), *C. foveata* Tes. et Rach., *Hechticythere belbekensis* Tes. et Rach. (Fig. 26r), as well as the species *Paracypris* aff. *parallela* Neale, *Cypridea funduklensis* Tes. et Rach., *Eucytherura* sp. 1, *Metacytheropteron* sp. A, ? *Fuhrbergiella* sp., *Acrocythere* aff. *hauteriviana* (Bart.), *Costacythere andreevi* Tes. et Rach., *Cythereis* sp. B, *Quasigermanites bicarinatus moravicus* Pok., and *Schuleridea* ex gr. *juddi* Neale. The zone was named by co-occurrence of index-species and the most numerous species *Costacythere khiamii.* Geographically the zone is distributed in central and southwestern Crimea.

Costacythere cf. khiamii, Bairdia sp. 9 Assemblage Zone (Berriasian, Occitanica Zone, T. occitanica, R. retowskyi Assemblage Zone; previously named as "Beds with *Robsoniella minima*") was distinguished by Savelieva in the Zavodskaya Balka section (Fig. 2: Kp2a). Fifty species referred to 22 genera were found, some of them were new. The typical assemblage consists of *Cytherella krimensis* Neale, *Sigillium* cf. *procerum* Kuzn., *Robsoniella minima* Kuzn., *Bairdia* sp. 9; *Paracypris* sp. 3; *P.* ex gr. *caerulea* Neale, *Eucytherura soror* Pok., *E. ardescae* Donze, *Hemicytherura moorei* Neale, *Eocytheropteron* sp.; *Loxoella variealveolata* Kuzn., *Neocythere protovanveeni* Kaye, and *Costacythere* cf. *khiamii* Tes. et Rach. The assemblage is close to the Robsoniella obovata, R. longa Assemblage Zone, identified earlier in the top Berriasian–lower Valanginian of eastern Crimea. Studied complex differs by lower taxonomic diversity and small number of representatives of genera *Robsoniella*, *Sigillium*, and *Eocytheropteron* and the absence of *Cytherelloidea* (Arkadiev et al., 2018b). The area of distribution is eastern Crimea.

Costacythere drushchitzi, Reticythere marfenini Assemblage Zone (Berriasian, Boissieri Zone, Euthymi Subzone, R. crassicostatum Subzone) was identified by Savelieva in central Crimea. It is represented by 65 species of 28 genera, in particular by *Cytherella lubimovae* Neale, *C. krimensis* Neale, *C. fragilis* Neale, *Cytherelloidea flexuosa* Neale, *C. mandelstami* Neale, *Costacythere drushchitzi* (Neale) (Figs. 26s, 26t), and *Reticythere marfenini* (Tes. et Rach.). The typical species are *Bairdia menneri* Tes. et Rach., *B. kuznetsovae* Tes. et Rach., *Bythoceratina* ex gr. *variabilis* (Donze), *Eucytherura ardescae* Donze, *Neocythere pyrena* Tes. et Rach., *N. dispar* Donze, and *Acrocythere diversa* Donze. The zone was named by co-occurrence of the index species and the most numeros species (Arkadiev et al., 2012, 2018b). The zone is distributed in southwestern? and central Crimea.

Reticythere marfenini, Bairdia sp. Assemblage was discovered by Savelieva in a section near Kuybyshevo village, southwestern Crimea (Arkadiev et al., 2012, 2018b). Representatives of 15 species referred to 10 genuses were found there. Typical species are *Cytherella lubimovae* Neale, *C. krimensis* Neale, *Reticythere marfenini* (Tes. et Rach.) (Fig. 26p), *R. serpentina* (Anderson), singular species are *Cytherelloidea* sp., Bairdia sp., *Paracypris* sp., and *Langtonia* aff. *kashevarovae* Neustr. Assemblage is distributed in southwestern Crimea (Berriasian, Euthymi Subzone, Boissieri Zone).

Robsoniella longa, **Sigillium sp. 1** (Fig. 26b) **Assemblage Zone** (topmost Berriasian, Boissieri Zone–basal Valanginian) was proposed by Savelieva in the Alekseevka village section (Fig. 2: Kp3), in the town of Belogorsk region (Savelieva et al., 2020). Fifty-four species referred to 24 genera were found, among them, *Loxoella* dominates, *Bairdia* subdominates, and *Robsoniella* and *Eocytheropteron* make up a small number. The greatest species diversity genera are *Eucytherura*, *Procytherura*, *Bairdia*, *Robsoniella*, and *Eocytheroptreron*. Apart index species, the following species are typical: *Bythoceratina* ex gr. *variabilis* (Donze), *Paranotacythere (P.) soror* Kubiat., *Eucytherura ardescae* Donze, *Loxoella variealveolata* (Fig. 26j) Kuzn., and *Neocythere urukhensis* Neale et Kolp. The studied assemblage is similar to the Robsoniella obovata, Robsoniella longa Assemblage Zone of the estern Crimea sections. However, the rarity of *R. obovata* and ability of other species do not allow a direct correlation. The zone is distributed in estern Crimea (Belogorsk Region, Alekseevka village).

Costacythere drushchitzi, Macrodentina sp. 1 Assemblage Zone (Berriasian, Boissieri Zone) was distinguished by Savelieva in the Alekseevka village section (Savelieva et al., 2020). Fifty-six species referred to 24 genera were found. *Eucytherura dominates*, *Eocytheroptreron*, and *Bairdia* are numerous. The base of the zone is marked by the occurrence of *Cytherelloidea*, *Hechticythere*, and *Schuleridea*. Typical species are *Cytherelloidea mandelstami* Neale, *C.* aff. *flexuosa* Neale, *Baidia menneri* Tes. et Rach., *Cypridea* cf. *funduklensis* Tes. et Rach., *Eucytherura soror* Pok., *E. mirifica* (Kuzn.), *Macrodentina* sp. 1 (Fig. 26k), *M. mediostricta* (Syl.-Brad.), *Acrocythere* cf. *diversa* Donze, *Klentnicella*? *klentnicensis* Pok., *Costacythere* sp. 2, *C. drushchitzi* (Neale), *Hechticythere* sp. 1, and *H.* aff. *belbekensis* Tes. et Rach. The assemblage is close to the Costacythere drushchitzi, Reticythere marfenini Assemblage Zone of the topmost Berriasian of central Crimea. The rarity of the *Reticythere marfenini* Tes. et Rach. and a number of typical species do not allow a direct correlation with it. The zone is distributed in eastern Crimea (Belogorsk Region, Alekseevka village).

Robsoniella obovata, Robsoniella longa Assemblage Zone (topmost Berriasian–basal Valanginian, Boisseri–Pertransiens? zones) was identified by Savelieva (Arkadiev et al., 2012). Earlier it was named "Robsoniella obovata Assemblage Zone." In total, 58 species of ostracods referred to 27 genera were found (Savelieva in Arkadiev et al., 2018b). The assemblage is represented by genera *Robsoniella* and *Sigillium*, with various and numerous *Bairdia*. Typical species are *Robsoniella longa* Kuzn. (Fig. 26c), *R. obovata* Kuzn. (Fig. 26d), *R. minima* Kuzn. (Fig. 26e), *Bairdia major* Donze, *B. kuznetsovae* Tes. et Rach. (Fig. 26f), *Sigillium procerum* Kuzn., *Pontocyprella* cf. *pertuisi Donze*, *Loxoella variealveolata* Kuzn., and *Eucytherura ardescae* Donze. The zone was recognized in eastern Crimea.

Protocythere praetriplicata (Fig. 26m), **Bairdia kuznetsovae Assemblage Zone** (topmost Berriasian–lower Valanginian, Otopeta–Pertransiens zones) was distinguished by Savelieva (Grishchenko et al., 2020). It contains 17 species referred to 13 genera. Typical species, apart index species, are *Bairdia* cf. *menneri* Tes. et Rach., *Costacythere* aff. *khiammii* Tes. et Rach., *C.* aff. *foveata* Tes. et Rach., *Hechticythere* aff. *belbekensis* Tes. et Rach., and *Neocythere urukhensis* Neale et Kolp. The zone was recognized in southwestern and eastern Crimea.

Protocythere ex gr. praetriplicata (Fig. 26n), **Costacythere sp. 1 Assemblage Zone** (upper Valanginian, Submartini–Tauricum Zone) was proposed by Savelieva (Grishchenko et al., 2020). The assemblage includs 7 species of 4 genera. A typical assemblage contains *Protocythere* sp. 1, *Costacythere* aff. *mesezhnikovi* Neale et Kolp., and *Hechticythere*? sp. 1. The zone was traced in southwestern Crimea.

Cytherella parallela Assemblage Zone (lower Hauterivian, Theodorites theodori Zone) was recognized by Savelieva (Savelieva and Shurekova, 2014). Sixty species referred to 28 genera were identified. Typical species are *Cytherella ovata* (Roem.), *C. dilatata* Donze, *C. paralella* (Reuss) (Fig. 26l), *C. cavilla* Lyub., *Cytherelloidea sincera* Kuzn., *Robsoniella* ex gr. *minima* Kuzn., *Bairdia* ex gr. *projecta* Kuzn., *Paracypris* aff. *levis* Kuzn., *P. sinuata* Neale, *Eucytherura (E.)* aff. *kotelensis* Pok., *Cytheropteron* sp. 1, and *Exophtalmocythere* sp. 1. The zone was named due to the high abundance of the index species, it is distributed in southwestern Crimea.

Paracypris explorata (Fig. 26g) **Assemblage Zone** (upper Hauterivian, Duvali to Inversum zones) was identified by Savelieva (Savelieva and Shurekova, 2014). It contains 38 species referred to 20 genera, 3 genera have not been identified. Typical species are *Pontocyprella rara* Kaye, *P.* aff. *maynci* Oertli, *P.* aff. *harrisiana* (Jones), *Vocontiana longicostata* Donze, and *Tethysia* sp. 1. The zone was named due to the high abundance ability of the index species. It is distributed in southwestern Crimea.

Protocythere triplicata (Fig. 26o) **Zone** (Hauterivian–Barremian, Desmoceroides–Uhligi Zone) is widely distributed. It was recognized in the UK (Neale, 1962, 1978) and traced in Middle Asia and southwestern Crimea (Karpuk, 2016a; Shurekova and Savelieva, 2016). The assemblage includes 43 species referred to 20 genera. Typical species are *Protocythere triplicata* (Roem.), *P. bedoulensis* Moul., *Cytherella exquisita* Neale, *C. infrequens*, *C. lubimovae*, *C. ovata* (Roem.), *Sigillium procerum* Kuzn., *Bairdia projecta* Kuzn., *Pontocyprella rara* Kaye, *P. harrisiana* (Jones), *Pontocypris explorata* Kuzn., *Eucytherura mirifica* (Kuzn.), *Cytheropteron latebrosum* Kuzn., *Procytheropteron* sp. 1, *Loxoella variealveolata* Kuzn., and *Exophthalmocythere posteropilosa* Karpuk.

Robsoniella minima, Loxoella variealveolata Zone (upper Barremian–lower Aptian, Giraudi–Forbesi zones) was identified by Karpuk in southwestern Crimea (Karpuk, 2016a; Shurekova and Savelieva, 2016). Fifty-seven species referred to 27 genera have been determined: *Cytherella dilatata* (Reuss), *Robsoniella longa* Kuzn., *Bairdia* sp. 2, *Bythocypris* sp., "Macrocypris" sp. 2, *Paracypris acuta* (Corn.), *Procytherura* sp. 7, *Loxoella macrofoveata* Karp. et Tes., *L. microfoveata* Karp. et Tes., *Protocythere* cf. *hannoverana* Bart. et Brand, *Protobrachycythere aptica Karpuk*, etc. The zone is distributed in southwestern and eastern Crimea (Karpuk, 2016a, 2016b).

Cytheropteron tesakovae total range Zone (terminal Barremian–lower Aptian, Sarasini–Forbesi zones) was distinguished by Karpuk in southwestern Crimea within the R. minima, L. variealveolata Zone (Karpuk, 2016a). The zone is characterized by 31 species, referred to 14 genera. Apart *C. tesakovae* Karpuk, it contains *R. minima* Kuzn. and *L. variealveolata* Kuzn., and species found in the P. triplicata Zone. *Robsoniella longa* Kuzn., *Bairdia* sp. 2, *"Macrocypris"* sp. 2, *Procytherura* sp. 7, *Protocythere* cf. *hannoverana* Bart. et Brand, and *Protobrachycythere aptica* Karpuk appear in it for the first time. The zone was recognized in southwestern Crimea.

Monoceratina bicuspidata (Fig. 26h) **total range Zone** (lower–upper Aptian, Deshayesi–Nolani zones). Initially the zone was identified in southwestern Crimea by Karpuk and Tesakova as ostracod assemblage (Karpuk and Tesakova, 2011; Karpuk and Shcherbinina, 2015). Later it was raised to the zonal rank (Karpuk, 2016a, 2016b). It contains *Cytherella* *ovata* (Roem.), *C. exquisite* Neale, *C. infrequens* Kuzn., *C. lubimovae* Neale, *Sigillium procerum* Kuzn., *Robsoniella minima* Kuzn., *Bairdia projecta* Kuzn., *Pontocypris explorata* Kuzn., *Pontocyprella harrisiana* (Jones), *P. rara* Kaye, *Eucytherura mirifica* (Kuzn.), *Dorsocythere stafeevi* Karp. et Tes., *Cytheropteron latebrosum* Kuzn., *Procytheropteron* sp. 1, *Pedicythere longispina* Karp. et Tes., *Loxoella microfoveata* Karp. et Tes., *Protocythere whatleyi* Karpuk, *Saxocythere omnivaga* (Lyub.), and *Exophthalmocythere posteropilosa* Karpuk et Tes. The zone is distributed in southwestern and eastern Cimea and is subdivided into three subzones: (1) M. bicuspidata, R. minima; (2) S. omnivaga; (3) M. bicuspidata, Dorsocythere stafeevi.

M. bicuspidata, R. minima Subzone (lower–middle Aptian, Deshayesi–Martini zones). Later, when studying sections of eastern Crimea, Karpuk zone of the same name was installed (Karpuk et al., 2018). Sixty five species referred to 25 genera were identified. The assemblage contains *Loxoella microfoveata* Karp. et Tes., *Dorsocythere stafeevi* Karp. et Tes., *Cytheropteron* sp. 2, *Rostrocytheridea* aff. *ornata* Bern. et Oertli, etc. The lower boundary coincides with the base of the zone; the upper boundary is determined by the appearance of *S. omnivaga*. The distribution is like that of the zone.

Saxocythere omnivaga total range Subzone (middle Aptian Martini–Melchioris zones). Originally it was distinguished as S. omnivaga, P. whatleyi Subzone (Karpuk, 2016a). Later only one index species *S. omnivaga* (Fig. 26u) was left (Karpuk, 2016b) and the rank of the unit was increased up to the zone (Karpuk et al., 2018). The assemblage contains 67 species referred to 27 genera. Typical species are *Robsoniella minima* Kuzn., *R. longa* Kuzn., *Pontocyprella harrisiana* (Jones), *Loxoella microfoveata* Karp. et Tes., *Protocythere whatleyi* Karp., etc. The distribution is like that of the Bicuspidata Zone.

M. bicuspidata, Dorsocythere stafeevi Subzone (middle Aptian Melchioris Zone) was identified by Karpuk (2016a, 2016b) in eastern Crimea. Fifty species from 18 genera were found in it. Typical species are *Cytherella exquisite* Neale, *C.* ex gr. *dilatata* Donze, *Pontocyprella rara* Kaye, *Cytheropteron latebrosum* Kuzn., *C. ventriosum* Karp. et Tes., *Parexophthalmocythere rodewaldensis* Bart. et Brand, and *Eucytherura mirifica* (Kuzn.). The lower boundary is outlined by the disappearance of *S. omnivaga* index species of the underlying subzone; the upper boundary by the disappearance of *M. bicuspidata* species. The distribution is like that of the zone.

D. stafeevi Assemblage Zone (upper Aptian Nolani Zone) was identified by Karpuk (2016a, 2016b) in eastern Crimea. The assemblage is extremely poor with two species of two genera and accompanying *Tethysia* sp. and Gen. sp. The lower boundary is drawn by the disappearance of *M. bicuspidata* and most of the zonal assemblage below. The upper boundary is accepted by the disappearance of *D. stafeevi* Karp. et Tes. The zone is distributed in eastern Crimea.

Cytherella Assemblage Zone (upper Aptian Nolani and perhaps H. jacobi? zones) was distinguished by Karpuk in eastern Crimea (2016a, 2016b). Representatives of three species of two genera were found (*Cytherella ovata* (Roem.), *C. dilatata* Donze, and *Dolocythere rara* Mert.). The lower boundary is determined by the disappearance of *D. stafeevi*, the upper one by the disappearance of ostracods in the section. The zone is distributed in eastern Crimea.

Savelieva studied two sections of boundary Albian-Cenomanian interval (Tur et al., 2000) in southwestern Crimea. The uppermost Albian contains rare poorly preserved ostracods *Cytherella* sp., *Bairdia* sp., *B.* cf. *simplicatilis* Mand. et Lyub.

Thus, ostracoda-based zonal scheme has been developed during the last twenty years. It covers Berriasian to Aptian intervals of southwestern and eastern Crimea. Biostratigraphic units ranked as assemblage zones, total range zones and subzones were distinguished, and their typical assemblages were identified. The Albian scheme is still in progress.

Early Cretaceous Organic-Walled Dinoflagellate Cysts

The history of the Early Cretaceous palynological investigation of Crimea began in the middle of the last century with the research of N.A. Bolkhovitina (1953), S.B. Kuvaeva (1963; Kuvaeva and Yanin, 1973), G.A. Orlova-Turchina (1968) and was continued by the works of S.B. Smirnova [maiden name Kuvaeva] (Gorbachik and Smirnova, 1977; Smirnova, 1981) and M.A. Voronova (1994). However, all these studies concerned only spores and pollen of terrestrial plants without serious study of marine palynomorphs, although their presence was mentioned.

The study of the lower Cretaceous organic-walled dinoflagellate cysts of the Crimean Mountains began in 2010 with the research of O.V. Shurekova. The material for the research includes more than 300 palynological samples from 36 localities: in southwestern Crimea, the basins of the Belbek (Arkadiev et al., 2012; Fig. 2: Kp13) and Kacha (Savelieva and Shurekova, 2014; Shurekova and Savelieva, 2016; Fig. 2: Kp18) rivers, Baidary depression (Shurekova et al., 2022a; Fig. 2: Kp15); in central Crimea, Novoklenovo, Balki, Mezhgorie villages (Arkadiev et al., 2015a; Fig. 2: Kp5); in eastern Crimea, Dvuyakornaya Bay, Cape of St. Elias (Arkadiev et al., 2012; Fig. 2: Kp2), Zavodskaya Balka quarry (Arkadiev et al., 2015b; Fig. 2: Kp2a), Yuzhnoe [Sultanovka], Izyumovka villages (Shurekova et al., 2022b; Fig. 2: Kp48, Kp69), Nanikovo village, Koklyuk Mountain (Arkadiev et al., 2017; Grishchenko and Shurekova, 2020; Fig. 2: Kp48, Kp81); in Tonas River basin, Krasnoselovka, Alekseevka villages (Savelieva and Shurekova, 2013; Savelieva et al., 2020; Fig. 2: Kp3). The Koklyuk

Mountain section (Fig. 2: Kp81; Figs. 27, 28) is of great interest. Eight dinocyst assemblage zones were identified in the Berriasian–lower Aptian in this section. They are correlated with magnetostratigraphic scale (Fig. 28) and the Mediterranean Ammonite Standard (Reboulet et al., 2018) for the Berriasian. The dinocysts events of the Valanginian–Aptian interval were correlated with paleomagnetic data. The important dinocyst taxa are figured in Fig. 29.

Scriniodinium campanula–Amphorulacysta expirata Assemblage Zone is distributed in the upper Tithonian and Berriasian (Jacobi Zone and Occitanica Zone without Tauricum Subzone) of eastern Crimea, southwestern Crimea and the Tonas River basin. The lower boundary of the zone is fixed by the first appearance (FA) of *Amphorula expirata* (Davey) Will. et Fens., and *Scriniodinium campanula* Gocht.

Key taxa are *Amphorulacysta expirata* (Davey) Will. et Fens. (Fig. 29b), *A. dodekovae* (Zotto et al.) Will. et Fens., *A. metaelliptica* (Dodek.) Will. et Fens., *Cometodinium habibii* Mont., *Dingodinium minutum* Dod., *Hystrichodinium pulchrum* Defl., *Hystrichosphaerina*? *orbifera* (Klem.) Stover et Evitt, *Wallodinium cylindricum* (Habib) Duxb., *Systematophora areolata* Klem., *Prolixosphaeridium parvispinum* (Defl.) Davey et al., *Kleithriasphaeridium eoinodes* (Eisen.) Davey, *Muderongia simplex* Alb. (Fig. 29q), *M. endovata* Riding et al., *M. longicorna* Mont., *Scriniodinium campanula* Gocht, *S. dictyotum* Cook. et Eisen., *Tubotuberella apatela* (Cook. et Eisen.) Ioan. et al. (Fig. 29l), and *Dichadogonyaulax*? *pannea* (Norris) Sarj.

The earliest appearance of *A. expirata* was recorded in the lower Volgian (Hudlestoni Zone) of the British Isles (Riding and Thomas, 1992).

Phoberocysta neocomica Assemblage Zone corresponds to the Occitanica Zone, Tauricum Subzone and the Boissieri Zone of the Berriasian (eastern, central and southwestern Crimea). The lower boundary of the zone is fixed by the FA of *Phoberocysta neocomica* (Fig. 30).

Key taxa are *Phoberocysta neocomica* (Gocht) Mill. (Fig. 29k), *Cometodinium habibii* Mont., *Systematophora areolata* Klem. (Fig. 29f), *Ctenidodinium elegantulum* Mill., *Tehamadinium daveyi* Jan du Chêne et al., *Muderongia tomaszowensis* Alb., *Egmontodinium toryna* (Cook. et Eisen.) Davey (Fig. 29c), *Hystrichodinium pulchrum* Defl., *Dichadogonyaulax culmula* (Norr.) Loeb. et Loeb. and *Dapsilidinium* spp.

Pseudoceratium pelliferum Assemblage Zone is established in eastern Crimea (Koklyuk Mountain) and corresponds to the Otopeta ammonite Subzone (uppermost Berriasian). The lower boundary of the zone is defined by FA of *Pseudoceratium pelliferum* Gocht.

Key taxa are *Pseudoceratium pelliferum* Gocht (Fig. 29d), *Cymososphaeridium validum* Davey, *Muderongia tetracantha* (Gocht) Alb., *M. mcwhaei* Cook. et Eisen., *M. endovata* Riding et al., *M. tomaszowensis* Alb., *Palaecysta palmula* (Davey) Will. et Fens., *Cassiculosphaeridia reticulata* Davey, *Pluriarvalium osmingtonense* Sarj., *Spiculodinium neptunii* (Eisen.) Duxb. (Fif. 29g), *Kleithriasphaeridium eoinodes* (Eisen.) Davey, *K. corrugatum* Davey, *Athigmatocysta glabra* Duxb., *Occisucysta tentorium* Duxb. and *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb.

The FA of *P. pelliferum* in the Boreal Realm occurs at the same level: in the middle part of the Tzikwinianus Zone of the Volga basin (Harding et al., 2011) and in the Stenomphalus Zone of northwestern Europe (Costa and Davey, 1992). The level corresponds to the base of the Otopeta Subzone (Ogg et al., 2008) in the Tethyan Realm.

Oligosphaeridium complex Assemblage Zone is identified in eastern Crimea (Koklyuk Mountain) and correlates with the lower Valanginian. It corresponds to the magnetic polarity Chron M14r (Grishchenko and Shurekova, 2020). The base of the zone is marked by the FA of *Oligosphaeridium complex* (White) Davey et Will., *Gonyaulacysta cladophora* sensu Duxb., 1977, and *Batioladinium*? *gochtii* (Alb.) Lent. et Will.

Key taxa are *Oligosphaeridium complex* (White) Davey et Will. (Fig. 29j), *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb., *Gardodinium trabeculosum* (Gocht) Alb., *Cymososphaeridium validum* Davey (Fig. 29e), *Aprobolocysta pustulosa* Smith et Hard., *Avellodinium falsificum* Duxb., *Batioladinium*? *gochtii* (Alb.) Lent. et Will., *Callaiosphaeridium tricheryum* Duxb., *Cymososphaeridium* sp. I Davey, *Gonyaulacysta cladophora* sensu Duxbury, *Nelchinopsis kostromiensis* (Vozzh.) Wigg. (Fig. 29s), *Pseudoceratium pelliferum* Gocht, *Subtilisphaera perlucida* (Alb.) Jain et Mill. and *Systematophora* sp. II Davey.

The FA of *O. complex*, *G. cladophora*, and *B.*? *gochtii* in northwestern Europe is recorded in the lower Valanginian Paratollia ammonite Zone, and *N. kostromiensis* in the Polyptychites Zone (Costa and Davey, 1992; Ogg et al., 2008). The FA of *O. complex*, *B.*? *gochtii*, and *N. kostromiensis* (? early Valanginian) in the Volga River basin is not characterized by ammonites (Harding et al., 2011).

Muderongia crucis, Batioladinium? gochtii Assemblage Zone is established in eastern Crimea (Koklyuk Mountain) and corresponds to the upper Valanginian. The base of the zone is recorded by the FA of *Muderongia crucis*. The upper boundary is correlated to last appearance (LA) of *Batioladinium*? *gochtii*.

Key taxa are *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb., *Batioladinium*? *gochtii* (Alb.) Lent. et Will. (Fig. 29n), *B. radiculatum* Davey, *Cymososphaeridium validum* Davey, *Gardodinium trabeculosum* (Gocht) Alb., *Gonyaulacysta cladophora* sensu Duxb., 1977, *Hystrichodinium pulchrum* Defl., *Meiourogonyaulax pertusa* (Duxb.) Below, *Muderongia crucis* Neale et Sarj., *M. endovata* Riding et al., *Oligosphaeridium complex* (White) Davey et Will., and *Systematophora* sp. II Davey.

Fig. 27. Koklyuk Mountain section, eastern Crimea.

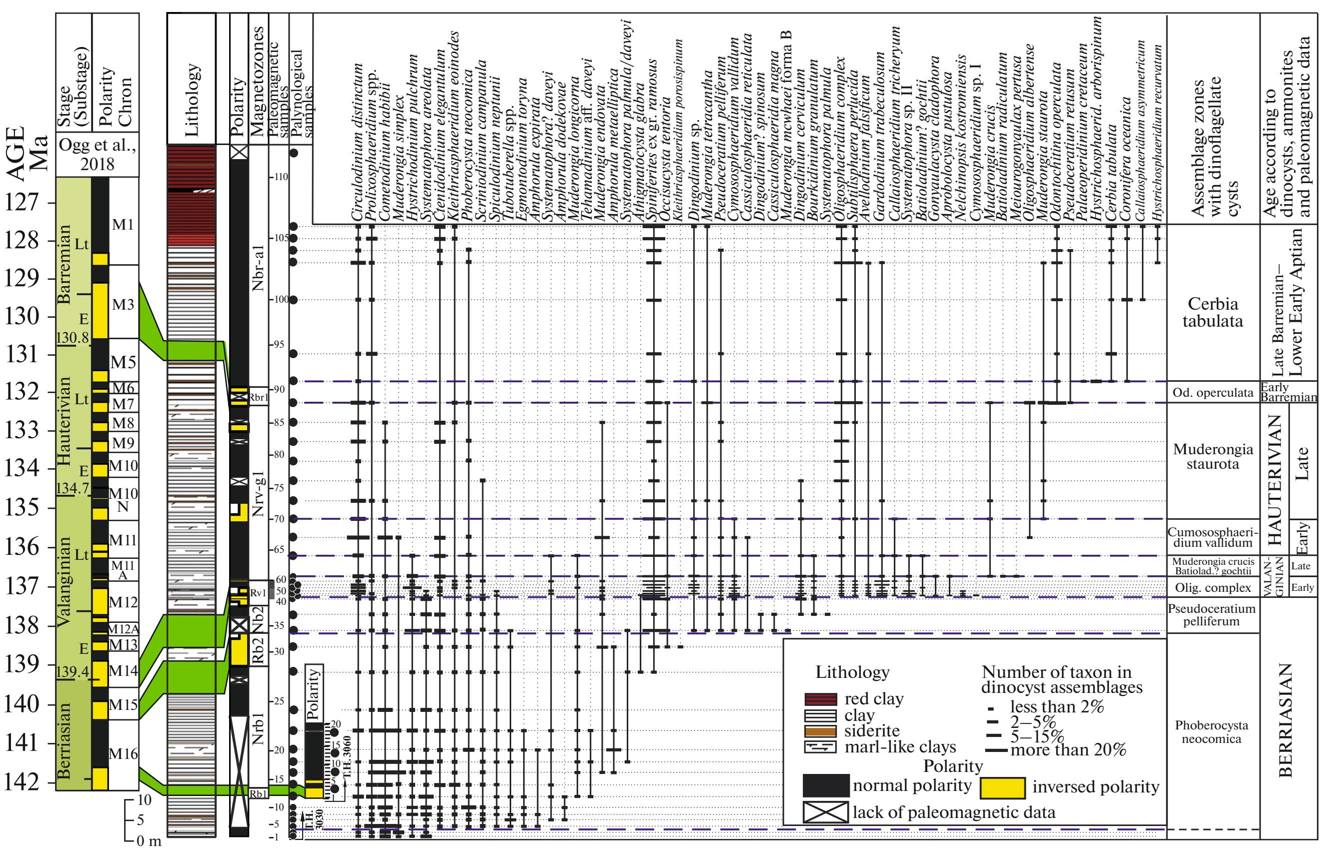

Fig. 28. Correlation of paleomagnetic and dinocyst zonations in the Koklyuk section.

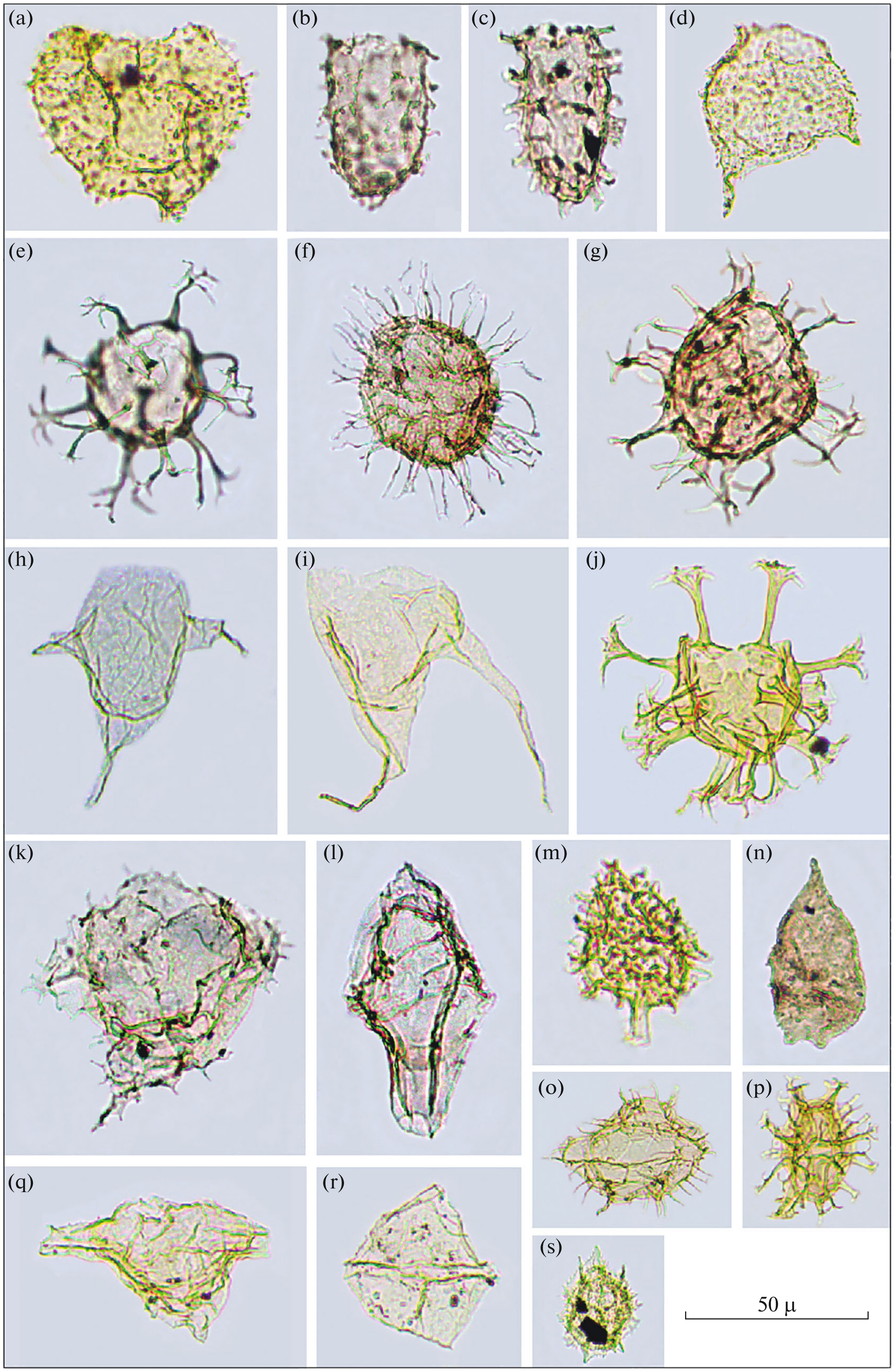
(a)
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Fig. 29. Dinoflagellate cysts from the Lower Cretaceous of eastern Crimea (Kokluk Mountain section). (a) *Cerbia tabulata* (Davey et Verdier, 1974) Below, 1981, sample 91; (b) *Amphorula expirata* (Davey, 1982) Courtinat, 1989, sample 20; (c) *Egmontodinium toryna* (Cookson et Eisenack, 1960) Davey, 1979, sample 8; (d) *Pseudoceratium pelliferum* Gocht, 1957, sample 34; (e) *Cymososphaeridium validum* Davey, 1982, sample 43; (f) *Systematophora areolata* Klement, 1960, sample 6; (g) *Spiculodinium neptunii* (Eisenack, 1958) Duxbury, 2018, sample 22; (h) *Muderongia staurota* Sarjeant, 1966, sample 88; (i) *Odontochitina operculata* (Wetzel, 1933) Deflandre et Cookson, 1955, sample 88; (j) *Oligosphaeridium complex* (White, 1842) Davey et Williams, 1966, sample 43; (k) *Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969, sample 8; (l) *Tubotuberella apatela* (Cookson et Eisenack, 1960) Ioannides et al., 1977, sample 22; (m) *Coronifera oceanica* Cook. et Eisen., 1958, sample 91; (n) *Batioladinium*? *gochtii* (Alberty, 1961) Lentin et Williams, 1977, sample 61; (o) *Ctenidodinium elegantulum* Millioud, 1969, sample 106; (p) *Spiniferites* ex gr. *ramosus* (Ehrenberg, 1837) Mantell, 1854, sample 106; (q) *Muderongia simplex* Alberti, 1961, sample 43; (r) *Palaeoperidinium cretaceum* Pocock, 1962, sample 91; (s) *Nelchinopsis kostromiensis* (Vozzhen., 1967) Wiggins, 1972, sample 43. Samples 6, 8, 20, 22, 34 are from the Berriasian; samples 43, 61, from the Valanginian; sample 88, from the Barremian; samples 91, 106, from the Barremian–lower Aptian. Palynological slides and residue are stored in the Department of Stratigraphy and Paleontology of Russian Geological Research Institute, Saint Petersburg.

The FA of *M. crucis* in northwestern Europe is in the base of the upper Valanginian (*BioStrat*..., 2023). The LA of *B.*? *gochtii* (as "B. varigranosum") is recorded in the basal part of the lower Hauterivian of England (Costa and Davey, 1992).

Cymososphaeridium validum Assemblage Zone is established in eastern Crimea (Koklyuk Mountain) and southwestern Crimea (Vysokoe and Verkhorechie villages; Fig. 2: Kp18). The zone is correlated to the lower Hauterivian. The lower boundary of the zone is fixed by the LA of *B.*? *gochtii*, *H. pulchrum*, the upper boundary, by the LA of *C. validum*.

Key taxa are *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb., *Muderongia endovata* Riding et al., *M. longicorna* Mont., *Batioladinium*? *gochtii* (Alb.) Lent. et Will., *Callaiosphaeridium tricheryum* Duxb., *Cymososphaeridium validum* Davey, *Gardodinium trabeculosum* (Gocht) Alb., *Hystrichodinium pulchrum* Defl., *Oligosphaeridium albertense* (Poc.) Davey et Will., *O. complex* (White) Davey et Will., *Pseudoceratium pelliferum* Gocht and *Systematophora* sp. II Davey.

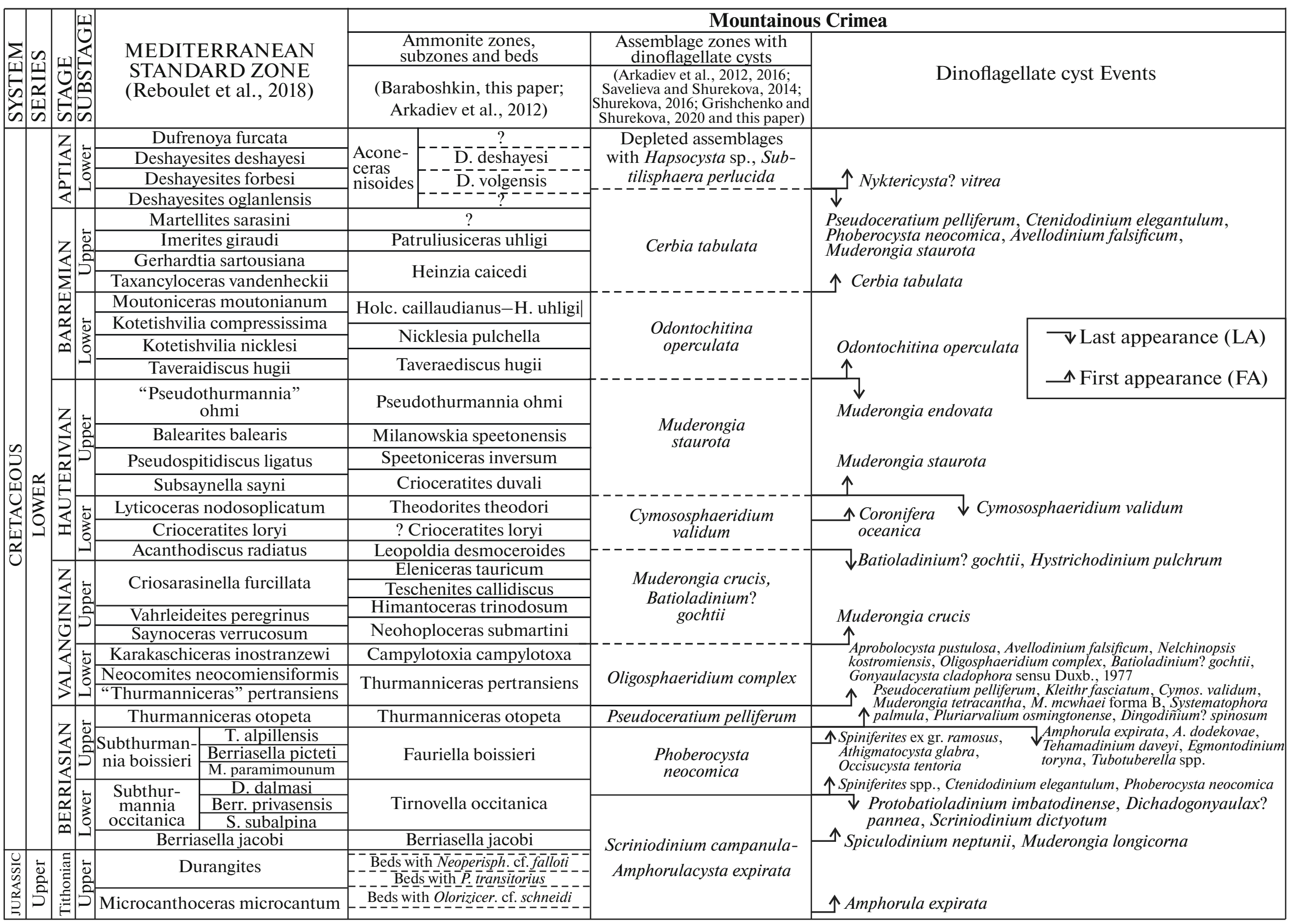


Fig. 30. The dinoflagellate cysts scale for the Lower Cretaceous of the Mountainous Crimea.

The LA of *C. validum* in northwestern Europe is recorded at the base of the upper Hauterivian (Costa and Davey, 1992; Duxbury, 2018).

Muderongia staurota Assemblage Zone is identified in eastern Crimea (Koklyuk Mountain) and corresponds to the upper Hauterivian. The base of the zone was drawn by the FA of *Muderongia staurota*. Its upper boundary coincides with the base of next zone.

Key taxa are *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb., *Oligosphaeridium complex* (White) Davey et Will., *O. poculum* Jain, *Callaiosphaeridium tricheryum* Duxb., *Gardodinium trabeculosum* (Gocht) Alb., *Kleithriasphaeridium eoinodes* (Eisen.) Davey, *Muderongia staurota* Sarj., *M. endovata* Riding et al., *M. crucis* Neale et Sarj., *M. tetracantha* (Gocht) Alb. and *Subtilishaera perlucida* (Alb.) Jain et Mill.

The FA of *Muderongia staurota* is recorded in the upper Hauterivian of England (Costa and Davey, 1992; *BioStrat*..., 2023).

Odontochitina operculata Assemblage Zone is established in eastern Crimea (Koklyuk Mountain) and is correlated to the lower Barremian. It corresponds with the magnetic polarity Chron M3 (Grishchenko and Shurekova, 2020). The lower boundary is marked by the FA of the index species. The upper boundary coincides with the base of next zone.

Key taxa are *Odontochitina operculata* (Wetz.) Defl. et Cook. (Fig. 29i), *Subtilishaera perlucida* (Alb.) Jain et Mill., *Oligosphaeridium complex* (White) Davey et Will., *O. albertense* (Poc.) Davey et Will., *Spiniferites* ex gr. *ramosus* (Ehren.) Loeb. et Loeb. (Fig. 29p), *Muderongia tetracantha* (Gocht) Alb., *M. crucis* Neale et Sarj., *M. staurota* Sarj. (Fig. 29h), *Phoberocysta neocomica* (Gocht) Mill. and *Pseudoceratium retusum* Brid.

The FA of *O. operculata* is fixed in the lower part of the lower Barremian of NW Europe (Williams and Dyer, 2015) and in the base of the Barremian (Costa and Davey, 1992).

Cerbia tabulata Assemblage Zone is identified in southwestern Crimea (Verkhorechie village section) in the Patruliusiceras uhigi Zone (Shurekova and Savelieva, 2016), and in two sections of eastern Crimea (Koklyuk Mountain (Fig. 2: Kp81) and Izyumovka village, Fig. 2: Kp69). The zone is compared with the upper Barremian–basal lower Aptian. The base of the zone is marked by the FA of *Cerbia tabulata*. The upper boundary was drawn by the LO of *Pseudoceratium pelliferum*, *Ctenidodinium elegantulum*, *Phoberocysta neocomica*, *Avellodinium falsificum*, and *Muderongia staurota*.

Key taxa are *Avellodinium falsificum* Duxb., *Callaiosphaeridium asymmetricum* (Defl. et Cout.) Davey et Will., *Ctenidodinium elegantulum* Mill. (Fig. 29o), *Cerbia tabulata* (Davey et Verd.) Below (Fig. 29a), *Odontochitina operculata* (Wetz.) Defl. et Cook., *Discorsia nannus* (Davey) Duxb., *Gardodinium trabeculosum* (Gocht) Alb., *Hystrichosphaeridium arborispinum* Davey et Will., *H. recurvatum* (White) Lej.-Carp., *Muderongia staurota* Sarj., *M. tetracantha* (Gocht) Alb., *Palaeoperidinium cretaceum* (Poc. ex Davey) Lentin et Will. (Fig. 29r), *Phoberocysta neocomica* (Gocht) Mill. and *Pseudoceratium pelliferum* Gocht.

The FA of *C. tabulata* was reported from the base of the upper Barremian (Costa and Davey, 1992); *P. cretaceum*, from the upper Barremian (*BioStrat*..., 2023; Duxbury, 2001). The LA of *P. pelliferum*, *C. elegantulum*, *P. neocomica*, *A. falsificum*, and *M. staurota* is registered in the basal lower Aptian of northwestern Europe (Costa and Davey, 1992; Nøhr-Hansen, 1993; Duxbury, 2001; *BioStrat*..., 2023).

The summary of the dinocyst zonation is in the Fig. 30. The taxonomic composition of the studied dinocysts is similar to the Boreal Realm dinocyst assemblages but includes few species common whith those in the Tethyan Realm. This particularity can be explained by the significant influence of boreal water masses entering through the Early Cretaceous Caspian and Danish-Polish straits (Baraboshkin et al., 2007).

Early Cretaceous Calpionellids

Calpionellids of the Mountainous Crimea have been studied for almost 90 years. During this time, various researchers have proposed different stratigraphic schemes of the boundary deposits of the Jurassic and Cretaceous (Table 8). The first description of the calpionellids in Crimea belongs to Vassoevich (1935), who described one species *Calpionella alpina* Lor. from Tithonian (?) limestones. Linetskaya carried out a more detailed study of calpionellids in this region. She provides (Linetskaya, 1968) an analysis of the stratigraphic distribution of calpionellids from sections in southwestern Crimea (including the Baidary depression; Fig. 2: Kp15), central Crimea (Chatyr-Dag Mountain; Fig. 2: Kp9; Zelenogorskoe village; Fig. 2: Kp5) and eastern Crimea (Feodosiya region, Fig. 2: Kp2). In a well in the Baidary depression, *Calpionellites darderi* (Col.) was determined at the depth of 355 m; *Crassicollaria brevis* Rem. *Crassicollaria parvula* Rem. and *Calpionella alpina* Lor. at the depth of 160 m; *Calpionella alpina* Lor., *Tintinnopsella carpathica* (Murg. et Fil.), and *Calpionellites neocomiensis* Col. at the depth of 120 m. Therefore, unexposed deposits were subdivided into the upper Tithonian (up to 160 m) and the Berriasian. Single *Tintinnopsella carpathica* (Murg. et Fil.) has been found on Chatyr-Dag Mountain. In the Feodosiya region (town of Koktebel region, Fig. 2: Kp48), *Calpionella alpina* Lor., *Tintinnopsella carpathica* (Murg. et Fil.), and *Calpionellites darderi* (Col.) were found. This association of Calpionellids was assigned to the Berriasian (Linetskaya, 1968).

Sazonova and Sazonov (1984) identified two calpionellid assemblages in the Feodosiya region, corresponding to different stratigraphic levels. The lower one was Tithonian (the lower part of the Jacobi Zone

Table 8. Calpionellid zonation for the Tithonian and Berriasian of the Crimea Mountains

System	Stage	Substage	Calpionellid zone		Southwestern Crimea: Linetskaya, 1968	Southwestern Crimea: Fedorova, 2000	Southeastern Crimea: Sazonova and Sazonov, 1984	Southeastern Crimea: Platonov, 2016
Cretaceous	Berriasian		Calpionella	elliptica	Assemblages Calpionella alpina, Tintinnopsella carpathica, Calpionellites neocomiensis	Assemblages Calpionellopsis oblonga, Calpionella alpina (spherical form)	Assemblages Calpionellopsis oblonga, Calpionellopsis simplex, Titinnopsella carpathica, Titinnopsella longa	Beds with Calpionella elliptica
				ferasini		Assemblages Calplonella elliptica		?
				alpina			Assemblages Crassicollaria intermedia, Crassicollaria sp.	Beds with Calpionella alpina
Jurassic	Tithonian	Upper	Crassicollaria	colomi	Assemblages Crassicollaria brevis, Crassicollaria parvula, Calpionella alpina, Calpionellites darderi			Beds with Crassicollaria parvula
				intermedia				Chitinoidella boneti
				remanei				
			Praet.					?
		Middle	Chitinoidella	boneti				
				dobeni				Beds with Longicollaria dobeni
		Lower				Assemblages Crassicollaria sp., Calpionella alpina (elliptical form)		

in the modern sense) with *Crassicollaria intermedia* Dur.-Del. and *Crassicollaria* sp. The upper one was Berriasian with *Calpionellopsis oblonga* (Col.), *Calpionellopsis simplex* (Col.), *Titinnopsella carpathica* (Murg. et Fil.), and *Titinnopsella longa* (Col.).

Fedorova (2000) identified beds with calpionellids for the Tithonian–Berriasian of southwestern Crimea, which were correlated with ammonite and foraminifer scales: Tithonian Beds with *Crassicollaria* sp., *Calpionella alpina* Lor. (elliptical form); mid-Berriasian Beds with *Calpionella elliptica* Cad. and the upper Berriasian Beds with *Calpionellopsis oblonga* (Col.), *Calpionella alpina* Lor. (spherical form).

The study of calpionellids from two sections in eastern Crimea (Tonas River, Fig. 2: Kp3 and Dvuyakornaya Bay, Fig. 2: Kp2) by Shchennikova and Arkadiev (2009) resulted in recognition of *Chitinoidella* sp. and *Calpionella* sp.

The detailed study of the Tithonian–Berriasian reference section of the Dvuyakornaya Bay led to recognition of 5 biostratigraphic levels with calpionellids (Platonov et al., 2014; Platonov, 2016) (Figs. 31, 32).

Beds with *Longicollaria dobeni*, upper Tithonian. The lower boundary is drawn by the first occurrence (FO) of the index species. Two species were found: *Longicollaria dobeni* (Bor.) and *Popiella oblongata* Reh. A similar assemblage was described in the Dobeni Subzone of the lower Tithonian Chitinoidella Zone of Sicily (Andreini et al., 2007), western Bulgaria (Lakova and Petrova, 2013), Spain (Pruner et al., 2010), etc.

Beds with *Chitinoidella boneti*, upper Tithonian. The lower boundary is accepted by the FO of the index species. *Chitinoidella boneti* Dob. (Figs. 31a, 31b), *Popiella oblongata* Reh., *Chitinoidella elongata* Pop, and *Dobeniella* cf. *bermudezi* (Fur.-Ber.) were found at this level. The beds correlate with the Dobeni Subzone of the Chitinoidella Zone of Poland (Grabowski and Pszczółkowski, 2006), Italy (Andreini et al., 2007), Spain (Pruner et al., 2010), Hungary (Grabowski et al., 2010), Bulgaria (Lakova and Petrova, 2013), etc.

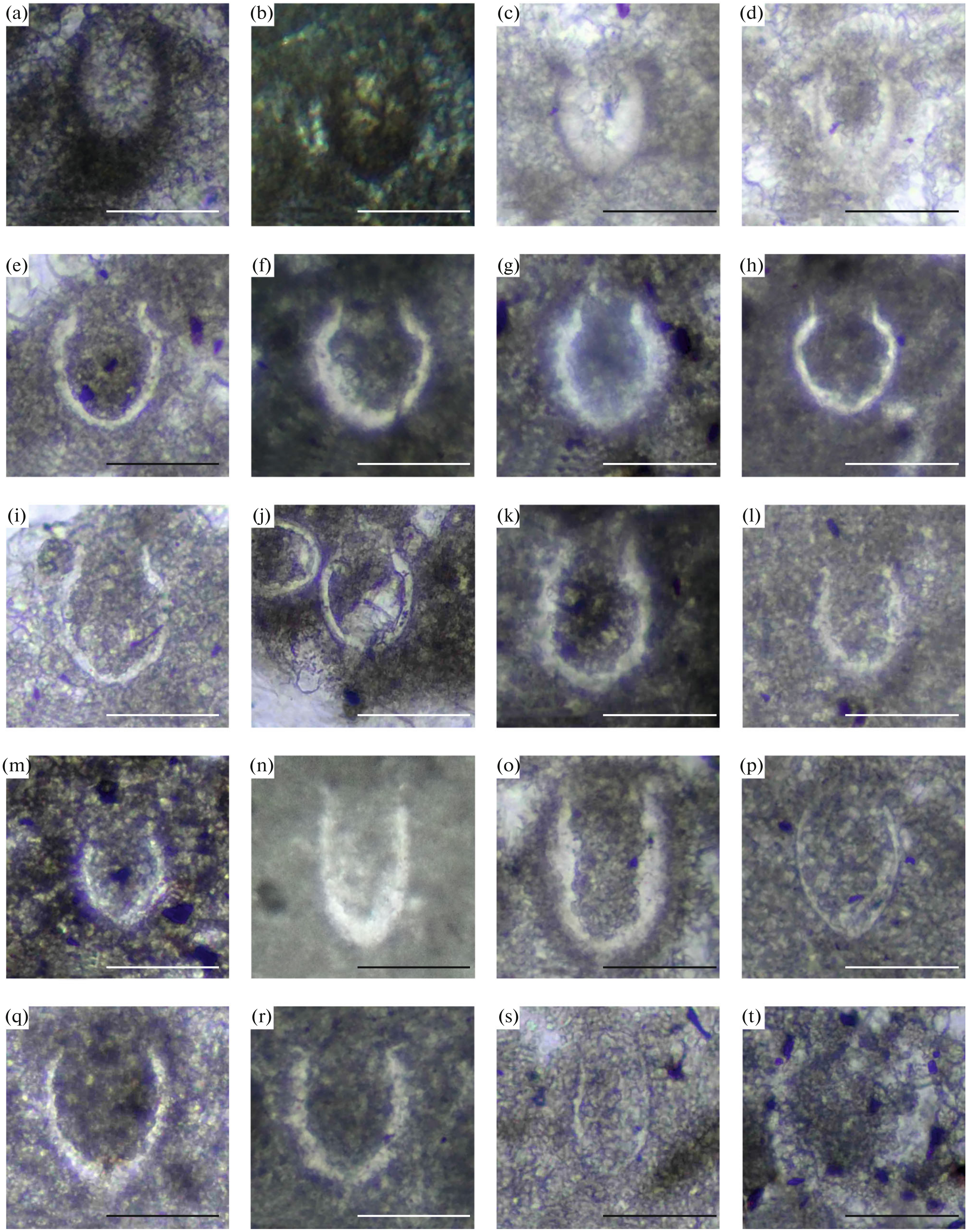
Beds with *Crassicollaria parvula*, upper Tithonian–Berriasian. The lower boundary is marked by the FO of Tithonian–Hauterivian *Tintinnopsella carpathica* (Murg. et Fil.). The beds are characterized by *Chitinoidella boneti* Dob., *Chitinoidella elongata* Pop, *Dobeniella cubensis* (Fur.-Ber.) (Fig. 31c), *Praetintinnopsella andrusovi* Bor. (Fig. 31d), *Tintinnopsella carpathica* (Murg. et Fil.), *Tintinnopsella remanei* Bor. (Fig. 31t), *Crassicollaria massutiniana* (Col.) (Figs. 31n, 31o), and *Crassicollaria* cf. *brevis* Rem. The assemblage indicative for to the Crassicollaria Zone of Bulgaria (Lakova and Petrova, 2013), Hungary (Grabowski et al., 2010), Italy (Andreini et al., 2007), Spain (Pruner et al., 2010), etc.

Beds with *Calpionella alpina*, Berriasian. The lower boundary is marked by the FO of *Calpionella alpina* Lor. Characteristic species are *Calpionella alpina* Lor. (Figs. 31f–31j), *Tintinnopsella carpathica* (Murg. et Fil.) (Figs. 31q, 31r), *Crassicollaria parvula* Rem., *Crassicollaria massutiniana* (Col.), *Tintinnopsella doliphormis* (Col.), *Calpionella grandalpina* Nagy, *Calpionella minuta* Houša (Figs. 31k–31m), and *Calpionella* aff. *elliptica* Cad. The Beds with *Calpionella alpina* are correlated with the Alpina Subzone of the Calpionella Zone of the Western Carpathians (Michalík et al., 2009), Bulgaria (Lakova and Petrova, 2013), Italy (Andreini et al., 2007), Spain (Pruner et al., 2010), Hungary (Grabowski et al., 2010), etc. The interval is traced in Berriasian sections on the Tonas River and the Kuchuk-Uzen creek (both Fig. 2: Kp3) (Platonov, 2016; Arkadiev et al., 2017; Savelieva et al., 2020).

Beds with *Calpionella elliptica*, Berriasian. The lower boundary is marked by the FO of *Calpionella elliptica* Cad. Characteristic species are *Calpionella elliptica* Cad., *Calpionella minuta* Houša, *Tintinnopsella longa* (Col.) (Fig. 31s), *Tintinnopsella carpathica* (Murg. et Fil.) (Fig. 31p), and *Crassicollaria parvula* Rem. The beds are correlated with the Elliptica Subzone of the Calpionella Zone in the Western Carpathians (Michalík et al., 2009), Bulgaria (Lakova and Petrova, 2013), Italy (Andreini et al., 2007), Spain (Pruner et al., 2010), etc.

Therefore, there are two biostratigraphic schemes for the Crimean Mountains based on calpionellides: one for southwestern Crimea and the other for south-

Fig. 31. Selected Tithonian and Berriasian Calpionellids. (a, b) *Chitinoidella boneti* Doben: (a) sample 135/13220, Dvuyakornaya bay, Tithonian, Beds with *Chitinoidella boneti*; (b) sample 226-14k from a conglomerate, Tonas river basin, Berriasian, Beds with *Calpionella alpina*; (c) *Dobeniella cubensis* (Fur.-Berm.), sample 142/13220, Dvuyakornaya bay, Tithonian, Beds with *Crassicollaria parvula*; (d) *Praetintinnopsella andrusovi* Borza, sample 142/13220, Dvuyakornaya bay, Tithonian, Beds with *Crassicollaria parvula*; (e–j) *Calpionella alpina* Lor.: (e) sample 17-50/3, Dvuyakornaya bay, Berriasian, Beds with *Calpionella alpina*; (f) sample 17-50/7, Dvuyakornaya bay, Berriasian, Beds with *Calpionella alpina*; (g) sample 17-51/14, Dvuyakornaya bay, Berriasian, Beds with *Calpionella alpina*; (h) sample 226-34-12k/2, Tonas river basin, Berriasian, Beds with *Calpionella alpina*; (i) sample Ky3/17, Kuchuk-Uzen creek, Berriasian, Beds with *Calpionella alpina*; (j) sampe Ky10/37, Kuchuk-Uzen creek, Berriasian, Beds with *Calpionella alpina*; (k–m) *C. minuta* Houša: (k) sample 17-50/7, Dvuyakornaya bay, Berriasian, Beds with *Calpionella alpina*; (l) sample 226-22-7k, Tonas river basin, Berriasian, beds with *Calpionella alpina*; (m) sampe Ky1/10, Kuchuk-Uzen creek, Berriasian, Beds with *Calpionella alpina*; (n, o) *Crassicollaria massutiniana* (Colom): (n) sample 137/13220, Dvuyakornaya bay, Berriasian, Beds with *Crassicollaria parvula*; (o) sample 133/13220, Dvuyakornaya bay, Berriasian, Beds with C*rassicollaria parvula*; (p–r) *Tintinnopsella carpathica* (Murg. et Fil.): (p) sample 131/13220, Dvuyakornaya bay, Berriasian, Beds with *Calpionella elliptica*; (q) sample 226-32-12k, Tonas river basin, Berriasian, Beds with *Calpionella alpina*; (r) sampe Ky7k/25, Kuchuk-Uzen creek, Berriasian, Beds with *Calpionella alpina*; (s) *T. longa* (Colom), 131/13220, Dvuyakornaya bay, Berriasian, Beds with *Calpionella elliptica*; (t) *T. remanei* Borza, sample 144/13220, Dvuyakornaya bay, Tithonian, Beds with *Crassicollaria parvula*. Scale bar is 50 µm. Thin sections with calpionellids are stored in the Chernyshev Central Research Geological Museum, Saint Petersburg.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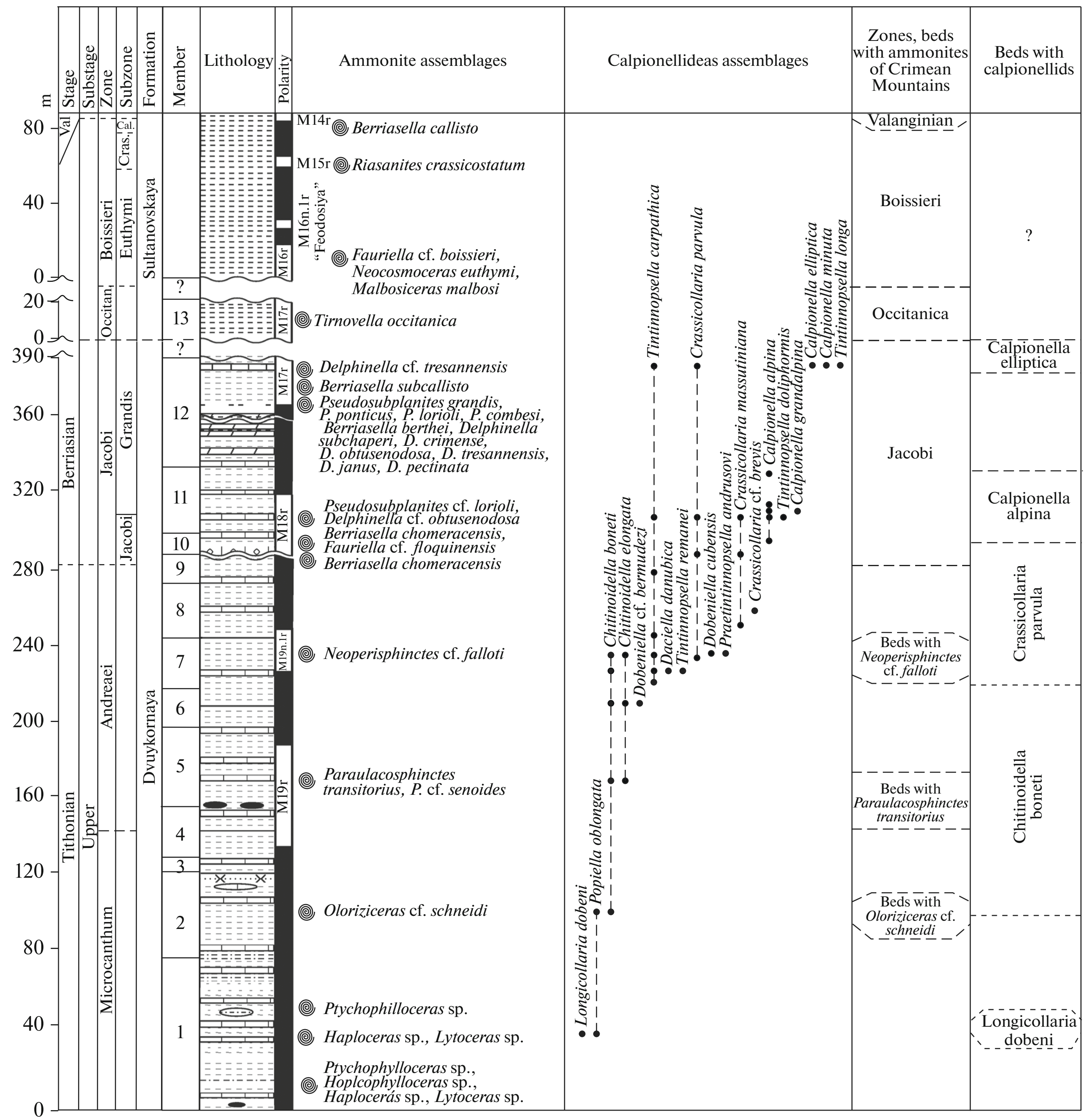

Fig. 32. Stratigraphic distribution of Calpionellids in the Tithonian–Berriasian section in eastern Crimea (Arkadiev et al., 2019, with changes). See the legend in Fig. 21.

eastern Crimea. Both schemes need further development, which is very difficult because of the rarity of calpionellid finds and their poor preservation (Table 8).

Early Cretaceous Nannoplankton

Cretaceous deposits in the Mountainous Crimea are represented by sandy, muddy, carbonate-muddy and carbonate rocks. Nannoplankton is present in all of them, except sandstones, but a degree of preservation ranging from very good in carbonates to very poor in mudstones. The amount of coccolites also varies from very low in muddy rocks to high in carbonates.

A great contribution to the study of Crimean nannofossils was made by Shumenko (1976), Matveev (2010, 2013), and Shcherbinina (Shcherbinina and Loginov, 2012; Shcherbinina and Gavrilov, 2016).

The first standard scale for the biostratigraphic subdivision of Cretaceous deposits by calcareous nannoplankton was proposed by Sissingh (1977), later it was detalized and refined by Perch-Nielsen (1985). Bown et al. (1998) presented a biostratigraphic scale for nannoplankton for the Lower Cretaceous of Boreal and Tethyan regions. They linked it to ammonite zones.

The available data on nannoplankton allow to identify biostratigraphic zones and to correlate them with the standard scales by ammonites, benthic and planktonic foraminifera. At the same time, there are problems of correlating them with the zones of the standard Mediterranean scale, caused both by the presence of hiatuses, changes in fossil assemblages due to changes in the type of rocks, and by the diachronism in the ranges of zonal markers (Shcherbinina and Loginov, 2012).

The Tithonian–Berriasian boundary deposits are widespread in the Crimean Mountains. The Berriasian is characterized by a complex tectonic structure and significant lithofacies variability (Bogdanova et al., 1981; Arkadiev et al., 2017). The completest and well studied succession of the lower Berriasian is exposed in the vicinity of Feodosiya City: Zavodskaya Balka quarry (carbonate clays of the Sultanovka Formation; Fig. 2: Kp2a), Cape St. Elias, and Dvuyakornaya Bay (muddy-carbonate turbidite of the Dvuyakornaya Formation; Fig. 2: Kp2) (Matveev, 2010; Arkadiev et al., 2019). Lescano and Concheyro from Argentina together with Russian geologists studied several nannoplankton samples from the Feodosiya section in 2019. The stage boundary was drawn by the first appearance of *Nannoconus kamptneri minor* Bralower in Bralower et al., a taxon whose distribution is limited to the Berriasian Stage and marks the base of the NJK Zone. The first appearance (FA) of *N. steinmannii steinmannii* Kamptner marks the base of the NK1 Zone (Arkadiev et al., 2019). The NK2 Zone, at the base of which *Retecapsa angustiforata* Black appears and which is corresponding with most of the Occitanica ammonite Zone and the Boissieri Zone (Bown et al., 1998), is not distinguished in this section, although the ammonite indexes are present.

The upper part of the NK2A Zone (Fig. 33) was distinguished by the presence of *Retecapsa angustiforata* and *Haqius circumradiatus* (Stover) Roth, in the Berriasian of the Kabanii Log section in the Belbek River (Fig. 2: Kp13, sandy-silty deposits and bioclastic limestones) (Shcherbinina and Loginov, 2012). The best outcrops of the Valanginian–lower Aptian sequences are known in the Kacha River basin, in the vicinity of Verkhorechie village (Fig. 2: Kp18) (Baraboshkin, 2003, 2016). Nannofossils of the Valanginian Stage were studied by Shcherbinina (Shcherbinina and Loginov, 2012) from a section on the southeastern slope of Rezanaya Mountain and in the result NK3B (Valanginian)–NC4A (Hautherivian) subzones were distinguished (Fig. 33). The base of the NK3 Zone is marked by the first appearance of *Calcicalathina oblongata* (Worsley) Thierstein, and the NK3B Sub-

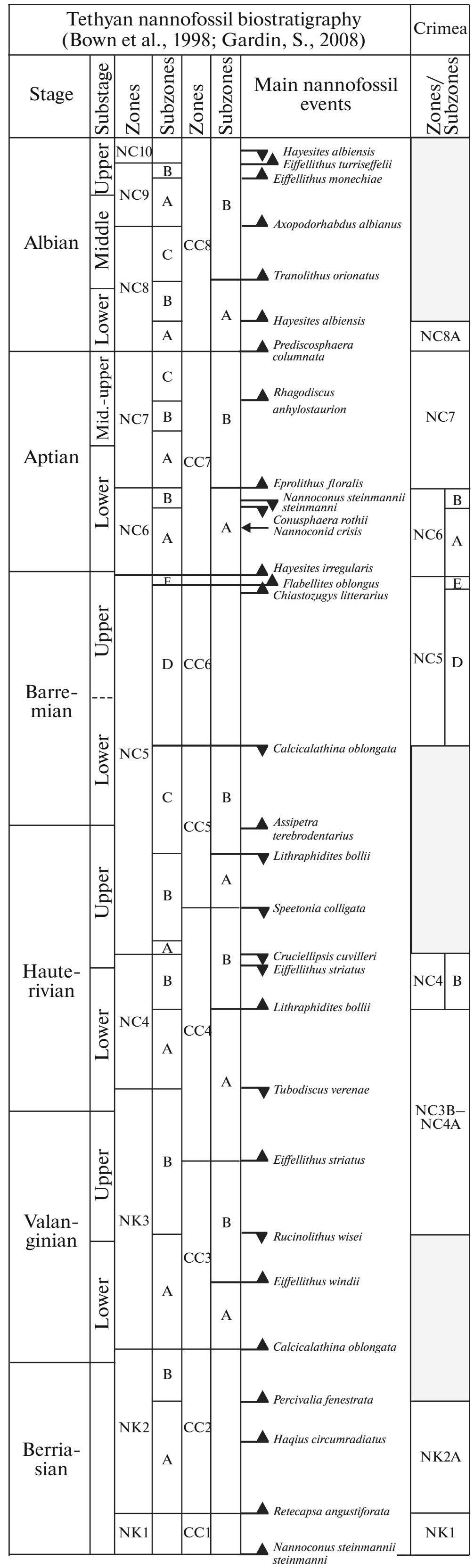

Fig. 33. Lower Cretaceous nannofossil biostratigraphy of the Mountainous Crimea.

zone is marked by the presence of *Eiffellithus striatus* (Black) Applegate et Bergen. *Eiffellithus windii* Applegate et Bergen, which disappears at the base of the NC4A Subzone is quite rare in the Crimea, which makes it difficult to draw the Valanginian/Hauterivian boundary. The upper Hauterivian of Verkhorechie village contains *Lithraphidites bollii* (Therstein) Thierstein, *Eiffellithus striatus*, and *Cruciellipsis cuvillieri* (Manivit) Thierstein, and the NC4B Subzone could be distinguished (Fig. 33).

Flabellites oblongus (Bukry) Crux in Crux et al., was identified from the upper Barremian carbonate clays of the lower part of the Biasala Formation of the Vrekhorechie section. It allows to define the NC5D/NC5E subzones boundary (Gardin, 2008). The Barremian/Aptian boundary in terms of nannoplankton was drawn by the first appearance of *Rucinolithus irregularis* Thierstein in Roth et Thierstein. It is quite rare in the Crimean sections, but it was recognized in the Verkhorechie section by Mutterlose (Baraboshkin et al., 2004), which became the basis for placing the Barremian/Aptian boundary. *Flabellites oblongus* was also identified by Mutterlose from this section, and the other species of the assemblage are represented by either cosmopolitan or Tethyan forms (Baraboshkin et al., 2004). The Aptian clays of the upper part of Biasala Formation are widely distributed in the eastern Crimea. The most complete section is Zavodskaya Balka quarry, where presence of *Conusphaera rothii* (Thierstein) Jakubowski, marks the lower Aptian NC6A Subzone and its disappearance marks the subzone NC6B (Fig. 2: Kp2a) (Karpuk and Shcherbinina, 2015). The middle-upper Aptian NC7 Zone (Fig. 33) was distinguished by the presence of *Eprolithus floralis* (Stradner) Stover in gray carbonate clays by Shcherbinina in the vicinity of Simferopol in Mar'ino quarry (Fig. 2: Kp10, (Shcherbinina and Loginov, 2012)) and in Zavodskaya Balka quarry (Fig. 2: Kp2a, (Karpuk and Shcherbinina, 2015)).

The NC8A Subzone was distinguished by the appearance of *Prediscosphaera columnata* (Stover, 1966) Perch-Nielsen, 1984 in Albian gray carbonate clays of the Balaklava quarry (Fig. 2: Kp17) (Shcherbinina and Loginov, 2012). The uppermost Albian NC10 Zone (=CC10 of Sissingh's scale) (Fig. 33) was identified on the southern slope of Mt. Selbukhra (Shcherbinina and Gavrilov, 2016). The uppermost Aptian–lowermost Albian are missing in the Mountainous Crimea due to tectonic movements (Baraboshkin, 2003, 2016), and nannofossils subdivisions are also missing.

Thus, calcareous nannoplankton is widespread in the Lower Cretaceous deposits of Crimea and is suitable for solving problems of biostratigraphy. The data obtained from it correlate well with the subdivisions of the Tethyan scale (Fig. 33), even though species markers of zones and subzones are not numerous and are not found everywhere in the zonal intervals. The degree of precision and reliability of age determinations are affected significantly by the preservation, taxonomic diversity, and the presence of hiatuses in the sections.

Although the Sissingh's scale (Sissingh, 1977) has not lost its significance, the Bown et al. scale (Bown et al., 1998) is more suitable for the Lower Cretaceous of the Tethyan region as it is more detailed. In case of taxonomically depleted assemblages, when index species of subzones are less common or missing, the Sissingh scale is more suitable, especially when age resolution of host deposits ranges from stage to substage.

Magnetostratigraphy of the Lower Cretaceous

The Lower Cretaceous in Crimea remained magnetostratigraphically unexplored up to the early 21th century, but the situation has changed cardinally over the past two decades. Data on magnetic properties and paleomagnetism of the Lower Cretaceous has been acquired from 26 sections over the Mountainous Crimea area. In total, samples from 2000 stratigraphic levels have been collected and examined. The integrated study comprised sedimentological, bio-, chemo- and magnetostratigraphic investigations. Samples for different analysis were taken exactly from the same place and therefore all the data are reliably linked.

The composite magnetostratigraphic section of the Lower Cretaceous from the Mountainous Crimea presents generalized information on the geomagnetic polarity regime and magnetic susceptibility of rocks (K). The paleomagnetic column of the section is matched to the geomagnetic polarity scale (GPTS) (Gradstein et al., 2020). Variations of magnetic susceptibility are interpreted as indicative of variable environments of Cretaceous accumulation. Information about the anisotropy of the magnetic susceptibility of Berriasian rocks are interpreted as indicators of tectonic stress directions and the rock deformation degrees.

Sedimentary rates (Chron duration to magnetozone thickness ratio) were calculated for the intervals of identified magnetozones using GPTS Chrones duration. The results of cyclostratigraphic analysis of vertical succession of petromagnetic parameters in the upper Berriasian Alekseevka section (central Crimea) were used to reveal cyclicity associated with periodical changes of the Earth's orbit parameters (Milankovitch cycles). This allowed evaluation of the absolute duration of stratigraphic units and sedimentary rates. The composite paleomagnetic section for the Lower Cretaceous from Crimea is based on the data from 26 reference sections located in all the structural-facies zones of Mountainous Crimea: in southwest, central and eastern Crimea (Fig. 2). The Berriasian–Hauterivian corresponds to alternated geomagnetic polarity, the Aptian–Albian, to essentially normal polarity. Reliability of magnetic-polarity characteristics for various age intervals, determined by the quality of paleomagnetic data and the number of examined section, is irregular. The Berriasian–lower Valanginian and the Barremian–Aptian are among the best studied intervals. All the magnetozones specified within the deposits of those ages have been correlated with the GPTS Chrones (Fig. 34).

The Berriasian has been studied in most detail. A sequence of magnetozones analogous to all the Berriasian magnetic chrones, from M19n to M14r, has been revealed by a group of Russian researchers in the Berriasian sections from eastern and central Crimea. They include Subchron M19n.1r ("Brodno") and Subchron M16n.1r ("Feodosiya") previously determined only from interpretations of linear magnetic anomalies (Tominaga and Sager, 2010). The bio- and magnetostratigraphic characteristics were used for elaborating the ages of the deposits and for magnetochronological calibration of minute Berriasian subdivisions from Crimea and from the stratotype area, for isochronous tracking of the Berriasian zonal boundaries, including existing and provisional stage boundaries. The base of magnetic Chrones M18r and M14r are proposed as markers for the lower boundary of the Berriasian and Valanginian respectively (Arkadiev et al., 2010, 2015a, 2015b, 2017, 2018b, 2019; Guzhikov et al., 2012, 2014; Grishchenko at al., 2016; Baraboshkin et al., 2019).

The lower Berriasian (Jacobi Zone) of eastern Crimea (in the vicinity of Feodosiya City; Fig. 2: Kp2) was also examined by Bakhmutov et al. (2018) and Wimbledon et al. (2022) during the integrated study of the Jurassic–Cretaceous boundary interval. The study was made by the international Berriasian Working Group led by Wimbledon. European (Bakhmutov et al., 2018; Wimbledon et al., 2020, 2022) and Russian researchers (Arkadiev et al., 2018b, 2019) in possession of similar paleomagnetic data from the same sections tend to provide different interpretations. The Russian researchers believe the problems are resulted from the erroneous compilation of the composite section by European colleagues (Arkadiev et al., 2019). Sure enough, comparing isolated outcrops over the areas of the Dvuyakornaya bay, the Saint Elias and Feodosiya capes makes quite a challenge, considering numerous slides and dislocations, gaps in outcropping and the lack of reliable lithological markers that may be traced between outcrops.

The results of identifying the detected magnetozones with the GPTS chrones are of key importance for detailed correlations of the Crimean Tithonian–Berriasian with the other regions and in choosing criteria for determination of the level of the Jurassic–Cretaceous boundary. The point of view of the Russian group is reflected in the composite magnetostratigraphic section (Fig. 34), since it is based on the analysis and generalization of the long-term integrated bio- and magnetostratigraphic study not just of the narrow Jurassic–Cretaceous boundary interval, but of the entire section from the upper Tithonian to the lower Valanginian in the vicinity of Feodosiya.

The examined Berriasian sections from the Baidary depression in southwestern Crimea (Fig. 2: Kp15) were proved to be inadequate for paleomagnetic measurements.

Continuous sequence of magnetozones—analogues of chrones from M14r up to and including M12r—have been specified in the Berriasian–Valanginian boundary interval (Fig. 34). The paleomagnetic data have allowed the most detailed correlation of the lower Valanginian from eastern and southwestern Crimea (Grishchenko et al., 2020).

Paleomagnetism of the upper Valanginian and Hauterivian from southwestern Crimea was studied in the Rezanaya Mountain and Belaya Mountain sections and in the Verkhorechie reference section (Yampolskaya et al., 2006; Fig. 2: Kp18), and from eastern Crimea, in the Koklyuk Mountain section (Fig. 2: Kp81). Low paleomagnetic quality of the rocks from southwestern Crimea and the lack of comprehensive biostratigraphic division of the Koklyuk section, along with complex paleomagnetic zonation peculiar for the Valanginian–Hauterivian, prevent unambiguous correlations of the recognized magnetozones with the GPTS chrones.

The Barremian stage is the most peculiar for a normal polarity zone comparable with late Barremian Chron M1n. The essentially reverse polarity (chrones M3 and M1r), common to the first half of the Barremian age, is recorded only in the basal layer, which is suggestive of the strongly condensed lower Barremian in both southwestern and eastern Crimea (Baraboshkin et al., 2004; Yampolskaya et al., 2006; Grishchenko and Shurekova, 2020).

Analogues of Chron M0 have been determined in the Aptian stage. That is why biostratigraphic data on the Barremian–Aptian boundary interval from southwestern and eastern Crimea correlates with minute subdivisions of the Aptian from other regions (Yampolskaya et al., 2006; Karpuk et al., 2018). Using a paleomagnetic feature as a primary criterion for substantiating the base of the Aptian makes it possible to stop discussions on the position of the stage boundary from different paleontological groups. A reverse polarity zone, presumably corresponding to Subchron M"-1"r (ISEA), has been revealed in the Aptian in central Crimea (Yampolskaya et al., 2006).

A reverse-polarity interval supposedly corresponding to Subchron M"-3"r has been recorded against the background of dominant normal polarity in the upper Albian substage (the M. rostratum Zone) within the section near Prokhladnoe village (Yampolskaya et al., 2006).

Magnetic textures of Lower Cretaceous clays from the Mountainous Crimea serve as good indicators of tectonic stress directions and the rock deformation degrees. For example, distinctly ordered long axes of

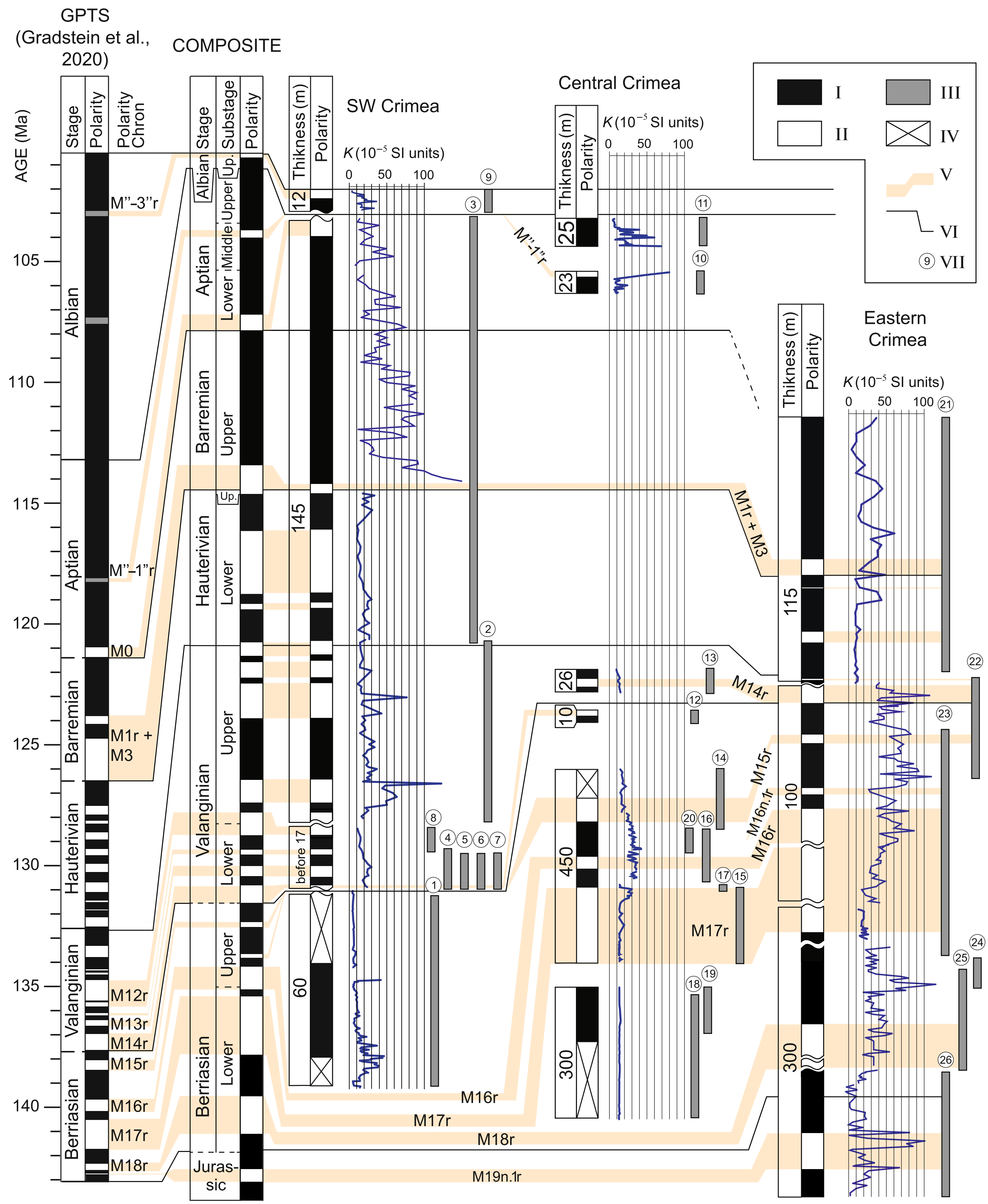
GPTS (Gradstein et al., 2020)
COMPOSITE
AGE (Ma)
Stage
Polarity
Polarity Chron
Substage
Thikness (m)
SW Crimea
Central Crimea
Eastern Crimea
K (10^−5 SI units)
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
Jurassic
Upper
Middle
Lower
M"–3"r
M"–1"r
M0
M1r + M3
M12r
M13r
M14r
M15r
M16r
M17r
M18r
M19n.1r
M16n.1r
I
II
III
IV
V
VI
VII

Fig. 34. Composite magnetostratigraphic section of the Lower Cretaceous from the Mountainous Crimea. (I, II and III) Normal, reverse and abnormal geomagnetic polarities, respectively; (IV) no polarity data available; correlations: (V and VI) polarity chron boundaries correlations and stage boundaries, respectively; (VII) section numbers: <u>SW Crimea:</u> the Belbek river valley: (1) Kabanii Log (K_1b_{2-3}); the Kacha river valley: (2) Rezanaya Mountain (K_1v), (3) Belaya Mountain (K_1h-a); the Bodrak river valley: (4) Selbukhra Mountain (K_1v_1), (5) Patil Mountain (K_1v_1), (6) Sheludivaya Mountain (K_1v_1), (7) Dlinnaya Mountain (K_1v_1), (8) Bolshoy Kermen Mountain (K_1v_1), (9) Prokhladnoe village (K_1al). <u>Central Crimea:</u> (10) Partizanskoe village (K_1a_2), (11) Mar'ino quarry, Simferopol (K_1a_3), (12) Taskor ravine (K_1b_3), (13) Mazanka village (K_1v_1), (14) Baksan Mountain (K_1b_3), (15) Enisaraj ravine (K_1b_2), (16) Balki village (K_1b_{2-3}), (17) Novoklenovo village (K_1b_2), (18) the Tonas river (K_1b_1), (19) the Kuchuk-Uzen creek (K_1b_1), (20) Alekseevka village (K_1b_3). <u>Eastern Crimea:</u> (21) Koklyuk Mountain (K_1b–br), (22) Sultanovka [Yuzhnoe] village (K_2b_3–v), (23) Zavodskaya Balka (K_2b_{2-3}–v_1), (24) Feodosiya Cape (K_2b_1), (25) Saint Elias Cape (K_2b_1), (26) Dvuyakornaya bay (J_3t_2–K_1b_1).

ellipsoids of magnetic susceptibility, along with the short axes being grouped in the center of stereo projection, indicate varied directions of the weak tectonic compression of rocks in southwestern (Fig. 35a) and eastern Crimea (Fig. 35b). Orderliness of the long axes, alongside with severe shift of the entire set of short axes to the equator of the stereo projection in outcrop 2952 within the Balki section (central Crimea, Fig. 2: Kp5), is associated with a limestone chump thrusted over the clay surface (Fig. 35c) (Bagaeva and Guzhikov, 2014). The mechanism of viscoplastic deformations being reflected in anisotropy of magnetic susceptibility has been analyzed in detail by the example of upper Berriasian–lower Valanginian clays from eastern Crimea (Grishchenko and Guzhikov, 2019). In southwestern Crimea, magnetic textures of limestones also tend to capture directions of tectonic stresses and various degrees of rock deformation, even if less expressively.

Many important geological events are adequately reflected in rock magnetism of Lower Cretaceous deposits from the Mountainous Crimea: activity variations in terrigenous ablation; involvement of highly magnetic igneous rocks into erosion in the vicinity of the Kacha–Simferopol uplift; intensity fluctuations of authigenic magnetite formation (Yampolskaya et al., 2006, 2007). In most cases, the listed factors are associated with the sea-level variations due to tectonic and/or eustatic factor. This is substantiated by similar trends of petromagnetic variations and by the paleobathymetric curve for the Mountainous Crimea basin in the Early Cretaceous (Fig. 36).

Sedimentation rates in the Early Cretaceous of the Mountainous Crimea varied from 1–2 cm/thousand years in the early Valanginian condensed sections of southwestern Crimea to 5–10 cm/thousand years in the Berriasian calciturbidites of eastern Crimea. Cycles of small eccentricity of the Earth's orbit (~100 thousand years) and of obliquity (~40 thousand years) are manifested in the upper Berriasian section from the village of Alekseevka (central Crimea, Fig. 2: Kp3) (Grishchenko et al., 2016). The deposits with those cycles recorded correspond to a portion of Chron M16n. According to cyclostratigraphic data, the process of the deposit formation took about 400 thousand years,

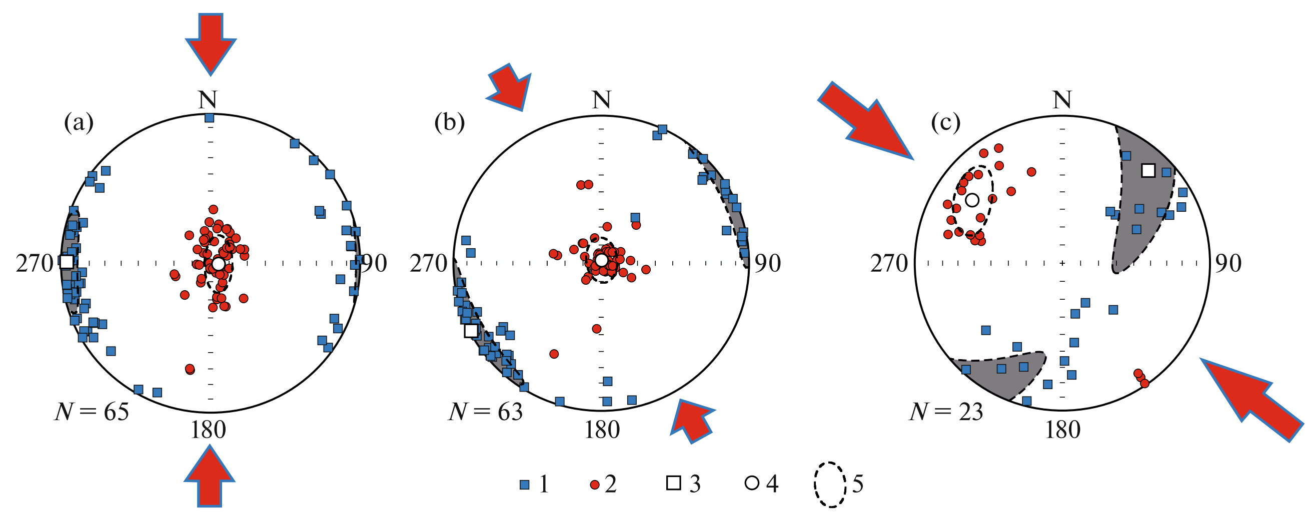

Fig. 35. Directions and degrees of tectonic stress intensities as reflected in the rock magnetic textures. (a) Barremian–Aptian clays in the Belaya Mountain section (SW Crimea), (b) Berriasian clays in the sections from the Tonas river and the Kuchuk-Uzen creek (central Crimea), (c) Berriasian clays under the thrust surface in the outcrop 2952 within the Balki section (central Crimea). Legend: (1, 2) projections of the AMS ellipsoid long (K1) and short (K3) axes (in paleogeographic coordinate system); (3, 4) average values of K1 and K3, respectively; (5) confidence ellipses for K1 and K3. N, number of samples. The arrows indicate the directions of tectonic stresses, with the arrow lengths in proportion to the tectonic stress intensities.

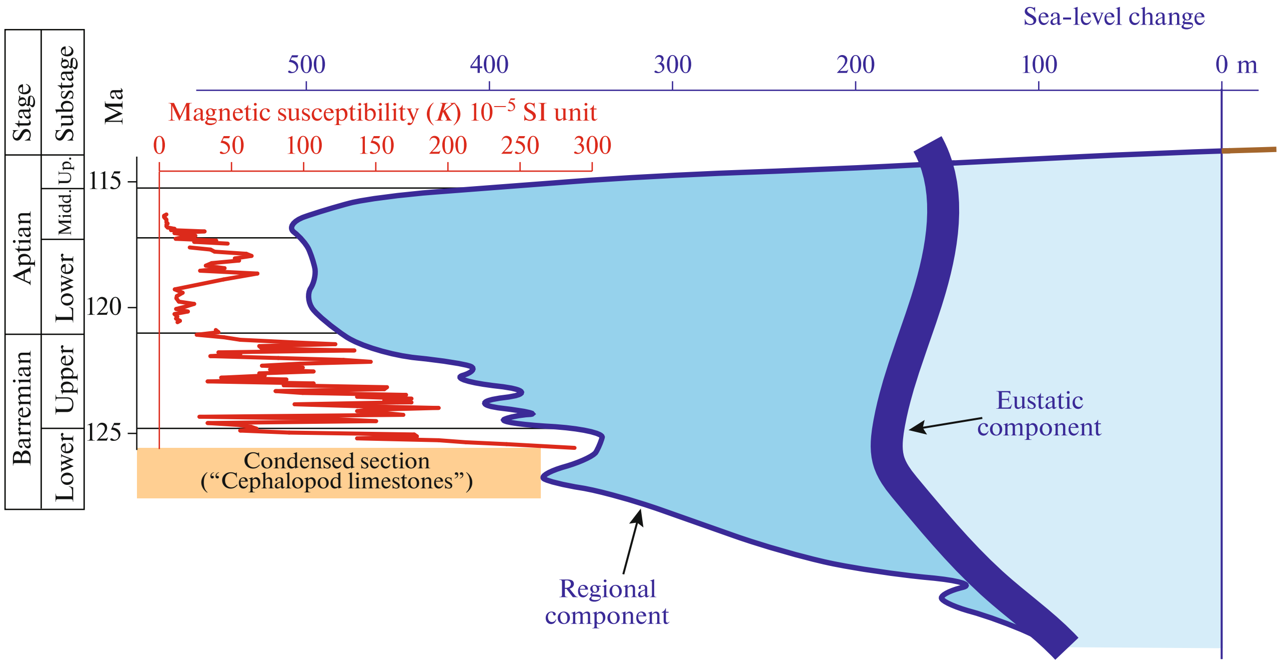

Fig. 36. Comparison of the composite chart of magnetic susceptibility for the Barremian–Aptian and a fragment of a paleobathymetric curve for the Valanginian–Aptian basin in the Mountainous Crimea drawn from the ammonite-shell strength indices and the facies analysis data (Yampolskaya et al., 2007).

which doesn't disagree with the data on M16n duration 1167 thousand years (Gradstein et al., 2020).

CONCLUSIONS

The Crimean Peninsula is one of the very interesting regions of the northern Peritethys area. Standing on the border of Boreal and Tethyan Realms it includes many features of the geological development of both of them. A wealth of intriguing data has been gathered over the past two centuries regarding the Cretaceous development and stratigraphy of the region. Significant progress in the stratigraphic studies has been reached during the last 20–30 years. Despite it a lot of geological problems have not been resolved yet, and there is a lack of new results of modern level. First of all, the results from non-paleontological methods are required: stable isotope data, geochronology, and fine geochemical and lithological research. It is crucial to examine a number of biostratigraphic groups, including forams, bivalves, echinoids and crinoids. It is indubitable that the analysis of calcareous algae will yield significant stratigraphical and sedimentological insights. In the other words, much has already been done, but much more remains to be done.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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