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Developments in the Cretaceous Stratigraphy of Crimea. Part 2. Upper Cretaceous and Conclusions

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Abstract—This is the second part of the paper on the Cretaceous of the Mountainous Crimea. A lot of new data has been received during last ten years. This paper summarizes the state of knowledge of the Upper Cretaceous stratigraphy, selected biostratigraphic groups (ammonites, belemnites, ostracods, foraminifers, gilianelles, nannoplankton) and magnetostratigraphy. Ammonite and belemnite biostratigraphic subdivisions are proposed for the first time for the Crimean Upper Cretaceous. Foraminifera-based biostratigraphy is updated, and new biostratigraphic units are proposed and correlated with the European scale. Stratigraphic hiatuses are recognised in the succession of southwestern Crimea: the base and the top of lower Cenomanian, upper Coniacian—lower Santonian, Campanian/Maastrichtian and Cretaceous/Paleogene boundary intervals.

Keywords: biostratigraphy, ammonites, belemnites, ostracods, foraminifers, gilianelles, nannoplankton, magnetostratigraphy

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INTRODUCTION

The paper continues the first part, which was focused on the Lower Cretaceous of the Mountainous Crimea. The present paper summarizes developments of the Upper Cretaceous stratigraphy during the last 20–30 years. The most important Upper Cretaceous sections (Figs. 1, 2) and selected fossil groups of macro- and microfossils are discussed. It is resulted in appearance of new detailed stratigraphic schemes of the Cretaceous rocks of the Mountainous Crimea. The state of knowledge for some of these groups is present here: ammonites (by E.Yu. Baraboshkin), ostracods (by E.M. Tesakova), Foraminifera (by I.P. Ryabov), gilianelles (by V.S. Vishnevskaya), and calcareous nannoplankton (by M.A. Ustinova). Several fossil groups are not included in this paper, but one can find additional information in the monographs on bivalves (Sobetsky, 1977); foraminifers (Kopaevich and Vishnevskaya, 2016), crustaceans (Ilyin, 2005), radiolarians (Vishnevskaya, 2001; Bragina, 2004, 2009, 2016), Late Cretaceous dynocists (Aleksandrova in Baraboshkin et al., 2020, 2024; Guzhikov et al., 2021a), Cretaceous sharks (Trikolidi, 2014).

The study was completed by non-paleontological methods (magnetostratigraphy and stable isotopes), and an overview of Cretaceous magnetostratigraphy is presented by A.Yu. Guzhikov. Stable isotopes data are not sufficient yet, but some of them were published by Naidin and Kiyashko (1994), Gabdullin (2002), Fisher et al. (2005), Baraboshkin et al. (2023a, 2023b, 2024), etc. The U–Pb data were received from volcanic material of the town of Balaklava (Nikishin et al., 2013) and from the lower Campanian tuff layer of the Kacha River (Baraboshkin et al., 2024).

The figured fossils are from the collections of The Earth Science Museum at Moscow State University, Moscow, Russia (MSU), The Moscow State University Field Station in Crimea, Russia (FS MSU) and Geological Institution of Russian Academy of Science, Moscow (GIN).

THE UPPER CRETACEOUS SUCCESSION

Upper Cretaceous deposits are distributed both in the Plain and Mountainous Crimea (Fig. 1). Their outcrops are traced along the Second Ridge of the Crimean Mountains from the village of Sakharnaya Golovka (Sevastopol, Fig. 2: Kp82) in the southwest to the town of Feodosiya in the east. These outcrops are interrupted between the city of Simferopol and the village of Zuya, as well as in the town of Stary Krym (Figs. 2, 3). To the east, there are outcrops of Upper Cretaceous rocks at Cape Karangat of the Kerch Peninsula. The thickness of Upper Cretaceous rocks is

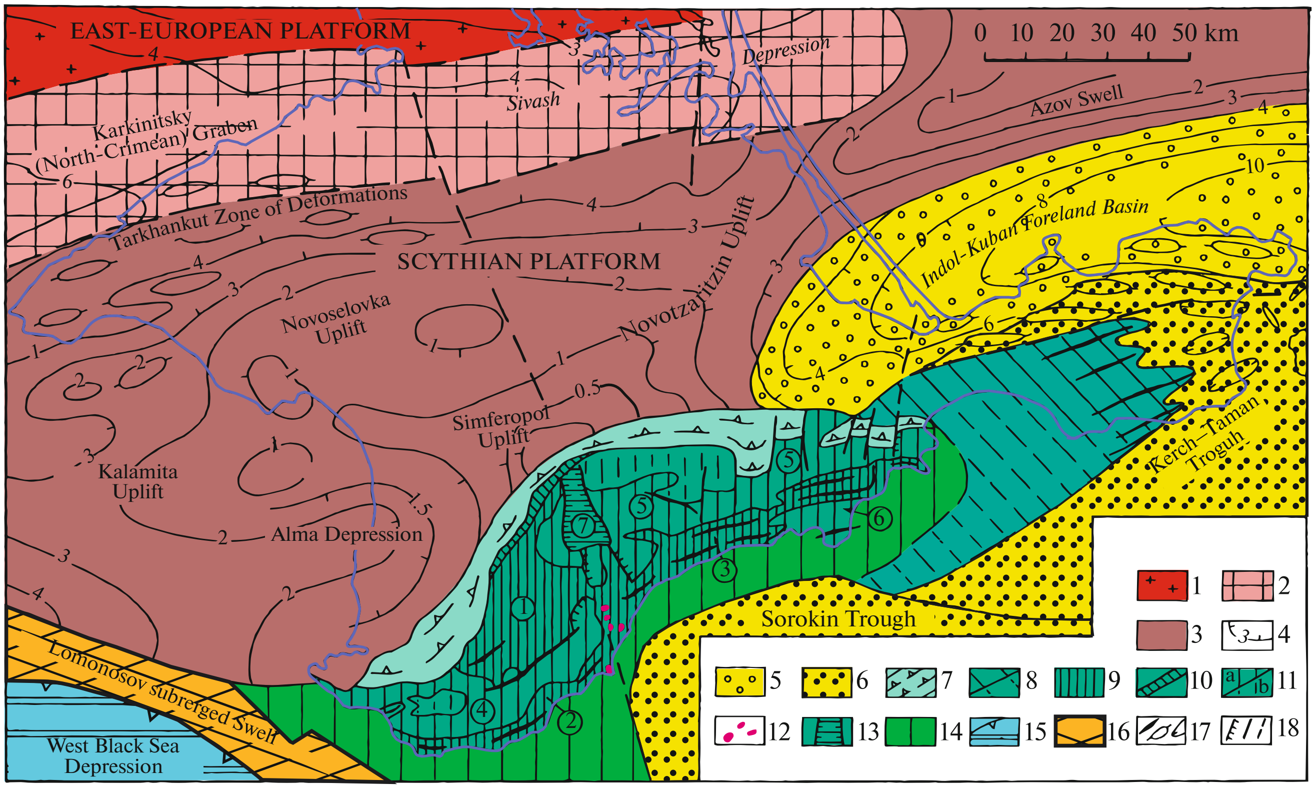


Fig. 1. Scheme of the tectonic structure of the Crimean Peninsula (Baraboshkin, 2016, after Milanovsky, 1996; Nikishin et al., 2015, with changes). (1) East European Platform; (2, 3) Plain Crimea structures: (2) North Crimean zone; (3) Scythian Platform; (4) stratoisohypses of the base of the Cretaceous-Cenozoic 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.

usually 450–500 m, increasing to 1 km on the Kerch Peninsula. In the Plain Crimea (Fig. 3), Upper Cretaceous deposits are widespread and penetrated by many wells; their thickness varies from tens of meters to almost 3 km in the Tarkhankut Peninsula.

The subdivision of Upper Cretaceous deposits of Crimea is based on the distribution of relatively rare remains of macrofossils: ammonites, belemnites, inoceramids, echinoids, and microfossils, mainly foraminifers. In recent years, Upper Cretaceous stratigraphy of Crimea has been significantly updated due to the study of microfossils and the use of non-paleontological methods. Sections located in the Belbek–Bodrak interfluve, which are considered as reference sections for the entire Crimean Mountains, have been studied in detail. They were subdivided into 24 units (Naidin and Alekseev, 1980; Alekseev, 1989), which can be traced and mapped. Many of the recent publications use this informal numbering.

In terms of facies, the rocks of the Upper Cretaceous are much more uniform than those of the Lower Cretaceous deposits.

Cenomanian deposits transgressively overlie upper Albian rocks or older deposits (Gozhyk et al., 2006; Nikishin et al., 2015). They are represented by marls and argillaceous limestones being usually poorly exposed. The succession usually starts from the tuffaceous sandstones in Crimea. The thickness of the Cenomanian varies from 20 to 80 m, reaching 220–250 m in Belogorsk town area, but in Simferopol and Stary Krym regions Cenomanian rocks are missing.

The reference section of the Cenomanian is the Kremennaya Mountain section in the Bodrak River Basin (Naidin and Alekseev, 1980, 1981), which is covered by a forest now. The other reference section is a Selbukhra Mountain section, recently re-examined (Baraboshkin and Zibrov, 2012; Avenirova, 2023; Baraboshkin et al., 2023c; Rtishchev, 2023) (Fig. 2: Kp12b, Figs. 4, 5).

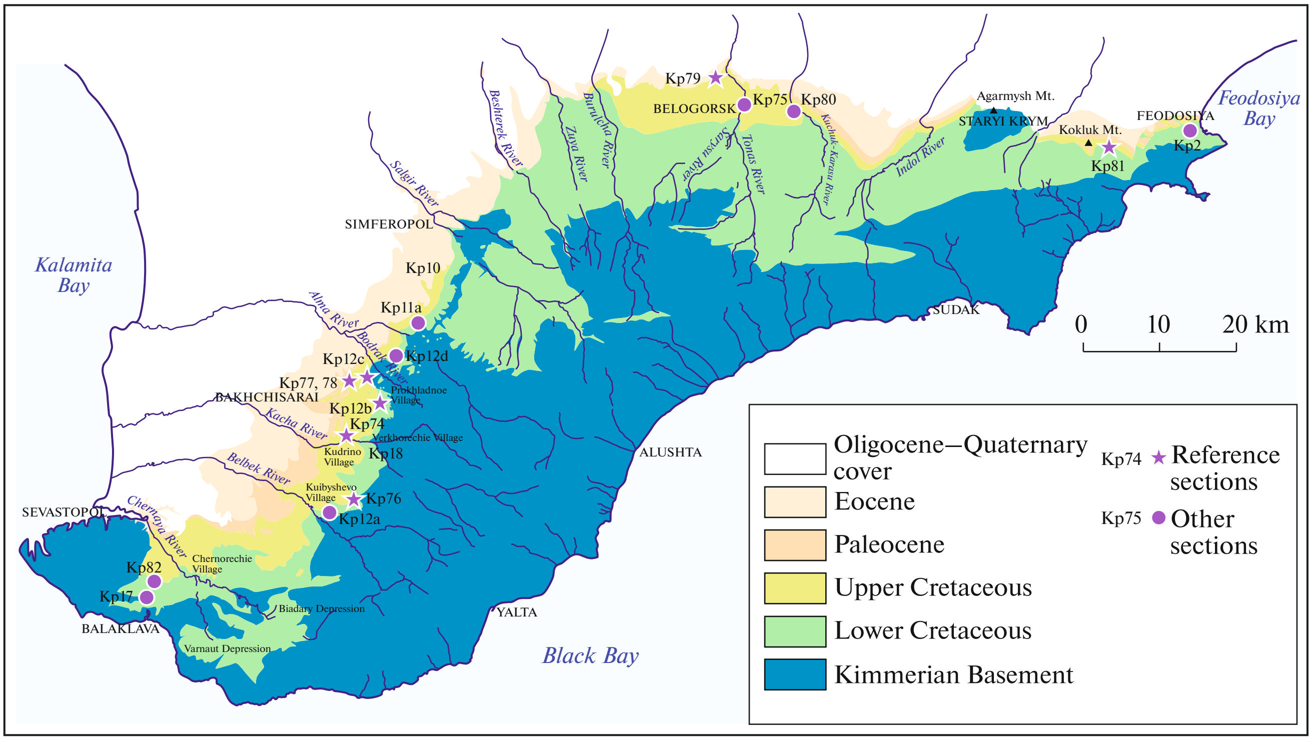


Fig. 2. Simplified scheme of the distribution of Cretaceous deposits in the Mountainous Crimea and main localities mentioned in the text. **Reference sections**: Kp2, Feodosiya; Kp12b, Selbukhra Mountain; Kp12c, Kremennaya and Mender mountains; Kp17, Balaklava town region; Kp18, Verkhorechie village (Rezanaya–Belaya mountains); Kp74, Aksu-Dere Ravine and Kudrino village; Kp76, Chuku (Polyus) Mountain, Belbek River; Kp77, Staroselie village and Beshkosh Mountain; Kp78, Chakhmakhly Ravine; Kp79, Ak-Kaya Mountain; Kp81, Koklyuk, Klement'eva, and Brodskaya mountains. **Other sections**: Kp11a, Alma River section; Kp12a, Sbrosovyi Log, Sukhoi Log, Belbek River; Kp12d, Bodrak River and Kizil-Chigir Mountain; Kp17, region of Balaklava town; Kp73, Nasypnoe village region; Kp75, Belogorsk town region; Kp80, Alan-Kyr Mountain; Kp82, Sakharnaya Golovka.

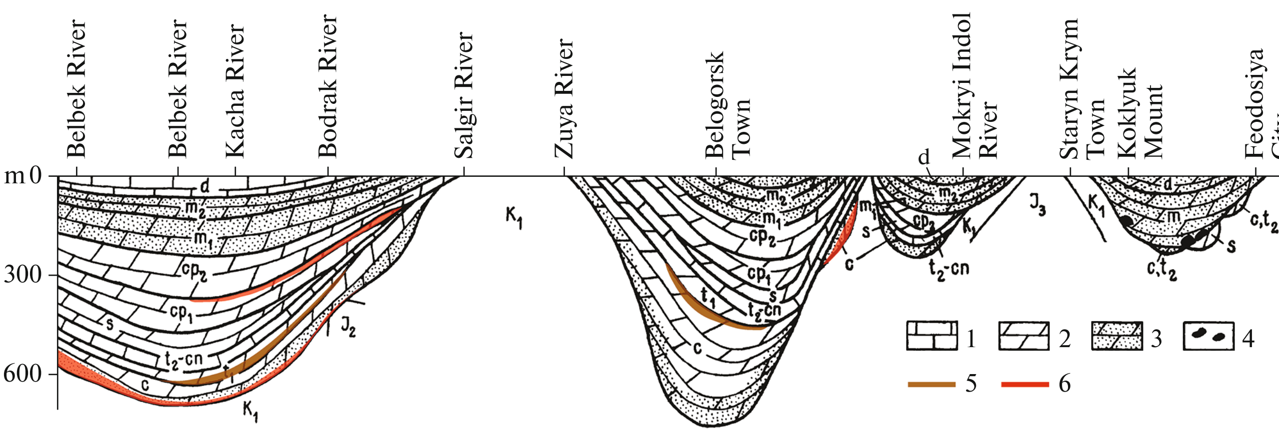


Fig. 3. Geological profile of the Upper Cretaceous of the Mountainous Crimea (after Maslakova in Moskvin, 1986–1987, with changes). (1) Limestones; (2) marls; (3) sandy marls; (4) Cenomanian to Campanian slide (? tectonic) blocks in Maastrichtian marls; (5) Cenomanian/Turonian black shales; (6) main tuff and volcanoclastic layers.

Lower Cenomanian deposits have different completeness. In southwestern Crimea, they disappear from the section in the interfluve of the Belbek and Kacha rivers and partially on the watershed of the Kacha and Bodrak rivers. Lower Cenomanian tuffaceous sandstones at the base of the section gradually pass upwards into sandy and silty quartz-glauconite marls (Unit I of Naidin and Alekseev (1980)). These rocks contain remains of ammonites *Schloenbachia varians* (J. Sow.), *Hypohoplites falcatus* (Mant.), *Man-*

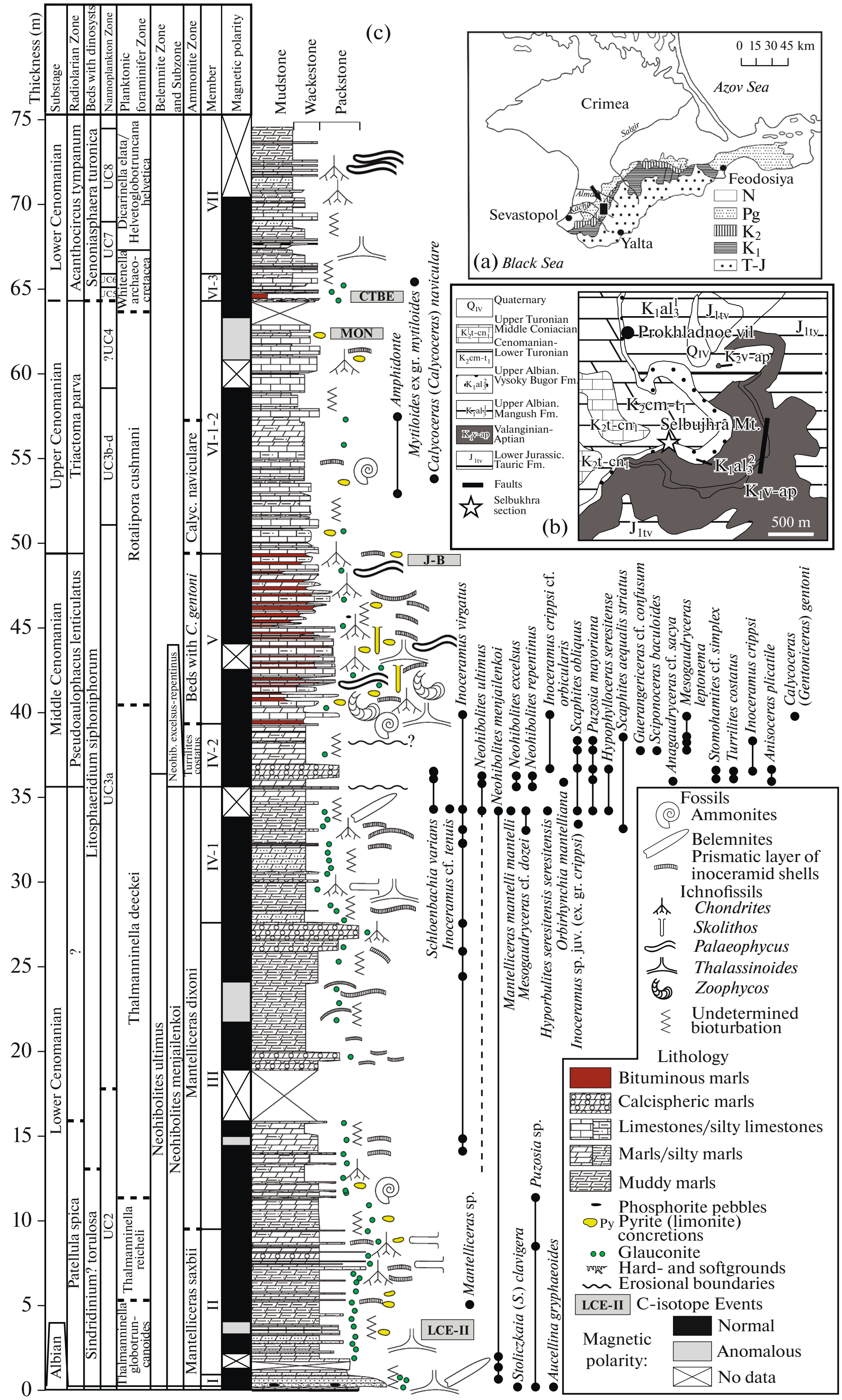


Fig. 4. Selbukhra Yuzhnaya Mountain reference section near Prokhladnoe village (Fig. 2: Kp12b) (Baraboshkin et al., 2023c). Nannoplankton zonation after Shcherbinina and Gavrilov (2016), radiolarian zonation after Bragina and Bragin (2023). Distribution of macrofossils after Naidin and Alekseev (1980); Jolkichev and Naidin (1999); Gale et al. (1999); Alekseev et al. (2007) with revision of determinations, and our original data.

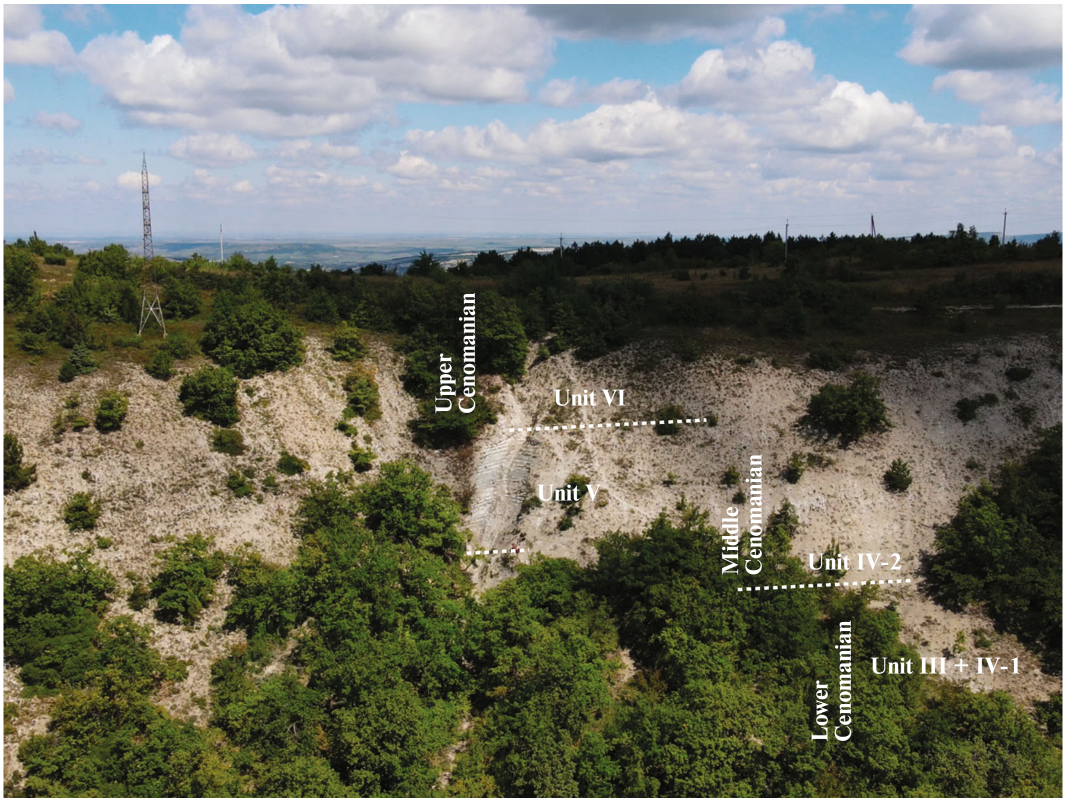


Fig. 5. Selbukhra Yuzhnaya Mountain reference section near Prokhladnoe village. Photo by M.Yu. Tomatkin (MSU) made in 2022.

telliceras mantelli (J. Sow.), *M. saxbii* (Sharpe), *M. picteti* Hyatt, *Puzosia (Puzosia) mayoriana* (d'Orb.), *Sharpeiceras* cf. *laticlavium* (Sharpe), *Mariella lewesiensis* Spath, belemnites *Neohibolites ultimus* (d'Orb.) and *Neohibolites menjailenkoi* Gust., *Inoceramus crippsi* Mant., and foraminifera *Thalmanninella globotruncanoides* (Sigal), and can be attributed to the upper part of the Mantelliceras mantelli Zone, Mantelliceras saxbii Subzone.

The overlying section is composed of alternating gray and light yellowish-gray marls with layers of calcispheric limestones (Units II–III, IV-1). The rocks contain numerous inoceramids *Inoceramus virgatus* Schlueter, ammonites *Zelandites dozei dozei* (Fallot), *Scaphites (Scaphites) obliquus* (Sow.), *Puzosia (Puzosia) mayoriana* (d'Orb.), *Mantelliceras dixoni* Spath, *Mantelliceras* sp. (Marcinowski and Naidin, 1976; Atabekyan in Arkadiev and Bogdanova (1997)), foraminifera *Thalmanninella deeckei* (Franke), plant remains (Krasilov, 1984) and even insect fragments (Pritykina, 1993). This part of the section can be correlated with the Mantelliceras dixoni Zone (Gale et al., 1999; Wright et al., 2017). The top is eroded and covered by marls with a rich **middle Cenomanian** faunal assemblage of the Acanthoceras rhotomagense Zone, Ttirrilites costatus Subzone: ammonites *Ttirrilites costatus* Lam., *Mesogaudryceras rarecostatum* Balan, *Sciponoceras baculoides* (Mant.), *Anisoceras plicatile* (Sow.), belemnites *Neohibolites ultimus* (d'Orb.), *N. excelsus* Naid. et Aleks., *N. repentinus* Naid. et Aleks., inoceramids *Inoceramus virgatus* Schlueter, etc. (Marcinowski and Naidin, 1976; Alekseev, 1989; Wright et al., 2017).

The middle Cenomanian is much more widespread than the lower Cenomanian. In the valley of the Belbek River, it lies with erosion on upper Albian glauconite sandstones, in the interfluve of the Kacha and Bodrak rivers, usually on the lower Cenomanian rocks. The thickness of the middle Cenomanian in southwestern Crimea ranges from 10 to 20 m.

The upper part of the middle Cenomanian succession is represented by a characteristic rhythmic member of alternating light-gray marls and limestones and dark-gray marls rich in organic material (Unit V). This structure of the unit is interpreted as Milankovich precession cycles (Gale et al., 1999; Naidin, 2005). The basal part of the middle Cenomanian contains rare ammonites: *Mesogaudryceras leptonema* (Sharpe), *M. rarecostatum* Balan, *Calycoceras (Gentoniceras) gentoni* (Brongn.), *Calycoceas* (?) sp. and inoceramids *Inoceramus* cf. *orbicularis* Muenst., *I. pictus* J. de C. Sow. According to the distribution of planktonic foraminifera, it belongs to the Rotalipora cushmani Zone (Alekseev, 1989; Avenirova, 2023). Rare bentonite layers in this unit reflect last volcanic impulses of the

Plain Crimea (Plakhotny et al., 1971) or volcanic activity in Eastern Pontides (Nikishin et al., 2013).

The **upper Cenomanian** consists of white chalky-like marls, grading upwards into white and light gray limestones, sometimes with concretions of light-gray flint. Findings of macrofauna are extremely rare; among the ammonites, only *Calycoceras (Calycoceras) naviculare* (Mant.) was found (Baraboshkin, 2024). Based on the distribution of planktonic foraminifers, the main part of the Upper Cenomanian is assigned to the Rotalipora cushmani Zone, and Whitenella archaeocretacea Zone is established in the upper part of the most complete sections (Alekseev, 1989; Fisher et al., 2005; Kopaevich and Vishnevskaya, 2016). There is a discontinuity in the top of succession. After the approval of the Cenomanian/Turonian GSSP (Kennedy et al., 2005) and the acquisition of data on stable isotopes of carbon in several sections, the Cenomanian–Turonian boundary is drawn within the interval of black shales and within the Whitenella archaeocretacea Zone (Fisher et al., 2005; Alekseev et al., 2007; Gavrilov et al., 2022). This made it possible to refine earlier ideas on the position of the boundary (Naidin and Kiyashko, 1994; Alekseev et al., 1997; Kuzmicheva, 2001).

The thickness of the upper Cenomanian in southwestern Crimea is 10–20 m, decreasing in the northward direction. The total thickness of the middle and upper Cenomanian varies from 120–130 m near Belogorsk to 2.5–3 m near Nasypnoye village in eastern Crimea (Fig. 2: Kp73).

The Cenomanian of the Plain Crimea was recognised in the Tarkhankut Peninsula, in the region of the Novoselovka Uplift, to the west of the town of Dzhankoy and on the Kerch Peninsula. The rocks are represented by dark-gray marls and argillaceous limestones with interlayers of calcareous clays. A Cenomanian section contains interbeds of tuffs, tuffites, tuff sandstones, and rare andesitic lavas on the Tarkhankut Peninsula and to the east of it (Plakhotny et al., 1971). The thickness is variable: it is maximal (600 m) in the west of the Tarkhankut Peninsula, and the Cenomanian is missing locally in the Novoselovka Uplift (Aliev and Mirkamalov, 1986; Gnidets et al., 2013).

Turonian deposits are traced from the Chernaya River to the Alma River in southwestern Crimea. Their thickness usually ranges from 30 to 50 m, decreasing to 10–15 m in the direction of the Simferopol Uplift. Turonian rocks are locally developed in eastern Crimea. According to the lithological composition Turonian deposits are divided into two intervals corresponding to the lower and upper Turonian. The Turonian–Cenomanian boundary is marked by a disconformity and in some places by the development of a black shale horizon. The base and the top of the upper Turonian are not lithologically expressed but can be determined paleontologically, although a few hardground surfaces are present near the base of the upper Turonian. They were recognized in the Aksu-Dere reference section near the Kudrino village in the basin of the Kacha River (Fig. 2: 74; Figs. 6, 7). The most important fossil groups for subdivision and correlation of the Turonian sections are inoceramids and foraminifers, and, to a lesser extent, echinoids and brachiopods. Ammonite remains are very rare and poorly preserved.

Cenomanian and Turonian boundary deposits have been repeatedly studied by different geologists due to the presence of a black shale interval attributed to the OAE2 anoxic event (Naidin and Kiyashko, 1994; Alekseev et al., 1997; Kuzmicheva, 2000, 2001; Fisher et al., 2005; Alekseev et al., 2007; Latypova et al., 2019; Gavrilov et al., 2022). This interval is most complete in the Aksu-Dere and Selbukhra sections between the Kacha and Bodrak Rivers, as well as on the Biyuk-Karasu River near the town of Belogorsk (Latypova et al., 2019; Gavrilov et al., 2022). The formation of black shale deposits is interpreted as a result of global warming and transgression against which short regressions occurred (Fisher et al., 2005; Latypova et al., 2019). During regressions, possibly associated with precession cycles, biophilic elements entered the basin, which resulted in a sharp increase in plankton bioproductivity. This led to the accumulation of organic matter, but stable conditions of oxygen deficiency did not arise. Anoxia developed locally in a thin layer of bottom water as a result of the oxidation of organic matter accumulated at the sediments (Gavrilov et al., 2022).

According to isotope data of the Aksu-Dere reference section (Fig. 2: 74; Figs. 6, 7), the base of the Turonian is in the upper part of black shales (Fisher et al., 2005; Alekseev et al., 2007). The overlying section is represented by light gray and white marls with fine terrigenous admixture, crushed prismatic layer of inoceremid shells and numerous remains of inoceramids *Mytiloides* ex gr. *labiatus* (v. Schloth.)–*M. mytiloides* (Mant.) group, *M. hercynicus* (Petr.) and foraminifers *Dicarinella hagni* (Scheib.), *D. elata* (Lamolda), *Praeglobotruncana oraviensis* Scheib., *Whiteinella praehelvetica* (Trujillo), *Helvetoglobotruncana helvetica* (Bolli), etc. (Kopaevich and Walaszczyk, 1990). These marls are irregularly bedded and contain numerous flint nodules and submarine slump folds. Interlayers of calcispheric limestones are present. An unique ammonite *Kamerunoceras* sp. ex gr. *turoniense* (d'Orb.) (Baraboshkin and Fokin, 2024) was recently found in the upper part of this unit. The thickness of the lower-middle Turonian in the Crimean Mountains reaches 40–50 m. It is missing in eastern Crimea.

The **upper Turonian** is more widespread in the Mountainous Crimea and overlies older deposits. Its basal horizons contain conglomerates and glauconite sandstones in case of covering pre-Cenomanian rocks. The succession is represented by white foraminiferal-calcispheric limestones (Unit X), often stylolithic, chalk-

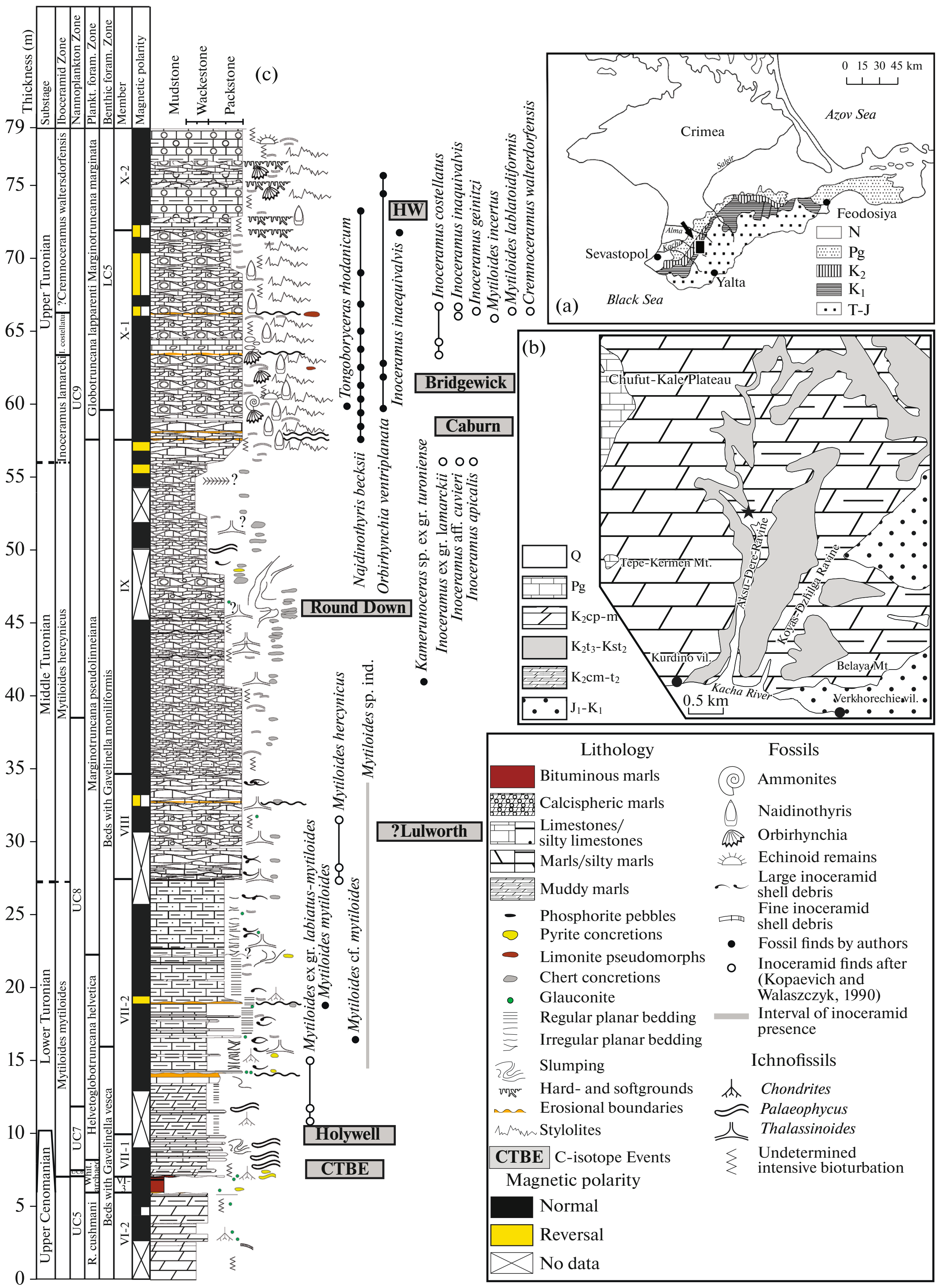


Fig. 6. Turonian reference section in Aksu-Dere Ravine near Kudrino village (Fig. 2: Kp74). Nannoplankton zonation after Shcherbinina and Gavrilov (2016), inoceramid zonation after Kopaevich and Walaszczyk (1990), planktonic foraminifer zonation after Alekseev (1989) and Fisher et al. (2005), and original data. C-isotopic Events: CTBE, Cenomanian–Turonian Boundary Event; HW, Hitch Wood Event.

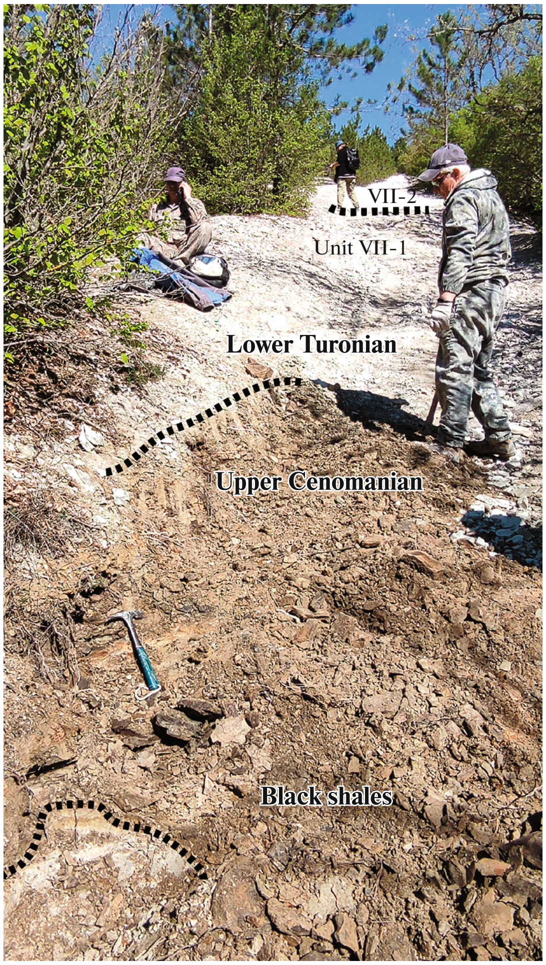


Fig. 7. Aksu-Dere Ravine reference section near Prokhladnoe village. Photo by E.Yu. Baraboshkin made in 2023.

like and nodular, with cherts. The limestones contain ammonites *Hyphantoceras reussianum* (Schlüt.), *Subprionocyclus* cf. *bravaisianus* (d'Orb.), inoceramids of the Mytiloides lamarcki, Inoceramus costellatus and Cremnoceramus waltersdorfensis zones (Kopaevich and Walaszczyk, 1990), very rare rudists, numerous brachiopods *Najdinothyris becksii* (Roem.), *Orbirhynchia ventriplanata* (Schloen.), echinoids *Infulaster excentricus* (Forb.), *Conulus subconicus* d'Orb., *Echinocorys gravesi* Desor and other fauna (Alekseev, 1989). Ammonites of the genus *Lewesiceras*, widely cited in the literature (Moskvin, 1959; Aliev and Mirkamalov, 1986; Alekseev, 1989), should be referred to *Tongoboryceras rhodanicum* (Rom. et Maz.). Foraminifers in the upper Turonian are used to distinguish the Marginotruncana pseudolinneana and M. coronata zones (Kopaevich and Vishnevskaya, 2016). The thickness of the upper Turonian in the Crimean Mountains is up to 25–30 m.

Turonian deposits are also widespread in the Plain Crimea but missing in the Novoselovka and Novotzaritzyn Uplifts. They are represented by light gray or white marls and microcrystalline and bioclastic limestones with chert concretions. In several wells, the Turonian of the central Plain Crimea contains volcanoclastic material (Plakhotny et al., 1971; Gnidets et al., 2013). The thickest deposits (300–500 m) were found on the Tarkhankut Peninsula (Aliev and Mirkamalov, 1986; Gnidets et al., 2010, 2013).

Coniacian deposits are limited to southwestern Crimea because of the later erosion. Lithologically they are indistinguishable from the upper Turonian and can only be recognized paleontologically. Limestones are white, silicified, chalky, with stylolites, containing chert concretions. Coniacian rocks have been confirmed in the basins of the Belbek, Kacha, and Churyuk-Su rivers in southwestern Crimea (Klikushin, 1985; Alekseev, 1989).

The lower Coniacian has been studied in the basin of the Kacha and Belbek rivers. The Cremnoceramus rotundatus and C. deformis inoceramid Zones were determined here (Kopaevich and Walaszczyk, 1990). Echinoids *Conulus subconicus* (d'Orb.) and brachiopods *Orbirynchia cuvieri* (d'Orb.), *Najdinothyris becksi* (Roem.), etc., are also known from these deposits (Alekseev, 1989). The middle Conaician age of the Aksu-Dere section was supported by benthic foraminifera (Guzhikov et al., 2024).

The presence of the upper Coniacian in the Mountainous Crimea is doubtful. The substage was distinguished by only two finds of *Volviceramus* cf. *involutus* (J. de C. Sow). The first find in the assemblage with the lower Coniacian inoceramids at the top of Selbukhra Mountain (Maslakova, 1958) has been already criticized (Kotsiubinsky, 1969). The second find was mentioned from Beds with *Austinocrinus albaticus* of the Chuku Mountain section (Belbek River basin; Klikushin, 1985; Fig. 2: Kp76). Inoceramids collected by Klikushin were published by Atabekyan in Arkadiev and Bogdanova (1997), but *Volviceramus* is not present among them. The Chuku Mountain section was recently re-examined (Guzhikov et al., 2024), but we were unable to confirm the presence of the upper Coniacian and lower Santonian there. Therefore, it is very possible that the upper Coniacian and lower Santonian are missing in southwestern Crimea. The thickness of the lower-middle Coniacian in the Crimean Mountains does not exceed 15–16 m. A possibility of the presence of Coniacian deposits in the Ak-Kaya Mountain section near Belogorsk, Central Crimea (Fig. 2: Kp76) was discussed by Korchagin et al. (2012), but it needs additional study. Coniacian rocks are missing in eastern Crimea.

Coniacian deposits of the Plain Crimea are lithologically similar to the upper Turonian. They are composed of limestones with clay laminae in some intervals. The age was confirmed by foraminiferal assemblages. The thickest Coniacian (250 m) was penetrated by wells on the Tarkhankut Peninsula (Aliev and Mirkamalov, 1986; Gnidets et al., 2013).

Santonian deposits are traced from the Chernaya River to the Kacha–Bodrak interfluve. They are also present in the Belogorsk region. The "Santonian deposits" mentioned from the Beliy Yar gully near the town of Feodosiya in eastern Crimea (Muratov, 1969) should now be assigned to the lower Campanian. The reference sections of the Santonian were described between the Belbek and Kacha rivers (Klikushin, 1985). Apparently, the most complete (65 m) sections are in the basin of the Belbek River, where the lower and upper Santonian were reported.

The **lower Santonian** (0–23 m) is represented by light greenish gray clayey limestones (Unit XIII) with clay interbeds according to Klikushin (1985) and Alekseev (1989). Klikushin (1985) published a fossil assemblage from these deposits, belonging to the lower and upper Santonian: *Cladoceramus undulatoplicatus* (Roem.), *Cordiceramus cordiformis* (J. de C. Sow.), *C. bueltenensis* (Seitz), *Sphenoceramus cardissoides* (Goldf.), *Cordiceramus muelleri* (Petr.), ammonites, crinoids, etc. Reexamination of the Klikushin's collection of ammonites demonstrated absence of Coniacian and lower Santonian taxa (Baraboshkin in Guzhikov et al., 2024). The study of microfossils also did not confirm their presence. The ammonite assemblage indicates a late Santonian–early Campanian age. Inoceramids are not depicted and characterize the entire Santonian. Their determinations were made by Kotsyubinsky, so this list can be trusted with some conditionality. As indicated above, we were unable to confirm the presence of upper Coniacian and lower Santonian in the area mentioned by Klikushin (1985). The question of the existance of the lower Santonian in the Crimean Mountains needs to be clarifyed in the future.

The **upper Santonian** is represented by light gray marls, calcispheric limestones with greenish gray clayey marl intercalations and chert concretions. The reference section of the upper Santonian was studied in the vicinity of Kudrino village, the Kacha River basin (Guzhikov et al., 2021a, 2021b; Fig. 2: Kp74; Figs. 8, 9). The rocks are characterized by a single find of the ammonite *Parapuzosia (Parapuzosia)* cf. *leptophylla* (Sharpe) and crinoids *Marsupites testudinarius* (Schloth.), *M. laevigatus* (Forbes), nannoplankton, dinocyst assemblages, benthic and planktonic foraminifera (Guzhikov et al., 2021a, 2021b). Paleo- and petromagnetic stable data and stable isotope analysis were used to identify the Santonian–Campanian boundary adopted to its later validation (Gale et al., 2023) at the base of Chron C33r. The thickness of the upper Santonian in southwestern Crimea is 35–40 m.

Santonian deposits of central Crimea (from the town of Belogorsk to Topolevka village; Fig. 2: Kp75) were reexamined recently (Korchagin et al., 2012). It was demonstrated that the upper Santonian can be recognized by foraminifera and radiolarians. Its thickness is 30–35 m.

Santonian deposits are present on the Tarkhankut Peninsula of the Plain Crimea and in the Novoselovka Uplift, where they are locally missing. They transgressively overlie older Cretaceous rocks and are represented by greenish limestones and marls. Judging by the foraminiferal assemblages (Muratov, 1969), these deposits should be partly attributed to the lower Campanian.

The Aksu-Dere and Kudrino reference sections contain a stratigraphic hiatus at the Santonian–Campanian boundary associated with low sedimentary rates and, possibly, with non-deposition (Guzhikov et al., 2021a, 2024). In other sections, **Campanian** deposits transgressively overlie older rocks.

Campanian deposits are more widespread than the Cenomanian-Santonian being present in eastern Crimea, but they are absent between the Salgir and Zuya rivers and in the vicinity of the town of Staryi Krym. The Campanian is represented by soft chalky marls and is therefore poorly exposed. The best-studied sections of the Campanian are located near Kudrino village (Fig. 2: Kp74, Figs. 8a, 8b) in the basin of the Kacha River, and in Beshkosh Mountain and Chakhmakhly ravine (Fig. 2: Kp77-78, Figs. 9a, 9b) in the interfluve of Churyuk-Su and Bodrak rivers of southwestern Crimea (Baraboshkin et al., 2020, 2023a, 2023b, 2024). The section of Ak-Kaya Mountain near Belogorsk (Fig. 2: Kp79) is among the reference sections but needs a revision. Comprehensive data were obtained from the Santonian/Campanian boundary interval in the Belogorsk area (Korchagin et al., 2012: Fig. 2: Kp75) and to the east of it, in the Alan-Kyr section (Beniamovsky and Kopaevich, 2016; Bragina et al., 2016; Guzhikov et al., 2020; Kopaevich et al., 2020; Ovechkina et al., 2021a; Fig. 2: Kp80). Some levels of the Campanian succession are rich in belemnites, inoceramids, and echinoderms; ammonite remains are less common; the entire section has been characterized micropaleontologically, which gives a possibility to subdivide it into two substages.

The **lower Campanian** exposed near Kudrino village (Guzhikov et al., 2021a, 2021b; Baraboshkin et al., 2024) in the Kacha River basin (Fig. 2: Kp74, Figs. 8, 9). The lower part of the succession is represented by clayey marls (Units XVI–XVIII), sometimes calcisphere-rich, bioturbated by *Zoophycos*, containing a small amount of chert, pyrite concretions, and sponge remains. There are several layers of bentonite in the upper part of the lower Campanian. The thickest layer (0.4–0.5 m) is of industrial interest. Zircons from this bentonite were dated as 77 ± 1 Ma and the early Campanian age was confirmed by finds of ammonite *Pachydiscus (Pachydiscus) launayi* (de Grossouvre) and inoceramids *Sphaeroceramus* cf. *sarumensis* (Woods) and *Cataceramus* sp. ex gr. *C. dariensis* (Dobr. et Pavl.) (Baraboshkin et al., 2024). The boundary between the lower and upper Campanian was taken in the lower part of Unit XIX at the base of Chron C33n, near the

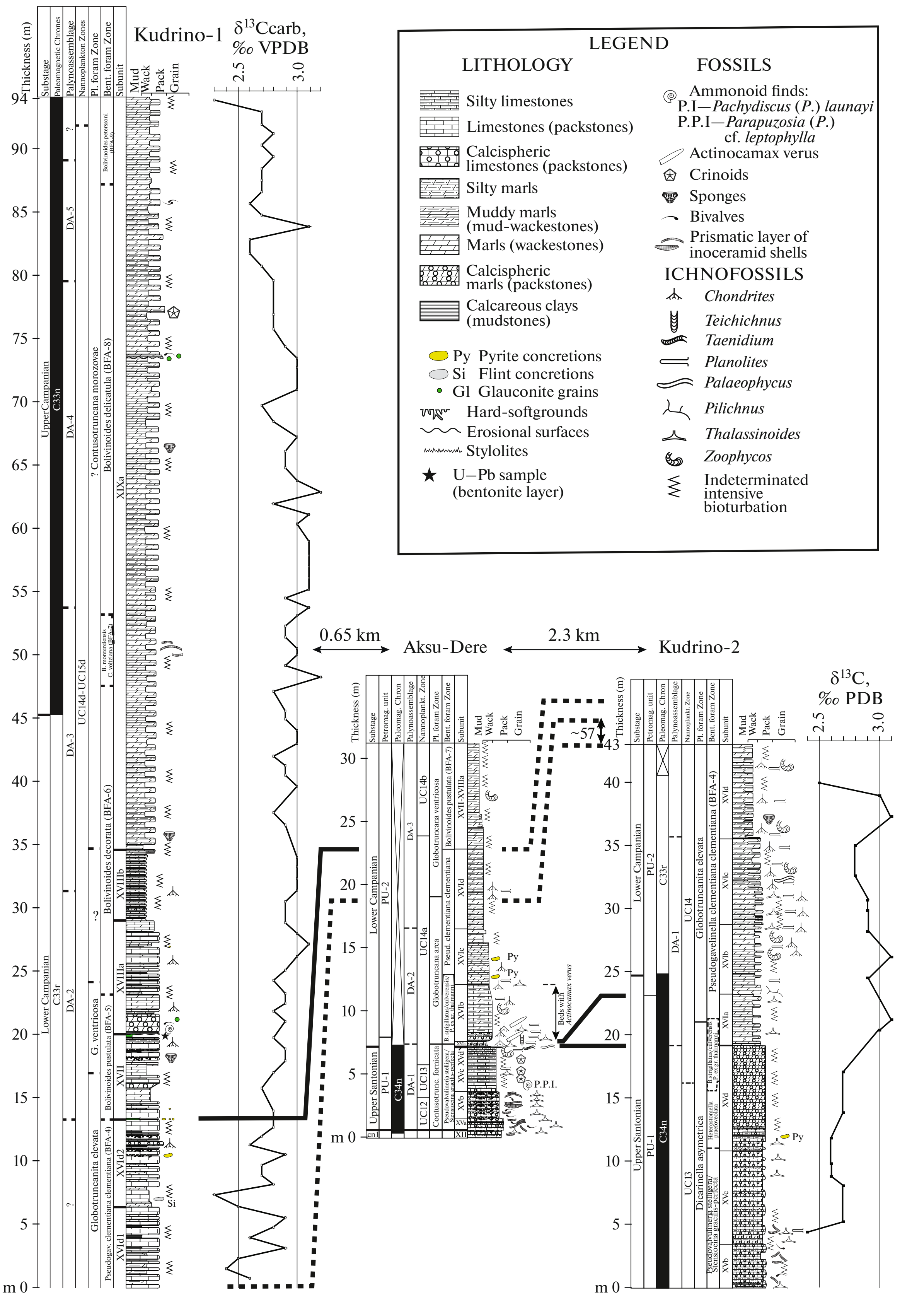


Fig. 8. Correlation of the Coniacian–lower Campanian reference sections in the region of Kudrino village and Aksu-Dere Ravine (after Guzhikov et al., 2020, 2021a, 2021b; Baraboshkin et al., 2023, 2024). DA, dinocyst assemblages; PU, petromagnetic units; BFA, benthic foraminifer assemblages.

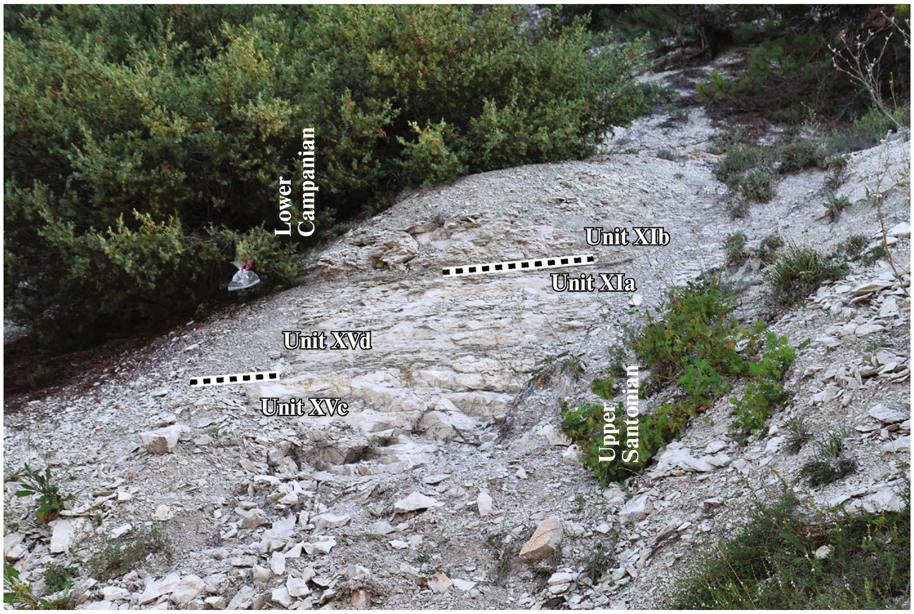


Fig. 9. Santonian–Campanian boundary interval of Aksu-Dere Ravine reference section near Prokhladnoe village. Photo by E.Yu. Baraboshkin made in 2018.

$\delta^{13}C$ pike (MCE, Mid-Campanian Event), by appearance of benthic foraminifers *Brotzenella monterelensis* (Marie) and the boundary of Globotruncana ventricosa/Contusotruncana morozovae planktonic foraminiferal zones. The thickness of the lower Campanian in the reference section is about 110 m.

The lower Campanian of central Crimea is cropped out in the vicinity of Belogorsk and is substantiated by microfauna and palynoassemblages (Korchagin et al., 2012; Guzhikov et al., 2020). Due to poor exposure, the boundary with the upper Campanian is questionable and estimated thickness of the lower Campanian is 50–60 m.

Lower Campanian deposits, previously referred to the Santonian, are present in the vicinity of Feodosiya. They are composed of gray marls with interlayers of gray clayey marls in the upper part and white chalk-like limestones with flint concretions. Their age was determined by the presence of *Gaudryceras mite* (von Hauer) (=*G. varagurense* (Kossm.)) and foraminiferal assemblage with *Dicarinella concavata* (Brotz.), *Gavelinella stelligera* (Marie), *G. costulata* (Marie), *Pseudogavelinella clementiana* (d'Orb.), and others (Muratov, 1969). The thickness is 30 m.

The **upper Campanian** is formed by white and light-gray marls, silicified in places, containing thin layers of greenish-gray clays, sponge remains, pyrite concretions, and numerous *Zoophycos* burrows. There is a discontinuity at the boundary with the Maastrichtian, so the negative excursion $\delta^{13}C$ (CMBE, Campanian–Maastrichtian Boundary Event), one of the GSSP markers (Odin and Lamaurelle, 2001), was not found in the Beshkosh–Chakhmakhly reference sections (Figs. 10, 11) of southwestern Crimea (Baraboshkin et al., 2020; Proshina and Ryabov, 2023).

The upper Campanian contains several levels with common belemnites: *Belemnitella mucronata* (v. Schloth.), *B. langei* Jeletzky, *B. profunda* Naid., and *B. conica* Arkh. Other macrofauna includes rare ammonites *Bostrychoceras polyplocum* (Roem.), *Pachydiscus koeneni* (Gross.), inoceramids *Cataceramus balticus* (Böhm), *C. buguntaensis* (Dobr. et Pavl.), and echinoids. Foraminifera, ostracods, nannoplankton, and dinocysts assemblages have been identified (Alekseev and Kopaevich, 1997; Baraboshkin et al., 2020, 2024; Proshina and Ryabov, 2023). The thickness of the upper Campanian in the Crimean Mountains reaches 100–110 m.

A member of gray limestones lies in the base of the Campanian deposits of the Plain Crimea on the Tarkhankut Peninsula. It passes upwards into a sequence of light gray limestones and marls. In the eastern part of the Plain Crimea and on the Kerch Peninsula, the amount of mud material increases. At the Novotsaritsyno Uplift, the upper horizons of Campanian gray silty marls erosionally overlie the Lower Cretaceous rocks (Muratov, 1969; Gnidets et al., 2013). The Campanian can be divided into two substages in wells on the base of microfauna, but after the approval of the GSSP (Odin and Lamaurelle, 2001), this division needs to be revised. The thickness of the Campanian deposits in the Plain Crimean varies from 40 m (Kerch Peninsula) to 90–100 m (Novoselovka Uplift) and 400–600 m on the Tarkhankut Peninsula (Muratov, 1969; Gnidets et al., 2013).

Maastrichtian deposits are most widespread in Crimea. In the Crimean Mountains they continue

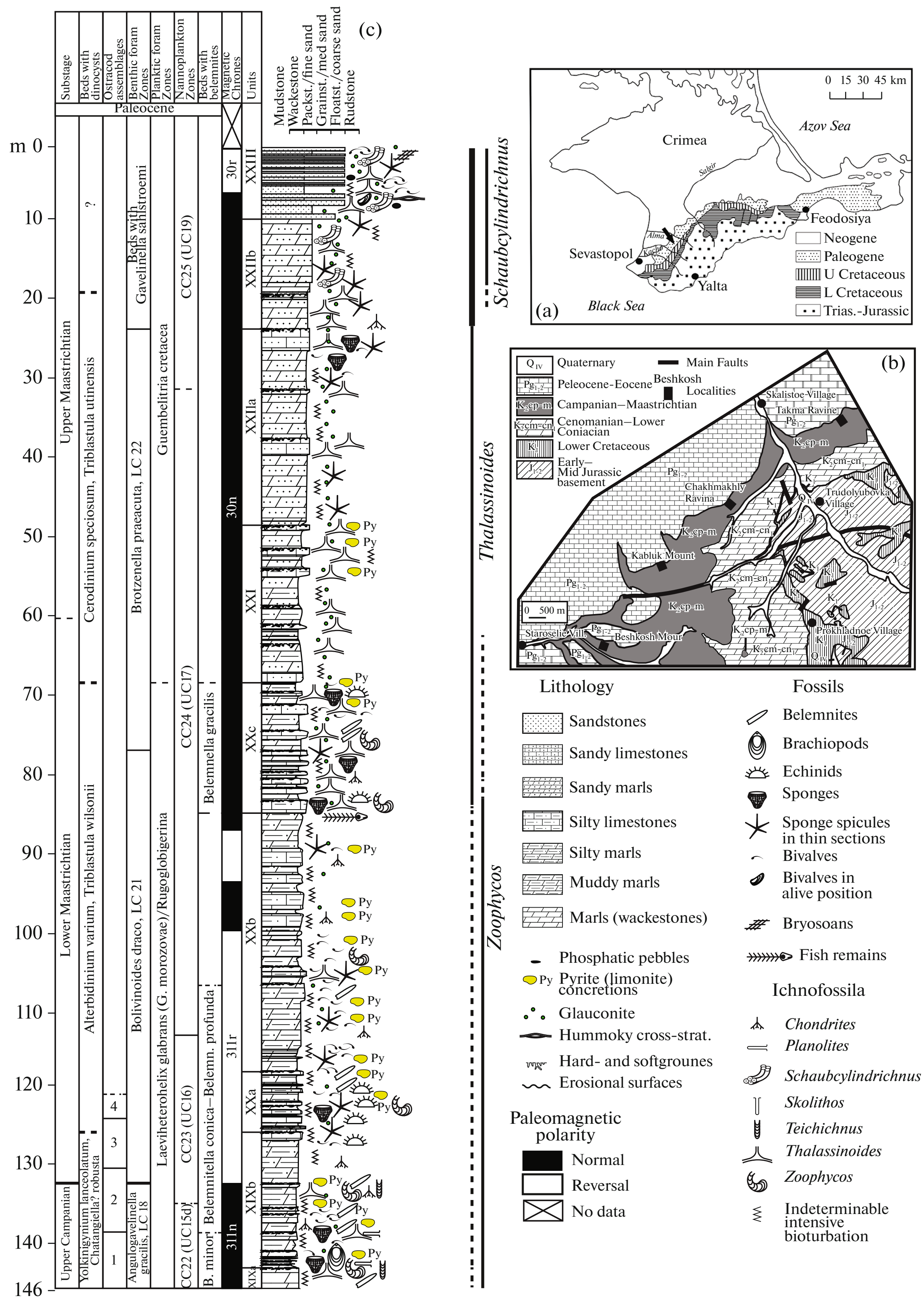


Fig. 10. Upper Campanian–Maastrichtian reference section in Chakhmakhly Ravine (after Baraboshkin et al., 2023c). (a, b) Location and (c) sedimentological characteristics of the section and distribution of the important ichnofossils.

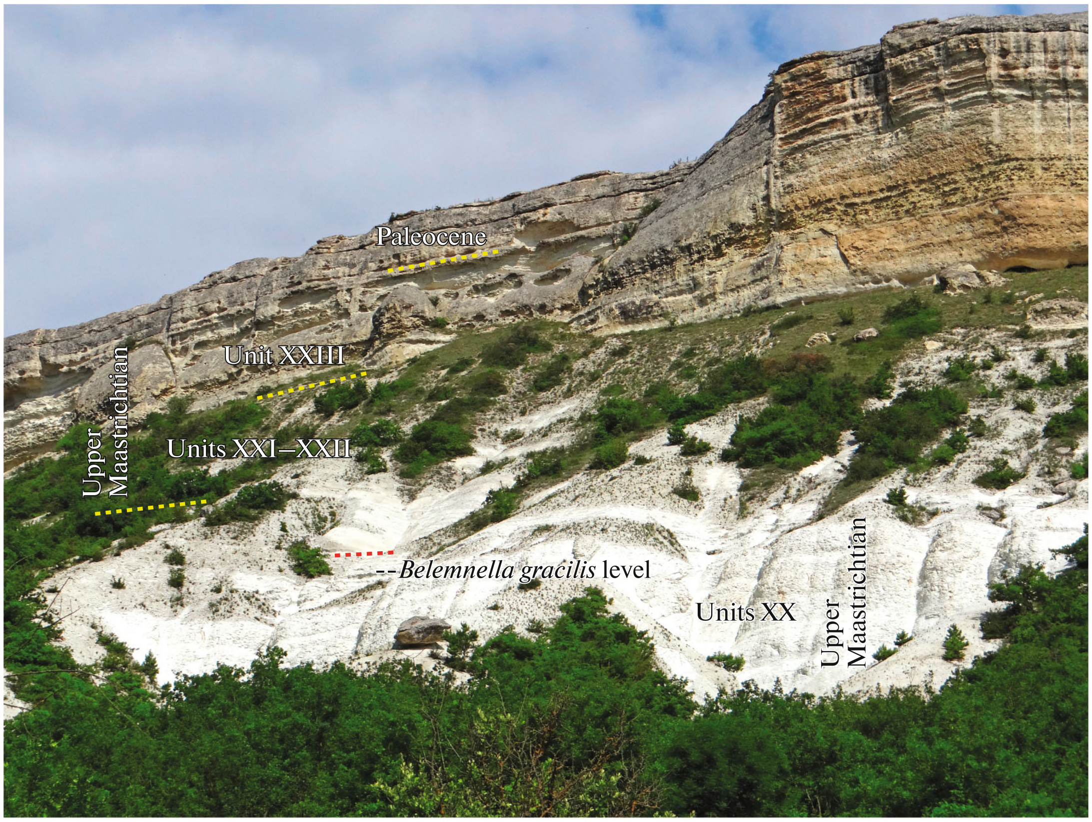


Fig. 11. Maastrichtian succession of Chakhmakhly Ravine reference section. Photo by E.Yu. Baraboshkin made in 2014.

Campanian succession or erosionally overlie older rocks. They are represented by gray sandy glauconite marls, siltstones, and sandstones. The sharp appearance of silty to fine sandy quartz-glauconite admixture in the section is one of the features of the Campanian/Maastrichtian boundary, which is supported by finds of ammonites *Pachydiscus (P.) neubergicus* (Hauer) and the absence of the LC19–LC21 zones by benthic foraminifers in the succession (Baraboshkin et al., 2020, 2023a, 2023b; Proshina and Ryabov, 2023). The thickness of the Maastrichtian deposits in the Crimean Mountains varies from 0 to 150 m.

Maastrichtian rocks contain, at some levels, remains of ammonites, belemnites, inoceramids, numerous oysters and other mollusks, and echinoderms. Rich microbiota assemblages become depleted upsection simultaneously with an increase in the size of quartz grains and a transition from deep water *Zoophycos* to shallow water *Schaubcylindrychnus–Ophiomorpha* ichnoassemblages, demonstrating a clear shallowing trend (Baraboshkin et al., 2020).

The reference sections of the Maastrichtian are Beshkosh Mountain and Chakhmakhly Ravine (Fig. 2: Kp77-78, Figs. 10, 11) in the interfluve of the Churyuk-Su and Bodrak rivers, southwestern Crimea (Alekseev and Kopaevich, 1997; Baraboshkin et al., 2020, 2023a, 2023b), as well as the Ak-Kaya Mountain section near Belogorsk (Fig. 2: Kp79).

The lower Maastrichtian is composed of gray silty marls, muddy at the base and silicified at the top, with numerous sponges, hardground horizons, and *Thalassinoides* burrows. The rocks constantly contain glauconite grains, which size grow upwards simultaneously with quartz grains. Paleontological remains are diverse, including early Maastrichtian ammonites *Hoploscaphites constrictus* (Sow.), *Hauericeras (Gardeniceras) sulcatum* (Kner), *Diplomoceras cylindraceum* (Defr.) and belemnites *Belemnella lanceolata* (Schloth.), *B. gracilis* (Arkh.), *B. sumensis occidentalis* Birk., numerous bivalves and echinoids. The rocks contain rich microfossil assemblages (Alekseev and Kopaevich, 1997; Baraboshkin et al., 2020, 2023a, 2023b; Proshina and Ryabov, 2023).

The lower horizons of the Maastrichtian of central and eastern Crimea contain slide (? or tectonic) blocks of older rocks (Turonian to Campanian), which indicate the presence of a steep paleoslope there. The thickness of the lower Maastrichtian in southwestern Crimea is 75–80 m, gradually decreasing towards Simferopol. In central Crimea (Belogorsk region) it increases to 80–90 m.

The **upper Maastrichtian** continues lower Maastrichtian sandy succession and truncated by Danian limestones of the Paleocene. The rocks of the Beshkosh and Chakhmakhly reference sections (Fig. 10) are represented by quartz-glauconite sandstones (Units XXI–XXIII), the quartz grain size of which coarsening upwards to medium-grained sandstones. They also contain oyster beds, broken shell horizons and numerous hardgrounds formed in a near-shore setting (Baraboshkin et al., 2020). There are sandy marls (Unit XXIV) with *Neobelemnella kazimiroviensis* (Skolozdr.) in the top of the most complete sequence of the Belbek River. This unit is eroded in other sections. Remains of dinosaurs (Lopatin et al., 2018) and evidences of subaerial exposure have been found at the K/T boundary.

Upper Maastrichtian rocks contain belemnites *Neobelemnella kazimiroviensis* (Skolozdr.), ammonites *Hoploscaphites constrictus* (J. Sow.), *Pachydiscus (P.) neubergicus* (Hauer), *P. gollevillensis* (d'Orb.) and other caphalopods. The upper horizons are saturated with bivalve remains of *Dhondtichlamys acuteplicatus* (Alth), *Pycnodonte mirabilis* (Rousseau), *P. similis* (Pusch), *Amphidonte decussata* (Goldf.) (Sobetsky, 1977; Dhondt, 2004); gastropods, brachiopods, echinoderms, and bryozoans, sometimes forming significant concentrations. Planktonic foraminifera were determined in the Guembelitria cretacea Zone here and benthic foraminifera, in the Brotzenella praeacuta Zone and Beds with *Gavelinella sahlstroemi* (Baraboshkin et al., 2023a, 2023b; Proshina and Ryabov, 2023). The upper Maastrichtian has a thickness of 40–80 m in southwestern Crimea.

A Maastrichtian reference section of eastern Crimea (Mountains Koklyuk, Klement'eva, Brodskaya, Fig. 2: Kp81) is represented by dark gray deep-water calcareous clays with of sandy marl intercalations. Slide (? or tectonic) blocks of Cenomanian and Turonian rocks are observed in the base. The section contains diverse assemblage of planktonic and benthic foraminifera (Proshina, 2022; Ryabov, 2022), but it has not yet been convincingly subdivided into substages (Aliev and Mirkamalov, 1986). Its total thickness there is 100–120 m.

Maastrichtian deposits have been established both in boreholes and in natural outcrops in the Plain Crimea. They are known from Melovoe village on the Tarkhankut Peninsula and in the vicinity of Karangat village on the Kerch Peninsula, where it is represented by light gray and white limestones with interlayers of dark gray clays. Spongoliths (10 m) are present in the upper Maastrichtian westward from the town of Dzhankoy. The deposits are composed of dark gray calcareous quartz-glauconite sandstones and silty marls in the eastward direction. The Maastrichtian is also represented by greenish-gray sandstones in the east margin of the Plain Crimea, near Slavyanskoe village. The rocks are represented by gray limestones, marls, sandstones and gravelstones on the Kerch Peninsula. The foraminiferal assemblages in boreholes are insufficiently studied and, therefore, subdivision of the Maastrichtian into substages is difficult in the Plain Crimea. The thickest Maastrichtian section (500–800 m) of the Plain Crimea was penetrated by wells on the Tarkhankut Peninsula (Aliev and Mirkamalov, 1986; Gnidets et al., 2013).

The Late Cretaceous paleogeography of Crimea is charactrised by prevalence of carbonate sedimentation following the marine transgression, which covered the entire Crimea. The regression of this basin, change to terrigenous sedimentary conditions and even continental environments in the Crimean Mountains appeared only at the Cretaceous/Paleogene boundary.

BIOSTRATIGRAPHY OF SELECTED PALEONTOLOGICAL GROUPS

Ammonites

Late Cretaceous ammonite finds are very rare in comparison with those of the Early Cretaceous interval. Due to this fact they are not so well studied, and a modern ammonite zonal scale is not developed. Finds of ammonites are not known from wells drilled in the Plain Crimea.

One of the first announcements on the Late Cretaceous ammonites of Crimea belongs to Lange and Mirchink (1910) (Table 1). Later Crimean geologists reported on additional finds of Late Cretaceous ammonites. The data were summarized by Weber and Malicheff (1923), but ammonites were not figured. A series of short papers on the Campanian-Maastrichtian ammonites and zonation was published by Mikhailov, who resumed his study in the monograph (Mikhailov, 1951). The Moscow State University Upper Cretaceous Group collected ammonites and other fossils in the 1950s. This collection was studied by Naidin, who published the results in a collective monograph "Atlas of the Upper Cretaceous fauna of the North Caucasus and Crimea" (Naidin in Moskvin, 1959). Some of the ammonites were additionally published and partially refigured in the "Atlas of the Upper Cretaceous fauna of the Donbass" (Krymholtz, 1974). Naidin donated the collection of the Cenomanian ammonites from Crimea to Marcinowski (Warsaw University), who published it in the monograph (Marcinowski, 1980). Some of determinations by Marcinowski were briefly revised recently (Wright et al., 2017). Atabekian's and Alekseev's determinations of the small collection of the Upper Cretaceous ammonites from the Belbek River were published in a list of Klikushin (1985). Atabekian described and figured his part of the collection later (Atabekian in Arkadiev and Bogdanova, 1997 and in Arkadiev et al., 2000). The available information on the stratigraphic distribution of the Upper Cretaceous ammonites of the Kacha Uplift (Belbek-Alma rivers interfluve) was published by Alekseev (1989) and by Naidin (Jolkichev and Naidin, 1999). Finally, short papers with rare Late Cretaceous ammonites were

Table 1. A review of ammonite and belemnite biostratigraphic subdivision of the Upper Cretaceous deposits of the Crimean Mountains

Bakhchisarai region Lange and Mirchink, 1910	Substage	Mountain Crimea, Weber and Malicheff, 1923	Substage	Cephalopod Campanian-Maastrichtian zones of south of USSR (based on the Crimea and West Ukraine sections), Mikhailov, 1951		Mountain Crimea, Maslakova, 1959a	Kacha Uplift, Southwestern Crimea Alekseev, 1989	
"Section"		Zone		Ammonite Zone, Subzone	Belemnite Zone	Zone, Subzone	Unit	Zone
	Maastrichtian	Marls and sandstones with *Nautilus restrictus* Griep., *N. Dekayi* Mort., *N. patens* Kner., *Gaudriceras Colloli* de Gross., *Hamites cylindraceus* Defr., *Baculites Knorri* Desm., *B. vertebralis* Lmk., *Scaphiles constrictus* Sow., *S. tenuistriatus* Kner., *S. trinodosus* Kner., *S. monasteriensis* Sghlut., *Hauericeraspseudo-gardeni* Schlut., *Pachydiscus neubergicus* Hauer., *Ancyloceras retrorsum* Schlut., *Belemnitella lanceolata* Schloth., *B. americana* Mort. (rare), etc.	Upp. Maastricht (Discosc. constrictus)	Pachydiscus neubergicus Hauer	Belemnitella americana Arkh. (non Mort.)	Belemnella archangelskii Naid.	XXII–XXIV	Neobelemnella kazimiroviensis
2 Section: Bel. lanceolata, Scapliites constrictits			LMaas (Discosc. constrictus)	Acantho-scaphites tridens Kner	B. lanceolata Schloth.	Belemnella lanceolata Schloth.	XXI	Belemnella sumensis
							XX	Belemnella lanceolata
1 Section: Bel. mucronata, Pachydiscus Neubergicus, Inoceramus Cripsii	Campanian	Marls with *Nautilus patens* Kner., *N. Dekai* Mort., *Hamites cylindraceus* Defr., *Baculites Knorri* Desm., *Helicoceras Schloenbachi* Favre., *Hauericeras pseudo-Gardeni* Schlut., *Pachydiscus* sp., *Belemnitella mucronata* Schloth., *Scalpellum maximum* Sow., *Avellana inverseslriata* Kner., *Voluta semilineata* Munst., *Scalaria decorala* Roem., *Rostellaria Parkinsoni* Soul., etc.	Upp. Campan	Bostrychoceras poiyplocum Roem.	B. langei Schatsk.	Belemnitella langei Schatsk.	XIX	Belemnitella langei
				Hoplitoplacenti-ceras coesfeldiense Schluet.	B. mucronata Schloth.	Belemnitella mucro-nata senior Now., Stensioina stellaria	XIX	?
Not studied			Low. Campan	Hauericeras pseudogardeni, Discoscaphites binodosus Roem.	Actinocamax mammillatus Nils, and Gonioteuthis quadrata Blv.	Hauericeras pseudogardeni (Schluet.)	XVI–XVIII	Micraster schroederi
				Ammonites not found	?	Micraster schroederi		
	Santon	Marls with *In. cardissoides* ? Goldf., *Marsupites* sp., etc.	Santon		Gonioteuthis granulata Blv. and Belemnitella praecursor Stoll.		XV	Marsupites testudinarius
							XIV	?
		Marls with kéfékilit (=bentonite)					XIII	Inoceramus cardissoides
	Coniacian	Hard marls		Not studied	Not studied		XII	Inoceramus involutus
		Marls with *Ammonites* sp., *Inoceramus Lamarcki* Park., *I. Cuvieri* Sow., *I. Schloenbachii* Boehm., *Infulaster excentricus* d'Orb., *Conulus albogalerus* Klein., *C. subconicus* d'Orb.					XI	Inoceramus schloenbachi
	Turanian	Marls with *Ammonites* sp., *Inoceramus labiatus* Schlot., etc.				Inoceramus lamarcki	X	I. costellatus; I. lamarcki–I. apicalis
						Inoceramus labiatus	VII–IX	Inoceramus labiatus
	Cenomanian	Marls with *Turrilites cenomanensis* Schluet., *T. tuberculatus* Bosk., *Scaphites* cf. *aequalis* Sow. *N. Puzosia planulata* Schlut., *Schloenbachia varians* Sow., *Acanthoceras Mantelli* Sow., *Hibolites ultimus* d'Orb., etc.				Scaphites aequalis Sow.	V–VI	Zones are not distinguished
							IV-2	Turrilites costatus
						Neohibolites ultimus, Rotalipora reicheli	I-IV-1	Mantelliceras mantelli
		Sandstones with *Hamites* sp., *Toxoceras* sp., *Schloenbachia varians* Sow., *Hibolites ultimus* d'Orb., etc.				Neohibolites ultimus (d'Orb.)		

recently published by Baraboshkin (Baraboshkin et al., 2020; Guzhikov et al., 2021a; Baraboshkin, 2023, Baraboshkin and Fokin, 2024).

There is no possibility to work out a zonal ammonite scale comparable with European one because of the rarity of finds and poor knowledge of their precise position in the section, but some of European zones or levels can be identified. Below we named some of these levels as "Zones" by the analogy of the other zonal scales, but it is necessary to keep in mind that precese position of their boundaries are not known, they are just levels with ammonite finds. In the practice of Russian stratigraphy, they should be named as "Beds with ammonites".

The upper part of the Mantelliceras mantelli Zone and the Mantelliceras dixoni Zone could be recognized in the **lower Cenomanian.**

Mantelliceras mantelli Zone was proposed by Naidin and Alekseev (1980) for Units I–IV-1 (Tables 1, 2). This interval was revised by Gale (Gale et al., 1999), who referred it to the **Mantelliceras dixoni Zone** argued by the wide distribution of *Inoceramus virgatus* Schlüt. in the section. The same idea is expressed by Wright et al. (2017). Finds of *Thalmanninella globotruncanoides* (Sigal), *Inoceramus crippsi* Mant., *Mantelliceras saxbii* (Sharpe), and *Sharpeiceras* cf. *laticlavium* (Sharpe), distributed mostly in the Saxbii Subzone, suggest the presence of the Mantelli Zone, Saxbii Subzone in Unit I (Baraboshkin et al., 2023c; Baraboshkin et al., 2024; Avenirova, 2023; Rtishchev, 2023) (Fig. 4). The ammonite assemblage is represented by *Mantelliceras mantelli* (J. Sow.), *M. saxbii* (Sharpe) (Figs. 12o, 12p), *M. picteti* Hyatt (Fig. 12q), *Hyphoplites falcatus* (Mantell) (Fig. 12r), *Sharpeiceras* cf. *laticlavium* (Sharpe), *Schloenbachia varians* (J. Sow.) (Fig. 12t), *Schloenbachia* sp., *Puzosia (Puzosia) mayoriana* (d'Orb.), *P.* sp., *Mariella lewesiensis* Spath.

Mantelliceras dixoni Zone (Units II–IV-1) contains *Mesogaudryceras* cf. *dozei* (Fallot), *Phylloceras (Hypophylloceras)* sp., *Hyporbulites seresitensis seresitensis* (Perv.), *Puzosia (Puzosia) mayoriana* (d'Orb.), *Schloenbachia varians* (J. Sow.), *Mantelliceras mantelli* (J. Sow.), *Hypoturrilites gravesianus* (d'Orb.), *Mariella* cf. *lewesiensis* Spath, *Scaphites obliquus* J. Sow. (Fig. 12s). Previously this interval was recognized as "Beds with *Scaphites equalis*" (Naidin and Alekseev, 1980).

Middle Cenomanian **Turrilites costatus Zone** (Unit IV-2) was proposed initially as "Beds with *Turrilites costatus*" (Naidin and Alekseev, 1980). This is an analogue of the Turrilites costatus Subzone of the Acanthoceras rhotomagense Zone in North European scale (Table 2). The base of this zone, just above the unconformity surface, contains rich ammonite assemblage (according to Wright et al., 2017): *Phylloceras*

Table 2. Ammonite- and belemnite-based biostratigraphy of the Upper Cretaceous of the Crimean Mountains

North European Zonation (Christensen, 1997; Hardenbol et al., 1998; Mitchell, 2005; Kennedy, 2019)

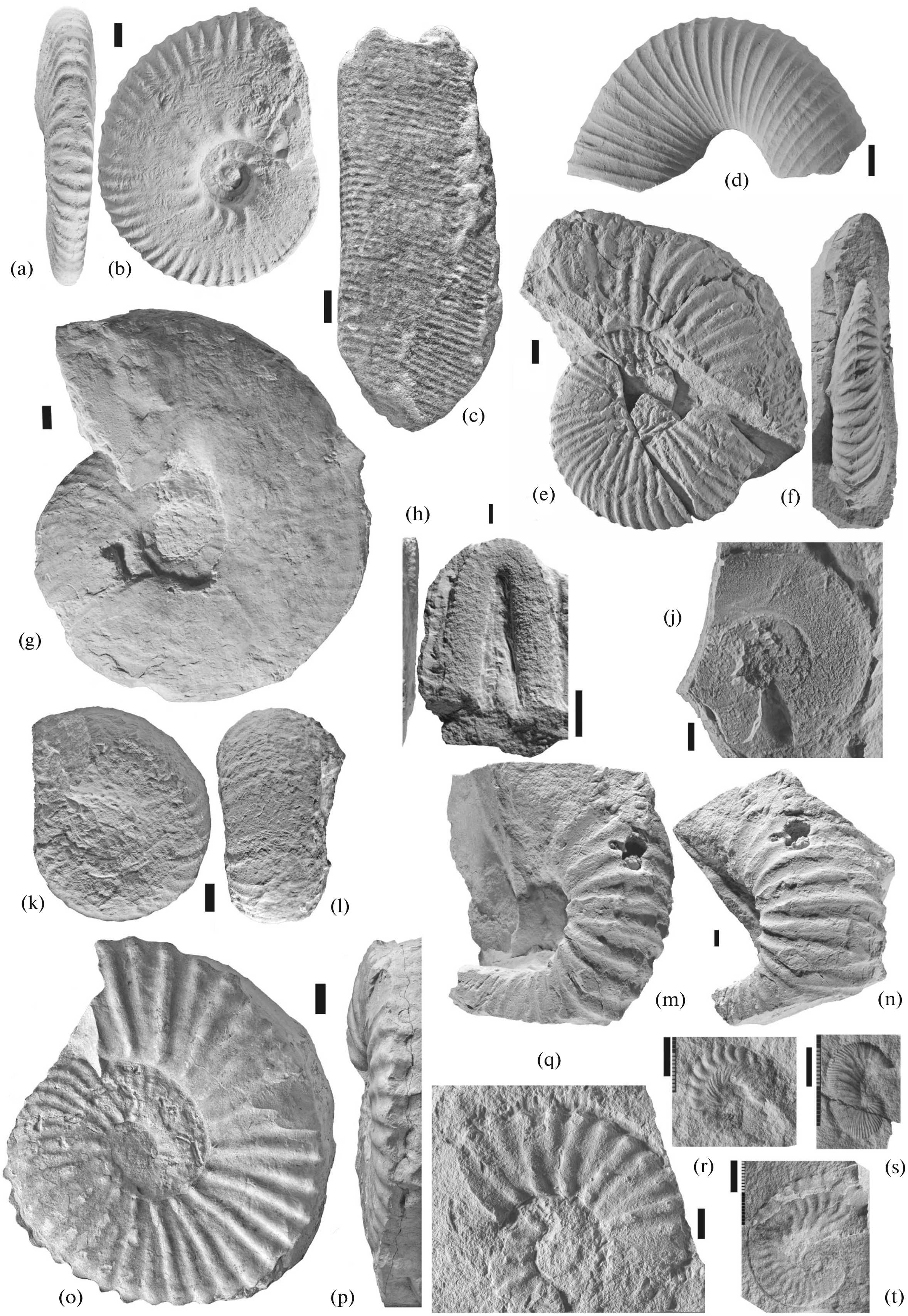
Substage	Ammonite Zone	Ammonite Subzone	Belemnite Zone	Belemnite Subzone
Upper Maastrichtian	Menuites terminus		B. casimirovensis	
				baltica /danica
	Menuites fresvillensis		Belemnella junior	danica / argenta
				argenta / junior
				tegulatus / junior
Lower Maastrichtian	Pachydiscus epiplectus / neubergicus		Belemnella occidentalis	Belemnella fastigata
				Belemnella cimbrica
				Belemnella sumensis
			Belemnella lanceolata	Belemnella obtusa
				Belemnella pseudobtusa
				Belemnella lanceolata
Upper Campanian	Nostoceras hyatti		Belemnitella "langei"	
	Didymoceras donetzianum		Belemnitella "minor"	
	Bostrychoceras polyplocum		Belemnitella mucronata	
	Hoplitoplacenticeras vari			
Lower Campanian	Menabites (Delawarella) delawarensis		Gonioteuthis quadrata gracilis / Belemnitella mucronata	
			Gonioteuthis quadrata gracilis	
	Placenticeras bidorsatum		Gonioteuthis quadrata quadrata	
			Gonioteuthis granulataquadrata / Belemnitella praecursor	
Upp. Sant	Boehmoceras arculus		Gonioteuthis granulata	
			Gonioteuthis westfalicagranulata	
L.Sant	Kitchinites emscheris		Gonioteuthis westfalica westfalica	
Upp. Coniac	Texanites pseudotexarus		Gonioteuthis westfalica praewestfalica	
	Paratexanites serratomarginatus			
Mid. Coniac	Gauthiericeras margae			
	Peroniceras tridorsatum			
L.Coniac	Forresteria petrocoriensis			
Upper Turon	Prionocyclus germari			
	Subprionocyclus neptuni			
M.Turon	Collignoniceras woollgari			
Lower Turon	Mammites nodosoides			
	Fagesia catinus			
	Watinoceras devonense			
Upper Cenomanian	Neocardioceras juddii			
	Metoicoceras geslinianum		Praeactinocamax plenus	BB8: Praeactinocamax plenus
	Calycoceras guerangeri			
Middle Cenomanian	Acanthoceras jukesbrownei			BB7: Belemnocamax boweri
	Acanthoceras rhotomagense	Turrilites acutus		
		Turrilites costatus	Praeactinocamax primus	BB6: Praeactinocamax primus-Belemnocamax boweri
		Cunningtoniceras inerme		BB5: Neohibolites ultimus
Lower Cenomanian	Mantelliceras dixoni		Neohibolites ultimus	BB4: Neohibolites ultimus
	Mantelliceras mantelli	Mantelliceras saxbii		BB3: Neohibolites ultimus
		Neostlingoceras carcitanense		BB2: Neohibolites ultimus
				BB1: Neohibolites praeultimus

Southwestern Crimea, This paper — Zone, Subzone, Beds with fauna

Substage	Unit	Belemnites	Ammonites
Upper Maastrichtian	XXIII-XXIV	Neobelemnella kazimiroviensis	?
	XXII	?Belemnitella junior	Pachydiscus neubergicus
Lower Maastrichtian	XXI	?	
	XX	Belemnella gracilis–B. lanceolata	
Upper Campanian	XIX	Belemnitella conica–B. profunda	Missing
		?Belemnitella minor	?
		Belemnitella langei langei	
		Belemnitella langei minor	
		Belemnitella mucronata	Bostrychoceras polyplocum
		Belemnitella submedia	Parasolenoceras phaleratum
Lower Campanian	XVI-XVIII	?	?
		Beds with *Actinocamax verus*	
Upp. Sant	XIII-XV	?	
L.Sant; Upp. Coniac	Missing?		
Mid. Coniac; L.Coniac	XI-XII	?	?
Upper Turon	X		Beds with *Tongoboryceras rhodanicum*
M.Turon	VIII-IX		Kamerunoceras turoniense
Lower Turon	VII		?
Upper Cenomanian	VI		Calycoceras (C.) naviculare
			?
Middle Cenomanian	V		Beds with *Calycoceras* (*Gent.*) *gentoni*
	IV-2	N.ult. / Neohib. excelsus - N.repentinus	Turrilites costatus
	Missing		
	IV-1	Neohibolites ultimus / Neohibolites menjailenkoi	Mantelliceras dixoni
Lower Cenomanian	III		
	II		Mantelliceras mantelli / Mantelliceras saxbii
	I		
	Missing		

(Hypophylloceras) sp., *Gaudryceras stefaninii* Venzo, *G.* cf. *cassisianum* (d'Orb.), *Gaudryceras* sp., *Zelandites dozei* (Fallot), *Tetragonites* spp., *Puzosia (Puzosia) subplanulata* (d'Orb.), *P. (Austiniceras) austeni* (Sharpe), *Schloenbachia* sp., *Acanthoceras confusum* (Guer.) (*Acanthoceras* sp. juv.), *Worthoceras* sp., abundant *Sciponoceras baculoides* (Mant.), *Anisoceras plicatile* (J. Sow.), *Idiohamites* sp. (*Anisoceras*? sp.), *Turrilites costatus* Lam., *Scaphites obliquus* J. Sow., and *S. bassei* Col.

Fig. 12. Selected Late Cretaceous ammonites of southwestern Crimea. (a, b) *Pachydiscus (Pachydiscus) neubergicus* (von Hauer), MSU 138/5: (a) ventral view, (b) lateral view, lower Maastrichtian, Beshkosh Mountain, MSU student's collection, 1964; (c) *Diplomoceras cylindraceum* (Defr.), FS MSU m-103, upper Maastrichtian, Chakhmakhly Ravine, MSU student's collection, 1977; (d) *Bostrychoceras polyplocum* (Roem.), MSU 138/6, upper Campanian, Bodrak River Valley, MSU student's collection; (e, f) *Pseudokossmaticeras tercense* (Seun.), MSU 138/7: (e) lateral view, (f) ventral view, lower Maastrichtian, Bodrak River Valley, MSU student's collection, 1968; (g) *Pachydiscus (Pachydiscus) launayi* (de Gross.), MSU 149-1, lower Campanian, Unit XVIIIa, an abandoned quarry on the northwestern outskirts of Kudrino village, lower Campanian, E.Yu. Baraboshkin's collection, 2018; (h, i) *Pseudoxybeloceras (Parasolenoceras) splendens* Coll., MSU 157/1: (h) ventral view, (i) lateral view, upper Santonian, region of Chuku Mountain, Belbek River basin, Klikushin's collection, 1983; (j) *Hauericeras (Gardeniceras) gardeni* (Baily), MSU 157/2, upper Santonian, region of Chuku Mountain, Belbek River basin, Klikushin's collection, 1983; (k, l) *Tongoboryceras rhodanicum* (Rom. et Maz.), MSU 158/1: (k) lateral view, (l) ventral view, upper Turonian, Beds with *Tongoboryceras rhodanicum*, Selbukhra Mountain, MSU student's collection, 1963; (m, n) *Calycoceras (Calycoceras) naviculare* (Mant.), MSU 158/2: (m) lateral view, (n) ventral view, upper Cenomanian, Calycoceras naviculare Zone, Selbukhra Mountain, E.Yu. Baraboshkin's collection, 2023; (o, p) *Mantelliceras saxbii* (Sharpe), FS MSU cm-6: (o) lateral view, (p) ventral view, lower Cenomanian, Mantelliceras mantelli/saxbii Zone, Selbukhra Mountain, MSU student's collection, 1958; (q) *Mantelliceras picteti* Hyatt, MSU 158/3, lower Cenomanian, Kremennaya Mountain, A. Voinov's collection, 1989; (r) *Hyphoplites curvatus curvatus* (Mant.), FS MSU cm-32, lower Cenomanian, Kremennaya Mountain, MSU student's collection, 1969; (s) *Scaphites obliquus* J. Sow., FS MSU cm-32, Cenomanian, Selbukhra Mountain, MSU student's collection, 1977; (t) *Schloenbachia varians* (J. Sow.), FS MSU cm-17, lower Cenomanian, Selbukhra Mountain, MSU student's collection, 1963. Scale bars are 1 cm.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Unit V of the middle Cenomanian contains (after Wright et al., 2017) *Mesogauryceras leptonema* (Sharp.), *M. rarecostatus* Balan, *Calycoceras* (?) sp., and *Pseudotissotia* sp. (? *Forbesiceras* sp.). Recently *Calycoceras (Gentoniceras) gentoni* (Brongn.) was determined in the base of this unit, and we propose to recognize **Beds with *Calycoceras (Gentoniceras) gentoni*** with the stratotype in Selbukhra Mountain. The maximum abundance of this species marks the Turrilites acutus Subzone of the A. rhotomagense Zone in Northern Europe.

The next level just found (Avenirova, 2023; Baraboshkin et al., 2023c; Rtishchev, 2023) is characterized by the single ammonite finding of *Calycoceras (Calycoceras) naviculare* (Mant.) (Figs. 12l, 12m) in the Unit VI of Selbukhra Mountain (Fig. 4). This ammonite is distributed in the topmost middle Cenomanian–basal upper Cenomanian.

Another new finding is single *Kamerunoceras* sp. ex gr. *turoniense* (d'Orb.) (Baraboshkin and Fokin, 2024) of poor preservation coming from Unit IX. It indicates analogue of the **Kamerunoceras turoniense Zone** of the uppermost lower Turonian–basal middle Turonian. This specimen was found in the Aksu-Dere reference section above the Lulworth C-isotope Event, which means the middle Turonian age of the ammonite. Naidin et al. (1981) reported the presence of "Collignoniceratinae Wright et Wright and *Prionocyclus*? aff. *neptuni* (Geinitz)" in Units VIII–IX, but this information is not possible to prove (no images or specimens in collections).

The upper Turonian is characterized by the ammonite assemblage with *Hyphantoceras reussianum* (Schlüt.), *Scaphites geinitzi* d'Orb., *Allocrioceras nodiger* (F. Roem.) [=*A. strangulatum* Wright] (Naidin et al., 1981; Alekseev, 1989; Atabekian in (Arkadiev and Bogdanova, 1997; Arkadiev et al., 2000)). Only *Scaphites geinitzi* d'Orb. and *Allocrioceras nodiger* (F. Roem.) were confirmed from this list. Ammonites of the genus *Lewesiceras* often mentioned in the literature were redetermined as *Tongoboryceras rhodanicum* (Rom. et Maz.) (Figs. 12k, 12l). The same species was figured by Atabekian (Arkadiev and Bogdanova, 1997; Arkadiev et al., 2000) and found in the Aksu-Dere reference section (Fig. 6). The ammonite assemblage is typical for the upper Turonian Subprionocyclus neptuni Zone of Northern Europe, and we propose here the **Beds with *Tongoboryceras rhodanicum*** (Table 2) with the stratotype in the upper part of Unit X of the Aksu-Dere section (Fig. 6).

Conaician ammonites are not known in Crimea.

Early Santonian ammonites published in a list of Klikushin (1985) from Unit XIII were not confirmed. The Klikushin's collection revised by Baraboshkin (Guzhikov et al., 2024) contains ? *Glyptoxoceras* sp., *Hauericeras (Gardeniceras) gardeni* (Baily) (Fig. 12j), ?*H.* sp., "*Nowakites*" *katschthaleri* (Imm., Kling. et Wiedm.), "*N.*" cf. *katschthaleri* (Imm., Kling. et Wiedm.), ? *N.* sp., ? *Pseudophyllites* sp., *Saghalinites* cf. *nuperus* (van Hoepen), *Baculites* cf. *incurvatus* Duj., *Pseudoxybeloceras (Parasolenoceras) splendens* Coll. (Figs. 12h, 12i). The assemblage characterizes the late Santonian–early Campanian interval. Unfortunately, the precise position of the ammonites from the collection is not known, so zonal identification is not possible. The new dating of the ammonites, however, is important as it indicates (together with other data) possible absence of the early Santonian in southwestern Crimea.

Except for previous ammonite assemblage, the upper Santonian (Unit XV) contains *Nowakites*? cf. *savini* (de Gross.), *Eupachydiscus* cf. *sayni* (de Gross.) (Alekseev, 1989; Atabekian in Arkadiev and Bogdanova, 1997 and Arkadiev et al., 2000) and *Parapuzosia (Parapuzosia)* cf. *leptophylla* (Sharpe) (Baraboshkin and Fokin, 2019; Guzhikov et al., 2021a). These ammonites of a wide stratigraphic range cannot indicate the ammonite zone more precisely.

Lower Campanian ammonites are extremely rare, which is probably related with the deepening of the basin. Only two samples are known from this interval: *Eupachydiscus levyi* (de Gross.) (Atabekian in (Arkadiev and Bogdanova, 1997; Arkadiev et al., 2000)) and *Pachydiscus (Pachydiscus) launayi* (de Gross.) from Unit XVIII (Baraboshkin, 2023; Baraboshkin et al., 2024; Fig. 18). Ammonite zones cannot be identified.

Upper Campanian Unit XIX contains *Pachydiscus (Pachydiscus) haldemsis* (Schlüt.) [=*Pachydiscus koeneni* Gross. in old papers] in the lower part, *Bostrychoceras polyplocum* (Roem.) in the upper part in the Kacha–Bodrak interfluve (Alekseev, 1989) and *Desmophyllites diphylloides* (Forb.), *Gaudryceras kayei* (Forb.), *Pachydiscus haldemsis* (Schlüt.), *Parasolenoceras* cf. *phaleratum* (Griep.), *Neoglyptoxoceras retrorsum* (Schlüt.), *Bostrychoceras polyplocum* (Roem.) (Fig. 12d), and *Hauericeras fayoli* de Gross. in the Belbek River basin (Atabekian in (Arkadiev and Bogdanova, 1997; Arkadiev et al., 2000)). The ammonite assemblage indicates the presence of the **Parasolenoceras phaleratum** and **Bostrychoceras polyplocum zones** of the basal upper Campanian of the North European scale (Hardenbol et al., 1998). The absence of uppermost Campanian zones is probably related with a stratigraphic unconformity at the Campanian/Maastrichtian boundary (Baraboshkin et al., 2020).

The next ammonite assemblage is characterized by the presence of *Hauericeras sulcatum* (Kner), *Pseudokossmaticeras tercense* (Seunes) (Figs. 12e, 12f), *P. brandti* (Redt.), *P. galicianum* (Favre), *P. muratovi* Mikh., *Pachydiscus (P.) epiplectus* (Redt.), *P. (P.) neubergicus* (von Hauer) (Figs. 12a, 12b), *Diplomoceras cylindraceum* (Defr.), and *Hoploscaphites constrictus* (J. Sow.). *Pachydiscus armenicus* Atab. et Akop. was found higher in the section than the first *P. neubergicus* (von Hauer) (Baraboshkin et al., 2020). It belongs to the uppermost Campanian–lower Maastrichtian, upper part of Unit XIX and Unit XX. These units are very similar lithologically (differing by a higher silt content in XX) and the unconformity surface between them is poorly recognizable in the field (Baraboshkin et al., 2020, 2023a). It is very possible therefore that the mentioned assemblage is a mixture of the two close stratigraphic intervals, so its zonal interpretation is doubtful.

The upper part of the Maastrichtian contains *Pachydiscus (P.) gollevillensis* (d'Orb.), *P. (P.) jacquoti jacquoti* (Seun.) (Unit XXII) and *Pachydiscus (P.) neubergicus* (von Hauer), *Diplomoceras cylindraceum* (Defr.) (Fig. 12c) (Unit XXIII). According to micropaleontological data, this part of the succession should be referred to the upper Maastrichtian. The topmost part of the Maastrichtian (Unuts XXIII–XXIV) contains poorly documented pachydiscids and belemnites *Neobelemnella kazimiroviensis* (Skolozdr.).

In conclusion, the present data on ammonite biostratigraphy is summarized in the Table 2. Obviously, the Upper Cretaceous ammonite record of the Mountainous Crimea is very incomplete, especially in the upper Cenomanian–lower Turonian, Coniacian–lower Santonian, lower Campanian and uppermost Maastrichtian intervals. The late Cenomanian–early Turonian and early Campanian coincide with the strong deepening of the basin. They produce poorly exposed base of the cuestas, and available outcrops are very limited. The Coniacian–lower Santonian interval is partly or completely missing. The uppermost Maastrichtian is represented by the regressive sandstones outcropping in vertical cliffs, problematic for studying. This could be an explanation of such poor ammonite characterization. The other problem is very imprecise indication of the ammonite position in the sections. Most of ammonite finds were made from the diluvial talus and it is difficult to recognize their precise stratigraphic position. One of the possibilities to solve some of these problems is in study of microfossils from the ammonite remains to have an idea on their correct stratigraphic position. At last, the preservation of the ammonites is difficult for their determination: most of them are represented by strongly compressed fragments, contorting the whorl section and the sculpture.

Belemnites

The study of Upper Cretaceous belemnites of the Mountainous Crimea was developed in parallel with the study of other cephalopods and was published in the same papers and Atlases (see above, Table 1). First Crimean belemnite was figured by Rousseau (1842). Some notes on the belemnites from the Crimean limestones were published later by Prendel (1876), Coquand (1877), Hébert (1877). Late Cretaceous belemnites from Crimea were studied and described by Eichwald (1865–1868), Arkhangelsky (1912), Naidin (Naidin, 1953, 1964a, 1964b, 1965, 1975; Naidin in Moskvin, 1959; Naidin in Krymholtz, 1974; Naidin and Alekseev, 1975; etc.). A number of belemnite levels were recognised (Jolkichev and Naidin, 1999) in the result of these works, but a belemnite scale was not developed. Some of the belemnite zones were integrated in the Upper Cretaceous scale of the European paleobiogeographic region (Naidin et al., 1984). The new Crimean belemnite zonation is summarized in the present paper (Table 2).

Naidin recognized two belemnite levels in the Cenomanian (Naidin and Alekseev, 1975, 1980, 1981; Jolkichev and Naidin, 1999). The "lower belemnite level" in the base of the Cenomanian contains *Neohibolites menjailenkoi* Gust. probably *N. ultimus* (d'Orb.), and rare *Parahibolites touritae* (Wegner). This level does not coincide with the Mitchell's (2005) biohorisons BB1-2 "Neohibolites praeultimus" (which is the junior synonym of *Neohibolites menjailenkoi* Gust. (Naidin, 1979)), as there is a gap at the base of the lower Cenomanian. The "upper belemnite level" at the base of the middle Cenomanian includes *Neohibolites ultimus* (d'Orb.) (Figs. 13p, 13r) as well as endemic *Neohibolites excelsus* Naid. et Aleks. and *N. repentinus* Naid. et Aleks. There is no direct analogue in NW Europe, but its stratigraphic position (Turrilites costatus Subzone) should be similar to BB8 "Praeactinocamax plenus biohorizon" of Mitchell (2005). In Crimea we therefore propose the **Neohibolites ultimus Zone** with two subzones: **Neohibolites menjailenkoi** and **Neohibolites excelsus–repentinus** with the stratotype section on the southern slope of Selbukhra Mountain (Fig. 4).

Naidin recognized "level with *Neohibolites menjailenkoi*", which he referred to Unit I to III of the lower Cenomanian (Naidin and Alekseev, 1980; Jolkichev and Naidin, 1999). In 1979 he renaimed this interval into "Beds with *Neohibolites menjailenkoi*" (Naidin, 1979) without indication of their stratotype. We made a find of *Neohibolites menjailenkoi* Gust. just below the lower/middle Cenomanian boundary in the Selbukhra South section (Figs. 13m–13o), so Neohibolites menjailenkoi Subzone includes Units I to IV-1 of the lower Cenomanian.

Neohibolites excelsus–repentinus Subzone coincides with the "upper belemnite level" of Naidin and includes Unit IV-2 of the middle Cenomanian (Naidin and Alekseev, 1980).

The only find of *Praeactinocamax plenus* (Blainv.) mentioned from the Trudolybovka section (Tröger, 1996) is doubtful because it was not figured and its position in the section seems to be very high.

No belemnites are known in the Turonian–Santonian interval. The primary interpretation of *Actinocamax quassiverus* Naidin as late Santonian (Naidin, 1953) was erroneous (Jolkichev and Naidin, 1999). *Actinocamax verus* Miller (=*A. quassiverus* Naidin) (Figs. 13i–13l) appear at the base of the Campanian succession (Baraboshkin and Fokin, 2019; Guzhikov et al., 2021a), which also contains poorly preserved *Gonioteuthis* sp. ind. (Jolkichev and Naidin, 1999). The interval could be separated as the **Beds with *Actinocamax verus*** with the stratotype in the Aksu-Dere section (Fig. 8). The interval includs Subunits XVIa and XVIb and the upper boundary is provisional.

The next belemnite level is already in the middle upper Campanian. It is the Belemnitella mucronata Zone (*s.l.*), which was originally introduced in the Crimean stratigraphy by Lange and Mirchink (1910) (Table 1). In the last version of Naidin's revision (Jolkichev and Naidin, 1999), this level contains "*Belemnitella praecursor submedia* Naidin" in the lower part, *B. mucronata mucronata* (v. Schloth.) in the middle, and *B. mucronata profunda* Naidin in the upper part of the succession. They are regarded as separate levels, but according to our data *Belemnitella profunda* Naidin is occurred together with *Belemnitella conica* Arkh. in the topmost Campanian–lowermost Maastrichtian (Baraboshkin et al., 2023a, 2023b; Fig. 10). We propose to recognize the **Belemnitella submedia Zone** with the stratotype in Kuibyshevo village (lower part of Unit XIX, between Gorkogo street and Staratelei street, Belbek River basin); **Belemnitella mucronata Zone** (s.s.) and **Belemnitella conica–B. profunda Zone** with the stratotype in the basal part of Chakhmakhly Ravine (Units XIXb–XXb; Fig. 10). These zones could be traced from the Belbek to Bodrak rivers and in the Ak-Kaya Mountain region (incl. Baraboshkin et al., 2024).

An interval with belemnites between the Belemnitella mucronata Zone and the Belemnitella conica–B. profunda Zone was subdivided into the **Belemnitella langei minor, Belemnitella langei langei** and **Belemnitella minor** subzones (Table 2). We did not register both subspecies of *B. langei* in one section and follow Naidin's concept (Jolkichev and Naidin, 1999).

The finds of *Belemnella lanceolata* (v. Schloth.) are very rare in Crimea (Alekseev, 1989). They are present in Naidin's collection (Figs. 13w–13y) and mark the **Belemnella lanceolata Zone**, which was previously proposed by Lange and Mirchink (1910). Unfortunately, its current position in the section needs a confirmation.

The **Belemnella gracilis Zone**, in opposite, can be traced in all lower Maastrichtian sections and contains *Belemnella gracilis* (Arkh.) (Baraboshkin et al., 2020), "*Belemnella sumensis sumensis* Jel.", and "*Belemnella sumensis occidentalis* Birk." of Naidin's scheme (Jolkichev and Naidin, 1999). According to Naidin, the upper part of the Belemnella sumensis succession near the lower/upper Maastrichtian boundary is characterized by the appearance of *B. sumensis praearkhangelskii* Naidin. Christensen (1997) thought that Naidin's *Belemnella* of the *B. sumensis* group differs from the originals of Jeletzky (1949). We can agree that these belemnites need a revision.

The upper Maastrichtian of southwestern Crimea can be subdivided into the **Belemnitella junior** and **Neobelemnella kazimiroviensis zones**. The position and validity of the Belemnitella junior Zone needs a confirmation, but Neobelemnella kazimiroviensis Zone is widely distributed in the interfluve of the Belbek and Bodrak rivers (Fig. 2: Kp76-78). The Kazimiroviensis Zone contains *Neobelemnella kazimiroviensis* (Skołozd.) (Figs. 12e–12h), *N. skolozdrownae* (Kong.), and *Fusiteuthis* sp. nov. and takes about 4–5 m of the topmost Maastrichtian section in the Belbek River outcrops.

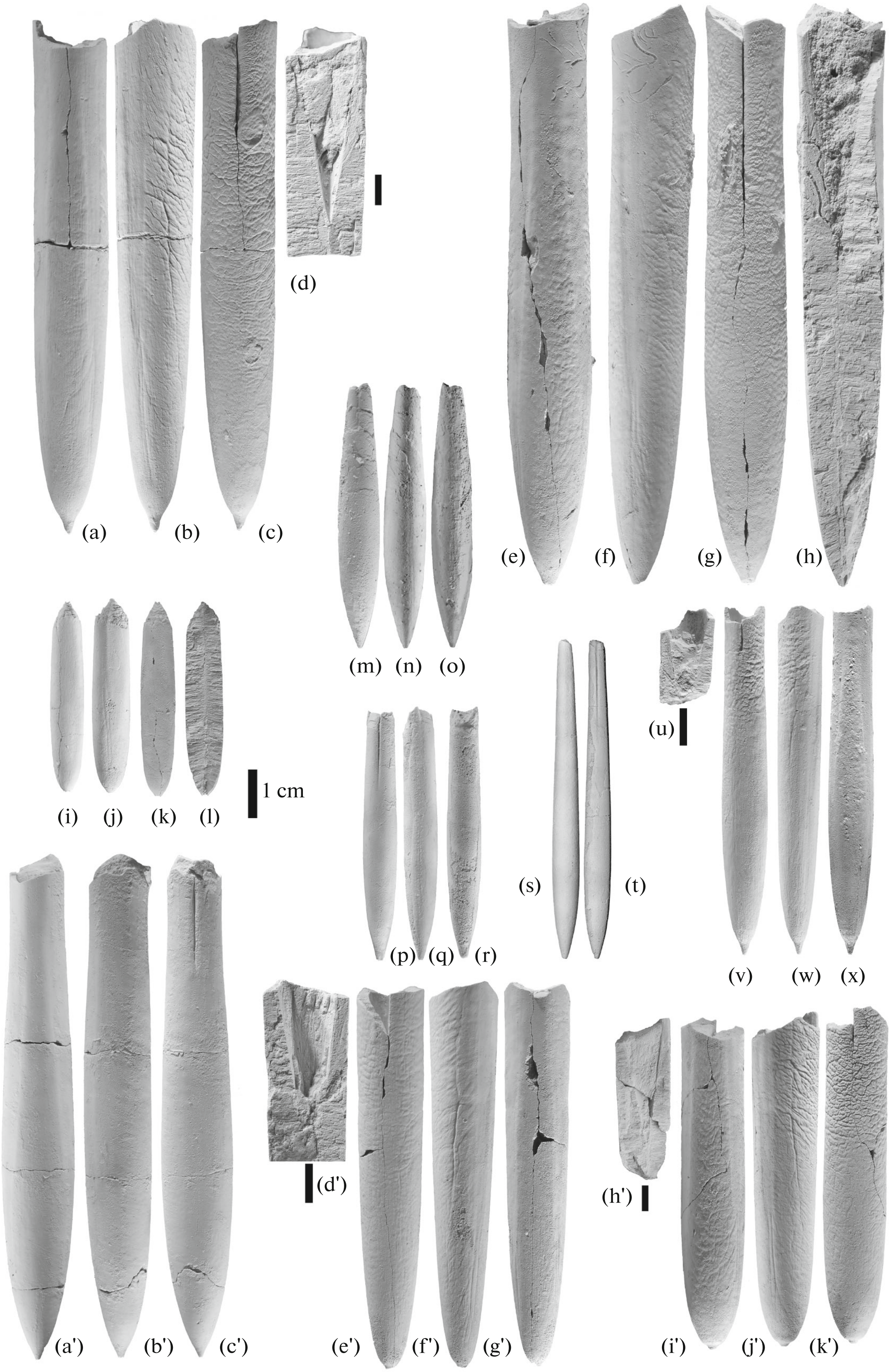
It is absolutely clear that belemnites are a useful cephalopod group for the Upper Cretaceous stratigraphy of Crimea even if their remains are not very frequent. These fossils need very tentative re-collecting with very precise marking the position in the section and linking to the other fossil groups. Such first data just appeared (Baraboshkin et al., 2020, 2024; Guzhikov et al., 2021a). It seems that there may be some endemic species different from European ones. It is difficult to solve the problem on the basis of the limited number of specimens, so additional collecting is required.

Ostracods

Surprisingly little is known on the ostracods from the Crimean Upper Cretaceous.

A list of the most common upper Maastrichtian species from the outcrops and boreholes was first pub-

Fig. 13. Selected Late Cretaceous belemnites. (a–d) *Belemnitella mucronata* (v. Schloth.), MSU 17/18: (a) ventral view, (b) lateral view, (c) dorsal view, (d) view of the split anterior end, upper Campanian, Belemnitella mucronata Zone; (e–h) *Neobelemnella kazimiroviensis* (Skoł.), MSU 310/22: (e) ventral view, (f) lateral view, (g) dorsal view, (h) view of the split anterior end. Upper Maastrichtian, Neobelemnella kazimiroviensis Zone; (i–l) *Actinocamax verus verus* Miller, MSU 136/3: (i) ventral view, (j) lateral view, (k) dorsal view, (l) view of the split, lower Campanian, Beds with *Actinocamax verus*, Aksu-Dere Ravine, Kudrino village region, E.Yu. Baraboshkin's collection, 2019; (m–o) *Neohibolites menjailenkoi* Gust., MSU 158/6: (m) ventral view, (n) lateral view, (o) dorsal view, lower Cenomanian, Neohibolites menjailenkoi Subzone, Selbukhra Mountain, E.Yu. Baraboshkin's collection, 2023; (p–r) *Neohibolites ultimus* (d'Orb.), MSU 158/5, (p) dorsal view, (q) lateral view, (r) ventral view, lower Cenomanian, Neohibolites ultimus Zone Selbukhra Mountain, E.Yu. Baraboshkin's collection, 2023; (s, t) *Neohibolites excelsus* Naid. et Aleks., 2588-5/7, holotype: (s) lateral view, (t) dorsal view, middle Cenomanian, Neohibolites ultimus Zone, N. excelsus–N. repentinus Subzone, Selbukhra Mountain; (u–x) *Belemnitella langei langei* Jel., MSU 106/22: (u) view of the split anterior end, (v) dorsal view, (w) lateral view, (x) ventral view, upper Campanian, Belemnitella langei langei Zone; (a'–c') *Belemnella lanceolata lanceolata* (Breyn. in v. Schloth.), MSU 230/22, (a') ventral view, (b') lateral view, (c') dorsal view, lower Maastrichtian, Belemnella lanceolata Zone; (d'–g') *Belemnitella conica conica* Arkh., MSU 98/22: (d') view of the split anterior end, (e') dorsal view, (f') lateral view, (g') ventral view, upper Campanian, Belemnitella conica Zone, Chufut-Kale Plateau, Bakhchisarai Region; (h'–k') *Belemnitella profunda* Naidin, MSU 91/22: (h') view of the split anterior end, (i') ventral view, (j') lateral view, (k') dorsal view, upper Campanian, Belemnitella profunda-conica Zone. Figs. a–d, s–v are from Crimea, Bakhchisarai region. Figs. e–h, w–y, e'–h' are from the upper Maastrichtian, Belogorsk region, Ak-Kaya Mountain. Figs. a–h, s–h', D.P. Naidin's collection and determinations. Scale bar is 1 cm; resized for Figs. d, u, d' and h'.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lished by Sheremeta (1969). To characterize the base of the Paleocene he only noted that these species are typical for the Maastrichtian of Europe and do not penetrate to the overlying deposits, except of few.

The first report on the ostracods at the Cretaceous/Paleogene boundary by Nikolaeva (1980) provides a detailed stratigraphic analysis of species from the Campanian–Thanetian interval of the former USSR, including Crimea. She mentioned the rarity of ostracods in the Campanian of the Beshkosh Mountain section and in the upper Maastrichtian of the Staroselie village section (Fig. 2: Kp77). Common species of these intervals are *Cytherella subreniformis* Jon. et Hind., *C. contracta* Veen, *Bairdia simplicatilis* (Mand. et Lüb.), *B. subdeltoidea* (Münst.), *B. jonesi* Mand., *Krithe kritheformis* (Veen); in the upper Maastrichtian (Abathomphalus mayaroensis Zone), aforementioned species accompanied by *Cytherella riparia* Mand., *Cytherelloidea inhonora* Choch., *Bairdia jonesi* Mand., *Brachycythere plena* (Alex.), *Opimocythere pustulosa* (Marl.), etc. There are the taxa common in Western Europe and in Mangyshlak, the Turgai Strait, and Western Siberia. Even though most of the listed ostracods disappeared at the K/T boundary, no biostratigraphic units were identified. Later Nikolaeva proposed the Limburgina ornatoidella Zone for the terminal Maastrichtian of the Bakhchisarai section (Nikolaeva, 2018).

Savelieva (2001, 2002) revealed rich ostracod assemblages at the Cretaceous–Paleogene boundary interval of the Alma–Chernaya interfluve (southwestern Crimea). 48 species belonging to 27 genera have been identified in the Maastrichtian; seven species are described as new. The Beds with *Bythoceratina hispida*, *Cythereis incerta, Golcocythere elegans* were recognized in the upper Maastrichtian N. kazimiroviensis belemnite Zone. The assemblage is close to Zone 4 (Deroo, 1966) established in the type locality of the Maastrichtian in South Limburg, Holland.

The ostracod and foraminifer assemblages were studied from the Albian-Cenomanian sections of Dusina Mountain and Sukhoi Log in the Belbek River valley by Savelieva (Fig. 2: Kp12a). Ostracods characterized Cenomanian marls most completely; very few and often poorly preserved remains were found in Albian sandy facies. An Albian ostracod assemblage (S. dispar ammonite Zone) is poorly preserved and consists of eurytopic *Cytherella* sp., and *Bairdoppilata* sp., and single *Cythereis* sp. and ?*Rehacythereis* sp. indicating extremely shallow water marine conditions. A Cenomanian ostracod assemblage (R. reicheli and R. cushmani foraminiferal zones) is rich and represented by 27 species from 19 genera. It was referred to the Beds with *Cythereis kelifensis* and *Praephacorhabdotus carrensis* (Savelieva, 2004). Species indices of the beds have a wide geographical distribution and allow correlations with the Cenomanian of Central Asia, which are traced in the Karakum, Mt. Kopetdag, Afghan-Tajik Depression, southwestern Gissar (Andreev, 1986). The habitat depth of the Cenomanian ostracods is deeper than the Albian ones, but less than 150 m.

Ostracods from the Campanian–Maastrichtian boundary interval in the Chakhmakhly reference section (SW Crimea, Fig. 2: Kp78) were briefly discussed by Proshina and Tesakova (2017a, 2017b) and Baraboshkin et al. (2023a). The stratigraphic potential of this ostracod assemblage is rather poor, but it provides a possibility to identify four paleoecological assemblages corresponding to eustatic cycles (from bottom to top): (1) *Phacorhabdotus semiplicatus* (Reuss) sensu Szczechura, 1965, (2) *Spinicythereis acutiloba* (Mars.), (3) *Cythereis (Trachyleberis) incerta* Szczech., and (4) *Cythereis latebrosa latebrosa* Szczech. They belong to light-sensitive ostracods. Thus, representatives of *P. semiplicatus* and *S. acutiloba* are blind, since they lived below the photic zone, while specimens *C. (T.) incerta* and *C. latebrosa latebrosa* with large eye tubercles correspond to the lower part of the photic zone. The changes in the assemblages are associated with different lighting of the bottom, which could vary due to changes in depth and/or eutrophication. These data are in preparation to the publication.

Foraminifera

The foraminiferal research of the Upper Cretaceous of the Crimea Peninsula was carried out by Maslakova (1959a, 1959b, 1967, 1977, 1978, etc.), Plotnikova (Plotnikova et al., 1984), Korchagin (Korchagin et al., 2012), Beniamovsky and Kopaevich (Kopaevich and Walaszczyk, 1993; Kopaevich et al., 2007, 2020; Kopaevich, 2010; Kopaevich and Khotylev, 2014; Beniamovsky and Kopaevich, 2016; Bragina et al., 2016; Kopaevich and Vishnevskaya, 2016; etc.) (Table 3). Maslakova proposed the first zonal scheme of planktonic foraminifera (PF) based on globotruncanids (Fig. 14). Kopaevich subsequently improved this zonal scheme for several times (Kopaevich, 2010; Kopaevich and Vishnevskaya, 2016; Fig. 14). The benthic foraminifera (BF) scale of East European paleobiogeographical province (EEP: Naidin et al., 1984; Beniamovsky, 2008a, 2008b) was used to date the Crimean Late Cretaceous (Fig. 14).

The **Cenomanian–Turonian** interval was studied in several reference sections of southwestern Crimea: Aksu-Dere Ravine (Fig. 2: Kp74), Belaya Mountain (Fig. 2: Kp18), Selbukhra and Mender mountains (Fig. 2: Kp12b, c), Kizil-Chigir Mountain (Fig. 2: Kp12d), Alma River (Fig. 2: Kp11a) (Maslakova and Naidin, 1958; Maslakova, 1959a, 1959b; Kopaevich and Walaszcyk, 1993; Kuzmicheva, 2000; Alekseev et al., 2007). A Cenomanian-Turonian PF foraminiferal assemblage consists of representatives of *Thalmanninella* spp., *Rotalipora* spp., *Hedbergella* spp., *Whiteinella* spp., *Praeglobotruncana* spp., *Heterohelix* spp.

Table 3. Development of foraminiferal zonal subdivision of the Upper Cretaceous.
(1) Stratigraphical division by Maslakova (1959b), (2) stratigraphical division by Kopaevich and Vishnevskaya (2016)

Stage[1]	Substage[1]	Key species BF and PF of the Mountain Crimea (Maslakova, 1959a)	PF Zones of the Crimea, the Caucasus and the Carpathians (Maslakova, 1967)	South Western Crimea: BF and PF Zones (Alekseev and Kopaevich, 1997)		Central Crimea: BF and PF Beds (Bragina et al., 2016)		Central Crimea: PF Beds (Korchagin et al., 2012)	Eastern Crimea: Aqqlutinated BF Zones (Kopaevich et al., 2007)	PF Zones Crimea and Caucasus (Kopaevich and Vishnevskaya, 2016)	This work (Guzhikova et al., 2020b; Ovechkina et al. 2021b; Guzhikov et al., 2021a,2021b; Proshina and Ryabov, 2023; Baraboshkin et al.,2024): PF Beds	This work: BF Beds	Stage[1]	Substage[1]
Maastrichtian	Upper	*Bolivinoides draco, Reusella minuta, Anomalina midwayensis*	Abathomphalus mayaroensis	H. ekblomi Br. praeacuta	Globotruncanita starti	?		?	Sp. spectabilis R. varians H. ovulum	Abathomphalus mayaroensis	Gu. cr.: Psg. har. Rc. fruct.	G. sahlstroemi Br. praeacuta	Maastrichtian	Upper
	Lower	*Pseudotextularia varians*	Globotruncanita starti	Gv. midwayensis Br. complanata						Globotruncanita starti	Laevi-heterohelix glabrans–Rugoglobige-rina	B. draco F. multipunctata (=G. complanata)		Lower
Campanian	Upper	*Stensioina stellaria, Bo. incrassata, Cibicides spiropunctatus*	G. morozovae	An. gracilis	G. morozovae	An. gracilis ?	Globotruncanita area			C. morozovae Gl. multispinus	C. morozovae ?	An. gracilis ? C. incrassata ? B. peterssoni B. delicatula Br. monterelensis/ C. voltziana	Campanian	Upper
	Lower	*Cibicides aktulagaensis, Anomalina menneri* *Bolivinoides decoratus, Orbignyna inflate*	G. arca			Eouvigerina aspera denticulo-carinata	Globotruncanita elevata			Globotruncanita elevata	Gl. elevata	B. decorate B. puslulala P cl. clementiana		Lower
Santonian	Upper	*B. opifex, Anomalina stelligera, A. clementiana, G. globigerinoides, Stensioina exculpta*	G. fornicata–G. arcoformis			S. pommerana-A. (?) insignis B. strigillatus	M. coronata-Concavatotruncana concavata	C. fornicata-M. marginata Sigalia carpatica		C. fornicata	C. fornicata	G. stelligera S. perfecta	Santonian	Upper
	Lower	*Anomalina infrasantonica, A. thalmmani, A. clementiana, A. umbilicatula, S. exculpta*	Globotruncana concavata	PF Zones (Alekseev et al., 2007)	PF Zones (Kopaevich and Walaszczyk, 1993)	PF Zones (Kuzmicheva, 2000)		M. austinensis - G. desioi		Concovatotrun-cana concavata	?	?		Lower
Coniacian	Upper	*Stensioina emscherica, Anomalina thalmmani, Anomalina infrasantonica, Rotundina imbricata, Cibicides eriksdalensis*	Globotruncana primitiva								Concovato-truncana primitiva–C. concavata	Stensioeina exculpta	Coniacian	Upp Mid
	Lower		Globotruncana coronata		M. renzi					Marginotrun-cana coronata	M. coronata	Protostensioeina granulata		Low
Turonian	Upper	*Rotundina imbricata, Stensioina praeexculpta*	Globotruncana lapparenti		M. marginata M. pseudolinneiana			?		M. pseudolin-neiana	M. pseudo-linneiana	Protostensioeina praeexculpta	Turonian	Upp Mid
	Lower	*Rotundina imbricata, Stensioina praeexculpta, Rotalipora turonica*	HIv. helvetica/ Praeglobotrun-cana imbricata	Dicarinella elata Whiteinella archaeocretacea	HIv. aff. helvetica Dicarinella hagni ?	Praeglobotruncana oraviensis Whiteinella archaeocretacea				HIv. helvetica Whiteinella archaeocretacea	Dicarinella elata Whiteinella archaeocretacea	?		Low
Cenomanian	Upper	*Rotalipora reicheli, R. turonica* *Rotalipora reicheli*	Thalmanninella deeckei	Rotalipora cushmani	Rotalipora cushmani	Rotalipora cushmani				Rotalipora cushman Thalmanninella deeckei	R.cushmani Rotalipora reicheli	Globorotalites brotzeni	Cenomanian	Upp Mid
	Lower	*Rotalipora apenninica*	Thalmanninella appenninica							Thalmanninella globotruncanoides	Thalmanninella globotruncanoides			Low

The FO (first occurrence) of index species *Thalmanninella globotruncanoides* (Sigal) at the Albian–Cenomanian boundary was recorded in the Selbukhra section (Gorbachik et al., 2000; Avenirova, 2023). First and last occurrences of *Rotalipora reicheli* (Morn.) were correlated with middle Cenomanian stable isotope excursion MCE-1 (Korchagin et al., 2008) (Fig. 14), but in Selbukhra section this species is limited by the early Cenomanian (Avenirova, 2023). The standard Rotalipora cushmani (middle–upper Cenomanian), Whitenella archaeocretacea (Cenomanian–Turonian boundary interval) and Dicarinella elata (lower Turonian) PF zones were recognized and documented in the reference sections (Figs. 4, 6).

The Cenomanian-Turonian BF assemblages are taxonomically and quantitively poor. A Cenomanian assemblage contains *Gavelinella baltica* Brotz., *G. cenomanica* (Brotz.), *Tappanina eouvigeriniformis* (Keller), *Cibicides jarzevae* Vass., *Eggerelina brevis* (d'Orb.), *Tritaxia piramidata* Reuss, etc. The middle Cenomanian Globorotalites brotzeni level was correlated with stable isotope excursion MCE-1 (Korchagin et al., 2008; Fig. 14).

The lower Turonian is characterized by *Frondicularia hastata* FO (Kuzmicheva, 2000). The middle-upper Turonian of the Aksu-Dere section (Fig. 2: Kp74, 17a) could be recognized by the appearance of *Globorotalites hangensis* Vass. (middle Turonian), *Gavelinella moniliformis* (Reuss) (upper middle Turonian), *Protostensioeina granulata laevis* (Koch), *G. praeinfrasantonica* (Vass. et Mjatl.), and *Cibicides praeeriksdalensis* (Vass.), which correlate with inoceramid succession (Kopaevich and Walaszczyk, 1993; Fig. 14). Recent revision of the Aksu-Dere section demonstrated poor BF assemblages including *Gyroidina subconica* Vass., *G. nitida* (Reuss), *Gavelinella vesca* (Byk.), *G.* cf. *moniliformis*, *Marssonella oxycona* (Reuss), and *Arenobulimina preslii* (Reuss). The lower part of the lower Turonian Inoceramus lamarcki Zone coincides with the FO of *Protostensioeina praeexculpta* (Kell.). This part of the section correlates with Zone LC5 (lower–middle upper Turonian) of the zonal scheme of EEP (Beniamovsky, 2008a, 2008b). Similar BF assemblages with the FO of *P. praeexculpta* (=*Stensioeina granulata humilis* (Koch)) (Figs. 15t–15v) were identified in the Kizil-Chigir section (Fig. 2: Kp12d; Guzhikov et al., 2024). Both sections contain previously unknown in Crimea benthic forams: *Berthelina berthelini* (Kell), *Reussella turonica* Akim., *Cibicides pollyrraphes* (Reuss), *Globorotalites multiseptus* (Brotz.), *Gavelinella praeinfrasantonica*, *Eponides concinna* Brotz., *C. praeeriksdalensis*, *Quadrimorphina* sp.

Finds of PF index species *H. helvetica* (Bolli) mark the lower Turonian PF Zone in Crimea (Fisher et al., 2005). The Dicarinella elata PF Zone is used instead of Helvetica Zone in case of the index absence. Its zonal assemblage contains *Praeglobotruncana oraviensis* Scheib., *Dicarinella biconvexiformis* Masl., *D. elata*

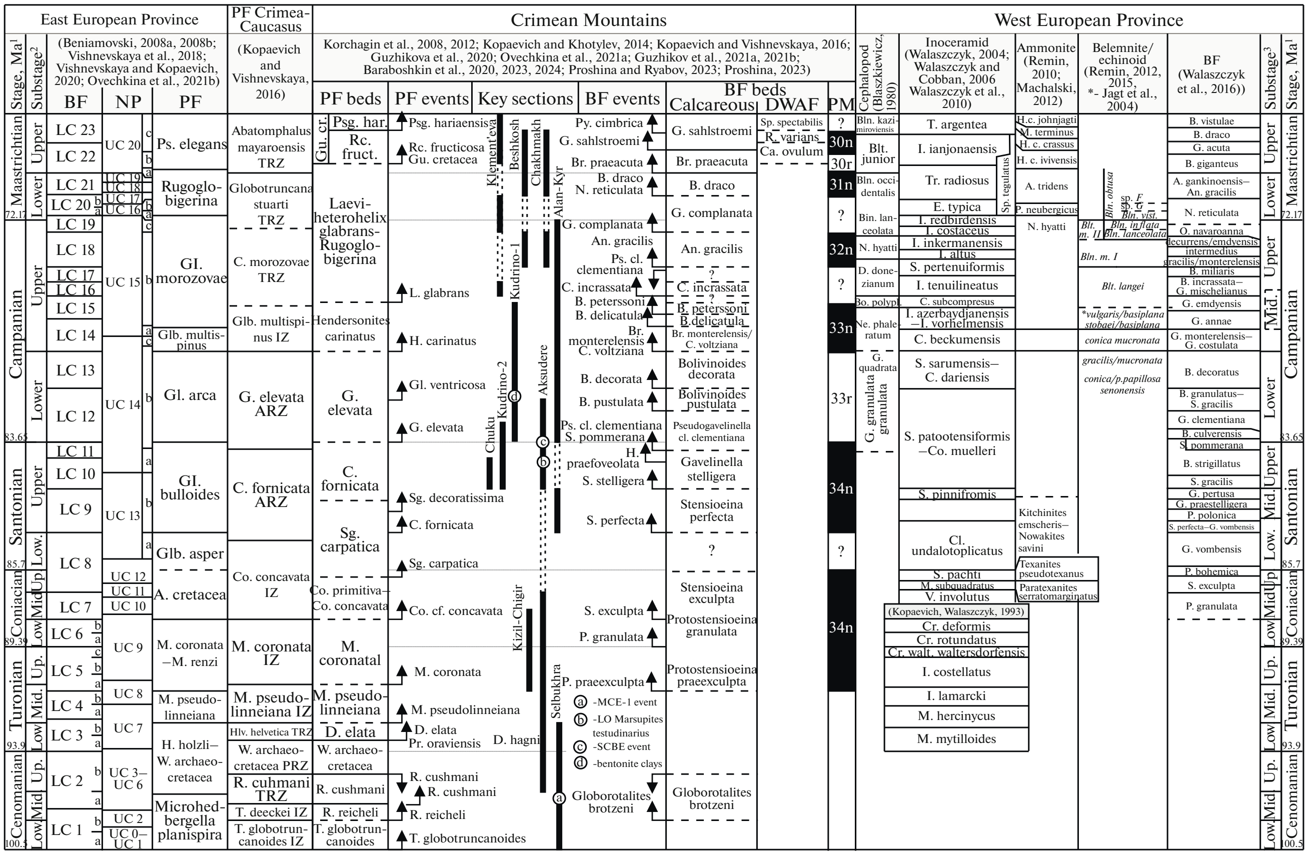
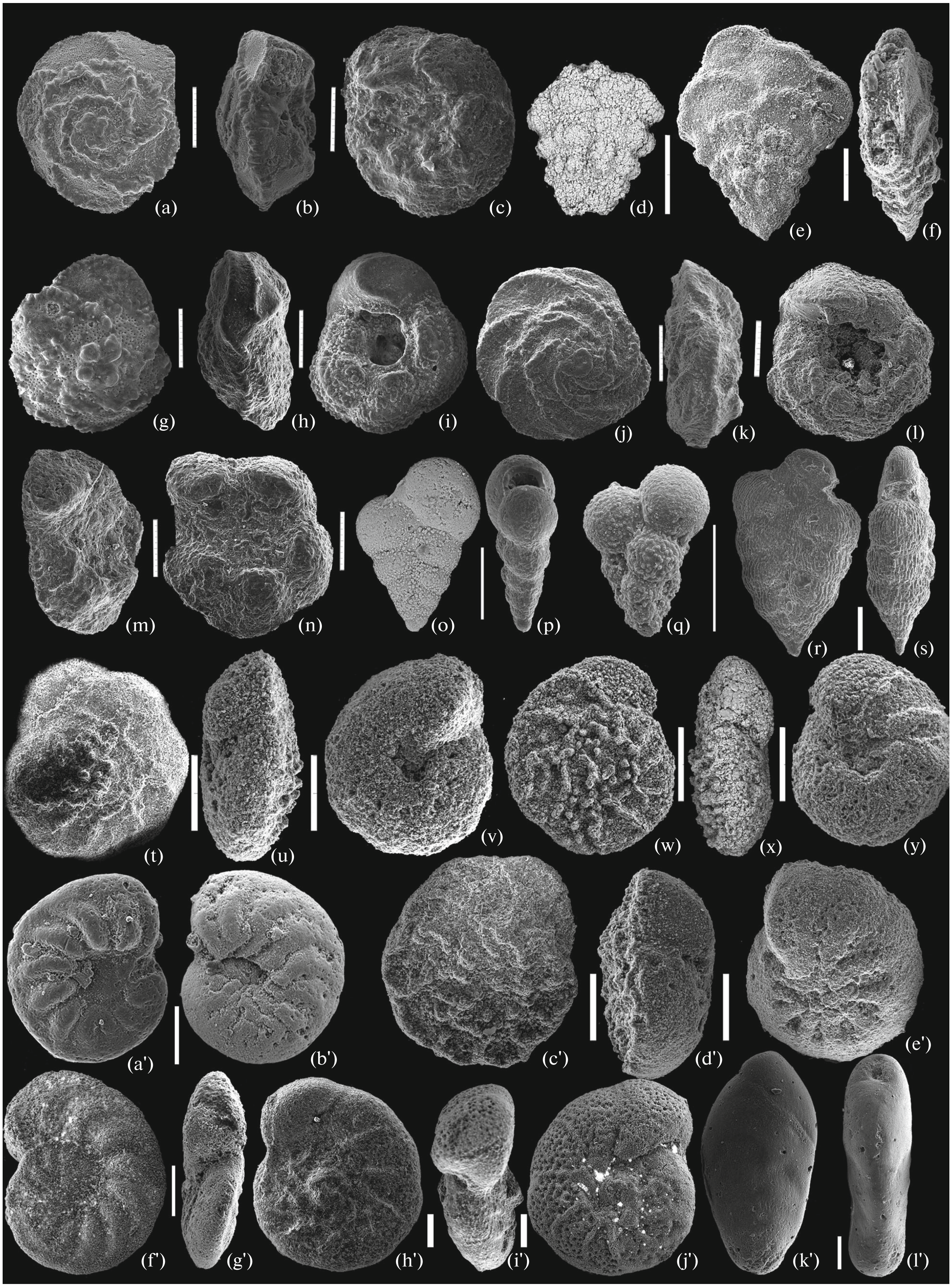


Fig. 14. Crimea Mountains BF and PF scale and their correlation with East European Province (EEP) and West European Province (WEP) biostratigraphical scales. ([1]) Stratigraphical division by Gale et al. (2020); ([2]) stratigraphical division by Olfer'ev and Alekseev (2003, 2005), ([3]) stratigraphical division by Walaszczyk et al. (2016). **BF:** A., *Anomalinoides*; An., *Angulogavelinella*; B., *Bolivinoides*; Br., *Brotzenella*; C., *Cibicides*; Ca., *Caudammina*; S., *Stensioeina*; Sp., *Spiroplectammina*; O., *Osangularia*; N., *Neofalbellina*; P., *Protostensioeina*; Ps., *Pseudogavelinella*; R., *Remessella*. **PF:** Pr., *Praeglobotruncana*; Ps., *Pseudotextularia*; Psg., *Pseudoguembelina*; G., *Globotruncanita*; Gl., *Globotruncana*; Gu., *Guembelitria*; Glb., *Globigerinelloides*; A., *Archaeoglobigerina*; M., *Marginotruncana*; H., *Hedbergella*; Hlv., *Helvetoglobotruncana*; W., *Whiteinella*; C., *Contusotruncana*; Co., *Concavatotruncana*; D., *Dicarinella*; R., *Rotalipora*; T., *Thalmanninella*; Sg., *Sigalia*; L., *Laeviheterohelix*. TRZ, Total Range Zone; PRZ, Partial Range Zone; IZ, Interval Zone; ARZ, Assemblage Range Zone. **Cephalopods:** Bln., *Belemnella*; Blt., *Belemnitella*; N., *Nostoceras*; Ne., *Neancyloceras*; D., *Didymoceras*; Bo. polypl., *Bostrychoceras polyplocum*; G., *Gonioteuthis*. H.c., *Hoploscaphites constrictus*; M., *Menuites*; A., *Acanthoscaphites*; P., *Pachydiscus*; **Inoceramids:** T., *Tenuipteria*; Tr., *Trochoceramus*; I., *"Inoceramus"*; E., *Endocostea*; S., *Sphaeroceramus*; Sp., *Spyridoceramus*; C., *Cataceramus*; Co., *Cordiceramus*; Cl., *Cladoceramus*; Cr., *Cremnoceramus*; M., Mytiloides; V., *Volviceramus*.

Fig. 15. Benthic and planktonic foraminifera of Crimean Mountains. The scale bar is 100 μm. (a-c) *Globotruncanita elevata* (Brotz.), Kudrino-2, sample 20 (Guzhikov et al., 2021a): (a) dorsal view, (b) lateral view, (c) ventral view; (d) *Sigalia* cf. *carpathica* Salaj et Sam., Chuku section, sample 51, coll. SSU IPR № 263/3177-51-33; (e, f) *S. decoratissima* (De Klasz), Chuku section, sample 55, coll. SSU IPR № 263/3177-57-36: (e) lateral view, (f) edge view; (g–i) *Contusotruncana fornicata* (Plummer), Kudrino-2, sample 1 (Guzhikov et al., 2021a): (g) dorsal view, (h) lateral view, (i) ventral view; (j–l) *Globotruncana ventricosa* White, Aksu-Dere, sample 55 (Guzhikov et al., 2021a): (j) dorsal view, (k) lateral view, (l) ventral view; (m, n) *Dicarinella concavata* (Brotz.), Kudrino-2, sample 15 (Guzhikov et al., 2021a): (m) lateral view, (n) ventral view; (o, p) *Lv. glabrans* (Cushm.), Beshkosh section, sample 3110-13, coll. No. 3110-13-108 (Proshina and Ryabov, 2023): (o) lateral view, (p) edge view; (q) *Guembelitria cretacea* Cushman, sample 3136-47, coll. № 3136-47-49 (Proshina and Ryabov, 2023); (r, s) *Pseudoguembelina hariaensis* Nederbr., Klementieva section, sample 33, coll. № 33-75 (Proshina, 2023): (r) lateral view, (s) edge view; (t–v) *Protostensioeina praeexculpta* (Kell.), Kizilchigir section, sample 6, coll. SSU IPR № 263/3186-06-01: (t) dorsal view, (u) lateral view, (v) ventral view; (w-y) *P. granulata* (Olbertz), Kizilchigir section, sample 6, coll. SSU IPR № 263/3186-06-03: (w) dorsal view, (x) lateral view, (y) ventral view; (a', b') *Gavelinella stelligera* (Marie), Aksu-Dere section, sample 58 (Guzhikov et al., 2021a): (a') dorsal view, (b') ventral view; (c'–e') *Stensioeina perfecta* (Koch), Chuku section, sample 40, coll. SSU IPR № 263/3177-40-18: (c') dorsal view, (d') lateral view, (e') ventral view; (f', g') *Gavelinella stelligera* (Marie), Aksu-Dere section, sample 58 (Guzhikov et al., 2021a): (f') dorsal view, (g') lateral view; (h'–j') *Pseudogavelinella clementiana clementiana* (d'Orb.), Aksu-Dere section, sample 15 (Guzhikov et al., 2021a): (h') dorsal view, (i') lateral view, (j') ventral view; (K', L') *Coryphostoma incrassata* (Reuss), Beshkosh section, sample 3110-10, coll. SSU IPR No. 263/3110-10-9: (k') lateral view, (l') edge view.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Lam., *D. hagni* Scheib. (Kopaevich and Vishnevskaya, 2016). The Marginotruncana pseudolinneiana Zone was recognized in the middle Turonian. It is based on the presence of the zonal index in association with *Marginotruncana marginata* (Reuss). The Marginotruncana coronata Zone was identified by the distribution of the index species in the upper Turonian–lower Coniacian.

PF, BF and inoceramid distribution in **Coniacian** rocks was studied in the Aksu-Dere section by Kopaevich and Walaszczyk (1993). Eleven previously unknown BF species were identified recently in this section by Ryabov (Guzhikova et al., 2020b). *Protostensioeina praeexculpta* (Figs. 15t–15v) (middle–upper Turonian), *P. granulata* (Figs. 15w–15y) (upper Turonian–lower Coniacian) and *Stensioeina exculpta* (lower–middle Coniacian) intervals were recognized, which correlate with LC5, LC6 and LC7 zones of EEP Zonal scheme (Beniamovsky, 2008a, 2008b) (Fig. 14).

PF assemblages were studied by Kopaevich (Kopaevich and Vishnevskaya, 2016). She identified the Marginotruncana coronata Zone (upper Turonian–lower Coniacian) and Concavatotruncana concavata Zone (middle Coniacian–lower Santonian), which are common for the Crimean and Caucasus zonal scales.

Santonian deposits are characterized by BF assemblage *Gavelinella vombensis* (Brotz.), *G. thalmmani* (Brotz.), *G. umbilicatula* (Vass. et Mjatl.), *Pseudogavelinella clementiana* (d'Orb.) (Figs. 15h'–15j'), and *Stensioeina exculpta* (Reuss) according to Maslakova (1959b). However, the lower Santonian is not characterized by foraminifers in the area, where it was recognized (Klikushin, 1985). It is very probably that the lower Santonian is missing in southwestern Crimea. Santonian-Campanian boundary interval was recently studied in several sections in the Kacha River basin (Fig. 2: Kp74): Aksu-Dere, Kudrino-2 (Guzhikov et al., 2021a, 2021b), Kudrino-1 (Baraboshkin et al., 2024) and in central Crimea: Alan-Kyr (Bragina et al., 2016; Ovechkina et al., 2021a; Fig. 2: Kp80) and Akkaya (Korchagin et al., 2012; Fig. 2: Kp79) sections.

The upper Santonian deposits characterized by the first occurrence of *Gavelinella stelligera* (Marie) (Figs. 15a', 15b', 15f', 15g') and *Stensioeina perfecta* (Koch) (Figs. 15c'–15e') are subdivided into *Stensioeina perfecta* (Ovechkina et al., 2021a) and *Pseudovalvulineria stelligera/Stensioeina gracilis/S. perfecta* intervals (Guzhikov et al., 2021a, 2021b), which correspond to the S. perfecta LC9 Zone (upper Santonian) and Gavelinella stelligera LC10a Zone (upper Santonian) of Beniamovsky (2008b) (Fig. 14).

The PF index species of the Contusotruncana fornicata Zone (Figs. 15g–15i) is very rare or absent in central Crimea. Its local analogue is the Dicarinella asymetrica Zone (Korchagin et al., 2012). Dicarinella asymetrica (upper Santonian) and Globotruncanita elevata (Figs. 15a–15c) zones (base of the Campanian) were recognized in the Kudrino-2 section (Guzhikov et al., 2021a, 2021b). The Aksu-Dere section is characterized by the presence of the Contusotruncana fornicata Zone (upper Santonian), Globotruncana arca/Globotruncanita elevata (base of the Campanian) and Globotruncana ventricosa (lower Campanian) zones (Guzhikov et al., 2021a, 2021b; Baraboshkin et al., 2024). The Contusotruncana morozovae Zone of Maslakova (1977) was proposed for the upper Campanian and was found in the Kudrino section (Baraboshkin et al., 2024 and our new data). *Sigalia carpatica* (Sal. et Sam.) (Fig. 15e), an important biostratigraphic marker of the terminal Coniacian–Santonian (Robaszynski and Caron, 1995; Georgescu, 2017), was found in the base of the middle Santonian in the Ak-Kaya reference section (Korchagin et al., 2012; Fig. 2: Kp79) and in the Stensioeina perfecta Zone (upper Santonian) of the Chuku Mountain section (Guzhikov et al., 2024; Fig. 2: Kp76) together with a descendent species *S. decoratissima* (de Klasz) (Figs. 14, 15e, 15f).

The upper Santonian–lower Campanian of the Kudrino-1, 2 and Aksu-Dere sections includes the *Pseudogavelinella clementiana clementiana* Beds, *Bolivinoides pustulata* Beds (lower Campanian), *B. decorata* Beds (upper lower Campanian), *Brotzenella monterelensis/Cibicides voltziana* Beds (lower upper Campanian), *B. delicatula* Beds (lower upper Campanian–"middle Campanian") and *B. peterssoni* Beds (upper Campanian) (Baraboshkin et al., 2024; Figs. 8, 14, 15h'–15i', 16a–16r, 16u). They are correlated with the benthic foraminiferal schemes of the eastern (Beniamovsky, 2008b) and western (Walaszczyk et al., 2016; Georgescu, 2018) parts of EEP (Baraboshkin et al., 2024; Fig. 14).

The *Marginotruncana coronata–C. concavata* Beds (equivalent of the C. fornacata Zone, the lower part of the Santonian), *Globotruncanita elevata* Beds (upper part of the Santonian) and *G. arca* Beds (suggested as Campanian) were recognized in the Alan-Kyr section (Ovechkina et al., 2021a; Fig. 2: Kp80).

The upper **Campanian–Maastrichtian** interval was studied in the Beshkosh Mountain (Fig. 2: Kp77) and Chakhmakhly Ravine (Fig. 2: Kp78, Figs. 19a, 19b) sections (Alekseev and Kopaevich, 1997; Baraboshkin et al., 2020, 2023a, 2023b; Proshina and Ryabov, 2023). The following foraminiferal subdivisions were recognized and proposed. Benthic foram-based biostrata are *Coryphostoma incrassata* Beds (upper Campanian) (15k'–15l'), Angulogavelinella gracilis LC 18 Zone (upper Campanian) (Figs. 16y, 16z), *Gavelinella complanata* Beds (lower Maastrichtian) (Figs. 16e'–16g'), Bolivinoides draco LC 21 Zone (lower Maastrichtian) (Figs. 16c', 16d'), Brotzenella praeacuta LC 22 Zone (lower upper Maastrichtian) (Figs. 16h'–16j'), and *Gavelinella sahlstroemi* Beds (upper Maastrichtian) (Figs. 16k'–16m'). The succession clearly indicates stratigraphic unconformity in the Campanian/Maastrichtian boundary interval. The PF allows recognition of *Laeviheterohelix glabrans–Rugoglobigerina* Beds below and Guembelitria cretacea Zone above. BF and PF zonations are compared with Campanian–Maastrichtian bioevents of the European paleobiogeographic region, regional stratigraphic scheme of Poland and Tethyan scale (Fig. 14). An interval of the upper B. peterssoni Beds and lower the A. gracilis BF Zone needs an additional study.

The Campanian and Maastrichtian are characterized by the presence of trochoid PF with advanced sculpture (genera *Globotruncana* Cushm., *Globotruncanita* Reiss, *Contusotruncana* Korch.), multiserial chamber heterohelicids (genera *Pseudotextularia* Rzeh. and *Racemiguembelina* Mont. et Gall.) and planispiral PF genera *Globigerinelloides* Cushm. et Ten Dam. Kopaevich followed Maslakova's (1977) zonation, but used three-fold subdivision of the Campanian Stage: Globotruncanita elevata Zone (uppermost Santonian–lower Campanian), Globigerinelloides multispinus Zone (middle Campanian) and Contusotruncana morozovae Zone (lower upper Campanian). The Campanian–Maastrichtian boundary is placed at the base of the Globotruncanita stuarti Zone, and lower/upper Maastrichtian boundary is placed at the base of the Abathomphalus mayaroensis Zone.

The Campanian-Maastrichtian zonation of eastern Crimea differs from that of southwestern Crimea. The succession is represented in the deeper-water Klement'eva section (Fig. 2: Kp77) and was studied recently (Kopaevich et al., 2007; Ryabov, 2022). The Guembelitria cretacea (Fig. 15q) and Pseudoguembelina hariaensis (Figs. 15r, 15s) zones were identified in the upper Maastrichtian, which is confirmed by nannoplankton data (Fig. 14).

BF assemblages of the Klement'eva section were studied by Beniamovsky (Kopaevich et al., 2007). A large number of deep-water agglutinated foraminifera (DWAF) was identified, and the Hormosina (=Caudammina) ovulum, Remessella varians and Spiroplectammina spectabilis zones were proposed. Analogues of these zones were found in the bathyal upper Maastrichtian deposits of North Atlantic and in western Tethys (Khunt et al., 1992; Kopaevich et al., 2007; Kaminski and Filipescu, 2011). The same section was studied recently by Ryabov, who recognized 24 calcareous BF species. The Bolivinoides draco LC20 Zone and Brotzenella praeacuta LC21 Zone were identified and correlated with DWAF zones in this paper (Fig. 14).

The published and newly received data suggest the following conclusions:

(1) The biostratigraphic subdivision of the Upper Cretaceous by planktonic foraminifera of Crimea and Caucasus is similar (Korchagin et al., 2008; Kopaevich and Vishnevskaya, 2016; Proshina and Ryabov, 2023). It includes 14 biostratigraphic units by PF (Fig. 14) and characterizes the whole Upper Cretaceous succession except for the lower Santonian and probably upper Coniacian. These units were correlated with the benthic foraminiferal scale of the EEP (Beniamovsky, 2008a, 2008b; Ovechkina et al., 2021b), Cretaceous Time Scale (Gale et al., 2020) and PF extra-Carpathian scale (Walaszczyk et al., 2016).

(2) The PF foram scale of Crimea contains Tethyan taxa, which makes easier correlation with the Standard scale. Unfortunately, index species are relatively rare (Kopaevich and Vishnevskaya, 2016).

(3) The biostratigraphic subdivision of the Upper Cretaceous by benthic foraminifera is based on the EEP scale (Beniamovsky, 2008a, 2008b), Bolivinoides biozones (Georgescu, 2018) and the new data (Korchagin et al., 2008; Baraboshkin et al., 2023a, 2023b; Proshina and Ryabov, 2023). The scale includes 16 biostratigraphic units by BF (Fig. 14) and characterizes Upper Cretaceous succession except for Campanian–Maastrichtian boundary interval, middle upper Campanian, lower Santonian, upper Coniacian, lower–middle Turonian, and lower and upper Cenomanian. This scale is more detailed than the PF scale and correlates with EEP nannoplankton, PF and radiolarian scales (Beniamovsky, 2008a, 2008b), extra-Carpathian BF/inoceramid bivalves/cephalopod/echinoid scales (Walaszczyk et al., 2016), Crimea-Caucasus PF and radiolarian scales (Kopaevich and Vishnevskaya, 2016), magnetostratigraphic scale of Crimea (see below).

(4) East Crimean foram successions demonstrate specific BF assemblage with DWAF species. This makes it possible to recognize 3 zones correlating with upper Maastrichtian bathyal successions from North Atlantic and Western Tethys (Khunt et al., 1992; Kaminski and Filipescu, 2011).

(5) The BF and PF Upper Cretaceous biostratigraphic scales of Crimea are integrated with different macro- and microbiostratigraphical, paleomagnetic and stable isotope data, which give a possibility for long-distant correlations.

Gilianelles

Gilianelles is a new fossil group for the Crimean biostratigraphy recently found in southwestern Crimea (Vishnevskaya et al., 2023).

New calcareous microproblematics were found in the Upper Cretaceous deposits of the Kudrino-1 section in the interfluve of the Kacha and Belbek rivers, dated to the late Santonian and a part of the early Campanian (Guzhikov et al., 2024; Baraboshkin et al., 2022, 2024) and calcispheric limestones of the Chuku (Polyus) Mountain section (Fig. 2: Kp76) in the valley of the Belbek River, which previously were considered as Turonian-Santonian (Klikushin, 1985).

For the first time, gilianelles, enigmatic calcareous microproblematics, ranging in size from 100 to 250 microns, characterized by distinct axial symmetry and currently conventionally attributed to calcareous dinocysts, were identified in the Upper Cretaceous deposits of Western Europe from a relatively narrow stratigraphic interval in the stratotype section of the Campanian-Maastrichtian boundary in a quarry Tercis (southern France, Odin and Lethiers, 2006; Odin, 2008a, 2008b, 2011). The name of the calcareous microproblematics “gillianelles” comes from the male name of their author Gilles Serge Odin, who described more than 60 species of these microproblematics in the Campanian–Maastrichtian limestone of France and Spain (Odin, 2009, 2011). They differ from calcispheres (Krasheninnikov and Basov, 1983) in the general shape and structure of the skeleton, and from dinocysts in size and the absence of tabulation (Odin, 2011). Gilianelles were not previously found on the territory of Russia and the former USSR.

For the extraction of calcareous microfossils, the method used for washing foraminifera shells, namely, the method of dissociation by acetolysis (treatment with concentrated acetic acid), was used.

Calcareous microproblematics were obtained from the samples collected by Baraboshkin et al. (2022) and were photographed at Borissiak Paleontological Institute of the Russian Academy of Sciences under the TESCAN.

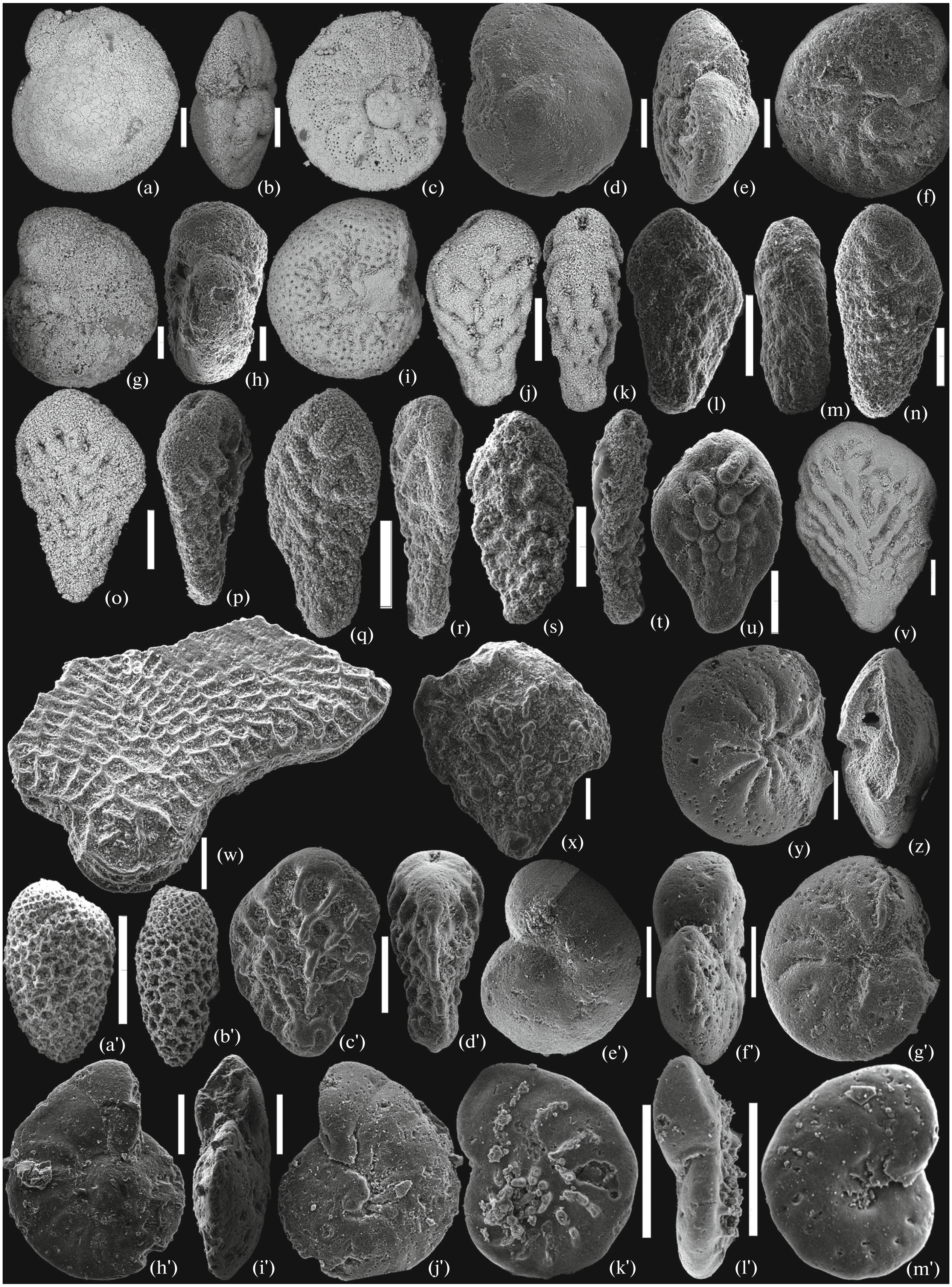
As a result, from the Upper Cretaceous deposits of Unit XVII of the Kudrino-1 section (Alekseev, 1989; Baraboshkin et al., 2022, 2024), in the interval of 2–5 m above the main bentonite layer, the following taxa were identified: *Aturella angulata* Odin (Figs. 17d–17e), *A. altodepressa* Odin (stratigraphic range is the Campanian–Maastrichtian), *Azymella cannabinata* Odin (Fig. 17b), *Gilianella tenuibrachialis* Odin (stratigraphic distribution is the Campanian), *Cimicellus nudatus* Odin (Fig. 17h), *Corniculum sinuosum* Odin (Fig. 17g), *Tubellus hunzikeri* (Odin) (Figs. 17i–17k), *Numismella tarbellica* Odin (Fig. 17a) (stratigraphic range is the Campanian-Maastrichtian). Similar discoid forms are found in the Polyus section (Vishnevskaya et al., 2023), including *Gilianella tenuibrachialis* Odin (Figs. 17c, 18a–18g), *Scutellella (Tetratropis) terrina* (Bison et al.) (Fig. 17l) (their stratigraphic distribution is the Campanian).

All the species encountered are very close to the forms described from a relatively narrow stratigraphic interval of the Campanian Stage: the upper Campanian part of the stratotype of the Campanian–Maastrichtian Tercis section of southwestern France (Odin, 2008a, 2009), the Campanian Radotruncana calcarata Zone of the Navarre section in northern Spain, where the marker species planktonic foraminifers are the Campanian *Schackoina multispinata*, *Globotruncana elevata*, *Globotruncana ventricosa* (Odin, 2008b, 2011), which are also present in the Kudrino-1 section, where *G. ventricosa* appears for the first time in sample 12, and *S. multispinus* in sample 11 of the underlying Unit XVI (Kopaevich and Vishnevskaya, 2016).

Since species *Azymella cannabinata* Odin, *Corniculum sinuosum* Odin, and *Tubellus hunzikeri* (Odin) are known from the Tercis and Navarra section, with the age of the host rocks ranged from 77.5 to 75 Ma (Odin, 2008a, 2008b), and the appearance of *Aturella angulata* Odin was recorded at the end of this stratigraphic interval (Odin, 2009), the age of the microproblematic complex can be defined rather as middle or late Campanian. This is in good agreement with the data on planktonic foraminifers and the U–Pb age of the main bentonite layer, which varies from 77 to 80 Ma, the weighted average age is 77.5 ± 1.5 Ma, but contradicts the early Campanian ages obtained from macrofauna, benthic foraminifers and organic-walled dinocysts (Baraboshkin et al., 2022, 2024).

Thus, there are species *Aturella angulata* Odin and *A. altodepressa* Odin among the calcareous microproblematics of gilianelles, which show evolutionary changes within the late Campanian–early Maastrichtian, as well as species of narrow stratigraphic distribution, which is of great stratigraphic interest. The pres-

Fig. 16. Benthic foraminifera of Crimean Mountains. The scale bar is 100 μm. (a–c) *Brotzenella monterelensis* (Marie), Kudrino-1 section, sample 55, coll. SSU IPR № 263/3169-55-86: (a) dorsal view, (b) lateral view, (c) ventral view; (d–f) *Cibicides voltziana* (d'Orb.), Kudrino-1 section, sample 55, coll. SSU IPR № 263/3169-55-234: (d) dorsal view, (e) lateral view, (f) ventral view; (g–i) *Pseudogavelinella clementiana laevigata* (Marie), Kudrino-1 section, sample 90, coll. SSU IPR No. 263/3169-90-63: (g) dorsal view, (h) lateral view, (i) ventral view; (j, k) *Bolivinoides strigillatus* (Chap.), Aksu-Dere section, sample 15 (Guzhikov et al., 2021a): (j) lateral view, (k) edge view); (l) *Bolivinoides culverensis* Barr, Kudrino-1 section, sample 10, coll. SSU IPR No. 263/3169-10-25; (m, n) *Bolivinoides pustulata* Reuss, Kudrino-1 section, sample 20, coll. SSU IPR No. 263/3169-20-15: (m) lateral view, (n) edge view; (o, p) *Bolivinoides decorata* (Jones), Kudrino-1 section, sample 30, coll. SSU IPR No. 263/3169-30-33: (o) lateral view, (p) edge view; (q, r) *Bolivinoides delicatula* Cushm., Kudrino-1 section, sample 60, coll. SSU IPR No. 263/3169-60-46: (q) lateral view, (r) edge view; (s, t) *Swiecickina clavata* (Plotn.), Kudrino-1 section, sample 100, coll. SSU IPR No. 263/3169-100-65: (s) lateral view, (t) edge view; (u) *Bolivinoides peterssoni* Brotz., Kudrino-1 section, sample 100, coll. SSU IPR No. 263/3169-100-12; (v) *Bolivinoides gigantea* Hilt. et Koch, Chakhmakhly section, sample 2016PP-18, coll. SSU IPR No. 263/2016PP-18-48; (w) *Neoflabellina reticulata* (Reuss), Chakhmakhly section, sample 2016PP-21, coll. SSU IPR No. 263/2016PP-21-51; (x) *Bolivinoides* sp., Chakhmakhly section, sample 2016PP-21, coll. SSU IPR No. 263/2016PP-21-55; (y, z) *Angulogavelinella gracilis* (Mars.), Beshkosh section, sample 3110-10, coll. SSU IPR No. 263/3110-10-7: (y) ventral view, (z) lateral view; (a', b') *Bolivina witwickae* Gaw.-Bied., Kudrino-1 section, sample 100, coll. SSU IPR No. 263/3169-100-67: (a') lateral view, (b') edge view; (c', d') *Bolivinoides draco* (Mars.), Beshkosh section, sample 3110-41, coll. SSU IPR No. 263/3110-41-69: (c') lateral view, (d') edge view; (e'–g') *Gavelinella complanata* (Reuss), Beshkosh section, sample 3110-40, coll. SSU RIP No. 263/3110-40-61: (e') dorsal view, (f') lateral view, (g') ventral view; (h'–j') *Brotzenella praeacuta* (Vas.), Klementyeva section, sample 15, coll. SSU IPR No. 263/Kl-15-62: (h') dorsal view, (i') lateral view, (j') ventral view; (k'–m') *Gavelinella sahlstroemi* (Brotz.), Beshkosh section, sample 3171-1, coll. SSU IPR No. 263/3171-1-1: (k') dorsal view, (l') lateral view, (m') ventral view.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ence of clearly related forms that replace each other in time (A4a, A4b, A4b' and A6 after Odin, 2008a, 2008b), short-lived taxa of calcareous microproblematics in other sections of the Crimean–Caucasian region will undoubtedly bring valuable additional information to modern knowledge.

The use of calcareous microproblematics has great potential not only for stratigraphy purposes, but also for deciphering paleogeography, since most sections of Crimea and the Caucasus contain a wide range of presumably calcareous dinocysts, which were previously repeatedly noted as "calcispheres".

According to the literature data for the southwest of France and the north of Spain (Odin, 2008a, 2008b), it is assumed that the gilianelles were limited to a clear sea without clastic material. Most are clearly planktonic, but some may have been benthic (Odin and Lethiers, 2006). Keelless cysts without protrusions and those with a more distinct oral surface than the aboral are better adapted to benthic habits (Odin, 2009).

Calcareous Nannoplankton

A great contribution to the study of Crimean Late Cretaceous nannofossils was made by Stetsenko (1975), Shumenko (1976, 1987), Shumenko and Stetsenko (1978), Lyulieva (Lyulieva and Permyakov, 1980), Matveev (2015), Shumnik (2002) and Shcherbinina (Shcherbinina and Gavrilov, 2016).

Cenomanian-Turonian nannoplankton (Belogorsk and Prokhladnenskaya Formations) was studied by Shcherbinina from the outcrops on the southern slope of Selbukhra Mountain (Shcherbinina and Gavrilov, 2016; Fig. 2: Kp12b; Fig. 4). There is a hiatus at the Albian/Cenomanian boundary, marked by the appearance of *Gartnerago theta* (Black in Black and Barnes) Jakubowski, characteristic for the upper part of the UC0 Zone. The lower boundary of the UC1 Zone is marked by the appearance of *Corollithion kennedyi* Crux, while the base of the UC2c Subzone is marked by the appearance of *Cylindralithus sculptus* Bukry. The FA of *Lithraphidites acutus* Verbeek et Manivit in Manivit et al., marks the base of the UC3 and CC10 zones, corresponding to the base of the middle Cenomanian, and the extinction level of *Gartnerago theta* corresponds to the lower boundary of the UC3b Subzone (Fig. 19). Subzones UC3c–UC3e are not distinguished, and the base of the UC4 Zone is marked by the appearance of *Rotellapilus biarcus* Bukry. The disappearance of *L. acutus* is the basis for the identification of the UC5 Zone. *Helenea chiastia* Worsley, disappears at the base of the Turonian, which corresponds to the base of the UC6 Zone and CC10a Subzone. The appearance of *Quadrum gartneri* Prins et Perch-Nielsen in Manivit et al., marks the base of Zone UC7 (CC11) (Fig. 19). The appearance of *Eiffellithus eximius* (Stover) Perch-Nielsen, makes it possible to define the base of the UC8 (CC12) Zone of the middle Turonian (Shcherbinina and Gavrilov, 2016) in the Aksu-Dere section (Fig. 2: Kp74; Fig. 6).

The upper Santonian UC12 Zone has no specific index nannofossils (Burnett, 1998), and its boundary with the lower Campanian UC13 Zone is determined by the appearance of *Arkhangelskiella cymbiformis* Vekshina at the top of the substage. The lower Campanian UC14 Zone can be divided into two subzones: UC14a, the base of which is determined by the appearance of *Broinsonia parca parca* (Stradner, 1963) Bukry, 1969, and UC14b, the base of which is determined by the appearance of *Broinsonia parca constricta* Hattner et al., 1980 in the Kudrino and Chuku sections (Guzhikov et al., 2021a, 2021b, 2024).

The study of nannofossils of the Campanian reference section in southwestern Crimea near Kudrino village revealed such a problem as the dependence of the accuracy of dating from the preservation of taxonomic diversity of nannofossils. The nannoplankton assemblage is depleted, and the absence of the late Campanian forms gave only the early Campanian age, while both substages were distinguished based on benthic foraminifers and other data (Baraboshkin et al., 2023a, 2024). The presence of *Reinhardtites levis* Prins et Sissingh in Sissingh, *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen, *Broinsonia parca parca*, *Broinsonia parca constricta*, distinguishes UC14d–UC15d zones of Burnett (1998). *Reinhardtites levis* is distributed in the lower Campanian–Maastrichtian (UC14d–UC18 zones of Burnett (1998)), *Broinsonia parca parca* characterises only of the Campanian (UC14–UC15d zones of Burnett (1998)). The boundary of UC14/UC15 zones was not defined, because it was drawn by the appearance of *Misceomarginatus pleniporus* Wind et Wise in Wise and Wind, 1977, which was not found in the Kudrino-1 section (Baraboshkin et al., 2023a, 2024).

The Campanian–Maastrichtian section of Chakhmakhly Mountain (Fig. 2: Kp78; Fig. 10) continue the Upper Cretaceous succession (Baraboshkin et al., 2023a, 2023b). The lower boundary of the UC15d Subzone is drawn by the appearance of *Uniplanarius*

Fig. 17. Calcareous microproblematics from the Kudrino 1 (a, b, d–k) and Polyus (c, l) sections. (a) *Numismella tarbellica* Odin, GIN No. 2022-4/24/3169/24; a radially radiant structure is observed; (b) *Azymella cannabinata* Odin, GIN No. 2022-4/573169/20; the structure of the canvas is clearly visible; (c, f) *Gilianella tenuibrachialis* Odin, GIN No. 2022-1/91/3177/45; (d, e) A*turella angulata* Odin: (d) GIN No. 2022-4/10/3169/24, (e) GIN No. 2022-4/43/3169/20; (g) *Corniculum sinuosum* Odin, GIN No. 2022-4/37/3169/20; (h) *Cimicellus nudatus* Odin, GIN No. 2022-4/44/3169/20; the reticulum of the inner layer is clearly visible in the center of the oral opening; (i–k) *Tubellus hunziker*i (Odin): (i) GIN No. 2022-4/14/3169/24, (j) GIN No. 2022-4/13/3169/24, (k) GIN No. 2022-4/19/3169/24; (l) *Scutellella (Tetratropis) terrina* (Bison, Wendler, Versteegh et Willems), GIN No. 2022-2/109/3177/20. Scale bar is 100 μm.

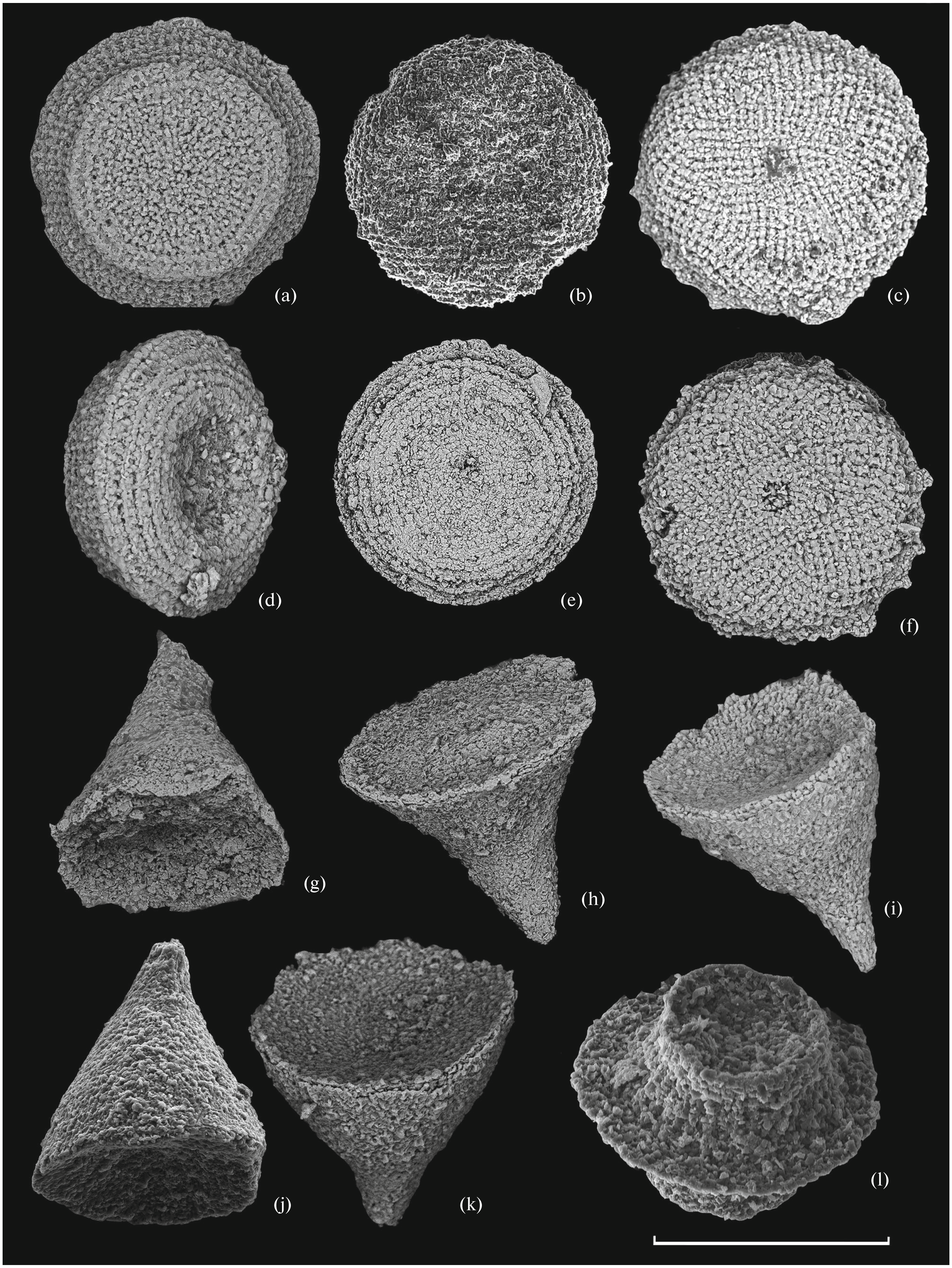
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Fig. 18. Calcareous microproblematics from the Polyus section. (a–g) *Gilianella tenuibrachialis* Odin: (a, a') GIN No. 2022-1/21/3177/32, (a) top view, the oral surface is clearly visible; (b, b') GIN No. 2022-1/74/3177/43, the lateral view shows holes from broken needles at the peripheral margin and elevation in the oral area; (c, c') GIN No. 2022-1/11/3177/32; (d, d') GIN No. 2022-1/76/3177/43, a gap is visible at the junction of the two wings; (e) GIN No. 2022-1/23/3177/32; (f, f') GIN No. 2022-1/13/3177/32; (g, g') GIN No. 2022-1/91/3177/45. Scale bar is 50 μm.

trifidus (Stradner in Stradner and Papp), distributed from the upper Campanian (UC15d Subzone) to the lower Maastrichtian (UC17 Zone of Burnett). It should be noted that there is a stratigraphic unconformity at the Campanian/Maastrichtian boundary, which is not possible to recognize by nannoplankton data. The UC15e Subzone was not recognized in the Crimean sections at the moment. The lower boundary of the UC16 Zone is drawn by the LO of *Eiffellithus eximius* (Stover) Perch-Nielsen, while the upper boundary is drawn from the LO of *Eprolithus rarus* Varol, and *Broinsonia parca constricta* (Burnett, 1998; Gale et al., 2020) in the section. The UC17 Zone was identified along the upper boundary of the distribution of *Biscutum dissimilis* Wind et Wise in Wise and Wind, *Tranolithus orionatus* (Reinhardt), *Uniplanarius gothicus* (Deflandre), and *Uniplanarius trifidus* (Burnett, 1998). The latter species is quite rare in Chakhmakhly, and it is problematic to define the boundary of the zone. The UC18 Zone is probably absent in the Chakhmakhly section, since its upper boundary is drawn by the disappearance of *Reinhardtites levis* (Burnett, 1998). The presence of the upper Maastrichtian UC19 Zone was established by the presence of *Biscutum magnum* Wind et Wise in Wise and Wind, 1977 in the section, which is unknown in higher succession (Baraboshkin et al., 2023a, 2023b).

Thus, calcareous nannoplankton is widespread in the Cretaceous deposits of Crimea and is suitable for solving biostratigraphic problems. The data obtained from it correlate well with the subdivisions of the Tethyan scale (Fig. 19), despite the fact that 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.

MAGNETOSTRATIGRAPHY

The integrated bio-, chemo and magnetostratigraphic studies of the Upper Cretaceous of Crimea began in 2014. By now, data on the magnetic properties and paleomagnetism of all Upper Cretaceous stages have been obtained from 10 reference sections in southwestern Crimea and only one, the Alan-Kyr section (Fig. 2: Kp80), in central Crimea. In total, samples from 1000 stratigraphic levels have been collected and examined. Samples for different types of analyzes were taken using the "sample-to-sample" system, so the data from all methods are reliably linked with each other.

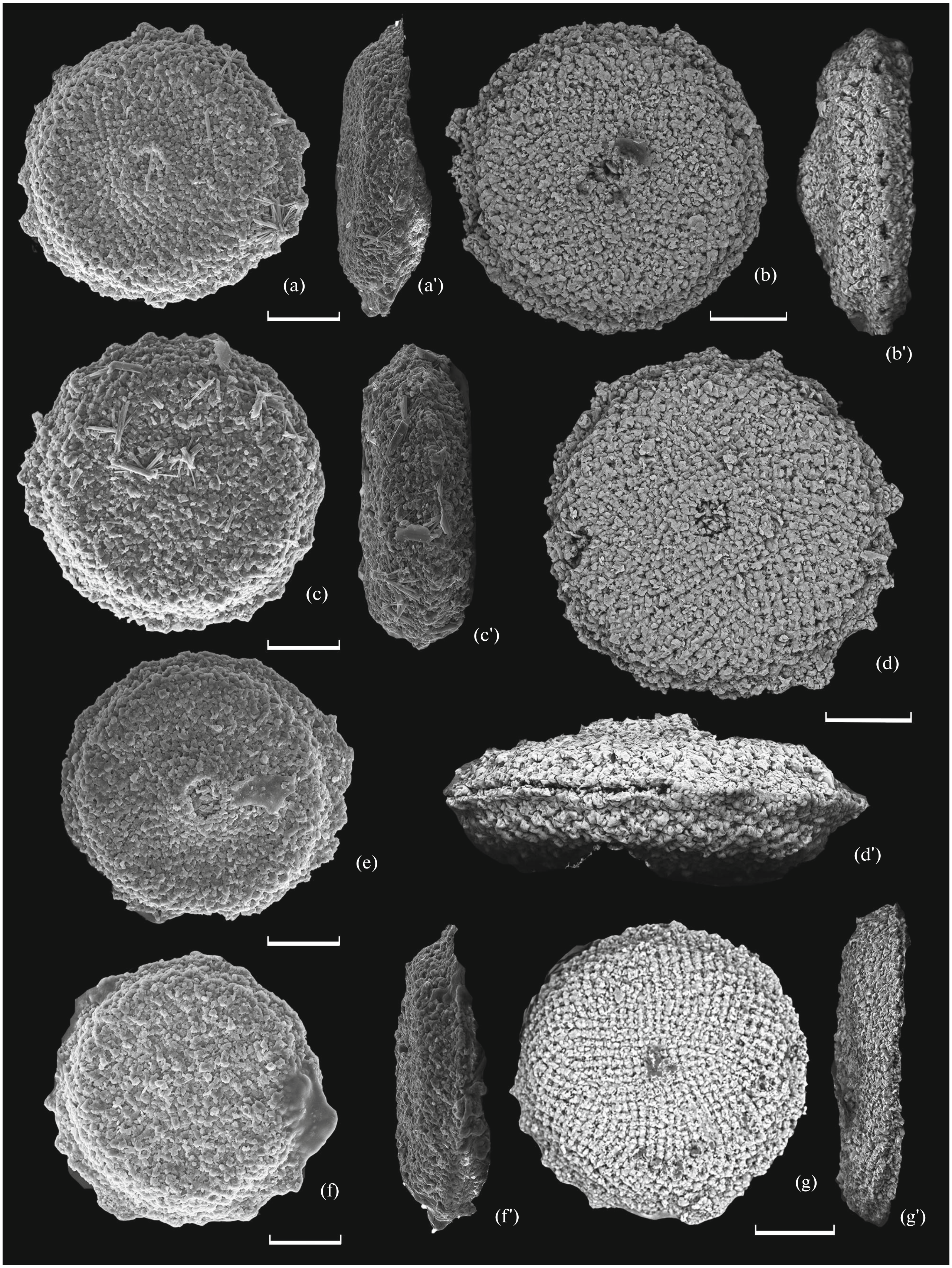
The composite magnetostratigraphic section of the Upper Cretaceous from southwestern Crimea (Fig. 20) presents generalized information on the geomagnetic polarity regime and data on magnetic susceptibility (K), its increase upon heating to 500°C (dK).[1] Three reverse polarity magnetozones have been recognized within the composite paleomagnetic column against the background of dominant normal polarity: one in the Campanian and two in the Maastrichtian (Fig. 20). These magnetozones identified with the GPTS Chrones, and sedimentary ratios (Chron duration to magnetozone thickness ratio) were calculated for them. The results of the cyclostratigraphic analysis of the vertical succession of magnetic susceptibility data in the Maastrichtian deposits were used to reveal cyclicity associated with periodical changes of the Earth's orbit parameters (Milankovitch cycles). Together with the sedimentary ratios, they has allowed evaluation of the absolute duration of stratigraphic units and sedimentary rates.

Variations of magnetic parameters are interpreted as indicative of variable environments of the Cretaceous accumulation.

Paleomagnetism of the Cenomanian and of the lowermost Turonian is the least studied in Crimea. Judging from the currently available data from the Selbukhra (Cenomanian, Fig. 2: Kp12b) and Kizil-Chigir (lower–middle Turonian, Fig. 2: Kp12d) sections (Guzhikov et al., 2024), this interval is peculiar for dominant normal polarity, which is in according with conventional ideas about the geomagnetic field regime at the beginning of the Late Cretaceous (Gradstein et al., 2020).

In the uppermost Turonian, in the Coniacian and Santonian (except for the top of the stage), an abnormal polarity zone has been recorded, peculiar for high-amplitude paleosecular variations and numerous excursions (Guzhikov et al., 2024). Similar abnormal regime of geomagnetic field is characteristic of the epochs of geomagnetic reversals, with durations, according to the current data, less than 20 thousand years (Valet and Herrero-Bervera, 2007). Nevertheless, sound paleontological support for the studied sections Chuku (Klikushin, 1985; Fig. 2: Kp76), Aksu-Dere and Kudrino-2 (Guzhikov et al., 2021a, 2021b; Kopaevich and Walaszczyk, 1990; Fig. 2: Kp74)

[1] The increase of $dK = K_t - K$ reflects the content of finely dispersed pyrite in the sample owing to phase transition of nonmagnetic FeS_2 to highly magnetic Fe_3O_4 at the temperatures above 400°C.


(a)
(a')
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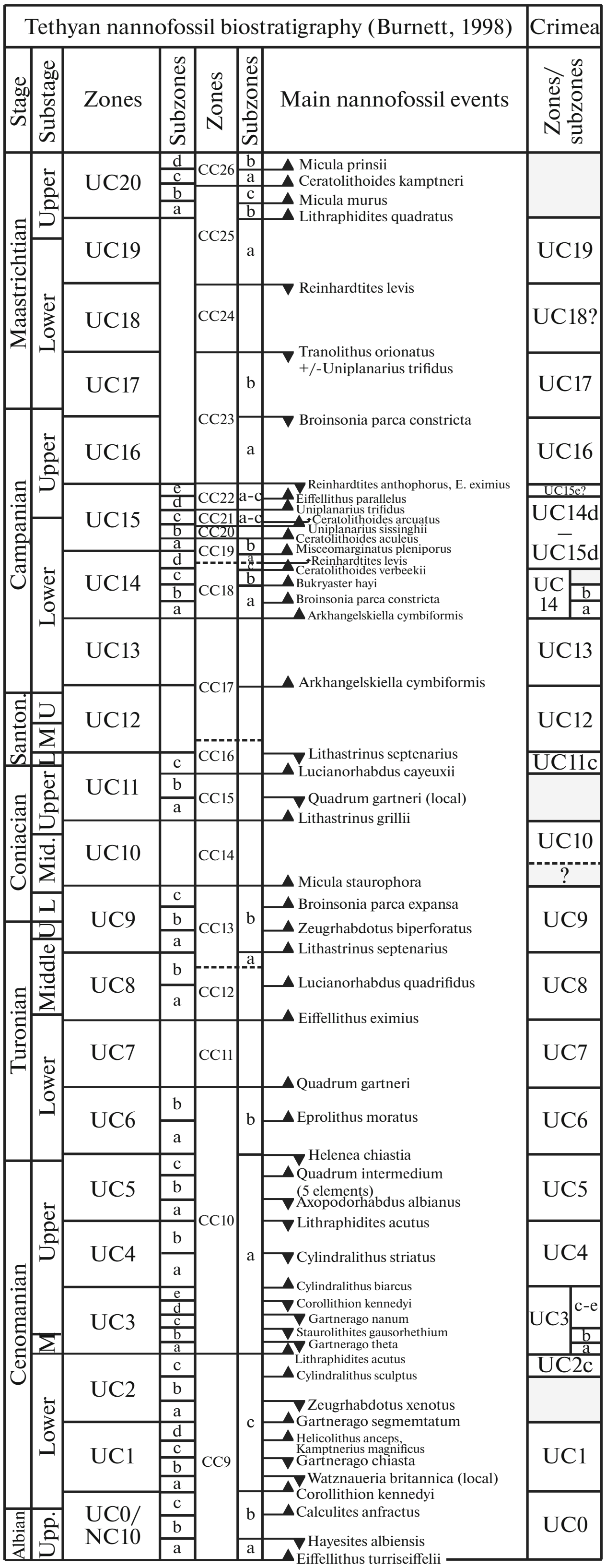

Fig. 19. Upper Cretaceous nannofossil biostratigraphy of the Mountainous Crimea.

prevents from any doubts regarding the stratigraphic completeness of the upper Turonian, Coniacian and lower (?)–upper Santonian deposits that were formed over a period of ~ 6 million years (Gradstein et al., 2020).

Paleomagnetic data on the upper Turonian, Coniacian and Santonian from SW Crimea are at variance with the concept of the stable normal polarity regime at that period (Gradstein et al., 2020), but is basically compliant with the data on coeval deposits from South England (Montgomery et al., 1998), the Volga Region (Guzhikova et al., 2019, 2020a, 2021), Tuarkyr (Guzhikov et al., 2003), West Siberia (Gnibidenko et al., 2014) and other regions with the records of complicated (alternating or abnormal) paleomagnetic zonation of the Turonian–Santonian. This information implies the possibility of reconsidering the ideas of the normal geomagnetic field regime at the end of the Cretaceous Superchron, given the fact that the alternative data making the basis for traditional notion of the simple monopolar structure of the Turonian–Santonian is similarly objectionable (Guzhikova et al., 2019).

Reverse polarity magnetozones, analogues of Chron 33r, have been recognised in the lower part of the Campanian in southwestern Crimea (Kudrino, Kudrino-2, Aksu-Dere sections) (Guzhikov et al., 2021a, 2021b; Baraboshkin et al., 2024). A reverse polarity magnetozone has also been revealed in the Santonian–Campanian boundary interval in Central Crimea (the Alan-Kyr section), but it has been assigned to the uppermost of the Santonian according to the micropaleontologic data (Ovechkina et al., 2021a).

The geomagnetic reversal 34n–33r represents an isochronous reference level of the global scale. Along with the level, corresponding to the carbon isotope event SCBE at the Santonian–Campanian boundary, also detected in SW Crimea, it could be used as the datum for calibration of paleontological reference levels on the global scale. The calibration results show that the time shift of nannoplankton-based stratigraphic boundaries, may constitute about 10^6 years in remote regions (Fig. 21). Therefore, it is advisable to determine the base of the Campanian in the base of magnetic Chron 33r, a marker allowing the most precise synchronizing of the stage boundary in different regions (Guzhikov et al., 2021a, 2021b). The idea has been repeatedly suggested by the authors of the Geological time scale (Gradstein et al., 2020) and other researchers (Wolfgring et al., 2018a, 2018b).

As to completeness of the geologic record, abundance of key fossils and the level of integrated study, the Santonian–Campanian boundary interval in SW Crimea is as good as its age analogues from North Texas and South England that claim to be the GSSP Campanian (Gale et al., 2023). This allows to look at the composite section Aksu-Dere-Kudrino as still concurrent of limitotype or an auxiliary section of the Campanian lower boundary (Guzhikov et al., 2021a, 2021b).

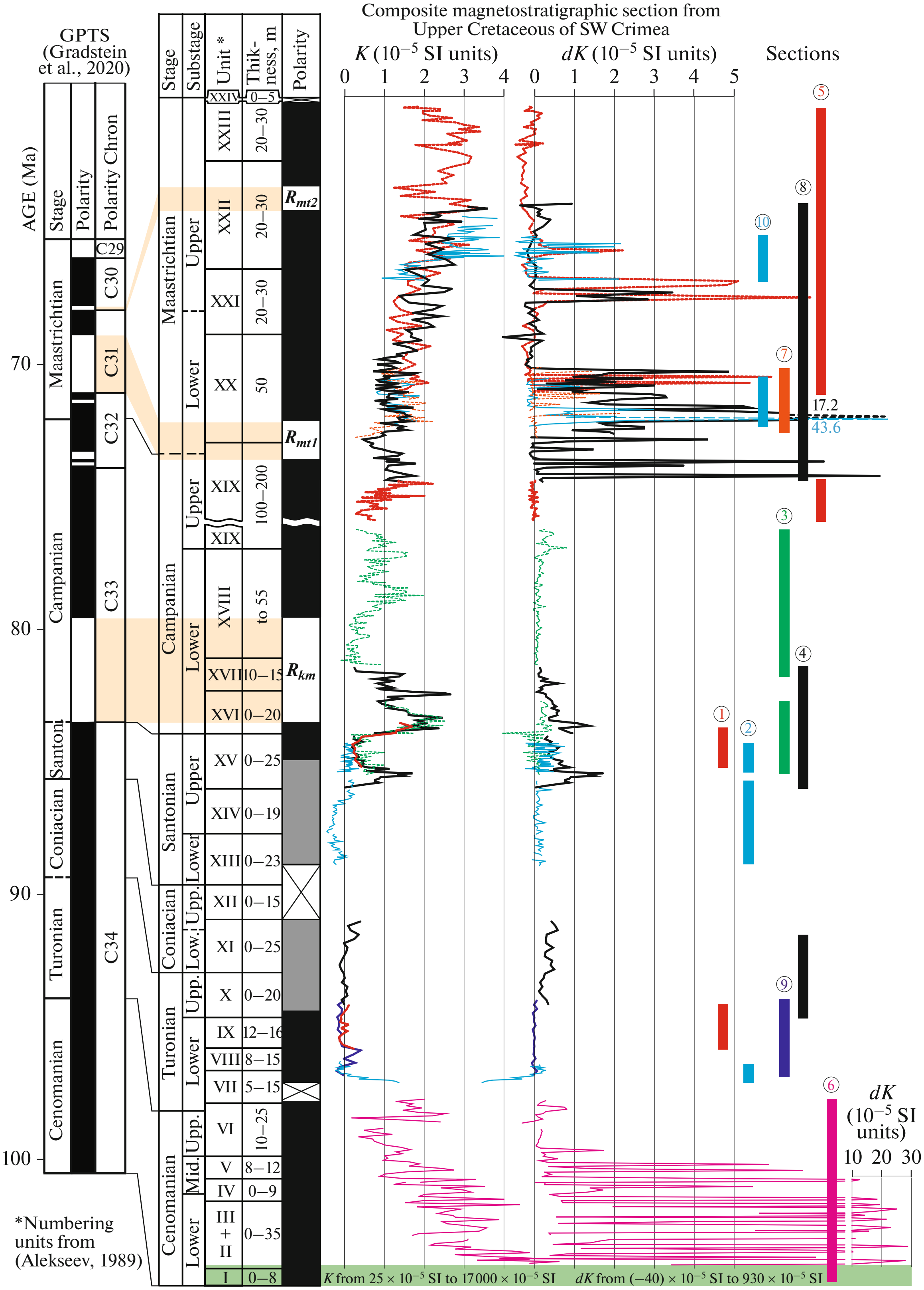

Fig. 20. Composite magnetostratigraphic section of the Upper Cretaceous from southwestern Crimea. Section numbers: SW Crimea: the Belbek river valley: (1) Turonian gully (K_2t-st), (2) Chuku Mountain (K_2t–st); the Kacha river valley: (3) Kudrino (K_2st–km), (4) Aksu-Dere ravine (K_2t–km); (5) Beshkosh Mountain; the Bodrak river valley: (6) Selbukhra Mountain (K_1s), (7) Biyuk-Charysh Mountain (K_2mt), (8) Chakhmakhly ravine (K_2km$_2$?–mt), (9) Kizil-Chigir Mountain (K_2t), (10) Takma ravine (K_2mt). I, II and III—normal, reverse and abnormal geomagnetic polarities, respectively, IV—no polarity data available.

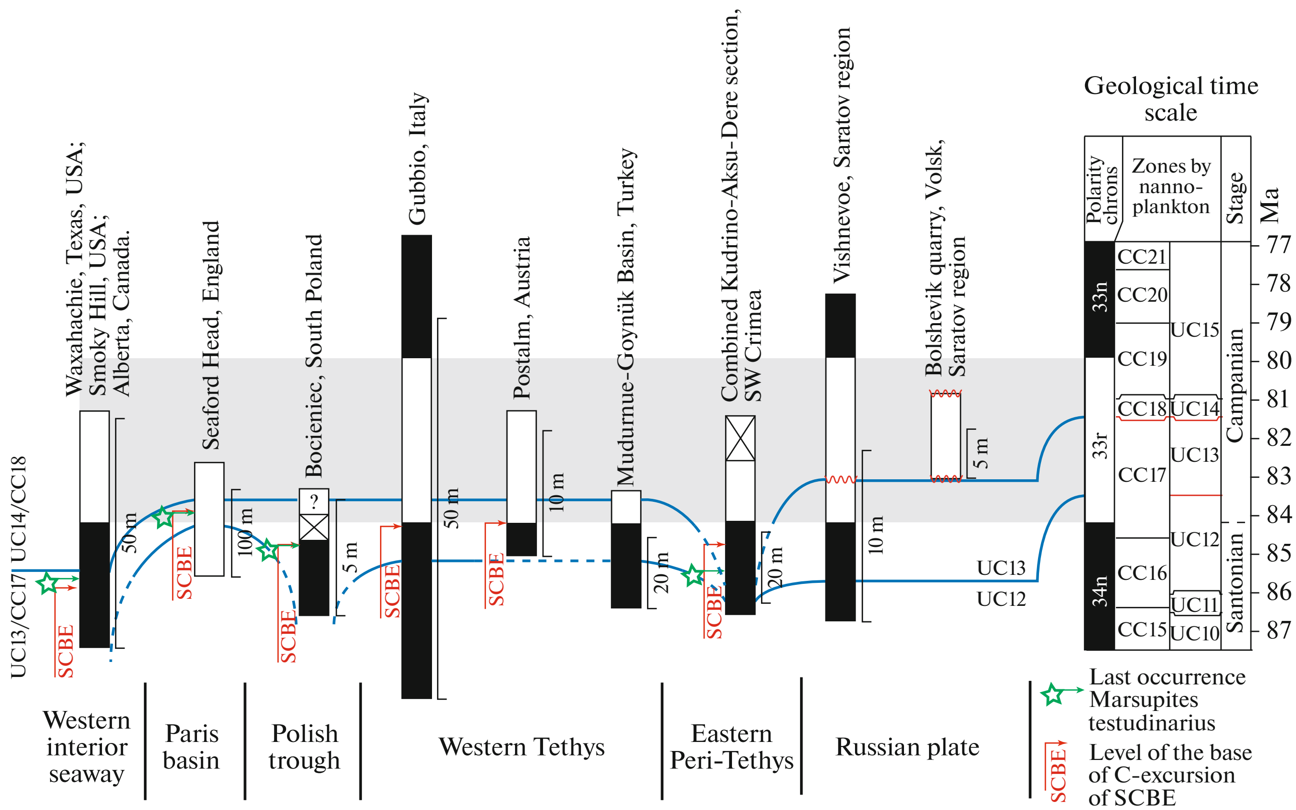

Fig. 21. Results of the interregional calibration of biostratigraphic boundaries (from nannoplankton and the LO of *M. testudinarius*) relative to 34n–33r inversion and SCBE carbon event from (Guzhikov et al., 2021b). See Fig. 20 for the legend.

Two reverse polarity zones have been recognized in the Maastrichtian. The lower magnetozone ($\boldsymbol{R_{mt1}}$) has been detected in the lowermost Maastrichtian from Chakhmakhly ravine (Guzhikova, 2018; Fig. 2, Kp78), and probably in the lowermost Maastrichtian of Biyuk-Charysh Mountain (the section between the Beshkosh and Chakhmakhly sections). No reversals have been found in the lower Maastrichtian deposits of Beshkosh Mountain (Baraboshkin et al., 2020; Fig. 2, Kp77). $\boldsymbol{R_{mt1}}$ is identified as Chron C31r, its absence in the Beshkosh section, as well as the small thickness in the Chakhmakhly section are associated with a stratigraphic hiatus at the top of the Campanian (Member XIX), registered by means of petromagnetic method, petrographic analysis and micropaleontological data (Baraboshkin et al., 2020, 2023a, 2023b).

The reverse polarity zone $\boldsymbol{R_{mt2}}$ was recorded in the upper Maastrichtian in the Beshkosh section. Its lower part was recorded in the uppermost Chakhmakhly section and the Takma (Fig. 2: Kp12d) section. $\boldsymbol{R_{mt2}}$ is identified with the short-term (0.173 million years according to (Gradstein et al., 2020)) Chron C30r (Baraboshkin et al., 2020). The thickness (~20 m) of the magnetozone is accounted for high deposition rates of the Maastrichtian in mixed carbonate-terrigenous conditions. The ratio of $\boldsymbol{R_{mt2}}$ thickness to duration of Chron C30r estimates the average sedimentation rate of 11.6 cm/thousand years, which coincides with the average sedimentation rate (11.7 cm/thousand years), obtained through cyclostratigraphic analysis of the petromagnetic data of the Maastrichtian from the Chakhmakhly and Takma sections (Surinskiy and Guzhikov, 2019).

The principal features of petromagnetic structure of the Upper Cretaceous of SW Crimea (Fig. 20) are the follows.

The trend of upward-decreasing magnetic susceptibility values, observed in the Cenomanian–Santonian reflects the steady declining activity of terrigenous input, coinciding with the basin deepening. Magnetic properties of Cenomanian rocks are largely controlled by the tuffaceous content, with its source in the Plain Crimea and/or Eastern Pontides (Nikishin et al., 2013). The Pontides volcanic activity has resumed in the Campanian (Nikishin et al., 2013), and the increase of *K* in the Santonian–Campanian boundary interval is associated with new arrival of tuffaceous materials. The increasing dK values in the lowermost Cenomanian and in the Santonian–Campanian boundary interval may also be associated with volcanogenic iron sulfides and with their concentration due to the slow sedimentation.

Varying magnetic susceptibilities in the Campanian, except the lower part, and in the lowermost Maas-

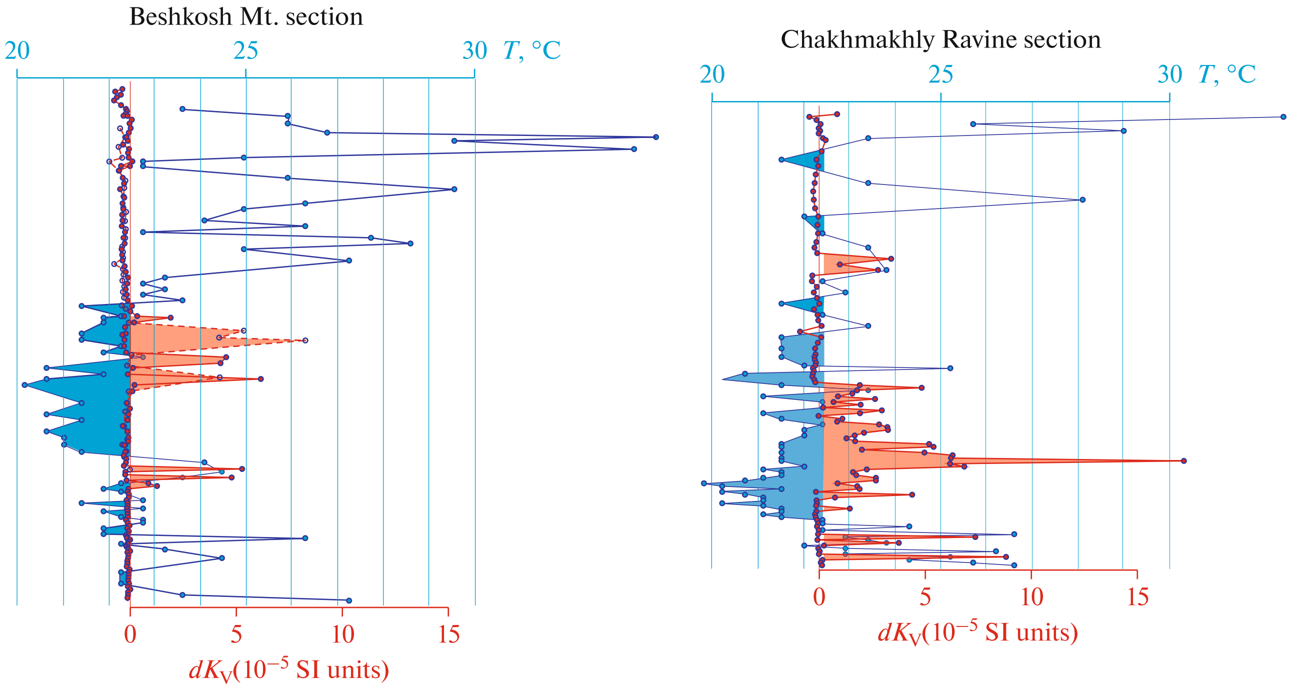

Fig. 22. Comparison of isotope (blue curves) and thermokappametric (red curves) data from Beshkosh and Chakhmakhly Campanian–Maastrichtian sections. The isotope-oxygen temperatures of carbonate formation have been calculated subject to equilibrium with recent average ocean water ($\delta^{18}O = 0‰$).

trichtian may be associated with varying rates of carbonate production affected the terrigenous content. In this case, K variations along the section are in inversed relevant to the sedimentary rates.

The apparent trend of growing magnetic susceptibility in the Maastrichtian is associated with the increasing terrigenous input. Therefore, the K curve reflects the dynamics of the paleobasin regression in the end of the Cretaceous finished by subsequent drying and erosion (see above).

The intervals of high dK values at the Campanian–Maastrichtian boundary and in the mid-Maastrichtian indicate dysoxia in the sediment. They are correlatable with the Campanian–Maastrichtian boundary event (CMBE) and the middle Maastrichtian boundary event (MME), respectively (Jung et al., 2013). The dysoxic conditions are associated with possible growing of the water stratification in the World Ocean with the increase of its duration due to the cooling episodes recorded in CMBE and MME. The interrelations between the thermokappametric characteristics and the paleoclimate variations may be proved by the fact that the increased dK values are confined to the section (Fig. 22).

CONCLUSIONS

The Crimea Peninsula is one of the very interesting regions of the northern Peritethys area. Standing on the boundary of Boreal and Tethyan Realms it includes many features of the geological development of both of them. A lot of interesting data on the Cretaceous development and stratigraphy of the region were received for almost 200 years of study. Significant progress in the stratigraphic studies has been reached during the last 20–30 years. Despite it a lot of geological problems are not solved and a lack of the new results of modern-level is present. First of all, the results from non-paleontological methods are required: stable isotope data, geochronology, and fine geochemical and lithological research. A study of a number of biostratigraphic groups will be very important: Late Cretaceous dinocysts, Early and Late Cretaceous forams, bivalves, echinoids and crinoids. The analysis of the calcareous algae will bring important stratigraphic and sedimentologic results with no doubt. 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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