Cretaceous Research 87 (2018) 5–41

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Biostratigraphy and magnetostratigraphy of the upper Tithonian–Berriasian of the Crimean Mountains

Vladimir Arkadiev [a], Andrey Guzhikov [b], Evgenyi Baraboshkin [c], Juliya Savelieva [d], Anna Feodorova [d], Olga Shurekova [d, *], Egor Platonov [d], Aleksey Manikin [b]

[a] Saint Petersburg State University, University Embankment 7/9, 199034 Saint Petersburg, Russia
[b] Saratov State University, Astrahanskaya Street 83, 410012 Saratov, Russia
[c] Moscow State University, Leninskie Gory Street 1, 119991 Moscow, Russia
[d] AO 'Geologorazvedka', Knipovich Street 11/2, 192019 Saint Petersburg, Russia

ARTICLE INFO

Article history:
Received 17 January 2017
Received in revised form
17 July 2017
Accepted in revised form 19 July 2017
Available online 25 July 2017

Keywords:
Calpionellids
Ammonite
Micropalaeontology
Magnetostratigraphy
Tethyan realm
Eastern Europe

ABSTRACT

Our data from studies over many years on upper Tithonian–Berriasian strata of the Crimean Mountains are summarised. Their zonal subdivision has been significantly refined using ammonites and foraminifera, as well as on the basis of calpionellid, ostracod and dinocyst distributions. We have been able to document the presence of all standard Tethyan zones in the Berriasian, i.e., the Jacobi, Occitanica and Boissieri Zones, identified on the basis of foraminifera, ostracods and dinocysts. Based on calpionellids (families Chitinoidellidae and Calpionellidae) in Eastern Crimea, three standard zones were identified: Chitinoidella (Dobeni and Boneti Subzones; Tithonian), Crassicollaria (Remanei and Massutiniana subzones; Tithonian) and Calpionella (Alpina and Elliptica subzones; Berriasian). Tithonian and Berriasian calpionellid assemblages were identified in Southwestern Crimea. A magnetostratigraphic scale for the upper Tithonian–Berriasian has been also developed, thus corroborating a continuous succession of magnetic chrons from M20 through M14. The existence of the M16n.1r subchron ('Feodosiya') is substantiated; it should be included into the Geomagnetic Polarity Time Scale. The base of polarity chron M18r appears to be the most likely choice among other palaeomagnetic intervals to determine the lower boundary of the Cretaceous System, because it is close to the base of the Grandis Subzone in Tethyan sections and the Chetae Zone in Boreal sections.

1. Introduction

The Tithonian–Berriasian boundary interval in the Crimean Mountains (Fig. 1) is known to extend from the northeast (Feodosiya) to the southwest (Sevastopol). The main features of these sections include significant facies variations, a wide range of variation with respect to thickness of deposits and the incomplete stratigraphical record. The Crimean Mountains are characterised by complex tectonics. Continuous sections of Berriasian strata are missing. A detailed historical review of the various approaches towards subdivision of these deposits has been recently published (Arkadiev et al., 2012).

Numerous scientists have previously studied the Berriasian of the Crimea, including Retowski (1893), Druschits (1975), Kvantaliani and Lysenko (1979), Bogdanova et al. (1981, 1984), Bogdanova and Kvantaliani (1983), Kuznetsova (1983), Glushkov (1997), Arkadiev et al. (2006), Arkadiev et al. (2015a,b), Platonov and Arkadiev (2011), Platonov et al. (2013), Platonov (2014), Arkadiev and Guzhikov (2016), Arkadiev et al. (2016) and others.

During their research several problematic issues have been encountered by ourselves, as follows:

1) a clarification of ammonite and foraminiferal zonations; 2) an improvement of calpionellid, ostracod and dinocyst zonations and comparison with the ammonite-based subdivision; 3) development of a magnetostratigraphic scheme for the upper Tithonian–Berriasian and correlation with the ammonite zones; 4) to provide biostratigraphic and magnetostratigraphic justification of the Jurassic–Cretaceous (Tithonian–Berriasian) boundary in the

* Corresponding author.
E-mail addresses: arkadievvv@mail.ru (V. Arkadiev), aguzhikov@yandex.ru (A. Guzhikov), ejbaraboshkin@mail.ru (E. Baraboshkin), Julia-savelieva7@mail.ru (J. Savelieva), annafedoroff@yandex.ru (A. Feodorova), o.antonen@gmail.com (O. Shurekova), platonov_egor@inbox.ru (E. Platonov), agmanikin@mail.ru (A. Manikin).

http://dx.doi.org/10.1016/j.cretres.2017.07.011
0195-6671/

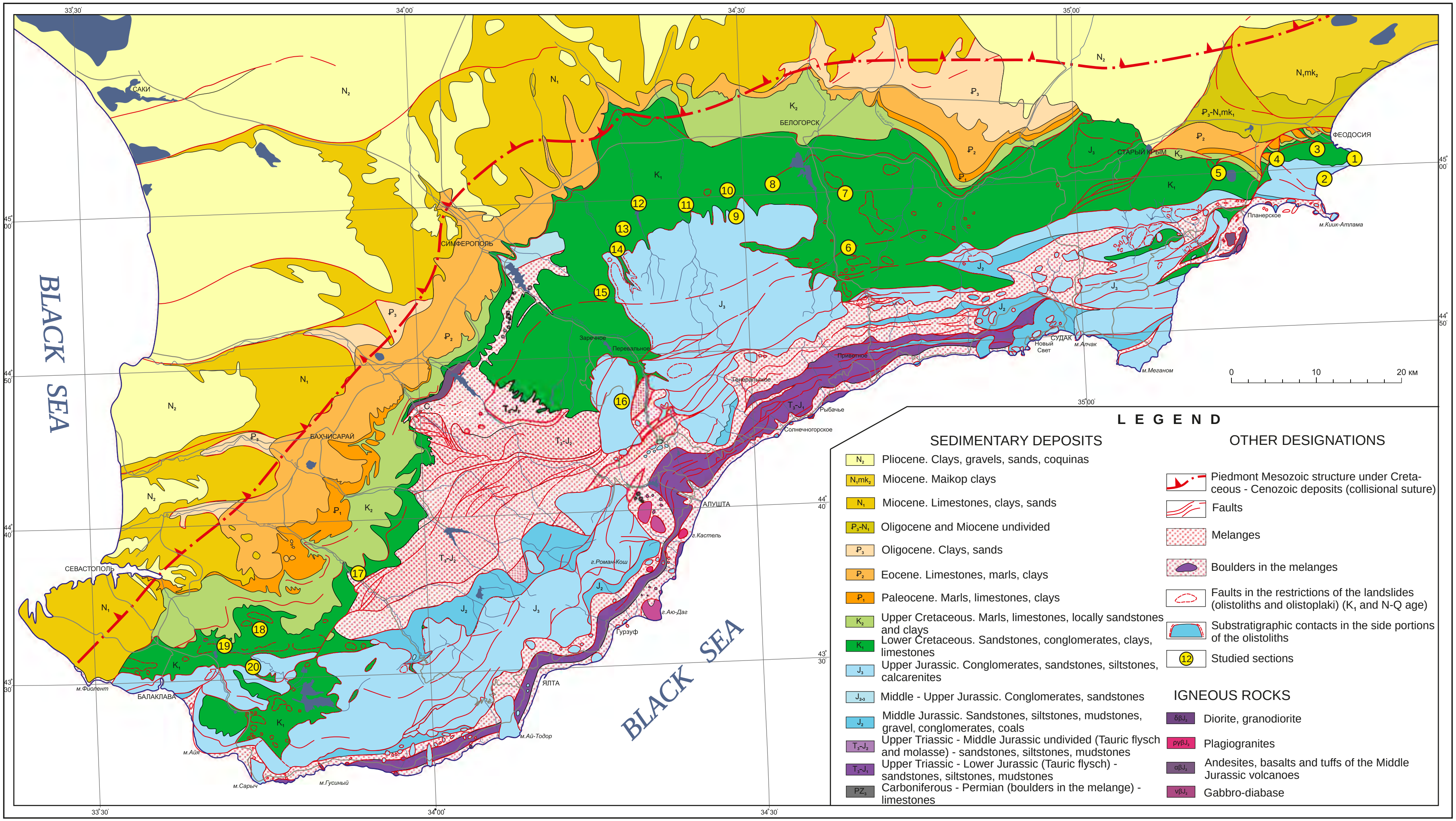


Fig. 1. Location of the sections studied (geological map by Yudin, 2009). 1 — Feodosiya and Saint Elias Cape; 2 — Dvuyakornaya Bay; 3 — Zavodskaya Balka; 4 — Sultanovka Village; 5 — Nanikovo Village, Koklyuk Mountain; 6 — Tonas River Basin, Krasnoselovka Village; 7 — Tonas River Basin, Alekseevka Village; 8 — Sary-Su River Basin, Novoklenovo, Kozlovka Villages; 9 — Karaby Yaila; 10 — Sary-Su River Basin, Balki Village, Enisaray Ravine; 11 — Mezhgor'e Village, Baksan Mountain, 12 — Zuya River Basin, Lesnoye Village; 13 — Fundukly River Basin, Petrovo Village; 14 — Beshterek River Basin; 15 — Maly Salgir River Basin; 16 — Chatyr Dag, Mramornoye Village; 17 — Belbek River Basin; 18 — Chernaya River Basin, Rodnoye and Kuchki Villages; 19 — Chernaya River Basin; 20 — Minester Ravine.

Crimean Mountains; 5) correlation of these zonations with Tethyan ammonite zones.

2. Material and methods

Between 2009 and 2015 a team of geologists from Saint Petersburg State University, Moscow State University, Saratov State University and AO 'Geologorazvedka' (Saint Petersburg) carried out interdisciplinary (biostratigraphic, magnetostratigraphic and lithological) studies of upper Tithonian–Berriasian sections in the Crimean Mountains. A total of 30 sections were studied comprehensively; while collecting ammonites, scientists also amassed samples for microfaunal, palynological and palaeomagnetic analyses, using a 'matching sample' system. In eastern Crimea the team worked out detailed descriptions of sections in which the boundary between Jurassic and Cretaceous deposits was exposed, such as those near Feodosiya (Dvuyakornaya Bay, Saint Elias Cape), as well as Berriasian–Valanginian sections at Zavodskaya Balka, Sultanovka and Nanikovo (Koklyuk) and Berriasian sections along the Tonas River (near the Krasnoselovka and Alekseevka Villages). In central Crimea, the team studied Berriasian sections near the Novoklenovka, Balki and Mezhgor'e Villages. Results of previous studies in southwestern Crimea were summarised (Atlas …, 1997; Arkadiev and Bugrova, 1999; Bogdanova and Arkadiev, 1999). Ammonites were identified by V.V. Arkadiev, T.N. Bogdanova and E. Yu. Baraboshkin, foraminifera by A.A. Feodorova, ostracods by J.N. Savelieva, organic-walled dinoflagellate cysts, spores and pollen by O.V. Shurekova and calpionellids by E.S. Platonov and I. Lakova (Bulgaria). Magnetostratigraphic studies were performed by A. Yu. Guzhikov, M.I. Bagaeva and A.G. Manikin.

Ammonite collections discussed in the present paper are housed at the CNIGR Museum (F.N. Chernyshev Central Research Geological Museum, Saint Petersburg) under registration numbers 10916, 12943, 13077, 13098, 13139, 13143, 13146, 13175 and 13209, as well as at the Museum of the National Mineral Resources University (Mining University, Saint Petersburg, no. 333), the Earth Science Museum of Moscow State University (no. 131), the Paleontological-Stratigraphical Museum of Saint Petersburg State University (nos 381, 382 and 409) and the Paleontological Museum of the Georgian Technical University, Tbilisi (no. 3017/1-10).

Microfaunal and palynological analyses were done on predominantly clayey rock samples (average weight 0.5–0.8 kg). Foraminifera were studied in preparations and in thin sections oriented in different planes. Polished sections of foraminiferal tests extracted from the matrix were prepared for several levels. A total of 400 preparations and >1000 thin sections and polished sections were studied. 162 samples were collected for palynological studies, while calpionellids were examined in approximately 1000 thin sections. Ostracods were photographed using a scanning electron microscope at the Electron Microscopy Laboratory of the Paleontological Institute (Moscow) by E.M. Tesakova (Moscow State University), whereas foraminifera and dinocysts were photographed using an optical microscope. Foraminifera, ostracods, palynological slides and residues are kept at the Department of Petroleum Geology of the AO 'Geologorazvedka', Saint Petersburg.

In total, nearly 700 oriented samples from different stratigraphic levels were taken. Each of the oriented samples was split into 3–4 cubes of 20 mm long. The palaeomagnetic study of these samples included series of magnetic cleaning using alternating field (in LDA-3 AF Demagnetiser) and temperature (in Aparin's Furnace), to isolate characteristic remnant magnetisation (ChRM) and determine polarity of the geomagnetic field. The ancient origin of the ChRM was substantiated by field test results (fold test, reversal test, etc.) and the data of magneto-mineralogical studies, which included measurements of magnetic susceptibility and its anisotropy, experiments of magnetic saturation and differential thermomagnetic analysis. A JR-6 Spinner Magnetometer and MFK-1FB Kappabridge were used to measure the remnant magnetisation and magnetic susceptibility, respectively.

3. Geological setting

3.1. Eastern Crimea and Tonas River Basin

Two formations are distinguished within the Berriasian strata in eastern Crimea and in the Tonas River Basin, i.e., the Dvuyakornaya Formation and Sultanovka Formation. The facies compositions of these two are similar, belonging to the same type which differs from sections of central and South-Western Crimea (Arkadiev, 2007a).

The Dvuyakornaya Formation consists of thin, flysch-like interbedding, predominantly of clay and limestone. It includes two parts, the lower of which is distinguished by thin interbeds of calcareous sandstones, absent in the upper, and a large number of siderite concretions. The upper part of the formation includes the Feodosiya Marlstones. We have previously described a section of the Dvuyakornaya Formation near Feodosiya, in the Bay of Dvuyakornaya, at Saint Elias Cape and Feodosiya Cape (Guzhikov et al., 2012) (Figs. 2A–C, 3). In the Tonas River Basin only the upper part of the formation has been identified, with an erosive boundary and conglomerates at the bottom where it follows on reef coral-algal biohermal framestones, presumably of Tithonian age (Figs. 2D, 4). In this particular area the Dvuyakornaya Formation contains thick (up to 2 m) beds of conglomerate-like limestones. The total thickness is 360 m.

The Sultanovka Formation consists of dark grey, monotonous clays with rare sandstone and limestone interbeds and marlstone concretions. It conformably overlies the Dvuyakornaya Formation. The most complete sections of this unit have been studied in the northern outskirts of Feodosiya, at the Zavodskaya Balka quarry (Arkadiev et al., 2010, Arkadiev et al., 2015b (Figs. 2F, 5), near the Nanikovo Village, on Koklyuk Mountain (Fig. 2E) and near the Sultanovka Village. Based on our observations, the contact with the overlying Nanikovo Unit is concordant. The total thickness of this formation is up to 200 m.

3.2. Central and southwest Crimea

In studied sections of central and southwest Crimea the Berriasian Stage is represented mainly by the Bechku and Kuchkinskaya formations. In central Crimea this stage may also include the upper part of the predominantly carbonaceous Bedenekyr Formation, where in the 1970s Tamara Bogdanova found ammonites in the upper part that were typical of the Berriasian Jacobi Zone, such as *Pseudosubplanites ponticus* and *Berriasella jacobi* (Bogdanova et al., 1981; Bogdanova and Kvantaliani, 1983; Arkadiev and Bogdanova, 2004). Near the village of Balki the ammonite *Malbosiceras* ex gr. *malbosi* was collected from limestones of the Bedenekyr Formation in 2012. Consequently, the upper part of this unit was assigned to the Occitanica Zone (Arkadiev et al., 2015a,b). In central Crimea we have studied sections of the Bechku and Kuchkinskaya formations near the villages of Novoklenovo, Balki and Mezhgor'e (Figs. 2G–H, 6) (Savelieva et al., 2014; Arkadiev et al., 2015a). In this area, Berriasian deposits consist of (from bottom to top) packstones and marlstones of the upper part of Bedenekyr Formation; siltstones and sandstones of the Bechku Formation and sponge packstones, clays, marlstones, siltstones and coral-algal biohermal framestones of the Kuchkinskaya Formation. The top of the framestones is eroded, karstified and penetrated by deep (>6 m) vertical fractures, filled with quartz sandstones (Arkadiev,

Fig. 2. A, Outcrop of Dvuyakornaya Formation in Dvuyakornaya Bay; upper Tithonian–lower Berriasian. B, Outcrop of the 'Feodosiya Marlstone Member', Saint Elias Cape; lower Berriasian. C, Outcrop of basal thick limestone, Saint Elias Cape; lower Berriasian. D, Outcrop of clays and limestones (Dvuyakornaya Formation), Tonas River Basin; lower Berriasian. E, Outcrop of clays, Nanikovo Village, Koklyuk Mountain; Berriasian–Valanginian. F, Outcrop of clays, Feodosiya, 'Zavodskaya Balka' section; upper Berriasian. G, Outcrop of clays, Balki Village, upper Berriasian. H. Outcrop of bioherm limestone, Mezhgor'e Village; upper Berriasian.

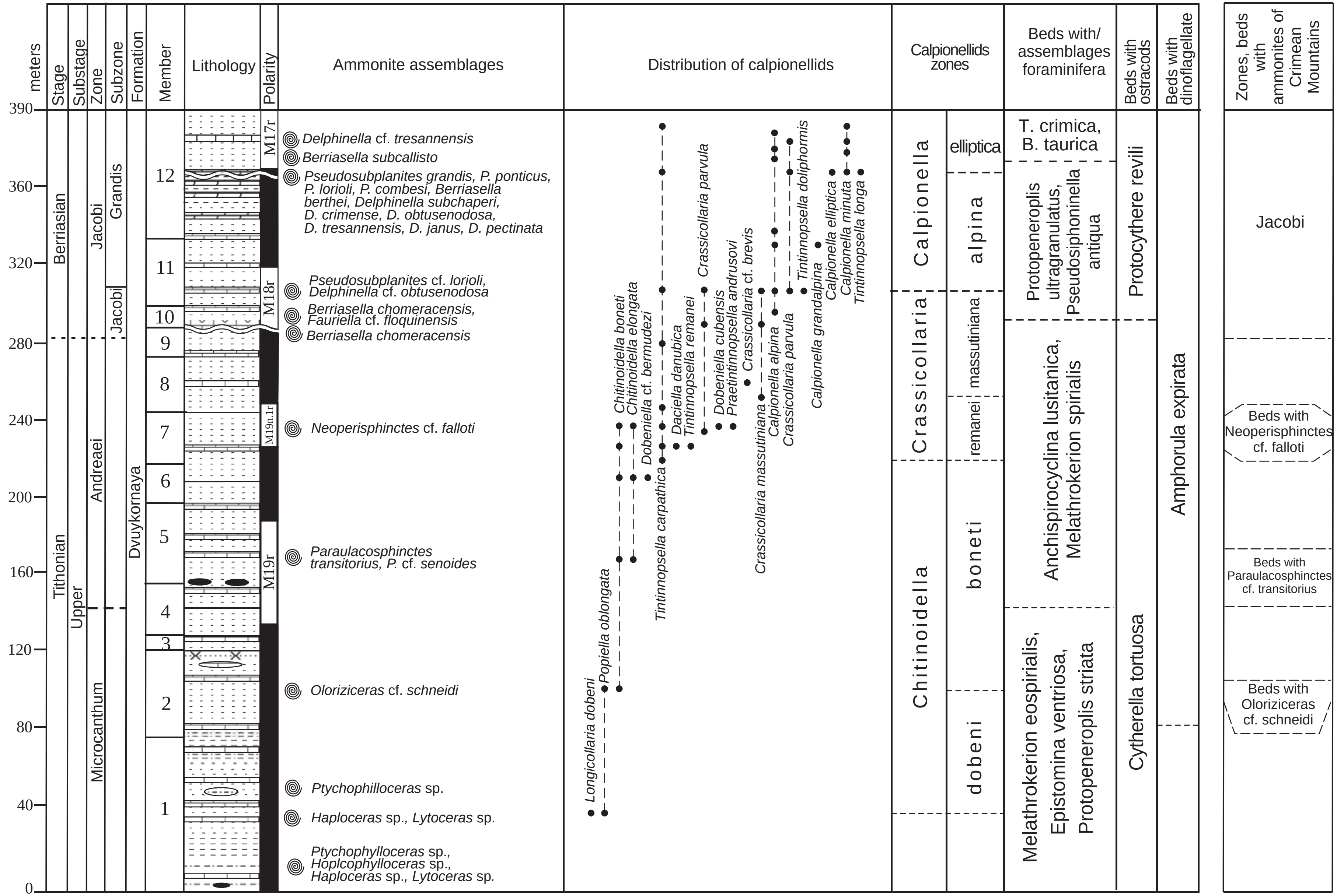


Fig. 3. Composite section of the Dvuyakornaya Formation of Eastern Crimea (Arkadiev et al., 2006; Guzhikov et al., 2012; Platonov et al., 2014).

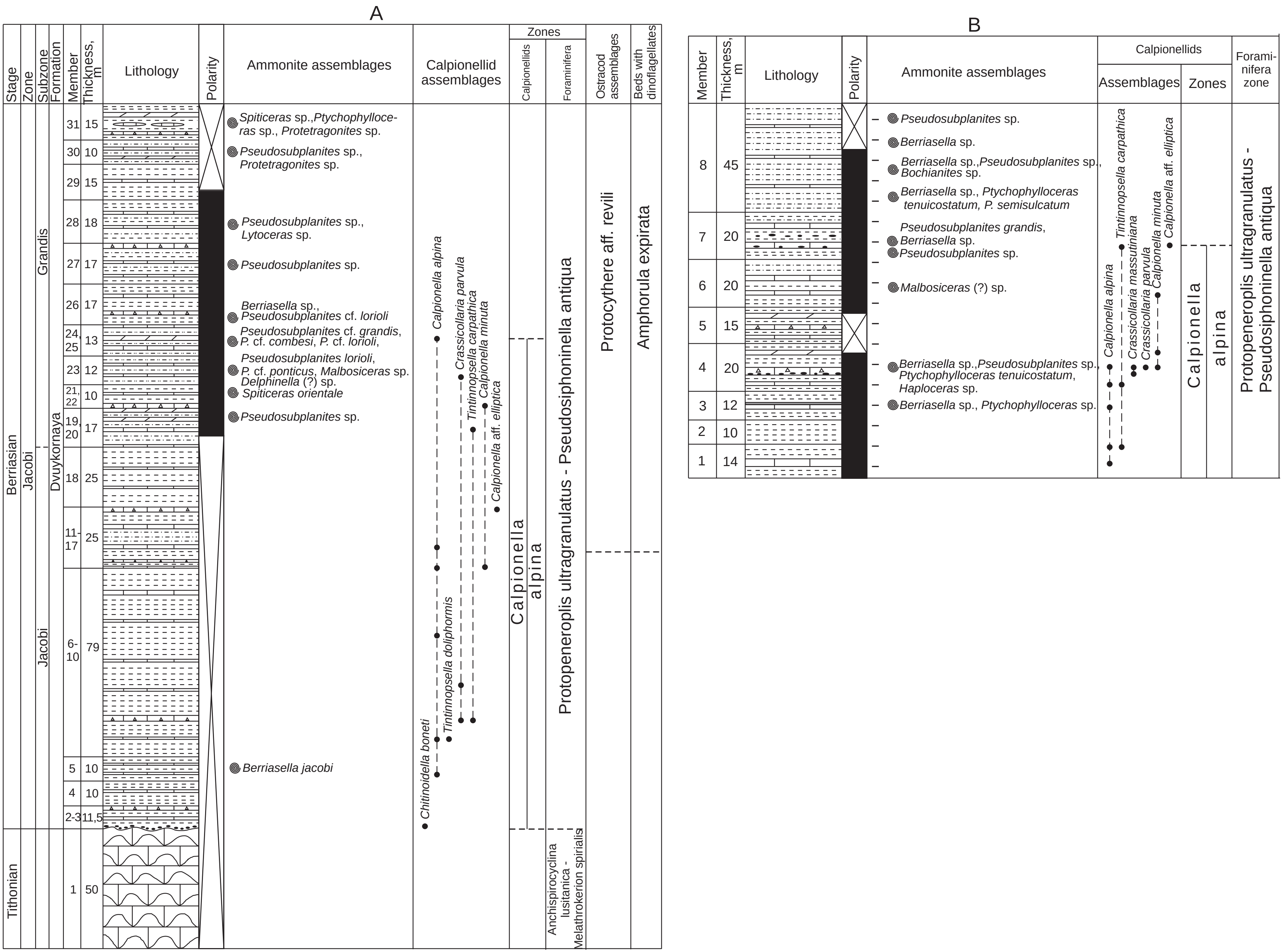


Fig. 4. A, Sections of the Dvuyakornaya Formation in the Tonas River Basin (Yampolskaya et al., 2009; Arkadiev et al., 2012). B, Kuchuk-Usen section (Arkadiev et al., 2012; new magnetic polarity data).

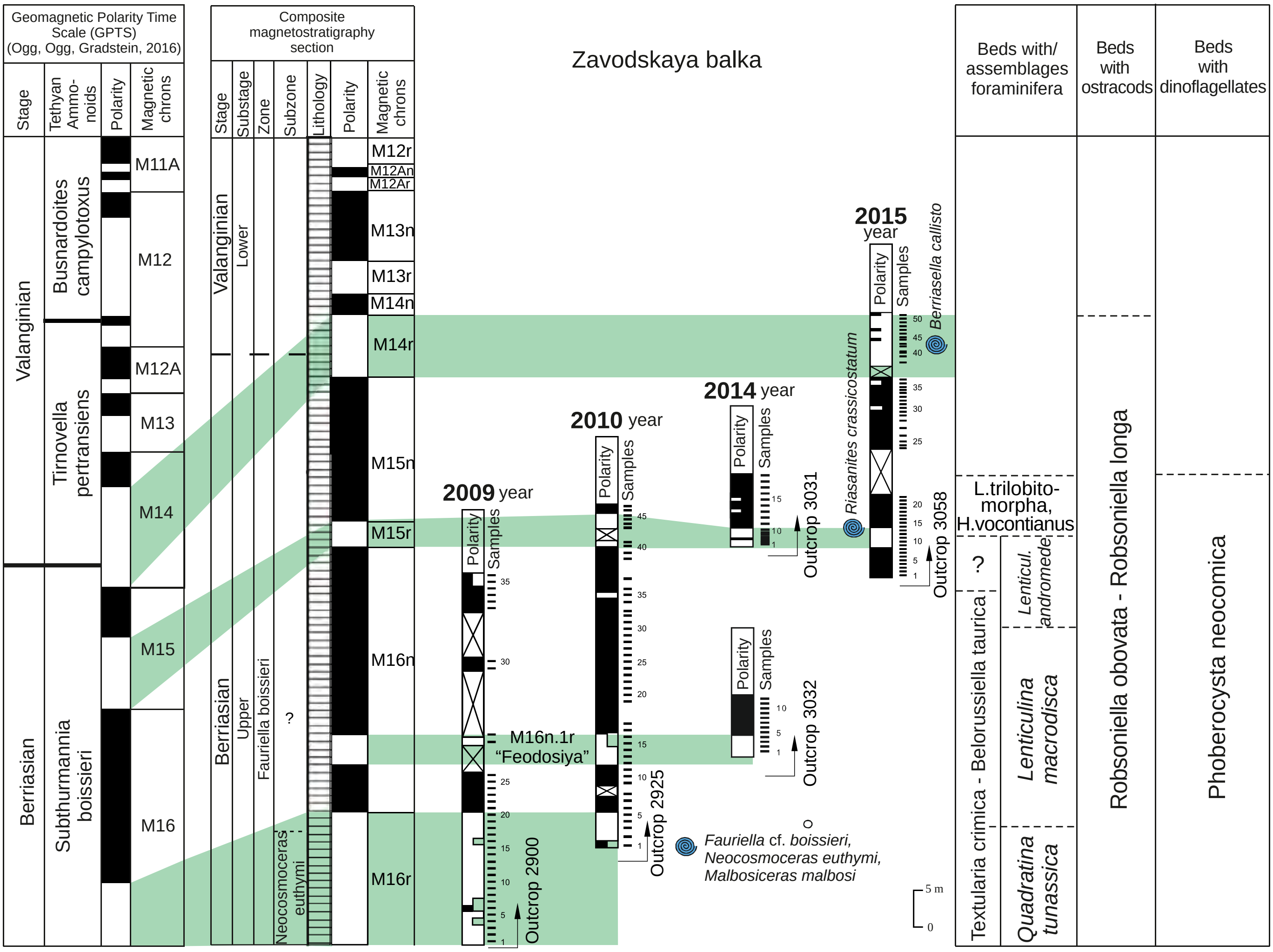


Fig. 5. Berriasian section 'Zavodskaya Balka' (eastern Crimea, Feodosiya) (Arkadiev et al., 2015b; Arkadiev et al., 2016).

2007a). The thickness of obscured parts of the section between isolated outcrops is up to tens of metres in the lower part (i.e., part of the Occitanica Zone) and varies from a few metres to tens of metres in the middle part (i.e., part of the Boissieri Zone). The total thickness of the Berriasian is approximately 600 m.

The Berriasian section in the Belbek River Basin in southwestern Crimea includes the following units (Arkadiev, 2007a): Belbek Unit, Bechku Formation, Kuchkinskaya Formation and Albat Unit.

The Belbek Unit consists of polymictic conglomerates with a sandy-clayey cement. It overlies with a structural unconformity rocks of the Tauric Group of Early Jurassic age, and is followed unconformably by the Bechku Formation. The thickness is up to 40 m. No ammonites were found within the unit, and its dating as Berriasian is only uncertain. The extent of this unit is limited to the Belbek River Basin.

The reference section of the Bechku and Kuchkinskaya formations in the Belbek River Basin is situated in the Kabaniy Ravine (Bogdanova and Arkadiev, 1999; Yanin and Baraboshkin, 2000; Arkadiev et al., 2002) (Fig. 7). The Bechku Formation consists of interbedded sandstones, calcareous sandstones and limestones, in a thickness of approximately 15 m. The overlying Kuchkinskaya Formation includes several discrete units, i.e., an oncolitic limestone bed (15–20 m), a bioclastic limestone bed (30–35 m) and a bioherm limestone bed (15–20 m) (Arkadiev, 2007a; Arkadiev et al., 2012). The last-named contains small (up to 3–5 m tall and 4 m wide), occasionally even larger, bioherms. The bioherms themselves consist of algae and hermatypic corals (Arkadiev and Bugrova, 1999). The thickness of the Kuchkinskaya Formation attains 70 m.

The overlying Albat Unit consists of quartz conglomerates with a carbonate cement. The unit does not contain ammonites and its dating as Berriasian is tentative. It occurs in the Belbek River Basin and in central Crimea, with an overall thickness of up to 70 m.

In the other part of South-Western Crimea, the Baydarskaya Valley and Chernaya River Basin, the Bechku Formation follows on the Eli Formation, which consists of beige oolitic, pseudo-oolitic and bioclastic, stratified and massive limestones with lenticular interbeds of quartz conglomerates (Fig. 8) (Feodorova, 2000). The thickness is up to 400 m. The Eli Formation is found on top of the Kizil-Kaya Formation, which comprises massive bioclastic coral and algal limestones, of white, grey, pink, purple and red colours. The thickness is > 650 m (Feodorova, 2000). The Kizil-Kaya Formation and a significant portion of the Eli Formation have been dated as Tithonian on the basis of foraminifera and calpionellids. The upper part of the Eli Formation is probably of Berriasian age.

4. Biostratigraphy

As an outcome of our studies we have proposed a zonal subdivision of the upper Tithonian, a significantly refined zonation of the

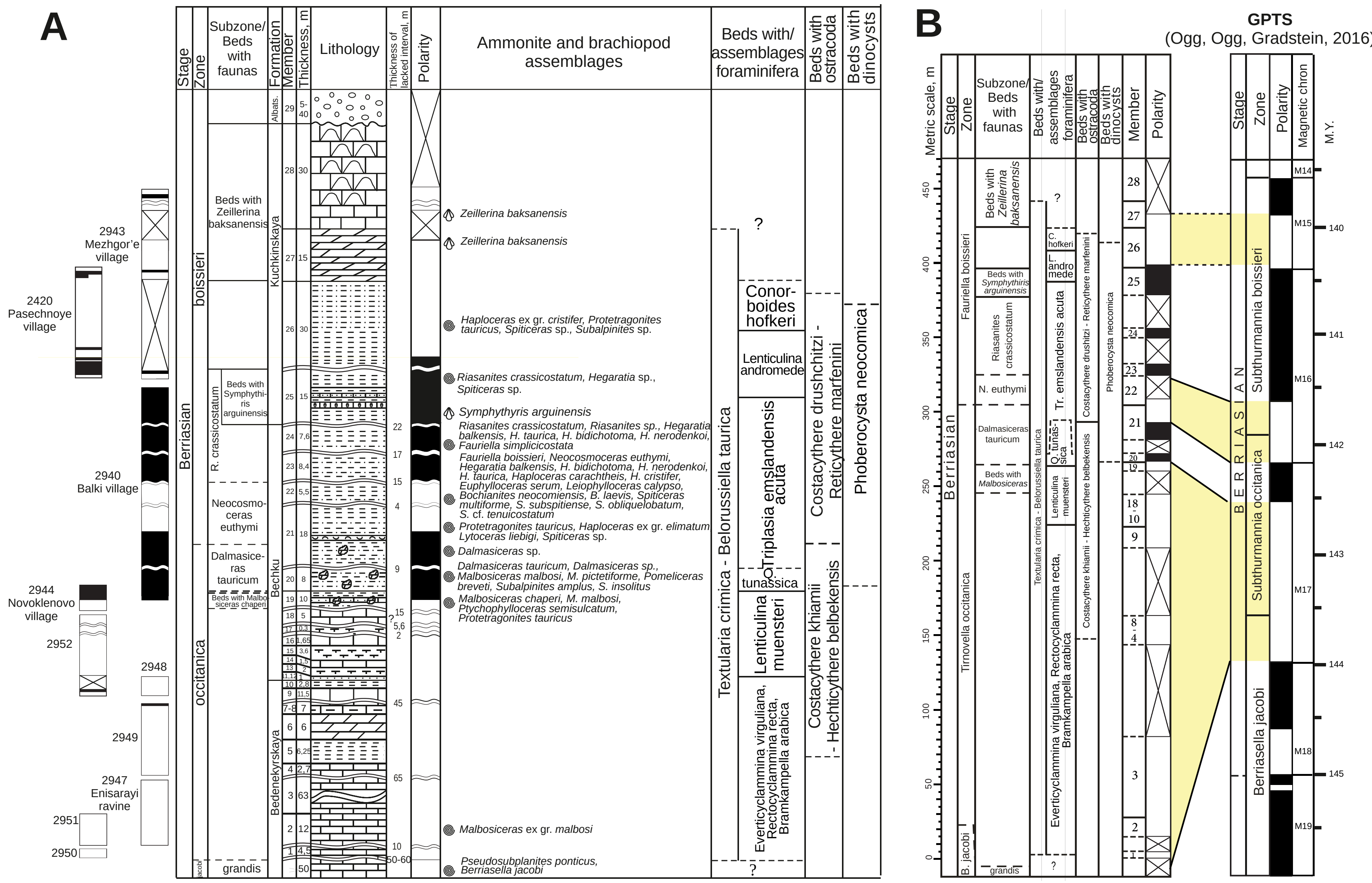


Fig. 6. Composite section of the Berriasian of central Crimea (Arkadiev et al., 2015a) (A) and its correlation to GPTS (B).

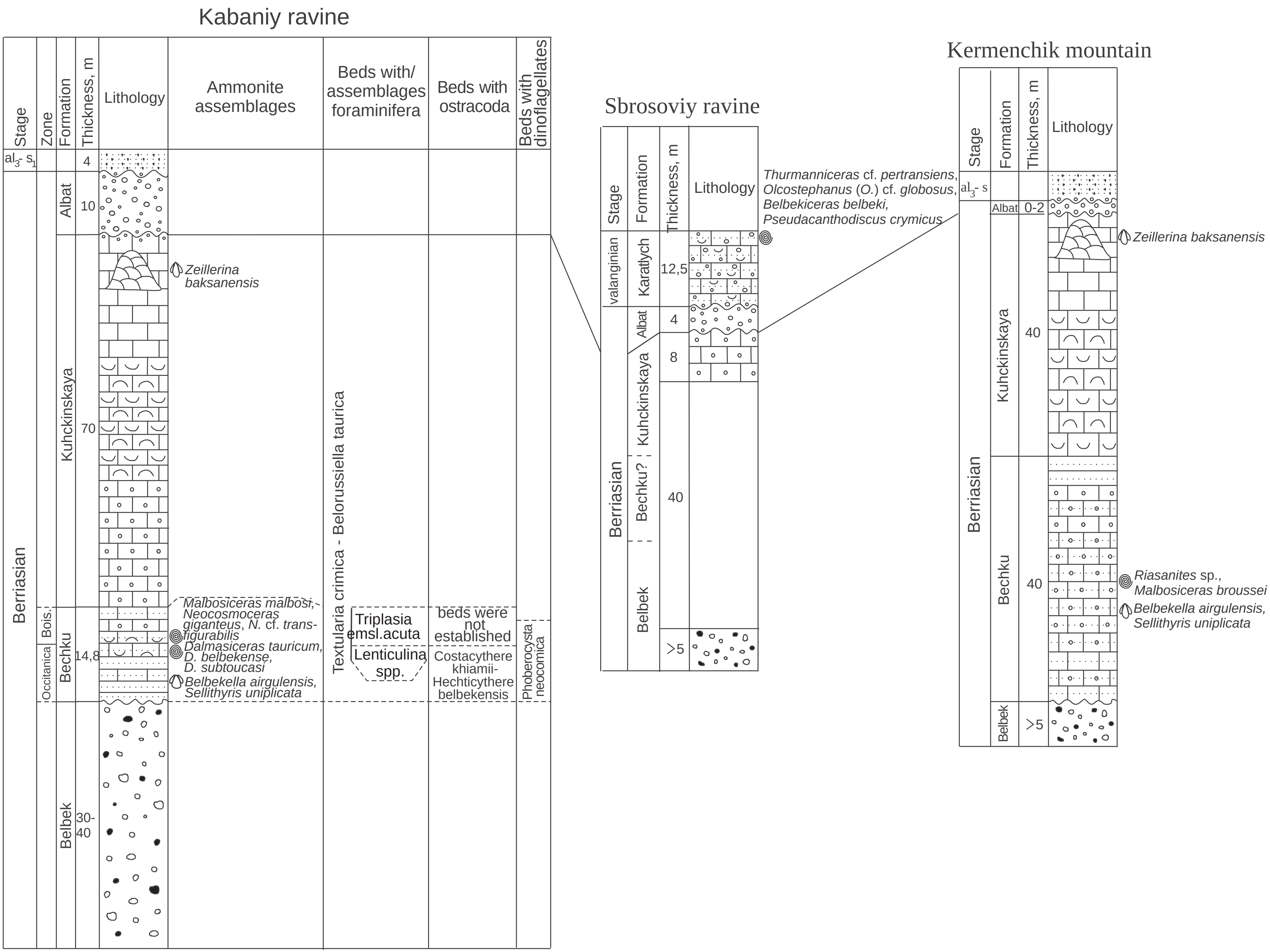


Fig. 7. Berriasian sections of the Belbek River Basin, South-Western Crimea (Arkadiev et al., 2012).

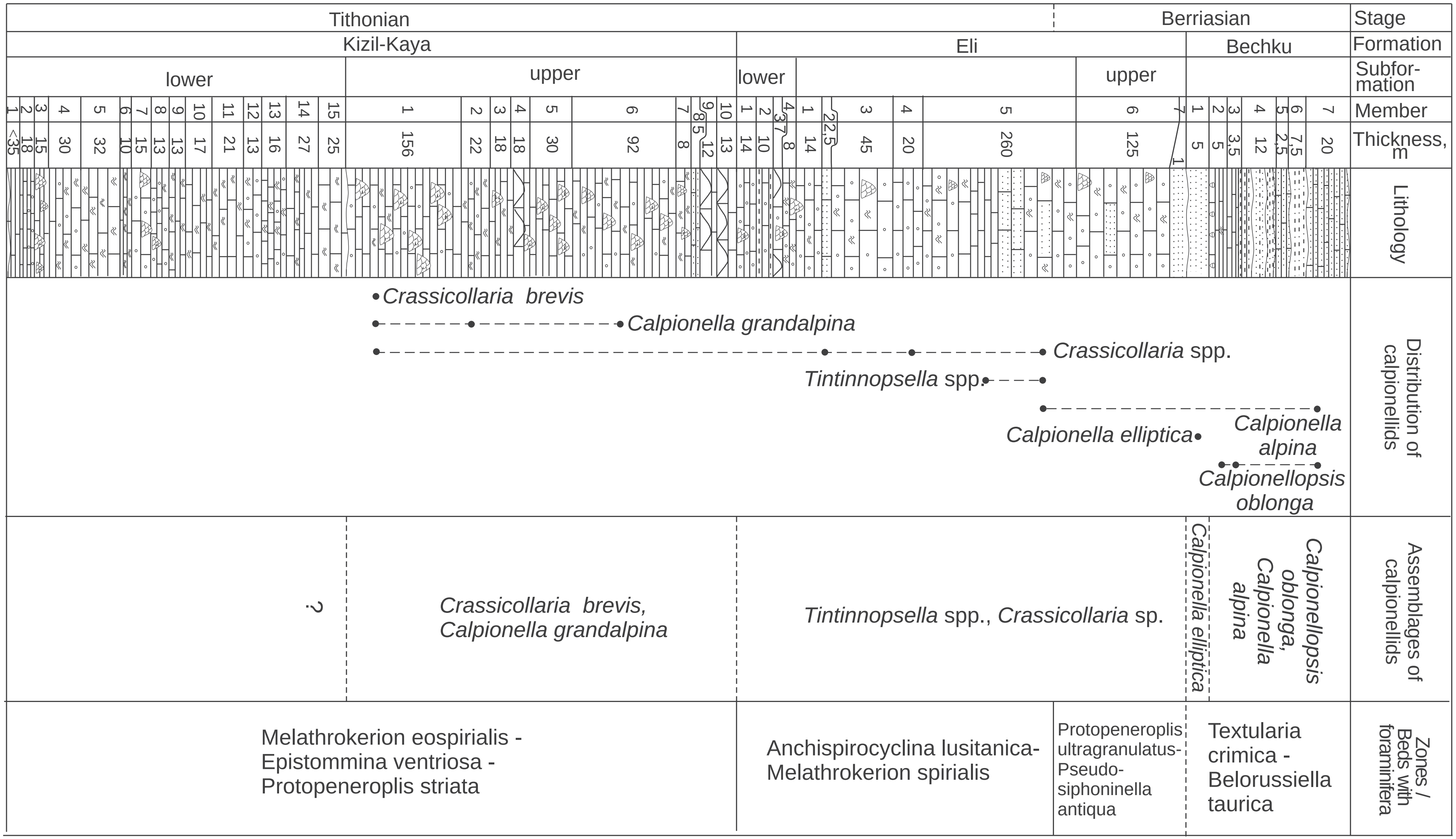


Fig. 8. Composite section of the Tithonian–Berriasian in the Chernaya River Basin (Baydarskaya Valley, South-Western Crimea) (Feodorova, 2000).

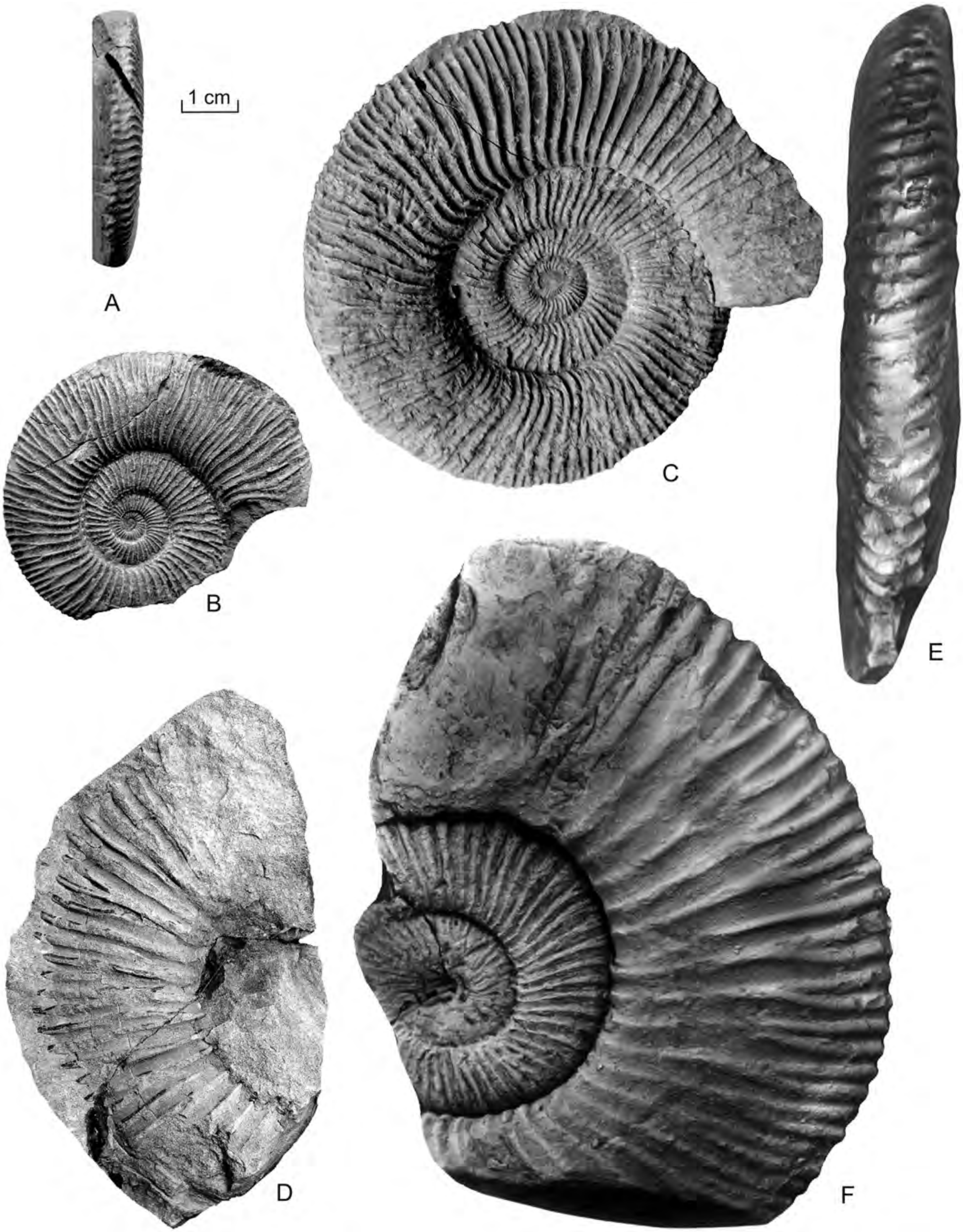
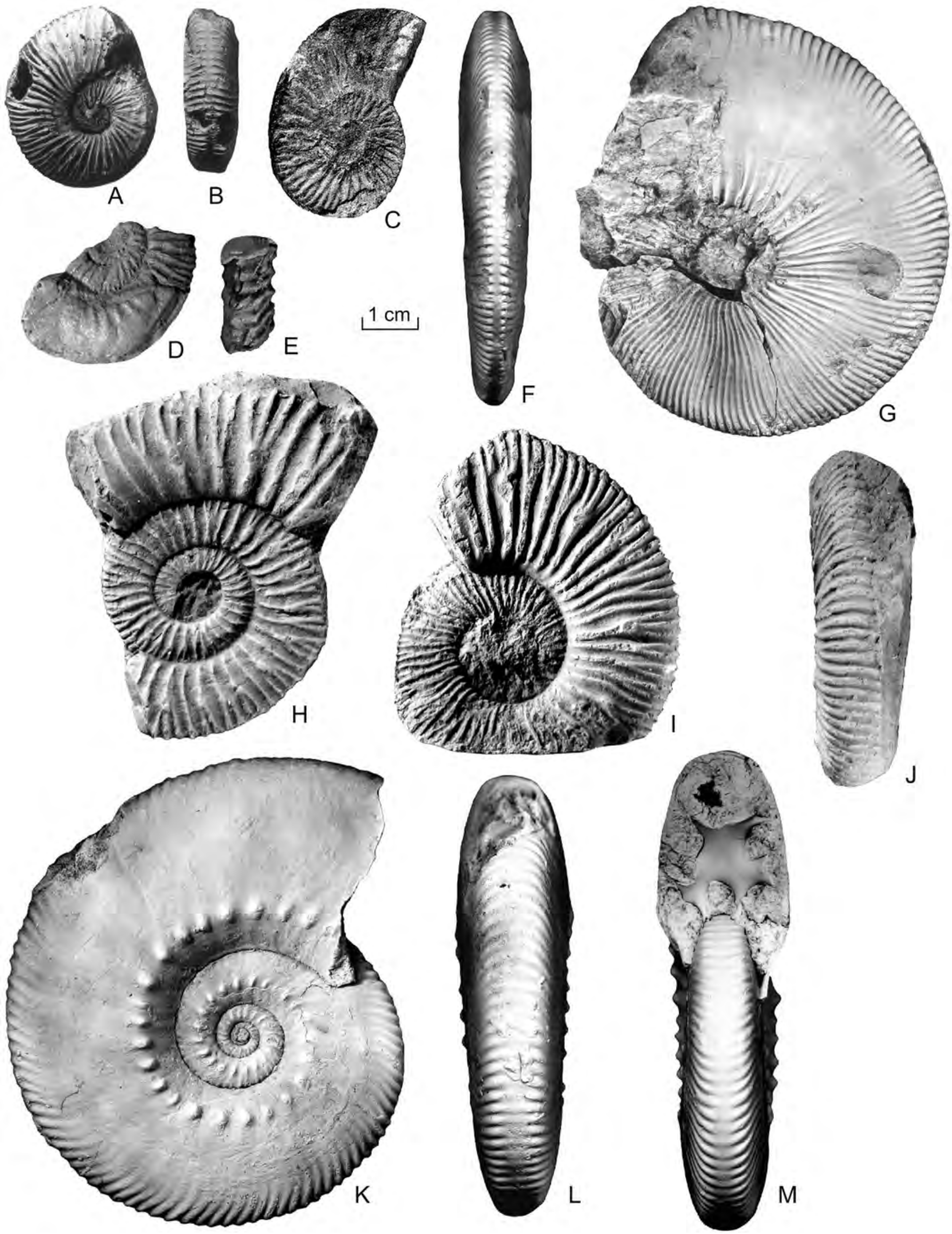


Fig. 9. Late Tithonian and Berriasian ammonites. A–C, *Paraulacosphinctes transitorius*. A, B, specimen 3/382 in ventral and lateral views; C, specimen 1/382 in lateral view, Feodosiya, Dvuyakornaya Bay, Andreaei Zone. D–F, *Pseudosubplanites grandis*. D, specimen 1/13139 in lateral view, Tonas River Basin, Krasnoselovka Village; E–F, specimen 18/13077 in ventral and lateral views, Feodosiya, Saint Elias Cape, Jacobi Zone.


A
B
C
D
E
1 cm
F
G
H
I
J
K
L
M

Berriasian based on ammonites and foraminifera as well as biostratigraphic schemes based on calpionellids, ostracods and dinocysts (Fig. 21). In the Crimean Mountains we have identified the standard ammonite zones of the upper Tithonian–Berriasian (Reboulet et al., 2014). In Crimean sections, zones are usually incomplete, which is a result of the complex tectonics of the region. For this reason, biostratigraphic units referred to as 'Beds with fauna' were used along with subzones.

4.1. Ammonites

In the Eastern Crimea, we have demonstrated the presence of two ammonite zones of the upper Tithonian, i.e., the Microcanthum and Andreaei Zones. The Microcanthum Zone was documented by specimens of *Oloriziceras* cf. *schneidi*, and the Andreaei Zone by *Paraulacosphinctes transitorius*, *Paraulacosphinctes* cf. *senoides* and *Neoperisphinctes* cf. *falloti.* Up to the present, the Durangites Zone has been equated with the Andreaei Zone in Crimea (Arkadiev et al., 2012) because finds of '*Durangites*' are unknown from here. On the basis of results of a study of the Le Chouet section in southern France, Wimbledon et al. (2013), proposed to replace the Durangites Zone by the Andreaei Zone. 'Mediterranean *Durangites*' have recently been revised (Frau et al., 2015).

Ammonite assemblages of all three standard zones, i.e., the Jacobi, Occitanica and Boissieri Zones (Figs. 9–13), have been identified in the Berriasian of the Crimean Mountains. However, their distribution within the study area is different.

4.1.1. Jacobi *Zone*

According to our data (Arkadiev et al., 2012), in the Crimean Mountains this Zone was subdivided into Jacobi and Grandis Subzones. One group of palaeontologists (Frau et al., 2016a) attributed *Berriasella jacobi* to the genus *Strambergella.* In their analysis of the distribution of the species there is almost no reference to the Russian literature on the genus *Berriasella,* except for the fact that in the synonymy of *Berriasella jacobi* all assignments of Russian researchers are listed as erroneous, but without explanation. Another group of biostratigraphers, led by Philip Hoedemaeker, have completed a comprehensive review of the Jurassic/Cretaceous boundary at Rio Argos in southeast Spain; they continue to use the specific name *Berriasella jacobi* (Hoedemaeker et al., 2016). We support the point of view of Hoedemaeker et al. (2016).

4.1.2. Jacobi *Subzone*

The ammonite assemblage consists of *Berriasella jacobi*, *Berriasella chomeracensis*, *Berriasella* sp., *Fauriella* cf. *floquinensis*, *Ptychophylloceras semisulcatum* and *Haploceras* sp.

Distribution. Eastern Crimea (Saint Elias Cape), Tonas River Basin (village of Krasnoselovka); central Crimea (village of Balki). *Berriasella jacobi* is known from sections in central Crimea and the Tonas River Basin, while *Berriasella chomeracensis* was identified only at Saint Elias Cape (Eastern Crimea).

4.1.3. *Grandis* Subzone

The ammonite assemblage comprises *Pseudosubplanites grandis*, *Pseudosubplanites ponticus*, *Pseudosubplanites subrichteri*, *Pseudosubplanites lorioli*, *Pseudosubplanites combesi*, *Pseudosubplanites crymensis*, *Pseudosubplanites fasciculatus*, *Delphinella subchaperi*, *Delphinella crimensis*, *Delphinella obtusenodosa*, *Delphinella tresannensis*, *Delphinella delphinensis*, *Delphinella janus*, *Delphinella pectinata*, *Berriasella berthei*, *Berriasella oppeli*, *Berriasella subcallisto*, *Berriasella paramacilenta*, *Retowskiceras andrussowi*, *Retowskiceras retowskyi*, *Spiticeras orientale*, *Negreliceras proteum*, *Negreliceras mirum*, *Negreliceras* ex gr. *negreli*, *Ptychophylloceras semisulcatum*, *Bochianites neocomiensis*, *Bochianites goubechensis* and *Bochianites crymensis*.

Distribution. Eastern Crimea (Saint Elias Cape), Tonas River Basin (Krasnoselovka Village) and central Crimea (Balki Village).

4.1.4. Occitanica *Zone*

Sections encompassing this zone are incomplete almost everywhere, with mostly the lower part missing. The index species of this zone was recorded from the Feodosiya section by Retowski (1893). *Tirnovella occitanica* from Retowski's Collection was revised by Bogdanova et al. (1999), who documented the presence of the Occitanica Zone in the Feodosiya section. However, its lower and upper boundaries and extent are still undefined. All Crimean specimens of *Tirnovella occitanica* have been assigned by Frau et al. (2016b) to *Pseudoneocomites retowskyi*. The main difference between *P. retowskyi* and *T. occitanica* has been considered to be the lack of umbilical tubercles at all ontogenetic stages. However, the presence of tubercles in the Crimean specimens was noted by Tamara N. Bogdanova (Bogdanova et al., 1999). Frau et al. (2016b) illustrated two incomplete specimens, without tubercles, which makes it difficult to assign these to species. We here retain the name 'Tirnovella occitanica Zone'.

The following regional units are distinguished within this zone: beds with *Malbosiceras chaperi*, beds with *Tirnovella occitanica* and *Retowskiceras retowskyi* and the *Dalmasiceras tauricum* Subzone.

4.1.5. *Beds with* Malbosiceras chaperi

The ammonite assemblage comprises *Malbosiceras chaperi* and *Malbosiceras malbosi.*

Distribution. Central Crimea (Balki Village, Karaby Yaila).

4.1.6. *Beds with* Tirnovella occitanica *and* Retowskiceras retowskyi

The ammonite assemblage comprises *Tirnovella occitanica*, *Retowskiceras Retowskyi* and *Berriasella moesica.*

Distribution. Eastern Crimea (Zavodskaya Balka).

4.1.7. Dalmasiceras tauricum *Subzone*

The ammonite assemblage comprises *Dalmasiceras tauricum*, *Dalmasiceras belbekense*, *Dalmasiceras subtoucasi*, *Dalmasiceras* ex gr. *punctatum*, *Malbosiceras malbosi*, *Malbosiceras broussei*, *Malbosiceras pictetiforme*, *Pomeliceras breveti*, *Pomeliceras* aff. *boisseti*, *Fauriella* sp., *Subalpinites insolitus*, *Subalpinites amplus*, *Spiticeras obliquelobatum* and *Ptychophylloceras semisulcatum*.

Distribution. Crimean Mountains (Zavodskaya Balka, Balki Village and Belbek River Basin).

4.1.8. Boissieri *Zone*

The following regional units are distinguished within this zone: the *Neocosmoceras euthymi* Subzone, the Riasanites crassicostatum Subzone and the Berriasella callisto Subzone.

Fauriella boissieri is present in a section along the Sary-Su River in central Crimea and in sections at the Chatyr-Dag Massif (Arkadiev, 2007b) and Zavodskaya Balka (Arkadiev et al., 2010).

Fig. 10. Berriasian ammonites. A–C, *Berriasella jacobi*. A–B, specimen 1/13098 in lateral and ventral views, Sary-Su River Basin; C, specimen 4/378 in lateral view, Tonas River Basin, Krasnoselovka Village, Jacobi Zone. D–E, *Berriasella chomeracensis*, specimen 1/131 in lateral and ventral views (×2), Feodosiya, Dvuyakornaya Bay, Jacobi Zone. F–G, *Tirnovella occitanica*, specimen 41/10916 in ventral and lateral views, Feodosiya, Occitanica Zone. H, *Retowskiceras retowskyi*, specimen 12/13209 in lateral view, Zavodskaya Balka, Occitanica Zone, beds with *Tirnovella occitanica* and *Retowskiceras retowskyi*. I–J, *Retowskiceras andrussowi*, specimen 1/13209 in lateral and ventral, Saint Elias Cape, Jacobi Zone, Grandis Subzone. K–M, *Dalmasiceras tauricum*, specimen 4/333 in lateral, ventral and apertural views, Belbek River Basin, Kuibyshevo Village, Occitanica Zone, Tauricum Subzone.

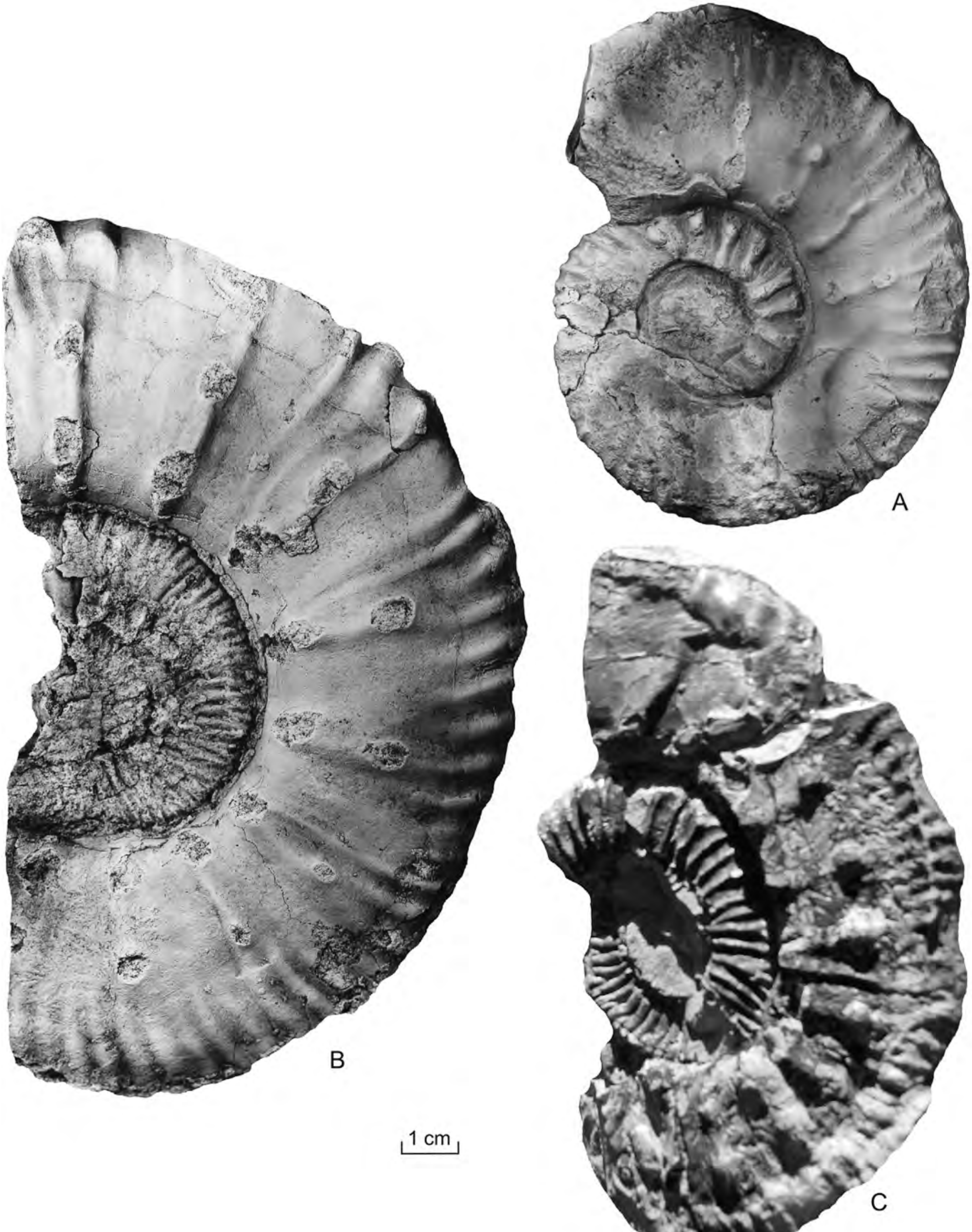


Fig. 11. Berriasian ammonites. A, *Malbosiceras chaperi*, specimen 20/13143 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, condensed horizon at the base of the Boissieri Zone. B–C, *Malbosiceras malbosi*. B, specimen 1/13143 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, Boissieri Zone; C, specimen 2/381 in lateral view, Zavodskaya Balka, Boissieri Zone, Euthymi Subzone.

4.1.9. Neocosmoceras euthymi *Subzone*

The ammonite assemblage comprises *Fauriella boissieri*, *Neocosmoceras euthymi*, *Neocosmoceras* cf. *transfigurabilis*, *Neocosmoceeras giganteus*, *Neocosmoceras minutus*, *Malbosiceras malbosi*, *Pseudosubplanites jauberti*, *Hegaratia balkensis*, *Hegaratia taurica*, *Hegaratia nerodenkoi*, *Hegaratia bidichotoma*, *Berriasella neocomiensis*, *Spiticeras multiforme* and *Spiticeras subspitiense*.

Distribution. Crimean Mountains (Nanikovo Village, Koklyuk Mountain, Balki Village and Belbek River Basin).

4.1.10. Riasanites crassicostatum *Subzone*

The ammonite assemblage comprises *Fauriella simplicicostata*, *Riasanites crassicostatum*, *Riasanites irregulatus*, *Riasanites tuberculatum*, *Riasanites petrovensis*, *Hegaratia balkensis*, *Hegaratia bidichotoma*, *Hegaratia taurica*, *Hegaratia Nerodenkoi* and *Pomeliceras*(?) *funduklense*.

Distribution. Crimean Mountains (Zavodskaya Balka, Balki Village).

Above the Crassicostatum Subzone in central Crimea there follow deposits without ammonite marker species. Only species of the genera *Haploceras*, *Protetragonites* and *Spiticeras* have been recovered, but these are insufficient for assignment to any of the Berriasian ammonite zones. This stratigraphic level requires further study.

4.1.11. Berriasella callisto *Subzone*

Earlier (Arkadiev et al., 2006) this Subzone was referred to as beds with *Jabronella* cf. *paquieri* and *Berriasella callisto*, as identified in the Tas-Kor ravine of the Chatyr-Dag Massif. In 2015, *Berriasella callisto* was collected at the Zavodskaya Balka section, above levels containing *Riasanites crassicostatum* (Arkadiev, 2015; Arkadiev et al., 2015b).

The ammonite assemblage comprises *Jabronella* cf. *paquieri*, *Fauriella boissieri*, *Fauriella rarefurcata*, *Fauriella* sp., *Tirnovella alpillensis*, *Tirnovella* sp., *Berriasella callisto*, *Berriasella* sp. and *Malbosiceras malbosi*.

Berriasella callisto may also be indicative of the presence of the Otopeta Subzone, as in Spain (Tavera, 1985).

Distribution. South-Western (Minester Ravine?), central (Chatyr Dag, Mramornoye Village) and Eastern Crimea (Zavodskaya Balka).

Berriasian deposits in most areas of the Crimean Mountains are unconformably overlain by Valanginian rocks. One of us (EB) has recently worked out an ammonite zonal scheme for the Valanginian Stage, on the basis of shallow-water sections of South-Western Crimea (Baraboshkin and Mikhailova, 1994, 2000; Baraboshkin and Yanin, 1997; Baraboshkin in Atlas…, 1997; Baraboshkin in Arkadiev et al., 2002). Valanginian strata transgressively overlap the Lower Jurassic–Berriasian sequence, but everywhere in South-Western Crimea it does contains a hiatus at the base. The most representative ammonite succession was described from the Kacha–Bodrak rivers watershed (Baraboshkin and Mikhailova, 1994, 2000; Baraboshkin and Yanin, 1997), but the Berriasian is not present there. Continuous Berriasian–Valanginian sections are known only in eastern Crimea, near the Sultanovka and Nanikovo Villages. The deposits near Sultanovka have traditionally been dated as Berriasian–Valanginian, on the basis of ammonites, belemnites and aptychi (Kvantaliani, 1989). Only in 2010, one of us (VA) (see Arkadiev, Rogov and Perminov, 2011) collected from this stratigraphic level the ammonites *Leptoceras studeri*, *Negreliceras mirum* and *Fauriella* sp., indicative of a late Berriasian–Valanginian age. The Valanginian age of the overlying Nanikovo Unit is proved by the early Valanginian *Kilianella roubaudiana*, the late Valanginian *Neocomites neocomiensis* and aptychi (*Didayilamellaptychus didayi*). We have been unable to find typical early Valanginian ammonites (Arkadiev et al., 2016).

4.2. Calpionellids

In the upper Tithonian and Berriasian we have confirmed the presence of portions of three standard zones, correlated with standard ammonite zones (Platonov et al., 2014) (Fig. 21). As a result of field work in 2016 at Cape Feodosiya we were able to document the Elliptica Subzone in more detail, expanding its volume. The most important calpionellids were collected from Eastern Crimea and the Tonas River Basin (Figs. 3–4, 14). Additionally, calpionellids were recovered from South-Western Crimea, in the Chernaya River Basin (Feodorova, 2000) (Fig. 8) and in the Baydarskaya Valley on the Biyuk-Sinor Mountain (Platonov and Rudko, 2015). Due to the paucity of calpionellids, the zonal boundaries are tentative. In the section at the Chernaya River we have been able to identify only Tithonian and Berriasian calpionellid assemblages.

4.2.1. Chitinoidella *Zone*

This zone was established in Spain by Enay and Geyssant (1975); a full description can be found in Borza (1984). This zone is identified on the basis of the presence of representatives of the family Chitinoidellidae (Trejo, 1975).

4.2.2. Dobeni *Subzone*

The calpionellid assemblage comprises *Longicollaria dobeni* and *Popiella oblongata*.

Distribution. Eastern Crimea, Dvuyakornaya Bay (Tithonian, Microcantum Zone).

4.2.3. Boneti *Subzone*

The calpionellid assemblage comprises *Chitinoidella boneti*, *Chitinoidella elongata*, *Dobeniella* cf. *bermudezi* and *Popiella oblongata*.

Distribution. Eastern Crimea, Dvuyakornaya Bay (Tithonian, Andreaei Zone).

4.2.4. Praetintinnopsella *Zone*

This zone is present everywhere within the Tethyan region (Lakova et al., 1999; Michalík et al., 2009). Only a single specimen of the zonal index species was found in Eastern Crimea, above the occurrence of the first Calpionellidae; consequently, it is impossible to identify this zone at this time.

4.2.5. Crassicollaria *Zone*

This zone has been referred earlier to as Zone A (Crassicollaria) (see Remane, 1963) in southeast France.

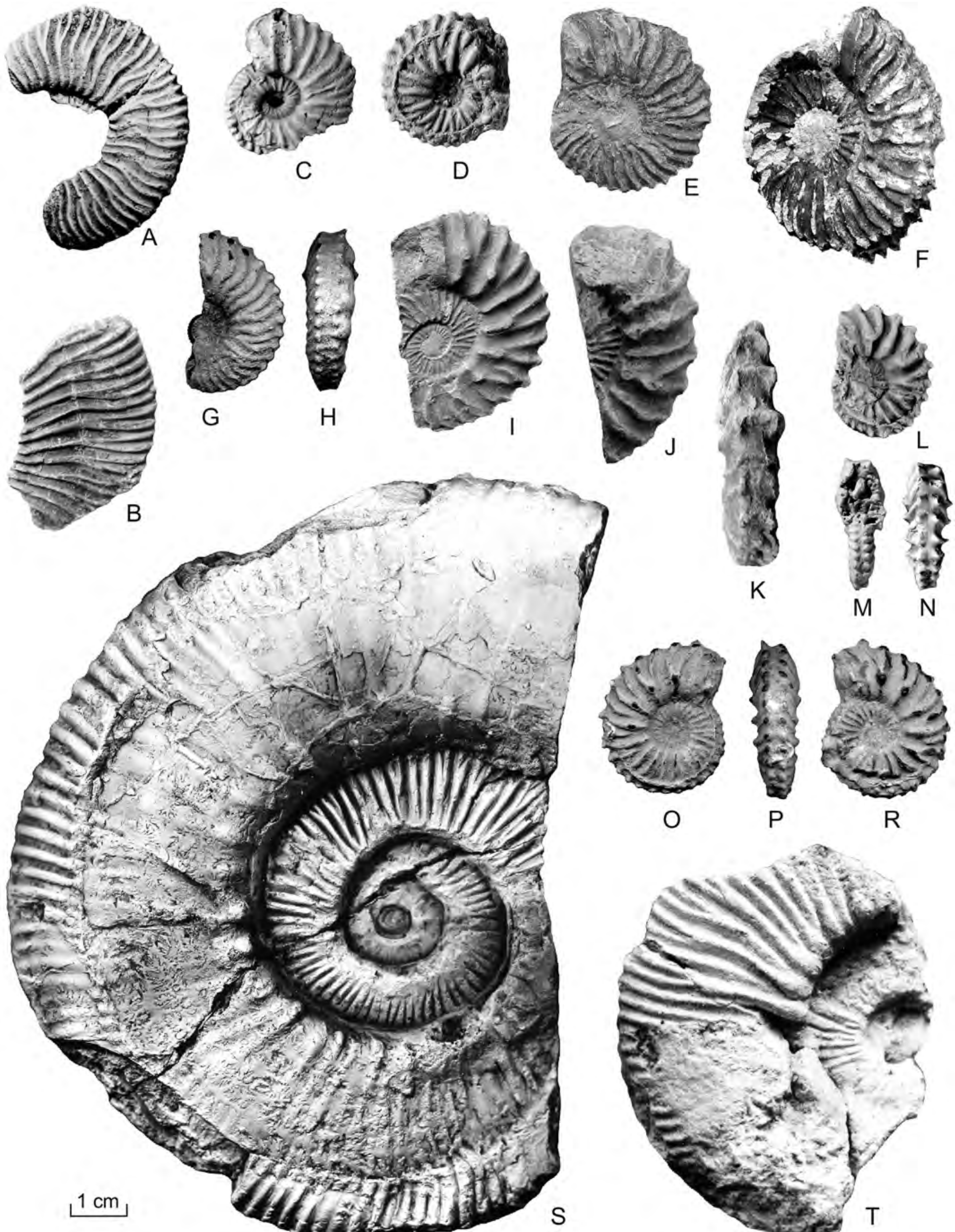
This zone is defined by the first occurrence of specimens of Calpionellidae with a hyaline shell in the section. Usually, these are *Tintinnopsella carpathica* or *T. remanei*.

4.2.6. Remanei *Subzone*

This subzone has been established by Remane for the western Mediterranean (Remane et al., 1986).

The calpionellid assemblage comprises *Tintinnopsella remanei*, *Tintinnopsella carpathica*, *Crassicollaria parvula*, *Calpionella alpina*, *Praetintinnopsella andrusovi*, *Chitinoidella boneti*, *Daciella danubica* and *Dobeniella cubensis*. The subzone is defined by the occurrence of *Tintinnopsella carpathica*.

Distribution. Eastern Crimea, Dvuyakornaya Bay (Tithonian, Andreaei Zone).


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
R
S
T
1 cm

4.2.7. Massutiniana *Subzone*

This subzone has been established by Remane for the western Mediterranean (Remane et al., 1986).

The calpionellid assemblage comprises *Crassicollaria massutiniana*, *Crassicollaria* cf. *brevis* and *Tintinnopsella carpathica*.

Distribution. Eastern Crimea, Dvuyakornaya Bay (Tithonian–Berriasian, Andreaei–Jacobi Zone).

4.2.8. Calpionella *Zone*

According to the Roman Zonal Standard (Allemann et al., 1971) the Calpionella Zone has been established by combining zones B (*Calpionella*) and C (*Tintinnopsella*) by Remane (1963).

The zone is characterised by an explosion of *Calpionella alpina*. The index species is usually accompanied by *Tintinnopsella carpathica* and *Crassicollaria parvula*. The base of the zone is defined by the replacement of Jurassic calpionellid assemblages by Cretaceous ones. However, due to the small numbers of calpionellids recovered, it was impossible to document the population explosion of *C. alpina*.

4.2.9. Alpina *Subzone*

The subzone has been established in the Carpathians (Pop, 1974).

The calpionellid assemblage comprises *Calpionella alpina*, *Calpionella grandalpina*, *Tintinnopsella carpathica*, *Crassicollaria parvula* and *Tintinnopsella doliphormis*. In sections at the Tonas River Basin this assemblage is represented by the following species: *Calpionella alpina*, *Calpionella minuta*, *Calpionella* aff. *elliptica*, *Calpionella* spp., *Tintinnopsella doliphormis*, *Tintinnopsella carpathica*, *Crassicollaria parvula*, *Crassicollaria massutiniana* and *remanié*, *Chitinoidella boneti*. In southwestern Crimea, on the Biyuk-Sinor Mountain, the following species were found: *Calpionella alpina*, *Tintinnopsella carpathica* and *Crassicollaria parvula* (Platonov and Rudko, 2015). The base of the zone is defined by the occurrence of the first Berriasian species, *Tintinnopsella doliphormis*.

Distribution. Eastern Crimea (Dvuyakornaya Bay), Tonas River Basin and South-Western Crimea (Chernaya River Basin) (Berriasian, Jacobi Zone).

In many areas of the Tethyan region the Remaniella Subzone may be identified in the middle of the Calpionella Zone (Lakova et al., 1999; Skourtsis-Coroneou and Solakius, 1999), as established by the occurrence of *Remaniella ferasini*. In Crimea, this biostratigraphic unit could not be documented in view of the paucity of calpionellid assemblages.

4.2.10. Elliptica *Subzone*

This subzone has been established by Catalano and Liguori (1971).

The calpionellid assemblage comprises *Calpionella elliptica*, *Calpionella alpina*, *Calpionella minuta*, *Tintinnopsella longa*, *Tintinnopsella carpathica* and *Crassicollaria parvula*.

Distribution. Eastern Crimea (Dvuyakornaya Bay) (Berriasian, Jacobi Zone).

There are no calpionellids in younger deposits in Crimea.

4.3. *Foraminifera*

In the interval between the upper Kimmeridgian and the Valanginian, foraminifera are represented by more than 300 species in 83 genera (Figs. 15–16), belonging to typical and transitional species. Zones and beds with foraminifera were correlated with ammonite zones; they can be traced throughout the Crimean Mountains (Fig. 21).

4.3.1. *Beds with* Melathrokerion eospirialis–Epistomina ventriosa–Protopeneroplis striata

Foraminiferal assemblage – These beds are identified by the cooccurrence of *Melathrokerion eospirialis*, *Epistomina ventriosa* and *Protopeneroplis striata* and by the presence of certain other species such as *Reophax giganteus*, *Ammobaculites* ex gr. *inconstans*, *Gaudryina chettabaensis*, *Textularia notha*, *Textularia densa*, *Lenticulina dilecta*, *Lenticulina undorica*, *Quinqueloculina mitchurini*, *Quinqueloculina verbizhiensis*, *Istriloculina rectoangularia*, *Istriloculina terekensis*, *Spirillina kubleri* and *Spirillina minima*. The most abundant genera are *Melathrokerion*, *Epistomina*, *Ammobaculites*, *Lenticulina* and *Quinqueloculina*.

As far as extent is concerned, these beds may be in part correlated with beds with Epistomina ventriosa–Textularia densa and the Astacolus laudatus–Epistomina omninoreticulata Zone (Kuznetsova and Gorbachik, 1985). The late Kimmeridgian (Hybonoticeras beckeri Zone) to Tithonian (Micracanthoceras microcanthum Zone) age of these beds is corroborated by the find of zonal ammonites (Arkadiev and Rogov, 2006).

Distribution. Eastern Crimea (Dvuyakornaya Bay), Tonas River Basin and South-Western Crimea (Chernaya River Basin).

4.3.2. Anchispirocyclina lusitanica–Melathrokerion spirialis *Zone*

This zone was established by Kuznetsova (1983), as an equivalent of the Tethyan Anchispirocyclina lusitanica Zone (Azema et al., 1978).

The foraminiferal assemblage comprises *Anchispirocyclina lusitanica*, *Melathrokerion spirialis*, *Charentia evoluta*, *Charentia compressa*, *Pseudocyclammina sphaeroidalis*, *Pseudocyclammina(?) rifica*, *Pseudocyclammina agglutinans*, *Pseudocyclammina cylindrica*, *Pseudocyclammina lituus*, *Feurltillia frequens*, *Ammobaculites tauricus*, *Haplophragmoides globigerinoides*, *Stomatostoecha enisalensis*, *Trochammina* aff. *globigeriniformis*, *Pseudonodosaria diversa*, *Lenticulina uspenskajea*, *Astacolus planiusculus*, *Trocholina alpina*, *Trocholina elongata* and *Trocholina infragranulata*.

The late Tithonian (Andreaei Zone) to early Berriasian (lower part of the Jacobi Zone) age of this stratigraphic unit is confirmed by ammonites (Guzhikov et al., 2012).

Distribution. Eastern Crimea (Dvuyakornaya Bay), Tonas River Basin (Krasnoselovka Village) and South-Western Crimea (Chernaya River Basin).

4.3.3. Protopeneroplis ultragranulatus–Pseudosiphoninella (=Siphoninella) antiqua *Zone*

This zone was established by Gorbachik (see Kuznetsova and Gorbachik, 1985); it is an equivalent of the Tethyan Protopeneroplis trochangulata Zone (Septfontaine, 1974).

Fig. 12. Berriasian ammonites. A–B, *Berriasella callisto*. A, specimen 20/13098 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, Boissieri Zone. B, specimen 11/409 in lateral view, Zavodskaya Balka, Boissieri Zone. C–K, *Neocosmoceras euthymi*. C, specimen 2/12943 in lateral view; D, specimen 1/12943 in lateral view, village of Balki, Boissieri Zone, Euthymi Subzone; E, specimen 9/13175 in lateral view, Tonas River Basin, Alekseevka Village, Boissieri Zone, Euthymi Subzone; F, specimen 80/13175 in lateral view, Zavodskaya Balka, Boissieri Zone, Euthymi Subzone; G–H, specimen 6/13175 in lateral and ventral views, village of Balki, Boissieri Zone, Euthymi Subzone; I, specimen 12/409 in lateral view, Nanikovo village, Koklyuk Mountain, Boissieri Zone, Euthymi Subzone; J–K, specimen 16/409 in lateral and ventral views, Nanikovo Village, Koklyuk Mountain, Boissieri Zone, Euthymi Subzone; L–R. *Neocosmoceras minutus*. L–N, specimen 58/13175 in lateral, apertural and ventral views; O–R, specimen 60/13175 (holotype) in lateral (twice) and ventral views, Balki Village, Boissieri Zone, Euthymi Subzone; S–T. *Fauriella boissieri*. S, specimen 1/13146 in lateral view, Sary-Su River Basin, Boissieri Zone; T, specimen 3/13146 in lateral view, Chatyr-Dag Massif, Tas-Kor Ravine, Boissieri Zone.

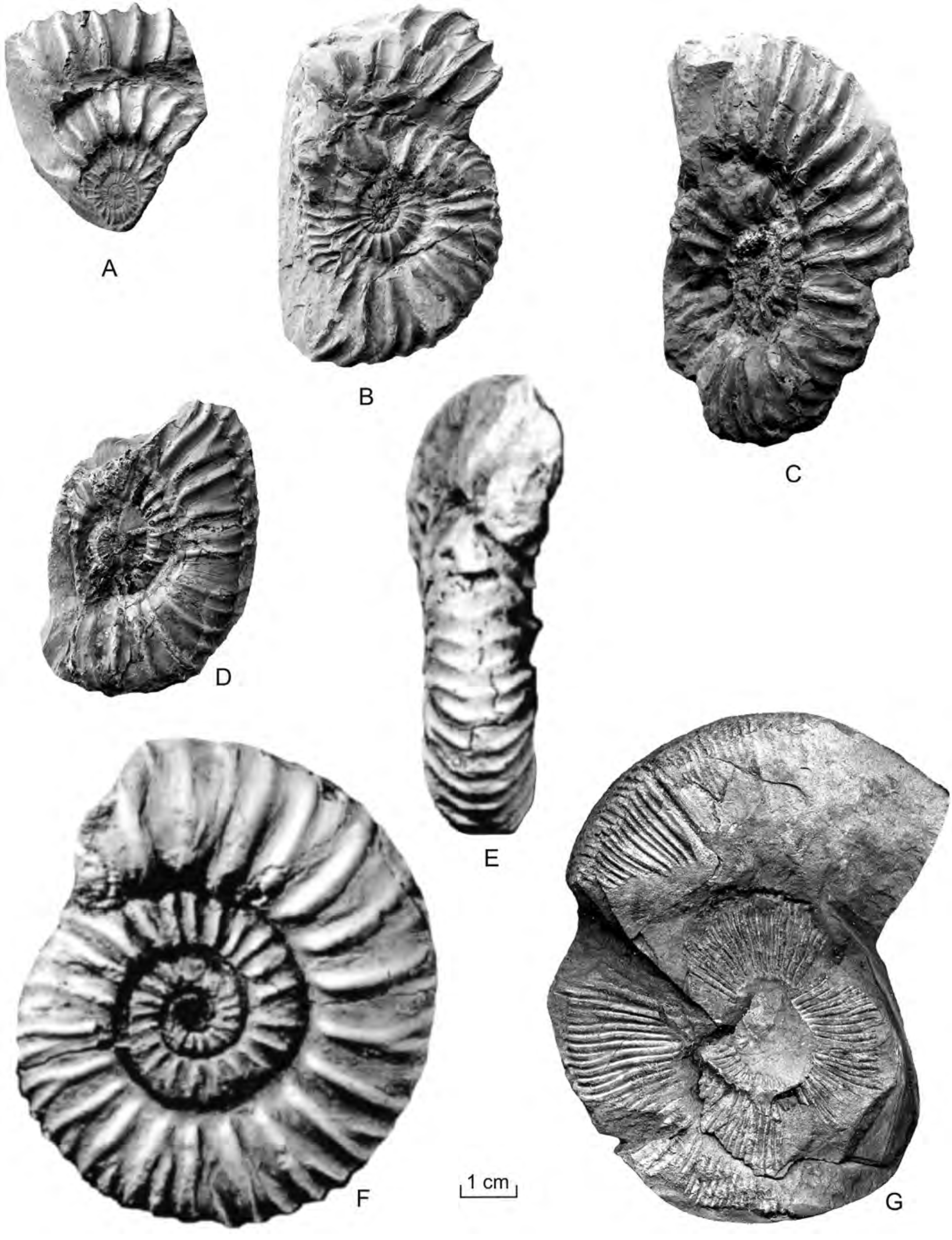


Fig. 13. Berriasian ammonites. A–D, *Riasanites crassicostatum*. A, specimen 8/409; B, specimen 9/409; C, specimen 1/409; D, specimen 10/409. All in lateral view, Zavodskaya Balka, Boissieri Zone, Crassicostatum Subzone. E–F, specimen 4 (3017/1-10), holotype, in apertural and lateral views, Fundukly River Basin, Petrovo Village, Boissieri Zone, Crassicostatum Subzone. G. *Fauriella* cf. *boissieri*, specimen 1/381 in lateral view, Zavodskaya Balka, Boissieri Zone.

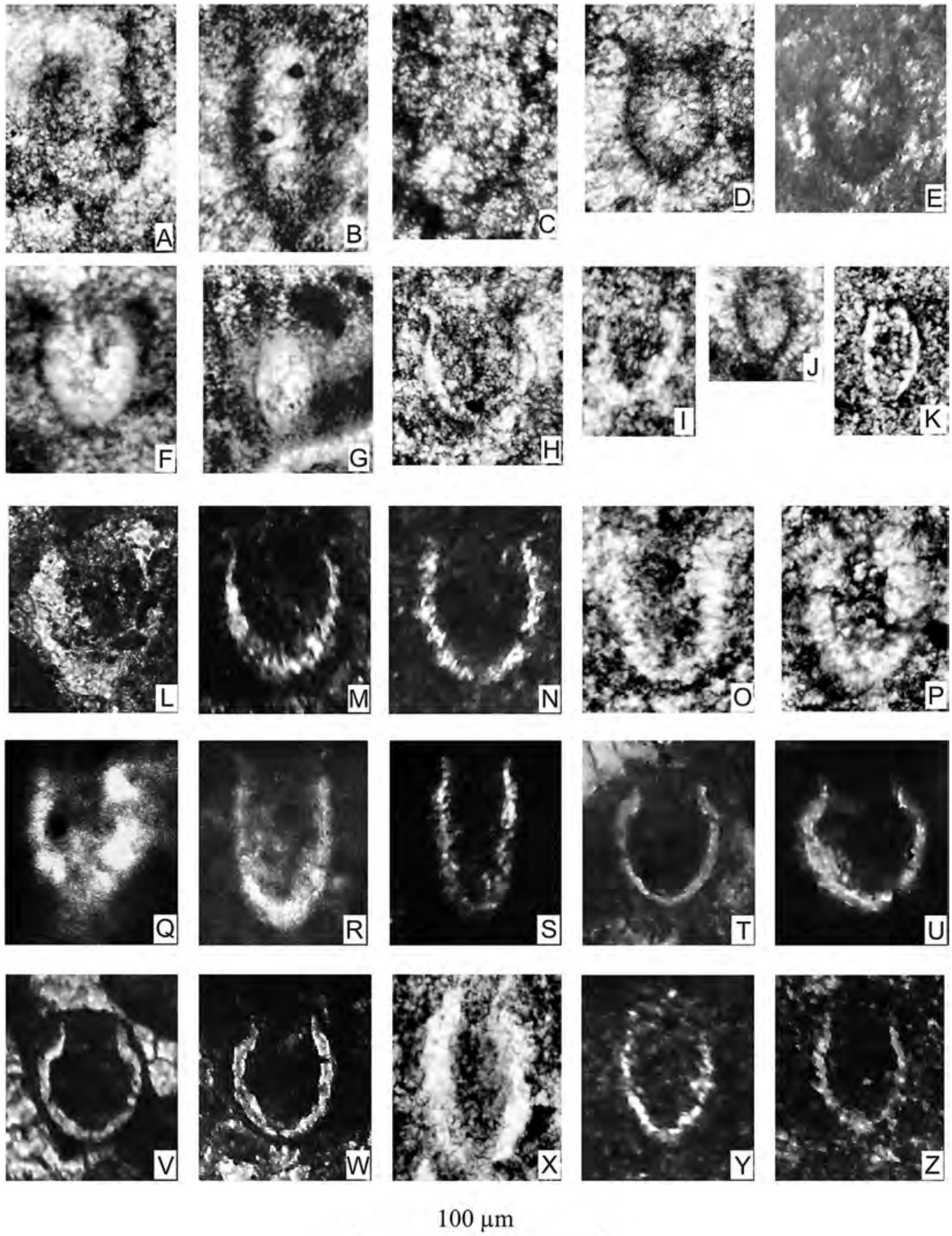


Fig. 14. Tithonian and Berriasian calpionellids. A, *Longicollaria dobeni*, specimen 140/13220, Dvuyakornaya Bay, Member 3, Chitinoidella Zone, Dobeni Subzone. B, *Popiella oblongata*, specimen 141/13220, Dvuyakornaya Bay, Member 7, Chitinoidella Zone, Boneti Subzone. C, *Chitinoidella elongata*, specimen 143/13220, Dvuyakornaya Bay, Member 9, Chitinoidella Zone, Boneti Subzone. D–E, *Chitinoidella boneti*. D – specimen 135/13220, Dvuyakornaya Bay, Member 11, Chitinoidella Zone, Boneti Subzone; E – specimen 226/14к, Tonas River Basin, Member 2, Calpionella Zone, Alpina Subzone. F, *Dobeniella cubensis*, specimen 142/13220, Dvuyakornaya Bay, Member 11, Crassicollaria Zone, Massutiniana Subzone. G, *Dobeniella* cf. *bermudezi*, specimen 135/13220, Dvuyakornaya Bay, Member 11, Chitinoidella Zone, Boneti Subzone. H, *Praetintinnopsella andrusovi*, specimen 142/13220, Dvuyakornaya Bay, Member 11, Crassicollaria Zone, Massutiniana Subzone. I, *Tintinnopsella remanei*, specimen 144/13220, Dvuyakornaya Bay, Member 11, Crassicollaria Zone, Massutiniana Subzone. J, *Daciella danubica*, specimen 144/13220, Dvuyakornaya Bay, Member 11, Crassicollaria Zone, Massutiniana Subzone. K, *Calpionella minuta*, specimen 131/13220, Dvuyakornaya Bay, Member 19, Calpionella Zone, Alpina Subzone. L–N, *Tintinnopsella carpathica*. L – specimen 16-32/367, Dvuyakornaya Bay, Member 12, Crassicollaria Zone, Massutiniana Subzone; M – specimen 226-18/5, Tonas River Basin, Member 20, Calpionella Zone, Alpina Subzone; N – specimen Ку7к/25, Tonas River Basin, Kuchuk-Uzen Creek, Member 7, Calpionella Zone, Alpina Subzone. O, *Tintinnopsella doliphormis*, specimen 133/13220, Dvuyakornaya Bay, Member 14, Calpionella Zone, Alpina Subzone. P, *Crassicollaria parvula*, specimen 133/13220, Dvuyakornaya Bay, Member 19, Calpionella Zone, Alpina Subzone. Q, *Crassicollaria* cf. *brevis*, specimen 15-25/323, Dvuyakornaya Bay, Member 12, Crassicollaria Zone, Massutiniana Subzone. R–S, *Crassicollaria massutiniana*. R – specimen 137/13220, Dvuyakornaya Bay, Member 13, Crassicollaria Zone, Massutiniana Subzone; S – specimen Ку6, Tonas River Basin, Kuchuk-Uzen Creek, Member 4, Calpionella Zone, Alpina Subzone. T, *Calpionella Grandalpina*, specimen 17-50/3, Dvuyakornaya Bay, Member 16, Calpionella Zone, Alpina Subzone. U–W. *Calpionella alpina*. U – specimen 17-50/7, Dvuyakornaya Bay, Member 15, Calpionella Zone, Alpina Subzone; V – specimen 226-26/9п, Tonas River Basin, Member 11, Calpionella Zone, Alpina Subzone; W – specimen Ку4, Tonas River Basin, Kuchuk-Uzen Creek, Member 4, Calpionella Zone, Alpina Subzone. X, *Calpionella elliptica*, specimen 131/13220, Tonas River Basin, Kuchuk-Uzen Creek, Member 19, Calpionella Zone, Alpina Subzone. Y–Z. *Calpionella minuta*. Y – specimen 226-18/5, Tonas River Basin, Member 9, Calpionella Zone, Alpina Subzone; Z – specimen Ку7, Tonas River Basin, Kuchuk-Uzen Creek, Member 6, Calpionella Zone, Alpina Subzone.

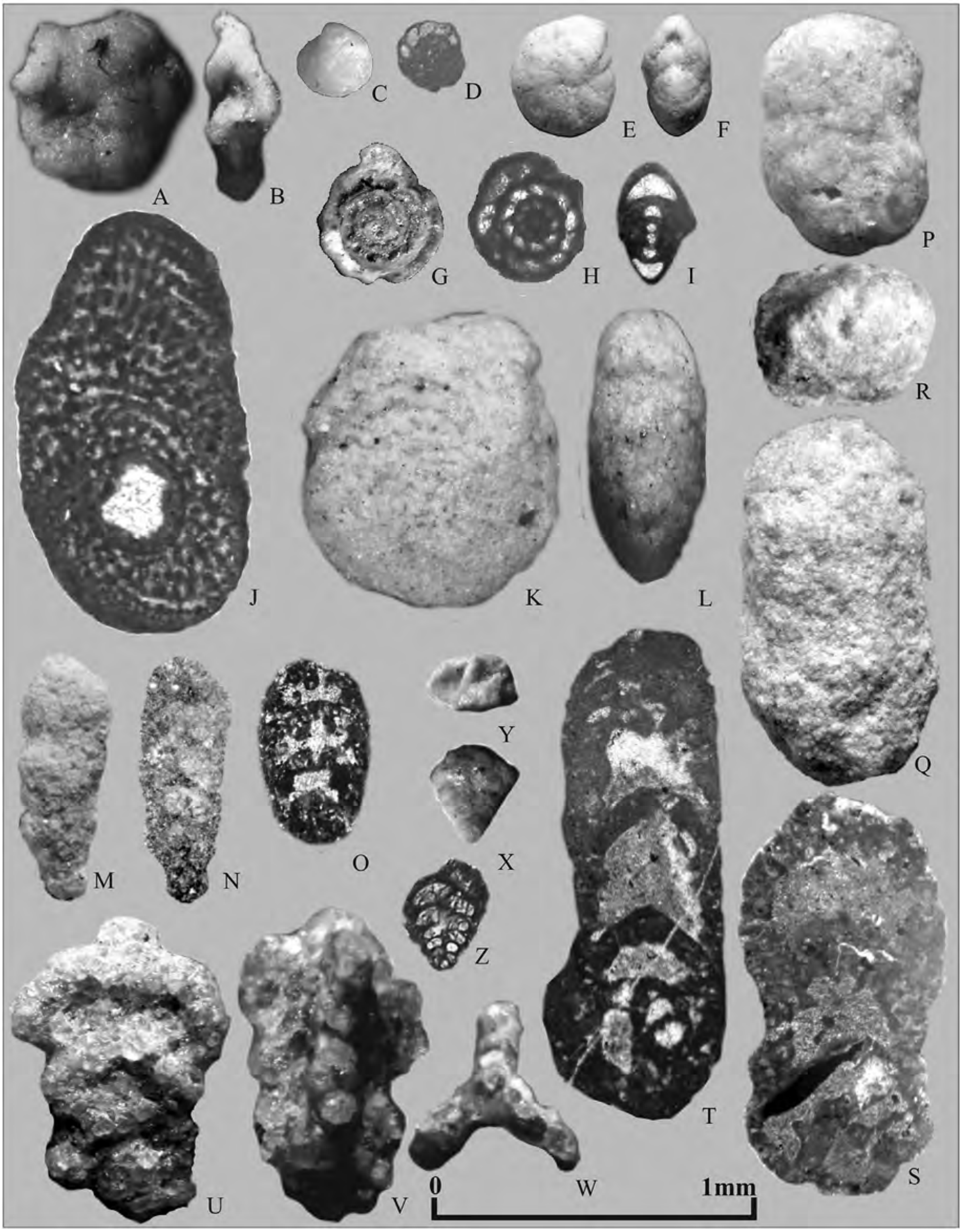


Fig. 15. Late Jurassic–Berriasian foraminifera. A–B. *Haplophragmoides vocontianus*, specimen 3031-7 in lateral and frontal views, Zavodskaya Balka, Boissieri Zone. C–D. *Melathrokerion eospirialis*, C, specimen 40-1-1, Dvuyakornaya Bay, upper Kimmeridgian–lower Tithonian, D, specimen 300-6, thin section, Dvuyakornaya Bay, Microcanthum Zone. E–I. *Melathrokerion spirialis*, specimen 33/1324, E, lateral view, F, frontal view, Balki Village, Occitanica Zone, G, specimen 20-1-1, polished section, Sultanovka, upper Tithonian, H, specimen 706-12a, thin section, Yatlauz Ravine, I, specimen 34/1324, thin section, Enisaray Ravine, Grandis Subzone. J–L. *Anchispirocyclina lusitanica*, J, specimen A3-19, thin section, Black River Basin, K, lateral view, L, frontal view, specimen 20-1-1, Sultanovka, Andreaei Zone. M–N. *Rectocyclammina recta,* specimen 52/1324, M, apertural view, N, oriented thin section, Enisaray Ravine, Occitanica Zone. O. *Bramkampella arabica*, specimen 55/1324, thin section, Enisaray Ravine, Occitanica Zone. P–S. *Everticyclammina virguliana*, P, specimen 42/1324, lateral view, Enisaray Ravine, Occitanica Zone, Q–S, specimen 44/1324, Q, lateral view, R, apertural view, S, oriented thin section, Enisaray Ravine, Occitanica Zone. T, *Everticyclammina elongata*, specimen 45/1324, oriented thin section, Enisaray Ravine, Occitanica Zone. U–W. *Triplasia emslandensis acuta*, specimen 30/1324, U–V, lateral view, W, apertural view, Balki, Boissieri Zone, Euthymi Subzone. X–Z. *Textularia crimica,* X–Y, specimen 56/1324, X, lateral view, Y, apertural view, Z, specimen 57/1324, thin section, Mezhgor'e, Boissieri Zone.

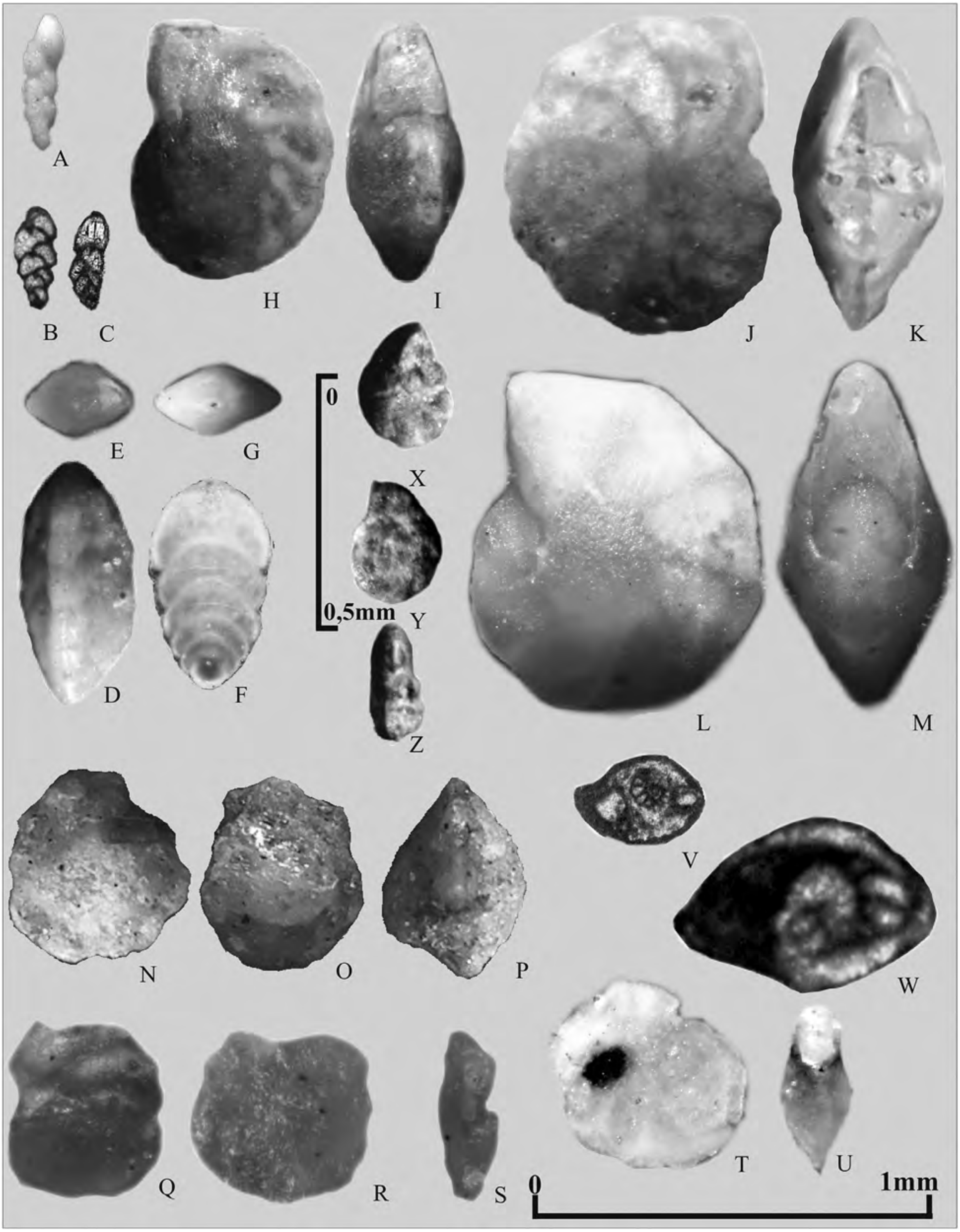


Fig. 16. Berriasian foraminifera. A–C. *Belorussiella taurica*, A, specimen 58/1324, lateral view, B, specimen 59/1324, thin section, C, specimen 60/1324, thin section, Mezhgor'e, Boissieri Zone. D–E. *Quadratina tunassica*, D, lateral view, E, apertural view, Balki, Occitanica Zone, Tauricum Subzone. F–G. *Lingulina trilobitomorpha*, specimen 3031-7, F, lateral view, G, apertural view, Zavodskaya Balka, Boissieri Zone. H–I. *Lenticulina andromede*, specimen 64a/13244, H, lateral view, I, frontal view, Mezhgor'e, Boissieri Zone. J–K, *Lenticulina muensteri*, specimen 63/13244, J, lateral view, K, frontal view, Mezhgor'e, Boissieri Zone. L–M. *Lenticulina macrodisca*, specimen 8-1-6, L, lateral view, M, frontal view, Zavodskaya Balka, Boissieri Zone. N–P. *Epistomina ventriosa*, specimen 40-1-1, N, dorsal view, O, ventral view, P, frontal view, Dvuyakornaya Bay, upper Kimmeridgian–lower Tithonian. Q–U. *Pseudosiphoninella antiqua*, Q, dorsal view, R, ventral view, S, frontal view, T. dorsal view in water, U, frontal view in water, Saint Elias Cape, Jacobi Zone, Grandis Subzone. V, *Protopeneroplis striata*, specimen 700-1-15, thin section, Black River Basin, Tithonian. W, *Protopeneroplis ultragranulatus*, specimen A3-25, thin section, Jacobi Zone, Grandis Subzone. X–Z. *Conorboides hofkeri*, specimen 111/13244, X, dorsal view, Y, ventral view, Z, frontal view, Mezhgor'e, Boissieri Zone.

The foraminiferal assemblage comprises *Everticyclammina virguliana*, *Rectocyclammina chouberti*, *Rectocyclammina arrabidensis*, *Pseudocyclammina lituus*, *Bramkampella arabica*, *Stomatostoecha rotunda*, *Stomatostoechia enisalensis*, *Feultillia frequensis*, *Lenticulina neocomina*, *Lenticulina* ex gr. *nodosa*, *Lenticulina macra*, *Lenticluina colligoni*, *Lenticulina vistulae*, *Protopeneroplis ultragranulatus*, *Pseudosiphoninella antiqua*, *Pseudonodosaria mutabilis*, *Pseudonodosaria diversa*, *Discorbis crimicus*, *Tritaxia pyramidata*, *Epistomina* cf. *ornata*, *Astacolus laudatus*, *Miliospirella* cf. *caucasica*, *Trochammina neocomiana*, *Trocholina molesta* and *Trocholina gigantea*.

The lower boundary of this zone is associated with an abrupt change of species composition of 'large lituolid', abundant *Protopeneroplis ultragranulatus*, small numbers of *Pseudosiphonniella antiqua* and the occurrence of *Bramkampella arabica*. The early Berriasian age (Jacobi Zone) is proven by ammonites (Arkadiev et al., 2012).

Distribution. Eastern Crimea (Dvuyakornaya Bay, Saint Elias Cape), Tonas River Basin (Krasnoselovka Village), central Crimea (Balki Village), South-Western Crimea (Chernaya River Basin).

4.3.4. *Beds with* Textularia crimica—Belorussiella taurica

These beds are identified by the occurrence of *Belorussiella taurica* and abundant *Textularia crimica* and, depending on the type of rocks, contain an enriched or an impoverished assemblage. In southwestern Crimea this assemblage is represented by individual specimens of the following (sub)species: *Ammobaculites* ex gr. *inconstans*, *Nautiloculina oolithica*, *Triplasia emslandensis acuta*, *Astacolus calliopsis*, *Mohlerina basiliensis*, *Globospirillina neocomina*, *Istriloculina fabaria* and *Trocholina alpina*.

More than 200 species, in 63 genera, of foraminifera were found in sections of central Crimea, which have allowed to identify six successive assemblages: 1 — *Everticyclammina virguliana*, *Rectocyclammina recta* and *Bramkampella arabica*; 2 — *Lenticulina muensteri*; 3 — *Quadratina tunassica*; 4 — *Triplasia emslandensis acuta*; 5 — *Lenticulina andromede*; 6 —*Conorboides hofkeri.*

In Eastern Crimea, within the beds of *Textularia crimica* and *Belorussiella taurica,* three foraminiferal assemblages have been identified: *Quadratina tunassica*, *Lenticulina macrodisca* and *Lenticulina andromede.*

The extent of these beds approximately corresponds to the Quadratina tunassica—Siphoninella antiqua Zone and the beds with *Conorboides hofkeri* and *Conorbina heteromorpha* (Kuznetsova and Gorbachik, 1985). Based on ammonite evidence these beds were correlated with the Jacobi Zone (i.e., upper part of the Grandis Subzone) and Occitanica and Boissieri Zones (Arkadiev et al., 2012) (Fig. 21).

Distribution. Eastern Crimea (Saint Elias Cape, Zavodskaya Balka), Tonas River Basin (Krasnoselovka Village), central Crimea (Balki Village), South-Western Crimea (Belbek River Basin, Chernaya River Basin).

4.3.5. *Beds with* Lingulina trilobitomorpha *and* Haplophragmoides vocontianus

This assemblage was identified in eastern Crimea in strata assigned to the Sultanovskaya Formation (Arkadiev et al., 2015b). It comprises over 130 species, in 31 genera, and is characterised by a maximum species diversity of Nodosariida (genera *Astacolus*, *Dentalina*, *Lenticulina* and *Pseudonodosaria*), with lower numbers of *Haplophragmoides* and *Recurvoides* and a visible increase in numbers of *Dorothia* and *Verneuilinoides*.

In addition to species that ranged upwards from lower assemblages, the association consists mainly of species that occur at the very top of the Berriasian Stage and develop during the Valanginian such as *Lenticulina saxonica*, *Lenticulina guttata*, *Lenticulina busnardoi* and *Conorboides hofkeri*. Additionally, we have found species which appear in the Valanginian such as *Haplophragmoides vocontianus*, *Gaudryina alternans*, *Dorothia pseudocostata*, *Lingulina trilobitomorpha*, *Lingulina nodosaria*, *Lenticulina lideri* and others. They also include index species of the Lingulina trilobitomorpha—Haplophragmoides vocontianus Zone, established in the Valanginian of the Crimean Mountains (Kuznetsova and Gorbachik, 1985) and correlated with the lower portion of the Thurmanniceras pertransiens Ammonite Zone (Reboulet et al., 2014).

4.4. Ostracoda

Ostracoda occur in almost all samples from the sections studied. They belong to 22 families (Fig. 17) and are well preserved. The assemblages are dominated by smooth-shelled genera such as *Cytherella*, *Bairdia*, *Paracypris* and *Pontocyprella.* It also contains many specimens of the genus *Cytherelloidea*, especially in the upper part of the Berriasian in central Crimea. Ornamented forms in southwestern and central Crimea are represented mostly by representatives of the family Protocytheridae (*Protocythere*, *Costacythere*, *Hechticythere* and *Reticythere*). In Eastern Crimea a significant number of species is represented by individual specimens, including numerous new forms. The thin-walled forms include *Robsoniella*, while ornamented taxa are dominated by species of the families Cytheruridae (*Eucytherura*) and Pleurocytheridae (*Acrocythere*).

4.4.1. *Beds with* Cytherella tortuosa

These beds are identified by the presence of the index species and an assemblage of typical species (Fig. 21). In upper Kimmeridgian and Tithonian deposits in the Dvuyakornaya Bay, Tesakova and Savelieva had earlier recognised beds with *Cytherella tortuosa* and *Palaeocytheridea grossi* (Arkadiev et al., 2006).

The ostracod assemblage comprises *Cytherella tortuosa*, ?*Mantelliana purbeckensis*, *Eocytheropteron* ex gr. *bispinosum*, *Quasigermanites implicata* and *Hechticythere* sp. 1.

Distribution. Eastern Crimea (Dvuyakornaya Bay), Tonas River Basin (Krasnoselovka Village) (upper Tithonian, Microcantum and Andreaei zones).

4.4.2. *Beds with* Protocythere revili

These beds were identified in deposits assigned to the Jacobi Zone. Initially, Tesakova and Savelieva had identified beds with *Raymoorea peculiaris*, *Eucytherura ardescae* and *Protocythetre revili* in this part of the section (Arkadiev et al., 2006). Later, it was proposed to use only the name *Protocythere revili* for these beds, it being the most typical of the lower Berriasian (Arkadiev et al., 2012).

The ostracod assemblage comprises *Cytherella* cf. *krimensis*, *Eucytherura ardescae*, *E. trinodosa*, *Raymoorea peculiaris*, *Acrocythere alexandrae*, *Costacythere foveata*, *Protocythere revili*, *Palaeocythereidella teres*, *Clitrocytheridea paralubrica*, *Phodeucythere eucretacea* and *Tethysia chabrensis*.

Distribution. Eastern Crimea (Saint Elias Cape), Tonas River Basin (Krasnoselovka Village) (Berriasian, Jacobi Zone).

4.4.3. *Beds with* Costacythere khiamii *and* Hechticythere belbekensis

These beds were detected for the first time by Savelieva in strata assigned to the Occitanica Zone (Arkadiev et al., 2012; Savelieva et al., 2014; Arkadiev et al., 2015a). The name of these beds is based on the co-occurrence of the index species and numerous individuals of *Costacythere khiamii.*

The ostracod assemblage comprises *Cytherella lubimovae*, *Cytherella krimensis*, *Cytherella fragilis*, *Eucytherura* sp. 1, *Eucytherura* sp. 2, *Pleurocythere* (*Klentnicella*) *klentnicensis*, *Costacythere*

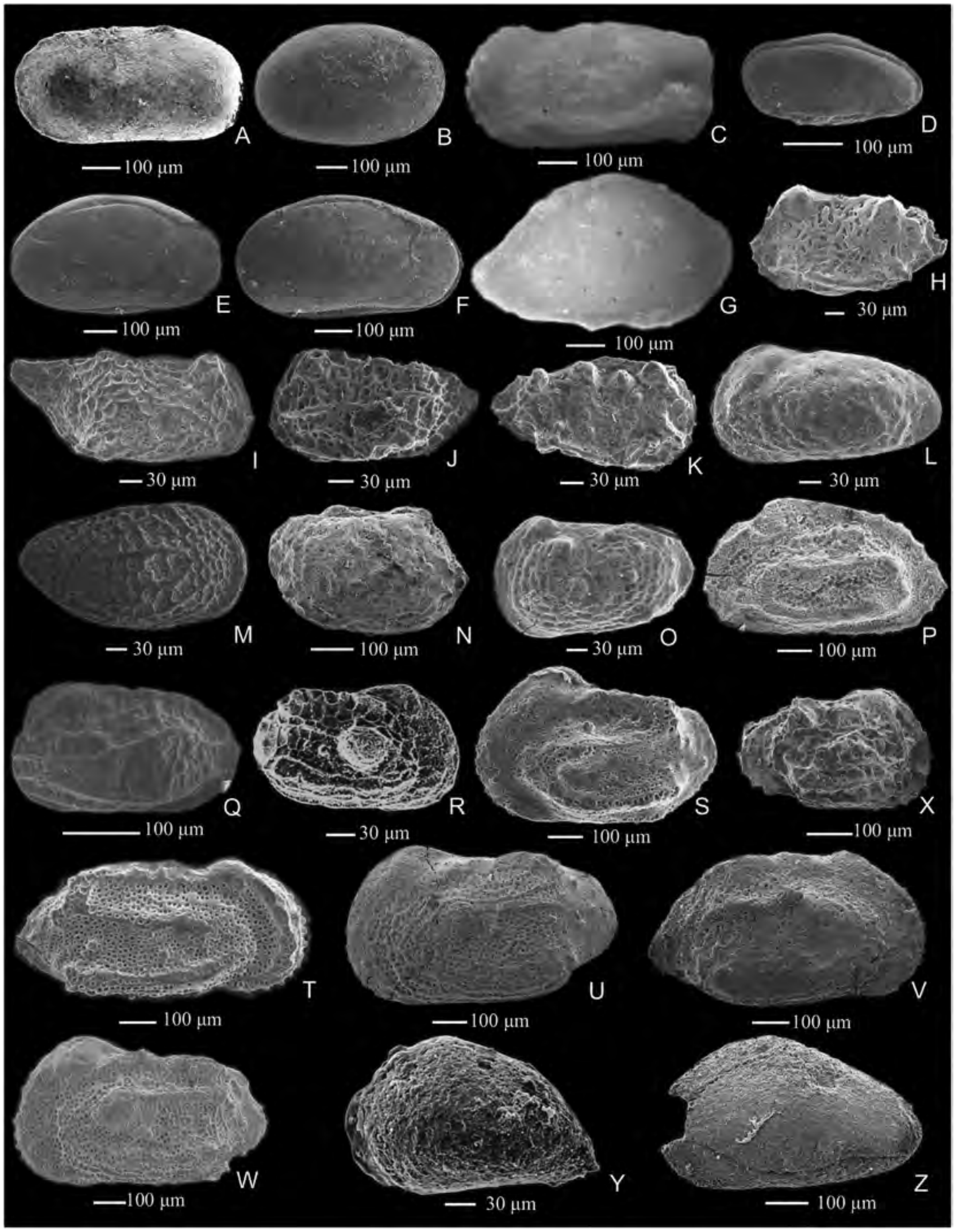


Fig. 17. Late Tithonian, Berriasian and Valanginian(?) ostracods. A, *Cytherella tortuosa*, specimen 172/13220, left valve, lateral view, Dvuyakornaya Bay, Andreaei Zone. B, *Cytherella krimensis*, specimen 600-46-4, right valve, lateral view, Koklyuk Mountain, Boissieri Zone. C, *Cytherelloidea flexuosa*, specimen 22-43-1, left valve, lateral view, Tonas River Basin, Boissieri Zone. D, *Sigillium procerum*, specimen 2900-2, carapace, right lateral view, Zavodskaya Balka, Boissieri Zone, Euthymi Subzone. E, *Robsoniella obovata*, specimen 301-8-1, carapace, right lateral view, Zavodskaya Balka, Boissieri Zone. F, *Robsoniella longa*, specimen 600-46-28, carapace, right lateral view, Koklyuk Mountain, Pertransiensis(?) Zone. G, *Bairdia menneri*, specimen 22-41-1, carapace, right lateral view, Tonas River Basin, Jacobi Zone. H, *Eucytherura*, specimen 9-1, left valve, lateral view, Belbek River Basin, Occitanica Zone. I, *Eucytherura ardescae*, specimen 8-1-3, right valve, lateral view, Zavodskaya balka, Boissieri Zone. J, *Eucytherura* (*E.*) aff. *kotelensis*, specimen 27-1-1, left valve, lateral view, Balki Village, Boissieri Zone. K, *Eucytherura trinodosa*, specimen 27-1-3, right valve, lateral view, village of Balki, Boissieri Zone. L, *Metacytheropteron* sp. A, specimen 8-1-3, left valve, lateral view, Zavodskaya Balka, Boissieri Zone. M, *Loxoella variealveolata*, specimen 2900-0, carapace, right valve, lateral view, Zavodskaya Balka, Boissieri Zone. N, *Neocythere pyrena*, specimen 9-9, carapace, right valve, lateral view, Belbek River Basin, Boissieri Zone. O, *Fuhrbergiella*? sp., specimen 34-1-1, left valve, lateral view, Novoklenovo Village, Boissieri Zone. P, *Pleurocythere* (*Klentnicella*) *klentnicensis*, specimen 9-1, left valve, lateral view, Belbek River Basin, Occitanica Zone. Q, *Acrocythere alexandrae*, specimen 301-8-19, left valve, lateral view, Zavodskaya Balka, Pertransiensis(?) Zone. R, *Protocythere revili*, specimen 220/13220, right valve, lateral view, Saint Elias Cape, Jacobi Zone. S, *Reticythere marfenini*, specimen 35-2-1, left valve, lateral view, Novoklenovo Village, Boissieri Zone. T, *Hechticythere belbekensis*, specimen 225/13220, right valve, lateral view; Belbek River Basin, Occitanica Zone. U, *Costacythere khiamii*, specimen 26-1-1, left valve, lateral view, Balki Village, Occitanica Zone. V, *Costacythere foveata*, specimen 26-1-1, right valve, lateral view, village of Balki, Occitanica Zone. W, *Costacythere drushchitzi*, specimen 41-5-1, left valve, lateral view, Balki Village, Occitanica Zone. X, *Quasigermanites bicarinatus moravicus*, specimen 26-1-1, right valve, lateral view, village of Balki, Occitanica Zone. Y, *Clitrocytheridea paralubrica*, specimen 1-5-1, left valve, lateral view, Sain Elias Cape, Jacobi Zone. Z, *Phodeucythere eocretacea*, specimen 1-10-4, left valve, lateral view, Saint Elias Cape, Jacobi Zone.

khiamii, *Costacythere foveata*, *Hechticythere belbekensis*, *Hechticythere moraviae* and *Schuleridea* ex gr. *juddi*.

Distribution. Central (Balki Village) and South-Western (Belbek River Basin) Crimea (Berriasian, Occitanica Zone).

4.4.4. *Beds with* Costacythere drushchitzi *and* Reticythere marfenini

These beds were recognised for the first time by Savelieva in strata assigned to the Boissieri Zone (Arkadiev et al., 2012). The name of these beds is based on the co-occurrence and abundance of the two index species.

The ostracod assemblage comprises *Cytherella lubimovae*, *Cytherella krimensis*, *Cytherelloidea flexuosa*, *Cytherelloidea mandelstami*, *Bairdia menneri*, *Bairdia kuznetsovae*, *Pontocypris cuneata*, *Bythoceratina* ex gr. *variabilis*, *Eucytherura* (*E.*) aff. *kotelensis*, *Neocythere pyrena*, *Neocythere dispar*, *Acrocythere diversa*, *Costacythere drushchitzi*, *Reticythere marfenini* and *Cythereis* aff. *senckenbergi*.

Distribution. Central Crimea (Balki Village) (Berriasian, Boissieri Zone).

4.4.5. *Beds with* Robsoniella obovata *and* Robsoniella longa

These beds were documented for the first time by Savelieva in the Zavodskaya Balka section (Boissieri and Pertransiens? Zones). Studies of new portions of the section in 2014–2015 have resulted in expansion and a more detailed description of the beds with *Robsoniella obovata* that had been identified earlier (Arkadiev et al., 2012). Based on the new data we propose to distinguish the beds with *Robsoniella obovata* and *Robsoniella longa* in this part of the section. The beds were named on the basis of predominance, co-occurrence and abundance of the two index species.

The ostracod assemblage comprises *Robsoniella longa*, *Robsoniella obovata*, *Robsoniella minima*, *Sigillium procerum*, *Bairdia menneri*, *Bairdia major*, *Pontocyprella* cf. *pertuisi*, *Paracypris caerulea*, *Loxoella variealveolata*, *Eucytherura ardescae* and *Hemicytherura moorei.*

Distribution. Eastern Crimea (Zavodskaya Balka) (Berriasian, Boissieri Zone; Valanginian, Thurmanniceras pertransiens Zone?).

4.5. *Palynological investigations: organic-walled dinoflagellate cysts*

Most of the samples contain numerous palynomorphs (spores, pollen, dinoflagellate cysts, prasinophytes and acritarchs), either well preserved or satisfactorily so. Our study of macerated organic material has revealed an absolute predominance of *Classopollis* pollen (70–90%), which is typical of the Tithonian–Berriasian deposits of the Crimean Mountains (Kuvaeva and Yanin, 1973; Vakhrameev, 1981). The remaining 10–30% palynomorphs are represented by spores, pollen and phytoplankton in various proportions. In the upper part of the Boissieri Zone the abundance of *Classopollis* pollen decreases, averaging 10–20% and the amount of bisaccate pollen of gymnosperms increases to 30–50%.

Based on a study of organic-walled dinoflagellate cysts we have identified beds with *Amphorula expirata* and those with *Phoberocysta neocomica* (Figs. 18, 21).

4.5.1. *Beds with* Amphorula expirata

The base of these beds is defined by the first appearance of *Amphorula expirata*, while the FAD of *Phoberocysta neocomica* defines its upper boundary.

The dinocyst assemblage comprises *Achomosphaera neptunii*, *Apteodinium* sp., *Amphorula expirata*, *Amphorula dodekovae*, *Cassiculosphaeridia pygmaeus*, *Chlamydophorella* sp., *Cometodinium habibii*, *Cribroperidinium* sp., *Cribroperidinium globatum*, *Chytroeisphaeridia chytroeides*, *Dichadogonyaulax* sp., *Dingodinium minutum*, *Epiplosphaera*? *areolata*, *Escharisphaeridia psilata*, *Heslertonia pellucida*, *Hystrichodinium pulchrum*, *Wallodinium cylindricum*, *Systematophora areolata*, *Prolixosphaeridium* spp., *Prolixosphaeridium parvispinum*, *Kleithriasphaeridium eoinodes*, *Muderongia simplex*, *Sirmiodinium grossi*, *Scriniodinium campanula*, *Scriniodinium dictyotum*, *Protobatioladinium imbatodinense*, *Tehamadinium* sp., *Tubotuberella egemenii*, *T. apatela* and *Wrevittia helicoidea*. Remanie cysts, such as *Nannoceratopsis pellucida*, *Nannoceratopsis gracilis* and *Ellipsodictium cinktum* are present everywhere.

In Eastern Crimea, *Amphorula expirata* was documented from the upper Tithonian at Dvuyakornaya Bay (upper part of the Microcanthum Zone) and in strata barren of ammonites that have been tentatively dated as late Tithonian based on micropalaeontological data (Feodorova, 2000) at the Tonas River. The earliest occurrence of *Amphorula expirata* is in the upper Kimmeridgian (Hudlestoni Zone) of the British Isles (Riding and Thomas, 1992). On the Russian Platform this species appears in the mid-Volgian Panderi Zone (Harding et al., 2011).

Distribution. Eastern Crimea (Dvuyakornaya Bay), upper Tithonian (upper part of the Microcanthum Zone and Andreaei Zone) and Berriasian (Jacobi Zone); Tonas River Basin (Krasnoselovka Village), upper Tithonian and Berriasian (Jacobi Zone); central Crimea (Balki Village), Occitanica Zone (without Tauricum Subzone) (Arkadiev et al., 2012).

4.5.2. *Beds with* Phoberocysta neocomica

The base of these beds is defined by the first appearance of *Phoberocysta neocomica* and the top by that of *Pseudoceratium pelliferum*.

In the dinocyst assemblage *Cometodinium habibii*, *Systematophora* sp., *Systematophora areolata*, *Prolixosphaeridium* spp. and *Hystrichodinium pulchrum* predominate. In addition, there are individual specimens of the taxa that first appeared in the Tithonian such as *Achomosphaera neptunii*, *Amphorula expirata*, *Amphorula dodekovae*, *Apteodinium* sp., *Chlamydophorella* sp., *Chytroeisphaeridia chytroeides*, *Cassiculosphaeridia pygmaeus*, *Cribroperidinium globatum*, *Dichadogonyaulax* spp., *Epiplosphaera*? *areolata*, *Epiplosphaera reticulospinosa*, *Heslertonia pellucida*, *Kleithriasphaeridium eoinodes*, *Muderongia simplex*, *Scriniodinium campanula*, *Scriniodinium dictyotum*, *Sirmiodinium grossi*, *Tanyosphaeridium* spp., *Tubotuberella* spp., *Wallodinium cylindricum* and *Wrevittia helicoidea.* Other taxa disappear in this zone, such as *Escharisphaeridia psilata*, *Dingodinium minutum* and *Protobatioladinium imbatodinense*. New taxa (Fig. 21) include *Muderongia longicorna* (upper part of the Jacobi Subzone), *Phoberocysta neocomica*, *Spiniferites* spp. and *Ctenidodinium elegantulum* (base of the Tauricum Subzone). Additionally, *Amphorula metaelliptica*, *Bourkidinium* sp., *Circulodinium distinctum*, *Dapsilidinium*? *deflandrei*, *Dapsilidinium warrenii*, *Egmontodinium torynum*, *Tanyosphaeridium* spp., *Valveodinium* sp. and *Muderongia endovata* appear in this assemblage. In the upper part of the Boissieri Zone in Eastern Crimea, in intervals without ammonites (Fig. 21), we have documented the last occurrence of *Systematophora areolata* and the first occurrence of *Systematophora palmula* and *Kleithriasphaeridium fasciatum* (Zavodskaya Balka section) and *Pseudoceratium pelliferum* (Koklyuk section). In the Tethyan region, these events correspond to the Otopeta Subzone (Ogg et al., 2008), which, together with the ammonite *Berriasella callisto* we have recovered from this level, have been described from the Otopeta Subzone in Spain, makes the assumption possible that this subzone is represented in Eastern Crimea.

Distribution. Central (Balki Village) and South-Western Crimea (Belbek River Basin), Berriasian, Tauricum Subzone of the

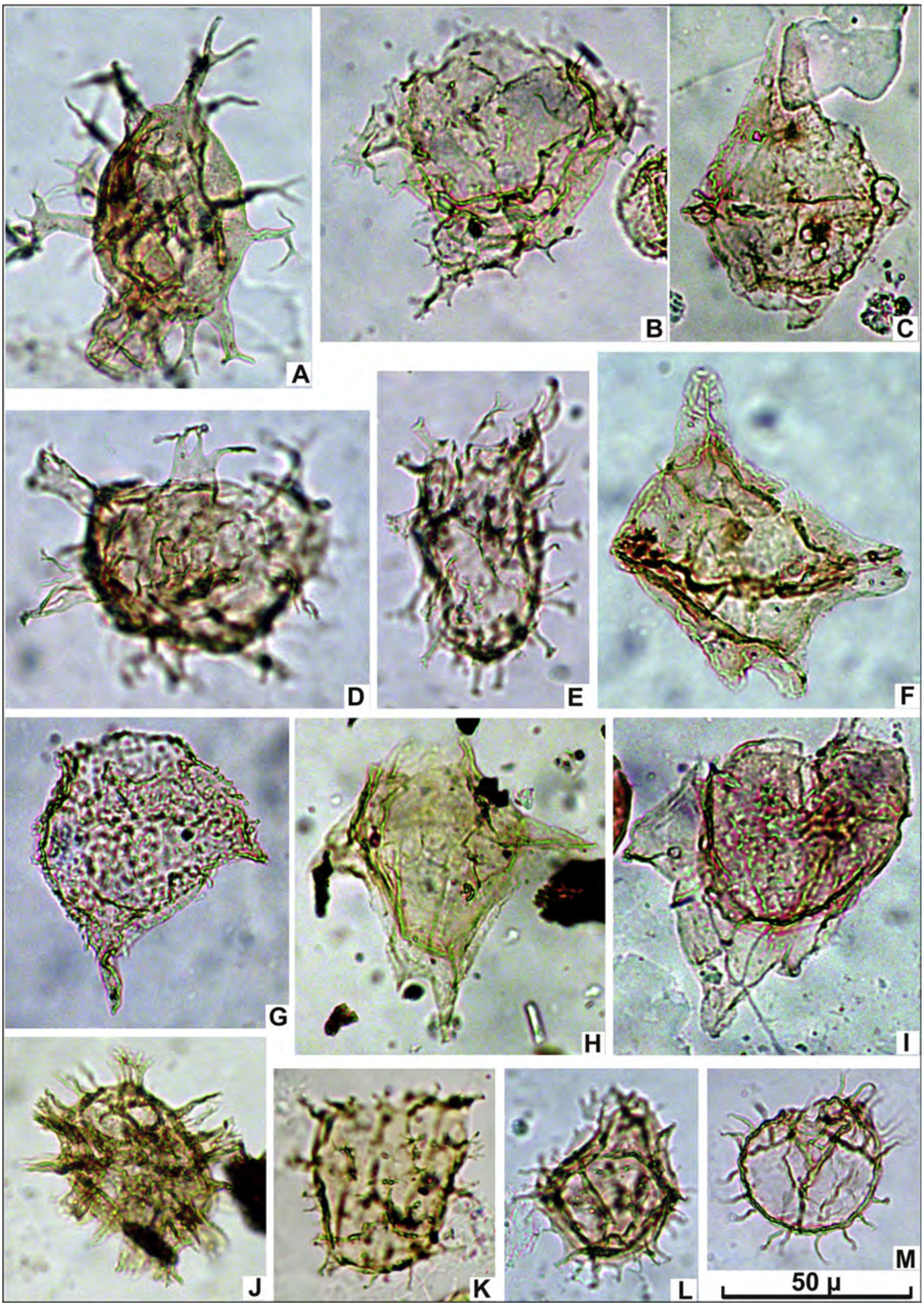


Fig. 18. Late Tithonian and Berriasian dinoflagellate cysts. A, *Achomosphaera neptunii*, specimen 600-46-8, Koklyuk Mountain, Boissieri Zone. B, *Phoberocysta neocomica*, specimen 3030-8, Koklyuk Mountain, Berriasian. C, *Muderongia endovata*, specimen 22-43-1, Tonas River Basin, Jacobi Zone, Jacobi Subzone. D, *Systematophora palmula*, specimen 3058-39, Zavodskaya Balka, Boissieri Zone. E, *Egmontodinium torinum*, specimen 3031-1. Zavodskaya Balka, Boissieri Zone. F, *Muderongia simplex*, specimen 17, Dvuyakornaya Bay, upper Tithonian, Andreaei Zone. G, *Pseudoceratium pelliferum*, specimen 600-46-34, Koklyuk Mountain, Berriasian. H, *Muderongia longicorna*, specimen 3031-1. Zavodskaya Balka, Boissieri Zone. I, *Muderongia* sp./*Phoberocysta* sp., specimen 22-43-1, Tonas River Basin, Jacobi Zone, Jacobi Subzone. J, *Kleithriasphaeridium fasciatum*, specimen 3031-3, Zavodskaya Balka, Boissieri Zone. K, *Amphorula expirata*, specimen 8-2-1, Zavodskaya Balka, Boissieri Zone. L, *Spiniferites* sp., specimen 3058-39, Zavodskaya Balka, Boissieri Zone. M, *Ctenidodinium elegantulum*, specimen 3030-14, Koklyuk Mountain, Berriasian.

Occitanica Zone and Boissieri Zone; Eastern Crimea (Zavodskaya Balka, Koklyuk section) – Boissieri Zone.

Phoberocysta neocomica is known to appear in the Otopeta Subzone, both in the Tethyan Boreal regions (Ogg et al., 2008). An earlier appearance of this species was described from Berriasian strata (Schrambach Formation) in the Eastern Alps, dated as middle Berriasian based on calpionellids (Boorová et al., 2015). In addition to the simultaneous appearance of *Phoberocysta neocomica* in the Eastern Alps and in Eastern Crimea, the taxonomic compositions of dinocyst assemblages of the middle and upper Berriasian in these regions have over 20 species in common.

Amongst dinocysts we have found forms of moderate preservation which, judging from their size, shape and overall ornamentation, may be morphologically transitional between *Muderongia simplex* and *Phoberocysta neocomica* (Fig. 18I). Earlier (Arkadiev et al., 2012) we had mistakenly identified these forms as *Phoberocysta neocomica*, and had consequently indicated the first occurrence of the species to be at the base of the Jacobi Zone. In the present paper these cysts are identified as *Muderongia* sp./*Phoberocysta* sp. It is worth mentioning that the presence of these morphotypes in the Ryazanian–Valanginian was noted during palynological studies of the Boreal Jurassic–Cretaceous boundary (Fisher and Riley, 1980).

In addition to dinocysts, acritarchs (*Micrhystridium* spp., *Veryhachium* spp.) and prasinophytes (*Pterospermella* spp., *Tasmanites* spp.) were found in all sections studied.

5. Magnetostratigraphy

Magnetic polarity data were obtained by us between 2009 and 2016 (Yampolskaya et al., 2009; Arkadiev et al., 2010, 2012; Guzhikov et al., 2012, 2014; Arkadiev et al., 2015a,b). Data for central (Fig. 6) and Eastern (Figs. 3–4) Crimea were summarised in the magnetostratigraphic scheme, and magnetozones correlated with magnetic polarity chrons of the Geomagnetic Polarity Time Scale (GPTS) (Ogg et al., 2016) (Fig. 19).

In 2016, we completed an additional study of the Dvuyakornaya Bay, Saint Elias Cape and Feodosiya Cape sections, which revealed two errors that had been made earlier during the compilation of the Dvuyakornaya Formation composite section (Guzhikov et al., 2012).

Sedimentary rocks at Feodosiya Cape belong to bed 12 of the Feodosiya Marl (Fig. 20I-b), rather than to beds 9–11 (Fig. 20I-a). The erroneous conclusion was based on the assumed absence of limestones within the Feodosiya Marlstones (Arkadiev et al., 2012), and as a result, the thick bed of rudstone at Feodosiya Cape was identified as an equivalent of the marker limestone in the lower portion of the Saint Elias Cape section (base of bed 10) (Guzhikov et al., 2012). In 2014–2016, while studying other Berriasian sections in the Feodosiya area (Koklyuk, Sultanovka, Zavodskaya Balka), we confirmed that interbeds of channel turbidites were present within the Sultanovka Formation and, therefore, may occur in the underlying marls. It is possible that the lower part of Outcrop 2920 with a normal polarity corresponds to the upper part of Outcrop 2456; however, most likely, there is a hiatus in the composite section.

The thick bed of rudstone at the top of Dvuyakornaya Bay section was also visually identified as an equivalent of the marker limestone at the bottom of the Saint Elias Cape section (Guzhikov et al., 2012). In 2016, oriented samples were taken from 12 levels of the overlying clays at Outcrop 3112 (co-ordinates N 45°00′21.3″, E 35°23′12.7″) and Outcrop 3113 (N 45°00′19.5″, E 35°23′04.5″), which showed normal polarity (Fig. 20I-b). However, the clays above the channel turbidite layer at the lower part of the Saint Elias Cape section have reversed polarity (Fig. 20I). Therefore, the thick limestone beds at Dvuyakornaya Bay and at Saint Elias Cape have different ages, and there is a hiatus between Outcrops 3112 and 2927 (Fig. 20I-b).

Palaeomagnetically, the sedimentary rocks studied at Outcrops 3112 and 3113 do not differ from the clays of the Dvuyakornaya Formation that had been studied earlier (Guzhikov et al., 2012). Eleven out of 12 samples (one from each level), cleaned using alternating magnetic fields, showed a high-coercivity characteristic magnetisation component (**ChRM**) in the range from 10 to 20 to 70–90 mT (Fig. 20II). The significant variance of **ChRM** (Fig. 20III) most likely results from the impossibility to determine true dip and strike of clay beds due to slump deformations, which was one of the reasons why these sediments were not sampled previously (Guzhikov et al., 2012). Due to the presence of landslide deformations, outcrops 3112 and 3113 cannot be considered in calculations of palaeopole co-ordinates and palaeolatitude.

Unlike data obtained in 2012 (Figs. 3, 20I-a), the updated palaeomagnetic column for the lower Berriasian (Jacobi Zone) near Feodosiya ends with a reversed polarity magnetozone at the top, the equivalent to chron M17r, and includes two hiatuses of unknown magnitude, i.e., between beds 9 and 10 and within bed 12 (Fig. 20I-b). However, in the sampling process these hiatuses are insignificant, because the summary magnetic susceptibility curve has no abrupt step-like changes at the levels that correspond to the hiatuses (Fig. 20I-b). Additionally, *Berriasella chomeracensis* (Figs. 3, 10D–E) was identified at Outcrop 3112, and a similar ammonite had been recovered previously from 4 m above the marker limestone at Saint Elias Cape (Arkadiev et al., 2006).

The data obtained from additional studies of calpionellids from the section on Cape Feodosiya are consistent with magnetostratigraphic data (Fig. 3).

The probability of missing magnetic chrons due to thin hiatuses in outcrops is too low to provide grounds for doubt over results of magnetic polarity interpretations (Guzhikov et al., 2012). Theoretically, the absence of subchron M19n/1r (Brodno), of short duration, between beds 9 and 10 may be assumed, but then, based on the continuity of the section, the underlying magnetozones of reversed polarity should be correlated either with chron M19r and subchron M20n/1r (Kysuca), or with chrons M19r and M20r. In the first case, the Kysuca section will have an unrealistically great thickness, and in the second, it will have to be assumed that M20n/1r is missing due to the large sampling trajectory. However, the main reason why we do not consider the second option is the early Tithonian age of chron M20r, which contradicts the ammonite-based biostratigraphy, which places the beds with *Oloriziceras* cf. *schneidi* in the upper Tithonian (Arkadiev et al., 2006).

The sequence of magnetozones from $\mathbf{N_1t}$ through $\mathbf{N_1b}$ was determined within the Dvuyakornaya Formation in the sections at Dvuyakornaya Bay, Feodosyia Cape and Saint Elias Cape (Figs. 3, 19) (Arkadiev et al., 2012; Guzhikov et al., 2012). $\mathbf{N_1t}$ corresponds to the Microcanthun Zone (upper Tithonian) and is equivalent to chron M20n. Magnetozone $\mathbf{R_1t}$ is located in the lower part of the Andreaei Zone; it was identified as equivalent to chron M19r. Magnetozones $\mathbf{N_1t\text{-}b}$, $\mathbf{R_1t\text{-}b}$ and $\mathbf{N_2t\text{-}b}$ were identified in the Andreaei/Jacobi boundary interval and, in our opinion, correspond to chron M19. $\mathbf{R_1t\text{-}b}$ corresponds to the Brodno subchron (M19n.1r), while $\mathbf{N_1t\text{-}b}$ and $\mathbf{N_2t\text{-}b}$ correspond to subchrons M19n2n and M19n1n, respectively. Magnetozone $\mathbf{R_1b}$ corresponds to the boundary of the Jacobi/Grandis subzones and correlates with chron M18r, and magnetozone $\mathbf{N_1b}$ above it, confined to within the Grandis Subzone, correlates with chron M18n. Equivalents of $\mathbf{N_1b}$ within the Grandis Subzone were also documented in the Tonas River Basin (Fig. 4) (Yampolskaya et al., 2009).

To date, magnetozones from $\mathbf{R_2b}$ through $\mathbf{N_2b}$ have been identified only in central Crimea, within the Bechku Formation (Fig. 6) (Arkadiev et al., 2015a). Subzone $\mathbf{R_2b}$ encompasses the beds with

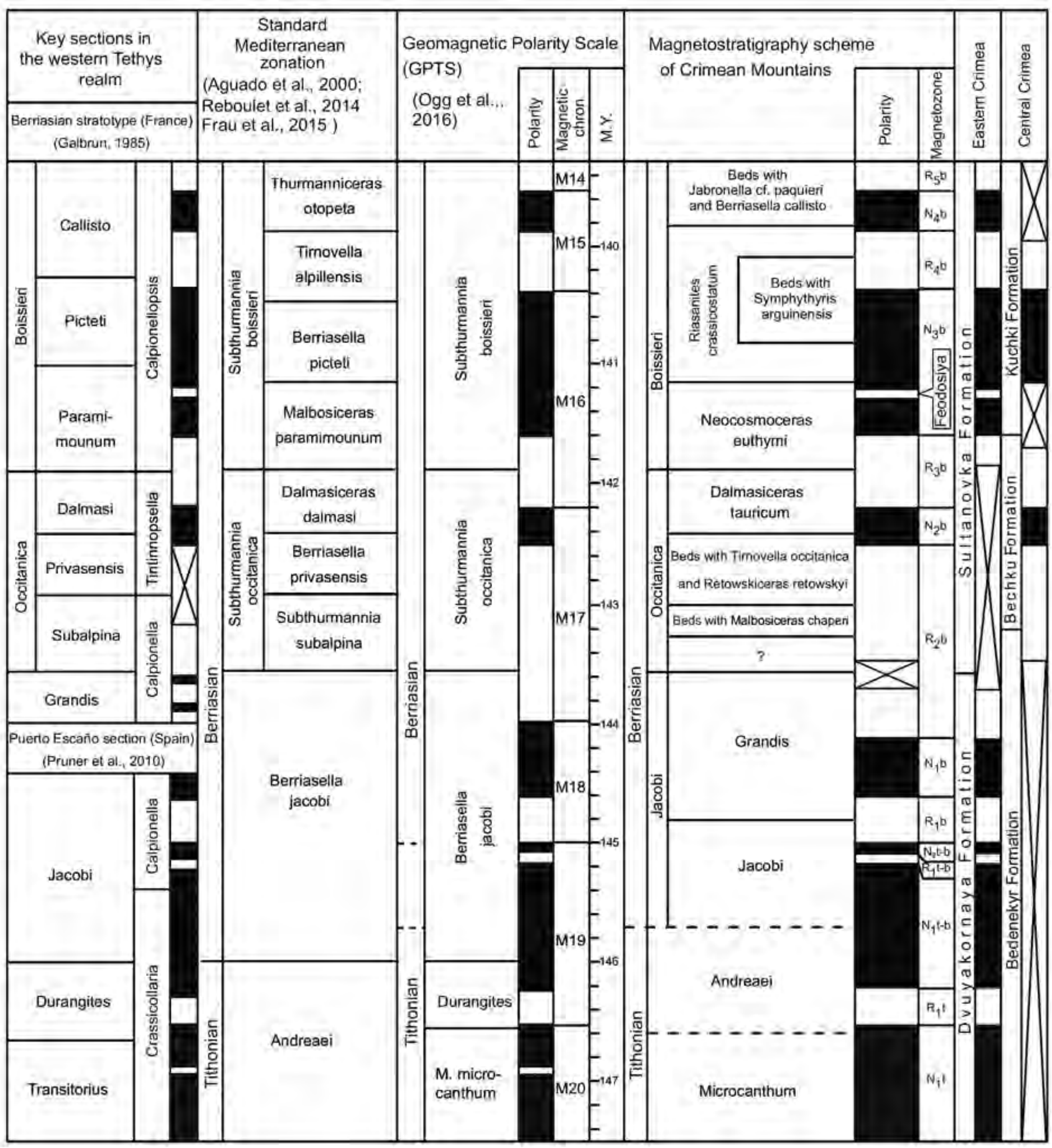


Fig. 19. Magnetostratigraphic scheme of the upper Tithonian–Berriasian of the Crimean Mountains.

Malbosiceras chaperi, *Tirnovella occitanica* and *Retowskiceras retowsky* (Occitanica Zone) and therefore is indisputably equivalent to chron M17r. Subzone $\mathbf{N_2b}$ is associated with the Tauricum Subzone of the Occitanica Zone, allowing reliable correlation with chron M17n.

The Berriasian magnetozones $\mathbf{R_3b}$**,** $\mathbf{N_3b}$ and $\mathbf{R_4b}$ were identified both in the Bechku Formation and in the Kuchkinskaya Formation of central Crimea (Fig. 6) (Arkadiev et al., 2015a,b), as well as in the Sultanovskaya Formation of eastern Crimea (Fig. 5) (Arkadiev et al., 2010; Arkadiev et al., 2015a,b).

Correlation of the upper part of the reversed polarity $\mathbf{R_3b}$ magnetozone with the Euthymi Subzone (equivalent to the Paramimounum Subzone of the western Tethys) of the Boissieri Zone in the Zavodskaya Balka section (Fig. 5) makes it possible to align $\mathbf{R_3b}$ with chron M16r (Arkadiev et al., 2010). Magnetozone $\mathbf{N_3b}$ described higher up the section corresponds to the Boissieri Zone and is equivalent to chron M16n.

A reversed polarity 'Feodosiya' interval was identified within the $\mathbf{N_3b}$ (Guzhikov et al., 2014; Arkadiev et al., 2015a,b). A similar R-interval was established earlier in coeval deposits in the Berriasian stratotype in France (Galbrun, 1985) and, possibly, in the Bosso section, Italy (Satolli et al., 2007). The results of marine magnetic surveys also support the presence of a short reversed polarity epoch within chron M16n (Tominaga and Sager, 2010). Therefore, there is sufficient evidence to include the 'Feodosiya' interval in GPTS as subchron M16n.1r.

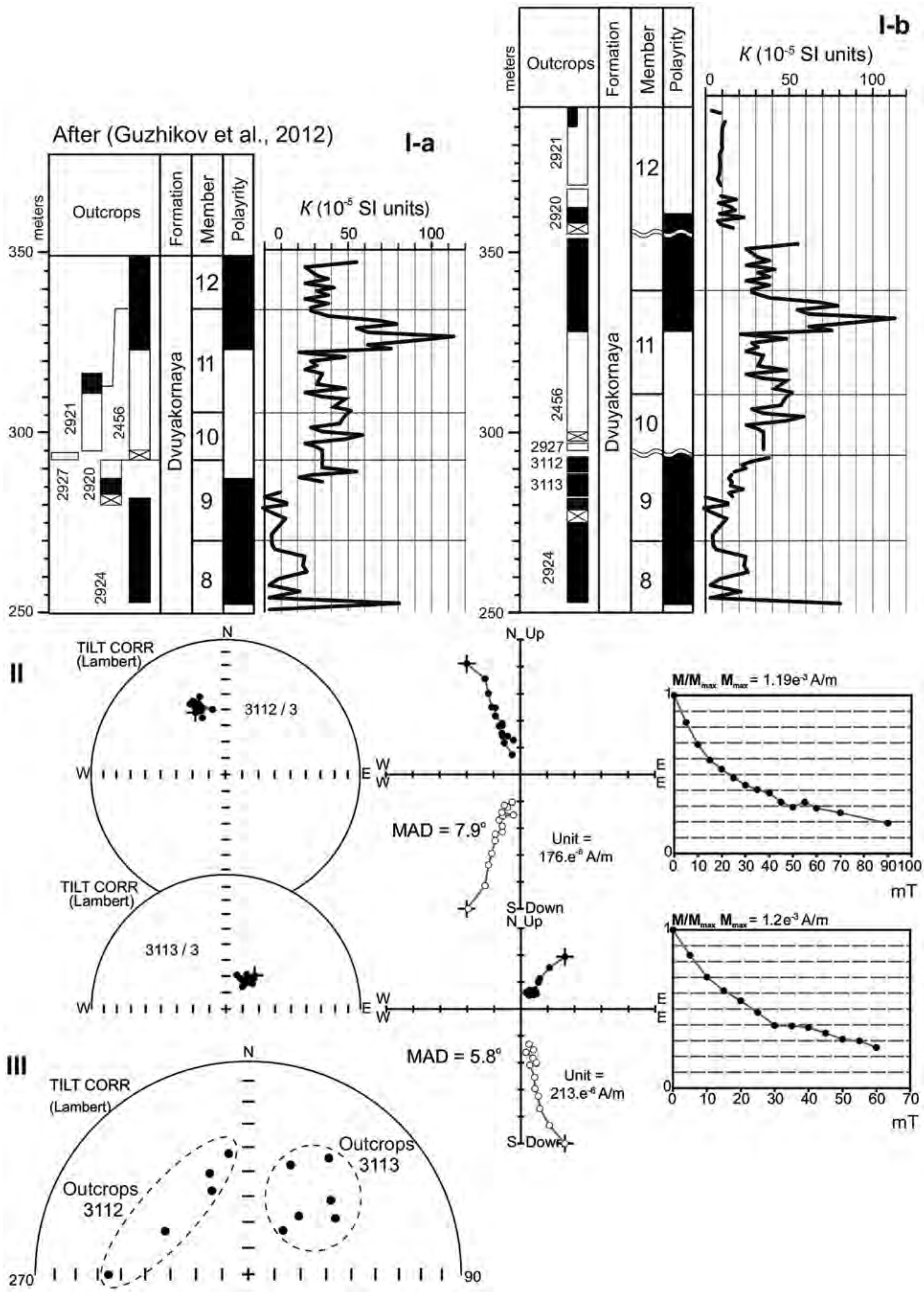


Fig. 20. Composite section of the uppermost part of the Dvuyakornaya Formation and magnetostratigraphic characteristics prior to (I-a) and subsequent to additional study of the section in 2016 (I-b). Magnetic component analysis results from left to right: stereographic presentation of **Jn** changes in the process of magnetic cleaning, Ziderweld diagrams, sample demagnetisation plots (II), **ChRM** stereographic projections (III). All stratigraphic images are presented in the stratigraphic system of co-ordinates. MAD – maximum angle deviation.

Subzone **R_4b** encompasses the top portion of the Boissieri Zone and corresponds to chron M15r.

In the Zavodskaya Balka section we were able to add to the Berriasian magnetostratigraphic scheme two other magnetozones, **N_4b** and **R_5b** (Arkadiev et al., 2015a,b), which were reliably correlated with chrons M15n and M14r as based on finds of the ammonites *Riasanites crassicostatum* and *Berriasella callisto*.

6. Discussion

6.1. Biostratigraphy

From the section exposing the Dvuyakornaya Formation, with ammonites of the Berriasian Jacobi Zone in the top part, we have recovered late Tithonian ammonites, such as *Oloriziceras* cf. *schneidi*, *Paraulacosphinctes transitorius*, *Paraulacosphinctes* cf. *senoides* and *Neoperisphinctes* cf. *falloti* (Arkadiev, 2004, 2011; Arkadiev et al., 2006; Guzhikov et al., 2012).

The change of Tithonian calpionellid assemblages to Berriasian ones has been noted throughout the Tethyan region near the base of the Calpionella Zone, which is defined by mass occurrences of the index species, *Calpionella alpina*. The base of the zone is located within the Jacobi Zone and in the M19n normal polarity chron, below chron M19n1r (Brodno) (Houša et al., 2004; Michalík et al., 2009; Pruner et al., 2010).

In the Crimean Mountains, based on calpionellids, we have been able to identify three zones with subzones, which were correlated with standard zones using ammonites and calpionellids (Platonov et al., 2014). The boundary between the Crassicollaria and Calpionella zones is located above the base of the Jacobi Zone, within the M18r reversed polarity chron. The special position of the boundary in Eastern Crimea can be explained by rare finds of calpionellids. Calpionellids were encountered in only 19 of 810 thin sections analysed from Dvuyakornaya Bay, the sampling interval having been 1.5–2 m. More detailed sampling was not possible because of the structure of the section. Determination of the exact position of the Chitinoidella/Crassicollaria and Crassicollaria/Calpionella boundaries in eastern Crimea requires additional study.

The change in assemblages of Anchispirocyclina lusitanica–Melathrokerion spirialis/Protopeneroplis ultragranulatus–Pseudosiphoninella antiqua foraminiferal zones in sections in Eastern Crimea occurs near the base of the Jacobi Zone (Fig. 21).

The study of ostracod distribution within the Dvuyakornaya Formation section has revealed a difference between the Tithonian–Berriasian boundary assemblages. The lower (tentatively Tithonian) assemblage includes 37 species in 27 genera, some species being new to science. They do not provide a clear indication of age, being known to range through the entire Tithonian and Berriasian. The upper (Berriasian, Jacobi Zone) assemblage is the most diverse, with 92 species in 61 genera. Along with the 13 species held over from the lower assemblage, a large number of new species occur. In this assemblage we have identified many species that had earlier been recorded from Berriasian deposits of Crimea (Arkadiev et al., 2012) and the Caucasus (Kolpenskaya, 2000) and the Berriasian–Valanginian from Western Europe (Donze, 1965).

In Crimean sections the J/K boundary cannot always be determined with the essential accuracy. This is caused by rare finds of ammonites and inaccuracy of micropalaeontological data in determining the exact age of sediments. Magnetozones established in the 'Feodosia' section may be identified as the succession of chrons M20n-M18n (Guzhikov et al., 2012) proceeding from layers that contain *Oloriziceras* cf. *schneidi*, of late Tithonian date, and documenting the absence of large sedimentary breaks. In this case the J/K boundary in Crimea must be placed within magnetozone **R1t-b**, the analogue of subchron M19n.2n (Guzhikov et al., 2012). The same can be seen in the Puerto Escano section (Pruner et al., 2010). However, such magnetostratigraphic interpretations may cause some problems, requiring a more specific discussion.

Firstly, the relationship between Calpionella fossil zones and magnetic chrons does not resemble that which appearsin most other Tethyan sections (Grabowski, 2011): the Crassicollaria/Calpionella and Chitinoidella/Crassicollaria boundaries in Crimea are related to the M18r and upper part of M19.2n (Platonov et al., 2014). The Crassicollaria Zone in Crimea has an anomously small duration in comparison with western Europe, where it may be associated with the duration of the late Tithonian substage (Grabowski, 2011). The poor calpionellid complexes, in conjunction with their insufficient sampling, are the most probable causes of these differences. One more potential cause is a disregard of possible diagenetic reworking (Reháková et al., 2009; Wimbledon et al., 2013). However, we cannot rule out the presence of diachronic boundaries of Calpionella zones as an explanation of this contradiction. It is important to note that data from Crimea are inconsistent with available views on the relationship of palaeomagnetic and Calpionella scales (Grabowski, 2011) under any variant of magnetostratigraphic interpretation of Crimean magnetozones. At the same time, data on ammonites and magnetic polarity in Crimea do not contradict the analogous material from other sections (Pruner et al., 2010; Wimbledon et al., 2013).

Secondly, sedimentation rates within the Dvuyakornaya Formation are much higher than in the Sultanovskaya Formation and other typical sections in the western Tethys (Grabowski, 2011). The range of rates for the Dvuyakornaya Formation varies about one to several hundreds of metres per myr, from a minimum of 100 m/myr. (in M18r) to *c.*500 m/myr (in M19r). Such depositional rates are specific for flysch sediments which form the Dvuyakornaya Formation. The only exception, not yet explained, is the absolutely low sedimentation rate in M19n.2n (~40 m/myr). Such a low sedimentation rate could be possible if a hiatus is included, but there are no signs of long-lasting breaks in the Dvuyakornaya section (Guzhikov et al., 2012). The Sultanovka and Dvuyakornaya formations differ much in sedimentological respects, such as sedimentation rates of about 40 m/myr, which is specific for deep-sea clays. Sedimentation rates in M15r and M15r are ~10 m/myr and 50 m/myr, respectively. However, these chrons are located in sedimentary rocks that are strongly deformed by faults and landslides, mostly in the upper part of the section; this explains why assessments of sedimentation rates are less trustworthy. In all, the late Tithonian appears to have had a tendency of raised sedimentation rates, reaching a maximum around the Tithonian–Berriasian boundary (508 m/myr in M19n/1r). Interesting is the fact that nearly the same trend of an increased sedimentation rate in the late Tithonian that lasted up to the start of the Berriasian has been noted in the Carpathians and southern Alps (Grabowski et al., 2010), but, alternatively, this may simply be coincidental.

Finally, in view of the complex tectonic structure of the study area, some casual errors may appear while making composite sections of the upper Tithonian–Berriasian in eastern Crimea. These errors may have an impact on the final result of our data interpretation.

6.2. Tithonian–Berriasian boundary

The position of the boundary between the Jurassic and Cretaceous (Tithonian–Berriasian) has been the topic of intense discussion lately, as a result of numerous new stratigraphic studies of this interval (Egoyan, 1975; Druschits and Vahrameev, 1976; Wimbledon, 2008; Zakharov, 2011; Wimbledon et al., 2011; Baraboshkin et al.,

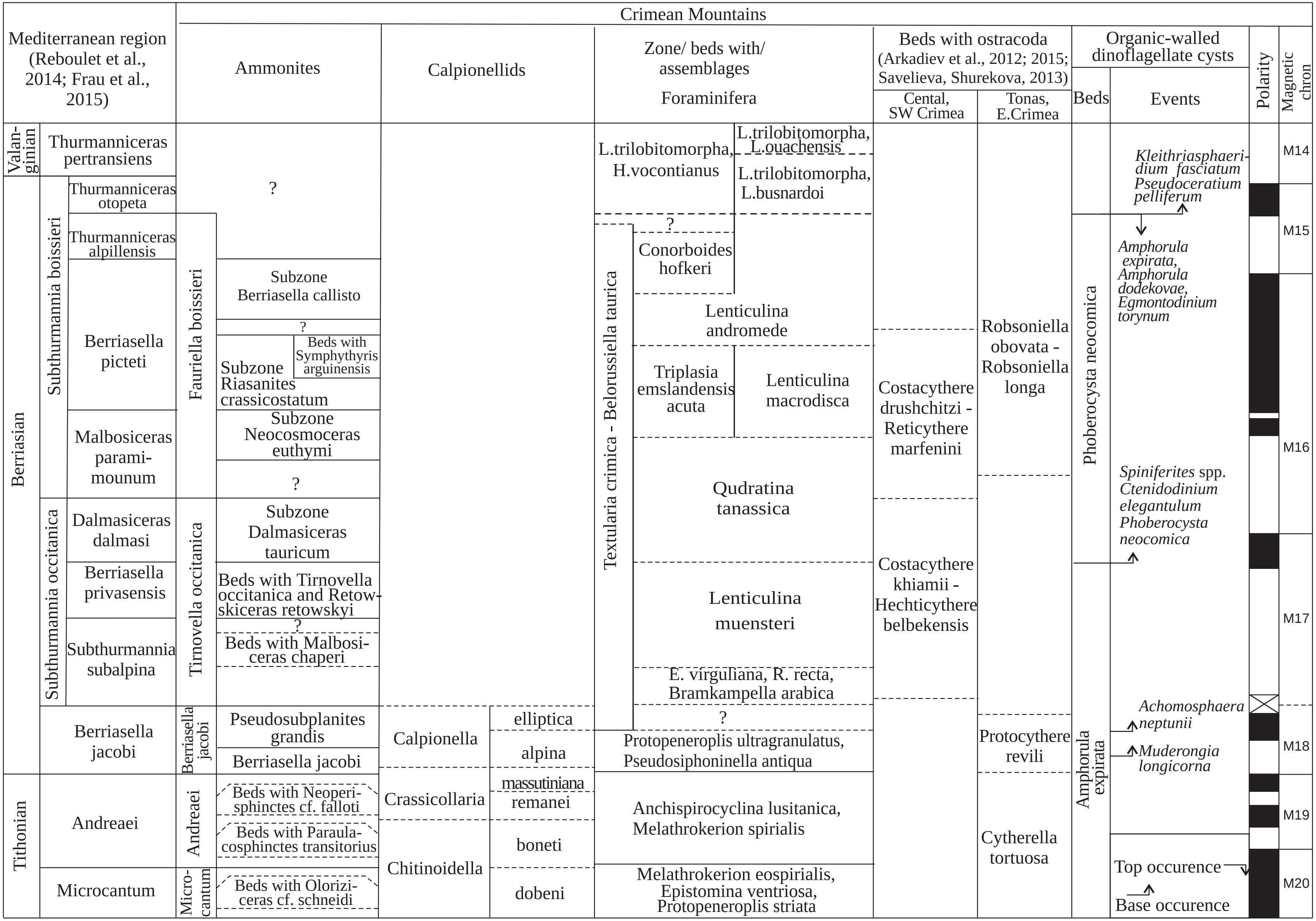
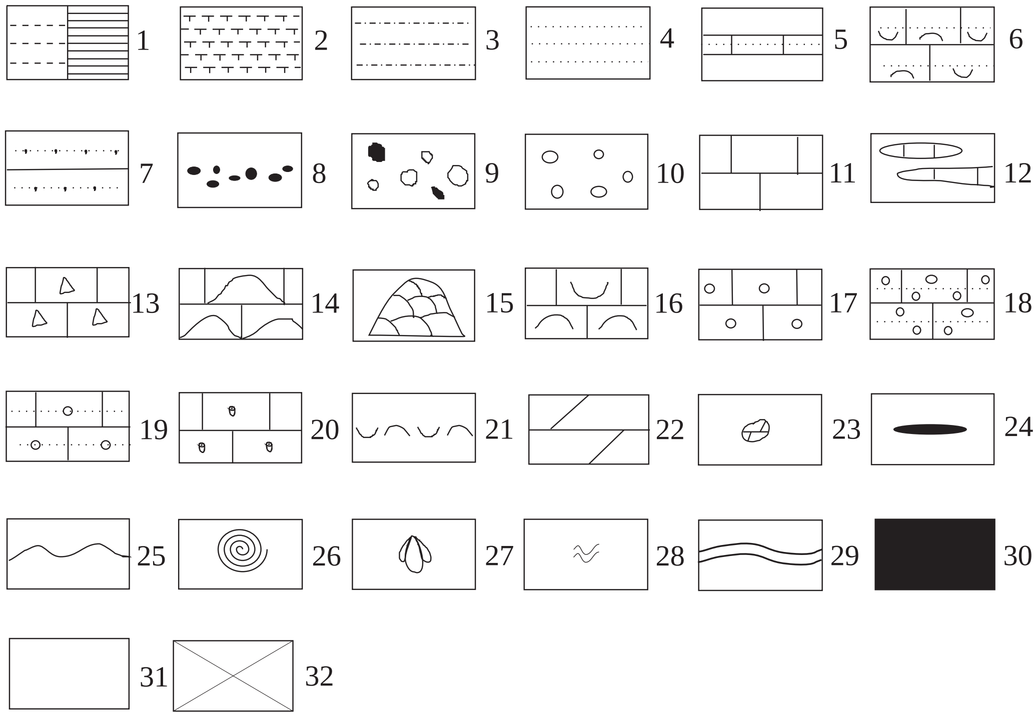


Fig. 21. Subdivision of the Berriasian Stage of the Crimean Mountains based on ammonites, calpionellids, foraminifera, ostracods and dinocysts.



1 - clay, 2 - calcareous clay, 3 - aleurolite, 4 - sandstone, 5 - calcareous sandstone, 6 - calcareous shell sandstone, 7 - glauconitic sandstone, 8 - conglomerate, 9 - polymictic conglomerate, 10 - quartz conglomerate, 11 - limestone, 12 - limestone lenses, 13 - brecciated limestone, 14 - reefal limestone, 15 - bioherms, 16 - organogenic-detrital limestone, 17 - onkolitic limestone, 18 - onkolitic limestone gravel and pebbles, 19 - calcareous onkolitic sandstone, 20 - sponge limestone, 21 - coquina, 22 - marlstone, 23 - marlstone concretions, 24 - siderite lenses, 25 - stratigraphic unconformities, 26 - ammonites, 27 - brachiopods, 28 - algae, 29 - not observed, 30-32 - geomagnetic polarity: 30 - normal, 31 - reverse, 32 - missing data.

Fig. 21. (*continued*).

2013; Arkadiev et al., 2014). Currently the Jurassic–Cretaceous boundary in the Tethyan realm is placed at the base of the Jacobi Zone (Reboulet et al., 2014), although in the last revision of the Geologic Time Scale it is proposed to equate it with the base of chron M18r (Ogg et al., 2016). Ammonites, very common in all palaeobiogeographic regions across the globe, must remain the main group for developing local scales and boundary identifications, because of the very rapid evolution within this group. Obviously, a boundary of higher rank (in this case a boundary between systems) ideally should be determined by a change of taxa at the family level, as pointed out by Egoyan (1975). The core of the Berriasian Stage in the Tethyan realm is the ammonite family Neocomitidae, as documented by studies of ammonite distribution in sections within that realm. The Tithonian has a completely different ammonite assemblage that is predominated by representatives of the families Perisphinctidae and Aspidoceratidae. In the Tethyan realm, the Jacobi Zone can be reliably traced over immense distances, from France to the Himalayas (Arkadiev et al., 2012). Difficulties arise when trying to correlate with the Boreal realm, where the Berriasian Stage has an utterly different composition of ammonite faunas and other biotic groups. Dr B. Wimbledon, Chairman of the International Working Group on the Jurassic–Cretaceous Boundary, proposed the following primary markers for that boundary: 1. The base of the Calpionella calpionellid zone; 2. The appearance of the calcareous nannofossil taxa *Nannoconus steinmanni minor* and *Nannoconus kamptneri minor*; and 3. The base of chron M18r (Wimbledon et al., 2011). At the meeting of the Berriasian Working Group in Slovakia (2016), it was proposed to use the base of the Calpionella zone as the primary marker of the Jurassic–Cretaceous boundary (Wimbledon, 2016).

Calpionellids, used as the basis for the development of the Tithonian–Berriasian zonal scale in southern regions of western Europe, the Caucasus, North Africa, Mexico, Cuba, Argentina, Iraq and, partially, Crimea, are restricted in distribution to the Tethyan realm. This precludes their use for correlation with the Boreal realm and other palaeobiogeographic regions across the globe. The magnetostratigraphic scale, as long as it is tied in to biostratigraphic data, is a unique tool for remote isochronous correlations and presents an attractive alternative from this point of view. The use of palaeomagnetic data would make it possible to trace this boundary not only throughout the various palaeobiogeographic regions, but also acrossmarine and terrestrial facies. The key role of palaeomagnetic data in correlations of the Boreal and Tethyan realms across the Jurassic–Cretaceous boundary interval has been emphasised by many researchers (Wimbledon et al., 2011; Zakharov, 2011; Guzhikov, 2013; Arkadiev, Baraboshkin and Guzhikov, 2014).

Significant progress in this respect was achieved during studies of Jurassic–Cretaceous boundary deposits in northern Siberia, on the Nordvik Peninsula, where the complete sequence of magnetozones of the M20n-M17r interval has been established (Houša et al., 2007). It was discovered that the Jurassic–Cretaceous boundary in the Boreal realm fell within the Craspedites taimyrensis Zone of the upper Volgian. Based on this, V.A. Zakharov and co-authors proposed to place this boundary at the base of the Boreal Kochi Zone and correlate the base of this zone with the base of the Tethyan Occitanica Zone (Zakharov et al., 2009). In support of their proposals, they noted that the Kochi Zone could be traced well from Siberia to England via the Russian Platform and that this level was proved by magnetostratigraphic data.

In our opinion, the base of chron M18r is a good level for placement of the Jurassic–Cretaceous boundary for the following reasons:

- it is close to the base of the Chetaites chetae ammonite Zone, which is easily identified in Arctic marine sections (Bragin et al., 2013) and, therefore, can be identified using palaeontological methods in the Boreal realm;
- it falls within the Berriasella jacobi Zone of the Tethyan sequence, although, apparently, it does not equate with its base. In the Crimean Mountains the base of chron M18r is close to the base of the Grandis Subzone (Guzhikov et al., 2012), as traced in sections in France, Spain, Bulgaria, the Crimean Mountains and the Caucasus more reliably than the base of the Jacobi Zone;
- it is close, or coincides with, another 'primary marker', i.e., the first occurrence of the nannofossil taxa *N. steinmannii minor* and *N. kamptneri minor* (Casellato and Erba, 2016);
- the boundaries of chron M18r are isochronous (unlike those of biostratigraphic units), and it has a sufficiently wide extent to be identified in most sections, irrespective of facies composition;
- another important isochronous and facies-independent marker has recently been found at this level: a carbon isotope anomaly, traced in both Tethyan and Boreal sections (Dzyuba et al., 2013).

6.3. Berriasian–Valanginian boundary

Foraminifera found in the Zavodskaya Balka section make it possible to identify the upper part of Berriasian beds with *Textularia crimica–Belorussiella taurica* and an assemblage with *Lingulina trilobitomorpha* and *Haplophragmoides vocontianus,* typical of the Valanginian, is identified above it.

The Berriasian–Valanginian boundary cannot be determined on the basis of ostracods. The studied boundary ostracod assemblage in the Zavodskaya Balka section (Boissieri and Pertransiens? zones) contains the genera *Robsoniella*, *Sigillium* and *Bairdia*, as noted earlier by Rachenskaya (1970). The studied community is similar to ostracod assemblages from the Tithonian(?) Klentnice Formation in the Czech Republic, the Berriasian stratotype in France and the Berriasian of the Caucasus (Neale, 1967; Pokorny, 1973; Kolpenskaya, 2000). The ostracod assemblage from Zavodskaya Balka has a middle–late Berriasian/Valanginian appearance.

The results of dinocyst studies from sections of eastern Crimea (Fig. 21) made it possible to determine the presence of stratigraphic levels that may be correlated with the Otopeta Ammonite subzone. Based on a preliminary analysis of dinocyst distribution in the Koklyuk section, a change of Berriasian dinocyst assemblages into Valanginian ones has been observed. Combined macro- and micropalaeontological data for the Zavodskaya Balka section allow to identify equivalents of chrons M15 and M14 within the complex reversed-polarity palaeomagnetic zonal division (Fig. 19). Therefore, the base of chron M14r, closest to the top of the Berriasian Stage in western Europe, is a reasonable criterion for determination of the Berriasian–Valanginian boundary in Crimea, as long as there is a biostratigraphic substantiation of that interval.

7. Integrated biostratigraphic and magnetostratigraphic data; conclusions

The zonal subdivision of the upper Tithonian–Berriasian of the Crimean Mountains has been significantly refined using ammonites and foraminifera; in addition, the first schemes on the basis of calpionellids, ostracods and dinocysts have been worked ut. We have documented the presence of all standard Tethyan zones, i.e., the Jacobi, Occitanica and Boissieri zones, in the Berriasian.

A continuous section of upper Tithonian and lower Berriasian rocks has been described by us in eastern Crimea, in the vicinity of Feodosia. However, there is a barren interval of at least 40 m between those that yield late Tithonian and Berriasian ammonites.

A magnetostratigraphic scale of the upper Tithonian and Berriasian has also been developed, substantiating a continuous succession of magnetic chrons from M20 through M14. The existence of subchron M16n.1r ('Feodosiya') has been corroborated, and this should be included into the Geomagnetic Polarity Time Scale. The bio- and magnetostratigraphic units that have been identified in the Crimean Mountains have been reliably correlated with similar units in western European (France and Spain). Magnetozones **N_1t-b**, **R_1t-b** and **N_2t-b** have been documented in the Andreaei/Jacobi boundary interval, and these correspond to chronM19. In our opinion, the base of chron M18r is a good criterion for placement of the Jurassic–Cretaceous boundary, because the base of this is close to the base of the Grandis Subzone, as traced in sections in France, Spain, Bulgaria, the Crimean Mountains and the Caucasus and is thus more reliable than the base of the Jacobi Zone.

Continuous sections of Berriasian–Valanginian strata have been recorded by us from eastern Crimea. In other areas of the Crimean Mountains, this boundary interval is incomplete. The base of chron M14r, closest to the top of the Berriasian in Western Europe (Aguado et al., 2000), is a reasonable criterion for determination of the Berriasian–Valanginian boundary in eastern Crimea.

Our data do not allow to draw firm conclusions as to differences in the synchroniety of calpionellid distribution in the eastern Tethys and the western Paratethys because the Calpionella scale in Crimea (Platonov et al., 2014) appears to be preliminary and, probably, available data for the Feodosiya section are simply insufficient to determine the boundaries of Calpionella zones with the required accuracy.

In this respect, the best way to determine the level of the J/K boundary in Crimea is to integrate magnetic and ammonite zonations. We propose that ammonites and geomagnetic inversions be the main criteria for determining this boundary not only across the various palaeogeographic zones, but also globally. Thus,, the base of chron M18r seems to be the most likely variant among other palaeomagnetic benchmarks for determination of the lower boundary of the Cretaceous System as it is close to the base of the Grandis Subzone (in Tethyan sections) and the Chetae Zone (in Boreal sections).

Acknowledgements

We are grateful to the journal reviewers for pertinent comments and the editors for other suggestions that have improved previous versions of the typescript. We wish to express our gratitude to Iskra Lakova (Geological Institute, Sofia), who provided consultations and assistance in calpionellid identification, to Tamara N. Bogdanova (All-Russian Geological Institute, Saint Petersburg) for critical comments and assistance in identification of ammonites, to Jacek Grabowski (Polish Geological Institute, National Research Institute, Warszawa) and Ottilia Szives (Hungarian Natural History Museum, Budapest), for scrupulous and critical reviews, to V.A. Perminov (Centre of Ecological-Naturalistic Creativity of Students Intellekt", Feodosiya) for assistance in arranging and carrying out field work, to E.M. Tesakova (Moscow State University, Moskva) for her help with photographing of ostracoda; and to engineers E.S. Ochkasova, A.V. Pal, N.N. Sukhomlinova (JSC Geologorazvedka", Saint Petersburg) for preparation of micropalaeontological samples. This study has been supported by RFBR grants 14-05-31152, 16-05-00207a, 16-35-00370 and 17-05-00716 the RF Ministry of Education and Sciences in the scientific field, project 1757, and the base part, project 1582, and RFH Foundation (grant 15-37-10100).

References

Aguado, R., Company, M., Tavera, J.M., 2000. The Berriasian/Valanginian boundary in the Mediterranean region: new data from the Caravaca and Cehegin sections, SE Spain. Cretaceous Research 21, 1–21.

Allemann, F., Catalano, R., Farès, F., Remane, J., 1971. Standard calpionellid zonation (Upper Tithonian-Valanginian) of the western Mediterranean province. Proceedings of the Second Planktonic Conference. Roma 1970 (1), 1337–1340.

Arkadiev, V.V., 2004. The first record of a Late Tithonian ammonite in the Feodosiya section of eastern Crimea. Paleontological Journal 38 (3), 265–267.

Arkadiev, V.V., 2007a. Formation subdivision of the Berriasian deposits of the Crimean Mountains. Bulletin of Saint Petersburg State University, Geology/Geography 7 (2), 27–43 (in Russian).

Arkadiev, V.V., 2007b. Ammonite *Fauriella boissieri* (Pictet), the index species of the Berriasian upper zone from the Crimean Mountains. Stratigraphy and Geological Correlation 15 (2), 185–192.

Arkadiev, V.V., 2011. New data on ammonoids of the genus *Paraulacosphinctes* from the Upper Tithonian of the Mountainous Crimea. Stratigraphy and Geological Correlation 19 (2), 238–242.

Arkadiev, V.V., 2015. New occurrences of the genus *Riasanites* (Ammonoidea) in the Upper Berriasian of the eastern Crimea. In: Leonova, T.B., Barskov, I.S., Mitta, V.V. (Eds.), Contributions to current cephalopod research 4: Morphology, systematics, evolution, ecology and biostratigraphy, Proceedings of Conference (Moscow, 2–4 April, 2012). Paleontological Institute, Moscow, pp. 109–111 (in Russian).

Arkadiev, V.V., Bogdanova, T.N., 2004. Genus *Berriasella* (Ammonoidea) and ammonoid zonation in the Berriasian of the Crimean Mountains. Stratigraphy and Geological Correlation 12 (4), 367–379.

Arkadiev, V.V., Bugrova, I.Yu, 1999. Facies of the Cretaceous (Berriasian) deposits from the River Belbek area (southwestern Crimea). Facies 40, 71–80.

Arkadiev, V.V., Guzhikov, A.Yu, 2016. Bio- and magnetostratigraphic subdivision of the Berriasian Stage of the Mountain Crimea: modern state and main problems. In: Baraboshkin, E.Yu. (Ed.), Cretaceous System of Russia and CIS countries: problems of stratigraphy and paleogeography. Proceedings of the 8th All-Russian meeting, 26 September–3 October 2016, Republic of Crimea. Publishing House Chernomor PRESS, Simferopol, pp. 34–37.

Arkadiev, V.V., Rogov, M.A., 2006. New data on Upper Kimmeridgian-Tithonian biostratigraphy and ammonites of the eastern Crimea. Stratigraphy and Geological Correlation 14 (2), 185–199.

Arkadiev, V.V., Atabekian, A.A., Baraboshkin, E.Y., Bogdanova, T.N., Bugrova, I.Yu., Lobacheva, S.V., Pechnikovskiy, A.A., Tur, N.A., 2002. Stratigraphy of Lower Cretaceous deposits of Belbek River Basin of south-west Crimea. In: Arkadiev, V.V. (Ed.), Geology of Crimea 2. SPbGU, Saint Petersburg, pp. 34–46 (in Russian).

Arkadiev, V.V., Fedorova, A.A., Savelieva, J.N., Tesakova, E.M., 2006. Biostratigraphy of Jurassic–Cretaceous boundary in the eastern Crimea. Stratigraphy and Geological Correlation 14 (3), 302–330.

Arkadiev, V.V., Bagaeva, M.I., Guzhikov, A.Yu., Manikin, A.G., Perminov, V.A., Yampolskaya, O.V., 2010. Bio- and magnetostratigraphy characteristics of the Upper Berriasian section "Zavodzkaya Balka" (eastern Crimea, Feodosia). Bulletin of Saint Petersburg State University, Geology/Geography 7 (2), 3–16 (in Russian).

Arkadiev, V.V., Rogov, M.A., Perminov, V.A., 2011. New occurrences of heteromorphy ammonites in the Berriasian-Valanginian of the Crimean Mountains. Paleontological Journal 45 (4), 390–396.

Arkadiev, V.V., Bogdanova, T.N., Guzhikov, A.Yu., Lobacheva, S.V., Myshkina, N.V., Platonov, E.S., Savel'eva, Yu.N., Shurekova, O.V., Yanin, B.T., 2012. Berriasian of Crimean Mountains. LEMA, Saint-Petersburg, 472 pp. (in Russian).

Arkadiev, V.V., Baraboshkin, E.Yu., Guzhikov, A.Yu, 2014. About the Jurassic-Cretaceous boundary. In: Baraboshkin, E.Yu., Markevich, V.S., Bugdaeva, E.V., Afonin, M.A., Cherepanova, M.V. (Eds.), Cretaceous system of Russia and the near abroad: problems of stratigraphy and paleogeography, Proceedings of the Seventh Russian Scientific Conference with International Participation, 10–15 September 2014. Vladivostok, Vladivostok, Dalnauka, pp. 27–30 (in Russian).

Arkadiev, V.V., Baraboshkin, E.Yu., Bagaeva, M.I., Bogdanova, T.N., Guzhikov, A.Yu., Manikin, A.G., Piskunov, V.K., Platonov, E.S., Savel'eva, Yu.N., Feodorova, A.A., Shurekova, O.V., 2015a. New data on Berriasian biostratigraphy, magnetostratigraphy and sedimentology in the Belogorsk area (central Crimea). Stratigraphy and Geological Correlation 23 (2), 155–191.

Arkadiev, V.V., Guzhikov, A.Yu., Savelieva, J.N., Feodorova, A.A., Shurekova, O.V., Bagaeva, M.I., Grishchenko, V.A., Manikin, A.G., 2015b. New data on bio- and magnetostratigraphy of Upper Berriasian section "Zavodskaya Balka" (eastern Crimea, Feodosiya). Bulletin of Saint Petersburg State University, Geology/Geography 7 (4), 4–36 (in Russian).

Arkadiev, V.V., Guzhikov, A.Yu., Grishchenko, V.A., Manikin, A.G., Savel'eva, Yu.N., Feodorova, A.A., Shurekova, O.V., 2016. Berriasian-Valanginian boundary in the Crimean Mountains, pp. 79–82. In: Michalík, J., Fekete, K. (Eds.), XII Jurassica Conference. Workshop of the ICS Berriasian Group and IGCP 632. Smolenice, Slovakia. Field Trip Guide and Abstracts Book. Earth Science Institute, Slovak Academy of Sciences, Bratislava.

Atlas of the Cretaceous fauna of the south-west Crimea. In: Arkadiev, V.V., Bogdanova, T.N. (Eds.), 1997. PANGEYA, Saint Petersburg, 357 pp. (in Russian).

Azema, J., Chabrier, G., Fourcade, E., Jaffrezo, M., 1978. Nouvelles données micropaléontologiques, stratigraphiques et paléogéographiques sur le Portlandien et le Néocomien de Sardaigne. Revue de Micropaléontologie 20 (3), 125–139.

Baraboshkin, E.Yu., Mikhailova, I.A., 1994. A revision of the Neocomian ammonites of the Crimea: the genera *Neohoploceras* Spath and *Luppovella* Nikolov. Paleontological Journal 3, 41–54 (in Russian).

Baraboshkin, E.Yu., Mikhailova, I.A., 2000. New and poorly known Valanginian ammonites from south-west Crimea. Bulletin de l'Institut royal des Sciences naturelles de Belgique. Sciences de la Terre 70, 89–120.

Baraboshkin, E.Yu., Yanin, B.T., 1997. The correlation of the Valanginian of the south-western and central Crimea. In: Milanovsky, E.E. (Ed.), Geology essays on the Crimea. Proceedings of the Crimean geological scientific and educational center named after Professor A.A. Bogdanov 1. Moscow State University, Geological Faculty Press, pp. 4–26 (in Russian).

Baraboshkin, E.Yu., Arkadiev, V.V., Benyamovskiy, V.N., Guzhikov, A.Yu., Kopaevich, L.F., Jagt-Yazykova, E.A., 2013. The stratigraphic scale of the Cretaceous of Russia: current state, main problems, ways of perfection. In: Gladenkov, Yu.B., Zakharov, V.A., Ippolitov, A.P. (Eds.), General stratigraphie scale of Russia: current state and ways of perfection. All-Russian meeting, May 23–25, 2013, Geological Institute of RAS, Moscow. Moscow, GIN RAS, pp. 289–297 (in Russian).

Bogdanova, T.N., Arkadiev, V.V., 1999. The genus *Dalmasiceras* (Ammonoidea) from the Berriasian of the Mountainous Crimea. Paleontological Journal 33 (4), 354–362.

Bogdanova, T.N., Kvantaliani, I.V., 1983. New Berriasian ammonites from the Crimea. Moscow Society of Naturalists, Department of Geology 58 (3), 70–83 (in Russian).

Bogdanova, T.N., Lobacheva, S.V., Prozorovsky, V.A., Favorskaya, T.A., 1981. Concerning the division of the Berriasian of the Crimean mountains. Bulletin of Leningrad State University, Geology/Geography 6 (1), 5–14 (in Russian).

Bogdanova, T.N., Lobacheva, S.V., Prozorovsky, V.A., Favorskaya, T.A., 1984. The Berriasian of eastern Crimea and the Jurassic-Cretaceous boundary. In: Boundary stages of the Jurassic and Cretaceous systems. Nauka, Moscow, pp. 28–35 (in Russian).

Bogdanova, T.N., Kalacheva, E.D., Sey, I.I., 1999. On the occurrence of the Tirnovella occitanica Zone (Lower Cretaceous, Berriasian) in the Feodosian section of eastern Crimea. Regional Geology and Metallogeny 9, 27–32 (in Russian).

Boorová, D., Skupien, P., Vašíček, Z., Lobitzer, H., 2015. Biostratigraphy of the Lower Cretaceous Schrambach Formation on the classical locality of Schrambachgraben (Northern Calcareous Alps, Salzburg Area). Bulletin of Geosciences 90 (1), 89–131.

Borza, K., 1984. The Upper Jurassic-Lower Cretaceous parabiostratigraphic scale on the basis of Tintinninae, Cadosinidae, Stomiosphaeridae, Calcisphaerulidae and other microfossils from the West Carpathians. Geologický Zborník–geologica Carpathica 35, 539–550.

Bragin, V.Yu., Dzyuba, O.S., Kazansky, A.Yu., Shurygin, B.N., 2013. New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia). Geology and Geophysics 54 (3), 438–455 (in Russian).

Casellato, C.E., Erba, E., 2016. Synthesis of calcareous nannofossil events across the Jurassic/Cretaceous boundary: implications for the definition of the Berriasian base. In: Michalíl, J., Fekete, K. (Eds.), XIIth Jurassica Conference. Workshop of the ICS Berriasian Group and IGCP 632. Field Trip Guide and Abstracts Book, April 19-23, 2016, Smolenice, Slovakia. Earth Science Institute, Slovak Academy of Sciences, Bratislava, pp. 119–120.

Catalano, R., Liguori, V., 1971. Facies a calpionelle della Sicilia Occidentale. Proceedings of the Second Planktonic Conference, Roma 1970 (1), 167–210.

Donze, P., 1965. Espèces nouvelles d'Ostracodes des couches de base du Valanginien de Berrias. Travaux des Laboratoires de Géologie de la Faculté des Sciences de Lyon, nouvelle série 12, 87–107.

Druschits, V.V., 1975. The Berriasian of the Crimea and its stratigraphical relations. Colloque sur la limite Jurassique-Crétacé (Lyon, Neuchâtel, September 1973). Mémoires du Bureau de Recherches Géologiques et Minières 86, 337–341.

Druschits, V.V., Vakhrameev, V.A., 1976. Jurassic-Cretaceous boundary. In: Peyve, A.V. (Ed.), Boundaries of geological systems. Nauka, Moscow, pp. 185–224 (in Russian).

Dzyuba, O.S., Izokh, O.P., Shurygin, B.N., 2013. Carbon isotope excursions in Boreal Jurassic–Cretaceous boundary sections and their correlation potential. Palaeogeography, Palaeoclimatology, Palaeoecology 381–382, 33–46.

Egoyan, V.L., 1975. About Jurassic-Cretaceous boundary and the volume of Berriasian. Soviet Geology 4, 33–47.

Enay, R., Geyssant, J.R., 1975. Faunes tithoniques des chaînes bétiques (Espagne méridionale). Mémoire du Bureau de Recherches Géologiques et Minières 86, 39–55.

Feodorova, A.A., 2000. Stratigraphic significance of foraminifers from the boundary carbonate Jurassic and Cretaceous deposits of Baydarskaya valley (south-west Crimea). In: Prozorovskyi, V.A. (Ed.), Stratigraphic and facial methods of study of the Phanerozoic 1, pp. 27–37 (in Russian).

Fisher, M.J., Riley, L.A., 1980. The stratigraphic distribution of dinoflagellate cysts at the boreal Jurassic-Cretaceous boundary. In: Proceedings of the Fourth International Palynological Conference, Lucknow (1976–77) 2, pp. 313–329.

Frau, C., Bulot, L.G., Wimbledon, W.A.P., 2015. Upper Tithonian Himalayitidae Spath, 1925 (Perisphinctoidea, Ammonitina) from Le Chouet (Drôme, France): implications for the systematics. Geologica Carpathica 66 (2), 117–132.

Frau, C., Bulot, L.G., Wimbledon, W.A.P., Ifrim, C., 2016a. Systematic palaeontology of the Perisphinctidae in the Jurassic/Cretaceous boundary interval at La Chouet (Drôme, France), and its implications for biostratigraphy. Acta Geologica Polonica 66 (2), 175–204.

Frau, C., Bulot, L.G., Rehákova, D., Wimbledon, W.A.P., Ifrim, C., 2016b. Revision of the ammonite index species *Berriasella jacobi* Mazenot, 1939 and its consequences for the biostratigraphy of the Berriasian Stage. Cretaceous Research 66, 94–114.

Galbrun, B., 1985. Magnetostratigraphy of the Berriasian stratotype section (Berrias, France). Earth and Planetary Science Letters 74, 130–136.

Glushkov, A.Yu, 1997. On the first find of the index-species of the lower zone of the Berriasian in the Crimea. Bulletin of Saint Petersburg State University, Geology/Geography 7 (1), 90–93 (in Russian).

Grabowski, J., 2011. Magnetostratigraphy of the Jurassic/Cretaceous boundary interval in the Western Tethys and its correlations with other regions: a review. Volumina Jurassica 9, 105–128.

Grabowski, J., Haas, J., Márton, E., Pszczółkowski, P., 2010. Magneto- and biostratigraphy of the Jurassic/Cretaceous boundary in the Lókút section (Transdanubian range, Hungary). Studia Geophysica et Geodaetica 54 (1), 1–26.

Guzhikov, A.Yu, 2013. Solving unsolvable problems in stratigraphy (Comments to the paper "New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia)" by V.Yu. Bragin, O.S. Dzyuba, A.Yu. Kazansky, and B.N. Shurygin). Russian Geology and Geophysics 54, 349–354.

Guzhikov, A.Yu., Arkadiev, V.V., Baraboshkin, E.Yu., Bagaeva, M.I., Piskunov, V.K., Rud'ko, S.V., Perminov, V.A., Manikin, A.G., 2012. New sedimentological, bio- and magnetostratigraphic data on the Jurassic–Cretaceous boundary interval of Eastern Crimea (Feodosiya). Stratigraphy and Geological Correlation 20 (3), 261–294.

Guzhikov, A.Yu., Bagayeva, M.I., Arkadiev, V.V., 2014. Magnetostratigraphy of the Upper Berriasian "Zavodskaya Balka" section (East Crimea, Feodosiya). Volumina Jurassica 12, 175–184.

Harding, I.C., Smith, G.A., Riding, J.B., Wimbledon, W.A.P., 2011. Inter-regional correlation of Jurassic/Cretaceous boundary strata based on the Titonian-Valanginian dinoflagellate cyst biostratigraphy of the Volga Basin, Western Russia. Review of Palaeobotany and Palynology 167, 82–116.

Hoedemaeker, P.J., Janssen, N.M.M., Casellato, C.E., Gardin, S., Rehákova, D., Jamrichová, M., 2016. Jurassic/Cretaceous boundaryin the Río Argos succession (Caravaca, SE Spain). Revue de Paléobiologie 35 (1), 111–247.

Houša, V., Krs, M., Man, O., Pruner, P., Venhodová, D., Cecca, F., Nardi, G., Piscitello, M., 2004. Combined magnetostratigraphic, palaeomagnetic and calpionellid investigations across Jurassic/Cretaceous boundary strata in the Bosso Valley, Umbria, central Italy. Cretaceous Research 25, 771–785.

Houša, V., Pruner, P., Zakharov, V.A., Kostak, M., Chadima, M., Rogov, M.A., Šlechta, S., Mazuch, M., 2007. Boreal–Tethyan correlation of the Jurassic–Cretaceous boundary interval by magneto- and biostratigraphy. Stratigraphy and Geological Correlation 15 (3), 297–309.

Kolpenskaya, N.N., 2000. Ostracods. In: Kirichkova, A.I. (Ed.), The Berriasian of the northern Caucasus (Urukh section). VNIGRI, Saint-Petersburg, pp. 42–52, 129–155 (in Russian).

Kuvaeva, S.B., Yanin, B.T., 1973. Palynological characteristic of the Lower Cretaceous of the Crimean Mountains. Bulletin of the Moscow State University 5, pp. 49–57 (in Russian).

Kuznetsova, K.I., 1983. Development and distribution of foraminifers in Late Jurassic of Crimea. Questions of Micropaleontology 26, 25–36 (in Russian).

Kuznetsova, K.I., Gorbachik, T.N., 1985. Jurassic and Lower Cretaceous stratigraphy and foraminifers of Crimea. Nauka, Moscow, 136pp. (in Russian).

Kvantaliani, I.V., 1989. Early Cretaceous ammonites of the Crimea and Caucasus and their biostratigraphic significance. Proceedings of Geological Institute AN GSSR 98, 228 (in Russian).

Kvantaliani, I.V., Lysenko, N.I., 1979. On the zonal sequence of the Berriasian of the Crimea. Bulletin of the Academy of Sciences of the Georgian SSR 94 (3), 629–632 (in Russian).

Lakova, I., Stoykova, K., Ivanova, D., 1999. Calpionellid, nannofossil and calcareous dinocyst bioevents and integrated biochronology of the titonian to valanginian in the Western Balkanides, Bulgaria. Geologica Carpathica 50 (2), 151–168.

Michalík, J., Reháková, D., Halásová, E., Lintnerová, O., 2009. The Brodno section – a potential regional stratotype of the Jurassic/Cretaceous boundary (Western Carpathians). Geologica Carpathica 60 (3), 213–232.

Neale, J.W., 1967. Ostracodes from the type Berriasian (Cretaceous) of Berrias (Ardèche, France) and their significance. University Kansas, Department of Geology, Special Publication 2, pp. 539–569.

Ogg, J.G., Ogg, I.G., Gradstein, F.M., 2008. The Concise Geologic Time Scale. Cambridge University Press, Cambridge, p. 177.

Ogg, J.G., Ogg, G.M., Gradstein, F.M., 2016. A Concise Geologic Time Scale 2016. Elsevier, Amsterdam, p. 240.

Platonov, E.S., 2014. Tintinnids from the Berriasian deposits of Eastern Crimea (Tonas River Basin). In: Baraboshkin, E.Yu., Markevich, V.S., Bugdaeva, E.V., Afonin, M.A., Cherepanova, M.V. (Eds.), Cretaceous system of Russia and the near abroad: problems of stratigraphy and paleogeography, Proceedings of the Seventh Russian Scientific Conference with International Participation, 10-15 September 2014. Dalnauka, Vladivostok.. Vladivostok, pp. 247–250 (in Russian).

Platonov, E.S., Arkadiev, V.V., 2011. Jurassic-Cretaceous boundary in the Eastern Crimea by ammonites and tintinnids. In: Bogdanova, T.N. (Ed.), Proceedings of the 57th Session of Paleontological Society at the Russian Academy of Sciences "Rates of evolution organic world and biostratigraphy", Saint-Petersburg, 5–8 April, pp. 98–100 (in Russian).

Platonov, E.S., Rudko, S.V., 2015. Substantiation of the Calpionella zone and Alpina subzone (Lower Berriasian) of assemblage of calpiuonellids from the limestone breccias in Baydarskaya Basin of Southwest Crimea. In: Zakharov, V.A., Rogov, M.A., Ippolitov, A.P. (Eds.), Jurassic system of Russia: problems of stratigraphy and paleogeography. Proceedings of the 6th All-Russian Scientific Conference. 15–20 September 2015, Makhachkala. ALEF, Makhachkala, pp. 216–217 (in Russian).

Platonov, E.S., Lakova, I., Arkadiev, V.V., 2013. Tintinnids from the Jurassic-Cretaceous boundary deposits of the Eastern Crimea. In: Zakharov, V.A., Rogov, M.A., Shurygin, B.A. (Eds.), Jurassic system of Russia: problems of stratigraphy and paleogeography, Proceedings of the 5th All-Russian Scientific Conference. Tyumen, 23–27 September 2013. "Izdat Nauka Servis" LLC, Ekaterinburg, pp. 169–171 (in Russian).

Platonov, E.S., Lakova, I., Petrova, S., Arkadiev, V.V., 2014. Tithonian and Lower Berriasian calpionellid against ammonite biostratigraphy of the Dvuyakornaya Formation in Eastern Crimea. Geologica Balcanica 43 (1–3), 63–76.

Pokorny, V., 1973. The Ostracoda of the Klentnice Formation (Tithonian?) Czechoslovakia. Rozpravy Ustredního Ustavu Geologickeho 40, 1–107.

Pop, G., 1974. Les zones des calpionelles tithoniques-Valanginiens du silon de Resita (Carpates méridionales). Revue Roumaine de Géologie, Géophysique et Géographie, Série Géologie 18, 109–125.

Pruner, P., Houša, V., Olóriz, F., Kostak, M., Krs, M., Man, O., Schnabl, P., Venhodová, D., Tavera, J.M., Mazuch, M., 2010. High-resolution magnetostratigraphy and biostratigraphic zonation of the Jurassic/Cretaceous boundary strata in the Puerto Escaño section (Southern Spain). Cretaceous Research 31, 192–206.

Rachenskaya, L.P., 1970. Ostracods of the Berriasian and Valanginian of Crimea, 30 pp. Unpubl. MSc thesis. Geological and Mineralogical Sciences, Moscow (in Russian).

Reboulet, S., Szives, O., Aguirre-Urreta, B., Barragán, R., Company, M., Idakieva, V., Ivanov, M., Kakabadze, M.V., Moreno-Bedmar, J.A., Sandoval, J., Baraboshkin, E.Yu., Çağlar, M.K., Fözy, I., González-Arreola, C., Kenjo, S., Lukeneder, A., Raisossadat, S.N., Rawson, P.F., Tavera, J.M., 2014. Report on the 5th International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the Kilian Group (Ankara, Turkey, 31st August 2013). Cretaceous Research 50, 126–137.

Reháková, D., Halásová, E., Lukeneder, A., 2009. The Jurassic-Cretaceous boundary in the Austrian Klippen Belt (Nutzhof, Lower Austria): implications on micro- and nannofacies analysis. Annalen des Naturhistorischen Museums in Wien A110, 345–381.

Remane, J., 1963. Les calpionelles dans les couches de passage Jurassique-Crétacé de la fosse vocontienne. Travaux du Laboratoire de Géologie de la Faculté des Sciences de Grenoble 39, 25–82.

Remane, J., Borza, K., Nagy, I., Bakalova-Ivanova, D., Knauer, J., Pop, G., Tardi-Filácz, E., 1986. Agreement on the subdivision of the standard calpionellid zones defined at the II planktonic conference, Roma 1970. Acta Geologica Hungarica 29 (1–2), 5–14.

Retowski, O., 1893. Die tithonischen Ablagerungen von Theodosia. Bulletin de la Société impériale des Naturalistes de Moscow. Nouvelle Série 7 (2–3), 1–95.

Riding, J.B., Thomas, J.E., 1992. Dinoflagellate cyst of the Jurassic System. In: Powell, A.J. (Ed.), A stratigraphic index of dinoflagellate cysts. Micropalaeontological Society Publications Series. Chapman and Hall, London, pp. 7–57.

Satolli, S., Besse, J., Speranza, F., Calamita, F., 2007. The 125–150 Ma high-resolutionapparent polar wander path for Adria from magnetostratigraphic sections in Umbria–Marche (Northern Apennines, Italy): timing and duration of the global Jurassic–Cretaceous hairpin turn. Earth and Planetary Science Letters 257, 329–342.

Savelieva, J.N., Feodorova, A.A., Shurekova, O.V., Arkadiev, V.V., 2014. Integrated palaeontological characteristics (ammonites, ostracods, foraminifers, and dinocysts) of the Berriasian deposits of central Crimea. Volumina Jurassica 12, 129–162.

Septfontaine, M., 1974. Presence de *Protopeneroplistrochangulata* sp. nov. (Foraminifera) dans le Crétacé inférieur du Jura méridional et revision de *Protopeneroplis* Weynschenk, 1950. Eclogae Geologicae Helvetiae 67 (3), 605–628.

Skourtsis-Coroneou, V., Solakius, N., 1999. Calpionellid zonation at the Jurassic/Cretaceous boundary within the Vigla Limestone Formation (Ionian Zone, western Greece) and carbon isotope analysis. Cretaceous Research 20, 583–595.

Tavera, J.M., 1985. Los ammonites del Tithónico superior–Berriasense de la zona Subbetica (Cordilleras Béticas) (unpubl. PhD thesis). Universidad de Granada, Granada, 381 pp.
Tominaga, M., Sager, W.W., 2010. Revised Pacific M-anomaly geomagnetic polarity timescale. Geophysical Journal International 182, 203–232.
Trejo, M., 1975. Los Tintinidos mesozoicos de Mexico. Mémoires du Bureau de Recherches Géologiques et Miniéres 86, 95–104.
Vakhrameev, V.A., 1981. Pollen *Classopollis*: indicator of Jurassic and Cretaceous climates. The Paleobotanist 28–29, 301–307.
Wimbledon, W.A.P., 2008. The Jurassic-Cretaceous boundary: an age-old correlative enigma. Episodes 31 (4), 423–428.
Wimbledon, W.A.P., 2016. Resolving the positioning of the Tithonian/Berriasian stage boundary and the base of the Cretaceous System. In: Michalík, J., Fekete, K. (Eds.), XIIth Jurassica Conference. Workshop of the ICS Berriasian Group and IGCP 632. Field Trip Guide and Abstracts Book, April 19–23, 2016, Smolenice, Slovakia. Earth Science Institute, Slovak Academy of Sciences, Bratislava, pp. 128–130.
Wimbledon, W.A.P., Castellato, C.E., Rehakova, D., Bulot, L.G., Erba, E., Gardin, S., Verreussel, R.M.C.H., Munsterman, D.K., Hunt, C.O., 2011. Fixing a basal Berriasian and Jurassic/Cretaceous (J/K) boundary – is there perhaps some light at the end of the tunnel? Rivista Italiana di Paleontologia e Stratigrafia 117 (2), 295–307.
Wimbledon, W.A.P., Reháková, D., Pszczółkowski, A., Casellato, C.E., Halásová, E., Frau, C., Bulot, L.G., Grabowski, J., Sobień, K., Pruner, P., Schnabl, P., Čižkova, K., 2013. An account of the bio- and magnetostratigraphy of the Upper Tithonian-Lower Berriasian interval at Le Chouet, Drôme (SE France). Geologica Carpathica 64 (6), 437–460.
Yampolskaya, O.B., Guzhikov, A.Yu., Baraboshkin, E.Yu., Bagaeva, M.I., 2009. Magnetostratigraphic characteristic of Jurassic-Cretaceous boundary beds of East Crimea. In: Zakharov, V.A. (Ed.), Jurassic system of Russia: problems of stratigraphy and paleogeography. Proceedings of the 3th All-Russian Scientific Conference, Saratov, 23–27 September 2009. Izdatel'skiy tsenr "Nauka", Saratov, pp. 265–267 (in Russian).
Yanin, B.T., Baraboshkin, E.Yu, 2000. The section of Berriasian deposits in the Belbek River Basin of the Crimean Mountains. Stratigraphy and Geological Correlation 8 (2), 66–77 (in Russian).
Yudin, V.V., 2009. Geological map and sections of Submountain and Mountain Crimea. Scale 1:200 000, Simferopol, Souzkarta, 2 pp. (in Russian).
Zakharov, V.A., 2011. Jurassic-Cretaceous boundary and Berriasian GSSP: is there light at the end of the tunnel? (Comments to proposals on the Jurassic-Cretaceous boundary by Berriasian Working Group). News of Paleontology and Stratigraphy. Supplement to the Journal of Geology and Geophysics 16/17, 69–86 (in Russian).
Zakharov, V.A., Rogov, M.A., Nikitenko, B.L., Pestchevitskaya, E.B., 2009. Key events around the J/K boundary of the Panboreal Superrealm, their correlative potential and relation with the base of the Berriasian. In: Hart, M.B. (Ed.), 8th International Symposium on the Cretaceous System. Abstract Volume, Plymouth, pp. 40–41.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.cretres.2017.07.011.

Appendix 1(list of taxa)

Acritarchs
Micrhystridium spp.
Veryhachium spp.
Ammonites
Berriasella sp.
Berriasella berthei (Toucas, 1890)
Berriasella callisto (d'Orbigny, 1847)
Berriasella chomeracensis (Toucas, 1890)
Berriasella moesica Nikolov and Mandov, 1967
Berriasella oppeli (Kilian, 1889)
Berriasella paramacilenta Mazenot, 1939
Berriasella subcallisto (Toucas, 1890)
Berriasella jacobi Mazenot, 1939
Bochianites crymensis Arkadiev, 2008
Bochianites neocomiensis (d'Orbigny, 1840)
Bochianites goubechensis Mandov, 1971
Dalmasiceras tauricum Bogdanova and Arkadiev, 1999
Dalmasiceras belbekense Bogdanova and Arkadiev, 1999
Dalmasiceras ex gr. *punctatum* Djanélidzé, 1922
Dalmasiceras subtoucasi Bogdanova and Arkadiev, 1999
Delphinella subchaperi (Retowski, 1893)
Delphinella crymensis (Burckhardt, 1912)
Delphinella obtusenodosa (Retowski, 1893)
Delphinella tresannensis Le Hégarat, 1973
Delphinella delphinensis (Kilian, 1889)
Delphinella janus (Retowski, 1893)
Delphinella pectinata Arkadiev and Bogdanova, 2005
Fauriella sp.
Fauriella rarefurcata (Pictet, 1867)
Fauriella boissieri (Pictet, 1867)
Fauriella cf. *floquinensis* Le Hégarat, 1973
Fauriella simplicicostata (Mazenot, 1939)
Haploceras sp.
Hegaratia balkensis (Bogdanova and Kvantaliani, 1983)
Hegaratia bidichotoma (Bogdanova and Kvantaliani, 1983)
Hegaratia nerodenkoi (Bogdanova and Kvantaliani, 1983)
Hegaratia taurica (Bogdanova and Kvantaliani, 1983)
Jabronella cf. *paquieri* (Simionescu, 1899)
Kilianella roubaudiana (d'Orbigny, 1850)
Kilianella clavicostata Nikolov, 1960
Leptoceras studeri (Ooster, 1860)
Malbosiceras broussei (Mazenot, 1939)
Malbosiceras chaperi (Pictet, 1868)
Malbosiceras malbosi (Pictet, 1867)
Malbosiceras paramimounum (Mazenot, 1939)
Malbosiceras pictetiforme Tavera, 1985
Negreliceras proteum (Retowski, 1893)
Negreliceras mirum (Retowski, 1893)
Negreliceras ex gr. *negreli* (Matheron, 1880)
Neocomites neocomiensis (d'Orbigny, 1841)
Neocosmoceras euthymi (Pictet, 1867)
Neocosmoceras giganteus Arkadiev and Bogdanova, 2009
Neocosmoceras minutus Arkadiev and Bogdanova, 2009
Neocosmoceras cf. *transfigurabilis* (Bogoslowski, 1895)
Neoperisphinctes cf. *falloti* (Kilian, 1889)
Oloriziceras cf. *schneidi* Tavera, 1985
Paraulacosphinctes transitorius (Oppel, 1865)
Paraulacosphinctes cf. *senoides* (Tavera, 1985)
Pomeliceras aff. *boisseti* Nikolov, 1982
Pomeliceras breveti (Pomel, 1889)
Pomeliceras (?) *funduklense* Lysenko and Arkadiev, 2007
Pseudoneocomites retowskyi (Sarasin and Schöndelmayer, 1901)
Pseudosubplanites grandis (Mazenot, 1939)
Pseudosubplanites lorioli (Zittel, 1868)
Pseudosubplanites combesi Le Hégarat, 1973
Pseudosubplanites ponticus (Retowski, 1893)
Pseudosubplanites fasciculatus Bogdanova and Arkadiev, 2005
Pseudosubplanites crymensis Bogdanova and Arkadiev, 2005
Pseudosubplanites subrichteri (Retowski, 1893)
Pseudosubplanites jauberti (Mazenot, 1939)
Ptychophylloceras semisulcatum (d'Orbigny, 1840)
Retowskiceras retowskyi Kvantaliani, 1999
Retowskiceras andrussowi (Retowski, 1893)
Riasanites crassicostatum (Kvantaliani and Lysenko, 1979)
Riasanites irregulatus (Kvantaliani and Lysenko, 1980)
Riasanites tuberculatum (Kvantaliani and Lysenko, 1980)
Riasanites petrovensis (Kvantaliani and Lysenko, 1980)
Spiticeras obliquelobatum (Uhlig, 1903)
Spiticeras subspitiense (Uhlig, 1903)
Spiticeras cf. *tenuicostatum* Djanélidzé, 1922
Spiticeras multiforme Djanélidzé, 1922
Spiticeras orientale (Kilian, 1910)
Subalpinites insolitus Arkadiev, 2012
Subalpinites amplus Arkadiev, 2012
Subthurmannia cf. *boissieri* (Pictet, 1867)
Subthurmannia latecostata (Mazenot, 1939)
Thurmanniceras pertransiens (Sayn, 1907)
Thurmanniceras thurmanni (Pictet and Campiche, 1860)
Tirnovella sp.
Tirnovella occitanica (Pictet, 1867)
Tirnovella alpillensis (Mazenot, 1939)
Aptychi
Didayilamellaptychus didayi (Coquand, 1841)
Lamellaptychus sp.
Belemnites
Pseudobelus cf. *bipartitus* Blainville, 1827
Calpionellids
Calpionella alpina Lorenz, 1902
Calpionella elliptica Cadisch, 1932
Calpionella aff. *elliptica* Cadisch, 1932
Calpionella grandalpina Nagy, 1986
Calpionella minuta Houša, 1990
Chitinoidella boneti Doben, 1963
Crassicollaria cf. *brevis* Remane, 1962
Crassicollaria massutiniana (Colom, 1948)
Crassicollaria parvula Remane, 1962
Daciella danubica Pop, 1998
Dobeniella cf. *bermudezi* (Furrazola Bermúdez, 1965)
Dobeniella cubensis (Furrazola Bermúdez, 1965)
Longicollaria dobeni (Borza, 1966)
Popiella oblongata Reháková, 2002
Praetintinnopsella andrusovi Borza, 1969
Tintinnopsella doliphormis (Colom, 1939)

Tintinnopsella carpathica (Murgeanu and Filipescu, 1933)
Tintinnopsella longa (Colom, 1939)
Tintinnopsella remanei Borza, 1969
Dinoflagellate cysts
Achomosphaera neptunii (Eisenack, 1958) Davey and Williams, 1966
Amphorula expirata (Davey, 1982) Courtinat, 1989
Amphorula dodekovae Zotto and al., 1987
Amphorula metaelliptica Dodekova, 1969
Apteodinium sp.
Bourkidinium sp.
Cassiculosphaeridia pygmaeus Stevens, 1987
Chlamydophorella sp.
Chytroeisphaeridia chytroeides (Sarjeant, 1962) Downie and Sarjeant, 1965
Circulodinium distinctum (Deflandre and Cookson, 1955) Jansonius, 1986
Cometodinium habibii Monteil, 1991
Cribroperidinium sp.
Cribroperidinium globatum (Gitmez and Sarjeant, 1972) Helenes, 1984
Ctenidodinium elegantulum Millioud, 1969
Dichadogonyaulax spp.
Dapsilidinium? deflandrei (Valensi, 1947) Lentin and Williams, 1981
Dapsilidinium warrenii (Habib, 1976) Lentin and Williams, 1981
Dingodinium minutum Dodekova, 1975
Egmontodinium torynum (Cookson and Eisenack, 1960) Davey, 1979
Ellipsodictium cinktum Klement, 1960
Epiplosphaera reticulospinosa Klement, 1960
Epiplosphaera? areolata (Klement, 1960) Brenner, 1988
Escharisphaeridia psilata Kumar, 1986
Heslertonia? pellucida Gitmez, 1970
Hystrichodinium pulchrum Deflandre, 1935
Kleithriasphaeridium eoinodes (Eisenack, 1958) Davey, 1974
Kleithriasphaeridium fasciatum (Davey and Williams, 1966) Davey, 1974
Muderongia endovata Riding and al., 2000
Muderongia longicorna Monteil, 1991
Muderongia simplex Alberti, 1961; emend. Riding and al., 2001
Muderongia sp./*Phoberocysta* sp.
Nannoceratopsis pellucida Deflandre, 1939
Nannoceratopsis gracilis Alberti, 1961
Phoberocysta neocomica (Gocht, 1957) Millioud, 1969
Prolixosphaeridium spp.
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey and al., 1966
Protobatioladinium imbatodinense (Vozzhennikova, 1967) Lentin and Vozzhenn., 1990
Pseudoceratium pelliferum Gocht, 1957
Scriniodinium campanula Gocht, 1959
Scriniodinium dictyotum Cookson and Eisenack, 1960
Sirmiodinium grossi Alberti, 1961
Spiniferites spp.
Systematophora sp.
Systematophora palmula Davey, 1982
Systematophora areolata Klement, 1960
Tanyosphaeridium spp.
Tehamadinium sp.
Tubotuberella spp.
Tubotuberella egemenii (Gitmez, 1970) Stover and Evitt, 1978
Tubotuberella apatela (Cookson and Eisenack, 1960) Ioannides and al., 1977
Valveodinium sp.
Wallodinium cylindricum (Habib, 1970) Duxbury,1983
Wrevittia helicoidea (Eisenack and Cookson, 1960) Helenes and Lucas-Clark, 1997
Foraminifera
Ammobaculites ex gr. *inconstans* Bartenstein and Brand, 1951
Ammobaculites tauricus K.Kuznetsova, 1985
Anchispirocyclina lusitanica (Egger, 1902)
Astacolus calliopsis (Reuss, 1863)
Astacolus laudatus (Hoffman), 1961
Astacolus planiusculus (Reuss, 1863)
Belorussiella taurica Gorbatchik, 1971
Bramkampella arabica Radmond, 1964
Charentia compressa Gorbatchik, 1985
Charentia evoluta Gorbatchik, 1968
Conorboides hofkeri (Bartenstein and Brand, 1951)
Discorbis crimicus Schokchina, 1960
Dorothia pseudocostata (Antonova, 1964)
Epistomina ornata (Roemer, 1841)
Epistomina ventriosa Espitalie and Sigal, 1963
Everticyclammina virguliana (Koechlin, 1942)
Feurltillia frequens Maync, 1958
Gaudryina alternans Gorbatchik, 1985
Gaudryina chettabaensis Sigal, 1952
Globospirillina neocomina (Moullade, 1961)
Haplophragmoides globigerinoides (Haeusler, 1882)
Haplophragmoides vocontianus Moullade, 1966
Istriloculina fabaria Matsieva and Temirbekova 1988
Istriloculina rectoangularia Matsieva and Temirbekova, 1988
Istriloculina terekensis Matsieva and Temirbekova, 1988
Lenticulina andromede Espitalie and Sigal, 1963
Lenticulina busnardoi Moullade, 1961
Lenticulina colligoni Espitalie and Sigal, 1963
Lenticulina dilecta Putrja, 1972
Lenticulina guttata (Ten Dam), 1946
Lenticulina ex gr. *nodosa* (Reuss, 1863)
Lenticulina lideri Romanova, 1960
Lenticulina macra Gorbatchik, 1960
Lenticulina macrodisca (Reuss, 1863),
Lenticulina muensteri (Roemer, 1839)
Lenticulina neocomina (Romanova), 1955
Lenticulina saxonica Bartenstein and Brand, 1951
Lenticulina undorica K.Kuznetsova, 1985
Lenticulina uspenskajae K.Kuznetsova, 1985
Lenticulina vistulae Bielecka and Pozaryski, 1954
Lingulina trilobitomorpha Pathy, 1968
Lingulina nodosaria Reuss, 1863
Melathrokerion eospirialis Gorbatchik, 1985
Melathrokerion spirialis Gorbatchik, 1968
Metacytheropteron sp. A Pokorny, 1973
Miliospirella cf. *caucasica* Antonova, 1968
Mohlerina basiliensis (Mochler, 1938).
Nautiloculina oolithica Mochler, 1938
Protopeneroplis striata Weynschenk, 1950
Protopeneroplis ultragranulatus (Gorbatchik, 1971)
Pseudocyclammina (?) *rifica* Zhabina, 1996
Pseudocyclammina agglutinans Zhabina, 1996
Pseudocyclammina cylindrica Redmond, 1953
Pseudocyclammina lituus (Yokoyama, 1890)
Pseudocyclammina spharoidalis Hottinger, 1967
Pseudonodosaria diversa (Hoffman, 1967)
Pseudonodosaria mutabilis (Reuss, 1962)
Pseudosiphoninella antiqua (Gorbatchik), 1966
Quadratina tunassica Schokhina, 1960
Quinqueloculina mitchurini Dain, 1971
Quinqueloculina verbizhiensis Dulub, 1964
Rectocyclammina arrabidensis Remalho, 1970
Rectocyclammina chouberti Hottinger, 1967
Rectocyclammina recta Gorbatchik and Machomad, 1997
Reophax giganteus Arnaud-Vanneau, 1988
Spirillina kubleri Mjatliuk, 1953
Spirillina minima Schacko, 1892
Stomatostoecha enisalensis Gorbatchik, 1971
Stomatostoecha rotunda Gorbatchik, 1971
Textularia crimica (Gorbatchik, 1971)
Textularia densa Hoffman, 1967
Textularia notha Gorbatchik, 1985
Triplasia emslandensis acuta Bartenstein and Brand, 1951
Tritaxia pyramidata Reuss, 1963
Trochammina aff. *globigeriniformis* (Parker and Jones, 1865)
Trochammina neocomiana Mjatliuk, 1939
Trocholina alpina (Leupold, 1935)
Trocholina elongata (Leupold, 1939)
Trocholina giganta Gorbatchik and Manzurova, 1982
Trocholina infragranulata Noth, 1951
Trocholina molesta Gorbatchik, 1959
Ostracoda
Acrocythere diversa Donze, 1964
Acrocythere alexandrae Neale and Kolpenskaya, 2000
Bairdia menneri Tesakova and Rachenskaya, 1996
Bairdia kuznetsovae Tesakova and Rachenskaya, 1996
Bairdia major Donze, 1964
Bythoceratina ex gr. *variabilis* (Donze, 1964)
Clitrocytheridea paralubrica Neale and Kolpenskaya, 2000
Costacythere khiamii Tesakova and Rachenskaya, 1996
Costacythere foveata Tesakova and Rachenskaya, 1996
Costacythere drushchitzi Neale, 1966
Cythereis aff. *senckenbergi* Triebel, 1940
Cytherella tortuosa (Luebimova, 1955)
Cytherella lubimovae Neale, 1966
Cytherella krimensis Neale, 1966
Cytherella fragilis Neale, 1962
Cytherelloidea flexuosa Neale, 1966
Cytherelloidea mandelstami Neale, 1966
Eocytheropteron ex gr. *bispinosum* Schmidt, 1954
Eucytherura sp.1
Eucytherura sp.2
Eucytherura ardescae Donze, 1965
Eucytherura trinodosa Pokorny, 1973
Eucytherura (Eucytherura) aff. *kotelensis* Pokorny, 1973
Hechticythere sp.1
Hechticythere belbekensis Tesakova and Rachenskaya, 1996
Hechticythere moraviae (Pokorny, 1973)
Hemicytherura moorei Neale, 1967
Loxoella variealveolata Kuznetsova, 1956
Mantelliana purbeckensis (Forbes, 1855)

Neocythere pyrena Tesakova and Rachenskaya, 1996
Neocythere dispar Donze, 1965
Palaeocythereidella teres Neale, 1962
Paracypris caerulea Neale, 1962
Phodeucythere eucretacea Neale and Kolpenskaya, 2000
Pleurocythere (Klentnicella) klentnicensis Pokorny, 1973
Pontocyprella cf. *pertuisi* Donze, 1964
Pontocypris cuneata Neale, 1966
Protocythere revili Donze, 1975
Quasigermanites implicata (Donze, 1965)
Raymoorea peculiaris (Donze, 1965)
Reticythere marfenini (Tesakova and Rachenskaya, 1996)
Robsoniella longa Kuznetsova, 1961
Robsoniella obovata Kuznetsova, 1956
Robsoniella minima Kuznetsova, 1961
Schuleridea ex gr. *juddi* Neale, 1962
Sigillium procerum Kuznetsova, 1960
Tethysia chabrensis Donze, 1975
Prasinophites
Pterospermella spp.
Tasmanites spp.