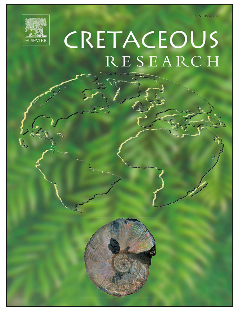

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A B S T R A C T

Our data from studies over many years on upper Tithonian–Berriasian strata of the Crimean Mountains are summarised and commented upon. 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, namely 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 also been 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 variant among other palaeomagnetic bench marks to determine the lower boundary of the Cretaceous System, because it is close to the base of the Grandis Subzone in Tethyan and the Chetae Zone in Boreal sections.

Keywords:
Calpionellids
Ammonite
Micropalaeontology
Magnetostratigraphy
Tethyan Realm
Eastern Europe

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 nature of the 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 recently been published (Arkadiev et al., 2012).

Numerous scientists have previously studied the Berriasian of 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. (2015), 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 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 villages of Krasnoselovka and Alekseevka). In central Crimea, the team studied Berriasian sections near the villages of Novoklenovka, Balki and Mezhgor'e. 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-Statigraphical 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 > 1,000 thin sections and polished sections were studied. 162 samples were collected for palynological studies, while calpionellids were examined in approximately 1,000 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), whereras 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 Joint-stock Company ‘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 remanent magnetism (ChRM) and determine polarity of the geomagnetic field. The ancient origin of the ChRM was substantiated by field test results (fold test, reverse_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 remanent 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 southwestern 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 metres.

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., 2015 (Figs. 2F, 5), near the village of Nanikovo, on Koklyuk Mountain (Fig. 2E) and near the village of Sultanovka. Based on our observations, the contact with the overlying Nanikovo Unit is concordant. The total thickness of this formation is up to 200 metres.

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., 2015). 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., 2015). 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, lastly, 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, 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 metres.

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 metres. No ammonites were found within the unit, and its dating as Berriasian is only tentative. 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 metres. 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 metres.

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 metres.

In another area of southwestern 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 metres. 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 metres (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 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 usually are 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 eastern Crimea, we have demonstrated the presence of two ammonite zones of the upper Tithonian, i.e., theMicrocanthum 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 resilts 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.

Jacobi *Zone*

According to data we have obtained (Arkadiev et al., 2012), in the Crimean Mountains this zone was subdivided into two subzones, the 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).

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).

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 (village of Krasnoselovka) andcentral Crimea (village of Balki).

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.

Beds with Malbosiceras chaperi

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

Distribution. Central Crimea (village of Balki, Karaby Yaila).

Beds with Tirnovella occitanica *and* Retowskiceras retowskyi

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

Distribution. Eastern Crimea (Zavodskaya Balka).

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, village of Balki and Belbek River Basin).

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).

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 (village of Nanikivo, Koklyuk Mountain, village of Balki and Belbek River Basin).

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, village of Balki).

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.

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 ofthe Chatyr-Dag Massif. In 2015, *Berriasella callisto* was collected at the Zavodskaya Balka section, above levels containing *Riasanites crassicostatum* (Arkadiev, 2015; Arkadiev et al., 2015).

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. Southwestern (Minester Ravine?), central (Chatyr Dag, village of Mramornoye) and eastern (Zavodskaya Balka) Crimea.

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 southwestern 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 southwestern 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. Continous Berriasian–Valanginian sections are known only in eastern Crimea, near the villages of Sultanovka and Nanikovo. 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 southwestern 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.

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).

Dobeni *Subzone*

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

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

Boneti *Subzone*

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

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

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 ineastern Crimea, above the occurrence of the first Calpionellidae; consequently, it is impossible to identify this zone at this time.

Crassicollaria *Zone*

This zone has earlier been referred 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*.

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).

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).

Calpionella *Zone*

According to the Roman Zonal Standard (Allemann et al., 1971) the Calpionella Zone has been established by combning 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*.

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 southwestern 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.

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).

Beds with Melathrokerion eospirialis–Epistomina ventriosa–Protopeneroplis striata

Foraminiferal assemblage – These beds are identified by the co-occurrence 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 southwestern Crimea (Chernaya River Basin).

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*, *Stomatostoechа 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 (village of Krasnoselovka) and southwestern Crimea (Chernaya River Basin).

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).

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 (village of Krasnoselovka), central Crimea (village of Balki), southwestern Crimea (Chernaya River Basin).

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 (village of Krasnoselovka), central Crimea (village of Balki), southwestern Crimea (Belbek River Basin, Chernaya River Basin).

Beds with Lingulina trilobitomorpha *and* Haplophragmoides vocontianus

This assemblage was identified in eastern Crimea in strata assignedto the Sultanovskaya Formation (Arkadiev et al., 2015). 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 familyProtocytheridae (*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*).

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 andTithonian 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 (village of Krasnoselovka) (upper Tithonian, Microcantum and Andreaei zones).

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 (village of Krasnoselovka) (Berriasian, Jacobi Zone).

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; Arkadiev et al., 2015; Savelieva et al., 2014). 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 khiamii*, *Costacythere foveata*, *Hechticythere belbekensis*, *Hechticythere moraviae* and *Schuleridea* ex gr. *juddi*.

Distribution. Central (village of Balki) and southwestern (Belbek River Basin) Crimea (Berriasian, Occitanica Zone).

Beds with Costacythere drushchitzi *and* Reticythere marfenini

These beds were recognised for the first time by Savelieva in strataassigned 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 (village of Balki) (Berriasian, Boissieri Zone).

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).

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*. Remanié 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 (village of Krasnoselovka), upper Tithonian and Berriasian (Jacobi Zone); central Crimea (village of Balki), Occitanica Zone (without Tauricum Subzone) (Arkadiev et al., 2012).

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 (village of Balki) and southwestern Crimea (Belbek River Basin), Berriasian, Tauricum Subzone of the 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 fromtheir 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 usbetween 2009 and2016 (Arkadiev et al., 2010, 2012; Arkadiev et al., 2015; Guzhikov et al., 2012; 2014; Yampolskaya et al., 2009). 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 10–20 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 previouslyfrom 4 metres 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 probabilility 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 **N_1t** through **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). **N_1t** corresponds to the Microcanthun Zone (upper Tithonian) and is equivalent to chron M20n. Magnetozone **R_1t** is located in the lower part of the Andreaei Zone; itwas identified as equivalent to chron M19r. Magnetozones **N_1t-b**, **R_1t-b** and **N_2t-b** were identified in the Andreaei/Jacobi boundary interval and, in our opinion, correspond to chron M19. **R_1t-b** corresponds to the Brodno subchron (M19n.1r), while **N_1t-b** and **N_2t-b** correspond to subchrons M19n2n and M19n1n, respectively.

Magnetozone **R_1b** corresponds to the boundary of the Jacobi/Grandis subzones and correlates with chron M18r, and magnetozone **N_1b** above it, confined to within the Grandis Subzone, correlates with chron M18n. Equivalents of **N_1b** within the Grandis Subzone were also documented in the Tonas River Basin (Fig. 4) (Yampolskaya et al., 2009).

To date, magnetozones from **R_2b** through **N_2b** have been identified only in central Crimea, within the Bechku Formation (Fig. 6) (Arkadiev et al., 2015). Subzone **R_2b** encompasses the beds with *Malbosiceras chaperi*, *Tirnovella occitanica* and *Retowskiceras retowsky* (Occitanica Zone) and therefore is indisputably equivalent to chron M17r. Subzone **N_2b** is associated with the Tauricum Subzone of the Occitanica Zone, allowing reliable correlation with chron M17n.

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

Correlation of the upper part of the reversed polarity **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 **R_3b** with chron M16r (Arkadiev et al., 2010). Magnetozone **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 **N_3b** (Arkadiev et al., 2015; Guzhikov et al., 2014). 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.

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., 2015), 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 to 2 metres. 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 noie that datafrom 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 formthe 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 thatare 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 impacton 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 ofnumerous new stratigraphic studies of this interval (Egoyan, 1975; Druschits and Vahrameev, 1976; Wimbledon, 2008; Arkadiev et al., 2014; Zakharov, 2011; Baraboshkin et al., 2013;; Wimbledon et al., 2011). 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 Tithonianhas 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 realmand 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; Arkadiev, Baraboshkin and Guzhikov, 2014; Guzhikov, 2013).

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 supportof 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 (Pokorny, 1973; Neale, 1967, 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 micropalaeontologicaldata 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 documentedthe 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 metres 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 criterionfor placement of the Jurassic–Cretaceous boundary, because the base of this is close to the base of the Grandis Subzone, as traced in sections inFrance, 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).

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Captions

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

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, village of Nanikovo, Koklyuk Mountain; Berriasian–Valanginian. F, Outcrop of clays, Feodosiya, ‘Zavodskaya Balka’ section; upper Berriasian. G, Outcrop of clays, village of Balki, upper Berriasian. H. Outcrop of bioherm limestone, village of Mezhgor’e; 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 (Arkadiev et al., 2012; Yampolskaya et al., 2009). B, Kuchuk-Usen section (Arkadiev et al., 2012; new magnetic polarity data).

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

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

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

Fig. 8. Composite section of the Tithonian–Berriasian in the Chernaya River Basin (Baydarskaya Valley, southwest 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, village of Krasnoselovka; E–F, specimen 18/13077 in ventral and lateral views, Feodosiya, Saint Elias Cape, Jacobi Zone.

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, village of Krasnoselovka, Jacobi Zone. D–E, *Berriasella chomeracensis*, specimen 1/131 in lateral and ventral views (x 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, village of Kuibyshevo, 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.

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, village of Alekseevka, 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, village of Nanikovo, Koklyuk Mountain, Boissieri Zone, Euthymi Subzone; J–K, specimen 16/409 in lateral and ventral views, village of Nanikovo, 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, village of Balki, 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, village of Petrovo, 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 Ky6, 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 Ky4, 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 Ky7,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, 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.

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*, specimen600-46-28, 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, village of Balki, 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, village of Novoklenovo, 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, right valve, lateral view, village of Novoklenovo, 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, village of Balki, 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, village of Balki, 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.

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.

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

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.

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

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 & 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

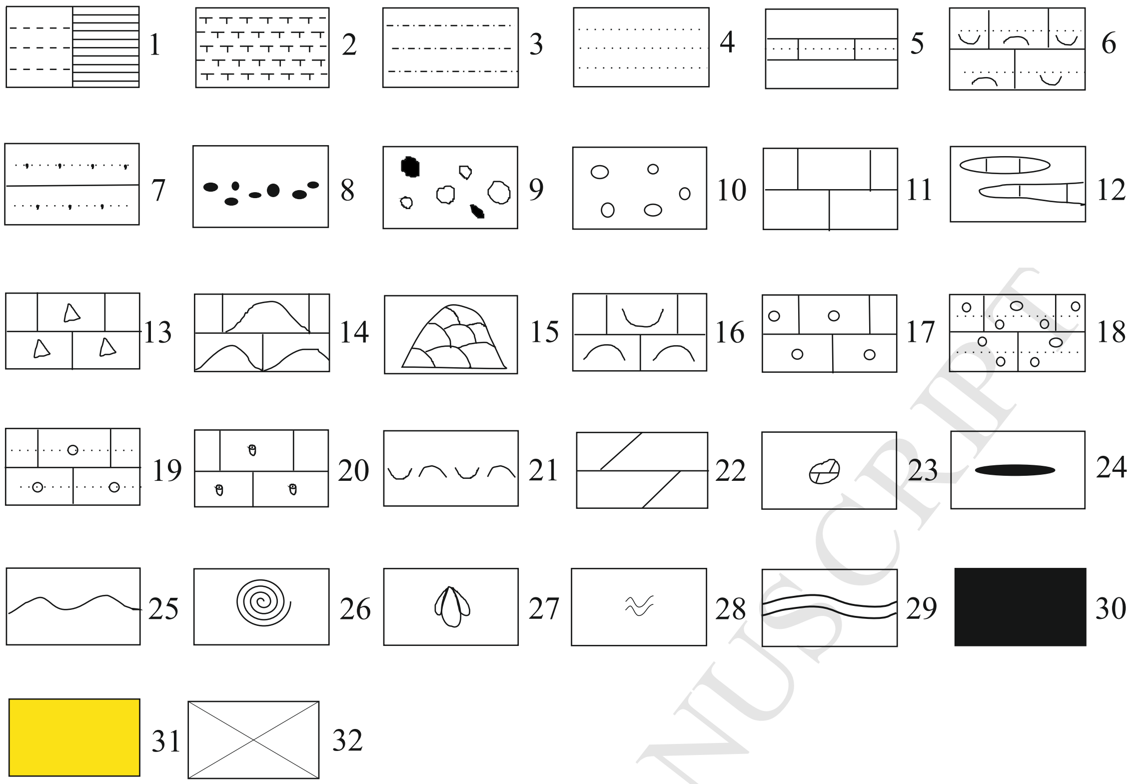
Tethysia chabrensis Donze, 1975

Prasinophites

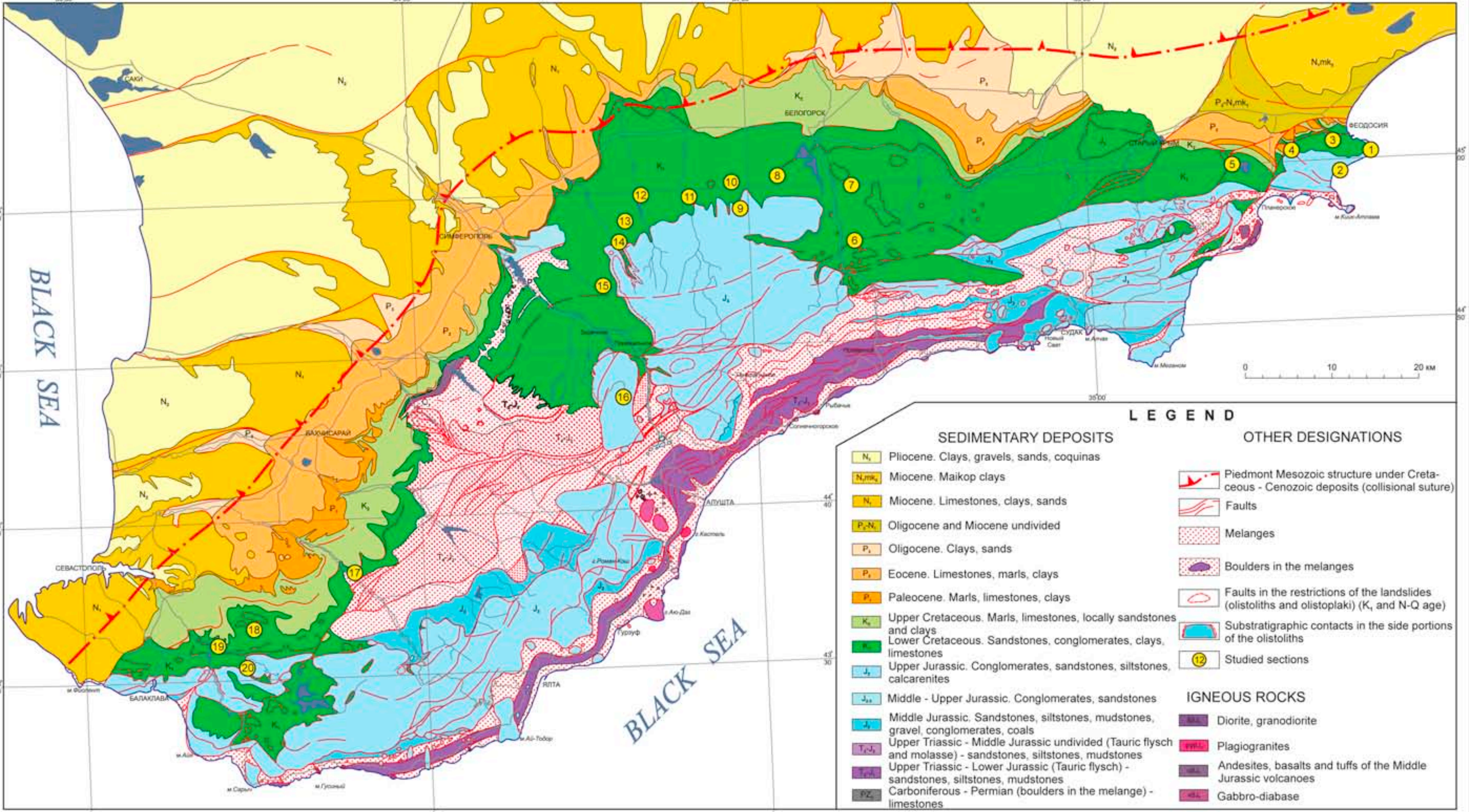
Pterospermella spp.

Tasmanites spp.

Legend to figs.

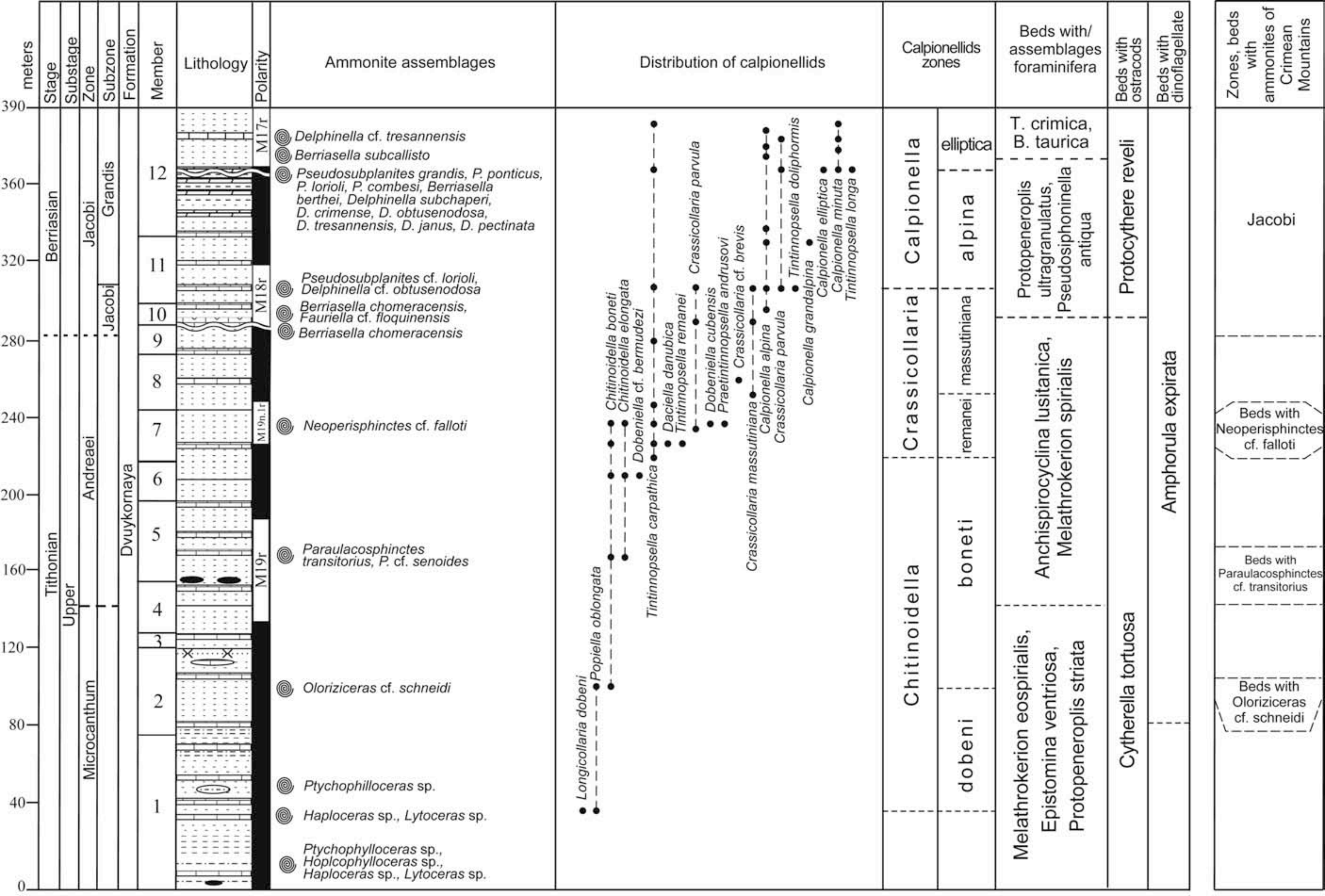


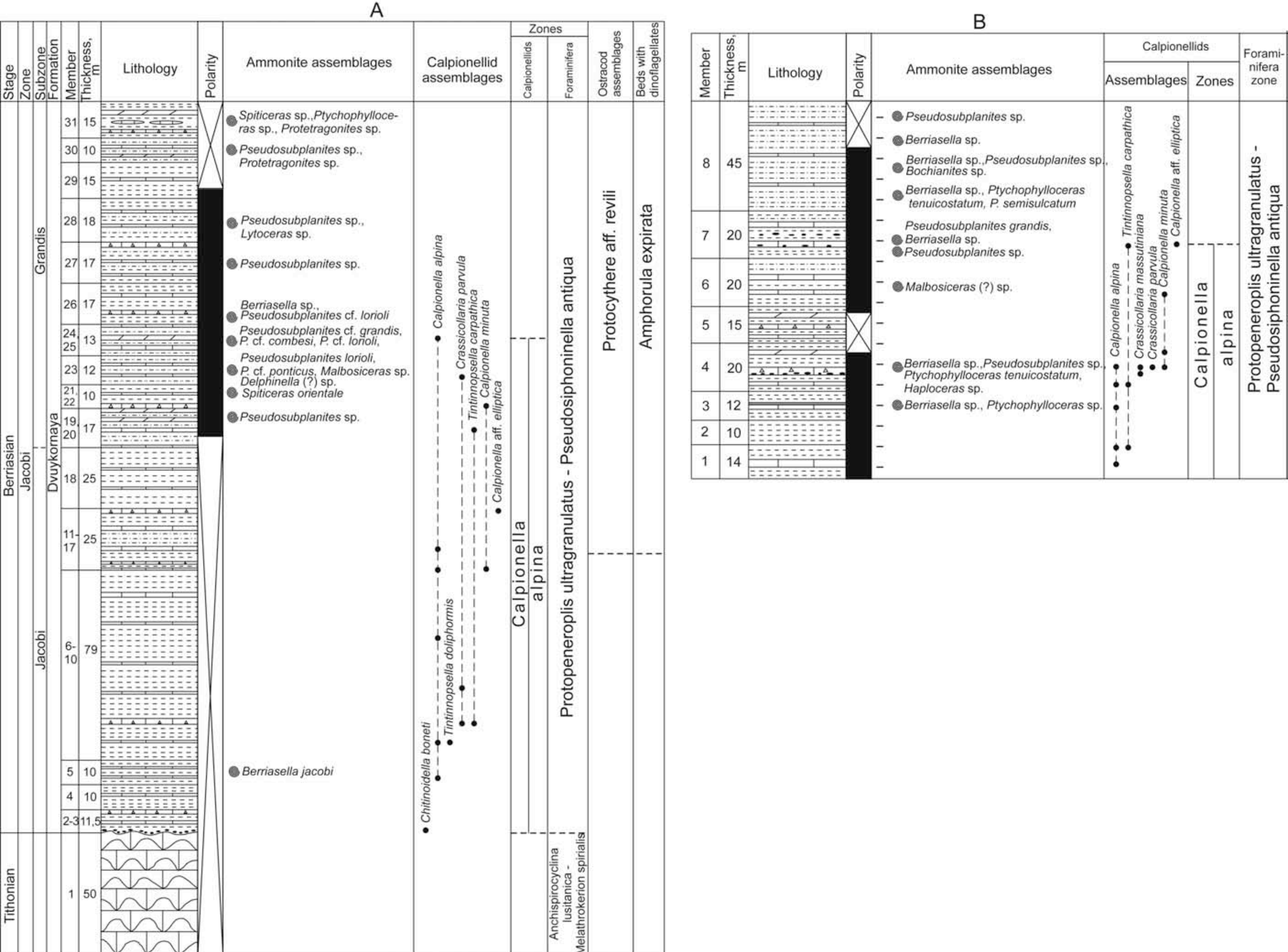
1 - clay, 2 - calcareous clay, 3 - aleurolite, 4 - sandstone, 5 - calcareous sandstone, 6 - calcareous shell sandstone, 7 - glauconitic sandstone, 8 - conglomerate, 9 - polymictic conglomerate, 10 - quartz conglomerate, 11 - limestone, 12 - limestone lenses, 13 - brecciated limestone, 14 - reefal limestone, 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.

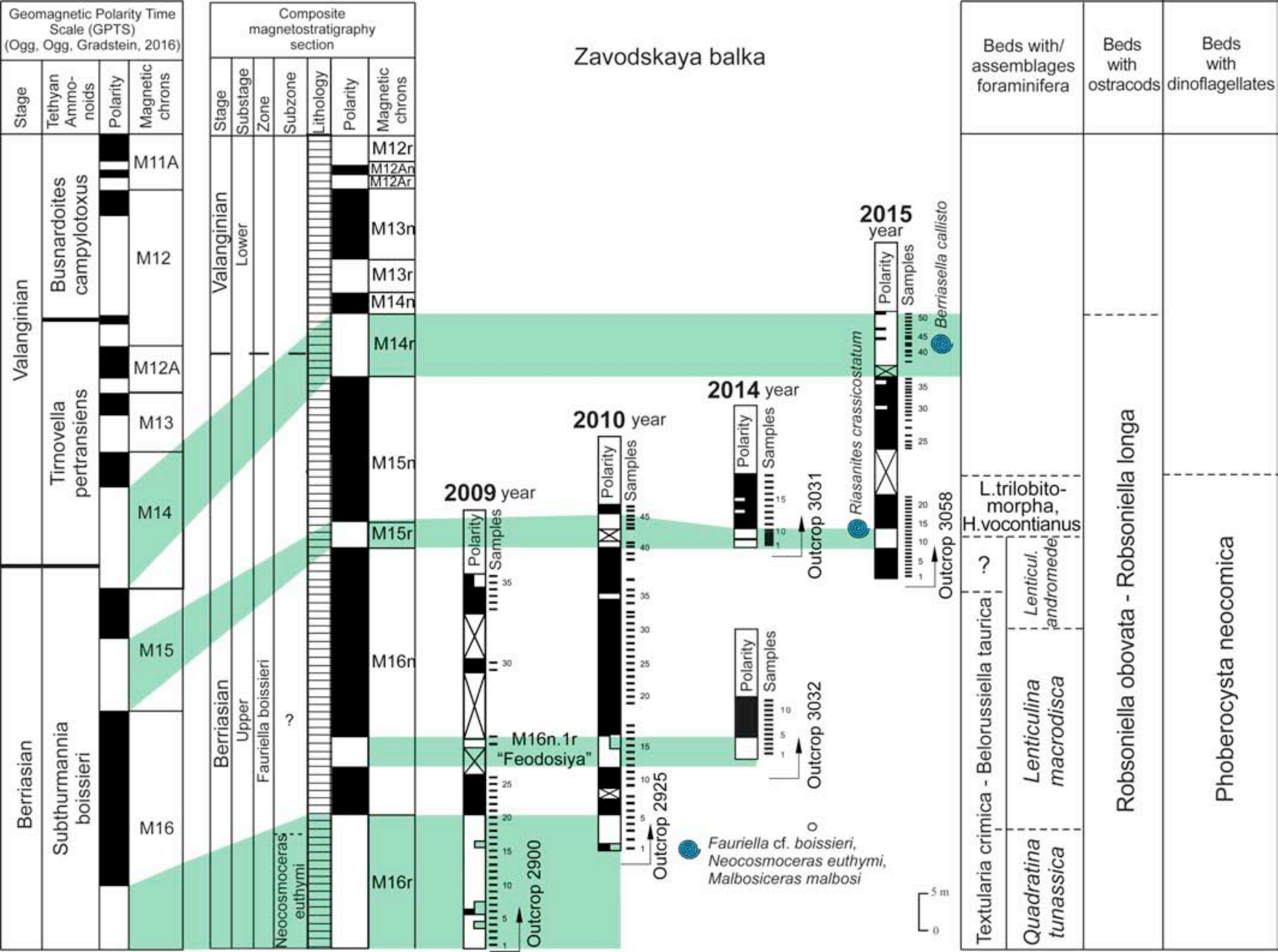


BLACK SEA
BLACK SEA
САКИ
СИМФЕРОПОЛЬ
БЕЛОГОРСК
ФЕОДОСИЯ
БАХЧИСАРАЙ
СЕВАСТОПОЛЬ
БАЛАКЛАВА
ЯЛТА
АЛУШТА
СУДАК
0 10 20 км
LEGEND
SEDIMENTARY DEPOSITS
N2 Pliocene. Clays, gravels, sands, coquinas
N1mk2 Miocene. Maikop clays
N1 Miocene. Limestones, clays, sands
P3-N1 Oligocene and Miocene undivided
P3 Oligocene. Clays, sands
P2 Eocene. Limestones, marls, clays
P1 Paleocene. Marls, limestones, clays
K2 Upper Cretaceous. Marls, limestones, locally sandstones and clays
K1 Lower Cretaceous. Sandstones, conglomerates, clays, limestones
J3 Upper Jurassic. Conglomerates, sandstones, siltstones, calcarenites
J2-3 Middle - Upper Jurassic. Conglomerates, sandstones
J2 Middle Jurassic. Sandstones, siltstones, mudstones, gravel, conglomerates, coals
T3-J2 Upper Triassic - Middle Jurassic undivided (Tauric flysch and molasse) - sandstones, siltstones, mudstones
T3-J1 Upper Triassic - Lower Jurassic (Tauric flysch) - sandstones, siltstones, mudstones
PZ3 Carboniferous - Permian (boulders in the melange) - limestones
OTHER DESIGNATIONS
Piedmont Mesozoic structure under Cretaceous - Cenozoic deposits (collisional suture)
Faults
Melanges
Boulders in the melanges
Faults in the restrictions of the landslides (olistoliths and olistoplaki) (K1 and N-Q age)
Substratigraphic contacts in the side portions of the olistoliths
12 Studied sections
IGNEOUS ROCKS
Diorite, granodiorite
Plagiogranites
Andesites, basalts and tuffs of the Middle Jurassic volcanoes
Gabbro-diabase

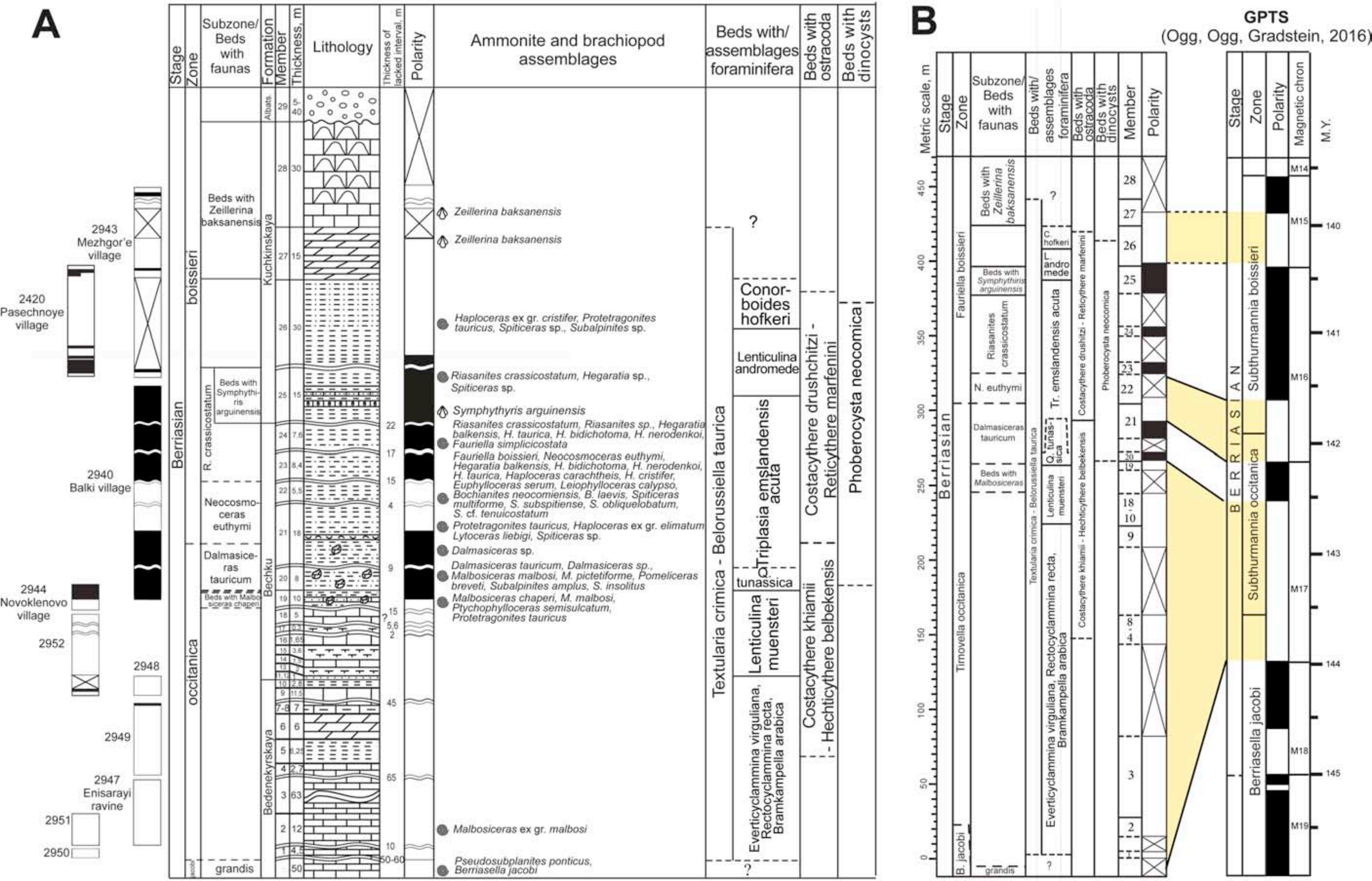

A
B
C
D
E
F
G
H

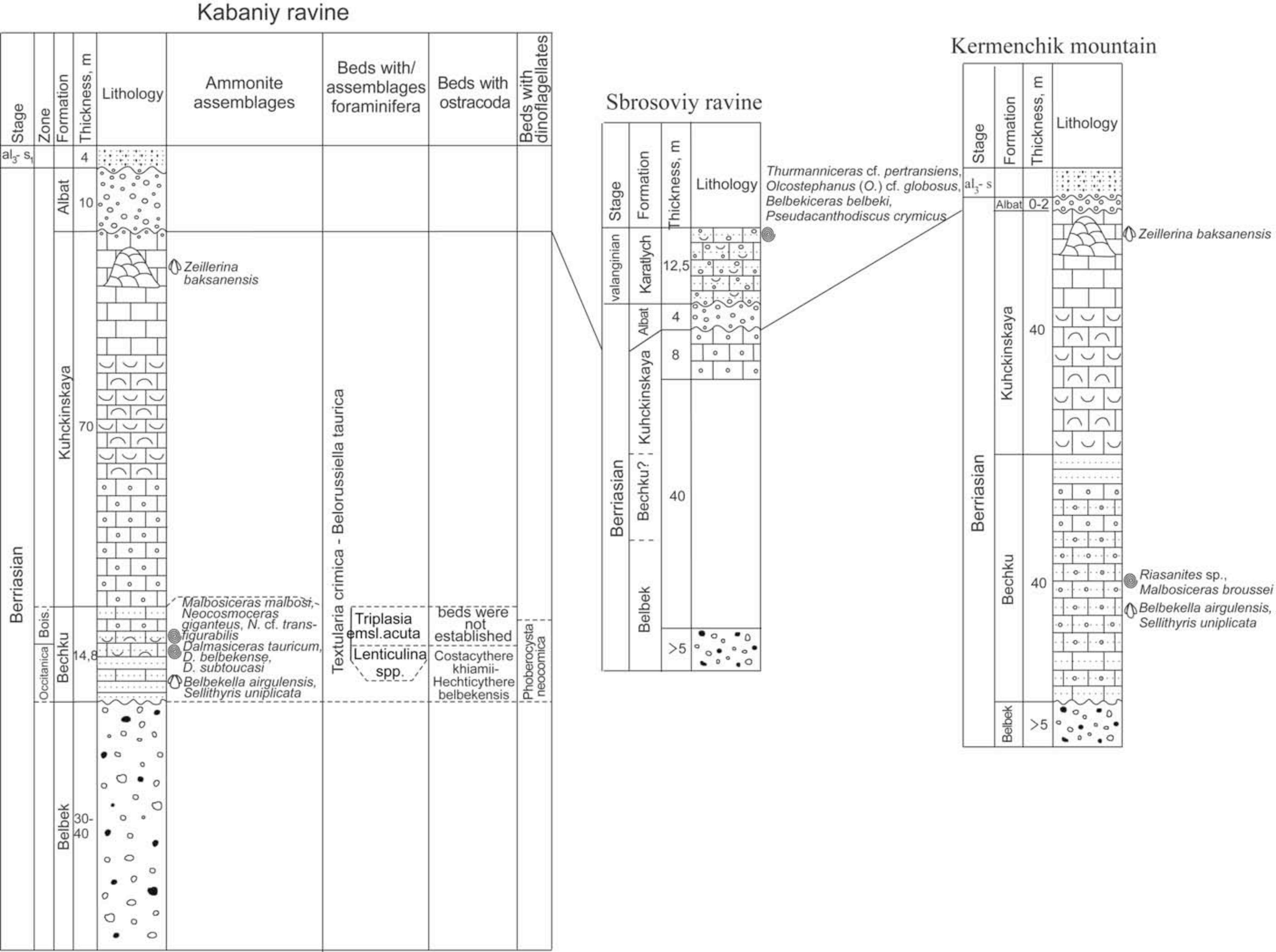

meters
Stage
Substage
Zone
Subzone
Formation
Member
Lithology
Polarity
Ammonite assemblages
Distribution of calpionellids
Calpionellids zones
Beds with/ assemblages foraminifera
Beds with ostracods
Beds with dinoflagellate
Zones, beds with ammonites of Crimean Mountains
390
360
320
280
240
200
160
120
80
40
0
Berriasian
Tithonian
Upper
Jacobi
Andreaei
Microcanthum
Grandis
Jacobi
Dvuykornaya
12
11
10
9
8
7
6
5
4
3
2
1
M17r
M18r
M19n.1r
M19r
Delphinella cf. tresannensis
Berriasella subcallisto
Pseudosubplanites grandis, P. ponticus, P. lorioli, P. combesi, Berriasella berthei, Delphinella subchaperi, D. crimense, D. obtusenodosa, D. tresannensis, D. janus, D. pectinata
Pseudosubplanites cf. lorioli, Delphinella cf. obtusenodosa
Berriasella chomeracensis, Fauriella cf. floquinensis
Berriasella chomeracensis
Neoperisphinctes cf. falloti
Paraulacosphinctes transitorius, P. cf. senoides
Oloriziceras cf. schneidi
Ptychophilloceras sp.
Haploceras sp., Lytoceras sp.
Ptychophylloceras sp., Hoplcophylloceras sp., Haploceras sp., Lytoceras sp.
Longicollaria dobeni
Popiella oblongata
Chitinoidella boneti
Chitinoidella elongata
Dobeniella cf. bermudezi
Tintinnopsella carpathica
Daciella danubica
Tintinnopsella remanei
Crassicollaria parvula
Dobeniella cubensis
Praetintinnopsella andrusovi
Crassicollaria cf. brevis
Crassicollaria massutiniana
Calpionella alpina
Crassicollaria parvula
Tintinnopsella doliphormis
Calpionella grandalpina
Calpionella elliptica
Calpionella minuta
Tintinnopsella longa
Calpionella
Crassicollaria
Chitinoidella
elliptica
alpina
massutiniana
remanei
boneti
dobeni
T. crimica, B. taurica
Protopeneroplis ultragranulatus, Pseudosiphoninella antiqua
Anchispirocyclina lusitanica, Melathrokerion spirialis
Melathrokerion eospirialis, Epistomina ventriosa, Protopeneroplis striata
Protocythere reveli
Cytherella tortuosa
Amphorula expirata
Jacobi
Beds with Neoperisphinctes cf. falloti
Beds with Paraulacosphinctes cf. transitorius
Beds with Oloriziceras cf. schneidi


A
Stage
Zone
Subzone
Formation
Member
Thickness, m
Lithology
Polarity
Ammonite assemblages
Calpionellid assemblages
Zones
Calpionellids
Foraminifera
Ostracod assemblages
Beds with dinoflagellates
Berriasian
Tithonian
Jacobi
Grandis
Dvuykornaya
Spiticeras sp., Ptychophylloceras sp., Protetragonites sp.
Pseudosubplanites sp., Protetragonites sp.
Pseudosubplanites sp., Lytoceras sp.
Pseudosubplanites sp.
Berriasella sp., Pseudosubplanites cf. lorioli
Pseudosubplanites cf. grandis, P. cf. combesi, P. cf. lorioli,
Pseudosubplanites lorioli, P. cf. ponticus, Malbosiceras sp.
Delphinella (?) sp.
Spiticeras orientale
Pseudosubplanites sp.
Berriasella jacobi
Calpionella alpina
Crassicollaria parvula
Tintinnopsella carpathica
Calpionella minuta
Calpionella aff. elliptica
Chitinoidella boneti
Tintinnopsella doliphormis
Calpionella alpina
Protopeneroplis ultragranulatus - Pseudosiphoninella antiqua
Anchispirocyclina lusitanica - Melathrokerion spirialis
Protocythere aff. revili
Amphorula expirata
B
Member
Thickness, m
Lithology
Polarity
Ammonite assemblages
Calpionellids
Assemblages
Zones
Foraminifera zone
Pseudosubplanites sp.
Berriasella sp.
Berriasella sp., Pseudosubplanites sp., Bochianites sp.
Berriasella sp., Ptychophylloceras tenuicostatum, P. semisulcatum
Pseudosubplanites grandis, Berriasella sp.
Pseudosubplanites sp.
Malbosiceras (?) sp.
Berriasella sp., Pseudosubplanites sp., Ptychophylloceras tenuicostatum, Haploceras sp.
Berriasella sp., Ptychophylloceras sp.
Calpionella alpina
Tintinnopsella carpathica
Crassicollaria massutiniana
Crassicollaria parvula
Calpionella minuta
Calpionella aff. elliptica
Calpionella alpina
Protopeneroplis ultragranulatus - Pseudosiphoninella antiqua

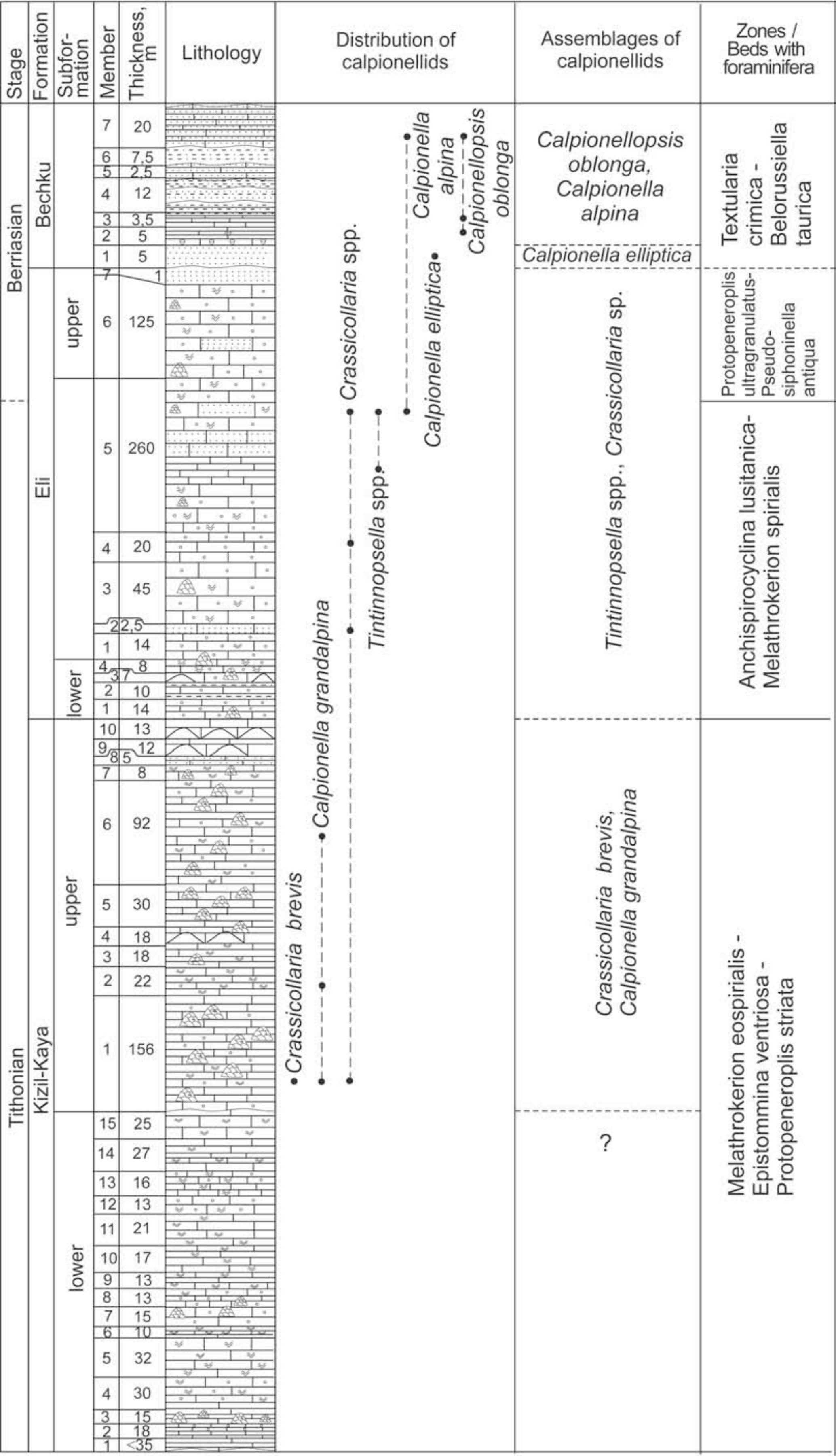


Geomagnetic Polarity Time Scale (GPTS) (Ogg, Ogg, Gradstein, 2016)
Stage
Tethyan Ammonoids
Polarity
Magnetic chrons
Valanginian
Berriasian
Busnardoites campylotoxus
Tirnovella pertransiens
Subthurmannia boissieri
M11A
M12
M12A
M13
M14
M15
M16
Composite magnetostratigraphy section
Stage
Substage
Zone
Subzone
Lithology
Polarity
Magnetic chrons
Valanginian
Lower
Berriasian
Upper
Fauriella boissieri
?
Neocosmoceras euthymi
M12r
M12An
M12Ar
M13n
M13r
M14n
M14r
M15n
M15r
M16n
M16r
Zavodskaya balka
2009 year
2010 year
2014 year
2015 year
Polarity
Samples
Outcrop 2900
Outcrop 2925
Outcrop 3031
Outcrop 3032
Outcrop 3058
M16n.1r
"Feodosiya"
Riasanites crassicostatum
Berriasella callisto
Fauriella cf. boissieri, Neocosmoceras euthymi, Malbosiceras malbosi
5 m
0
Beds with/ assemblages foraminifera
Beds with ostracods
Beds with dinoflagellates
L.trilobitomorpha, H.vocontianus
?
Lenticul. andromede
Lenticulina macrodisca
Quadratina tunassica
Textularia crimica - Belorussiella taurica
Robsoniella obovata - Robsoniella longa
Phoberocysta neocomica

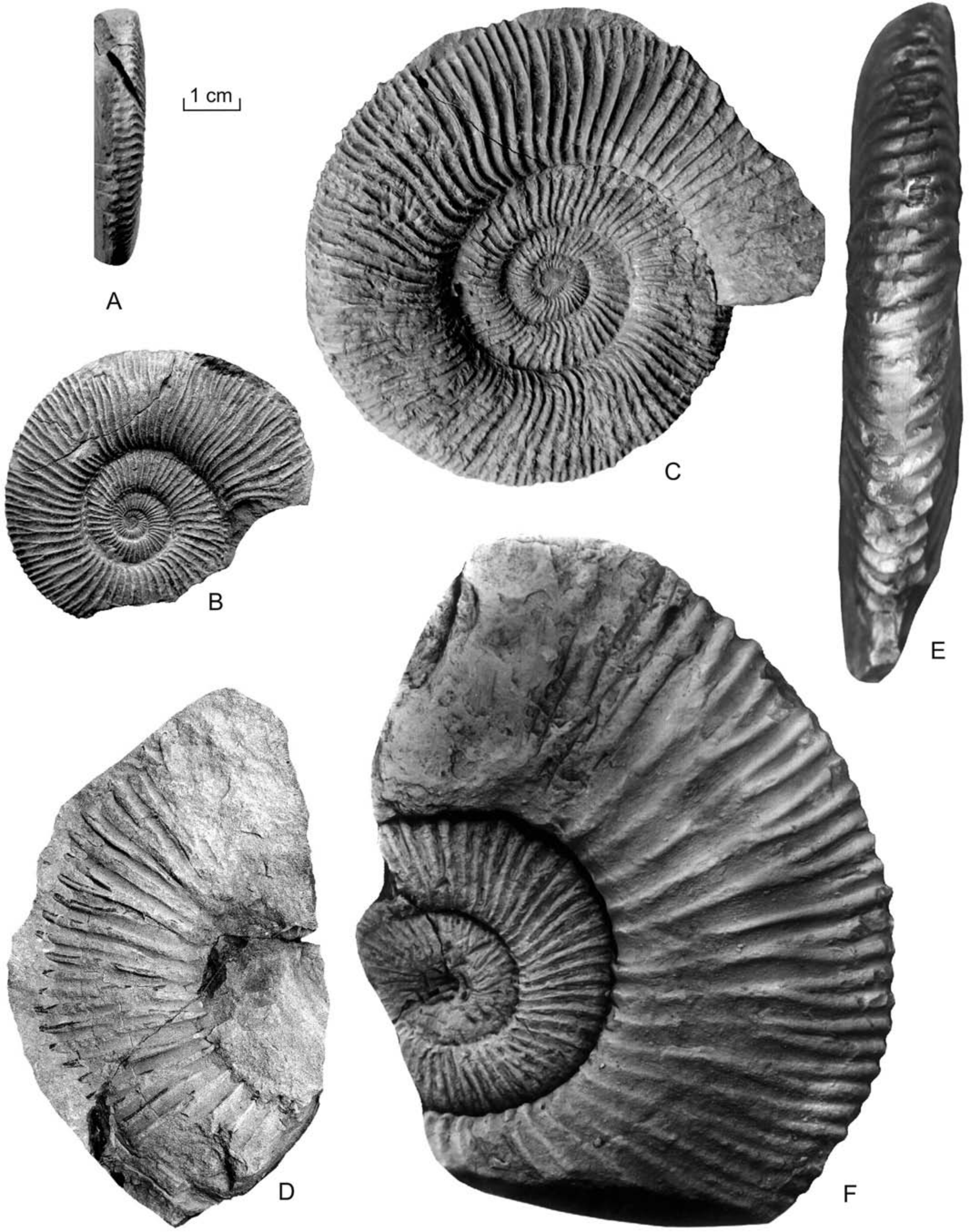

A
B
Stage
Zone
Subzone/ Beds with faunas
Formation
Member
Thickness, m
Lithology
Thickness of lacked interval, m
Polarity
Ammonite and brachiopod assemblages
Beds with/ assemblages foraminifera
Beds with ostracoda
Beds with dinocysts
2943 Mezhgor'e village
2420 Pasechnoye village
2940 Balki village
2944 Novoklenovo village
2952
2948
2949
2947 Enisarayi ravine
2951
2950
Berriasian
boissieri
occitanica
grandis
Beds with Zeillerina baksanensis
Beds with Symphythiris arguinensis
R. crassicostatum
Neocosmoceras euthymi
Dalmasiceras tauricum
Beds with Malbosiceras chapeni
Albats.
Kuchkinskaya
Bechku
Bedenekyrskaya
Zeillerina baksanensis
Haploceras ex gr. cristifer, Protetragonites tauricus, Spiticeras sp., Subalpinites sp.
Riasanites crassicostatum, Hegaratia sp., Spiticeras sp.
Symphythyris arguinensis
Riasanites crassicostatum, Riasanites sp., Hegaratia balkensis, H. taurica, H. bidichotoma, H. nerodenkoi, Fauriella simplicicostata
Fauriella boissieri, Neocosmoceras euthymi, Hegaratia balkensis, H. bidichotoma, H. nerodenkoi, H. taurica, Haploceras carachtheis, H. cristifer, Euphylloceras serum, Leiophylloceras calypso, Bochianites neocomiensis, B. laevis, Spiticeras multiforme, S. subspitiense, S. obliquelobatum, S. cf. tenuicostatum
Protetragonites tauricus, Haploceras ex gr. elimatum Lytoceras liebigi, Spiticeras sp.
Dalmasiceras sp.
Dalmasiceras tauricum, Dalmasiceras sp., Malbosiceras malbosi, M. pictetiforme, Pomeliceras breveti, Subalpinites amplus, S. insolitus
Malbosiceras chaperi, M. malbosi, Ptychophylloceras semisulcatum, Protetragonites tauricus
Malbosiceras ex gr. malbosi
Pseudosubplanites ponticus, Berriasella jacobi
Textularia crimica - Belorussiella taurica
Conorboides hofkeri
Lenticulina andromede
Triplasia emslandensis acuta
Q. tunassica
Lenticulina muensteri
Everticyclammina virguliana, Rectocyclammina recta, Bramkampella arabica
Costacythere drushchitzi - Reticythere marfenini
Costacythere khiamii - Hechticythere belbekensis
Phoberocysta neocomica
Metric scale, m
Fauriella boissieri
Tirnovella occitanica
B. jacobi
Beds with Malbosiceras
N. euthymi
Riasanites crassicostatum
Beds with Symphythiris arguinensis
Tr. emslandensis acuta
C. hofkeri
L. andromede
Lenticulina muensteri
GPTS
(Ogg, Ogg, Gradstein, 2016)
Magnetic chron
M.Y.
BERRIASIAN
Subthurmannia boissieri
Subthurmannia occitanica
Berriasella jacobi
M14
M15
M16
M17
M18
M19
140
141
142
143
144
145

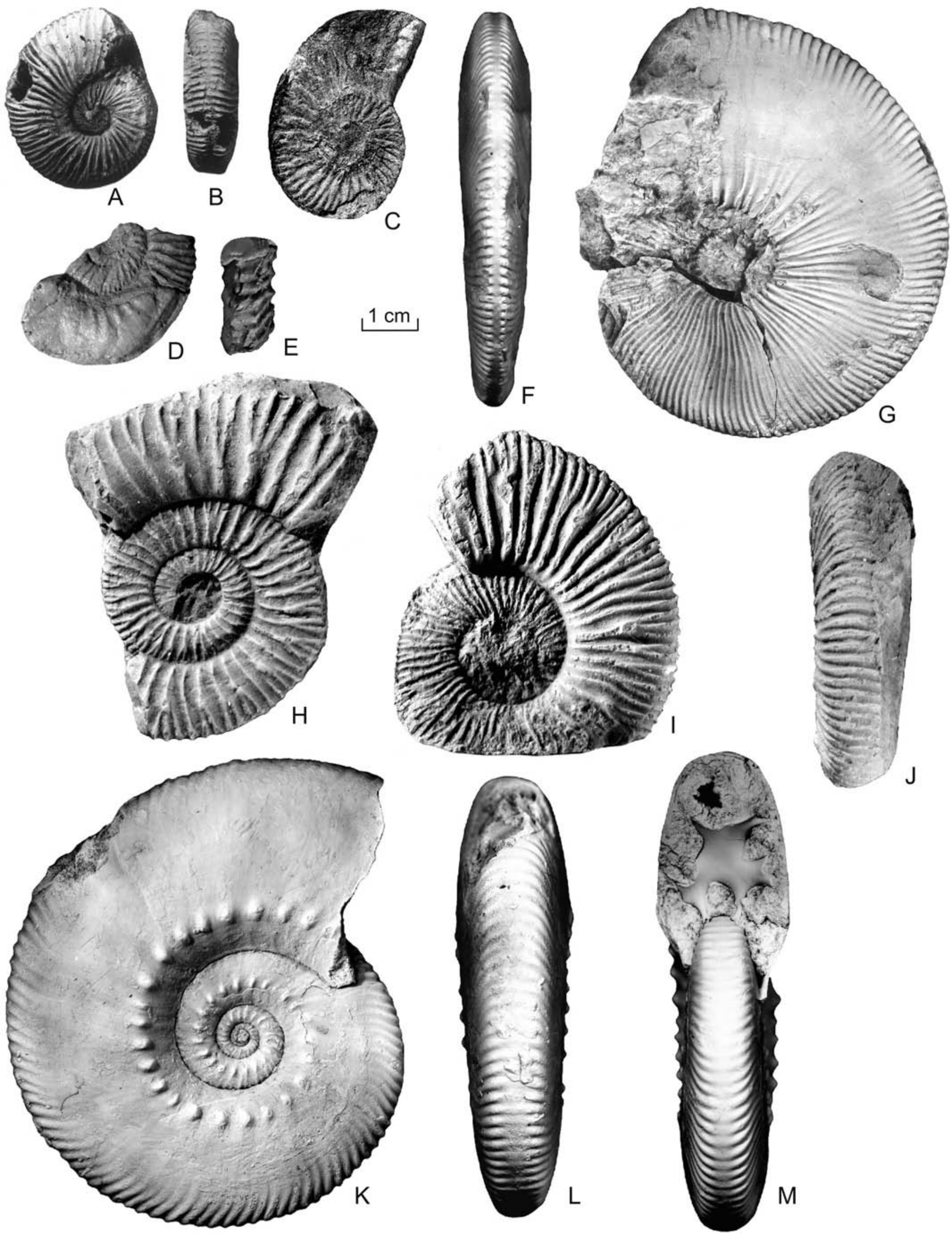


Kabaniy ravine
Stage
Zone
Formation
Thickness, m
Lithology
Ammonite assemblages
Beds with/ assemblages foraminifera
Beds with ostracoda
Beds with dinoflagellates
al3- s1
4
Albat
10
Zeillerina baksanensis
Kuhckinskaya
70
Berriasian
Bois.
Occitanica
Bechku
14,8
Malbosiceras malbosi, Neocosmoceras giganteus, N. cf. transfigurabilis
Dalmasiceras tauricum, D. belbekense, D. subtoucasi
Belbekella airgulensis, Sellithyris uniplicata
Textularia crimica - Belorussiella taurica
Triplasia emsl.acuta
Lenticulina spp.
beds were not established
Costacythere khiamii-Hechticythere belbekensis
Phoberocysta neocomica
Belbek
30-40
Sbrosoviy ravine
Stage
Formation
Thickness, m
Lithology
valanginian
Karatlych
12,5
Thurmanniceras cf. pertransiens, Olcostephanus (O.) cf. globosus, Belbekiceras belbeki, Pseudacanthodiscus crymicus
Albat
4
Kuhckinskaya
8
Berriasian
Bechku?
40
Belbek
>5
Kermenchik mountain
Stage
Formation
Thickness, m
Lithology
al3- s
Albat
0-2
Zeillerina baksanensis
Kuhckinskaya
40
Berriasian
Bechku
40
Riasanites sp., Malbosiceras broussei
Belbekella airgulensis, Sellithyris uniplicata
Belbek
>5



Stage
Formation
Subformation
Member
Thickness, m
Lithology
Distribution of calpionellids
Assemblages of calpionellids
Zones / Beds with foraminifera
Berriasian
Tithonian
Bechku
Eli
Kizil-Kaya
upper
lower
upper
lower
7 20
6 7,5
5 2,5
4 12
3 3,5
2 5
1 5
7 1
6 125
5 260
4 20
3 45
2 2,5
1 14
4 8
3 7
2 10
1 14
10 13
9 12
8 5
7 8
6 92
5 30
4 18
3 18
2 22
1 156
15 25
14 27
13 16
12 13
11 21
10 17
9 13
8 13
7 15
6 10
5 32
4 30
3 15
2 18
1 <35
Calpionella alpina
Calpionellopsis oblonga
Calpionella elliptica
Crassicollaria spp.
Tintinnopsella spp.
Calpionella grandalpina
Crassicollaria brevis
Calpionellopsis oblonga, Calpionella alpina
Calpionella elliptica
Tintinnopsella spp., Crassicollaria sp.
Crassicollaria brevis, Calpionella grandalpina
?
Textularia crimica - Belorussiella taurica
Protopeneroplis ultragranulatus-Pseudosiphoninella antiqua
Anchispirocyclina lusitanica-Melathrokerion spiralis
Melathrokerion eospirialis - Epistommina ventriosa - Protopeneroplis striata


1 cm
A
B
C
D
E
F


A
B
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1 cm
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I
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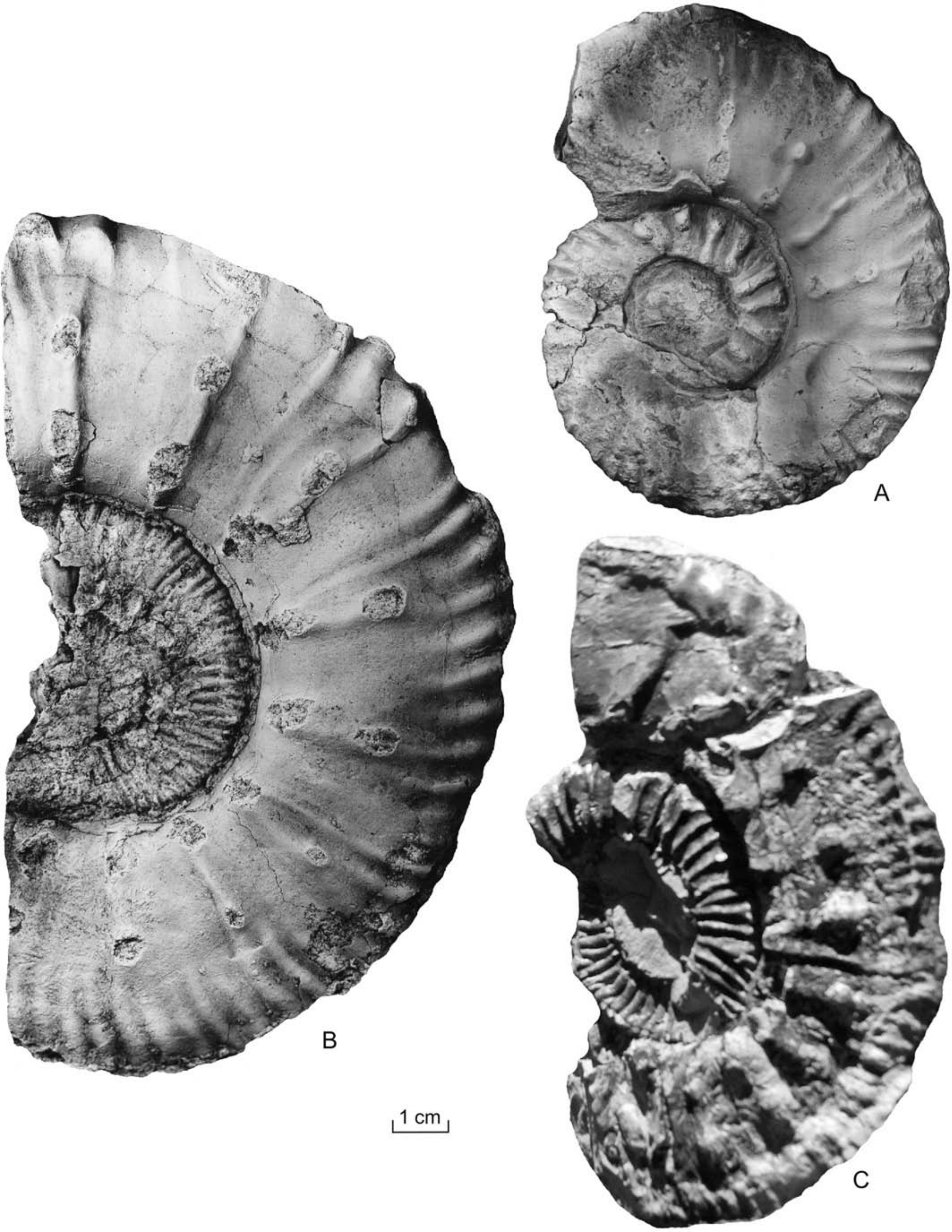
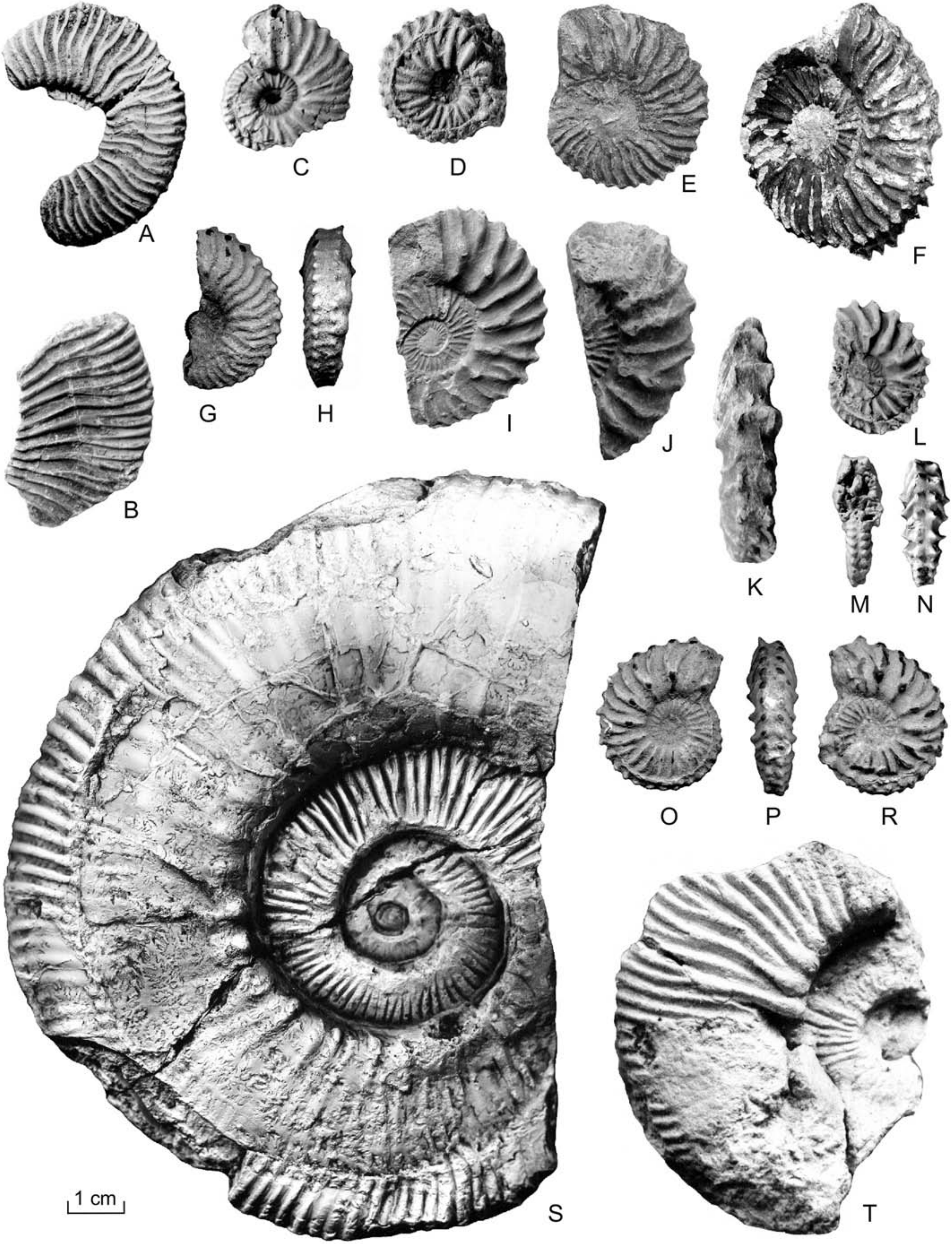
M


A
B
C
1 cm


A
B
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G
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I
J
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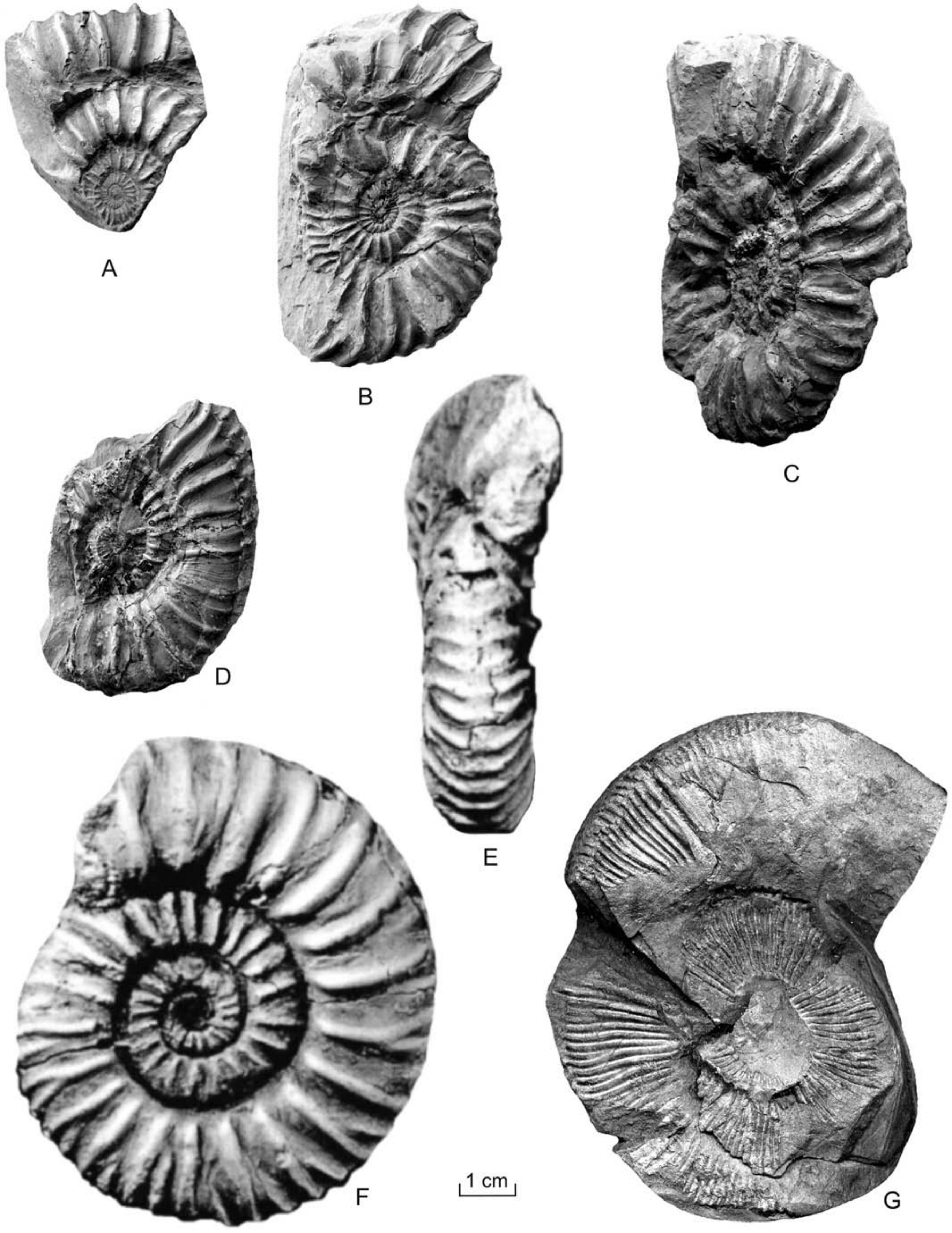
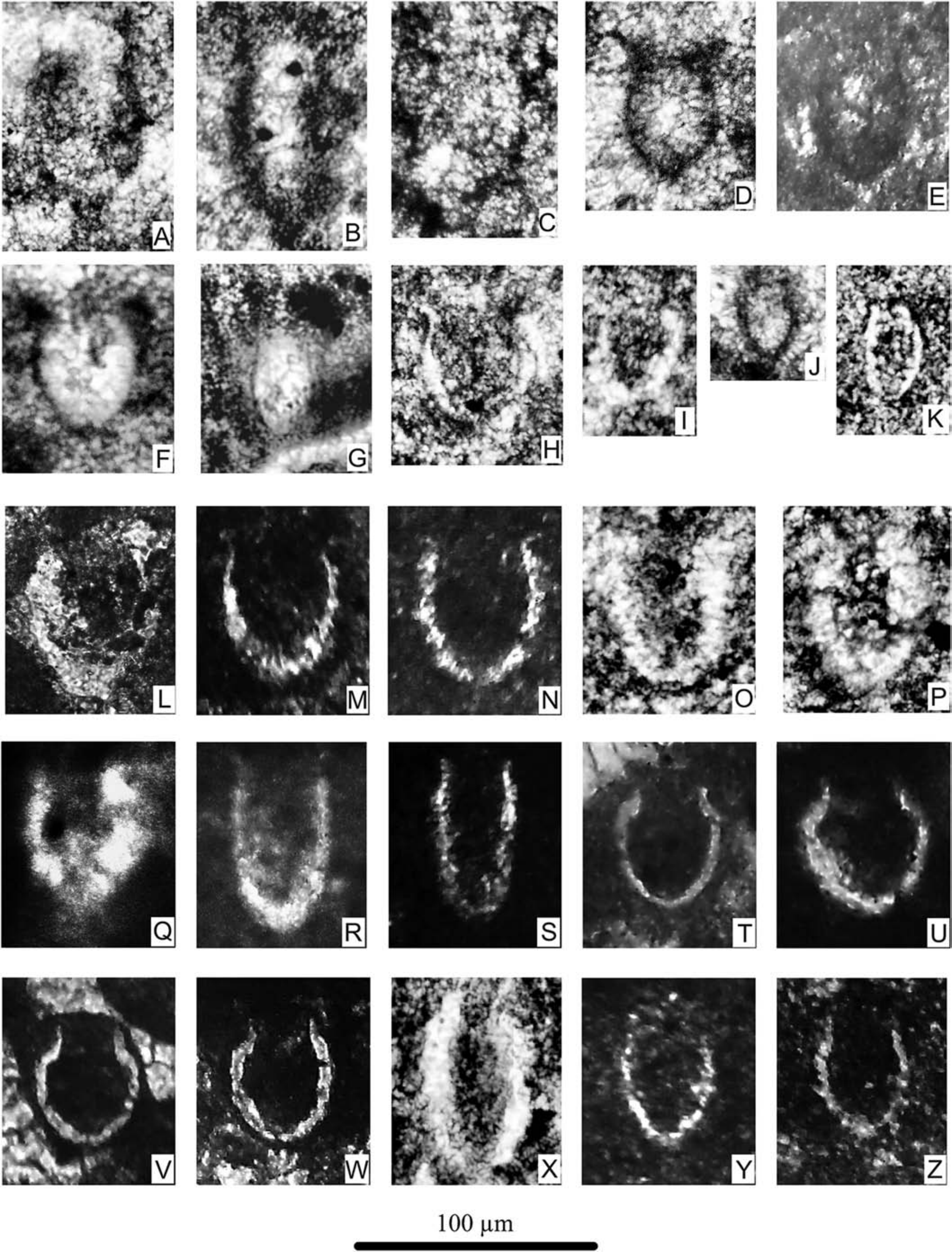
M
N
O
P
R
S
T
1 cm


A
B
C
D
E
F
1 cm
G


A
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T
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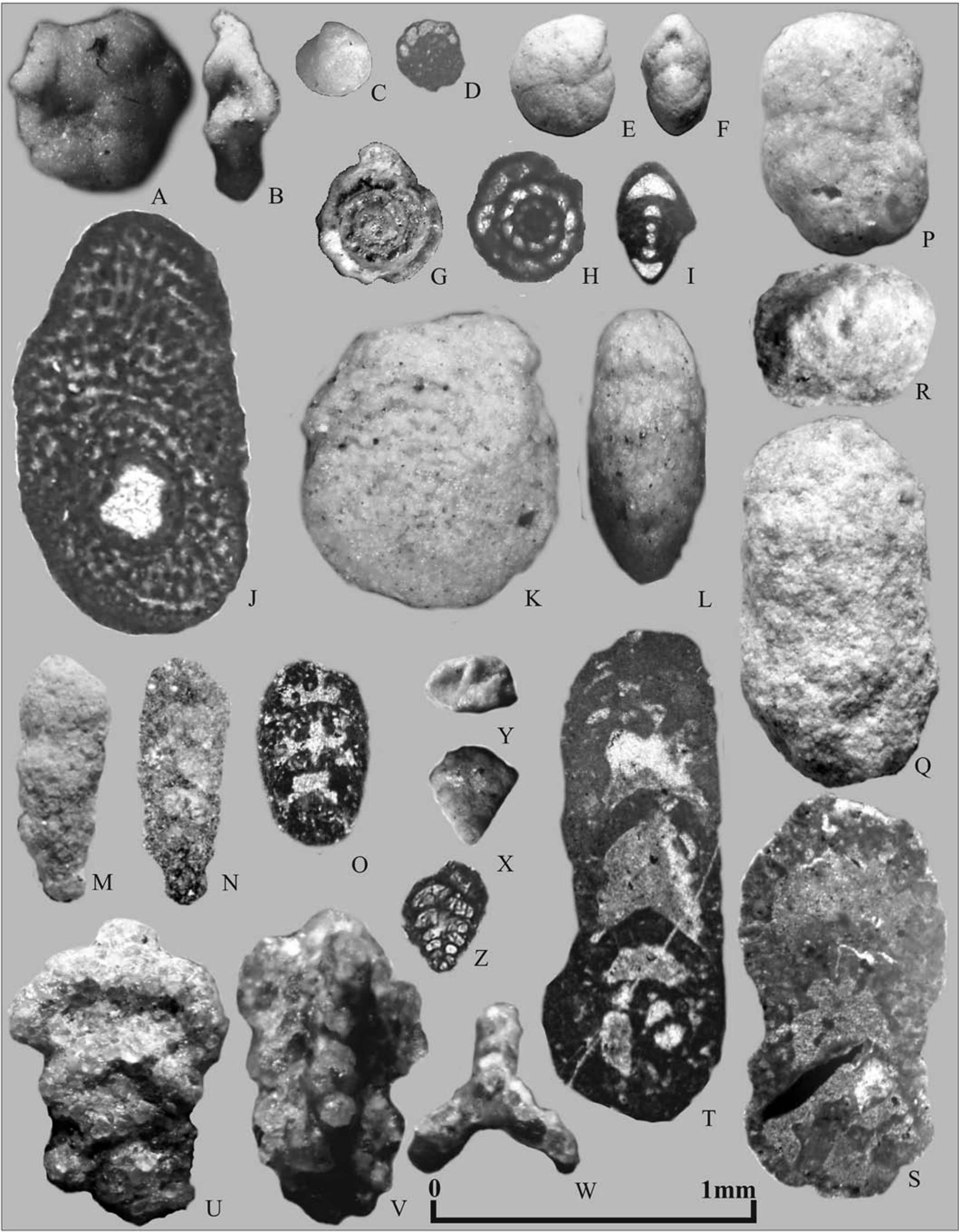
V
W
X
Y
Z
100 μm


A
B
C
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I
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N
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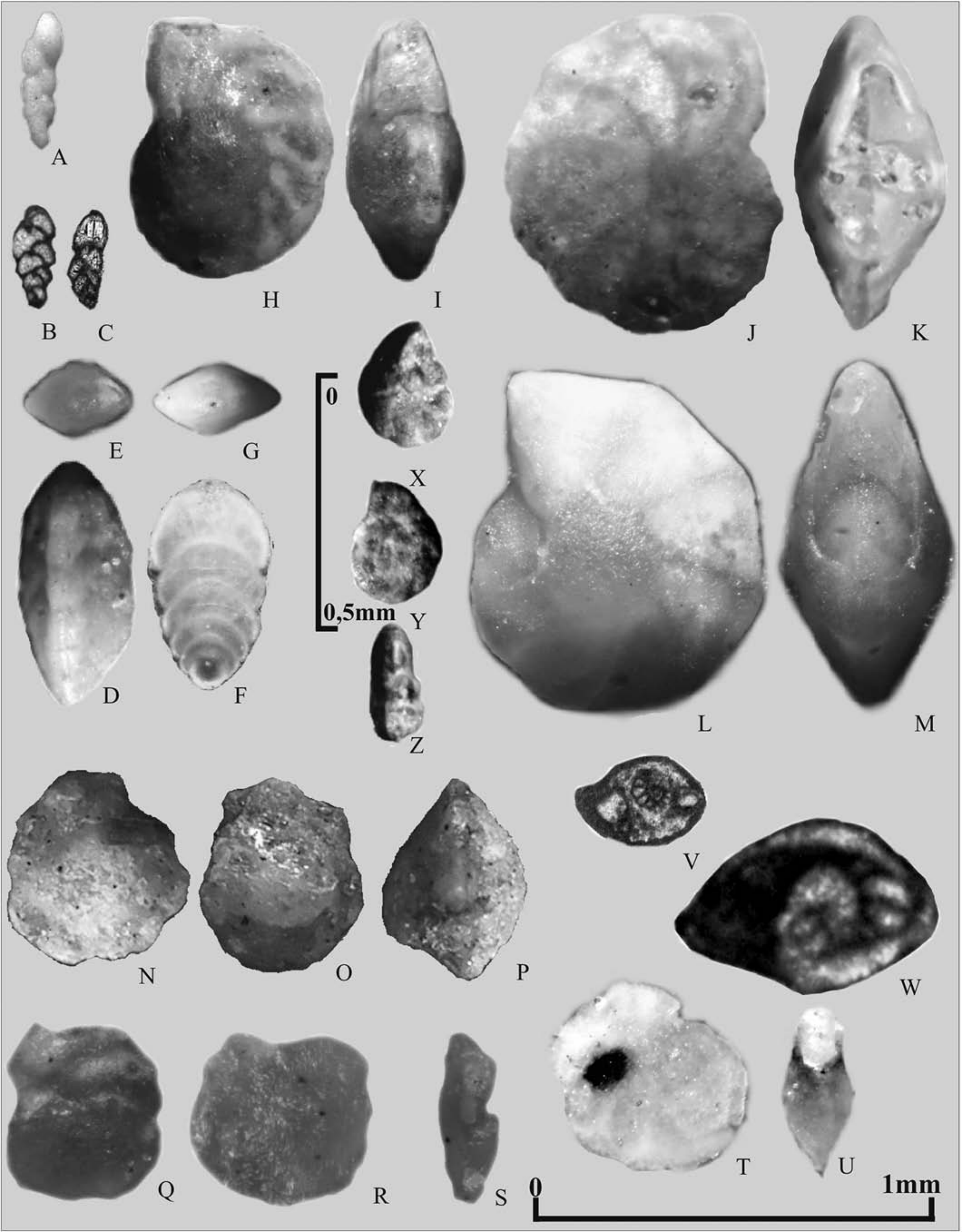
Q
R
S
T
U
V
W
X
Y
Z
0
1mm


A
B
C
H
I
J
K
E
G
0
0,5mm
X
Y
Z
D
F
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M
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O
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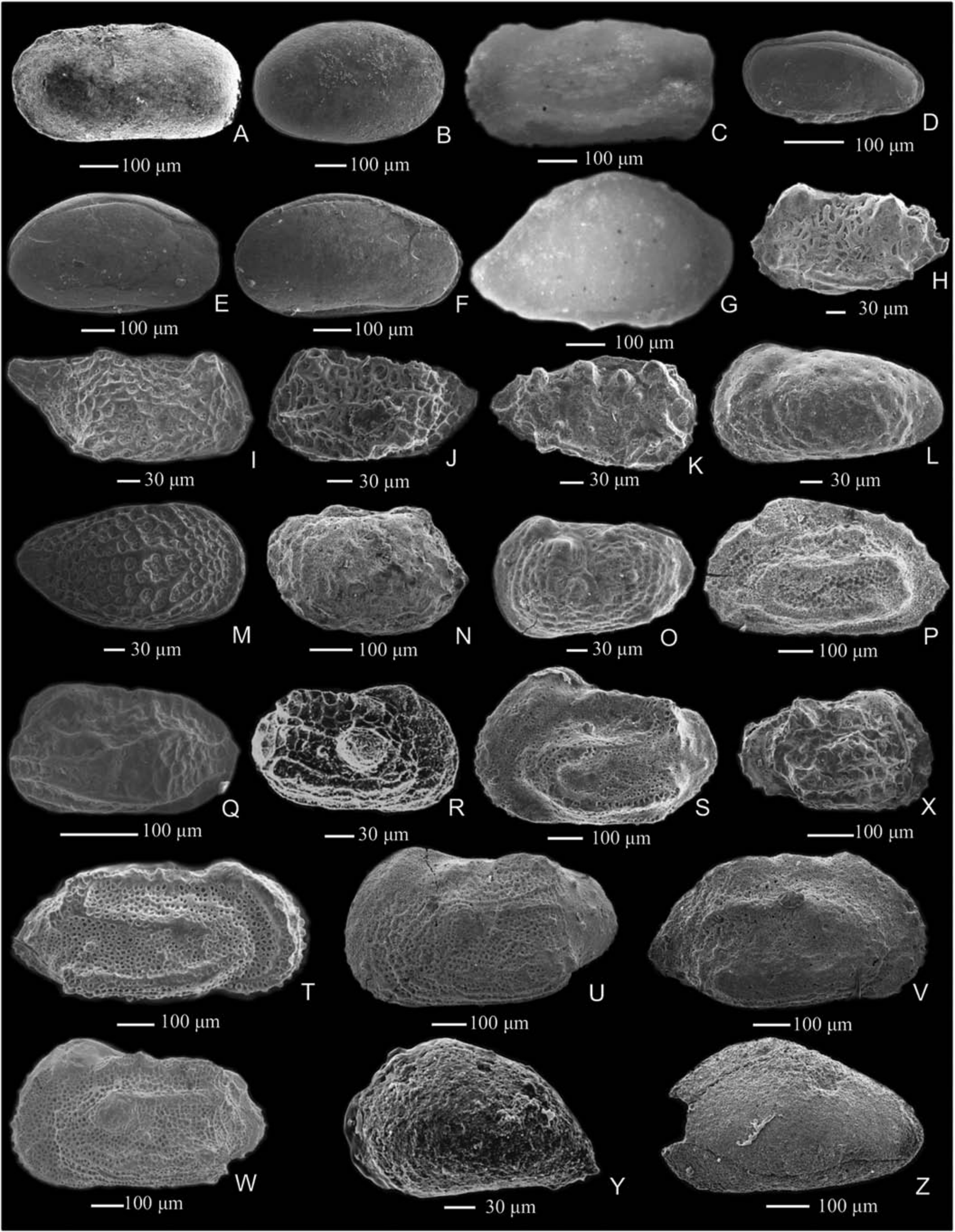
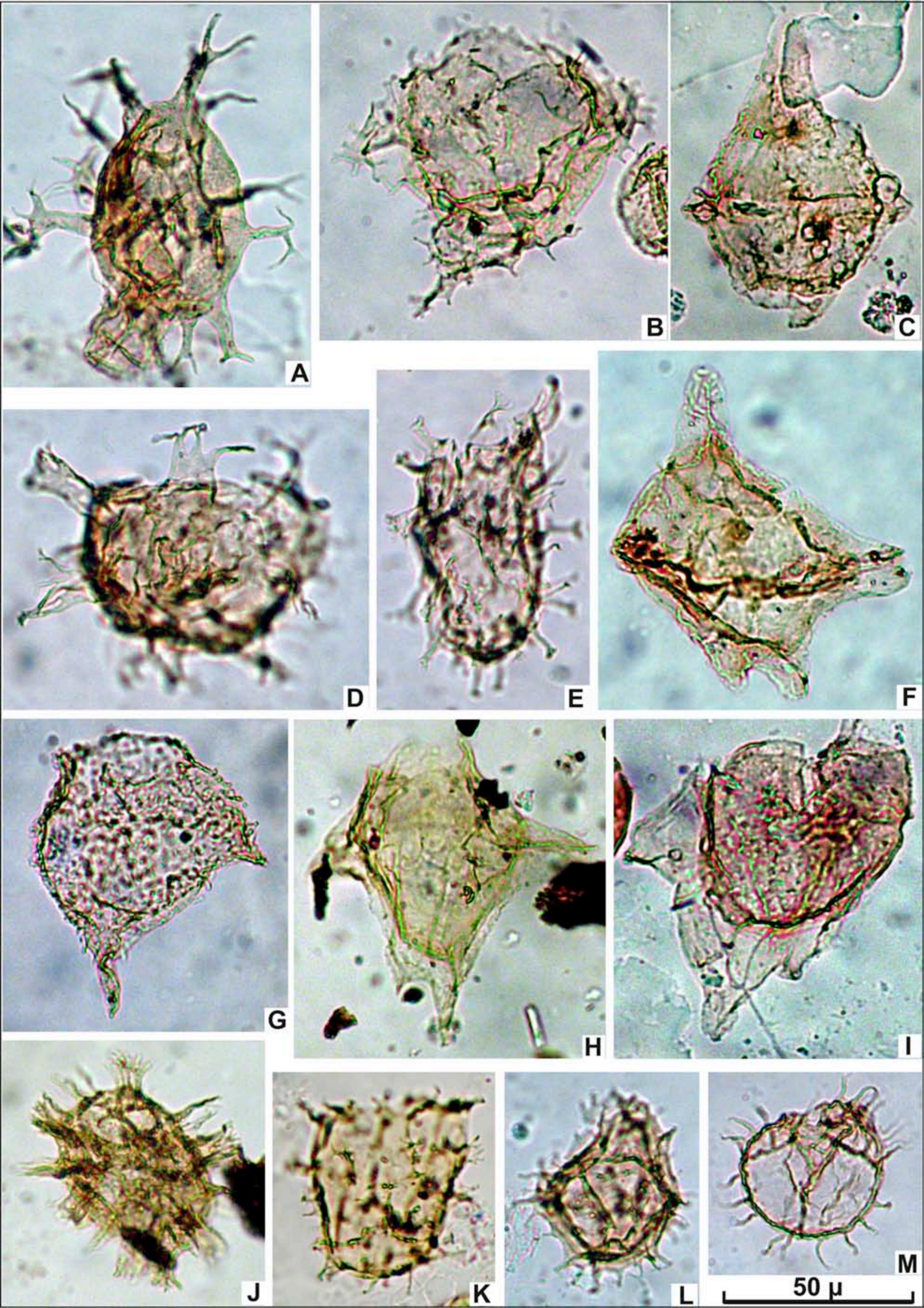
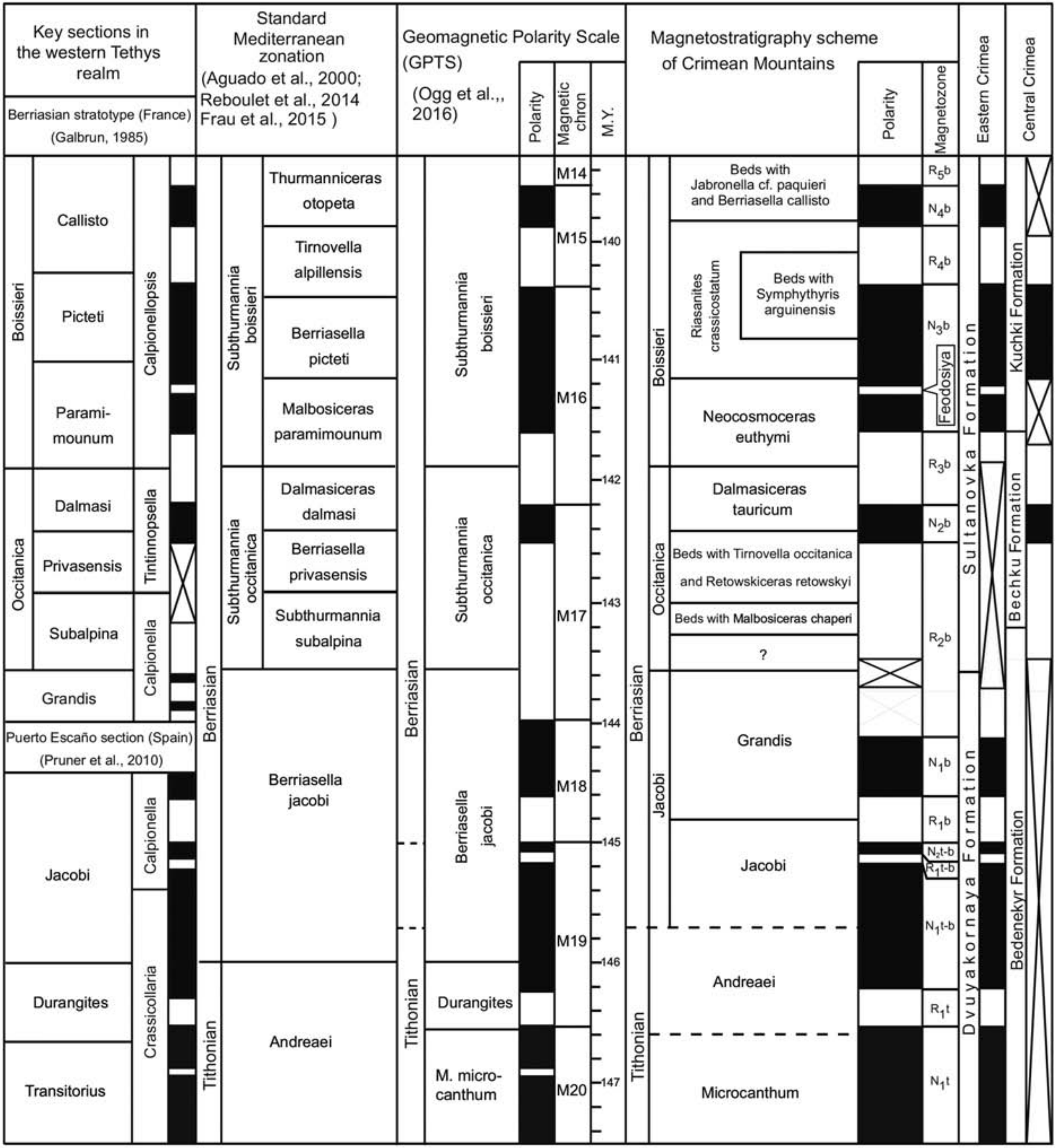
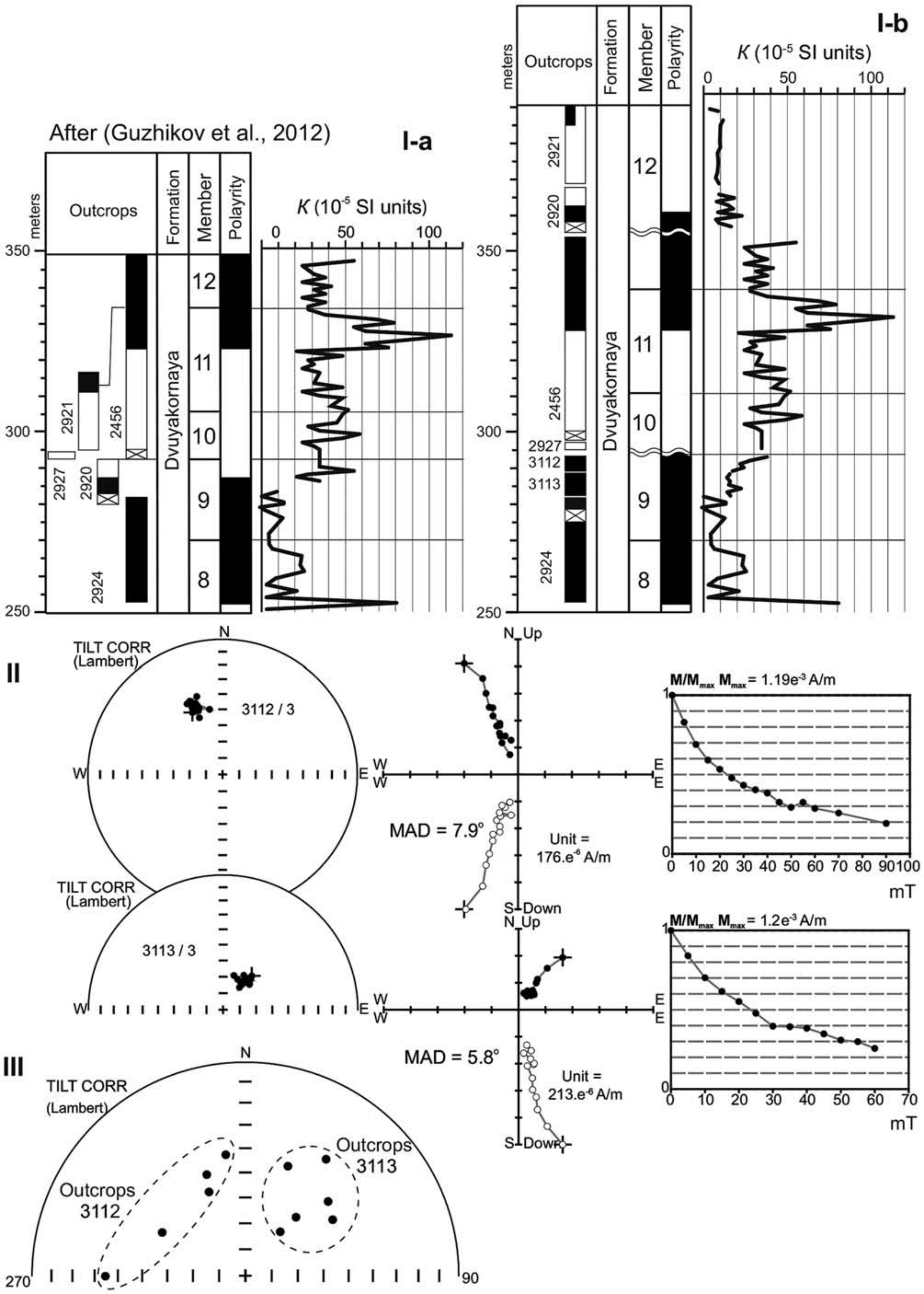
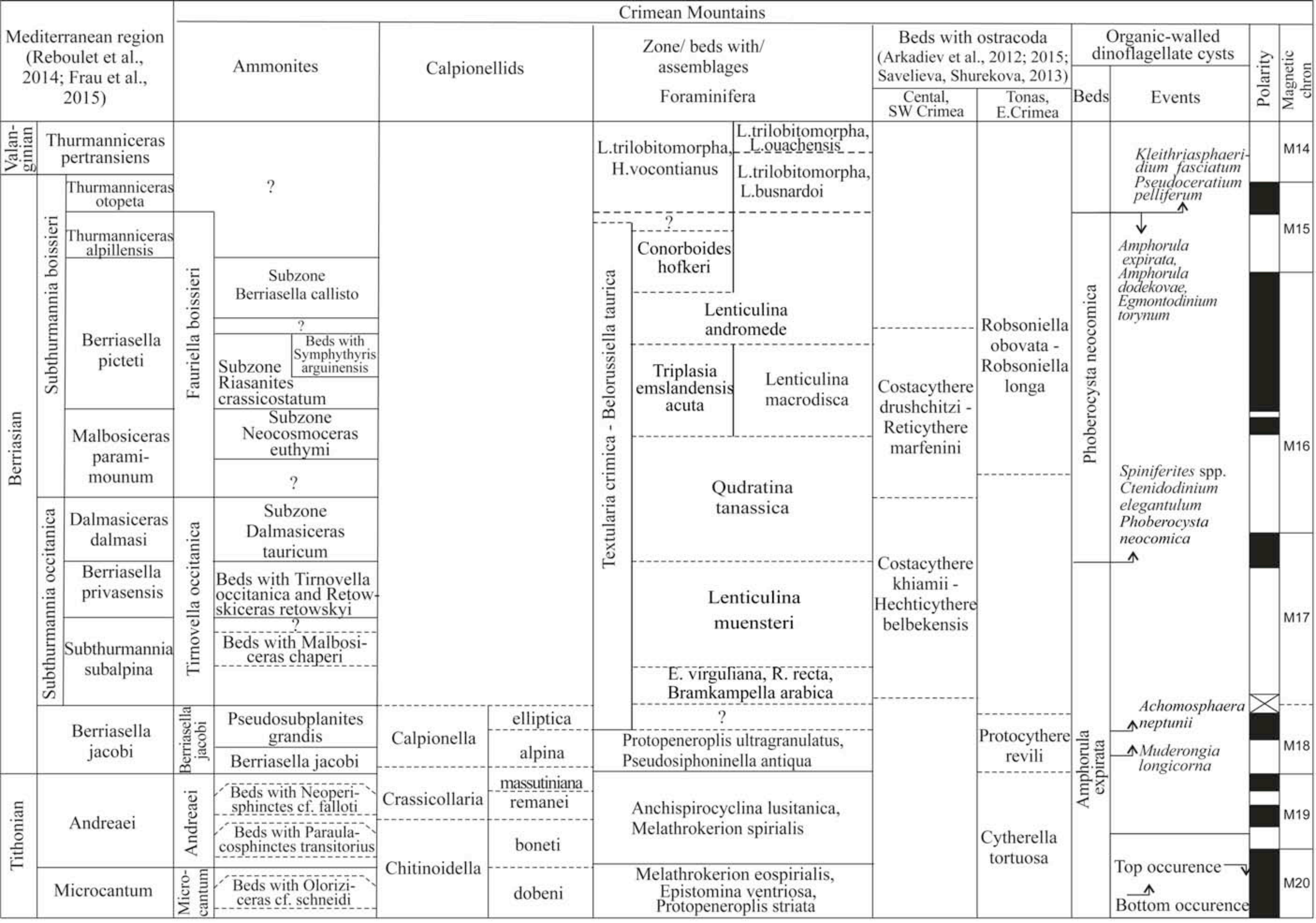
V
W
Q
R
S
T
U
0
1mm


A
100 µm
B
100 µm
C
100 µm
D
100 µm
E
100 µm
F
100 µm
G
100 µm
H
30 µm
I
30 µm
J
30 µm
K
30 µm
L
30 µm
M
30 µm
N
100 µm
O
30 µm
P
100 µm
Q
100 µm
R
30 µm
S
100 µm
X
100 µm
T
100 µm
U
100 µm
V
100 µm
W
100 µm
Y
30 µm
Z
100 µm

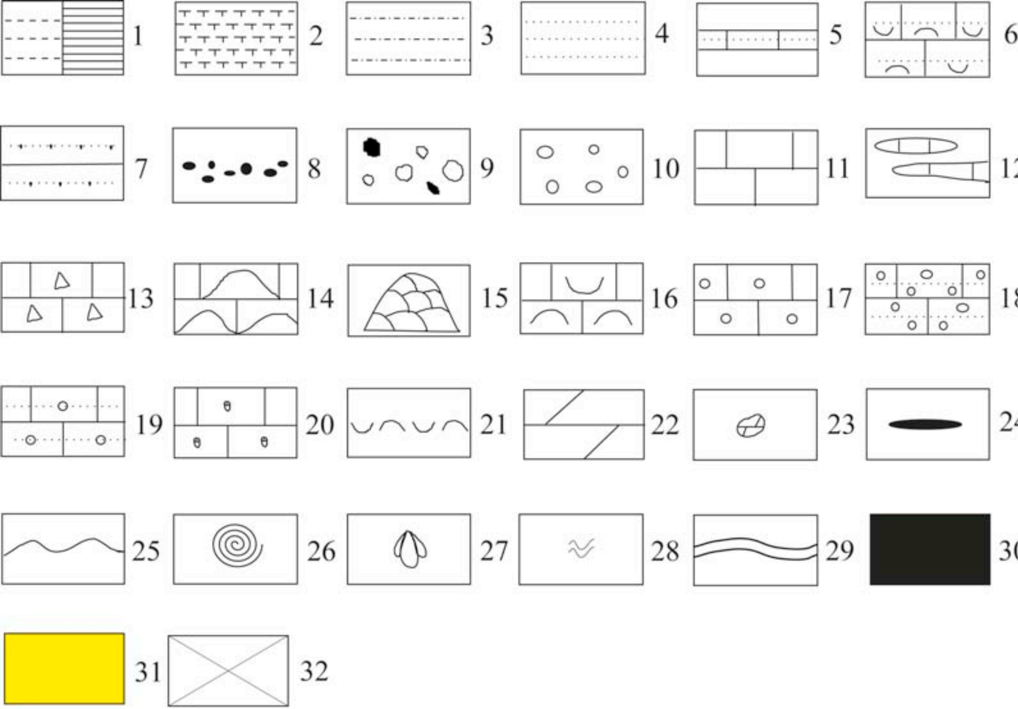

A
B
C
D
E
F
G
H
I
J
K
L
M
50 µ


Key sections in the western Tethys realm
Berriasian stratotype (France) (Galbrun, 1985)
Standard Mediterranean zonation (Aguado et al., 2000; Reboulet et al., 2014 Frau et al., 2015)
Geomagnetic Polarity Scale (GPTS) (Ogg et al.,, 2016)
Polarity
Magnetic chron
M.Y.
Magnetostratigraphy scheme of Crimean Mountains
Polarity
Magnetozone
Eastern Crimea
Central Crimea
Boissieri
Callisto
Picteti
Parami-mounum
Calpionellopsis
Occitanica
Dalmasi
Privasensis
Subalpina
Tintinnopsella
Calpionella
Grandis
Puerto Escaño section (Spain) (Pruner et al., 2010)
Jacobi
Durangites
Transitorius
Crassicollaria
Berriasian
Tithonian
Subthurmannia boissieri
Thurmanniceras otopeta
Tirnovella alpillensis
Berriasella picteti
Malbosiceras paramimounum
Subthurmannia occitanica
Dalmasiceras dalmasi
Berriasella privasensis
Subthurmannia subalpina
Berriasella jacobi
Andreaei
Durangites
M. micro-canthum
M14
M15
M16
M17
M18
M19
M20
140
141
142
143
144
145
146
147
Beds with Jabronella cf. paquieri and Berriasella callisto
Riasanites crassicostatum
Beds with Symphythyris arguinensis
Neocosmoceras euthymi
Dalmasiceras tauricum
Beds with Tirnovella occitanica and Retowskiceras retowskyi
Beds with Malbosiceras chaperi
?
Grandis
Jacobi
Andreaei
Microcanthum
R_5b
N_4b
R_4b
N_3b
Feodosiya
R_3b
N_2b
R_2b
N_1b
R_1b
N_2t-b
R_1t-b
N_1t-b
R_1t
N_1t
Sultanovka Formation
Dvuyakornaya Formation
Kuchki Formation
Bechku Formation
Bedenekyr Formation


After (Guzhikov et al., 2012)
I-a
I-b
meters
Outcrops
Formation
Member
Polayrity
K (10-5 SI units)
Dvuyakornaya
2921
2456
2927
2920
2924
3112
3113
II
TILT CORR
(Lambert)
3112 / 3
3113 / 3
N Up
S Down
MAD = 7.9°
MAD = 5.8°
Unit =
176.e-6 A/m
Unit =
213.e-6 A/m
M/Mmax Mmax = 1.19e-3 A/m
M/Mmax Mmax = 1.2e-3 A/m
mT
III
Outcrops
3112
Outcrops
3113



Crimean Mountains
Mediterranean region (Reboulet et al., 2014; Frau et al., 2015)
Ammonites
Calpionellids
Zone/ beds with/ assemblages
Foraminifera
Beds with ostracoda (Arkadiev et al., 2012; 2015; Savelieva, Shurekova, 2013)
Cental, SW Crimea
Tonas, E.Crimea
Organic-walled dinoflagellate cysts
Beds
Events
Polarity
Magnetic chron
Valan-ginian
Berriasian
Tithonian
Thurmanniceras pertransiens
Subthurmannia boissieri
Thurmanniceras otopeta
Thurmanniceras alpillensis
Berriasella picteti
Malbosiceras parami-mounum
Subthurmannia occitanica
Dalmasiceras dalmasi
Berriasella privasensis
Subthurmannia subalpina
Berriasella jacobi
Andreaei
Microcantum
?
Fauriella boissieri
Subzone Berriasella callisto
?
Beds with Symphythyris arguinensis
Subzone Riasanites crassicostatum
Subzone Neocosmoceras euthymi
?
Tirnovella occitanica
Subzone Dalmasiceras tauricum
Beds with Tirnovella occitanica and Retowskiceras retowskyi
?
Beds with Malbosiceras chaperi
Berriasella jacobi
Pseudosubplanites grandis
Berriasella jacobi
Andreaei
Beds with Neoperisphinctes cf. falloti
Beds with Paraulacosphinctes transitorius
Micro-cantum
Beds with Oloriziceras cf. schneidi
Calpionella
elliptica
alpina
Crassicollaria
massutiniana
remanei
Chitinoidella
boneti
dobeni
L.trilobitomorpha, H.vocontianus
L.trilobitomorpha, L.ouachensis
L.trilobitomorpha, L.busnardoi
?
Textularia crimica - Belorussiella taurica
Conorboides hofkeri
Lenticulina andromede
Triplasia emslandensis acuta
Lenticulina macrodisca
Qudratina tanassica
Lenticulina muensteri
E. virguliana, R. recta, Bramkampella arabica
?
Protopeneroplis ultragranulatus, Pseudosiphoninella antiqua
Anchispirocyclina lusitanica, Melathrokerion spirialis
Melathrokerion eospirialis, Epistomina ventriosa, Protopeneroplis striata
Costacythere drushchitzi - Reticythere marfenini
Costacythere khiamii - Hechticythere belbekensis
Robsoniella obovata - Robsoniella longa
Protocythere revili
Cytherella tortuosa
Phoberocysta neocomica
Amphorula expirata
Kleithriasphaeridium fasciatum
Pseudoceratium pelliferum
Amphorula expirata, Amphorula dodekovae, Egmontodinium torynum
Spiniferites spp.
Ctenidodinium elegantulum
Phoberocysta neocomica
Achomosphaera neptunii
Muderongia longicorna
Top occurence
Bottom occurence
M14
M15
M16
M17
M18
M19
M20



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.