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Integrated palaeontological characteristics (ammonites, ostracods, foraminifers, dinocysts) of the Berriasian deposits of central Crimea

Julia N. SAVELIEVA[1], Anna A. FEODOROVA[1], Olga V. SHUREKOVA[1], Vladimir V. ARKADIEV[2]

Key words: Berriasian, biostratigraphy, ostracods, foraminifers, spores, pollen, dinoflagellates, ammonites, palaeoecology, correlation, central Crimea.

Abstract. The Berriasian deposits of the central Crimea have been studied in order to compose a composite sequence of the stage with detailed palaeontological characterization. The Berriasian includes the Bedenekyrskaya Formation (packstones), Bechku Formation (siltstones, sandstones) and Kuchkinskaya Formation (sponge packstones, clays, siltstones, and coral-algal bioherm framestones). The Jacobi, Occitanica and Boissieri zones were identified based on ammonites found in the sections. A micropalaeontological analysis determined the following: 6 foraminiferal assemblages, the *Costacythere khiamii – Hechticythere belbekensis* and *Costacythere drushchitzi – Reticythere marfenini* ostracod assemblages, and a *Phoberocysta neocomica* dinocyst assemblage. Palaeoecological analysis of the ostracod and foraminiferal associations indicates a moderately warm marine basin with normal salinity and shallow depths (tens of meters). Only the sponge horizon was probably deposited in a deeper-water environment.

INTRODUCTION

The Crimea region provides unique opportunities to study Jurassic and Cretaceous boundary deposits, represented mostly by marine sediments with a diverse fossil fauna. The Berriasian deposits of central Crimea have been studied by many researchers (Druschits, Yanin, 1959; Kvantaliani, Lysenko, 1979; Bogdanova *et al*., 1981; Bogdanova, Kvantaliani, 1983; Druschits, 1975). An historical review of the different opinions concerning the subdividing of these deposits is outlined in detail in the recently published multi-author monograph (Arkadiev *et al*., 2012). The Berriasian in this part of Crimea is represented in a series of isolated outcrops, which makes comparison with the sections previously studied challenging, as some of these have been lost due to Man-made impact or natural processes (weathering, overgrowth of vegetation, destruction, construction, *etc*.). In the last decade the Tithonian-Berriasian boundary deposits of Crimea have been the target of integrated studies with the participation of various experts. Such work was carried out by the authors in 2004 and 2011, and addressed sections in the Enysarai Ravine, the River Sary-Su, the villages of Balki, Novoklenovo and Mezhgorie, and the river Burulcha. In 2012 a comprehensive study of previously known and newly-found sections in the vicinity of Balki, Novoklenovo and the Enysarai Ravine was undertaken by a group of specialists from Saint Petersburg, Saratov, and Moscow universities and FGU NPP "Geologorazvedka". During this fieldwork the outcrops were described in detail and sampled for palaeontological (ammonites, bivalves, corals), micropalaeontological (foraminifers, ostracods, palynomorphs), sedimentological and palaeomagnetic studies. A total of 18 outcrops were examined. The locations of the most important sections are shown in Figure 1. Further processing of the data allowed

[1] FGU NPP "Geologorazvedka", Saint Petersburg, Russia; e-mail: julia-savelieva7@mail.ru, annafedoroff@yandex.ru, o.antonen@gmail.com
[2] St Petersburg State University, Saint Petersburg, Russia; e-mail: arkadievvv@mail.ru

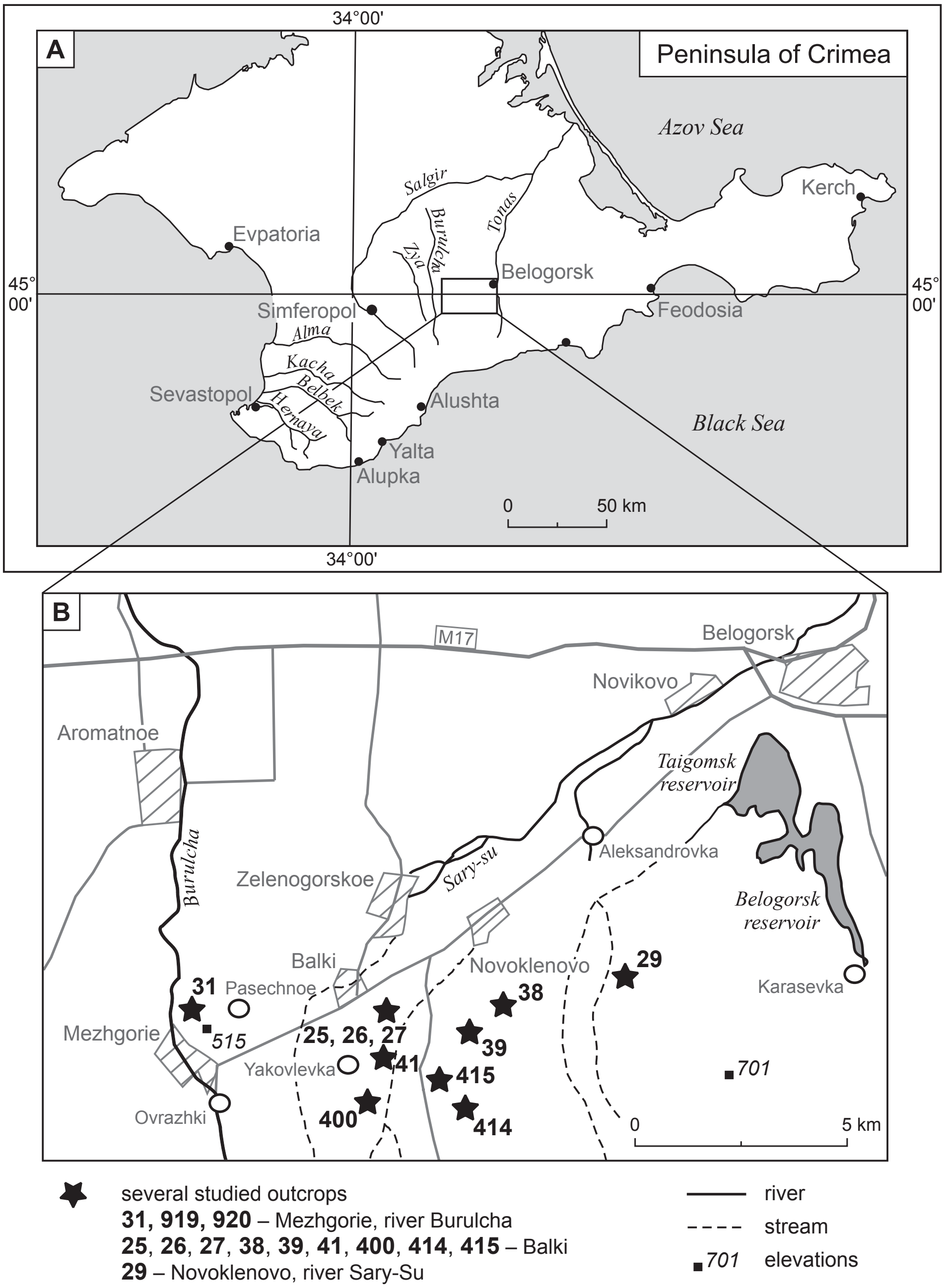

Fig. 1. A. Location of study area. B. Location of key Berriasian outcrops studied

the correlation of isolated outcrops, the estimation of thicknesses of obscured parts of sequence and the development of the most complete composite sequence of the Berriasian of central Crimea compared with that of previous researchers (Druschits, Yanin, 1959; Bogdanova *et al*., 1981).

Ammonites were identified by V.V. A., foraminifers by A.A. F., ostracods by Ju.N.S., and dinocysts, spores, and pollen by O.V.Sh. For microfossils, 44 samples were collected, mainly from argillaceous rocks (average weight 0.5–0.8 kg), and 50 samples for thin sectioning, mostly from carbonate rocks. Photographs of the ostracods were taken using a scanning electron microscope JEOL-JSM-6390 LA at the Botanical Institute of the Russian Academy of Science (BIN RAN), of the foraminifers – using a binocular microscope LOMO MCP-1, and of the dinocysts – using a light microscope LOMO Mikmed-6. The foraminifers and the ostracods are stored in the TsNIGRM Museum (Central Scientific Museum of Geological Exploration) in Saint Petersburg under no. 13220 and no. 13244, and the palynomorphs under no. 13220.

LITHOSTRATIGRAPHY

In the area of Balki, Novoklenovo and Mezhgorie, the Berriasian deposits consist of (from bottom to top): packstones and marls of the upper Bedenekyrskaya Formation (Fig. 2); siltstones and sandstones of Bechku Formation (Fig. 3); sponge packstones, clays, marls, siltstones and coral-algal biohermal framestones of the Kuchkinskaya Formation (Fig. 4). The top of the framestones is eroded, karstified, and penetrated by deep (more than 6 m deep) vertical fractures, filled with quartz sandstones (Arkadiev, 2007). The thickness of the obscured parts of succession between the isolated outcrops is up to tens of meters in the lower part (part of the Occitanica Zone) and varies from few meters to tens of meters in the middle part (part of Boissieri Zone). The total thickness of the Berriasian is approximately 600 m. The composite sequence completed by Arkadiev *et al*. (2014) is presented in Figure 5. Based on lithological analysis, the section was subdivided into 29 members. Detailed lithological description of these members is present in Arkadiev *et al*. (2014). The numbering of the members is continuous, and is based on the composite sequence, which considers all the available data (Arkadiev *et al*., 2014). The numbering of the sections and samples is that according to the field documentation of A.A. Arkadiev (observation locations no. 400, 414, 415), J.N. Savelieva (no. 25–29, 31, 38–41) and A.A. Feodorova (no. 919-920).

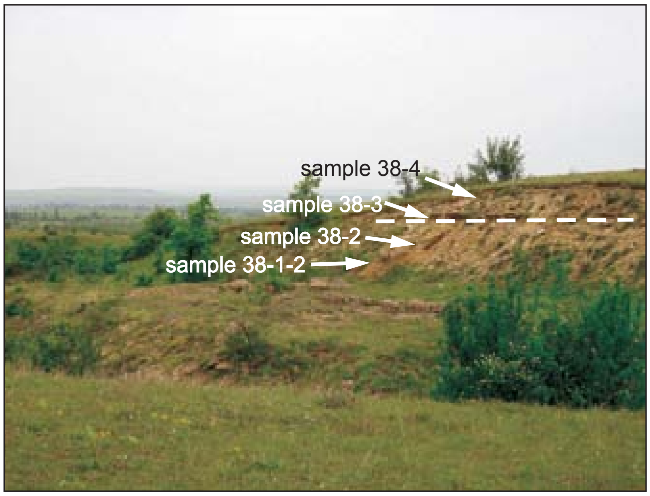

Fig. 3. Bedenekyrskaya/Bechku formations boundary

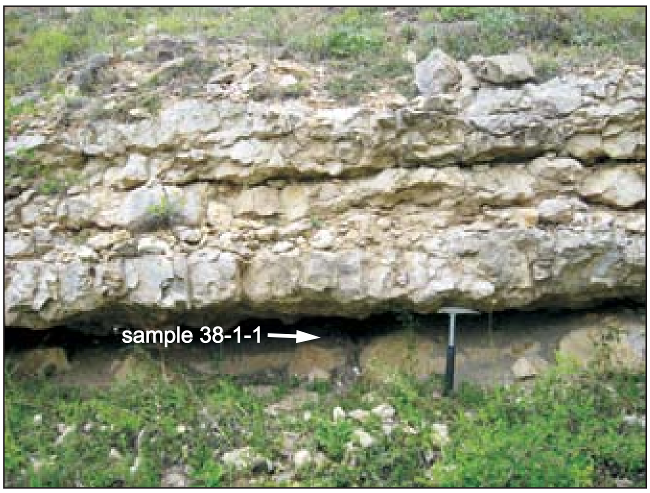

Fig. 2. Clayey bed in limestone of Bedenekyrskaya Formation

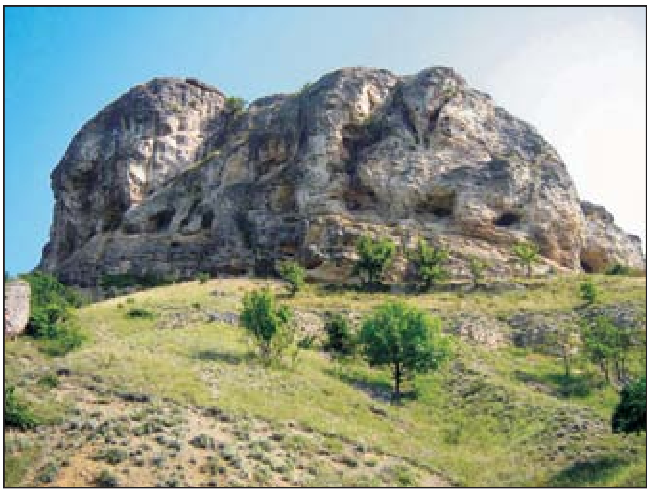

Fig. 4. Outcrop of bioherm limestone near Mezhrorie village. Upper Berriasian

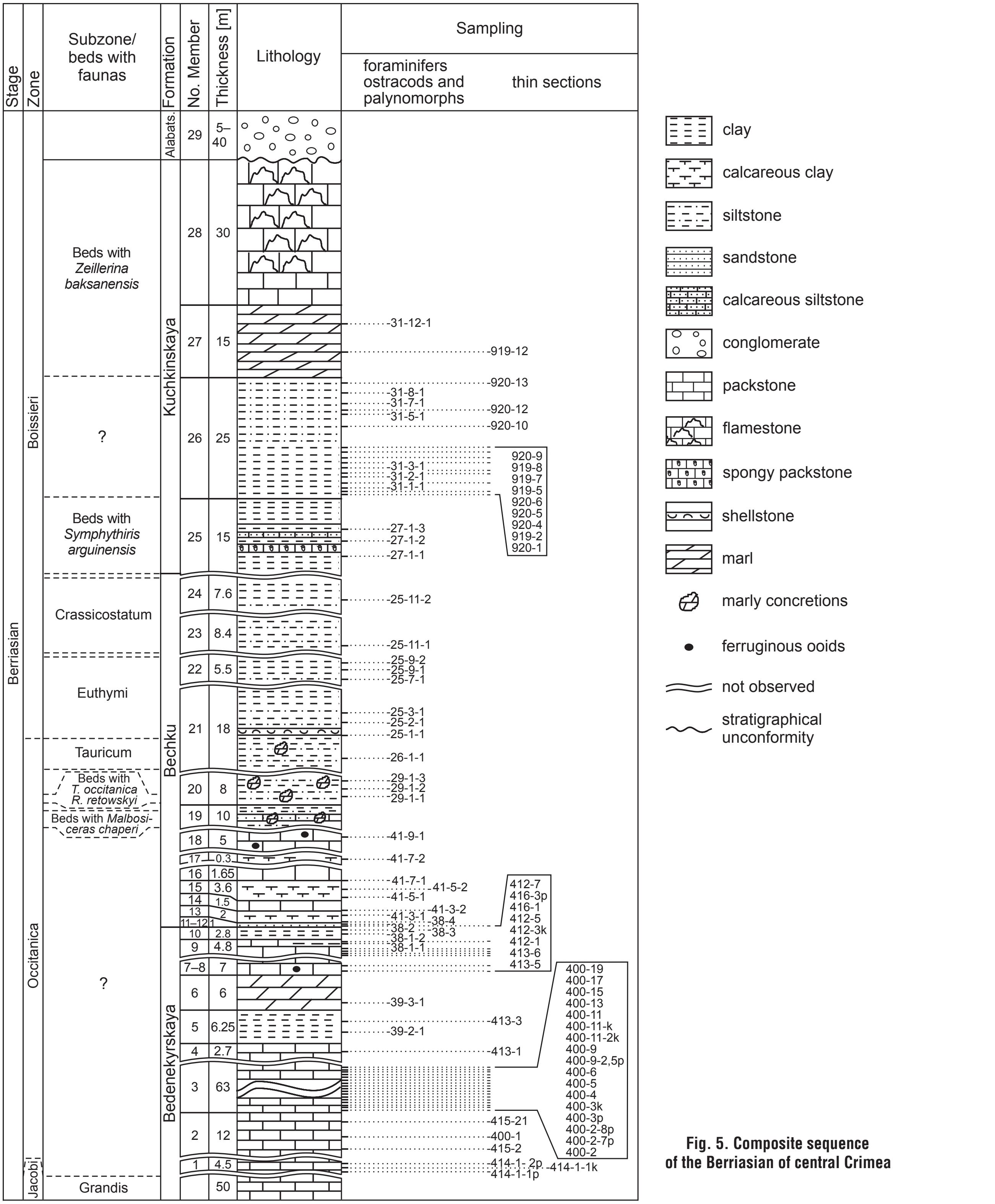

Fig. 5. Composite sequence of the Berriasian of central Crimea

BIOSTRATIGRAPHY

AMMONITES

Ammonites of the Jacobi Zone (*Pseudosubplanites ponticus* (Ret.), *Berriasella jacobi* Maz.) (Bogdanova *et al*., 1981) have been found in packstones of the Bedenekyrskaya Formation at Karabi-Yayla, south of the village of Balki. The following ammonites are characteristic of the Bechku Formation in the central Crimea: *Dalmasiceras tauricum* Bogd. et Ark., *Malbosiceras chaperi* (Pict.), *M. malbosi* (Pict.), *M. pictetiforme* Tav., *Pomeliceras breveti* (Pom.), *Neocosmoceras euthymi* (Pict.), *N. minutus* Ark. et Bogd., *Hegaratia bidichotoma* (Bogd. et Kvant.), *H. nerodenkoi* (Bogd. et Kvant.), *Fauriella simplicicostata* (Maz.), *F. boissieri* (Pict.), *etc*., which places it in the Occitanica and Boissieri zones. In the Kuchkinskaya Formation in the river Sary-Su basin, ammonites are rare. The Sponge packstone contains numerous examples of the brachiopod *Symphythiris arguinensis* (Moiss.), which mark the beds of the same name. The ammonite *Riasanites crassicostatum* (Kvant. et Lys.) was found in the Sponge packstone, and so at least the bottom of the Sponge packstone may be placed in the Crassicostatum Subzone. Near Mezhgorie, the siltstone beds, which lie above the Sponge packstone, contain poorly preserved ammonites: *Haploceras* ex gr. *cristifer* (Opp.), *Protetragonites tauricus* (Kulj.-Vor.) and *Subalpinites* sp. Species of the genera *Haploceras*, *Protetragonites* and *Spiticeras* occur throughout the Berriasian sequence in the Crimea. Species of the genus *Subalpinites* have been found in all zones of the Berriasian Stage in France (Le Hegarat, 1973). The stratigraphic position of the beds and the ammonites found within are consistent with their position in the Boissieri Zone. No ammonite was found in the biohermal framestones that form the upper portion of the section: consequently, according to the previously proposed stratigraphic scheme (Arkadiev *et al*., 2012) they have been tentatively placed in the Berriasian. The comparison of these framestones with those in the section in the River Belbek (beds with *Megadiceras koinautense*), where similar facies and faunal assemblages are found certainly below the Lower Valanginian, allows us to date these rocks as Upper Berriasian (Yanin, Baraboshkin, 2000).

FORAMINIFERS

The foraminifers of the Crimea have been studied from the 1950’s (Gofman, 1956, 1961; Mamontova, 1963, 1972; Voloshina, 1974, 1976,1977; Plotnikova *et al*., 1976; Plotnikova, 1978, 1979). One of the most concise publications is the monograph by T.N. Gorbachik and K.I. Kuznetsova, which summarizes the results of their work in the Crimea from the 1960’s through the 1980’s (Kuznetsova, Gorbachik, 1985). Data on the Berriasian foraminifers of the central Crimea are available only for three stratigraphic sections in the basins of the rivers Sary-Su, Burulcha and Beshterek.

During this study, foraminifers were studied in specimens and thin sections cut in various directions. Orientated thin sections were prepared from fossils extracted from some units. Over 200 species of foraminifers, in 63 genera, were encountered; the distribution of key species is shown in Figure 6. The lower part of the section studied has a predominant agglutinated benthos, and the middle and the top a calcareous benthos, whereas planktonic forms are only occasionally found. The foraminifers present are generally typical of the beds with *Textularia crimica – Belorussiella taurica*, beds with present throughout Crimea (Feodorova, 2004). However, in the deposits sampled, the taxonomic composition and quantitative parameters of the foraminifers change significantly, allowing us to distinguish 6 distinct successive foraminiferal assemblages.

Assemblage with *Everticyclammina virguliana*, *Rectocyclammina recta*, *Bramkampella arabica* (members 1–12 and 18)

This assemblage is characterized by the predominance of Lituolidae (including those with a complex structure), with subordinate Nodosariidae. A total of about 70 species belonging to 45 genera was encountered. The most typical are abundant and diverse *Everticyclammina* and *Rectocyclammina*, including *Rectocyclammina* ex gr. *chouberti* Hottinger, *R. recta* Gorb., *Everticyclammina virguliana* (Koechl.), *E. elongata* Gorb., as well as *Haplophragmium subaequale* (Mjatl.), *Melathrokerion spirialis* Gorb., *Charentia evoluta* (Gorb.), *Pseudocyclammina lituus* (Yok.), *P. spharoidalis* Hott., *Stomatostoecha rotunda* Gorb., *S. compressa* Gorb., *S. enisalensis* Gorb., *Bramkampella arabica* Radmond, *Amijiella amiji* (Henson), *Belorussiella taurica* Gorb., *Alveosepta jaccardi* (Schrodt), *Lenticulina* ex gr. *subalata* Reuss, *L.* aff. *akmetchetica* Mjatl., L. sp. 2 (Gorb., 1978), *Astacolus* ex gr. *proprius* K. Kuzn., *A. mutilatus* Esp. et Sigal, *A. inspissatus* (Loeblich et Tappan), *A. favoritus* Gorb., *A. hamililis* (Reuss), *Discorbis miser* Gorb., *Trocholina alpina* (Leupold), *T. elongata* (Leup.), *T. molesta* Gorb., *T. burlini* Gorb., *T. infragranulata* Noth. Individual specimens of *Protopeneroplis ultragranulatus* (Gorb.) and *Pseudosiphoninella antiqua* (Gorb.) were found in thin sections made from samples from Member 2. The assemblage is named after the predominant species *E. virguliana* (Koechl.), *R. recta* Gorb. and after the species *B. arabica* Radmond, which has a limited stratigraphic distribution.

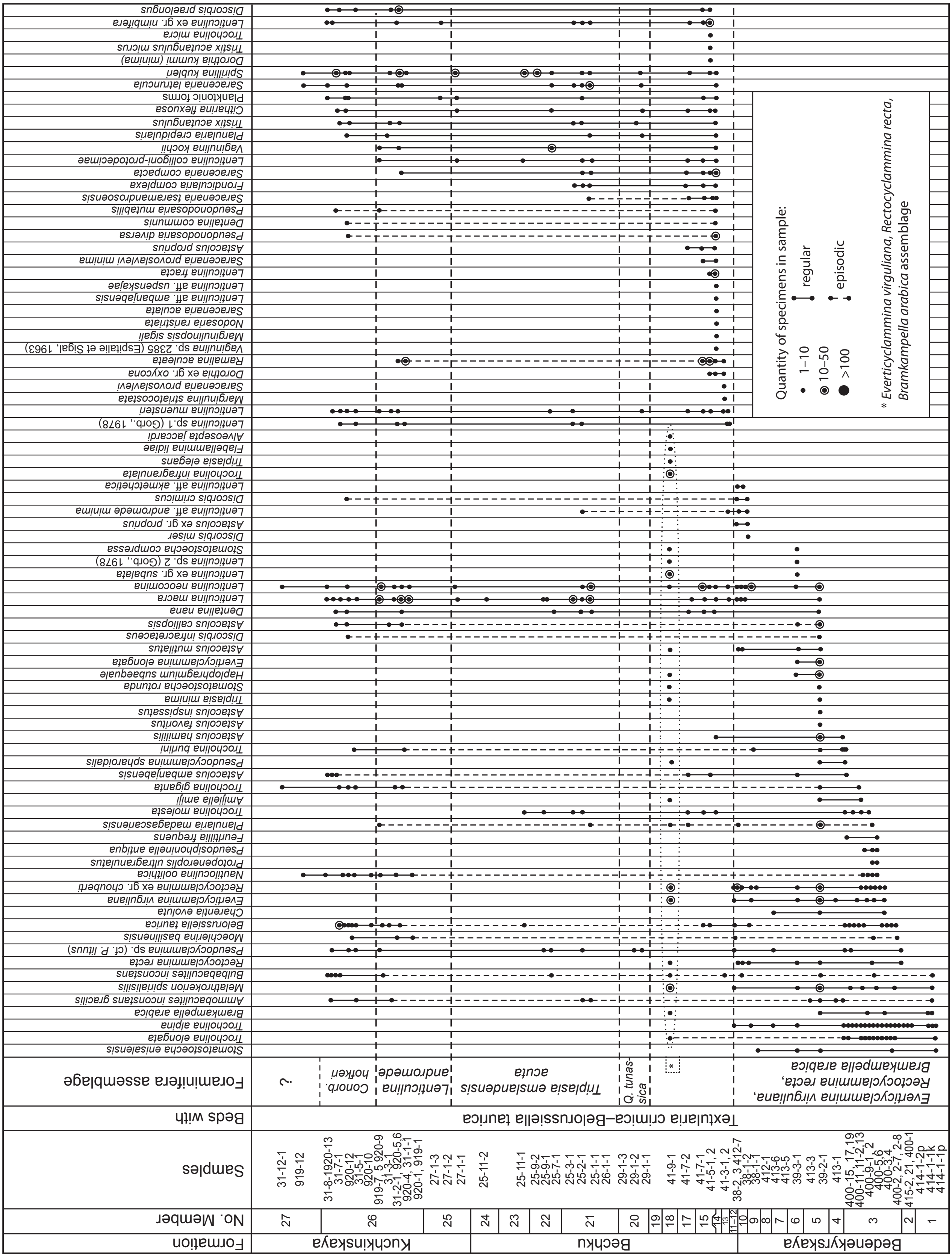

Fig. 6. Distribution of foraminifers in the Berriasian composite section of central Crimea

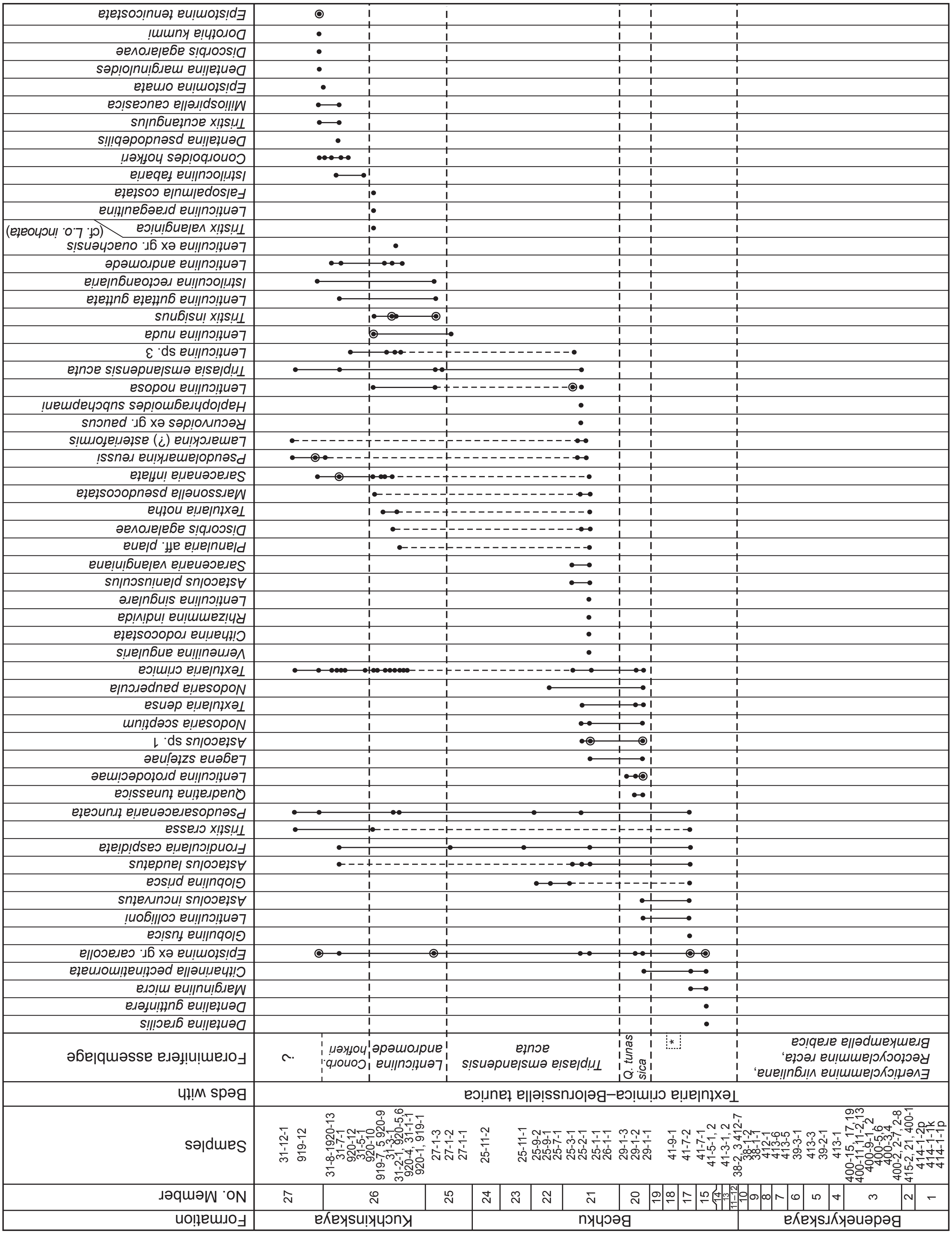
Epistomina tenuicostata
Dorothia kummi
Discorbis agalarovae
Dentalina marginuloides
Epistomina ornata
Miliospirella caucasica
Tristix acutangulus
Dentalina pseudodebilis
Conorboides hofkeri
Istriculina fabaria
Falsopalmula costata
Lenticulina praegaultina
Tristix valanginica
(cf. L.o. inchoata)
Lenticulina ex gr. ouachensis
Lenticulina andromede
Istriculina rectoangularia
Lenticulina guttata guttata
Tristix insignus
Lenticulina nuda
Lenticulina sp. 3
Triplasia emslandensis acuta
Lenticulina nodosa
Haplophragmoides subchapmani
Recurvoides ex gr. paucus
Lamarckina (?) asteriformis
Pseudolamarkina reussi
Saracenaria inflata
Marssonella pseudocostata
Textularia notha
Discorbis agalarovae
Planularia aff. plana
Saracenaria valanginiana
Astacolus planiusculus
Lenticulina singulare
Rhizammina individa
Citharina rodocostata
Verneuilina angularis
Textularia crimica
Nodosaria paupercula
Textularia densa
Nodosaria sceptrum
Astacolus sp. 1
Lagena sztejnae
Lenticulina protodecimae
Quadratina tunassica
Pseudosaracenaria truncata
Tristix crassa
Frondicularia caspidiata
Astacolus laudatus
Globulina prisca
Astacolus incurvatus
Lenticulina colligoni
Globulina fusica
Epistomina ex gr. caracolla
Citharinella pectinatimomata
Marginulina micra
Dentalina guttinfera
Dentalina gracilis
Foraminifera assemblage
?
Conorb. hofkeri
Lenticulina andromede
Triplasia emslandensis acuta
Q. tunassica
*
Everticyclammina virguliana, Rectocyclammina recta, Bramkampella arabica
Beds with
Textularia crimica–Belorussiella taurica
Samples
No. Member
27
26
25
24
23
22
21
20
19
18
17
15
14
13
11–12
10
9
8
7
6
5
4
3
2
1
Formation
Kuchkinskaya
Bechku
Bedenekyrskaya

Fig. 6 cont.

It should be noted that the assemblage with *E. virguliana*, *R. recta* and *B. arabica*, encountered in members 1–12, was also found in Member 18 (Section 41, sample 41-9-1), which is placed much higher in the composite succession. The foraminiferal associations in these members, though dominated by multilayer Lituolidae, also include a large number (a few hundred) of specimens of *Melathrokerion spirialis* Gorb., as well as the species *Flabellammina lidiae* Gerke et Polenova and *Triplasia elegans* (Mjatl.), which are known from terminal Jurassic deposits of Boreal and Arctic provinces (Azbel *et al*., 1991; Basov *et al*., 1991).

Assemblage with *Lenticulina muensteri*

This assemblage is distinguished by the visible predominance of Nodosariidae, *Lenticulina* species are particularly numerous and diverse. *Saracenaria* and *Pseudonodosaria* are subdominant. The assemblage is named after the typical species, which is present in all samples. A total of 65 species, belonging to 22 genera were encountered, including high numbers of *Ramalina aculeata* Wright, *Lenticulina nimbifera* Esp. et Sigal, *L. fracta* Esp. et Sigal, *Pseudonodosaria diversa* (Hoffman), *Saracenaria compacta* Esp. et Sigal, *Epistomina* ex gr. *caracolla* (Roemer). The following species are also typical: *Dorothia* ex gr. *oxycona* (Reuss), *D. kummi* Zedler, *Nodosaria raristriata* Chapman, *Tristix acutangulus* (Reuss), *Lenticulina muensteri* (Roemer), *L.colligoni* Esp. et Sigal, *L.* aff. *ambanjabensis* (Esp. et Sigal), L. aff. *uspenskajae* K.Kuzn., *Astacolus proprius* K. Kuzn., *A. incurvatus* (Reuss), *Marginulina striatocostata* Reuss, *M. micra* Tairov, *Marginulinopsis sigali* Bart., Bett. et Bolli, *Saracenaria provoslavlevi* Furs. et Polenova, *S. aculata* Esp. et Sigal, *Dentalina gracilis* d'Orbigny, *D. guttinfera* d'Orbigny, *Vaginulina* sp. 2385 (Espitalie, Sigal, 1963), *Citharinella pectinatimornata* Esp. et Sigal, *Globulina fusica* Mjatl., *Trocholina micra* Dulub. This assemblage was identified in members 13–17 and 19, and is characterized by changing of size from normal to dwarfish or gigantic in some beds.

Assemblage with *Quadratina tunassica*

This is the least diverse assemblage, it contains 30 species belonging to 23 genera. The peculiarity of this assemblage is the presence of gigantic forms of primitive Lituolidae. It is named after the index species of the Quadratina tunassica–Siphoninella antiqua Zone (Druschits, Gorbachik, 1979), which corresponds approximately to the upper part of the Grandis Subzone and the lower part of the Occitanica Zone. The assemblage was identified only in Member 20, based on the appearance of *Quadratina tunassica* Schokhina and *Lenticulina protodecimae* Dieni et Massari. The long-ranging species are predominate: *Textularia crimica* (Gorb.), *Textularia densa* Hoffman, *Citharinella pectinatimornata* Esp. et Sigal, *Citharina flexuosa* (Bruckmann), *Tristix acutangulus* (Reuss), *Lenticulina colligoni* Esp. et Sigal, *Lenticulina muensteri* (Roemer), *Astacolus incurvatus* (Reuss), *Nodosaria paupercula* Reuss, *N. sceptium* Reuss, *Saracenaria latruncula* (Chalilov), *Planularia crepidularis* Roemer, *Lagena sztejnae* Dieni et Massari, *Epistomina* ex gr. *caracolla* (Roemer) and *Spirillina kubleri* Mjatl.

Assemblage with *Triplasia emslandensis acuta*

This assemblage contains over 100 species of 47 genera, dominated, in numbers and in species diversity, by *Lenticulina*, with subdominant *Saracenaria* and *Verneuilina* (members 21–24 and 25 (lower part)). It is named after the index subspecies of the Triplasia emslandensis acuta Subzone (Kuznetsova, Gorbachik, 1985) which approximately corresponds to the upper part of the Occitanica Zone and the lower part of the Boissieri Zone. The assemblage is defined by the occurrence of *Recurvoides* ex gr. *paucus* Dubrovskaja, *Haplophragmoides subchapmani* Kuznetsova, *Triplasia emslandensis acuta* Brat. et Brand, *Pseudolamarkina reussi* (Antonova), *Lenticulina nuda* (Reuss), *L. nodosa* (Reuss), ?*Lamarckina asteriaformis* Kuznezova et Antonova and *Saracenaria inflata* Pathy. It also contains long-ranging species: *Lenticulina macra* Gorb., *L. neocomina* Romanova, *Vaginulina kochii* Roemer, *Saracenaria latruncula* (Chalilov) and *Spirillina kubleri* Mjatl.

Assemblage with *Lenticulina andromede*

This assemblage is represented by over 70 species of 40 genera, with the clearly predominant genus *Lenticulina* (members 25 (upper) and 26 (lower)), and the occurrence of numerous: *Lenticulina andromede* Esp. et Sigal, as well as *Tristix valanginica* Schokhina, *Lenticulina guttata guttata* (Dam), *L.* ex gr. *ouachensis* Sigal, *L. praegaultina* Bart., *Falsopalmula costata* Gorb. and *Istriloculina rectoangularia* Mats. et Temirb. The assemblage also contains numerous species derived from lower deposits: *Rumulina aculeata* Wright, *Ammobaculites inconstans gracilis* Brat. et Brand, *Nautiloculina oolithica* Mochler, *Textularia crimica* (Gorb.), *Belorussiella taurica* Gorb., *Lenticulina nuda* (Reuss), *L. macra* Gorb., *L. neocomina* Romanova, *Epistomina* ex gr. *caracolla* (Roemer), *Discorbis praelongus* Gorb. and *Spirillina kubleri* Mjatl.

Assemblage with *Conorboides hofkeri*

This assemblage is identified in the upper part of Member 26 and is named after the index species of Conorbina heteromorpha–Conorboides hofkeri Zone (Druschits, Gorbachik, 1979), which approximately corresponds to the upper part of the Occitanica and Boissieri zones. The assemblage contains over 50 species from 30 genera, with no clearly dominant taxa. The following species occur at this level: *Dorothia kummi* Zedler, *Dentalina marginuloides* Reuss, *D. pseudodebilis* (Dieni et Massari), *Miliospirella caucasica* Ant., *Discorbis agalarovae* Ant., *Epistomina tenuicostata* Bart. et Brand, *E. ornata* (Roemer), *Conorboides hofkeri* (Bart. et Brand); with massive presence of *Belorussiella taurica* Gorb., *Pseudolamarkina reussi* (Ant.), *Saracenaria inflata* Pathy, *Epistomina* ex gr. *caracolla* (Roemer), *Spirillina kubleri* Mjatl.; and often *Bulbabaculites inconstans* (Brat. et Brand), *Nautiloculina oolithica* Mochler, *Textularia crimica* (Gorb.), *Lenticulina macra* Gorb., *L. muensteri* (Roemer), *L. ambanjabensis* (Esp. et Sigal), *Discorbis praelongus* Gorb. and *Trocholina giganta* Gorb. et Manz.

The foraminiferal species encountered in the sequence described here are known in Tithonian-Valanginian deposits of Crimea, the Caucasus and Caspian regions, Syria, Germany, France, Italy and Madagascar (Septfontaine, 1974; Azema *et al*., 1977; Gorbachik, 1978; Myatluk, 1980; Pelissie *et al.*, 1983; Kuznetsova, Gorbachik, 1985; Gorbachik, Kuznetsova, 1994; Bassoullet, 1997; Feodorova, 2004; Todriya, 2005). Within Tethys the assemblage with *Everticyclammina virguliana*, *Rectocyclammina recta* and *Bramkampella arabica* is closest to the Berriasian foraminiferal assemblages of Syria, N Caspian, Caucasus, SE France, and Italy. The Middle and Upper Berriasian assemblages of central Crimea are closest to those of Cenozone D (Upper Portland–Lower Valanginian) in Madagascar (Espitalie, Sigal, 1963).

The comparison of the Berriasian foraminiferal assemblages described here with contemporaneous ones in the Berriasian type section in France (Busnardo *et al*., 1965; Gorbachik, 1978) is challenging, due to low species diversity, poor preservation and lack of data from that section.

OSTRACODS

Studies of Lower Cretaceous ostracods of the Crimea began only in the later 1960's. The first monographic description of new species with an evaluation of their stratigraphic significance was completed by John W. Neale (Neale, 1966). Later the ostracods were studied by: L.P. Rachenskaya, E.M. Tesakova, A.V. Manushkina, J.N. Savelieva (Rachenskaya, 1970; Tesakova, Rachenskaya, 1996 a, 1996b; Manushkina, Tesakova, 2009; Tesakova *et al*., 2010; Feodorova *et al*., 2011). Further studies of central Crimean ostracods allowed the determination of several stratigraphic levels, with changes in taxonomic composition (Savelieva *in* Arkadiev *et al*., 2012).

Studies of previously geologically unknown parts of central Crimea in 2012 allowed us to expand the scope and description of the previously identified beds with *Costacythere khiamii – Hechticythere belbekensis* (Arkadiev *et al*., 2012).

The ostracods studied belong to 16 families: Cytherellidae, Bairdidae, Macrocyprididae, Pontocyprididae, Paracyprididae, Cyprideidae, Bythocytheridae, Cytheruridae, Progonocytheridae, Neurocytheridae, Pleurocytheridae, Protocytheridae, Trachyleberididae, Brachycytheridae, Cytherideidae, Schulerideidae. A total of 85 species in 33 genera was identified; the distribution of characteristic species is presented in Figure 7. The bulk of the assemblages is comprised of smooth-walled forms: *Cytherella*, *Paracypris* and *Pontocyprella*. There are numerous specimens of genus *Cytherelloidea*. Sculptured forms are represented by numerous genera of the familes Protocytheridae (*Protocythere*. *Reticythere*, *Hechticythere*, *Costacythere*) and Cytheruridae (*Eucytherura*).

The analyses of the systematic and quantitative composition of ostracods in the sequence allows us to distinguish two beds with ostracods.

Beds with *Costacythere khiamii–Hechticythere belbekensis*

These are distinguished in the lower part of the section (members 5–21 (lower part)), and are approximately correlated to part of the Occitanica ammonite Zone. 45 species belonging to 24 genera were found here. The most typical and abundant are: *Cytherella lubimovae* Neale, *C. krimensis* Neale, *Costacythere khiamii* Tes. et Rach., *C. foveata* Tes. et Rach, *Hechticythere belbekensis* Tes. et Rach., as well as species: *Paracypris* aff. *parallela* Neale, *Eucytherura* sp. 1, *E.* sp. 2, *Metacytheropteron* sp. A Pokorny, ?*Fuhrbergiella* sp., *Acrocythere* aff. *hauteriviana* (Bart.), *Costacythere andreevi* Tes., *Cythereis* sp. B, *Quasigermanites bicarinatus moravicus* Pok., *Schuleridea juddi* Neale and *Schuleridea* ex gr. *juddi* Neale. Individual beds are named after the combined occurring indexes species, and also after the abundant species *Costacythere khiamii*.

It should be noted that the ostracods encountered in the upper part of Section 41 (Member 18, sample 41-9-1), on its taxonomic composition and by the abundance of *Cytherella lubimovae* Neale, *Costacythere khiamii* Tes. et Rach. and *C. foveata* Tes. et Rach., is similar to the assemblage from section 39 (Member 5, sample 39-2-1).

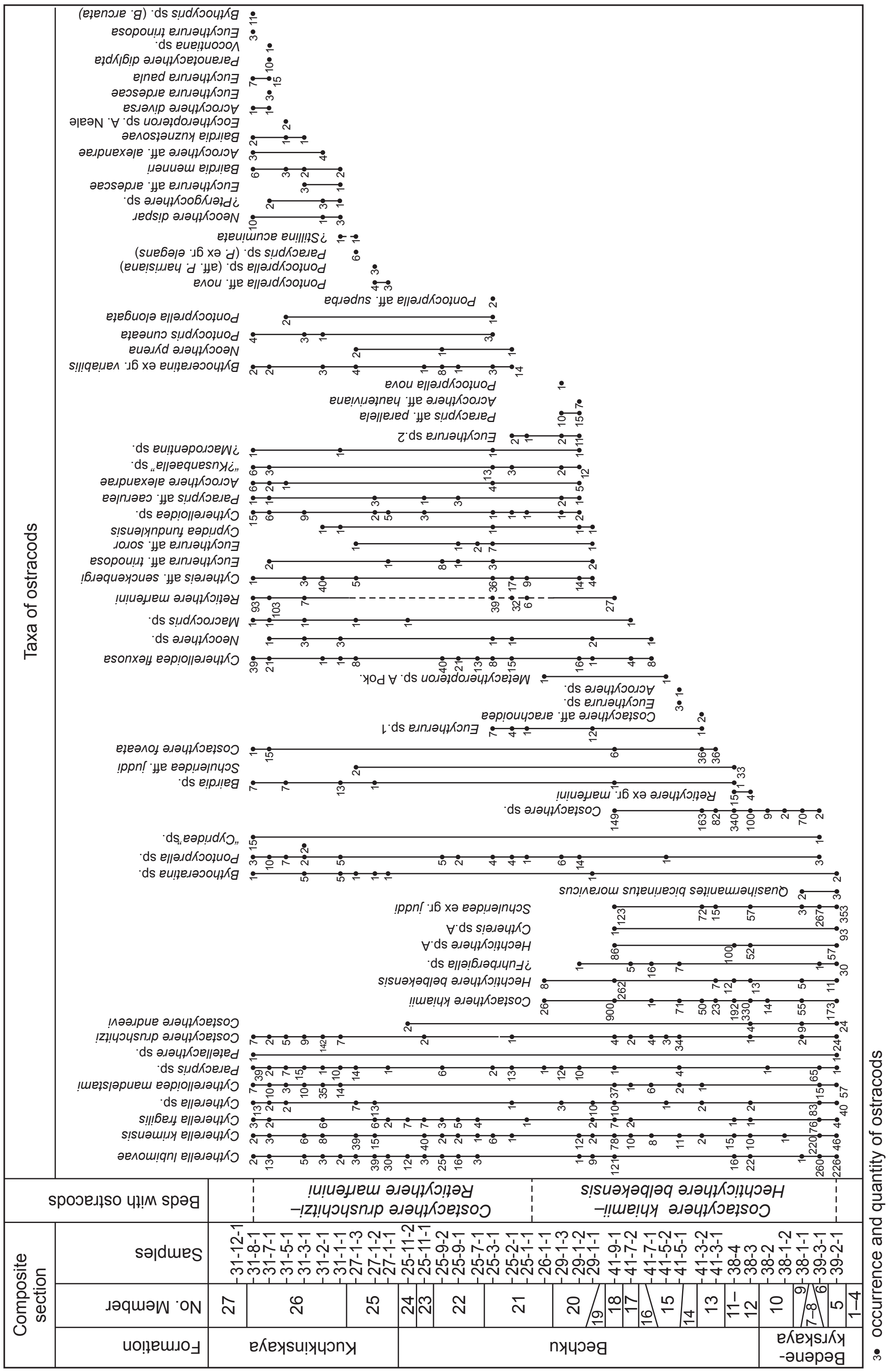

Fig. 7. Distribution of ostracods in the composite section of the Berriasian of central Crimea

Beds with *Costacythere drushchitzi*–*Reticythere marfenini*

These are distinguished in the upper part of the section, corresponding to a part of the Boissieri ammonite Zone. 71 species in 28 genera of ostracods were identified here (members 21 (upper part) – 26). Specimens of the following genera are numerous: *Cytherella*, *Cytherelloidea*, *Paracypris*, *Costacythere*, *Reticythere*, including such species as *Cytherella fragilis* Neale, *Cytherelloidea flexuosa* Neale, *C. mandelstami* Neale, *Costacythere drushchitzi* (Neale), *Reticythere marfenini* Tes. et Rach. and *Paracypris* sp. The characteristic species are: *Bairdia menneri* Tes. et Rach., *B. kuznetsovae* Tes. et Rach., *Bythoceratina* ex gr. *variabilis* Donze, *Eucytherura ardescae* Donze, *Neocythere pyrena* Tes. et Rach., *N. dispar* Donze, *Acrocythere diversa* Donze *et al*. Many species are derived from lower beds (36 common species belonging to 20 genera). 35 species in 22 genera appear here. These beds are named after the dominating species *Costacythere drushchitzi* (Neale) and *Reticythere marfenini* Tes. et Rach.

The species of ostracods encountered are known mostly in the Lower Cretaceous deposits (Berriasian–Hauterivian) of Crimea (Neale, 1966; Tesakova, Rachenskaya, 1996a, b), N Caucasus (Kolpenskaya, 2000), central Asia (Andreev, 1986), England (Neale, 1962, 1967, 1978; Slipper, 2009), France (Donze, 1964, 1965; Babinot *et al*., 1985), Germany (Triebel, 1938; Grundel, 1964) and Poland (Kubiatowicz, 1983). The species *Acrocythere diversa* Donze and *Bythoceratina variabilis* Donze were first described in the Berriasian of France (Donze, 1964). Species *Metacytheropteron* sp. A Pokorny, *Quasigermanites bicarinatus moravicus* Pok., *Eucytherura trinodosa* Pok. as well as related species *Eucytherura* ex gr. *trinodosa* Pok. and *Eucytherura* aff. *soror* Pok. have been identified in the ?Tithonian in the Czech Republic (Pokorny, 1973). *E. trinodosa* Pok.; *E.* ex gr. *trinodosa* Pok. and *E.* aff. *soror* Pok. have been encountered in the Upper Tithonian–Lower Berriasian deposits of the E Crimea. The subspecies *Quasigermanites bicarinatus moravicus* Pok. has previously been found in the Upper Berriasian here, and the related species *Quasigermanites* aff. *bicarinatus* Gruendel in the Middle Berriasian of SW Crimea (Arkadiev *et al*., 2006, 2012). The species *Neocythere dispar* Donze was first described in the lowest Valanginian at Berrias (Donze, 1965), and later found in the Berriasian deposits of Mangyshlak (Andreev, Oertli, 1970), as well as in the Upper Berriasian of central Crimea and Middle–Upper Berriasian of SW Crimea (Arkadiev *et al*., 2012). The species *Cytherella krimensis* Neale, *C. lubimovae* Neale, *Cytherelloidea flexuosa* Neale, *C. mandelstami* Neale, *Bairdia menneri* Tes. et Rach., *B. kuznetsovae* Tes. et Rach., *Cypridea funduklensis* Tes. et Rach., *Pontocyprella nova* Neale, *Pontocypris cuneata* Neale, *Neocythere pyrena* Tes. et Rach., *Costacythere khiamii* Tes. et Rach., *C. druschitzi* (Neale), *C. andreevi* Tes., *C. foveata* Tes. et Rach., *Hechticythere belbekensis* Tes. et Rach., *Reticythere marfenini* Tes. et Rach. and *Eocytheropteron* sp. A Neale were first described in the Berriasian of central Crimea (Neale, 1966; Tesakova, Rachenskaya, 1996a, b). The ostracods of central Crimea have the highest similarity at the genus and species level with the assemblage of the Berriasian type locality (13 common genera and 2 species: *Cytherella* sp., *Cytherelloidea* sp., *Bairdia* sp., *Paracypris* sp., *Neocythere* sp., *Macrodentina* sp., *Acrocythere alexandrae* Neale, *Orthonotacythere* sp., *Protocythere* sp., *Costacythere* sp., *Cytheropteron* sp., *Schuleridea juddi* Neale, *Xestoleberis* sp. (Neale, 1967; Grekoff, Magne, 1966)) and with Berriasian assemblage in the N Caucasus (river Urukh) (10 common genera and 7 species: *Cytherella* cf. *krimensis* Neale, *Cytherelloidea mandelstami* Neale, *Paracypris* sp., *Paranotacythere* sp., *Neocythere pyrena* Tes. et Rach., *Costacythere druzhchitzi* (Neale), *Hechticythere belbekensis* Tes. et Rach., *Acrocythere alexandrae* Neale, *Macrodentina* sp., *Schuleridea* aff. *juddi* Neale (Kolpenskaya *et al*., 2000)). The assemblage of the beds with *Costacythere khiamii*–*Hechticythere belbekensis* correlates with the similar assemblage identified in the Middle Berriasian (Tauricum Subzone) at Belbek in SW Crimea (Arkadiev *et al*., 2012).

PALYNOMORPHS

All the previous palynological studies of the Lower Cretaceous of the Crimea were focused on studies of spores and pollen of terrestrial plants, not considering the marine palynomorphs (Bolchovitina, 1953; Kuvaeva, Yanin, 1973; Smirnova, 1981; Voronova, 1994), although their presence has sometimes been mentioned. Systematic studies of the Late Tithonian – Early Cretaceous microphytoplankton in this region began only very recently, as part of the integrated study of the local Berriasian (Shurekova *in* Feodorova *et al*., 2011; Arkadiev *et al*., 2012).

In the samples studied the palynomorphs are represented by well-preserved spores, pollen, dinoflagellate cysts, prasinophytes and acritarchs: their distribution is shown in Figure 8. The proportion of palynomorphs varies in different parts of the sequence. In Member 20 *Classopollis* pollen accounts for 47% of palynomorphs, whereas spores and pollen *Disaccites* gen. spp. make up only 1%, and marine microphytoplankton 52%. In the remainder of the sequence, *Classopollis* pollen accounts for up to 90% of palynomorphs, and spores and the pollen *Disaccites* gen. spp. from 1% to 5%. The amount of microphytoplankton varies from 5% to 15% of the total number of palynomorphs.

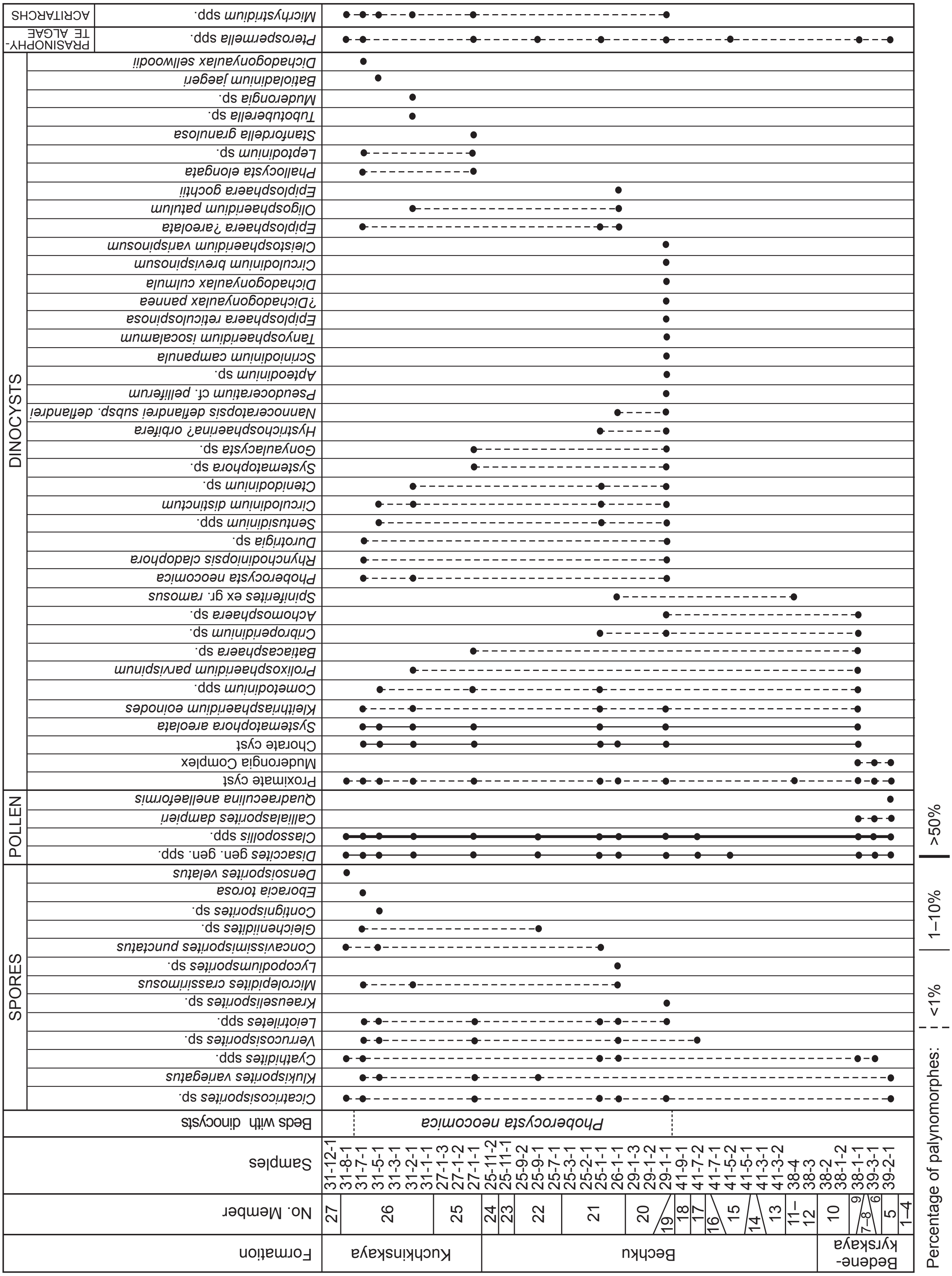

Fig. 8. Distribution of palynomorphs in the composite section of the Berriasian of central Crimea

Spores and pollen

The spore part of the spectrum through the entire sequence is represented by smooth *Leiotriletes* spp., *Cyathidites* sp., spores of Schizaeaceae ferns (*Cicatricosisporites* sp., *Verrucosisporites* sp. and *Klukisporites variegatus* Coup.), spores of *Concavissimisporites punctatus* (Delcourt et Sprumont), *Microlepidites crassirimosus* Timosch. and spores of *Gleichenia* ferns *Gleicheniidites* spp. Isolated specimens of *Eboracia torosa* (Sach. et Iljina), *Kraeuselisporites* sp., and spores of Lycopodiaceae ferns *Lycopodiumsporites* sp. and *Densoisporites velatus* Weyland et Krieger are encountered.

Pollen is represented by *Classopollis* spp., *Piceapollenites* spp., *Pinuspollenites* spp., *Callialasporites dampieri* (Balme) and *Quadraeculina anellaeformis* Mal.

Dinocysts

Phoberocysta neocomica dinocyst assemblage was identified in the deposits studied. The ubiquitous elements of the assemblage are: ?*Hystrichosphaerina orbifera* (Klement), *Spiniferites* ex gr. *ramosus* (Ehrenberg), *Systematophora* sp., *S. areolata* Klement, *Kleithriasphaeridium eoinodes* (Eisenack), *Prolixosphaeridium parvispinum* (Deflandre), *Batiacasphaera* sp., *Cribroperidinium* sp., *Phoberocysta neocomica* (Gocht), *Rhynchodiniopsis cladophora* (Deflandre), *Durotrigia* sp., *Sentusidinium* spp., *Circulodinium* spp., *Epiplosphaera* ?*areolata* (Klement), *Oligosphaeridium patulum* Riding et Thomas, *Gonyaulacysta* sp., *Ctenidodinium* sp., *Achomosphaera* sp., *Cometodinium habibii* Monteil. Additionally, prasinophytes of the genus *Pterospermella* and acritarchs *Micrhystridium* spp. are constantly present.

In the deposits that are richest for marine microphytoplankton (52%) (Member 20), besides the taxa mentioned above, individual *Nannoceratopsis deflandrei* Evitt subsp. *deflandrei*, *Pseudoceratium* cf. *pelliferum* Gocht, *Apteodinium* sp., *Scriniodinium campanula* Gocht, *Tanyosphaeridium isocalamum* (Deflandre et Cookson), *Epiplosphaera reticulospinosa* Klement, ?*Dichadogonyaulax pannea* (Norris), *D. culmula* (Norris), *Circulodinium brevispinosum* (Pocock), *Cleistosphaeridium varispinosum* (Sarjent), *Epiplosphaera gochtii* (Fensome) have also been discovered.

In the upper part of the section, in Member 26, *Batioladinium jaegeri* (Alberti), *Leptodinium* sp., *Tubotuberella* sp., *Muderongia* sp. and re-deposited *Dichadogonyaulax sellwoodii* (Sarjeant) and *Phallocysta elongata* (Beju) sporadically occur.

The beds with *Phoberocysta neocomica* have been traced from central Crimea to its southwestern and eastern parts. It is noteworthy that the dinocyst assemblage of the E Crimea is more diverse (Arkadiev *et al*., 2012).

The comparison of the *Phoberocysta neocomica* dinocyst assemblage with coeval assemblages recorded from the other regions was made considering the taxa from the E Crimea assemblage as well. The dinocyst assemblage of beds with *Phoberocysta neocomica* of the Crimea has nine species in common with the dinocyst Dichadogonyaulax bensonii Zone of the French Berriasian (Monteil, 1992), and thirteen species in common with the dinocyst assemblage of the Ryazan deposits of the Volga River Basin at Kashpir (Harding *et al*., 2011). Additionally, the presence of the index species in significant numbers, and eight other common species is similar to the Dingodinium ?spinosum Subzone, Phoberocysta neocomica Zone, in the regional Ryazanian (Upper Berriasian) in Canada and NW Europe (Fisher, Riley, 1980).

DISCUSSION

Based on our results we present a complete composite section supported by detailed palaeontological data. Parts of all the Berriasian ammonite zones (Jacobi, Occitanica and Boissieri) of Mediterranean Tethys have been confirmed. Beds with foraminifers, ostracods and dinocysts were identified (Fig. 9). The critical analysis of the taxonomic diversity of the microfossils, their vertical and lateral distribution, both within the study area and outside, allows us to identify and evaluate the biostratigraphic potential of the faunal and floral assemblages studied.

The wide diversity of foraminifers, and the specifics of their quantitative and species composition variation throughout the entire composite section has made it possible to distinguish six distinct fossil assemblages. However, the stratigraphic continuity of these assemblages cannot be traced throughout Crimea. All the identified foraminiferan taxa are generally typical of the assemblage of beds with *Textularia crimica–Belorussiella taurica*, which has a wide range, from the top of the Jacobi Zone through to the Boissieri Zone. In all likelihood, the changes of the foraminiferal assemblages in the Berriasian of central Crimea is facies controlled, but these changes can be used to derive a biostratigraphy at the local level.

Two beds with ostracods were distinguished in the deposits studied. Beds with *Costacythere khiami–Hechticythere bebekensis* are most reliably traced to the SW Crimea. Unfortunately, the overlying beds with *Costacythere drushchitzi–Reticythere marfenini* cannot be identified in SW Crimea due to poor characterization of the deposits, and the predominance of long ranging taxa. More deep-water sediments are typical of the E Crimea, containing different ostracod assemblages (Arkadiev *et al*., 2012). Outside Crimea the most similar assemblages, at the genus and species level, are those

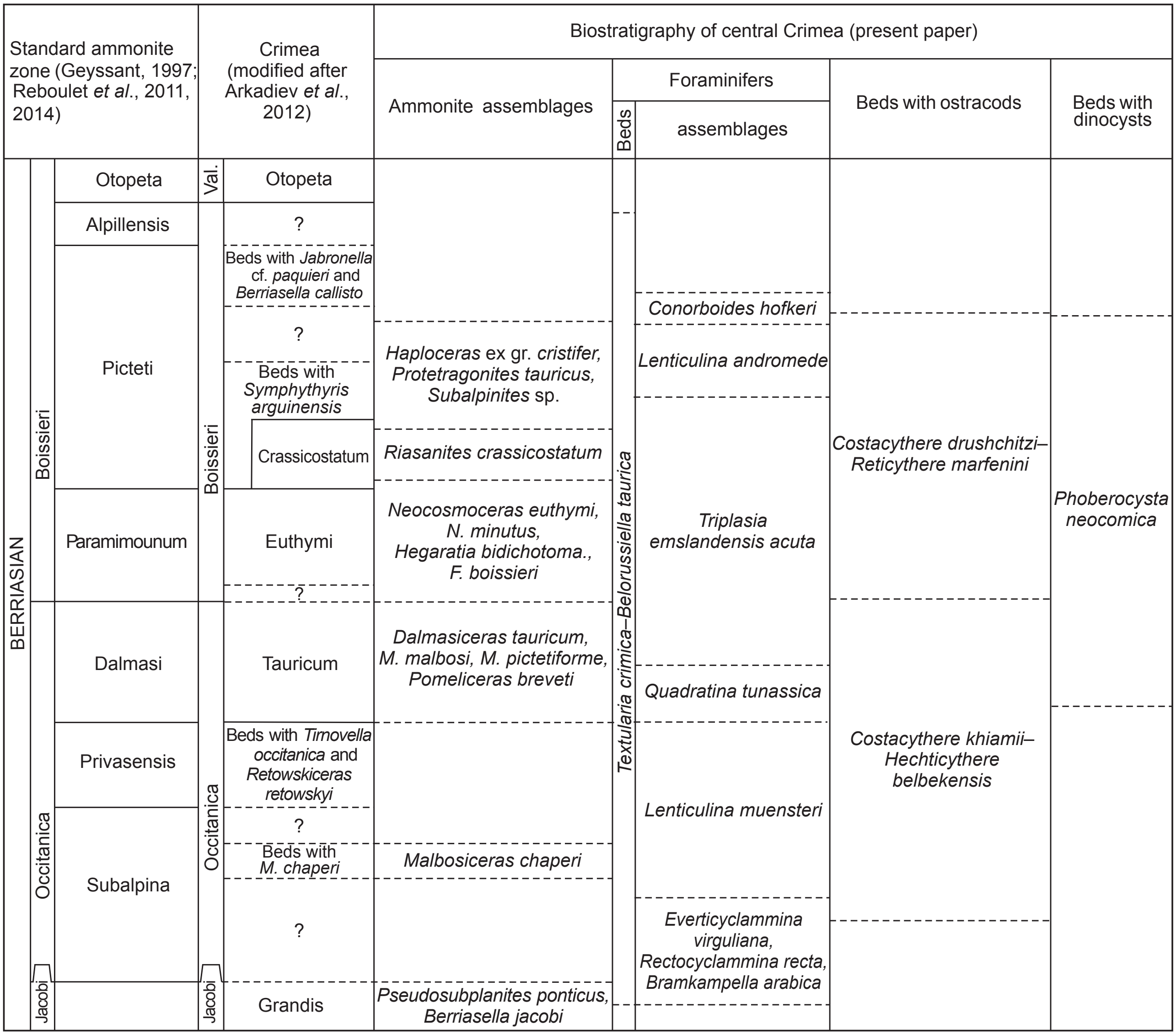

Fig. 9. Berriasian biostratigraphy of central Crimea based on different fossil groups

found at Berrias in France and in the the Urukh section in the Caucasus.

The taxonomic diversity of fossil microphytoplankton in central Crimea is not high. In Berriasian deposits only beds with *Phoberocysta neocomica*, corresponding to the upper Occitanica Zone and lower Boissieri Zone, could be identified. However, clear taxonomic characteristics and the continuity of composition (despite the lateral variations in diversity) allow us to identify the dinocyst *Phoberocysta neocomica* assemblage both in the SW and E Crimea. Outside of Crimea this dinocyst assemblage is reliably identified on the Volga, in France, Canada and NW Europe, which makes it correlation potential very high.

Studies of ancient marine basins involve not only stratigraphic studies, but also the investigation of the living environment of the biota, reflecting all the changes that occured in the basin. The benthic fauna, ostracods and foraminifers have been the most studied. The benthos, in particular, is closely correlated with the near-bottom environment of the basin. The reconstruction of the palaeoenvironment is based primarily on an actualistic approach, and the environmental parameters of modern communities are extrapolated to the ancient fauna, with certain assumptions (Bandy, 1956;

Murray, 2006; Murray, Alve, 2011). The main external factors impacting the benthic fauna and determining the specifics of the taxonomic composition were: water temperature, water depth, water mobility, organic calcite and oxygen content, illumination, substrate and salinity (Andreev *et al*., 1999; Denne, Sen Gupta, 2003; Murray, 2006).

Our palaeoecological analysis of the foraminiferal associations uses a quantitative estimate of taxa at the family and genus level, with further calculation of percentages (as used by Azbel, 1975; Reolid, Nagy *et al*., 2008). The analysis also included: proportions of agglutinated and secreted benthic and planktonic foraminifers; proportions of eurybiontic/stenobiontic forms (Nikitenko, 2009); total number of genera and species in the association; morphological features of specimens and presence of additional elements in the sample (other microfossils, fragments of macrofossils; mineral particles – pyrite, glauconite, quartz, *etc*.).

Based on the analysis of these parameters we plotted diagrams for the quantitative and qualitative characteristics of families and genera, and distinguished 4 palaeocenoses, which describe certain bionomic benthic zones (Fig. 10), as follows.

No. 1. A Lituolidae–Trocholina palaeocenosis (no. 1), consisting mostly of Lituolidae (including multilayer forms) (30–100%) and *Trocholina* (10–100%): identified in the lower part of the section (members 1–9, 18). Lituolidae are represented by 1–2 species from 14 genera, predominantly by *Melathrokerion*, *Pseudocyclammina*, *Everticyclammina* and *Rectocyclammina*; the genus *Trocholina* is represented by 5 species (high and low spired). The association also includes a small number of Ataxophragmiidae and Textularidae (3–15%, up to 50% in some samples) and individual Nodosariidae and Polymorphinidae (3–10%, up to 20% in some samples). The presence of *Pseudocyclammina lituus* (Yokoyama) and the high conic *Trocholina elongata* (Leupold) is typical of the upper twenty meters of the water column. Representatives of the genera *Charentia*, *Melathrokerion*, *Choffatella* and *Alveosepta* are rare in the first meters of depth and are often below a depth of fifteen meters. Representatives of the genus *Everticyclammina* appear at a depth of ten meters and become numerous below a depth of twenty meters (Arnaud-Vanneau *et al*., 1987; Banner, Simmons, 1994). Such palaeobiocenosis, which consist of numerous inhabitants of shallow water environments and sporadic taxa living in comparatively deeper water conditions, could occur at a relatively shallow depth in the upper sublittoral zone (few tens of meters), under conditions of relatively calm hydrodynamics and with normal salinity (Krasheninnikov, Trofimov, 1969; Arnaud-Vanneau *et al*., 1987; Banner, Simmons, 1994; Hottinger, 1997).

No. 2. A Nodosariidae palaeocenosis (no. 2) was identified in the middle part of the section (uppermost Member 9 to Member 25). Nodosariidae account for up to 90%, and they are represented by numerous species belonging to 15 genera, with predominant *Lenticulina* and *Saracenaria*. The primitive forms (*Rhizammina*, *Saccammina*, *Hyperammina*, *Lituotuba*) and simple Lituolidae, Ataxophragmiidae, Miliolidae and Polymorphinidae vary from individual specimens to 40%; thin-walled planktonic forms are rare. Such a palaeobiocenosis with the strong domination of Nodosariidae could occur in a normal marine basin, at moderate depths on a shallow shelf, in the mid-sublittoral zone (Burnaby, 1962; Azbel, 1975; Nikitenko, 2009).

However, some of the beds contain dwarfed or abnormal forms of secreted benthos; sometimes gigantism of agglutinated forms occurs. Occasional unfavourable conditions for foraminifers in near-bottom waters, in the context of an overall gradual deepening of the basin inducing a redistribution of the fauna, may be explained by a lowered temperature, changes in chemical composition, gas regime and the impact of near-bottom currents (Bugrova, Bugrova, 2011).

The alternation of the two palaeocenoses (nos 3 and 4) is typical of foraminiferal associations in the upper part of the sequence (Member 26):

No. 3. This Ataxophragmiidae–Lituolidae palaeocenosis (no. 3) is impoverished in species. Ataxophragmiidae and Textularidae contribute 40–100%, and simple-Lituolidae – 30–50%. Small Miliolida (*Quinqueloculina* and *Istriloculina*) are rare. This palaeobiocenosis could have formed in the upper sublittoral zone (Burnaby, 1962; Azbel, 1975; Arnaud-Vanneau *et al*., 1987; Banner, Simmons, 1994; Nikitenko, 2009).

No. 4. The Ataxophragmiidae–Nodosariidae palaeocenosis (no. 4) consists of species and genera of Ataxophragmiidae (25–40%) and taxonomically diverse Nodosariidae (40%), represented by 10 genera, with predominant *Lenticulina* (15 species; up to 30%). *Trocholina* represented by small and medium size low spired forms are not abundant. Small Miliolida (*Quinqueloculina* and *Istriloculina*) are rare. Isolated thin-walled planktonic forms occur. The percent of Polymorphinidae increases (up to 15%). Such a palaeobiocenosis could have formed in a somewhat deeper water part of the upper sublittoral zone (Parker *et al*., 1953; Bandy, 1956; Arnaud-Vanneau *et al*., 1987; Banner, Simmons, 1994; Nikitenko, 2009).

Generally, through the sequence we have observed changes in the proportions of foraminiferan families, reflecting transgressive and regressive periods on the shallow shelf in the upper- and mid-sublittoral zones.

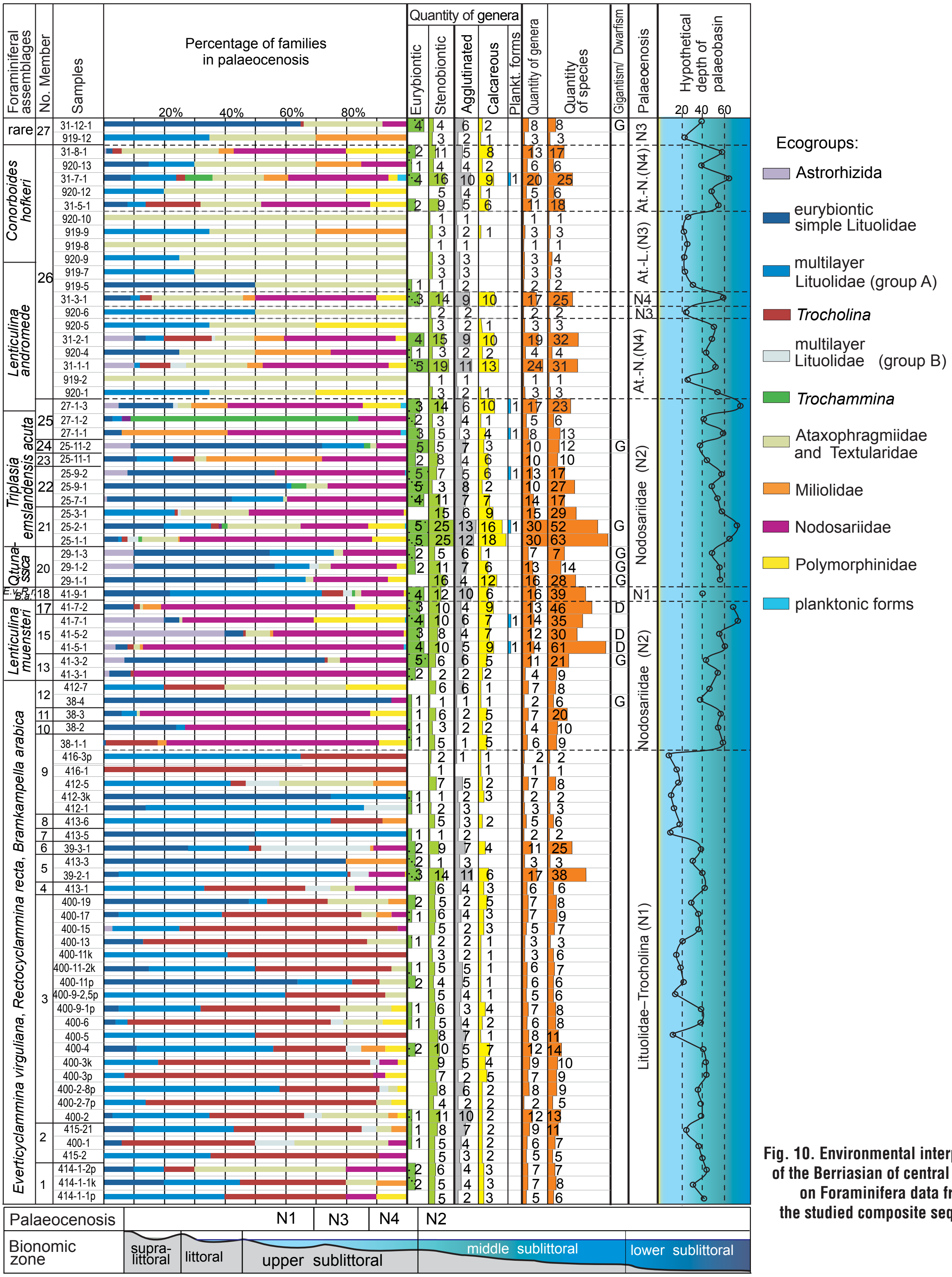

Fig. 10. Environmental interpretation of the Berriasian of central Crimea on Foraminifera data from the studied composite sequence

The ostracod associations studied from predominantly argillaceous rocks suggest the favorable conditions of a warm shallow basin with normal salinity. The ostracod shells are mostly well preserved, without size differentiation, and adult and larval specimens are often present together, indicating autochthonous burial. Pokorny (1971) recorded a dependence of the diversity of marine benthic ostracods on shoreline changes. Diversity of ostracods is increased during transgression and is decreased during regression in relatively shallow seas (Ballent, Whatley, 1996). The core of the assemblages is formed by smooth-walled eurybiontic specimens of the genus *Cytherella* (Donze, 1975; Neale, 1976; Dobrova, 1996). Most of the *Cytherella* species are stenohaline. They live in shallow water under a salinity of 32–37‰ and in deep water under a salinity of 34–35‰ (Sohn, 1964).The sculptured forms comprise predominantly members of the family Protocytheridae (*Protocythere*, *Costacythere*, *Hechticythere*, *Reticythere*), with heavy shells adapted to wave motion which is typical of shallow environments (Shornikov, 1971; Neustrueva, 1981; Babinot, 1995). The presence of numerous diverse specimens of the genus *Cytherelloidea*, inhabitants of modern tropical and subtropical shallow waters, also suggests shallow environments (Sohn, 1964; Schudack, 1999). They live under a temperature varying from 10°C in high latitudes to 30–32°C in the tropics (Sohn, 1964; Neale, 1973). The overwhelming majority of the taxa studied are typical of basins with normal marine salinity, and individual genera which may withstand salinity fluctuations do not change the overall picture (Morkhoven, 1963; Donze, 1971; Babinot *et al*., 1985; Colin, Oertli, 1985; Neale, 1988; Andreev *et al*., 1999; Horne, 2009).

Palaeoecological analysis of foraminiferan and ostracod associations shows that the environment in general was favourable for the development of a benthic fauna. It was a moderately warm and shallow (few tens of meters) marine basin with normal salinity. In general, the basin was deepening, and some shallowing may be inferred only during sedimentation of Member 26.

Pollen of *Classopollis* has an extremely wide geographical distribution and ranges from the Norian to the Turonian (Srivastava, 1976). Peaks in *Classopollis* in the Berriasian are known in NW Europe in the Purbeckian (Francis, 1983) and in Moldova, Crimea, Caucasus and southern Kazakhstan (Vakhrameev, 1981). *Classopollis* pollen was produced by plants belonging to the extinct gymnosperm conifer family Cheirolepidiaceae (Pocock, Jansonius, 1961; Francis, 1983). They occupied well-drained soils of upland slopes and lowlands near coastal areas, or possibly they were salt marsh shrubs or trees resembling modern mangroves (Riding, 2013). Abundant of *Classopollis* pollen in sample (up to 90%) indicated that it was deposited under hot/warm palaeoclimatic conditions (Pocock, Jansonius, 1961; Srivastava, 1976; Alvin, 1982; Riding, 2013).

The Berriasian sequence ends locally with the drainage of the carbonate platform, accompanied by karstification and restructuring of the sedimentary system: in Valanginian times terrigenous sedimentation became predominant.

CONCLUSIONS

Using an integrated approach to the study of the Berriasian deposits has allowed us to compile the most complete composite section for central Crimea, strongly supported by palaeontological data. The ammonites confirm the Jacobi, Occitanica and Boissieri zones. The beds identified by foraminifers, ostracods and dinocysts have been correlated between each other, as well as with the ammonite zones. The dinocysts have the highest correlation potential, while the studies of the benthic microfauna (foraminifers, ostracods) are of high importance for refining local Berriasian stratigraphy. The palaeoecological analysis shows that the Berriasian sediments of central Crimea were deposited in a warm shallow marine basin with normal salinity under conditions of a warm palaeoclimate.

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PLATE 1
Berriasian foraminifers from central Crimea

Fig. 1. *Triplasia* cf. *elegans* (Mjatl.); no. 26/13244, sample 41-9-1, 1a – lateral view, 1b – frontal view, 1c – apertural view; Balki, Occitanica Zone

Fig. 2, 3. *Haplophragmium subaequale* (Mjatl.); sample 41-9-1; Balki, Occitanica Zone: **2** – no. 27/13244, 2a – lateral view, 2b – frontal view, 2c – oriented thin section; **3** – no. 28/13244, 3a, b – lateral view, 3c – apertural view

Fig. 4. *Haplophragmium elongatum* Dain; no. 29/13244, sample 39-3-1, 4a, b – lateral view; Balki, Occitanica Zone

Fig. 5. *Triplasia emslandensis acuta* Brat. et Brand; no. 30/13244, sample 30-1-2, 5a, b – lateral view, 5c – apertural view; Balki, Boissieri Zone, Euthymi Subzone

Fig. 6. *Amijiella amiji* (Henson); no. 54/13244, sample 413-1, thin section; Enysaraui ravine, Occitanica Zone

Fig. 7. *Bramkampella arabica* Radmond; no. 55/13244, sample 412-7, thin section; Enysaraui ravine, Occitanica Zone

Fig. 8, 9. *Charentia evoluta* Gorb.; Occitanica Zone: **8** – no. 31/13244, sample 38-3-1, 8a – lateral view, 8b – frontal view; Balki; **9** – no. 32/13244, sample 400-3k, thin section, Enysaraui ravine

Fig. 10, 11. *Melathrokerion spirialis* Gorb.; Occitanica Zone: **10** – no. 33/13244, sample 41-9-1, 10a, b – lateral view, 10c – frontal view; Balki; **11** – no. 34/13244, sample 400-2-1, thin section; Enysaraui ravine

Fig. 12, 13. *Stomatostoecha compressa* Gorb.; Occitanica Zone: **12** – no. 35/13244, sample 38-3-1, 12a, – lateral view, 12b – frontal view; Balki; **13** – 36/13244, sample 414-1-1p, thin section; Enysaraui ravine

Fig. 14, 15. *Stomatostoecha enisalensis* Gorb.; Balki, Occitanica Zone: **14** – no. 37/13244, sample 38-3-1, 14a, b – lateral view, 14c – frontal view; **15** – no. 38/13244, sample 412-1, thin section

Fig. 16. *Stomatostoecha enisalensis* Gorb.; no. 39/13244, sample 400-2p-11, thin section; Enysaraui ravine, Occitanica Zone

Fig. 17–20. *Everticyclammina virguliana* (Koechl.); Balki, Occitanica Zone: **17** – no. 40/13244, sample 39-2-1, 17a – lateral view, 17b – oriented thin section; **18** – no. 41/13244, sample 38-3-1; **19** – no. 42/13244, sample 38-3-1; **20** – no. 44/13244, sample 39-2-1, 20a – lateral view, 20b – apertural view, 20c – oriented thin section

Fig. 21. *Everticyclammina elongata* Gorb.; no. 45/13244, sample 413-1, thin section; Enysaraui ravine, Occitanica Zone

Fig. 22. *Rectocyclammina arrabidensis* Remalho; no. 46/13244, sample 38-3-1, 22a – lateral view, 22b – apertural view, 22c – oriented thin section; Balki, Occitanica Zone

Fig. 23, 24. *Rectocyclammina chouberti* Hottinger; Occitanica Zone: **23** – no. 48/13244, sample 39-2-1, 23a – lateral view, 23b – apertural view, 23c – oriented thin section; Balki; **24** – no. 49/13244, sample 400-2-1, thin section; Enysaraui ravine

Fig. 25, 26. *Rectocyclammina recta* Gorb.; Balki, Occitanica Zone: **25** – no. 51/13244, sample 39-3-1, lateral view; **26** – no. 52/13244, sample 39-3-1, 26a – lateral view, 26b – apertural view, 26c – oriented thin section

Fig. 27. *Rectocyclammina* ex gr. *chouberti* Hottinger; no. 50/13244, sample 400-13k, thin section; Enysaraui ravine, Occitanica Zone

Fig. 28. *Alveosepta jaccardi* (Schrodt); no. 62/13244, sample 41-9-1, 28a, b – lateral view, 28c – frontal view; Balki, Occitanica Zone

Fig. 29, 30. *Textularia crimica* (Gorb.); Boissieri Zone: **29** – no. 56/13244, sample 41-9-1, 29a – lateral view, 29b – apertural view; Balki; **30** – no. 57/13244, sample 919-12, thin section; Mezhgorie

Fig. 31–33. *Belorussiella taurica* Gorb.; **31** – no. 58/13244, sample 31-2-1, lateral view; Mezhgorie, Boissieri Zone; **32** – no. 59/1324, sample 400-2-1, thin section; Enysaraui ravine, Occitanica Zone ; **33** – no. 60/13244, sample 920-12, thin section; Mezhgorie, Boissieri Zone

Magnification ×20

Julia N. Savelieva *et al*. — Integrated palaeontological characteristics (ammonites, ostracods, foraminifers, dinocysts) of the Berriasian deposits of central Crimea

PLATE 2

Berriasian foraminifers from central Crimea

Fig. 1. *Lenticulina muensteri* (Roemer); no. 63/13244, sample 34-1-1, 1a – lateral view, 1b – frontal view; Mezhgorie, Boissieri Zone

Fig. 2. *Lenticulina andromede* Espitalie et Sigal; no. 64/13244, sample 34-1-1, 2a – lateral view, 2b – frontal view; Mezhgorie, Boissieri Zone

Fig. 3. *Lenticulina colligoni* Espitalie et Sigal; no. 65/13244, sample 41-7-1, 3a – lateral view, 3b – frontal view; Balki, Occitanica Zone

Fig. 4. *Lenticulina ongkodes* Espitalie et Sigal; no. 66/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 5. *Lenticulina aquilonica* Mjatliuk; no. 67/13244, sample 41-5-1, 5a – lateral view, 5b – frontal view; Balki, Occitanica Zone

Fig. 6. *Lenticulina* aff. *uspenskajae* K. Kuznetsova; no. 68/13244, sample 41-5-1, 6a – lateral view, 6b – frontal view; Balki, Occitanica Zone

Fig. 7. *Lenticulina bifurculla* Bartenstein et Brand; no. 69/13244, sample 41-5-1, 7a – lateral view, 7b – frontal view; Balki, Occitanica Zone

Fig. 8. *Lenticulina* ex gr. *nimbifera* Espitalie et Sigal; no. 71/13244, sample 41-7-1, 8a – lateral view, 8b – frontal view; Balki, Occitanica Zone

Fig. 9. *Lenticulina macra* Gorb., no. 70/13244; sample 41-3-1, 9a – lateral view, 9b – frontal view; Balki, Occitanica Zone

Fig. 10. *Lenticulina* ex gr. *nodosa* (Reuss); no. 72/13244, sample 34-1-1, 10a – lateral view, 10b – frontal view; Balki, Boissieri Zone

Fig. 11. *Lenticulina fracta* Espitalie et Sigal; no. 73/13244, sample 41-3-1, 11a – lateral view, 11b – frontal view; Balki, Occitanica Zone

Fig. 12. *Lenticulina neocomina* Romanova; no. 74/13244, sample 34-1-1, 12a – lateral view, 12b – frontal view; Balki, Boissieri Zone

Fig. 13. *Lenticulina* ex gr. *guttata* (Dam.); no. 75/13244, sample 34-1-1, 13a – lateral view, 13b – frontal view; Balki, Boissieri Zone

Fig. 14. *Lenticulina* ex gr. *subalata* Reuss; no. 76/13244, sample 41-9-1; Balki, Occitanica Zone

Fig. 15, 16. *Lenticulina ambanjabensis* (Espitalie et Sigal); **15** – no. 77/13244, sample 30-1-3, 15a – lateral view, 15b – frontal view; Balki, Boissieri Zone; **16** – no. 78/13244, sample 400-9p, thin section; Enysarai ravine, Occitanica Zone

Fig. 17. *Lenticulina* ex gr. *neocomina* Romanova; no. 79/13244, sample 35-1-1, 17a – lateral view, 17b – frontal view; Balki, Boissieri Zone

Fig. 18. *Lenticulina* sp. (L. sp. 1 Gorb., 1978); no. 80/13244, sample 25-2-1, 18a – lateral view, 18b – frontal view; Balki, Boissieri Zone, Euthymi Subzone

Fig. 19. *Lenticulina* cf. *eichenbergi* Bartenstein et Brand; no. 81/13244, sample 35-1-1, 19a – lateral view, 19b – frontal view; Balki, Boissieri Zone

Fig. 20. *Lenticulina eichenbergi* Bartenstein et Brand; no. 82/13244, sample 35-2-1, 20a – lateral view, 20b – frontal view; Balki, Boissieri Zone.

Fig. 21. *Astacolus* aff. *proprius* K. Kuznetsova; no. 83/13244, sample 35-1-1, 21a – lateral view, 21b – frontal view; Balki, Boissieri Zone

Fig. 22. *Astacolus mutilatus* Espitalie et Sigal; no. 84/13244, sample 41-9-1; Balki, Occitanica Zone

Fig. 23. *Astacolus proprius* K. Kuznetsova; no. 85/13244, sample 41-9-1; Balki, Occitanica Zone

Fig. 24. *Astacolus folium* (Wisn.); no. 86/13244, sample 41-9-1; Balki, Occitanica Zone

Fig. 25. *Saracenaria latruncula* (Chalilov); no. 87/13244, sample 25-2-1; Balki, Boissieri zone, Euthymi Subzone

Fig. 26. *Saracenaria* ex gr. *tsaramandrosoens* Espitalie et Sigal; no. 88/13244, sample 41-5-1, 26a – lateral view, 26b – frontal view; Balki, Occitanica Zone

Fig. 27. *Saracenaria aculata* Espitalie et Sigal; no. 89/13244, sample 41-5-1, 27a – lateral view, 27b – frontal view; Balki, Occitanica Zone

Fig. 28. *Saracenaria* cf. *inflata* Pathy; no. 90/13244, sample 34-1-1, 28a – lateral view, 28b – frontal view; Balki, Boissieri Zone

Fig. 29. *Saracenaria compacta* Espitalie et Sigal; no. 91/13244, sample 41-7-1, 29a – lateral view, 29b – frontal view; Balki, Occitanica Zone

Fig. 30. *Pseudosaracenaria truncata* Pathy; no. 92/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 31. *Saracenaria provoslavlevi* Fursenko et Polenova; no. 94/13244, sample 41-3-2, 31a – lateral view, 31b – frontal view; Balki, Occitanica Zone

Fig. 32. *Saracenaria tsaramandrosoensis* Espitalie et Sigal; no. 93/13244, sample 34-1-2; Balki, Boissieri Zone

Fig. 33, 34. *Planularia madagascariensis* Espitalie et Sigal; **33** – no. 98/13244, sample 34-1-1, 33a – lateral view, 33b – frontal view, Balki, Boissieri Zone; **34** – no. 97/13244, sample 400-9p thin-section; Enysaraui ravine, Occitanica Zone

Fig. 35. *Citharina flexuosa* (Bruckmann); no. 99/13244, sample 34-1-1, 35a – lateral view, 35b – frontal view; Balki, Boissieri Zone

Fig. 36. *Frondicularia* cf. *cuspidiata* Pathy; no. 100/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 37. *Frondicularia crimica* Schokhina; no. 101/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 38. *Frondicularia complexa* Pathy; no. 102/13244, sample 34-1-1; Balki, Boissieri Zone

Fig. 39. *Frondicularia hastata* (Roemer); no. 103/13244, sample 25-2-1, Balki, Boissieri Zone, Euthymi Subzone

Fig. 40. *Citharina* ex gr. *orbigny* (Mariep); no. 104/13244, sample 41-9-1; Balki, Occitanica Zone

PLATE 2 cont.

Fig. 41. *Discorbis crimicus* Schokchina; no. 105/13244, sample 38-1-1, 41a – dorsal view, 41b – ventral view, 41c – frontal view; Balki, Occitanica Zone

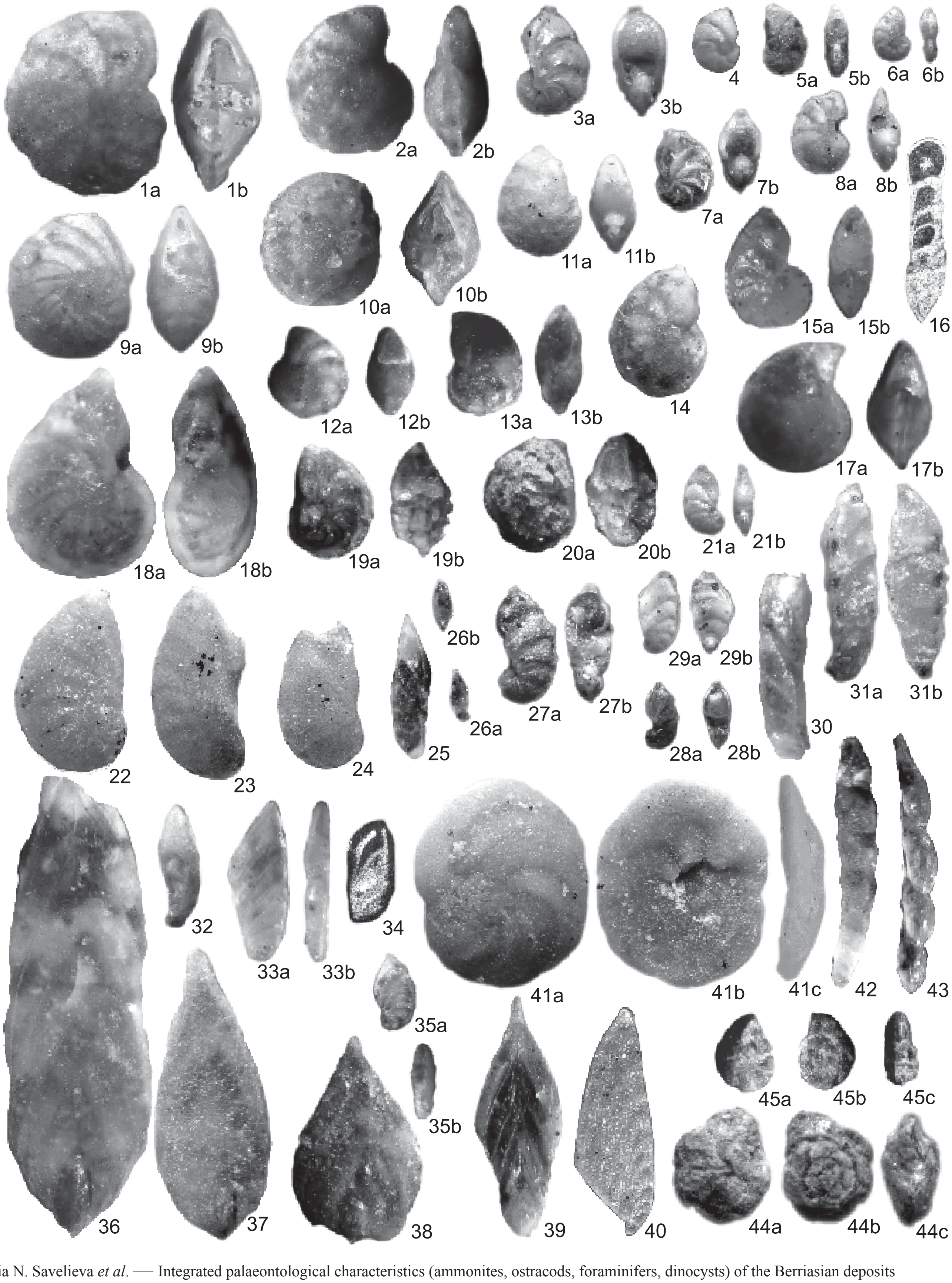
Fig. 42. *Dentalina communis* Reuss; no. 106/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 43. *Dentalina nana* Reuss, no. 107/13244, sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone

Fig. 44. *Epistomina caracolla* (Roemer); no. 110/13244, sample 41-7-1, 44a – dorsal view, 44b – ventral view, 44c – frontal view; Balki, Occitanica Zone

Fig. 45. *Conorboides hofkeri* (Bart. et Brand); no. 111/13244, sample 35-2-1, 45a – dorsal view, 45b – ventral view, 45c – frontal view; Balki, Occitanica Zone, magnification ×60

Magnification ×35 if not specified otherwise



Julia N. Savelieva *et al*. — Integrated palaeontological characteristics (ammonites, ostracods, foraminifers, dinocysts) of the Berriasian deposits of central Crimea

PLATE 3

Berriasian ostracods of central Crimea

Fig. 1. *Cytherella krimensis* Neale; no. 2/13244, sample 39-2-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 2, 3. *Cytherella lubimovae* Neale; **2** – no. 176/13220, sample 29-1-2, left valve, lateral view; Novoklenovo, Boissieri Zone, beds with *Symphythiris arguinensis*; **3** – no. 120/13244, sample 39-2-1, carapace, left lateral view; Balki, Occitanica Zone

Fig. 4. *Cytherella fragilis* Neale; no. 121/13244, sample 39-2-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 5. *Cytherelloidea flexuosa* Neale; no. 4/13244, sample 41-7-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 6. *Cytherelloidea mandelstami* Neale; no. 5/13244, sample 39-2-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 7. *Paracypris felix* (Neale); no. 3/13244, sample 41-7-2, carapace, left lateral view; Balki, Occitanica Zone

Fig. 8. *Pontocyprella rara* Kaye; no. 122/13244, sample 27-1-2, carapace, left lateral view; Balki, Boissieri Zone, beds with *Symphythiris arguinensis*

Fig. 9. *Bythoceratina* ex gr. *variabilis* Donze; no. 123/13244, sample 25-2-1; carapace, right lateral view; Balki, Boissieri Zone, Euthymi Subzone

Fig. 10, 11. *Eucytherura* ex gr. *trinodosa* Pokorny; Balki, Occitanica Zone, sample 41-5-1: **10** – no. 124/13244, right valve, lateral view; **11** – no. 6/13244, left valve, lateral view

Fig. 12. *Eucytherura* sp.; no. 8/13244, sample 41-5-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 13. *Eucytherura* sp. 1; no. 7/13244, sample 41-3-2, right valve, lateral view; Balki, Occitanica Zone

Fig. 14. *Eucytherura* ex gr. *soror* Pokorny; no. 125/13244, sample 29-1-2; right valve, lateral view; Novoklenovo, Sary-Su river, Occitanica Zone, Tauricum Subzone

Fig. 15. *Paranotacythere* sp.; no. 9/13244, sample 27-1-3, left valve, lateral view; Balki, Occitanica Zone

Fig. 16. *Eucytherura* aff. *ardescae* Donze; no. 126/13244, sample 27-1-3; left valve, lateral view; Balki, Boissieri Zone, beds with *Symphythiris arguinensis*

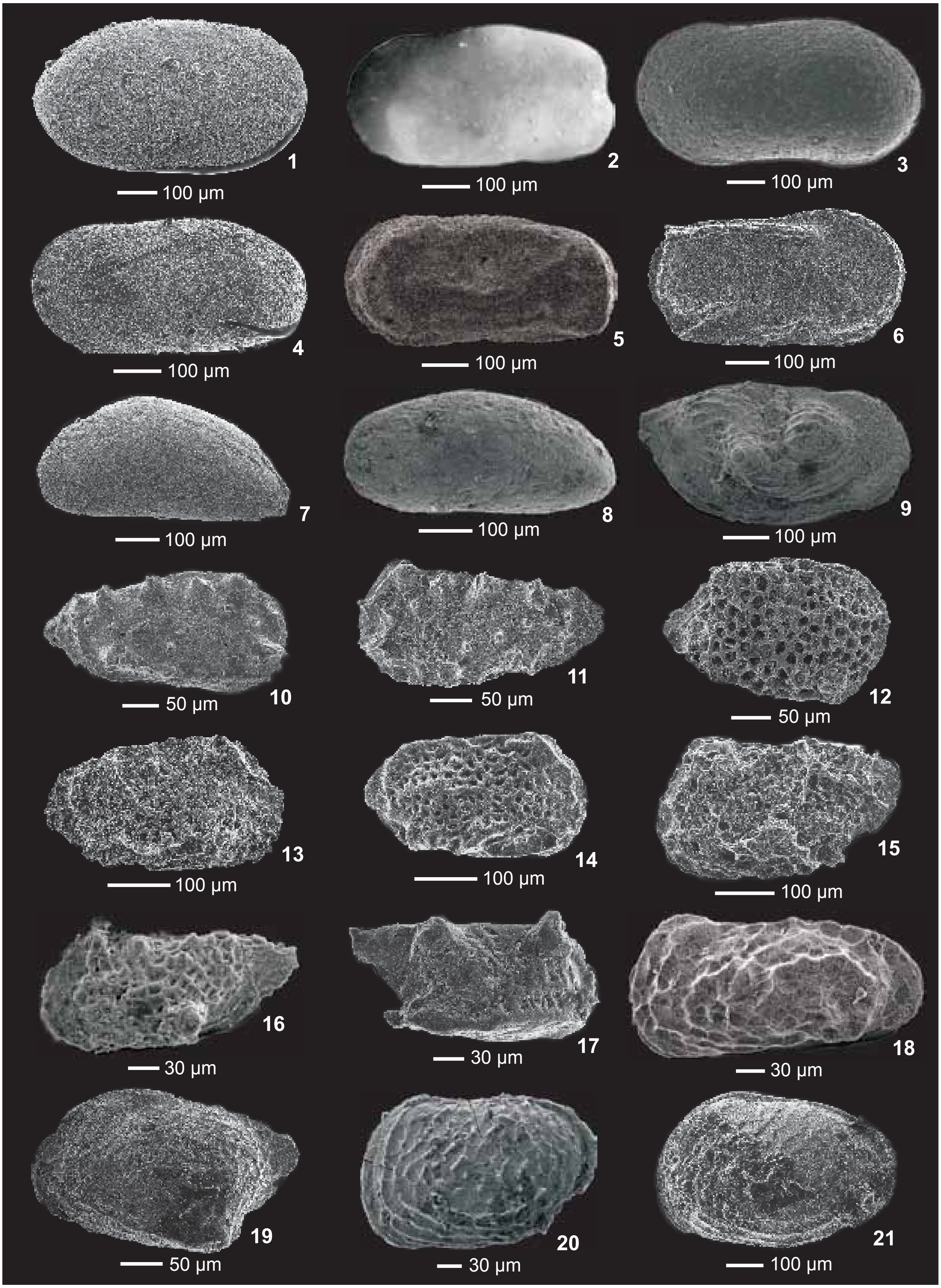
Fig. 17. *Renicytherura* sp.; no. 127/13244, sample 31-1-1; right valve, lateral view; Mezhgorie, Burulcha river, Boisseieri Zone

Fig. 18. *Metacytheropteron* sp. A. Pokorny; no. 128/13244, sample 29-1-3; left valve, lateral view; Novoklenovo, Sary-Su river, Occitanica Zone, Tauricum Subzone

Fig. 19. *Eocytheroteron* sp.; no. 10/13244, sample 41-3-2, left valve, lateral view; Balki, Occitanica Zone

Fig. 20. *Neocythere pyrena* Tesakova et Rachenskaya; no. 212/13220, sample 25-9-2, left valve, lateral view; Balki, Boissieri Zone, Euthymi Subzone

Fig. 21. *Neocythere* sp.; no. 129/13244, sample 41-7-1; left valve, lateral view; Balki, Occitanica Zone



Julia N. Savelieva *et al*. — Integrated palaeontological characteristics (ammonites, ostracods, foraminifers, dinocysts) of the Berriasian deposits of central Crimea

PLATE 4

Berriasian ostracods of central Crimea

Fig. 1, 2. ?*Fuhrbergiella* sp.; sample 41-5-1, left valve, lateral view; Balki, Occitanica Zone: **1** – no. 11/13244; **2** – no. 130/13244

Fig. 3, 4. *Reticythere marfenini* Tesakova et Rachenskaya; sample 25-2-1; Balki, Boissieri Zone, Euthymi Subzone: **3** – no. 13/13244, female carapace, left lateral view; **4** – no. 131/13244, male right valve, lateral view

Fig. 5, 6. *Costacythere drushchitzi* (Neale); **5** – no. 230/13220, sample 31-2-1, male right valve, lateral view; Mezhgorie, Burulcha river, Boissieri Zone; **6** – 12/13244, sample 41-5-2, carapace, left lateral view; Balki, Occitanica Zone

Fig. 7–9. *Costacythere khiamii* Tesakova et Rachenskaya; sample 39-2-1; Balki, Occitanica Zone: **7** – no. 14/13244; **8** – no. 15/13244, carapace, left lateral view; **9** – no. 16/13244, female right valve, lateral view

Fig. 10–11. *Costacythere foveata* Tesakova et Rachenskaya; sample 41-3-2, left valve, lateral view; Balki, Occitanica Zone: **10** – no. 17/13244, female; **11** – no. 18/13244, male

Fig. 12, 13. *Costacythere foveata* Tesakova et Rachenskaya; Balki, Occitanica Zone: **12** – no. 132/13244, sample no. 41-3-1, female carapace, left lateral view; **13** – no. 133/13244, sample 38-3; female left valve, lateral view

Fig. 14. *Costacythere andreevi* Tesakova; no. 19/13244, sample 39-2-1, left valve, lateral view; Balki, Occitanica Zone

Fig. 15, 16. *Hechticythere belbekensis* Tesakova et Rachenskaya; **15** – no. 134/13244, sample 41-9-1, left valve, lateral view; Balki, Occitanica Zone; **16** – no. 20/13244, sample 26-1-1, right valve, lateral view; Balki, Occitanica Zone, Tauricum Subzone

Fig. 17. *Costacythere* sp.; no. 135/13244, sample 31-2-1, left valve, lateral view; Mezhgorie, Burulcha river, Boissieri Zone

Fig. 18. *Quasigermanites bicarinatus* aff. *moravicus* Pokorny; no. 136/13244, sample 26-1-1, carapace, right lateral view; Balki, Occitanica Zone, Tauricum Subzone

Fig. 19. *Cythereis* sp. B.; no. 21/13244, sample 39-2-1, right valve, lateral view; Balki, Occitanica Zone

Fig. 20, 21. *Schuleridea* ex gr. *juddi* Neale; Balki, Occitanica Zone: **20** – no. 137/13244, sample 39-3-1; **21** – no. 22/13244, sample 39-3-1, carapace, right lateral view

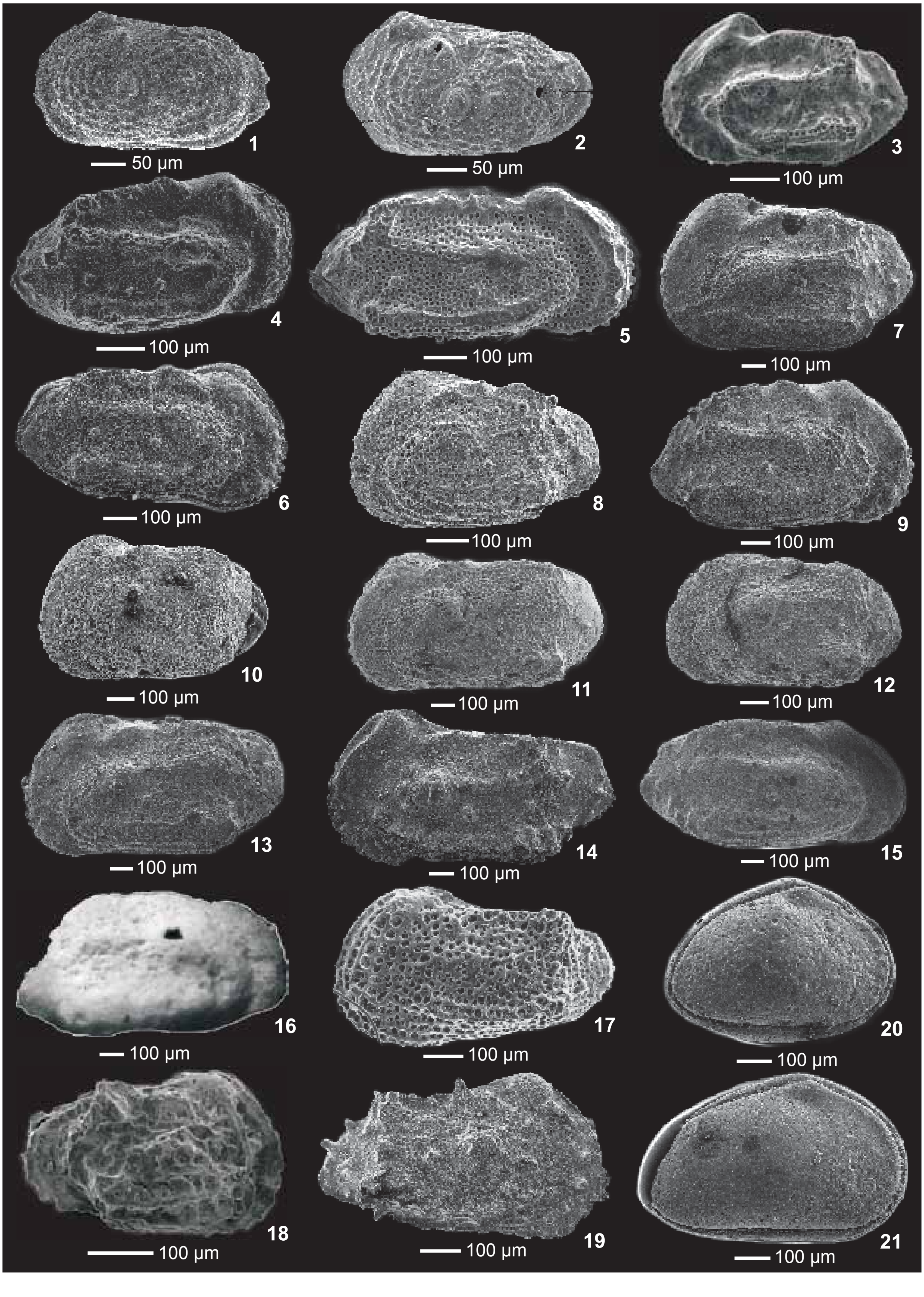

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PLATE 5

Berriasian dinocysts of central Crimea, Balki Village

Fig. 1. *Phoberocysta neocomica* (Gocht) Millioud, emend. Helby; 1a – ventral view, 1b – dorsal view; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 2. *Achomosphaera neptuni* (Eisenack) Davey et Williams; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 3, 4. ?*Hystrichosphaerina orbifera* (Klement) Stover et Evitt; slide 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 5. *Oligosphaeridium patulum* Riding et Thomas; no. 147/13220, sample 26-1-1; Occitanica Zone, Tauricum Subzone

Fig. 6. *Kleithriasphaeridium eoinodes* (Eisenack) Davey; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 7. *Cribroperidinium* sp.; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 8. *Epiplosphaera gochtii* (Fensome) Brenner; no. 147/13220, sample 26-1-1; Occitanica Zone, Tauricum Subzone

Fig. 9. *Scriniodinium campanula* Gocht; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 10. *Tanyosphaeridium* sp.; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 11. *Tanyosphaeridium isocalamum* (Deflandre et Cookson) Davey et Williams; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 12. *Protoellipsodinium* sp.; no. 147/13220, sample 26-1-1; Occitanica Zone, Tauricum Subzone

Fig. 13. *Circulodinium distinctum* (Deflandre et Cookson) Jansonius; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 14. *Circulodinium brevispinosum* (Pocock) Jansonius; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 15. *Dichadogonyaulax culmula* (Norris) Loeblich et Loeblich; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 16. *Ctenidodinium* sp.; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 17. ?*Dichadogonyaulax pannea* (Norris) Sarjeant; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 18. *Leptodinium* sp.; no. 148/13220, sample 27-1-1; Boissieri Zone, beds with *Symphythiris arguinensis*

Fig. 19 *Nannoceratopsis deflandrei* Evitt subsp. *deflandrei*; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

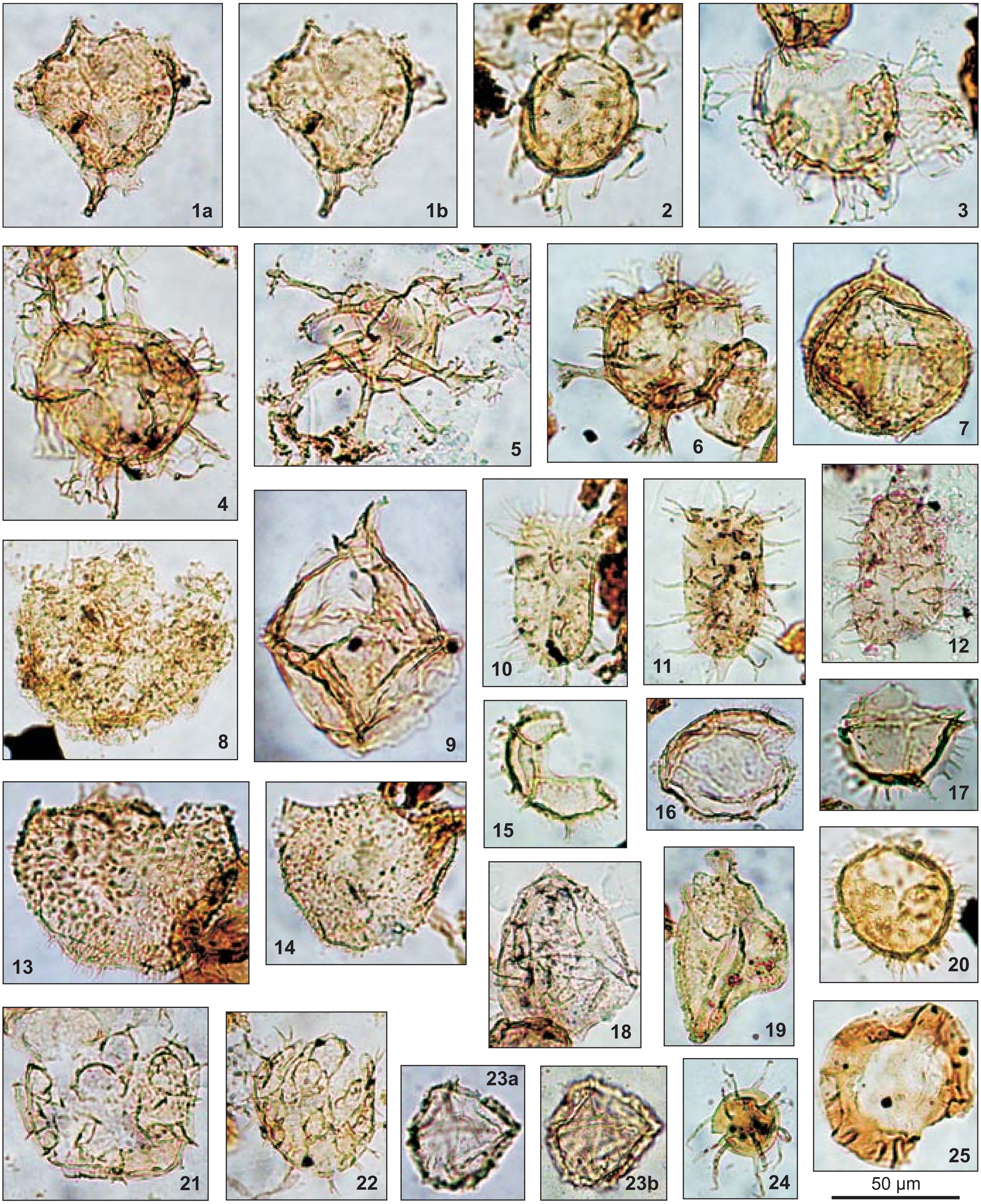
Fig. 20. *Epiplosphaera* ?*areolata* (Klement) Brenner; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 21, 22. *Systematophora areolata* Klement; no. 148/13220, sample 27-1-1; Boissieri Zone, beds with *Symphythiris arguinensis*

Fig. 23. *Stanfordella granulosa* Helenes et Lucas-Clark; 23a – ventral view, 23b – dorsal view; no. 148/13220, sample 27-1-1; Boissieri Zone, beds with *Symphythiris arguinensis*

Fig. 24. *Micrhystridium* sp.; no. 149/13220, sample 29-1-1; Occitanica Zone, Tauricum Subzone

Fig. 25. *Pterospermella* sp.; no. 148/13220, sample 27-1-1; Boissieri Zone, beds with *Symphythiris arguinensis*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