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Berriasian Stage of the Crimean Mountains: Zonal Subdivisions and Correlation

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Abstract—Biostratigraphy of the Berriasian Stage in the Crimean Mountains is specified and substantiated. Fragments of all the standard stage zones (*jacobi, occitanica*, and *boissieri*) are distinguished based on the found index species, and position of the Jurassic–Cretaceous boundary is targeted. According to verified distribution of ammonites, the *jacobi* Zone is divided into the *jacobi* and *grandis* subzones crowned by the *Malbosiceras chaperi* Beds. The *Tirnovella occitanica–Retowskiceras retowskyi* Beds and overlying *Dalmasiceras tauricum* Subzone are recognized in deposits of the *occitanica* Zone. The upward succession of biostratigraphic units established in the *boissieri* Zone includes the *Euthymiceras–Neocosmoceras* Beds, *Riasanites crassicostatus* Subzone, *Symphythyris arguinensis* and *Jabronella* sf. *paquieri–Berriasella callisto* Beds. The last biostratigraphic unit is suggested in this work instead the former *Zeillerina baksanensis* Beds. Except for the *jacobi* Zone, the substantiated ammonoid zonation is practically identical to the Berriasian biostratigraphic scale of the northern Caucasus, although the Berriasian–Valanginian boundary has not been defined in the Crimean Mountains based on ammonites. Several marker levels of bivalve mollusks and four biostratigraphic subdivisions of brachiopod scale are distinguishable here. As for the latter, these are (from the base upward) the *Tonasirhynchia janini, Belbekella airgulensis–Sellithyris uniplicata, Symphythyris arguinensis*, and *Zeillerina baksanensis* beds.

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Key words: Crimean Mountains, Berriasian, biostratigraphic scheme, ammonites, bivalves, brachiopods, correlation.

INTRODUCTION

The last biostratigraphic scheme of Berriasian deposits in the Crimean Mountains was suggested and substantiated 25 years ago (Bogdanova et al., 1981). In distinction from the previous schemes, where biostratigraphic zones had been defined (Kvantaliani and Lysenko, 1979a; Druschits and Gorbachik, 1979), the last one included mostly the local biostratigraphic subdivisions of the faunal bed rank. The only exception was the *ponticus–grandis* Zone, a part of the standard ammonite zonation in the Tethyan realm. Distinguishing of local stratigraphic units was a consequence of the complicated nappe structure of the Crimean Mountains (Kazantsev et al., 1989; Yudin, 2000) and high facies variability of the Berriasian deposits containing disjointed ammonite assemblages. Five type sections of the Berriasian Stage studied at that time (Bogdanova et al., 1981) corresponded to those of the southwestern, central and eastern Crimea, and of the Belbek and Tonas rivers (Fig. 1).

Researchers continued biostratigraphic investigations in the Crimea during the last 25 years. A team of stratigraphers from the St. Petersburg State University (SPGU) studied the Berriasian deposits of the Crimea in 1990s under guidance of A.Yu. Glushkov who identified a series of ammonite taxa important in terms of stratigraphy, the index species of standard zones inclusive, and suggested a new Berriasian zonation, though without comments to it (Glushkov, 1997a, 1997b). We regard that zonation as unsatisfactory especially in its lower half. Asserting that all the zones and subzones of the stage stratotype are recognizable in the Crimea, Glushkov defined nevertheless the local stratigraphic units only saying that "they are well distinguishable in the peninsula and can be correlated with zonations of the northern Caucasus and Mangyshlak" (Glushkov, 1997b, p. 99). Being aware of paleontological materials on the Berriasian of the Crimea, northern Caucasus and Mangyshlak, we doubt correctness of the last statement.

Beginning since 1982, Arkad'ev studied the Berriasian sections of the Crimean Mountains, in the later period of 2001–2004 in collaboration with Yu.N. Savel'eva (SPGU) and A.A. Fedorova (VNIGRI). Results of this work were used to revise considerably the Cretaceous stratigraphic scheme of the southwestern Crimea (*Atlas of the Cretaceous*…, 1997; Arkadiev et al., 2000, 2002) and to consider new data on distribu-

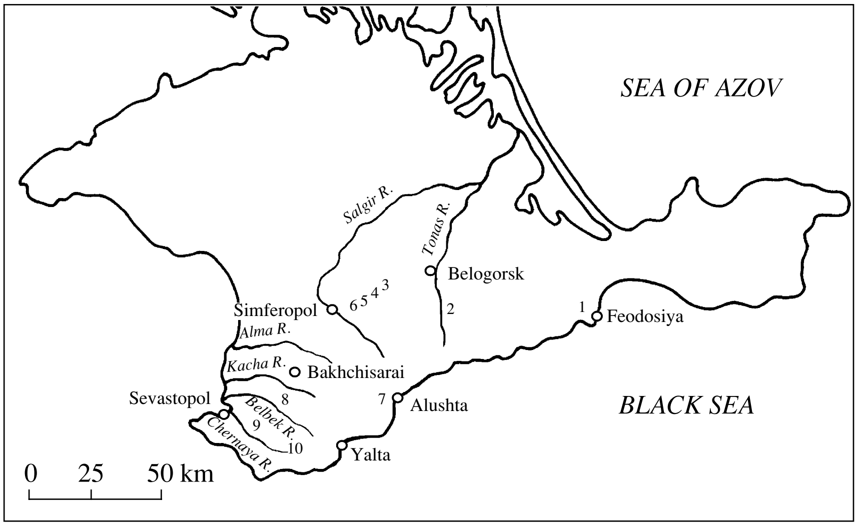

Fig. 1. Localities of the Berriasian sections studied in the Crimean Mountains: (1) eastern Crimea (Feodosiya, Svyatogo Il'i Cape, Dvuyakornaya Bay, villages of Ordzhonikidze, Sultanovka and Nanikovo); (2) Tonas River (village of Krasnoselovka, Kuchuk-Uzen Creek, and village of Alekseevka); (3) Enisarai Ravine, village of Balki and Sary-Su River, (4) Burulcha River, village of Mezhgor'e, (5) Fundukly River, village of Petrovo, (6) Beshterek River, village of Solov'evka, all in the central Crimea; (7) Chatyr-dag massif, Tas-Kor Ravine; (8) Belbek River (Kabanii and Sbrosovyi ravines, town of Kermenchik); (9, 10) southwestern Crimea: (9) Minester Ravine and (10) Chernaya River.

tion of ammonites, bivalves, and brachiopods in the Tonas River section of the Berriasian (Arkad'ev et al., 2005). At the same time there was reexamined the famous Feodosiya section of the eastern Crimea containing the ammonite assemblage known since the time of O. Retowski (1893), and the other scheme of the stage subdivision based on ammonites, foraminifers, and ostracodes was suggested (Arkad'ev, 2002, 2003a, 2004a, 2004b, 2004c; Arkad'ev and Savel'eva, 2002; Rogov et al., 2005; Arkadiev, 2005; Arkad'ev et al., 2006; Arkad'ev and Rogov, 2006).

In addition, Arkad'ev and Bogdanova revised the principal ammonite genera of stratigraphic importance from the Berriasian of the Crimean Mountains. Subjected to revision were ammonite specimens collected during more than fifty years by V.V. Druschits, N.I. Lysenko, B.M. Nerodenko, B.T. Yanin, T.N. Bogdanova, V.A. Prozorovskii, T.A. Favorskaya, S.V. Lobacheva, and A.Yu. Glushkov, and found recently by Arkad'ev, Savel'eva, and Fedorova. Ammonites from the Feodosiya section collected by Retowski and deposited in the TSNIGRMuseum of St. Petersburg have been reexamined as well. The Crimean ammonite genera studied in detail at present are *Dalmasiceras* (Bogdanova and Arkad'ev, 1999), *Berriasella* (Arkad'ev and Bogdanova, 2004), *Delphinella* (Arkad'ev and Bogdanova, 2005), *Pseudosubplanites* (Arkad'ev, 2003b; Bogdanova and Arkadiev, 2005), *Malbosiceras, Pomeliceras* (Arkad'ev et al., 2007), *Jabronella, Tirnovella*, and *Fauriella* (Arkad'ev, 2007a, 2007b).

In this work, we suggest a specified scheme of the Berriasian Stage subdivision in the Crimean Mountains (Table 1) that is based on new ammonites found in recent years with due account for their stratigraphic position and revision of paleontological materials collected earlier. The scheme was first expounded at the 3rd All-Russia Conference on the Cretaceous System held in Saratov in 2006 (Arkad'ev et al., 2006). The scheme is correlative well with ammonite zonation in the Urukh River section of the northern Caucasus (Sey and Kalacheva, 2000). In essence, it is close to zonations established in France and Spain and represents transitional link between the Mediterranean standard (Hoedemaeker et al., 2003) and the Caucasian regional scheme thus characterizing connections of ammonoid communities from these regions, which were variably close during separate time spans.

We distinguished parts of all three standard (*jacobi, occitanica*, and *boissieri*) zones in the Crimean Mountains (Arkad'ev and Bogdanova, 2004). To get a more high resolution, we also practiced recognition of units in the rank of ammonite beds. Some of these beds having persistent paleontological characterization and well-recognizable in the Crimean Mountains and northern Caucasus (Sey and Kalacheva, 2000) can be confidently correlated with subzones of the standard scale (Hoedemaeker et al., 2003), being ranked therefore as subzones, as it is done in this work with respect to the *Dalmasiceras tauricum* and *Riasanites crassicostatus* beds. After subsequent study of ammonite assemblages and Berriasian sections in the Crimean Mountains, all the ammonite beds can be ranked apparently as the respective subzones.

Ammonite, bivalve, and brachiopod specimens figured in the plates are stored in collections of the

Table 1. Berriasian ammonite zonations in the Crimean Mountains as suggested in different works

Mediterranean standard (Hoedemaeker et al., 2003)		Crimean Mountains: Kvantaliani and Lysenko, 1979		Crimean Mountains: Bogdanova et al., 1981	Crimean Mountains: Glushkov, 1997		Crimean Mountains: Arkad'ev et al., 2006; this work		Northern Caucasus (Sey and Kalacheva, 2000)	
Fauriella boissieri	*Thurmanniceras otopeta*	?		?	?		Valanginian	*otopeta* Zone	?	
	Thurmanniceras alpillensis			*Zeillerina baksanensis* Beds			*Fauriella boissieri*	?		
	Berriasella picteti	*Fauriella boissieri*			*Berriasella callisto*			*Jabronella cf. paquieri–Berriasella callisto* Beds	*Fauriella boissieri*	*Jabronella paquieri–Berriasella callisto* Beds
				?	*Fauriella simplicicostata*			?		*Riasanites rjasanensis – R. angulicostatus*
				Symphythyris arguinensis Beds				*Symphythyris arguinensis* Beds		
		Tauricoceras crassicostatus		*Tauricoceras crassicostatus* Beds	*Tauricoceras*			*Riasanites crassicostatus* Subzone		
	Malbosiceras paramimounum	*Euthymiceras euthymi*		*Euthymiceras–Neocosmoceras* Beds	*Euthymiceras – Balkites*			*Euthymiceras–Neocosmoceras* Beds		*Euthymiceras euthymi*
					Dalmasiceras khimchiachvili	?		?		*Riasanites rjasanensis – Spiticeras cautleyi*
Tirnovella occitanica	*Dalmasiceras dalmasi*	*Dalmasiceras dalmasi*		*Dalmasiceras crassicostatus* local zone			*Tirnovella occitanica*	*Dalmasiceras tauricum* Subzone	*Tirnovella occitanica*	*Dalmasiceras tauricum*
	Berriasella privasensis	*Spiticeras spitiense*		*Malbosiceras* (?) sp. Beds		*Berriasella privasensis*		*Tirnovella occitanica–Retowskiceras retowskyi* Beds		*Tirnovella occitanica*
	Tirnovella subalpina				*Subalpinites remanei*			?		*Mazenoticeras malbosiforme*
Berriasella jacobi		*P. grandis – B. jacobi* Zone	*Malbosiceras malbosi* Subzone		*Malbosiceras nikolovi*	*Delphinella janus*	*Berriasella jacobi*	*Malbosiceras chaperi* Beds		
			Pseudosubplanites euxinus Subzone	*Pseudosubplanites ponticus – P. grandis*				*Pseudosubplanites grandis*		
			Pseudosubplanites grandis Subzone		*Pseudosubplanites subrichteri*			*Berriasella jacobi*		

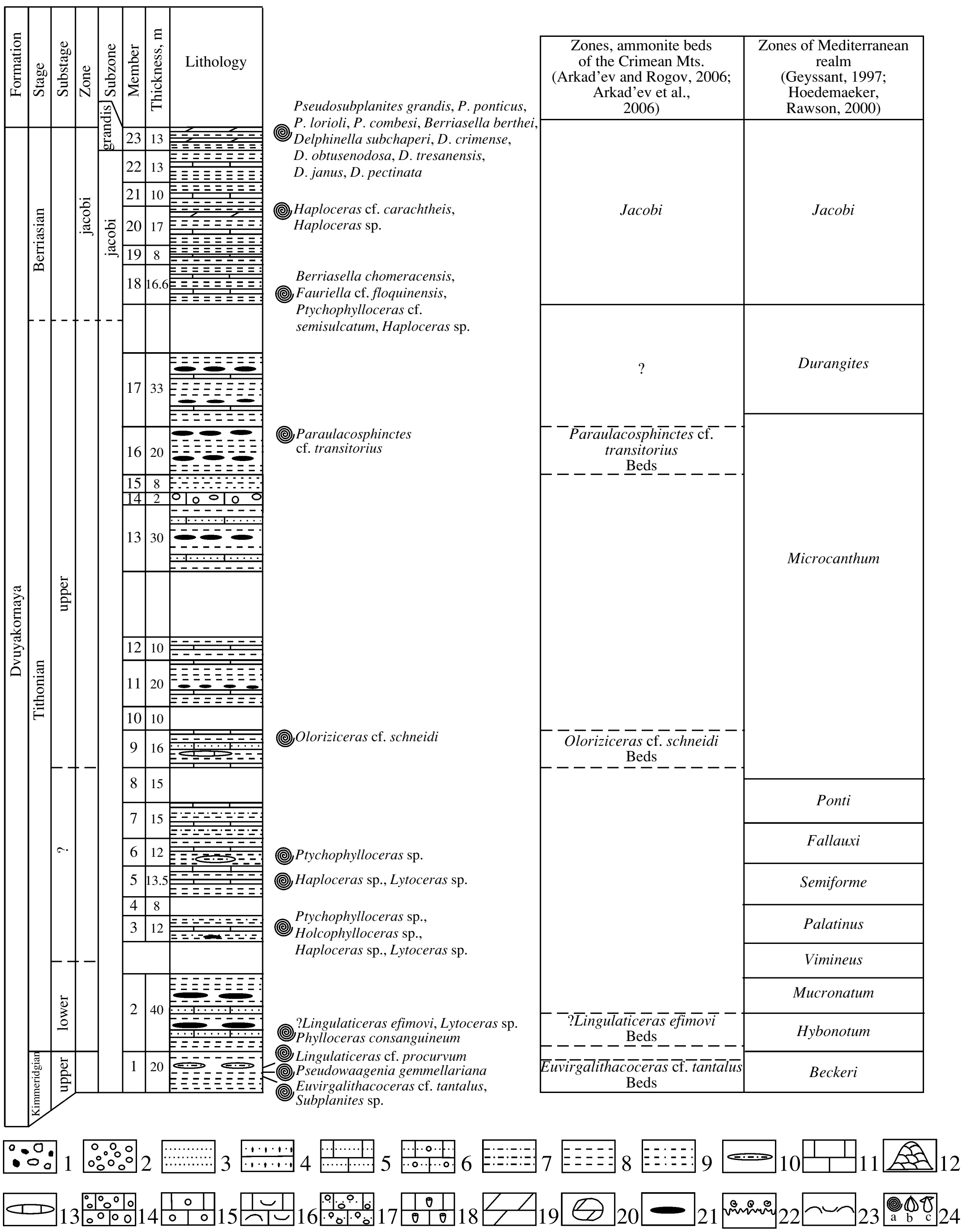

Fig. 2. Composite section of the Dvuyakornaya Formation, the eastern Crimea (Arkad'ev et al., 2006): (1) polymictic and (2) quartz conglomerates; (3) quartz, (4) glauconite, (5) calcareous, and (6) calcareous-oncolitic sandstones; (7) siltstones; (8) clays; (9) sandy clays; (10) aleuritic lentils; (11) limestones; (12) coral-algal bioherms; (13) limestone lentils; (14) conglomeratic, (15) oncolitic, (16) organogenic-detrital, (17) oncolitic gravel-pebbly, and (18) sponge limestones; (19) marls; (20) marly and (21) siderite nodules; (22) hardground; (23) coquinas; (24) occurrence levels of (a) ammonites, (b) brachiopods and (c) bivalves.

TSNIGRMuseum (nos. 10916, 12075, 12701, 12943, 12950, 13077, 13098, 13139, 13143, 13146, and 13147), museum of the St. Petersburg State Mining Institute (nos. 332 and 333), and Paleontological museum of the Chair of Geology and Paleontology of the Georgian Polytechnic Institute (no. 4).

TITHONIAN–BERRIASIAN BOUNDARY IN THE CRIMEAN MOUNTAINS

Problems of paleontological substantiation of the Jurassic (Tithonian) deposits and, consequently, of the Jurassic–Cretaceous boundary in the Crimean Mountains are inadequately solved so far. In many ridge areas of the mountains, this boundary is defined predominantly based on lithologic criteria: the upper part of thick carbonate succession lacking ammonites is conventionally attributed to the Tithonian, whereas the overlying sand-clayey deposits with ammonites are regarded as corresponding in age to the Berriasian. The eastern Crimea is the only region, where the boundary is detectable based on distribution of ammonites. In 2001–2004, a group of scientists headed by Arkad'ev discovered here the upper Tithonian ammonites *Oloriziceras* cf. *schneidi* Tavera and *Paraulacosphinctes* cf. *transitorius* (Oppel) in the Dvuyakornaya Formation section of uniform lithology (Fig. 2; Arkad'ev, 2004a, 2004b; Arkad'ev et al., 2004, 2006; Arkad'ev and Rogov, 2006). Unfortunately, ammonites were discovered not in a single succession with the Berriasian forms, but in a series of spaced outcrops, and the Jurassic–Cretaceous boundary has not been defined precisely therefore. The interval between beds bearing the upper Tithonian and Berriasian ammonites is 40 m thick at least. Species *O. schneidi* is described from the *simplisphinctes* Zone in Spain (Tavera, 1985), whereas *P. transitorius* is index species of synonymous zone in the Mediterranean region (Geyssant, 1997; Hoedemaeker and Rawson, 2000). In the Feodosiya section there were established accordingly the *Oloriziceras* cf. *schneidi* and *Paraulacosphinctes* cf. *transitorius* beds of the upper Tithonian *microcanthum* Zone.

THE *JACOBI* ZONE

Kvantaliani and Lysenko (1979a) originally distinguished this unit as the *Pseudosubplanites grandis*–*Berriasella jacobi* Zone divided into three units of lower rank (from the base upward): the *P. grandis, P. euxina*, and *Malbosiceras malbosi* subzones correlated with the *jacobi* and *grandis* zones and *subalpina* subzone of the *occitanica* Zone of southeastern France. They included the *malbosi* Subzone into the *grandis*–*jacobi* interval of their scale with certain reservations. Later on, the interval was renamed into the *ponticus*–*grandis* Zone corresponding in range to the *jacobi* and *grandis* zone of southeastern France in the work by Bogdanova et al. (1981) who studied the Berriasian sections and followed recommendations of the Cretaceous Commission of the ISC. The aforementioned authors mentioned themselves, however, that both zone boundaries and distribution of ammonites inside the zone remained problematic. In recent years, the zone used to be named for one index species *B. jacobi* only (Tavera, 1985; Rawson et al., 1999; Hoedemaeker et al., 2003; Arkad'ev and Bogdanova, 2004).

The most complete sections of the *jacobi* Zone are known in the vicinity of Feodosiya and near villages of Nanikovo and Sultanovka of the eastern Crimea. In 2001–2004, Arkad'ev who studied these sections obtained new data on distribution of ammonites inside the zone. In the Svyatogo Il'i Cape, the *jacobi* Zone has been traditionally regarded as spanning the 13-m-thick member of the Feodosiya Marl that bears in upper part the ammonite genera *Pseudosubplanites, Berriasella, Delphinella, Tirnovella, Retowskiceras*, and *Spiticeras.* Glushkov (1997a) identified in this assemblage the index species *P. grandis* (Mazenot) (Plate I, Fig. 4). In 2001, Arkad'ev found for the first time the Berriasian ammonites *Berriasella chomeracensis* (Touc.) and *Fauriella* cf. *floquinensis* Le Hég. at the level of 60 m below the Feodosiya Marl member (Fig. 2; Arkad'ev, 2003a). Beds bearing these ammonites were attributed to the *jacobi* Zone and ranked as the *chomeracensis* Subzone, whereas the Feodosiya Marl was correlated with the *grandis* Subzone (Arkad'ev and Savel'eva, 2002; Arkad'ev, 2003a). Thus, the *jacobi* Zone was considered as consisting of two lower-rank units, the *chomeracensis* and *grandis* subzones (Arkad'ev and Bogdanova, 2004). However, the *chomeracensis* species is known so far from the Feodosiya section only. On the other hand, Arkad'ev who studied distribution of *Berriasella* forms in the sections showed first that the *jacobi* forms tend to occur in the zone lower part and, second, that they are widespread beyond the eastern Crimea as well, i.e., in the central Crimea and the Tonas River basin. In section of the latter, *B. jacobi* was found close to the base of flyschoid sequence approximately 130 m below the member containing *Pseudosubplanites lorioli, P.* cf. *grandis, P.* cf. *ponticus* and others (Arkad'ev et al., 2005). This forced to replace the zonal index species *B. chomeracensis* for *B. jacobi* (Arkad'ev and Bogdanova, 2005; Arkad'ev et al., 2006). The *B. jacobi* occurrence level in the Tonas section is correlative with that of *B. chomeracensis* in the Feodosiya section.

The data on distribution of ammonites in the Feodosiya and Tonas sections are well consistent with data

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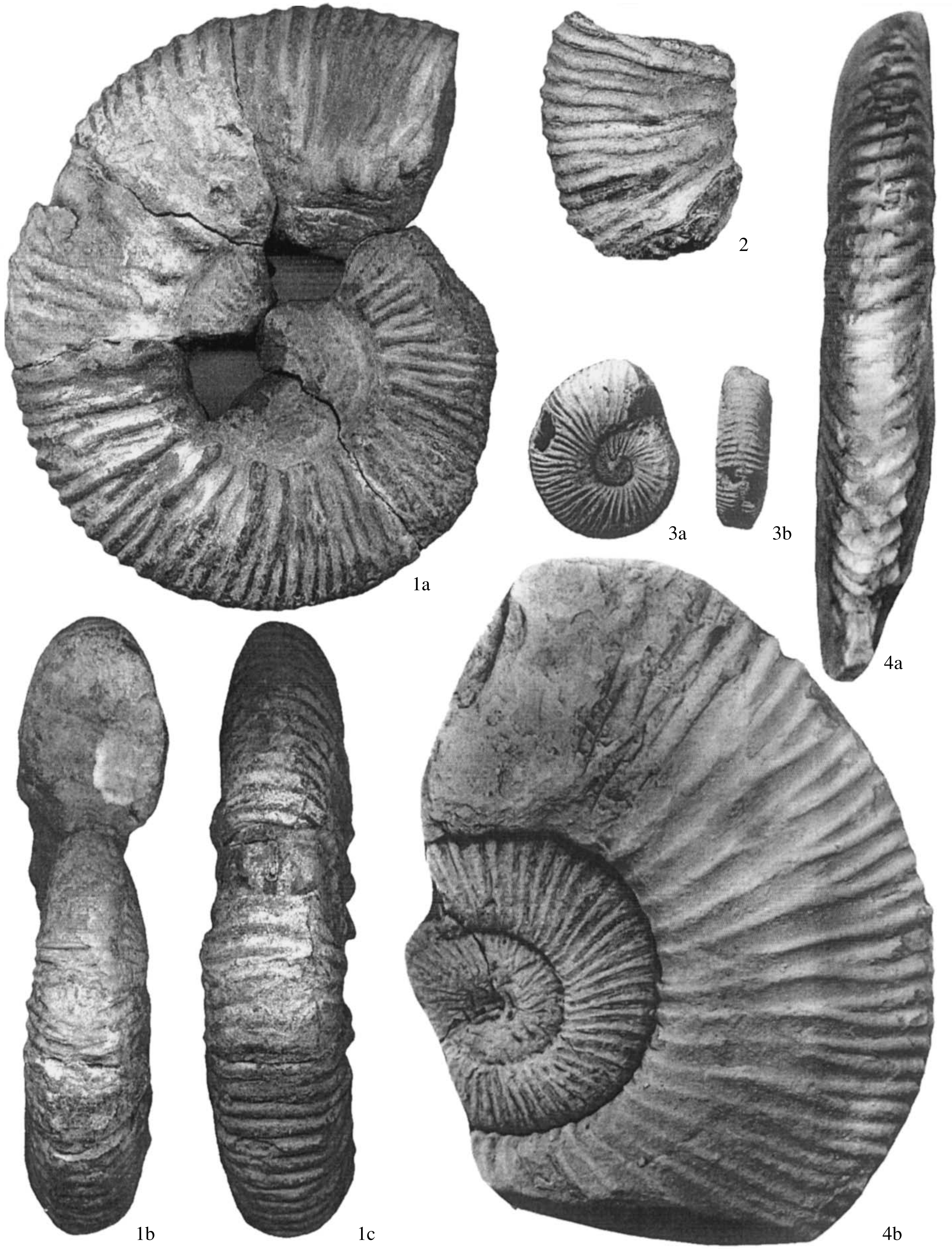
Plate I. Index ammonite species of the Berriasian Stage from the Crimean Mountains.

(1, 2) *Malbosiceras chaperi* (Pict.): (1) specimen no. 19/13143, (a) lateral (×1), (b) apertural (×1), and (c) ventral (×1) views; central Crimea, Enisarai Ravine, *jacobi* Zone, *M. chaperi* Beds, collections of V.V. Druschits and B.T. Yanin; (2) specimen no. 21/13143, lateral view (×1), the same locality and age, collection of T.N. Bogdanova. (3) *Berriasella jacobi* Maz., specimen no. 1/13098, (a) lateral (×1) and (b) ventral (×1) views; central Crimea, Sary-Su River, *jacobi* Zone, collection of V.V. Druschits. (4) *Pseudosubplanites grandis* (Maz.), specimen no. 18/13077, (a) ventral (×1) and (b) lateral (×1) views; eastern Crimea, Feodosiya, Svyatogo Il'i Cape, *jacobi* Zone, *grandis* Subzone, collection of A.Yu. Glushkov.

Plate I



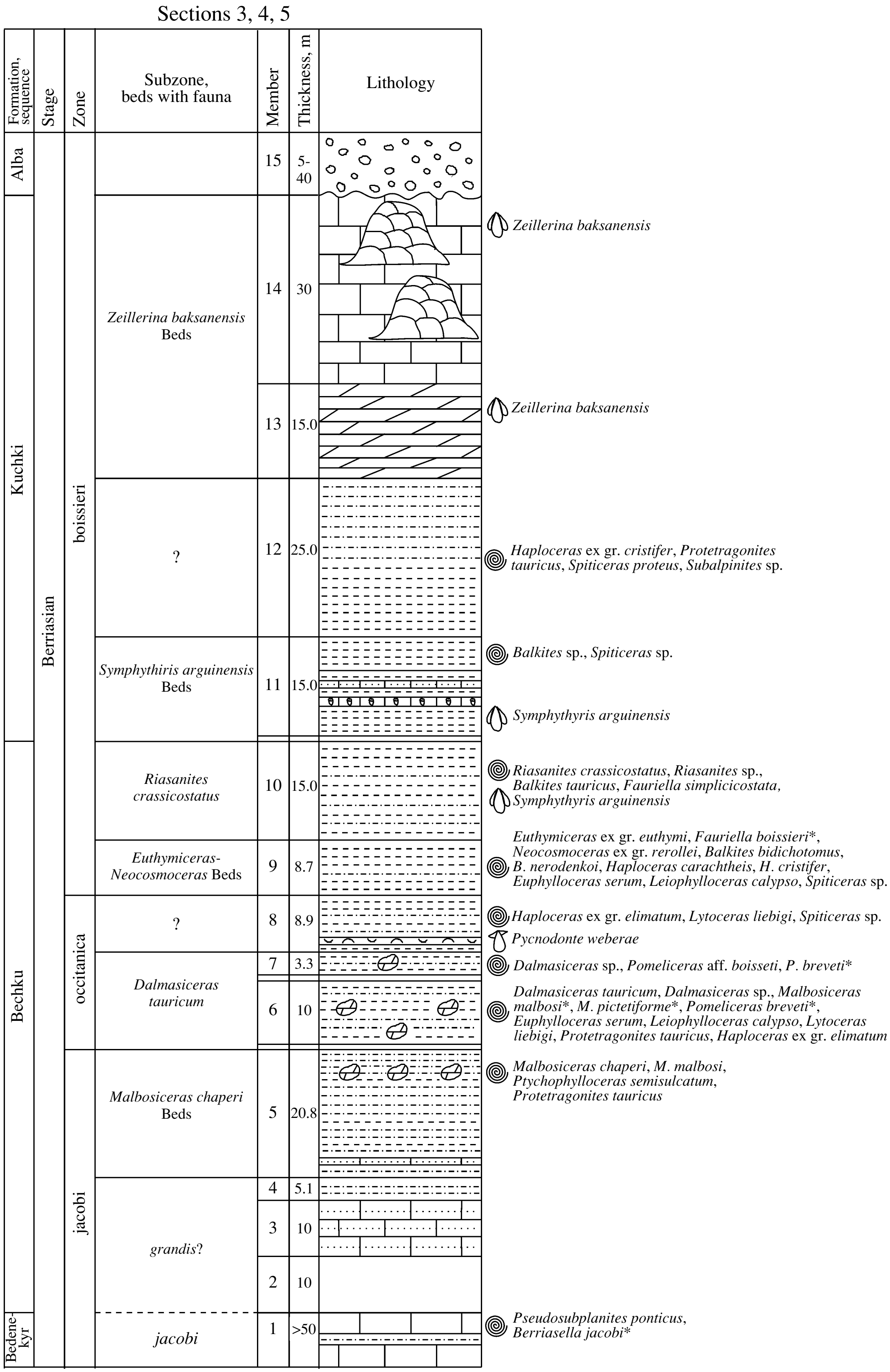


Fig. 3. Composite section of Berriasian deposits in the central Crimea, outcrops of the Enisarai Ravine, Sary-Su and Burulcha rivers (after original observations of Arkad'ev and data of Bogdanova et al., 1981; asterisks denote species with doubtful position in the section; symbols for lithology as in Fig. 2).

known from Tunisia in particular (Memmi and Salaj, 1975). Tavera et al. (1986) who analyzed the ammonite stratigraphy in Tunisia distinguished (from the base upward) the *chomeracensis, pseudogroteanum*, and *grandis* zones of the Berriasian. In Tunisia, species *B. chomeracensis* and *B. jacobi* also characterize the lower part of the Berriasian, but they occur here in association with the other *Berriasella* (*B. oppeli, B. berthei*) and *Delphinella* (*D. delphinensis*) forms.

Beyond the eastern Crimea, the *jacobi* Zone has been distinguished in the central Crimea (sections of the Enisarai Ravine and Sary-Su River), where occurrence of *Pseudosubplanites ponticus* (Ret.) is established (Bogdanova et al., 1981; Fig. 3). In addition, Arkad'ev and Bogdanova (2004) identified here the zonal index species *B. jacobi* though without its precise positioning in the section (Plate I, fig. 3). This taxon was derived, as the species *P. ponticus*, most likely from upper part of the clayey limestone sequence. Besides, we obtained new data concerning age of sand-clayey deposits overlying the *jacobi* Zone and containing ammonites *Malbosiceras malbosi* (Kvantaliani and Lysenko, 1979a) and *Malbosiceras (?)* sp. (Bogdanova and Kvantaliani, 1983). As is mentioned above, the occurrence of first taxon was used to distinguish the *malbosi* Subzone in the *grandis–jacobi* Zone, whereas the *Malbosiceras (?)* sp. Beds of greater range than that of the subzone in the scheme by Kvantaliani and Lysenko were attributed to the *occitanica* Zone. After a careful examination of specimen identified earlier by Bogdanova with *Malbosiceras (?)* sp., Arkad'ev et al. (2007) showed that it can be attributed to species *M. chaperi* (Plate I, fig. 2). Moreover, the *chaperi* form was identified among specimens collected by Druschits and Yanin from the same section (Plate I, fig. 1). Distribution of this taxon in southeastern France is constrained by the *jacobi* Zone (Le Hégarat, 1973), and the section part under consideration can be included therefore into the range of the *jacobi* Zone. Taking this into account, we suggest distinguishing the *Malbosiceras chaperi* Beds of the Crimean Mountains corresponding in range to the *jacobi* Zone upper part. The beds have higher stratigraphic position than the occurrence level of *Pseudosubplanites grandis* (Table 1). There is no doubt that the suggested biostratigraphic unit should be carefully studied further, because it changes to a great extent the acknowledged distribution scheme of ammonites in the *jacobi* Zone (Le Hégarat, 1973). As is known, Le Hégarat constrained distribution of the *chaperi* form by the *jacobi* Zone corresponding in range to synonymous lower subzone of the *jacobi* Zone in the later biostratigraphic schemes.

In the Berriasian sections of the central Crimea, Arkad'ev discovered species *Malbosiceras malbosi* at the occurrence level of *M. chaperi* (Arkad'ev et al., 2007). In southeastern France, the distribution range of *malbosi* form corresponds predominantly to the *boissieri* Zone (Le Hégarat, 1973). In opinion of Arkad'ev, stratigraphic range of this form is much wider in the Crimea: from upper part of the *jacobi* Zone up to the *boissieri* Zone.

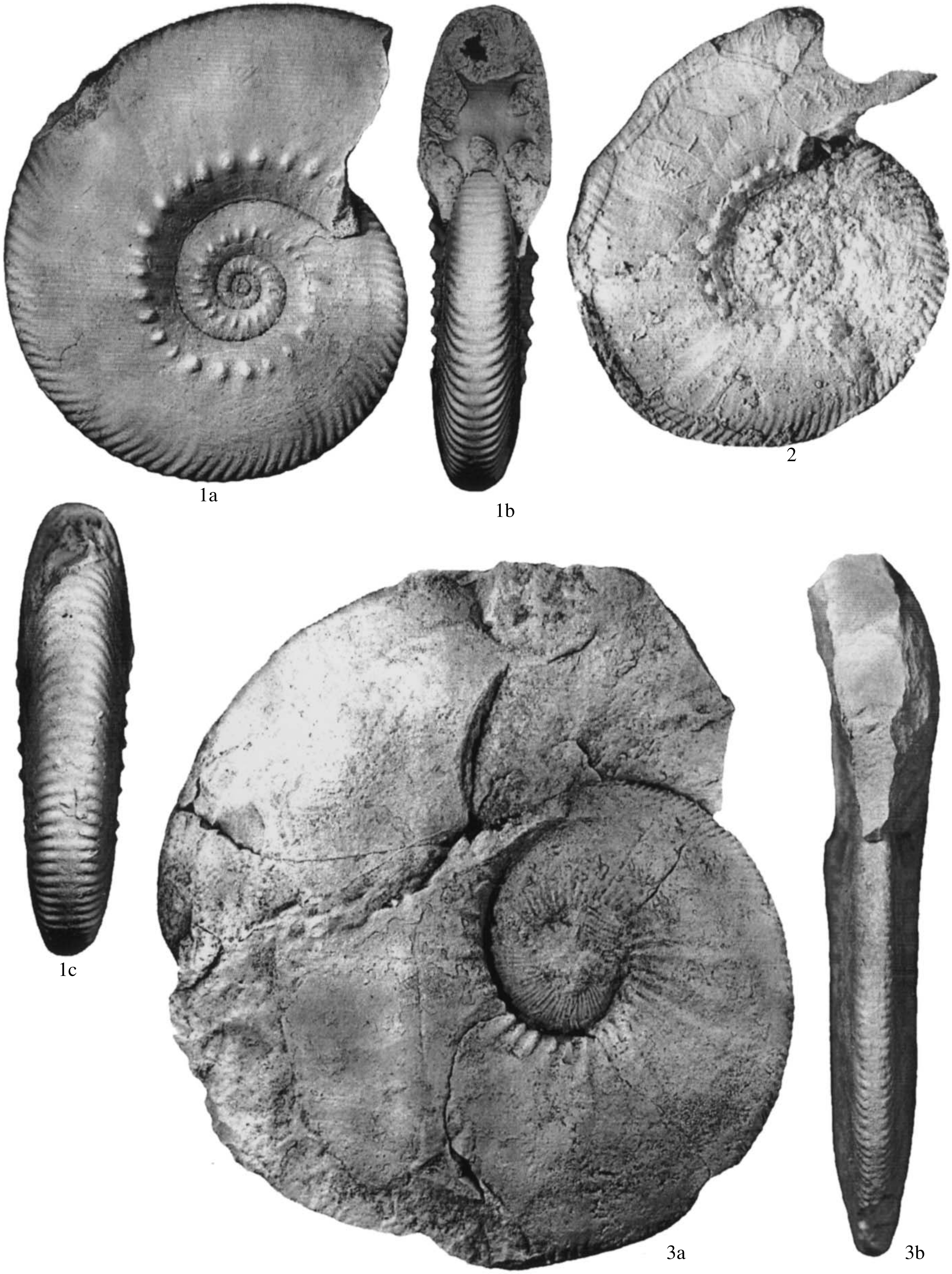
We cannot agree with the scheme of subdivisions suggested for the interval under consideration by Glushkov who distinguished, having specimens of *Pseudosubplanites grandis* and *Berriasella jacobi* in his collection, the *Pseudosubplanites subrichteri* Beds at the Berriasian base. Above this subdivision, he recognized the *Delphinella janus–Berriasella privasensis* and concurrent *Malbosiceras nikolovi–Subalpinites remanei* beds (Table 1). In the Berriasian stratotype, however, the *Delphinella* species is characteristic in general of the lower part of the standard *jacobi* Zone, being confined in the Crimea to this zone exactly (Bogdanova et al., 1981; Arkad'ev and Bogdanova, 2005). Despite the new data obtained, there are still the unsolved problems concerning lower and upper boundaries of the *jacobi* Zone in the Crimean Mountains.

THE *OCCITANICA* ZONE

Being fragmentary, sections of this zone are incomplete practically everywhere in the Crimean Mountains, and its lower part is missing most likely. Index species *Tirnovella occitanica* of the zone was described long ago by Retowski (1893) from the Feodosiya section, where its precise position remained unclear. On the Svyatogo Il'i Cape there are no natural outcrops of deposits directly overlying sediments of the *jacobi* Zone, which are exposed in the Feodosiya surroundings (the outcrops probably existed in the XIX century, being now eliminated by the town housing development). The *occitanica* specimen from collection of Retowski (Plate II, fig. 3) has been revised (Bogdanova et al., 1999), and the *occitanica* Zone is distinguished in the Feodosiya section based on the revision results.

At the Zavodskaya Ravine site in the Feodosiya suburbs northward of the Svyatogo Il'i Cape, there are exposures of dark gray clays different from outcrops of light-colored marls on the cape. Specimens of *T. occitanica* could be collected by Retowski from these clays. Anyway, ammonites *Retowskiceras retowskyi* Kvant. (Plate IV, fig. 1), *Neocosmoceras, Jabronella*, and maybe some others have been undoubtedly collected by Retowski from clays of the Zavodskaya Ravine site. The *Retowskiceras* forms are known at the level of the *occitanica* Zone in southeastern Spain (Tavera, 1985), and we suggest to define the respective section interval as the *T. occitanica–R. retowskyi* Beds approximately corresponding in range to the *privasensis* Subzone. The arguments in favor are the *T. occitanica* epibole at this level in France, on the one hand, and the beds position below sediments containing *Dalmasiceras* forms and correlative with the *occitanica* Zone upper part, on the other. Occurrence of *Dalmasiceras* in clays of the Feodosiya section has been reported by Druschits (1975). Arkad'ev and Bogdanova actually identified specimen of *Dalmasiceras* sp. from clays of the Zavodskaya Ravine in collections of Druschits. The *T. occitanica–*

Plate II



R. retowskyi Beds can be correlated with the *T. occitanica* of the Urukh River section of the northern Caucasus (Sey and Kalacheva, 2000), where ammonites *Tirnovella* cf. *occitanica* have been found. Besides, the *occitanica* forms occur in the Assa River section of the northern Caucasus, as is reported (Sakharov, 1975, 1976).

Above the *T. occitanica–R. retowskyi* Beds, we distinguish the *Dalmasiceras tauricum* Subzone well recognizable in many sections of the Crimea. Revising representatives of the genus *Dalmasiceras* from the Crimea, Bogdanova and Arkad'ev (1999) analyzed in detail their distribution in the section and distinguished the *D. tauricum* Beds (Plate II, fig. 1), which represent an equivalent of the *D. crassicostatus* local zone recognized formerly in the Crimea (Bogdanova et al., 1981). In subsequent work (Arkad'ev et al., 2002), the last unit was ranked as a zone based on distribution of ammonites in the Belbek section of the southwestern Crimea (Fig. 4). Discussing at present the *occitanica* Zone of the Crimean section, it is more reasonable however to rank the biostratigraphic unit under consideration as a subzone. Beyond the southwestern Crimea, the *D. tauricum* Subzone is well recognizable in the Tonas River basin of the central Crimea and, judging from occurrence of *Dalmasiceras* sp. in the Feodosiya suburbs (Zavodskaya Ravine site), in the eastern Crimea also. At the level of the *Dalmasiceras tauricum* Subzone, Glushkov (1997b) distinguished the *Dalmasiceras khimchiachvilii* Beds of essentially wider stratigraphic range. As in France the last taxon occurs above the *dalmasi* Subzone, Glushkov enlarged the range of beds containing *Dalmasiceras* forms in the Crimea. Our examination of ammonites collected by Glushkov showed that specimens identified by him as *D. khimchiachvilii* actually represent species *D. belbekense* characteristic of the *D. tauricum* Subzone in the Crimea and of synonymous unit in the northern Caucasus (Bogdanova and Arkad'ev, 1999). Sey and Kalacheva (2000) who studied representatives of the genus *Dalmasiceras* from the Caucasus arrived at the conclusion that they are practically identical to the Crimean forms in the species composition (Plate II, fig. 2) and probably in the stratigraphic range. We consider this as a reason for renaming the *crassicostatus* Subzone of the Caucasus into the *D. tauricum* Subzone (Table 1). As the ammonite assemblage of *D. tauricum* Subzone of the Crimea–Caucasus region includes species *D. punctatum*, this biostratigraphic unit is reliably correlative with the *dalmasi* Subzone of the stage stratotype and can be regarded as a confident biostratigraphic marker, because the *dalmasi* Subzone of identical range is included practically in all stratigraphic schemes suggested for the Berriasian Stage of southern Europe.

THE *BOISSIERI* ZONE

The Berriasian Stage upper part is attributed in the Crimea to the *Fauriella boissieri* Zone. Many researchers noted occurrence of the respective index species in the Crimean Mountains, though without describing and figuring it. The species has been found in the Belbek River basin (Druschits and Yanin, 1958) and Baidarskaya Valley (Lychagin, 1969) of the southwestern Crimea and in section near the village of Balki (Druschits and Yanin, 1959) of the central Crimea. Sazonova and Sazonov (1974) listed this species among ammonite taxa from the Eastern Crimea, although later on researchers failed to find it here. After examination of Crimean collections, Arkad'ev (2007a, 2007b) showed that species *F. boissieri* is present for sure in the Sary-Su River section of the Central Crimea (Plate III, fig. 7; collection of Druschits) and in the Chatyr-Dag massif section (Plate III, fig. 6; collection of Lysenko). Thus, the zone in question is a reliable biostratigraphic unit of the Crimea. Dividing it into lower-rank units, we distinguished separate ammonite beds as in the lower part of the Berriasian.

The *Euthymiceras–Neocosmoceras* Beds distinguished as the lower subdivision of the *F. boissieri* Zone coincide in name with respective unit in the scheme of 1981 (Bogdanova et al., 1981), being of somewhat narrower range however. Representatives of both genera from the Berriasian of the Crimean Mountains are inadequately studied. Their single specimens from the Kabanii Ravine of the Belbek River basin (southwestern Crimea) are poorly preserved, identifiable at the generic level only. In a more representative collection of small intact shells representing genera *Euthymiceras* and *Neocosmoceras*, Bogdanova identified species *E.* ex gr. *euthymi* (Pictet) (Plate III, fig. 5) and *N.* ex gr. *rerollei* (Paquieri) (Plate III, figs. 3, 4) sampled near the village of Balki (central Crimea). This collection should be revised later on.

In sections of the Crimean Mountains, boundary between the *occitanica* and *boissieri* zones is of variable character. In the Kabanii Ravine section, zones are closely spaced, and the barren interval of 1.5 m only separates here beds containing *Dalmasiceras* forms from the occurrence level of *Euthymiceras* and *Neocosmoceras* (Bogdanova and Arkad'ev, 1999; Arkad'ev et al., 2002; Fig. 5). In the section near the village of

Plate II. Index ammonite species of the Berriasian Stage from the Crimean Mountains.

(1, 2) *Dalmasiceras tauricum* Bog. et Ark.: (1) specimen no. 4/333, (a) lateral (×1), (b) apertural (×1), and (c) ventral (×1) views; southwestern Crimea, Belbek River, *occitanica* Zone, *D. tauricum* Subzone, collection of V.V. Arkad'ev; (2) specimen no. 25/12950, lateral view (×1); Northern Caucasus, Urukh River, *occitanica* Zone, *D. tauricum* Subzone, collection of E.D. Kalacheva and I.I. Sey. (3) *Tirnovella occitanica* (Pictet), specimen no. 110/10916, (a) lateral (×1) and (b) ventral (×1) views; eastern Crimea, Feodosiya, Berriasian, *occitanica* Zone, collection of O. Retowski.

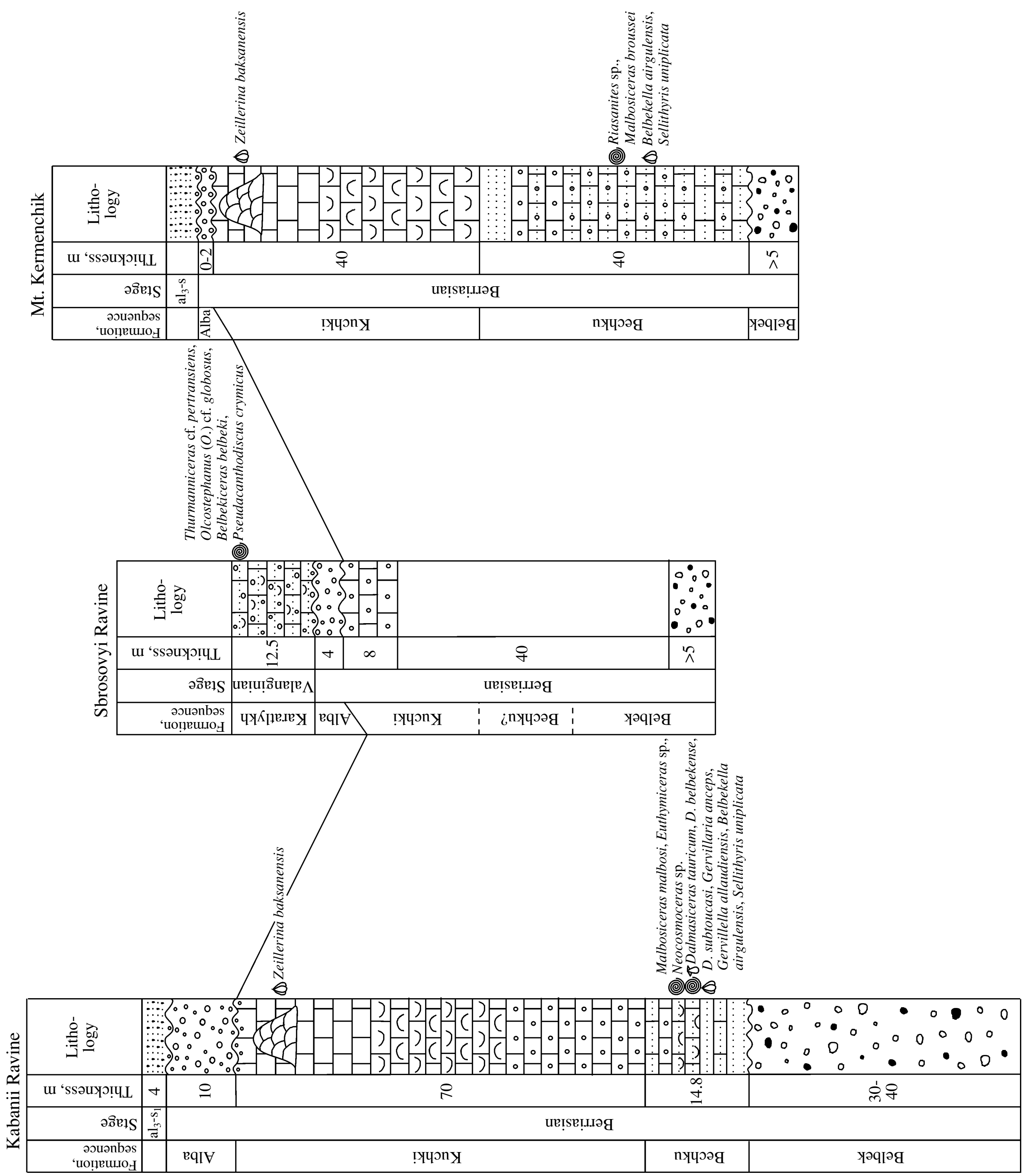


Fig. 4. Sections of Berriasian deposits in the Belbek River basin (after observations of Arkad'ev; symbols for lithology as in Fig. 2).

Balki, the last occurrence level of the genus *Dalmasiceras* is separated from first occurring *Euthymiceras* forms by the interval of 7.5 m (Bogdanova and Kavantaliani,1983), and beds containing representatives of genera *Dalmasiceras* and *Euthymiceras* are disjoined therefore. In the Urukh River section of the Northern Caucasus, the *D. tauricum* Subzone is separated from the *Euthymiceras euthymi* Subzone, which is correlative with the above beds, by the *Riasanites rjasanensis–Spiticeras cautleyi* Subzone (Table 1). The last subzone established in the Caucasus may correspond in the central Crimea to the beds barren of ammonites. We do not exclude also that the respective sediments represent a part of the condensed bed in the Belbek River section. According to hypothesis of Sey and Kalacheva (1999), there was no first migration wave of *Riasanites* forms to the west from their radiation center in the northern Caucasus, and this explains why they do not occur under the *Euthymiceras* Beds in the Crimean sections. In the Belbek River section of the southwestern Crimea, ammonites close to species *Malbosiceras malbosi* and *M. paramimounum* have been found in the *Euthymiceras–Neocosmoceras* Beds above the occurrence level of the genus *Dalmasiceras* (Bogdanova and Arkad'ev, 1999), and the *Euthymiceras–Neocosmoceras* Beds can be correlated therefore with the *paramimounum* Subzone of the *boissieri* Zone distinguished in many regions. It is very likely that specimen of *Fauriella boissieri* stored in collection of Druschits from the Sary-Su River section was sampled from the *Euthymiceras–Neocosmoceras* Beds. This is evident from the preservation degree of the specimen, although we failed to establish its precise stratigraphic position.

The overlying stratigraphic unit has been formerly termed the *Tauricoceras* Beds. Being well recognizable near the village of Petrovo and in the Sary-Su River section of the central Crimea, the beds in question are distinguished above the *Euthymiceras–Neocosmoceras* Beds (Fig. 2). In their time, Kvantaliani and Lysenko (1979a) distinguished the *Tauricoceras crassicostatus* Zone (Plate III, fig. 2). As we established, *Fauriella simplicicostata* (Mazenot) in collection of Yanin was sampled from the *Tauricoceras* beds in the Sary-Su River basin. Glushkov (1997b) defined in his scheme the *Fauriella simplicicostata* Beds, assuming that the only specimen of this taxon in the collection was sampled near the village of Mezhgor'e from a sequence of siltstones and sandstones above the *Tauricoceras* and *Symphythyris arguinensis* (Sponge Horizon) beds. According to results of our consultation with Yanin, the specimen is however from the *Tauricoceras* Beds. According to Le Hégarat (1973), species *F. simplicicostata* is known in the stratotype area from the *paramimounum* and *picteti* subzones, being especially characteristic of the latter. Hence, stratigraphic position of the beds in the Sary-Su River section is very clear. At the Fundukly River, their relations with the other Berriasian subdivisions is problematic however, because characteristic Berriasian ammonites, except for representatives of the genus *Tauricoceras*, have not been found here as yet.

Paleontologists who studied in detail ammonites of genera *Riasanites* and *Tauricoceras* arrived at the conclusion that the latter is younger synonym of the genus *Riasanites* (Sey and Kalacheva, 1997; Howarth and Morris, 1998; Wright et al., 1996). New species of the Crimean genus *Tauricoceras*, which have been described by Kvantaliani and Lysenko (1979b, 1982), have been discovered also in the northern Caucasus, where Kalacheva and Sey established the *Riasanites rjasanensis–R. angulicostatus* Subzone and correlated it with the *picteti* Subzone of the stage stratotype (Table 1; Plate III, fig. 1). In the Crimea, the section interval with *Riasanites crassicostatus*[1] corresponds only, as we believe, to lower part of the *R. rjasanensis–R. angulicostatus* Subzone. Our opinion is based on the fact that a part of the Crimean section below the *Jabronella paquieri–Berriasella callisto* Beds of identical ranges in the Caucasus and Crimea is barren of the guide ammonite species (the Sponge Horizon and beds without characteristic fauna). Age of the Sponge Horizon is problematic as yet despite abundant brachiopods *Symphythyris arguinensis* (Moisseev) found in this subdivision. Lysenko and Popov (1962) and then Kuznetsov and Shemyakin (1965) have reported on occurrence of *Fauriella boissieri* in the Sponge Horizon of the southwestern Crimea, but our investigations do not confirm this fact. In the Sponge Horizon of the Sary-Su River basin, Arkad'ev has found *Balkites* sp. and *Spiticeras* sp., which do not suggest the unit affiliation with a particular ammonite zone. Based on position in the section, we tentatively regard the Sponge Horizon as a part of the *picteti* Subzone of the *boissieri* Zone.

The *Jabronella* cf. *paquieri–Berriasella callisto* Beds distinguished in the topmost Berriasian of the Crimea correspond most likely to synonymous beds at the top of the Urukh section in the northern Caucasus (Table 1). The beds are readily recognizable in section of the Tas-Kor Ravine on northern slope of the Chatyr-Dag massif (the Mramornoe quarry in surroundings of synonymous village). The Berriasian deposits are exposed here in a separate fault-bounded tectonic block and overlie denuded surface of limestones of the same age (opinion of Lysenko), being represented by clays and siltstones of about 60 m thick (Fig. 5). Abundant belemnite rostra *Duvalia* sp., bivalves *Gervillella anceps* (Deshayes in Leymerie), and corals *Montlivaltia* sp. (Lysenko and Vakhrushev, 1974) occur in clays filling sagged pockets at the contact with limestones. Arkad'ev identified here *Fauriella boissieri* (Pictet), *Malbosiceras malbosi* (Pictet) and *M. chaperi* (Pictet). Approximately 5 m above the limestone top, there is second occurrence level of abundant fossils. Dominant at this level are large (up to 200 mm in diameter) shells of *Malbosiceras malbosi* (Pictet) found in association with *Berriasella* sp., *B. callisto* (d'Orbigny) (Plate IV,

[1] Synonym of *R. rjasanensis* in opinion of Sey and Kalacheva (1999).

Plate III

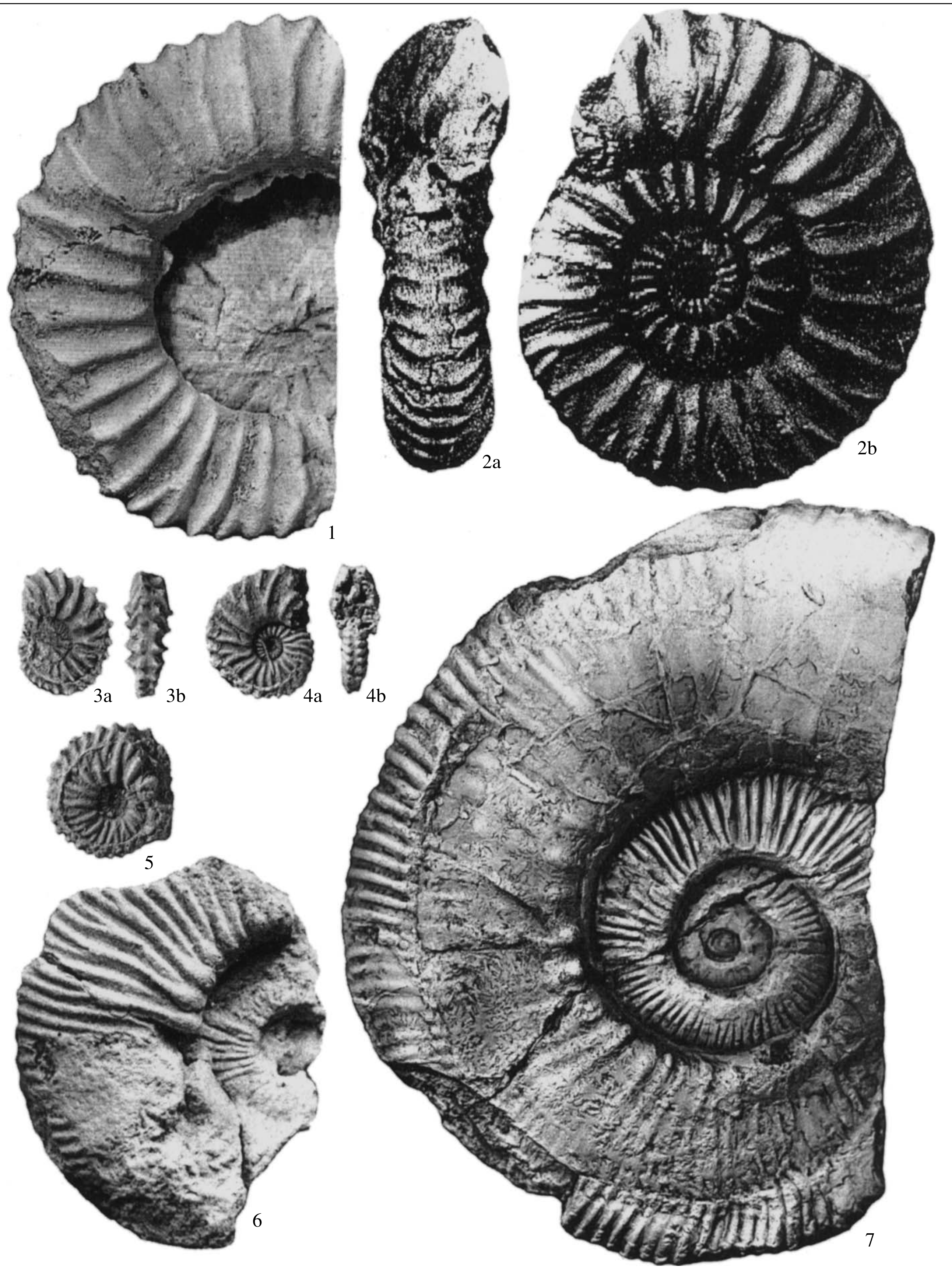


fig. 2), *Jabronella* cf. *paquieri* (Simionescu) (Plate IV, fig. 3), *Fauriella* sp., *F. rarefurcata* (Pictet), *Tirnovella* sp., and *T. alpillensis* (Mazenot). Siltstones fine- to medium-grained are loose and can be easily broken by hands. At this level, all ammonites are compressed, deformed and replaced by siltstone material. In distinction from them, ammonites of the lower level near limestones retained in general their morphology. Besides ammonites, siltstones contain bivalves, brachiopods, aptychi, shark teeth, and plant detritus. Ammonites of different zones are identified at the sequence base: *Fauriella boissieri* is typical of synonymous zone of the upper Berriasian, while *Malbosiceras chaperi* is a taxon of the *jacobi* zone only, being redeposited therefore. Ammonites of the second level (*B. callisto, F. boissieri, F. rarefurcata, T. alpillensis, J.* cf. *paquieri*) are characteristic in France predominantly of middle and upper parts of the *boissieri* Zone, whereas species *M. malbosi* is dominant taxon of the lower *paramimounum* Subzone. In general, the ammonite assemblage appears to be typical of the *boissieri* Zone upper part (*picteti* Subzone). To specify our scheme of the Berriasian biostratigraphy, we include in it the *Jabronella* cf. *paquieri–Berriasella callisto* Beds instead the *Zeillerina baksanensis* Beds. In addition, Arkad'ev identified species *Jabronella paquieri* in collection of Glushkov from the Minester Ravine, the southwestern Crimea.

BERRIASIAN–VALANGINIAN BOUNDARY IN THE CRIMEAN MOUNTAINS

The issue has been already expounded in work by Arkad'ev (2007b). Here we should mention only that the problem of the Berriasian–Valanginian boundary in the Mediterranean region is debatable, because stratigraphic ranges of some ammonite genera and species of the upper Berriasian are imprecisely defined as yet. For instance, there have been published data on occurrence of *Tirnovella alpillensis* in the *otopeta* Zone and *Fauriella boissieri* in lower part of the Valanginian *pertransiens* Zone in Spain (Company, 1987). In Morocco, these species are also known from the *otopeta* Zone (Aguado et al., 2000; Wippich, 2003). As a result, the *otopeta* Zone has been transposed into the Berriasian to be the upper subzone of the *boissieri* Zone according to last resolutions of the "Kilian Group" on the Berriasian–Valanginian boundary in the Mediterranean region (Hoedemaeker et al., 2003).

None of the sections in the Crimean Mountains is suitable for observation of successive stratigraphic units substantiated by paleontological data and characterizing uninterrupted transition from the upper Berriasian to lower Valanginian. The Valanginian deposits transgressively overlap here either the lower Berriasian beds and Jurassic sequences, or the Tavricheskaya Group rocks. The only site, where E.Yu. Baraboshkin established based on ammonites the lower Valanginian deposits of the *pertransiens* Zone (*Atlas of the Cretaceous*..., 1997; Arkad'ev et al., 2002) is section of the Sbrosovyi Ravine in the Belbek Valley (Fig. 4). Deposits with ammonites of the *otopeta* Zone known in the other region of the southwestern Crimea, namely in the Kacha and Bodrak river basins (Baraboshkin and Mikhailova, 2000), can be also appropriate for defining the concrete position of the Berriasian–Valanginian boundary, as they discordantly overlie here the Tavricheskaya Group rocks. In the Crimean Mountains, species *Tirnovella alpillensis* and *Fauriella boissieri* have not been found so far in association with ammonites of the *otopeta* or *pertransiens* zones of the lower Valanginian (Baraboshkin and Mikhailova, 2000). In such a situation, it is impossible either to accept or to disprove soundly the resolutions of the "Kilian Group" based on biostratigraphic data from the Crimea.

CHARACTERISTIC BIVALVE ASSEMBLAGES FROM THE CRIMEAN MOUNTAINS

About a hundred of bivalve species are known from the Berriasian deposits of the Crimean Mountains. They have been collected mostly from sections of the central Crimea (near villages of Balki, Mezhgor'e, Petrovo, Solov'evka, and others) and from outcrops of the Belbek River basin in the southwestern Crimea. These fossils are irregularly distributed in sections forming sometimes monotypic coquinas useful for stratigraphic orientation in those horizons, which are barren of ammonites (Table 2).

Bivalve species most important in terms of stratigraphy are *Neithea simplex* Mord. (Plate V, fig. 4), *Plesiopecten subspinatus* (Schloth.) (Plate IV, figs. 9, 10), *Pycnodonte weberae* (Yanin in Tschelzova) (Plate V, figs. 1, 2), *Rhynchostreon tombeckianum* (d'Orb.) (Plate IV, fig. 5), *Myophorella loevinsonlessingi* (Ren.)

Plate III. Index ammonite species of the Berriasian Stage from the Crimean Mountains.

(1) *Riasanites rjasanensis* (Nikitin), specimen no. 55/12950, lateral view (×1); Northern Caucasus, Urukh River, *boissieri* Zone, *R. rjasanensis–S. cautleyi* Subzone, collection of E.D. Kalacheva and I.I. Sey. (2) *Riasanites crassicostatus* (Kvant. et Lys.), specimen no. 4(3017/I-10) (holotype), (a) apertural (×1) and (b) lateral (×1) views; central Crimea, village of Petrovo, Fundukly River, collection of N.I. Lysenko. (3, 4) *Neocosmoceras* ex gr. *rerollei* (Paq.): (3) specimen no. 74/134, (a) lateral (×1) and (b) ventral (×1) views; (4) specimen no. 75/134, (a) lateral (×1) and (b) apertural (×1) views; central Crimea, village of Balki, *boissieri* Zone, *Euthymiceras–Neocosmoceras* Beds, collection of T.N. Bogdanova. (5) *E.* ex gr. *euthymi* (Pict.), specimen no. 1/12943, lateral view (×1), the same locality, age and collection. (6, 7) *Fauriella boissieri* (Pict.), (6) specimen no. 3/13146, lateral view (×1), central Crimea, Chatyr-Dag massif, Tas-Kor Ravine, *boissieri* Zone, *Jabronella* cf. *paquieri–Berriasella callisto* Beds, collection of N.I. Lysenko; (7) specimen no. 1/13146, lateral view (×1); central Crimea, Sary-Su River, *boissieri* Zone, collection of V.V. Druschits.

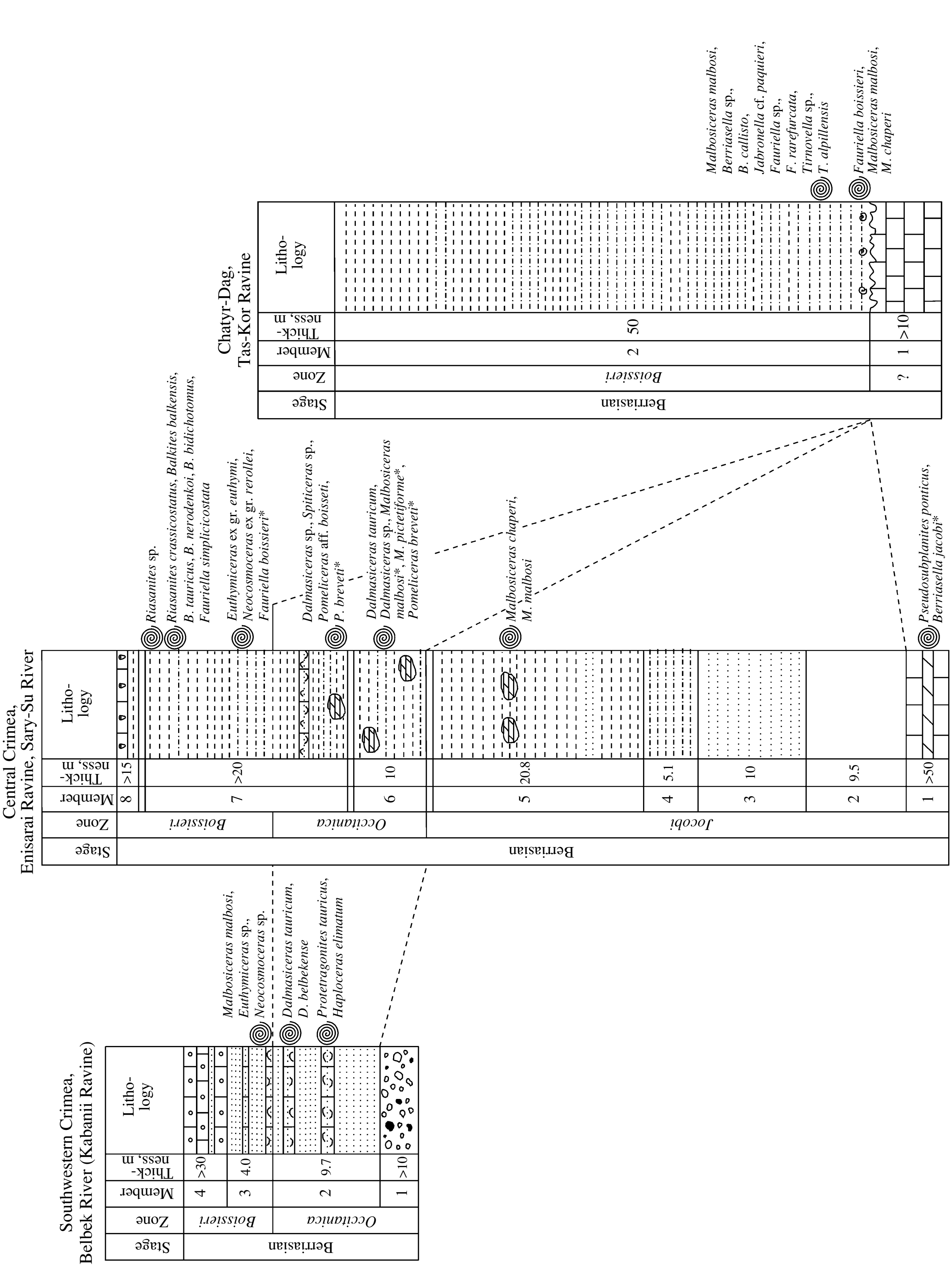


Fig. 5. Correlation scheme for Berriasian sections of the southwestern to central Crimea and the Chatyr-Dag massif (asterisks denote species with doubtful position in the section; symbols for lithology as in Fig. 2).

Table 2. Berriasian zonation and characteristic ammonite, bivalve and brachiopod assemblages from the Crimean Mountains

Mediterranean standard (Hoedemaecker et al., 2003)		Crimean Mountains: Bogdanova et al., 1981	Crimean Mountains: Arkad'ev et al., 2006; this work		Crimean Mountains: Fossil assemblages: Ammonites	Crimean Mountains: Fossil assemblages: Bivalves	Crimean Mountains: Fossil assemblages: Brachiopods
Fauriella boissieri	*Thurmanniceras otopeta*	?	Valanginian	*Otopeta* Zone	*Kilianella otopeta*, *K.* cf. *pexiptycha*, *K. roubaudiana*, *Thurmanniceras gueymardi*, *Bodrakiceras* ex gr. *inostranzewi* and others (after Baraboshkin and Mikhailova, 2000)		
Fauriella boissieri	*Thurmanniceras alpillensis*	*Zeillerina baksanensis* Beds	Fauriella boissieri	?		*Spondylus dutempleanus*, *Inoperna gillieroni*, *Ctenoides neocomiensis*, *Lima gemmata*, *Antiquilima dubisiensis* var. 2	*Zeillerina baksanensis* Beds *Zeillerina baksanensis*, *Mesocrania barskovi*, *Echinirhynchia nucleatoformis*, *Cyclothyris rectimarginata*, *Adoposia lorioli*, *Krimargirotheca concinna*, *Symphythyris kojnautensis*, *Terebrataliopsis quadrata*
Fauriella boissieri	*Berriasella picteti*	*Zeillerina baksanensis* Beds	Fauriella boissieri	*Jabronella paquieri*–*Berriasella callisto* Beds	*Jabronella* cf. *paquieri*, *Berriasella callisto*, *Timovella alpillensis*, *Fauriella boissieri*, *F. rarefurcata*, *Malbosiceras malbosi*		
Fauriella boissieri	*Berriasella picteti*	?	Fauriella boissieri	?	*Haploceras* ex gr. *cristifer*, *Spiticeras proteus*, *Protetragonites tauricus*	*Gervillaria terekensis*, *Neithea atava*, *Antiquilima dubisiensis* var. 2, *Rhynchostreon subsinuatum*, *Rutitrigonia longa*	
Fauriella boissieri	*Berriasella picteti*	*Symphythyris arguinensis* Beds	Fauriella boissieri	*Symphythyris arguinensis* Beds	*Balkites* sp., *Spiticeras* sp.		*Symphythyris arguinensis* Beds *Symphythyris arguinensis*, *Conocrania spinocostatus*, *Echinirhynchia balkensis*, *Monticlarella korlukensis*, *Dictyothyris spinulosa*, *Ismenia perillustris*, *Weberithyris moisseivi*
Fauriella boissieri	*Berriasella picteti*	*Tauricoceras crassicostatus* Beds	Fauriella boissieri	*Riasanites crassicostatus* Subzone	*Fauriella simplicicostata*, *Riasanites crassicostatus*, *R. irregularis*, *R. tuberculatum*, *Balkites balkensis*, *B. tauricus*, *B. nerodenkoi*, *Pomeliceras* (?) *funduklense* sp. nov.	*Antiquilima dubisiensis*, *Inoperna gillieroni*, *Arcomytilus couloni*, *Lithophaga auberso-nensis*, *Rutitrigonia longa*, *Pholadomya gillieroni*	
Fauriella boissieri	*Malbosiceras paramimounum*	*Euthymiceras*–*Neocosmoceras* Beds	Fauriella boissieri	*Euthymiceras*–*Neocosmoceras* Beds	*Euthymiceras* ex gr. *euthymi*, *Neocosmoceras* ex gr. *rerollei*, *Malbosiceras malbosi*, *Fauriella boissieri*, *Berriasella* (*Hegaratella*) *jauberti*	*Spondylus complanatus*, *Plesiopecten subspinatus*	*Belbekella airgulensis*–*Sellithyris uniplicata* beds *Belbekella airgulensis*, *B. mutabilis*, *Praecyclothyris gracilis*, *P. berriasensis*, *Sellithyris uniplicata*, *S. gratianopolitensis*, *Loriolithyris valdensis*, *Zeillerina walkeriformis*, *Psilothyris airgulensis*
Fauriella boissieri	*Malbosiceras paramimounum*	*Euthymiceras*–*Neocosmoceras* Beds	Fauriella boissieri	?			
Timovella occitanica	*Dalmasiceras dalmasi*	*Dalmasiceras crassicostatus* local zone	Tirnovella occitanica	*Dalmasiceras tauricum* Subzone	*Dalmasiceras tauricum*, *D. belbekense*, *D. subtoucasi*, *Malbosiceras malbosi*, *M. broussei*, *M. pictetiforme*, *Pomeliceras breveti*, *P.* aff. *boisseti*, *Fauriella* sp.	*Nanonavis gabrielis*, *Gervillaria anceps*, *Neithea simplex*, *Plesiopecten subspinatus*, *Inoperna gillieroni*, *Pycnodonte weberae*, *Platymyoidea agassizi*, *Gervillella allaudiensis*	
Timovella occitanica	*Berriasella privasensis*	*Malbosiceras* (?) sp. Beds	Tirnovella occitanica	*Tirnovella occitanica*–*Retowskiceras retowskyi* Beds	*Tirnovella occitanica*, *Retowskiceras retowskyi*, *Berriasella moesica*		
Timovella occitanica	*Tirnovella subalpina*	*Malbosiceras* (?) sp. Beds	Tirnovella occitanica	?			
Berriasella jacobi		*Malbosiceras* (?) sp. Beds	Berriasella jacobi	*Malbosiceras chaperi* Beds	*Malbosiceras chaperi*, *M. malbosi*	*Syncyclonema germanica*, *Antiquilima* ex gr. *dubisiensis* sp. nov., *Ceratostreon minos*, *Integricardium deshayesianum*	
Berriasella jacobi		*Pseudosubplanites ponticus*–*P. grandis*	Berriasella jacobi	*Pseudosubplanites grandis*	*Pseudosubplanites grandis*, *P. ponticus*, *P. subrichteri*, *P. lorioli*, *P. combesi*, *P. crymensis*, *P. fasciculatus*, *Delphinella subchaperi*, *D. crimensis*, *D. obtusenodosa*, *D. tresanensis*, *D. delphinensis*, *D. janus*, *D. pectinata*, *Fauriella shipkovensis*, *Berriasella oppeli*, *B. subcallisto*, *B. berthei*, *Retowskiceras andrussowi*, *Spiticeras orientale*		*Tonasirhynchia janini* Beds *Tonasirhynchia janini*, *Rhactorhynchia corallina neocomiensis*, *Lacunosella* ex gr. *malbosi*, *L.* cf. *montsalvensiformis*, *Symphythyris substriata*, *S. latirostris*, *Ismenia pectunculoides*, *Dictyothyris* sp., *Tropeothyris* sp. (ex gr. *immanis*), "*Rhynchonella*" *subvariabilis*
Berriasella jacobi		*Pseudosubplanites ponticus*–*P. grandis*	Berriasella jacobi	*Berriasella jacobi*	*Berriasellajacobi*, *B. chomeracensis*, *B.* sp., *Fauriella* cf. *floquinensis*		

Plate IV

(Plate IV, fig. 6), *Antiquilima dubisiensis* (Pict. et Camp.) (Plate V, figs. 6, 7), *Inoperna gillieroni* (Pict. et Camp.) (Plate IV, fig. 4), *Arcomytilus couloni* (Marcou) (Plate V, fig. 5), *Ptychomya* ex gr. *kouensis* Krymh., *Gervillaria* cf. *terekensis* Renng., *G. allaudiensis* (Matheron) (Plate IV, fig. 8), and *Gervillella anceps* (Deshayes in Leymerie) (Plate IV, fig. 7). All the species, except for *Plesiopecten subspinatus* and *Pycnodonte weberae*, determine the Berriasian age of their host deposits. Among two rare species *Ptychomya kouensis* and *Gervillaria terekensis*, the first one is known from the Berriasian deposits of the Kopetdag; the second taxon from the Berriasian of the northern Caucasus. The widespread species *Neithea simplex, Myophorella loewinsonlessingi, Antiquilima dubisiensis, Inoperna gillieroni*, and *Arcomytilus couloni* are known from sections of the northern Caucasus, Turkmenistan, and Mangyshlak. Species *Pycnodonte weberae* is local endemic unknown outside the Crimea. *Pycnodonte* forms unknown for a long time from deep horizons of the Lower Cretaceous have been regarded as fossils constrained in their stratigraphic range by the Upper Cretaceous, and Chel'tsova (1969) initially considered them as species of the genus *Gryphaea.* Later on, representatives of the genus *Pycnodonte* were discovered in the Berriasian and lower Valanginian of the Mangyshlak (Bogdanova, 1978, 1980).

Another interesting form is *Plesiopecten subspinatus.* Distribution range of the genus *Plesiopecten* was considered until recent time as constrained by the Jurassic. In the Berriasian of the Crimean Mountains, the above species has been discovered for the first time (Arkad'ev et al., 2005). Species *Rhynchostreon tombeckianum* has morphological features transitional between those of the Jurassic *Nanogyra* and Cretaceous *Amphydonte* (*The Berriasian of Mangyshlak*, 1988; Arkad'ev et al., 2005).

The greatest amount of bivalve shells have been collected from upper part of the *jacobi* Zone, *Malbosiceras chaperi* Beds, *Dalmasiceras tauricum* and *Riasanites crassicostatus* subzones, and from the upper Berriasian horizons (Table 2). Shells and casts of *Syncyclonema germanica* (Plate V, fig. 3) occur as mass burials in the *Malbosiceras chaperi* beds of the central and southwestern Crimea. Coquinas composed of *Pycnodonte weberae* (central Crimea), *Gervillella* and *Gervillaria* (Belbek River basin) are confined to the *Dalmasiceras tauricum* Subzone. Species *Antiquilima dubisiensis, Inoperna gillieroni*, and *Arcomytilus couloni* are abundant in the *Riasanites crassicostatus* Subzone (the Fundukly River, central Crimea). Dominant in upper Berriasian horizons (*Zeillerina baksanensis* beds of the former scheme) are different varieties of *A. dubisiensis* and *I. gillieroni* (village of Mezhgor'e, central Crimea). In terminology of Mordvilko (1953), these mass accumulations of fossil bivalve are of the marker type, because they are well recognizable in the study region and represent reliable stratigraphic reference levels.

BRACHIOPOD BIOSTRATIGRAPHIC SUBDIVISIONS OF THE BERRIASIAN IN THE CRIMEAN MOUNTAINS

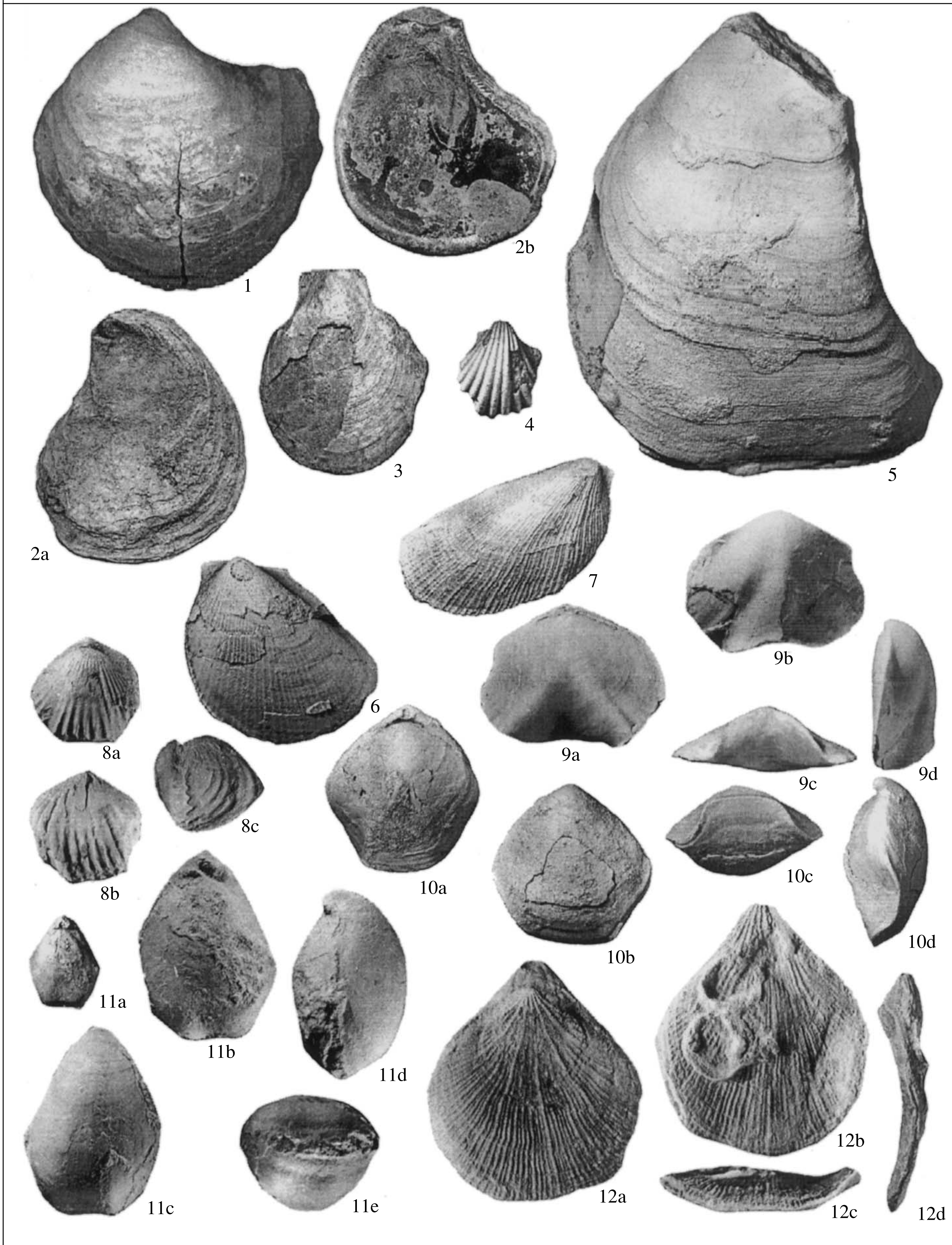
Brachiopods represent one of the fossil groups occurring most frequently in the Berriasian marine shallow-water deposits of the Crimea. Specimens of brachiopod species are abundant, as a rule, and often occur in accumulations and coquina interlayers. Three brachiopod orders of very diverse taxonomic composition are represented by 44 species of 27 genera and 14 families. Terebratulids most diverse among these fossils largely correspond to reefal forms confined to biohermal and clay-aleuritic facies.

Being well-preserved and regularly occurring, brachiopods have been used to distinguish four biostratigraphic subdivisions (brachiopod beds) correlated with the Berriasian ammonite zones of the Crimea (Bogdanova et al., 1981; Lobacheva, 1983). Distribution of brachiopods in separate intervals of the Berriasian succession (the *Malbosiceras chaperi, Tirnovella occitanica* and *Retowskiceras retowski* beds), which are studied to a lesser extent than the other ones, is inadequately known as yet. Naturally, the brachiopod beds span greater intervals than the ammonite beds, but they are nevertheless comparable in range with subzones. The oldest *Tonasirhynchia janini* Beds (Plate V, fig. 9) yield 7 species of 6 genera, dominant among which are

Plate IV. Index ammonite and characteristic bivalve species of the Berriasian Stage from the Crimean Mountains.

(1) *Retowskiceras retowskyi* Kvant., specimen no. 296/1, lateral view (×1); eastern Crimea, Feodosiya, Zavodskaya Ravine, *occitanica* Zone, *T. occitanica–R. retowskyi* Beds, collection of T.N. Bogdanova. (2) *Berriasella callisto* (d'Orb.), specimen no. 21/13098, lateral view (×1), central Crimea, Chatyr-Dag massif, Tas-Kor Ravine, *boissieri* Zone, *Jabronella* cf. *paquieri–Berriasella callisto* Beds, collection of N.I. Lysenko. (3) *Jabronella* cf. *paquieri* (Sim.), specimen no. 3/13147, lateral view (×1); the same locality and age, collection of V.V. Arkad'ev and N.I. Lysenko. (4) *Inoperna gillieroni* (Pict. et Camp.), specimen no. 43/332, right valve (×1); southwestern Crimea, Belbek River, Berriasian, collection of V.V. Arkad'ev. (5) *Rhynchostreon tombeckianum* (d'Orb.), specimen no. 21/13139, (a, b) external view of upper valve (×1 and ×3, respectively); Tonas River, Kuchuk-Uzen Creek, *jacobi* Zone, collection of V.V. Arkad'ev. (6) *Myophorella loewinsonlessingi* (Renn.), specimen no. 23/332, right valve (×1); southwestern Crimea, Bel'bek River, Berriasian, collection of V.V. Arkad'ev. (7) *Gervillella anceps* (Desh. in Leym.), specimen no. 28/332, left valve (×1); the same locality, age and collection. (8) *Gervillaria allaudiensis* (Math.), specimen no. 18/332, left valve (×1); the same locality, age and collection. (9, 10) *Plesiopecten subspinatus* (Schloth.): (9) specimen no. 375, (a) lateral view (×2) and (b) right valve (×2); southwestern Crimea, village of Kuchki, Berriasian, collection of B.T. Yanin; (10) specimen no. 8/13139, right valve (×5); central Crimea, village of Mezhgor'e, Burul'cha River, collection of V.V. Arkad'ev.

Plate V


1
2b
5
2a
3
4
7
9b
6
8a
9a
9c
9d
8c
10a
10c
8b
10d
10b
11a
11b
11d
12b
12a
12c
12d
11c
11e

Tethyan forms close in composition to the Tithonian–lower Berriasian brachiopod assemblages known from southeastern France, Stramberk, Slovakia, and Poland. Sediments of the beds are widespread in the eastern Crimea, Tonas River basin, and central Crimea.

The *Belbekella airgulensis–Sellithyris uniplicata* Beds (Plate V, figs. 8, 10) are most completely represented in outcrops of sandy limestones of the southwestern (Belbek River basin) and central (outcrops near the village of Balki) Crimea. Characteristic of these beds is appearance of abundant brachiopod species representing the Cretaceous genera *Belbekella, Loriolithyris, Sellithyris, Praecyclothyris, Psilothyris, Advenina*, and *Zeillerina.* Many of these species are widespread as well in concurrent deposits of the northern Caucasus, Mangyshlak, France, and Switzerland. This is indicative of broad connections between the Berriasian basins of the Crimea, western and eastern Mediterranean regions.

Brachiopods of the next *Symphythyris arguinensis* Beds (Plate V, fig. 12) concurrent to sponge bioherms and underlying clay-siltstone-limestone sequence with ammonites of the genus *Riasanites* are very diverse (16 species of 14 genera). They are represented by endemic forms characteristic of these beds only: *Craniscus spinocostatus* Smirn., *Echinirhynchia balkinensis* Smirn., *Symphythyris arguinensis* (Moiss.), *Dictyothyris spinulosa* Smirn., and others, which are abundant in sponge bioherms of the central and southwestern (Baidarskaya Valley) Crimea.

The *Zeillerina baksanensis* Beds (Plate V, fig. 11) correspond to the upper subdivision of the Crimean brachiopod scale. They contain 15 species of 14 brachiopod genera practically represented by the local forms only. Brachiopods of the beds are especially diverse in bioherms and underlying calcareous siltstones and marls of the central Crimea (villages of Mezhgor'e and Solov'evka) and also in bioherms of southwestern Crimea (the Belbek River basin). The brachiopod assemblage from the beds includes *Craniscus barskovi* Smirn., *Echinirhynchia nucleatoformis* Smirn., coquinas of diverse terebratulids, *Weberithyris moisseevi* (Weber) and *Symphythyris kojnautensis* (Moiss.) inclusive, megathyrid and thesideid forms, etc. (Table 2). Brachiopods of similar diversity are unknown from Berriasian sections of the other regions.

CONCLUSION

Based on fieldworks of recent years and revision of paleontological collections, primarily of ammonites, we got insight into the high-resolution biostratigraphy of the Berriasian Stage in the Crimea. The substantiated biostratigraphic zonation is well correlative with the schemes suggested earlier for the Crimea and northern Caucasus (Druschits, 1975; Kvantaliani and Lysenko, 1979a; Bogdanova et al., 1981), except for the scheme of Glushkov (1997b). At the same time, our careful analysis showed that the Berriasian succession in the study region includes a series of hiatuses, which should be studied further. Such a situation is normal, as we believe.

In the Crimean Mountains, we discovered all index species of the standard *jacobi, occitanica*, and *boissieri* zones of the Berriasian Stage. Accordingly, we distinguished fragments of these zones containing ammonite assemblages comparable in specific and generic composition to assemblages known from sections of France and Spain. As the Crimean sections are incomplete and ammonite assemblages are disjoined, we divided the established zone fragments into subordinate units of the ammonite beds rank.

According to distribution ranges of ammonites, the *jacobi* Zone is divided into the *jacobi* and *grandis* subzones crowned by the *Malbosiceras chaperi* Beds. Lower part of the *occitanica* Zone is missing nearly from all the sections of the Crimean Mountains, which are fragmentary. In deposits attributed to the *occitanica* Zone, we distinguished (from the base upward) the *Tirnovella occitanica–Retowskiceras retowskyi* Beds

Plate V. Characteristic bivalve and brachiopod species of the Berriasian Stage from the Crimean Mountains.

(1, 2) *Pycnodonte weberae* (Yanin): (1) specimen no. 401-9, lower valve (×1); central Crimea, village of Balki, Berriasian, collection of V.V. Arkad'ev; (2) specimen no. 410, upper valve (a) outside (×1) and (b) inside (×1); central Crimea, Sary-Su River, Berriasian, collection of V.V. Arkad'ev. (3) *Syncyclonema germanica* Wollemann, specimen no. 409-2, left valve (×1); the same locality, age and collection. (4) *Neithea simplex* Mord., specimen no. 20/12701, lower valve (×1), southwestern Crimea, Bel'bek River, Berriasian, collection of T.N. Bogdanova. (5) *Arcomytilus couloni* (Marc.), specimen no. 12/332, left valve (×1); the same locality and age, collection of V.V. Arkad'ev. (6, 7) *Antiquilima dubisiensis* (Pict. et Camp.): (6) specimen no. 56/332, left valve (×1), (7) specimen no. 57/332, right valve (×1); the same locality, age and collection. (8) *Belbekella airgulensis* Moiss., specimen no. 8/12075, (a) dorsal (×1) and (b) ventral valves (×1), (c) lateral view (×1); southwestern Crimea, Bel'bek River, village of Solnechnosel'e, Mt. Kermenchik, Berriasian, *Belbekella airgulensis–Sellithyris uniplicata* Beds, collection of S.V. Lobacheva. (9) *Tonasirhynchia janini* Lobatsch. et Smirn., specimen no. 1/12075 (holotype), (a) dorsal (×2) and (b) ventral valves (×2), (c) frontal (×2) and (d) lateral views (×2); eastern Crimea, Feodosiya, Svyatogo Il'i Cape, *jacobi* Zone, *T. janini* Beds, collection of S.V. Lobacheva. (10) *Sellithyris uniplicata* Smirn., specimen no. 264/332, (a) dorsal (×1) and (b) ventral valves (×1), (c) frontal (×1) and (d) lateral (×1) views; southwestern Crimea, Bel'bek River, village of Solnechnosel'e, Mt. Kermenchik, Berriasian, *Belbekella airgulensis–Sellithyris uniplicata* Beds, collection of V.V. Arkad'ev. (11) *Zeillerina baksanensis* Smirn., specimen no. 22/12075: (a, b) dorsal valve (×1 and ×2, respectively), (c) ventral valve (×2), (d) lateral (×2) and (e) frontal (×2) views; central Crimea, village of Mezhgor'e, Burul'cha River, Berriasian, *Z. baksanensis* Beds, collection of S.V. Lobacheva. (12) Symphythyris arguinensis (Moiss.), specimen no. 18/12075, (a) dorsal (×2) and (b) ventral (×2) valves, (c) frontal (×2) and (d) lateral views (×2); central Crimea, village of Balki, Berriasian, *S. arguinensis* Beds, collection of S.V. Lobacheva.

and *Dalmasiceras tauricum* Subzone. The *D. tauricum* Subzone is well recognizable throughout the Crimea–Caucasus region and corresponds to the standard *dalmasi* Subzone, representing thus a reliable biostratigraphic marker.

Subdivisions distinguished from the base upward in the *boissieri* Zone are the *Euthymiceras–Neocosmoceras* Beds, *Riasanites crassicostatus* Subzone, *Symphythyris arguinensis* and *Jabronella* cf. *paquieri–Berriasella callisto* beds. The last biostratigraphic unit is suggested instead the *Zeillerina baksanensis* Beds distinguished in the scheme of Bogdanova et al. (1981). This unit is correlated with upper part of the *picteti* Subzone. The section interval below it is barren of index ammonite taxa. In our opinion, the respective barren sediments underlying the *Euthymiceras–Neocosmoceras* Beds corresponds in range to the *Riasanites rjasanensis–Spiticeras cautleyi* Subzone in the scheme substantiated for the Caucasus by Sey and Kalacheva (2000).

The *alpillensis* Subzone is indistinguishable at present in the Crimean Mountains, and the Berriasian–Valanginian boundary has therefore no paleontological substantiation. Some characteristic (marker) levels are recognizable in the Berriasian of the Crimea based on distribution of bivalve mollusks. In the *Dalmasiceras tauricum* Subzone, for instance, these are the coquina horizons with *Pycnodonte weberae* in the central Crimea or with *Gervillella* and *Gervillaria* forms in the Belbek River Basin.

Four biostratigraphic subdivisions are distinguished based on distribution of brachiopods in the Berriasian section of the Crimea. From the base upward, these are the *Tonasirhynchia janini, Belbekella airgulensis–Sellithyris uniplicata, Symphythyris arguinensis*, and *Zeillerina baksanensis* Beds. In the suggested scheme, the last subdivision is replaced partially for the ammonite beds bearing *Jabronella* cf. *paquieri* and *Berriasella callisto.*

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