ISSN 0869-5938, Stratigraphy and Geological Correlation, 2006, Vol. 14, No. 2, pp. 185–199. © MAIK "Nauka/Interperiodica" (Russia), 2006
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New Data on Upper Kimmeridgian–Tithonian Biostratigraphy and Ammonites of the Eastern Crimea

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Received January 11, 2005; in final form, April 4, 2005

Abstract—Based on ammonites, Upper Kimmeridgian sediments are first established in the Crimean Mountains. The Kimmeridgian–Tithonian boundary recognizable in a continuous section is placed inside the Dvuyakornaya Formation of uniform largely clayey sediments. Assemblages of Kimmeridgian ammonites *Lingulaticeras* cf. *procurvum* (Ziegler), *Pseudowaagenia gemmellariana* Oloriz, *Euvirgalithacoceras* cf. *tantalus* (Herbich), *Subplanites* sp.) and Tithonian forms (?*Lingulaticeras efimovi* (Rogov), *Phylloceras consaguineum* Gemmellaro, *Oloriziceras* cf. *schneidi* Tavera, and *Paraulacosphinctes* cf. *transitorius* (Oppel) are described. A new biostratigraphic scheme proposed for the upper Tithonian–Berriasian of the Crimean Mountains includes the following new biostratigraphic units: the *Euvirgalithacoceras* cf. *tantalus* Beds of the upper Kimmeridgian, ?*Lingulaticeras efimovi* Beds of the lower Tithonian, and *Oloriziceras* cf. *schneidi* and *Paraulacosphinctes* cf. *transitorius* beds of the upper Tithonian. The middle Tithonian is proposed to consist of the *fallauxi* and *semiforme* (presumably) zones. The ammonites found determine the early Kimmeridgian–Berriasian age of the Dvuyakornaya Formation that is most likely in tectonic contact with the underlying Khutoran Formation.

DOI: 10.1134/S0869593806020067

Key words: Crimean Mountains, upper Kimmeridgian, Tithonian, ammonites, zonation, correlation, regional tectonics.

INTRODUCTION

Upper Kimmeridgian and Tithonian ammonites of the Crimean Mountains remain poorly studied so far. Descriptions and figures of characteristic taxa are available only in works by Ovechkin (1956) and Khimshiashvili (1967). At the same time, lists of numerous ammonites from this region include species of genera *Lithacoceras, Aspidoceras, Richterella* (*Kossmatia* auct.), *Paraulacosphinctes, Haploceras*, and *Semiformiceras* known from Tithonian sediments (Pchelintsev, 1959; Lysenko, 1964; Uspenskaya, 1969; Permyakov et al., 1984, 1991; Permyakov and Sapunov, 1990). Among Tithonian and Berriasian ammonites considered traditionally as typical of the Tithonian in the Crimea, there are however species characteristic of the upper Kimmeridgian, e.g., *Lithacoceras ulmense*. Nevertheless, the recent version of the unified stratigraphic scheme proposed for the Jurassic sediments of the Crimea (Permyakov et al., 1991) is lacking the Kimmeridgian Stage.

Ovechkin (1956) was the first to describe and illustrate Kimmeridgian and Tithonian ammonites from the Crimean Mountains. Inasmuch as ammonites were sampled in the course of geological survey usually without indicated confinement to particular sections, Ovechkin did not discriminated particular zones, although he noted forms characteristic of the lower Kimmeridgian and of the lower (s.l.) and upper Tithonian. Some species among these ammonites played subsequently important role in Tithonian stratigraphy of the Crimea, and we pay therefore a special attention to them. An ammonite specimen attributed to *Lithacoceras* cf. *ulmense* (Ovechkin, 1956, p. 23, Plate II, fig. 1) is represented by a fragment of internal whorls. Until recently, this species was considered as characteristic of the lower Tithonian, but as was shown lately this form is of the late Kimmeridgian age (Schweigert, 1998; Schweigert and Zeiss, 1999). In characters, the specimen figured by Ovechkin can be classed with ammonites of either the late Kimmeridgian or Tithonian genera *Lithacoceras, Euvirgalithacoceras, Franconites*, and others. Other important forms that are regarded until recently as index species of Tithonian zones are *Virgatosphinctes (=Paraulacosphinctes) transitorius* (Ovechkin, 1956, p. 23, Plate IV, fig. 2) represented by a small hardly determinable fragment and well-preserved macroconch of *Kossmatia (=Richterella)* aff. *richteri* (Ovechkin, 1956, p. 28, Plate IV, fig. 5).

Zonal subdivision of upper Kimmeridgian–Tithonian sediments of the Crimean Mountains and correlation with the standard chart of Southern West Europe

Crimean Mountains: Muratov et al., 1960		Uspenskaya, 1969			Muratov et al., 1972				Uspenskaya (in Gorbachik and Kuznetsova, 1984)				Permyakov et al., 1991			This work				Southern West Europe (Spain, Italy) Geyssant, 1997			
Stage	Zone	Stage	Substage	Zone	Stage	Substage	Zone or beds		Stage	Substage	Zone, subzone		Stage	Substage	Zone	Stage	Substage	Zone	Beds with ammonites	Subzone	Zone	Substage	Stage
Tithonian	*Virgatosphinctes transitorius* and *Berriasella chaperi**	Tithonian	upper	*Virgatosphinctes transitorius**	Tithonian	upper	*Virgatosphinctes transitorius**	*Virgatosphinctes transitorius–Berriasella callysto* Beds*	Tithonian	upper	*Virgatosphinctes transitorius*	*Berriasella chaperi–B. delphinensis**	Tithonian	upper	*Paraulacosphinctes transitorius*	Tithonian	upper	*Transitorius*			*Durangites*	upper	Tithonian
																			P. cf. *transitorius* Beds	*Transitorius*	*Microcanthum*		
												Semiformiceras semiforme							*O.* cf. *schneidi* Beds	*Simplisphinctes*			
								Semiformiceras semiforme Beds						middle	*Semiformiceras semiforme*		middle	*Fallauxi*			*Ponti*	middle	
																				Admirandum/Biruncinatum	*Fallauxi*		
			lower	*Kossmatia richteri*		lower	*Kossmatia richteri*			lower	*Kossmatia richteri–Glochiceras lithographicum*			lower	*Kossmatia richteri*					*Richteri*			
																		Semiforme			*Semiforme*		
																	lower				*Darwini Albertinum*	lower	
																		Hybonotum	? *L. efimovi* Beds		*Hybonotum*		
Kimmeridgian (partly)	*Streblites oxypictus* and *Lithacoceras pseudobangei*	Kimmeridgian (partly)	upper	Paleontologically unsubstantiated	No sediments											Kimmeridgian (partly)	upper (partly)	Beckeri	*E.* cf. *tantalus* Beds		*Beckeri*	upper (partly)	Kimmeridgian
																					Cavouri (Eudoxus)		

Note: asterisks designate units previously defined in the Tithnian of the Crimea and now attributed completely or partly to the Berriasian.

The first ammonite zonation for the Kimmeridgian–Tithonian of the Crimean Mountains was elaborated a bit later (Muratov et al., 1960; see the table). In this scale, the Kimmeridgian and Tithonian corresponded to a single zone each: to *Streblites oxypictus–Lithacoceras pseudobangei* and *Virgatosphinctes transitorius–Berriasella chaperi* zones respectively. At the same time, the authors noted that two assemblages can be distinguished in the Tithonian of the southwestern Crimea, the upper one with *Virgatosphinctes transitorius, Aulacosphinctes occultefurcatus*, and *Berriasella subchaperi* and the lower assemblage with *Kossmatia* aff. *richteri* and *Phylloceras ptychostoma.* For the synclinorium of the eastern Crimea, only the upper part of the Tithonian with the *Berriasella chaperi* and *Oppelia macrotela* (=the Berriasian, according to recent views) was indicated. Of interest is the inference in that work that "sediments of the Kimmeridgian and Tithonian stages in the Crimea correspond to a single complex because of gradual transition between them, similar lithology, and occurrence conditions" (Muratov et al., 1960, p. 89).

Khimshiashvili (1967) described and figured several Tithonian ammonite species from the southwestern Crimea. The following species characterizing different stratigraphic levels in the middle Tithonian of West Europe should be noted: *Oppelia (=Semiformiceras)* aff. *gemmellaroi* (p. 113, Plate V, fig. 5), *Semiformiceras fallauxi* (p. 114, Plate II, figs. 2, 3).

Uspenskaya (1969) proposed a new more detailed Kimmeridgian–Tithonian zonation that represented a modified version of the previous scheme (Muratov et al., 1960). In her scale, the Tithonian was subdivided into the lower and upper substages each corresponding to a single zonal unit (the table): *Kossmatia richteri* and *Virgatosphinctes transitorius* zones, respectively. She noted also that the *transitorius* Zone of the southwestern Crimea "can, probably be divided into several subzones" (Uspenskaya, 1969, p. 155). In addition to zonal species, Uspenskaya mentioned also *Aspidoceras* cf. *rogoznicense* and *Semiformiceras semiforme* as characteristic of the lower and middle parts of the upper Tithonian. At the same time, her list of ammonites from the upper part of the *transitorius* Zone included various *"Berriasella"* forms and phylloceratids. In addition, *Kossmatia (=Richterella) richteri* found in the eastern Crimea was mentioned. The lower Kimmeridgian was correlated with the *Streblites tenuilobatus* Zone containing various species of genera *Lithacoceras, Ataxioceras*, and *Aspidoceras (A. acanthicum,* a zonal species of the upper Kimmeridgian, included), in addition to the index species. The upper Kimmeridgian missed in this scheme was shown as "paleontologically unsubstantiated" for the southwestern Crimea and as corresponding to a hiatus in the eastern part. Since that time, the Kimmeridgian biostratigraphic scheme of the Crimea remained unchanged, except for the fact that all the subsequent researchers considered the upper Kimmeridgian interval corresponding to a regional hiatus.

Several years later, the idea of the *transitorius* Zone complex structure in the Crimean Mountains was developed further. In their work on the Jurassic stratigraphy of the Crimea, Muratov et al. (1972) subdivided the *transitorius* Zone in two autonomous zones: the lower one with *Virgatosphinctes transitorius, V. senex, Aspidoceras* spp., *Perisphinctes virguloides*, and *Semiformiceras semiforme* and the upper zone (belonging to the Berriasian, according to recent views) with phylloceratids and diverse *Berriasella* species. Simultaneously, it was assumed that the upper Kimmeridgian is missing from both the eastern and southwestern parts of the Crimea. At the same time, no zones were shown for the Tithonian of the Crimea in the Jurassic correlation scheme of the USSR published in the same work. Instead, it was divided into beds (from the base upward) with *Kossmatia richteri* and *Aulacosphinctes occultefurcatus*, with *Semiformiceras semiforme* and others, and with *Virgatosphinctes transitorius, Berriasella callisto*, and others.

Sazonova and Sazonov (1974) proposed the first zonation for the Tithonian–Berriasian boundary sediments of Feodosia outskirts. They defined two upper zones of the Tithonian and all the zones of the French Berriasian. Nevertheless, discrimination of the Tithonian zones was rather formal: it was lacking the section description and neither figures, nor description of *Virgatosphinctes transitorius* were presented.

Subsequently, the lower zone of the Tithonian (*richteri* Zone) corresponding by range to the lower Tithonian remained practically unchanged. The sole modification consisted in replacement of the former zonal index for the *lithographicum–richteri* one (reference to Uspenskaya in Gorbachik and Kuznetsova, 1984). The *transitorius* Zone was subdivided in the *semiforme* and *Berriasella delphinensis–Berriasella chaperi* subzones.

Approximately in the same years, the first work summarizing data on the Kimmeridgian–Tithonian stratigraphy of the Crimea appeared (Permyakov et al., 1984), where many local lithostratigraphic units were recognized. Based on different organic remains (foraminifers, corals, brachiopods, bivalves, gastropods, and ammonites), the Dvuyakornaya Formation was attributed to the upper Tithonian–Berriasian, but the biostratigraphic scheme remained practically unchanged: the *semiforme* and *transitorius* subzones became ranked as zones and the *semiforme* Zone was attributed to the middle Tithonian. Subsequently, Permyakov et al. (1984) focused their attention on perfection of the local stratigraphic scheme. Unfortunately, formations in different parts of the Crimea were regarded as synchronous within the synonymous "horizons," and this played a negative role in determining their ages. In line with this concept, the Dvuyakornaya Formation was entirely included into the upper Tithonian despite the presence of *Richterella richteri.* The uncritical approach to previous identifications of taxa also nega-

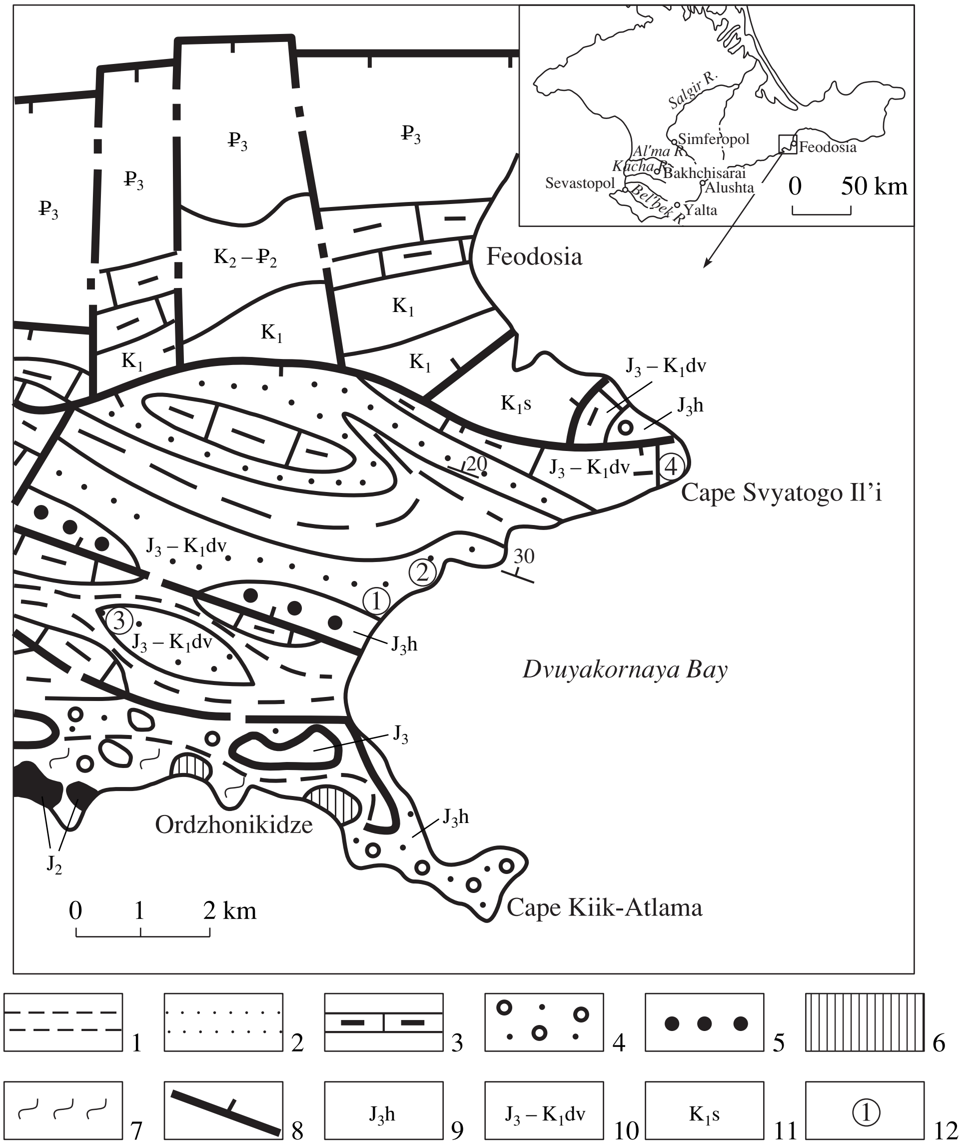


Fig. 1. Schematic geological structure of the area (after Kazantsev et al., 2989) and location of examined sections of the Dvuyakornaya Formation: (1) clay, siltstone; (2) sandstone; (3) marl; (4) conglomerate; (5) blocky conglomerate; (6) volcano-sedimentary sediments; (7) tectonites; (8) thrust; (9) Khutoran Formation; (10) Dvuyakornaya Formation; (11) Sultanovka Formation; (12) location of examined sections. Numbers in figure correspond to sections (1, 2) in the Dvuyakornaya Bay, (3) 1 km southeast of the Yuzhnoe Settlement, and (4) in the Cape Svyatogo Il'i.

tively influenced the last stratigraphic schemes proposed for the Tithonian of the Crimea (Permyakov et al., 1991). As a result, the same taxon (*Richterella richteri*) was used under different generic names as characteristic of the lower Tithonian (*Kossmatia richteri*), on the one hand, and of the upper Tithonian (*Richteria richteri*), on the other. It should be noted here that we deal with the index species of one of the *middle Tithonian* subzones in the West European scale!

In 2001–2004, V.V. Arkad'ev together with Yu.N. Savel'eva (St. Petersburg University), A.A. Fedorova (All-Russian Geological Research Institute), and G.K. Solov'ev revisited the famous Feodosia section of the Dvuyakornaya Formation in the eastern Crimea (Arkad'ev and Savel'eva, 2002; Arkad'ev, 2003; Arkad'ev et al., in press), which was repeatedly studied by researchers (Sokolov, 1886; Retowski, 1893; Sazonova and Sazonov, 1974; Druschits, 1975; Bogdanova et al., 1981, 1984; Glushkov, 1997). The composite section of the formation is compiled based on four individual exposures in Feodosia outskirts: on the Cape Svaytogo Il'i (Section 1), in the Dvuyakornaya Bay (Section 2), and near the Ordzhonikidze (Section 3) and Yuzhnoe (Section 4) settlements (Fig. 1). The formation of uniform lithology is largely composed of flyschoid calcareous clays, marls, and con-

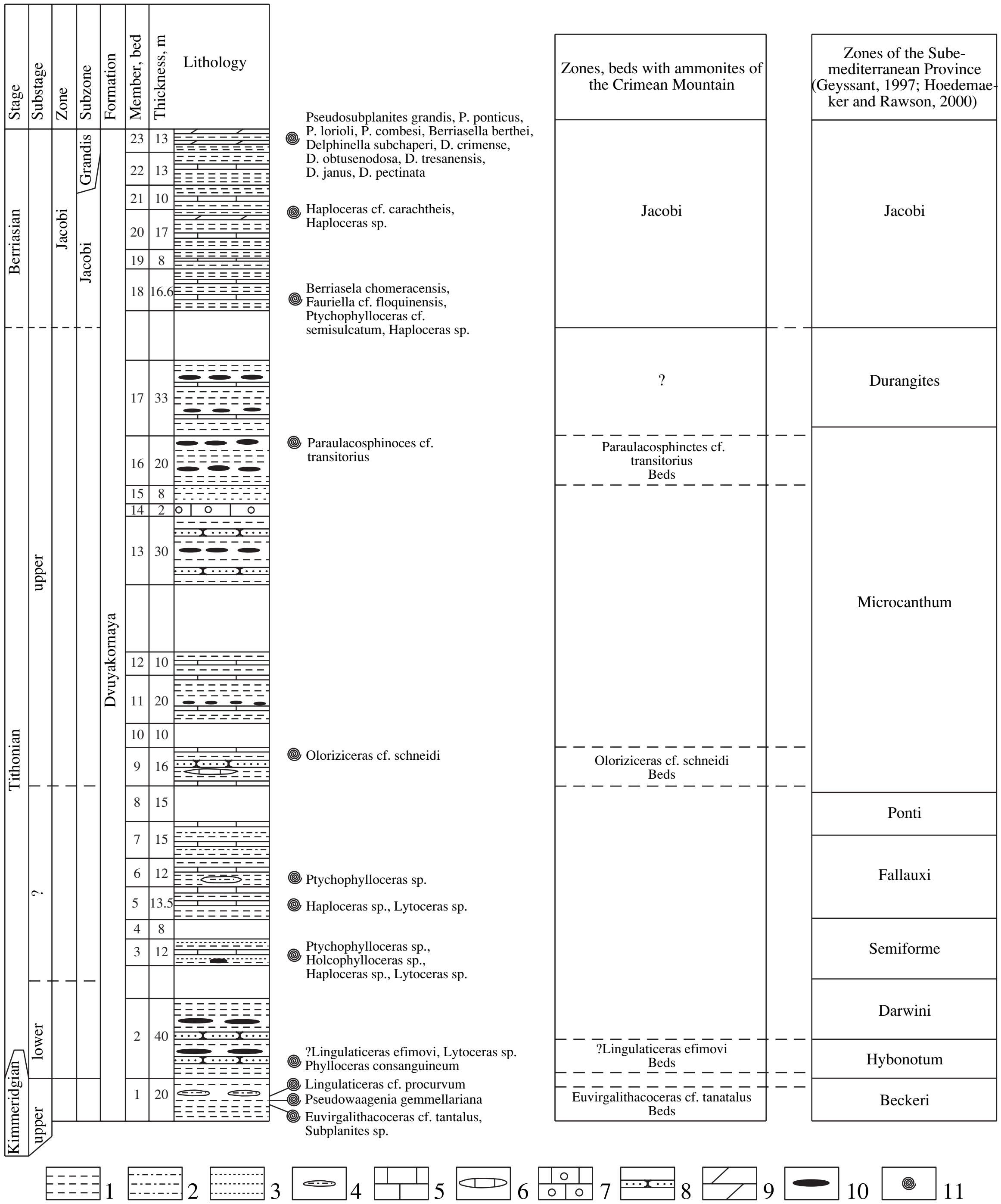


Fig. 2. Composite section of the upper Kimmeridgian–Tithonian Dvuyakornaya Formation, the eastern Crimea: (1) clay; (2) siltstone; (3) sandy clay; (4) siltstone lens; (5) limestone; (6) limestone lens; (7) conglomerate-like limestones; (8) calcareous sandstone; (9) marl; (10) siderite concretions; (11) ammonite finds.

glomerate-like limestones 360 m thick (Fig. 2). Members 1–2, 3–12, 13–17, and 18–23 are defined in sections 1, 2, 3, and 4, respectively. Sediments are conditionally united into a common succession based on ammonite finds. Practically in all the mentioned works, the upper part of the Dvuyakornaya Formation with the diverse ammonite assemblage of the Berriasian *jacobi* Zone was under consideration. In 2002, the late Tithonian ammonite *Oloriziceras* cf. *schneidi* Tavera was found in the section lower part (Arkad'ev, 2004), while *Paraulacosphinctes* cf. *transitorius* (Oppel) and other ammonites were discovered in the lower Member 1 (Fig. 2) in 2003. Arkad'ev determined species *Aspidoceras* sp. and *Kossmatia* cf. *exceptiona-*

lis (Aguilera) in this member, Rogov subsequently revised these determinations. Besides, outcrops of the Dvuyakornaya Bay were reexamined in 2004. Samples collected here from the lower part of the continuous Dvuyakornaya Formation section (Member 1, Fig. 2) yielded the late Kimmeridgian species *?Euvirgalithaceras* cf. *tantalus* (Herbich), *Subplanites* sp. (earlier determined by Arkad'ev as *Kossmatia* forms), *Lingulaticeras* aff. *procurvum* (Ziegler), and *Pseudowaagenia gemmellariana* Olóriz (*Aspidoceras* sp. in former determination of Arkad'ev). In overlying Member 2 (Fig. 2), there were identified the lower Tithonian forms *?Lingulathiceras efimovi* (Rogov), *Phylloceras consanguineun* Gemmellaro, and *Lytoceras* sp. These finds are of crucial importance for the upper Kimmeridgian and Tithonian biostratigraphy and correlation. They allow a substantial revision of the stratigraphic scheme proposed earlier for the Jurassic–Cretaceous sediments of the region under consideration (Arkad'ev and Bogdanova, 2004). The new biostratigraphic scheme is preliminarily described in (Arkad'ev et al., in press). Here, it is specified and substantiated in detail.

Unfortunately, the unified biostratigraphic scheme accepted now for the Jurassic System of the Crimean Mountains (Permyakov et al., 1991) is of a lower resolution as compared with regional biostratigraphic scales adopted in other areas of Europe. That scheme is also ineffective, because paleontological identifications have not been substantiated frequently by descriptions or figures and discriminated assemblages include mixed species characteristic of different zones. The new finds of Kimmeridgian–Tithonian ammonites and revision of available materials allow us to suggest the new stratigraphic scheme for subdivision of the Tithonian in the Crimean Mountains (table). Ages of the upper Kimmeridgian, lower and upper Tithonian units are substantiated in the section "Discussion". The middle Tithonian part of the scheme is briefly considered below. By analogy with Mediterranean successions (Geyssant, 1997), ammonites *Richterella richteri, Semiformiceras fallauxi*, and *S. gemmellaroi* found in the southwestern Crimea (Ovechkin, 1956; Khimshiashvili, 1967) define the *fallauxi* Zone with *richteri* and *admirandum/biruncinatum* subzones. The *fallauxi* Zone and *richteri* Subzone are substantiated by finds of their index species, while the *admirandum/biruncinatum* Subzone is established based on occurrence of *Semiformiceras gemmellaroi*, the species characteristic of this unit (Olóriz, 1978; Sarti, 1985). The *semiforme* Zone can be defined only arbitrarily, because identifications of its index species and other characteristic ammonites are not accompanied by descriptions and figures, although they are frequently cited in lists of fossils. These stratigraphic units are recognizable in the southwestern Crimea; in the eastern Crimea, its analogues are not distinguished so far.

The description of the Dvuyakornaya Formation sections is already submitted to publication (Arkad'ev et al., in press).

Collections of ammonites described in this paper are stored in the museum at the Historical Geology Chair, St. Petersburg State University (nos. 376, 378). When identifying ammonite taxa, we consulted with G. Schweigert from the Staatliches Museum für Naturkunde in Stuttgart, Germany.

FAMILY PERISPHINCTIDAE STEINMANN, 1890

Genus *Paraulacosphinctes* Schindewolf, 1925

Paraulacosphinctes cf. *transitorius* (Oppel, 1865)

Plate I, fig. 10

cf. *Ammonites transitorius:* Oppel, 1865, p. 554; Zittel, 1868, p. 103, Plate 22, figs. 1–4, 6 (not fig. 5).

cf. *Perisphinctes transitorius:* Toucas, 1890, p. 599, Plate 16, figs. 5, 6.

cf. *Virgatosphinctes transitorius:* Ovechkin, 1956, p. 23, Plate 4, fig. 2.

cf. *Paraulacosphinctes transitorius:* Sapunov, 1977, Plate 5, fig. 2; 1979, p. 127, Plate 36, figs. 1, 2; Tavera, 1985, p. 84, Plate 11, figs. 1–5, text-figs. 7A, 7D.

Shape. Shell is large, discoid, evolute, with flattened flanks. Venter is not preserved. Umbilicus is wide, shallow, with steep walls.

Sculpture. Flanks are covered with sharp bifurcate ribs. Originating near the suture, ribs are posteriorly deflected up to umbilical shoulder and cross the flanks slightly curving anteriorly. In the upper part of the whorl, each rib bifurcates forming two equal branches.

Dimensions (mm), ratios (%), and number of ribs:

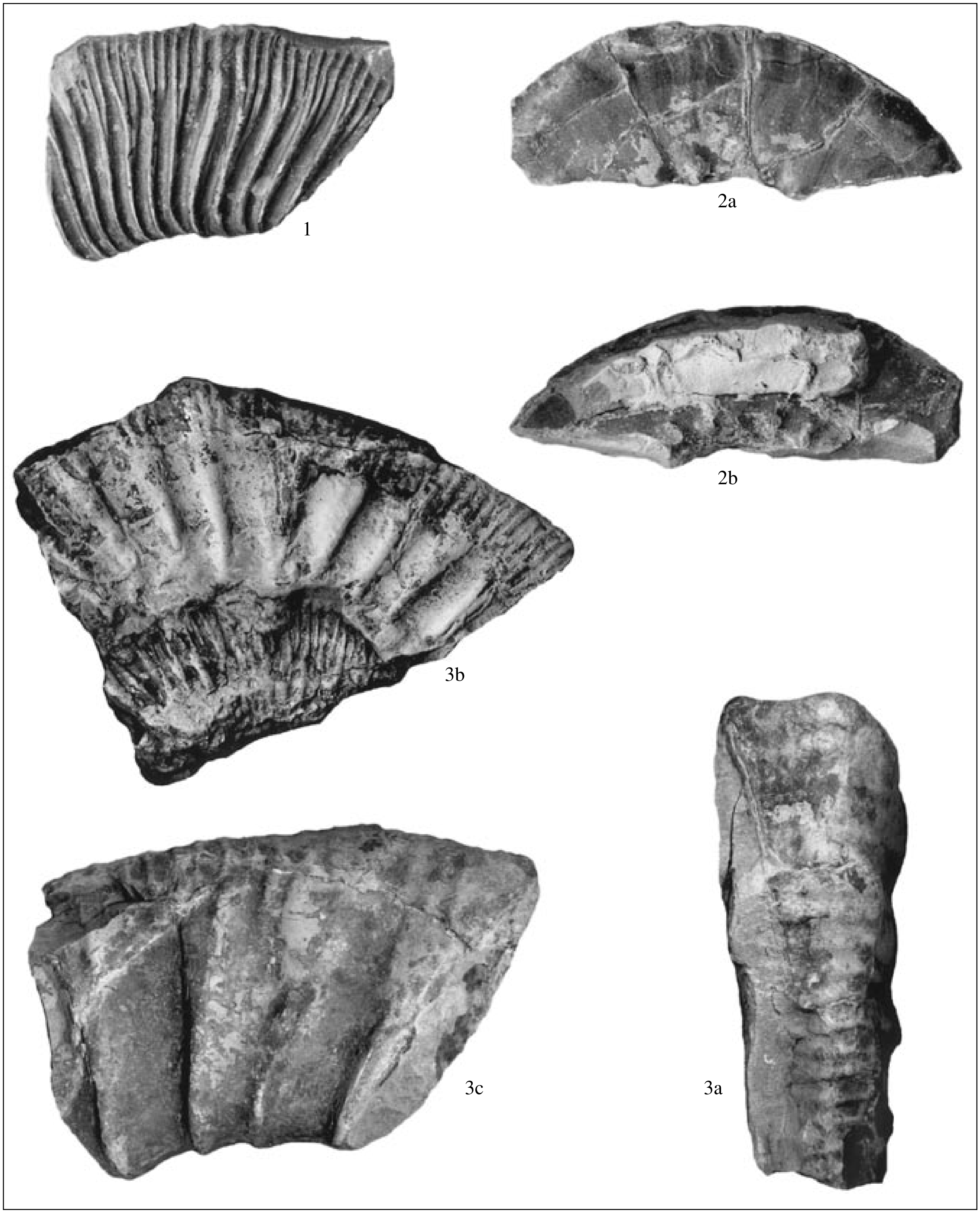
Specimen	D	H	W	D_u	H/D	W/D	D_u/D	Number of ribs per half of the whorl	
								internal	external
3/378	90?	35?	?	37	0.39	–	0.41	29	58

Comparison. The described specimen is most similar to species from the upper Tithonian sediments of Spain (Tavera, 1985, Plate 11, fig. 1). It demonstrates also similarity with a specimen described from the Tithonian of the Ai-Petri mountain pasture in the Crimean Mountains (Ovechkin, 1956, Plate 4, fig. 2).

Distribution: upper Tithonian, *microcanthum* Zone, *transitorius* Subzone of Spain, Czechia, Bulgaria, and North Caucasus; upper Tithonian, *Paraulacosphinctes* cf. *transitorius* Beds of the Crimea.

Material: one specimen (no. 3/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, 1 km southeast of the Yuzhnoe Settlement).

Plate I



P l a t e I. Upper Kimmeridgian ammonites of the eastern Crimea:
(1) *Subplanites* sp.,), specimen 2/378, (×2), lateral view; (2a, 2b) *Pseudowaagenia gemmellariana* Olóriz, specimen 1/378, (×1), lateral view; (3) *Euvirgalithacoceras* cf. *tantalus* (Herbich), specimen 4/378, (×1): (a) ventral view, (b, c) lateral view. All the specimens originate from outskirts of the Ordzhonikidze Settlement, Dvuyakornaya Bay, upper Kimmeridgian, *beckeri* Zone, Beds with *Euvirgalithacoceras* cf. *tantalus*.

Genus *Oloriziceras* Tavera, 1985

Oloriziceras cf. *schneidi* Tavera, 1985

Plate I, fig. 9

Oloriziceras schneidi: Arkad'ev, 2004a, p. 37, Fig. 3.

Shape. Shell is discoid, evolute, with flattened flanks. Venter patterns are unobservable. Whorl section is elongated, most likely rounded–rectangular. Umbilicus is wide, shallow, with steep walls.

Sculpture. Flanks are covered wit thin sharp bifurcate ribs. They start near the suture, slightly deviate posteriorly on the umbilicus wall, and cross straightly the flank. At two thirds of the flank height, ribs bifurcate into equal branches with the posterior branch deflected slightly backward and anterior one, slightly forward. Ornamentation of venter is unknown. Frequency of ribs in observed internal and external whorls is constant. The last whorl (D = 41.0 mm) has approximately 50 internal ribs, while in the preserved part of adult specimen (slightly less than a half-whorl) there are 23 internal ribs.

Dimensions (mm), ratios (%), and number of ribs:

Specimen	D	H	W	D_u	H/D	W/D	D_u/D
1/376	61.0	22.0	–	32.0	36.06	–	52.4

Comparison. By some morphological features (character of shell coiling, bifurcate ribs), the described specimen belongs undoubtedly to perisphinctids. Unfortunately, the venter ornamentation is unknown, although in flanks it is most similar to specimens figured by Tavera (1985, Plate 6, figs. 2–3, Fig. 6) and described as a new genus and new species *Oloriziceras schneidi*.

Remarks. In distinction from other perisphinctids described by Tavera from the upper Tithonian of Spain, shells of the genus *Oloriziceras* are more evolute. By this character and gradually growing whorls, *O. schneidi* differs from representatives of the genus *Berriasella*.

Distribution. *O. schneidi* is known from the upper Tithonian of Spain, *microcanthum* Zone, *simplisphinctes* Subzone. *O.* cf. *schneidi* is found in the upper Tithonian of Crimea, *microcanthum* Zone, *O.* cf. *schneidi* Beds.

Material: one specimen (no. 1/376) from the eastern Crimea (Dvuyakornaya Bay).

Genus *Subplanites* Spath, 1925

Subplanites sp. [m]

Plate II, fig. 1

Shape. Shell is most likely evolute, discoid, with slightly convex wide flanks. Venter is not preserved. Umbilicus is wide, with steep walls. Whorl section is most likely elongated, oval.

Sculpture. Shell flanks are covered by embossed ribs, bifurcate, triple, and intermediate single. Starting near the suture, ribs deflect posteriorly on the umbilical wall and then cross the flank slightly curving anteriorly. Approximately in the middle of the flank or slightly higher, ribs are divided in two or three branches with the anterior branch separating lower and deflecting toward the mouth and posterior one separating higher and deflecting backward. Between double and triple ribs, there are intermediate single ribs originating in the upper half of the flank. The phragmocone 45 mm long and 40 mm high has 12 internal and 29 external ribs.

Comparison. By sculptural elements (alternating double, triple, and single ribs), our specimen is close to the genus *Subplanites* and resembles mostly its lower Tithonian species, in particular *S. rueppellianum* (Quentstedt) figured in two works (Berckhemmer and Hölder 1959, p. 51, Plate 12, fig. 56; Schlegelmilch, 1994, p. 89, Plate 40, fig. 1).

Distribution: upper Kimmeridgian *beckeri* Zone–lower Tithonian *hybonotum* Zone of West Europe; upper Kimmeridgian, *beckeri* Zone, *Euvirgalithacoceras* cf. *tantalus* Beds of the Crimea.

Material: one specimen (no. 2/378) representing an incomplete phragmocone (approximately one fourth of the whorl) of adult shell from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

Genus *Euvirgalithacoceras* Zeiss, Schweigert et Scherzinger, 1996

Euvirgalithacoceras cf. *tantalus* (Herbich, 1878) [M]

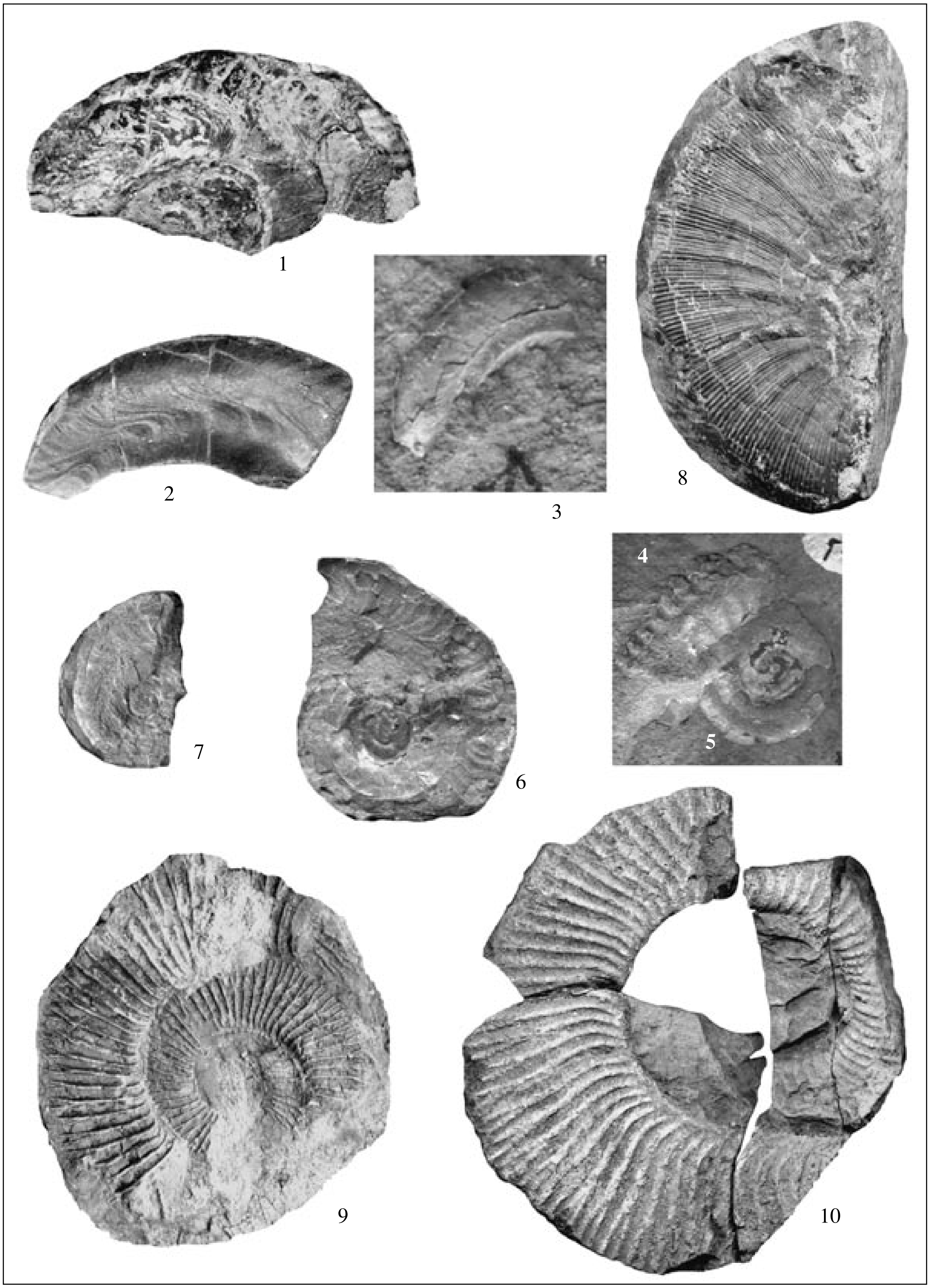
Plate II, figs. 3a–3c

Shape. Shell is large, evolute, with slowly growing whorls, slightly convex flanks, and wide flattened venter. Umbilicus is wide, stepped, with steep walls. The whorl section is elongated, oval-rectangular.

Plate II. Kimmeridgian and Tithonian ammonites of the eastern Crimea:

(1) *Lingulaticeras* cf. *procurvum* (Ziegler), specimen 5/378, (×2), lateral view, outskirts of the Ordzhonikidze Settlement, Dvuyakornaya Bay, upper Kimmeridgian, *beckeri* Zone, Beds with *Euvirgalithacoceras* cf. *tantalus*; (2–7) *?Lingulaticeras efimovi*: (2) specimen 6/378, (×2), lateral view, outskirts of the Ordzhonikidze Settlement, Dvuyakornaya Bay, lower Tithonian, *hybonotum* Zone, Beds with *?Lingulaticeras efimovi*, (3) specimen MIV597, (×4), lateral view, Gorodishchi Village, lower Volgian, *efimovi* faunal horizon, 0.7 m above the base of Bed 6 (bed number after Rogov, 2002), (4) specimen no. MIV595, (×2), lateral view. Locality and age the same, (5) specimen no. MIV596, (×2), lateral view, locality and age the same, (6) specimen no. MIV751, (×2), lateral view, locality and age the same, talus, (7) specimen no. MIV443, (×2), lateral view, locality and age the same, 0.15 m above the base of Bed 6; (8) *Phylloceras cansanguineum* Gemmellaro, specimen 7/378, (×2), lateral view, outskirts of the Ordzhonikidze Settlement, Dvuyakornaya Bay, lower Tithonian, *hybonotum* Zone, Beds with *?Lingulaticeras efimovi*; (9) *Oloriziceras* cf. *schneidi* Tavera, specimen 7/376, (×1), lateral view, Dvuyakornaya Bay, upper Tithonian, Beds with *Oloriziceras* cf. *schneidi*; (10) *Paraulacosphinctes* cf. *transitorius* (Oppel), specimen 3/378, (×1), lateral view, outskirts of the Yuzhnoe Settlement, upper Tithonian, Beds with *Paraulacosphinctes* cf. *transitorius*.

Plate II



Sculpture. Flanks bear almost straight embossed ribs. Ribs originate at the umbilical wall, where they are deflected backward. On the umbilical kink, ribs are slightly deflected anteriorly and cross almost straightly the flank. Near the middle of the flank, each rib bifurcates in two branches, then one of them or both bifurcate again. Ribs are thin and compactly arranged. One fourth of the whorl approximately 25 mm high hosts 12–13 internal and 28–30 external ribs. When H = 38–40 mm, internal ribs become thicker and less frequent, while the number of external ribs increases: in this case, there are 9 internal and 40 external ribs a quarter of the whorl. There are also intermediate ribs between rib fascicles that originate in the upper third of the whorl. On the adult whorl (H = 60 mm), internal ribs are loosely spaced, clearly embossed and ridge-shaped up to the middle of the flank, being slightly flattened higher. Bifurcation style remains unchanged. Anterior deflection of ribs increases closer to the mouth. All the ribs cross the flank without any changes.

Dimensions. Judging from preserved fragments, diameter of the shell was approximately 180 mm. The last whorl is 60 mm high and about 30 mm thick.

Comparison. More evolute shell with the rib bifurcation point uncovered by next whorls differs the described species from most of the *Euvirgalithacoceras* forms. Close *Euvirgalithacoceras mamlarguense* Spath from lower Tithonian sediments of Argentina (Parent, 2003, figs. 1, 4, 5A, 6A–6D, 7A–7E) has coarser sculpture on the living chamber and higher bifurcation coefficient in internal whorls.

Remarks. Because of coarser sculpture and slightly lower position of bifurcation points than in typical representatives of the species (Hebrich, 1878, p. 163, Plates XII–XIII, fig. 1; Schweigert, 1994, p. 3, Plate 1, fig. 1), the described insufficiently preserved specimen can be attributed to *E. tantalus* (Herbich) only in the open nomenclature. Associated microconchs (*Subplanites* described above) differ from *"Virgalithacoceras" fruticans* (Schweigert, 1994, p. 4, Plate 1, figs. 2–4) occurring together with *?E. tantalus* in their substantially larger size and generally coarser sculpture.

Distribution. *E. tantalus* (Hebrich) is described from the *setatum* Subzone of the Upper Kimmeridgian *beckeri* Zone of Germany and Upper Kimmeridgian of Hungary. In the Crimea, *E.* cf. *tantalus* (Hebrich) is found in the *Euvirgalithacoceras* cf. *tantalus* Beds of the upper Kimmeridgian *beckeri* Zone.

Material: one incomplete specimen (no. 4/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

FAMILY ASPIDOCERATIDAE ZITTEL, 1895

Genus *Pseudowaagenia* Spath, 1931

Pseudowaagenia gemmellariana Olóriz, 2002

Plate II, figs. 2a, 2b

Pseudowaagenia gemmellariana: Olóriz, 2002, p. 350, Fig. 228.

Holotype. Specimen 019.71 (collection of G. Gemmellaro) is stored in the Museo Geologico "G.G. Gemellaro," Palermo, Italy, the Kimmeridgian of Sicily.

Shape. Sell is discoid, evolute (?), with wide flattened flanks and narrow slightly rounded venter. Umbilicus is wide, with steep walls. Height of the whorl is much greater than its thickness. Whorl section is narrow, elongated-oval.

Sculpture. Flanks are smooth, covered only by thin sinusoidal growth lines, which form obscure folds near venter. On the umbilical wall of the preserved shell quarter, there are five spinous tubercles 1.5–2.0 mm high, extended slightly in radial direction. Distance between tubercles is 4–5 mm. In the near-venter part (approximately 6–8 mm away from venter), the shell side facing the living chamber hosts two small spinous tubercles 1.0–1.5 mm high and set apart for 2 cm.

Dimensions. Judging from the preserved phragmocone fragment 25 cm high, the intact shell was at least 80 mm in diameter. The fragment most likely deformed is 7 mm thick.

Comparison. Despite insufficient preservation of the described specimen, some features, such as wide umbilicus and radially elongated tubercles, imply that it can be attributed to the genus *Pseudowaagenia.* Most species of this genus are small in size (adult shells are usually less than 5 cm in diameter). As for relatively large species *P. contemporanea* (Favre), *P. dietli* Checa, and *P. gemmellariana* Olóriz, our specimen is most close in ornamentation (lateral tubercles on the living chamber) to *P. gemmellariana.* Because of sculpturing, flattened whorls, and involute shell, the described form is similar to early *Hybonoticeras* species *H. pressulum* (Neum.) and *H. kachlense* (Spath), but it lacks depression or flattening on the venter and cannot be attributed to this genus.

Remarks. Stratigraphic position of *P. gemmellariana* is unclear. The holotype originates from the unknown level of the lower–basal upper Kimmeridgian section (Olóriz, 2002). Stratigraphic range of close species *Pseudowaagenia haynaldi* (Herbich) and *Hybonoticeras sesquinodosum* (Fontannes) correspond to the upper Oxfordian–basal Tithonian.

Distribution: Kimmeridgian of Sicily; upper Kimmeridgian, *beckeri* Zone (with *Euvirgalithacoceras* cf. *tantalus* Beds) of the Crimea.

Material: one specimen (no. 1/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

FAMILY HAPLOCERATIDAE ZITTEL, 1884

Genus *Lingulaticeras* Ziegler, 1958

Lingulaticeras cf. *procurvum* (Ziegler, 1958)

Plate I, fig. 1

Shape. Shell is of medium size, discoid, semievolute, with flattened flanks. Umbilicus is moderately wide.

Sculpture. Flanks bear numerous falcate ribs. Ribs start slightly below the mid-flank on the furrow and then sharply deflect backward becoming slightly flattened and sharply curved toward the mouth in the upper third of the whorl. There are also numerous intermediate ribs.

Comparison. From other *Lingulaticeras* forms, our specimen differs by presence of numerous intermediate ribs in the upper part of the flank. Ribs of the *L. procurvum* holotype (Ziegler, 1958, Plate 14, fig. 7; Schlegelmilch, 1994, Plate 16, fig. 21) originate above the flank furrow and, therefore, they are lacking distinct deflections forward in the mid-flank in distinction from our specimen. Nevertheless, peculiar intermediate ribs of the Crimean find allow it to be attributed with a certain reservation to this species.

Distribution: upper Kimmeridgian (*beckeri* Zone, *subeumela* Subzone) of southern Germany; upper Kimmeridgian (*beckeri* Zone, *Euvirgalithacoceras* cf. *tantalus* Beds) of the eastern Crimea.

Material: one specimen (no. 5/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

?Lingulaticeras efimovi (Rogov, 2002)

Plate I, figs. 2–7

Glochiceras (Paralingulaticeras) lithographicum efimovi: Rogov, 2002, p. 47, Plate, fig. 2.

Paralingulaticeras efimovi: Rogov, 2004, Plate, fig. 7; Rogov, 2004, Plate I, figs. 12, 13.

Holotype. Specimen GGM-572-11 is stored in the V.I. Vernadsky State Geological Museum, Moscow; Ul'yanovsk region, right bank of the Volga River near the Gorodishchi Village; lower Volgian Substage, *klimovi* Zone, *efimovi* faunal horizon.

Shape. Shell is of medium size, discoid, semievolute (?), with flattened flanks. Umbilicus is wide.

Sculpture. Flanks are covered with numerous filiform ribs, falcate in the upper part of the whorl and sharply bending on the flank furrow in the mid-flank or slightly below. On venter, ribs resemble coarser and rarely spaced ridges curved anteriorly.

Dimensions. Judging from available fragment, shell diameter does not exceed 40 mm. The whorl height is approximately 12 mm.

Comparison. From most Kimmeridgian representatives of this genus, *L. efimovi* differs by more evolute shell and stronger developed furrow in the mid-flank. In discrimination from *?L. efimovi*, *L.* cf. *procurvum* Ziegler (Plate I, fig. 1) with similar sculpturing in the upper part of the whorl has numerous intermediate ribs and less developed flank furrow. Morphologically similar *L. pseudoperceivali* Schweigert, 1998 (Schweigert, 1998, Plate 2, figs. 3, 4) has slightly narrower umbilicus and ribs, which are more regularly arranged and do not thicken near venter. The described species differs from *Paralingulaticeras* representatives by the absence of ventrolateral tubercles, smaller size, and less developed sculpture.

Remarks. The taxonomic position of this species is doubtful. Although ornamentation of the shell flank and observed variability in the whorl sculpture and shape are similar to those in *Paralingulaticeras lithographicum* (Oppel), the *efimovi* species is smaller and lacking ventrolateral tubercles, thus being closer to *Lingulaticeras. ?L. efimovi* from the Volgian Stage of the Russian platform shows very high intraspecific variability that is consistent in general with the "Beckman covariation rule" (Westermann, 1966) – most evolute shells have usually wider whorls and coarser sculpture. At the same time, our collection includes relatively evolute ammonites with a weak sculpturing, which are indistinguishable from the Crimean specimen (Plate I, fig. 3). In the Gorodishchi section, the "extreme" morphotypes similar to the Crimean specimen occur largely in the upper part of the *efimovi* faunal horizon. The *klimovi* Zone yields abundant more evolute ammonites usually with poorly developed sculpture (Table 1, figs. 6, 7). The Crimean specimen is slightly larger as compared with evolute poorly sculptured representatives of this species from the Volga region.

Distribution: lower Volgian Substage, *klimovi* and *sokolovi* zones, *efimovi* faunal horizon of central Russia; lower Tithonian, *hybonotum* Zone, *?Lingulaticeras efimovi* Beds of the eastern Crimea.

Material: one phragmocone fragment (no. 5/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

FAMILY PHYLLOCERATIDAE ZITTEL, 1884

Genus *Phylloceras* Suess, 1865

Phylloceras consanguineum Gemmellaro, 1876

Plate I, fig. 8

Phylloceras consanguineum: Gemmellaro, 1876, p. 160, Plate 1, figs. 2, 3.

Phylloceras serum: Khimshishvili, 1967, p. 89, Plate III, fig. 3.

Phylloceras (Phylloceras) consanguineum: Checa, 2002a, p. 28. Fig. 2.

Lectotype. Specimen 019.4 (collection of G. Gemmellaro) is stored in the Museo Geologico "G.G. Gemellaro," Palermo, Italy, the Kimmeridgian of Sicily.

Shape. Shell is discoid, involute, with wide flattened flanks. Venter is most likely rounded. Whorl section is elongated-oval.

Sculpture. Flanks are covered with thin closely spaced radial ribs, slightly convex toward the mouth only in the mid-whorl. Ribs cross venter without any changes. In addition, there are sharp radial folds located at distance of 0.3–0.5 cm from each other. Folds repeat deflection of ribs.

Dimensions. Judging from the available fragment, shell diameter is approximately 40 mm, the whorl height is about 18 mm.

Comparison. The Crimean specimen is practically indistinguishable from the lectotype of *P. consanguineum* (Checa, 2002a, Fig. 2) differing only by smaller size. *P praeposterium* Fontannes, 1876 (Dumortier and Fontannes, 1876, p. 38, Plate IV, figs, 1, 2; Joly, 200, p. 49, Plate 9, figs. 3–6) is another close form that differs from the described species by slightly less distinct and denser fascicles of ribs. These species are coeval, and it cannot be ruled out that the indicated differences are of intrapopulation, rather than intraspecific character that needs to be studied further. In distinction from similar species *P. subplicatus* Burckhardt described from the lower Tithonian of Mexico (Verma and Westermann, 1973, p. 162, Plate 25, figs. 1, 2), *P. consanguineum* has more deflected ribs and sharper folds.

Remarks. Ammonite figured by Khimshiashvili (see synonymy) as *Phylloceras serum* is also attributed to the species under consideration. Khimshiashvili noted that "radial sinuous folds" representing a characteristic feature of the figured specimen are missing in typical representatives of *P. serum.*

Distribution: Kimmeridgian–Tithonian of Italy, lower Kimmeridgian of Bulgaria, lower Tithonian, *hybonotum* Zone, *?Lingulaticeras efimovi* Beds of the Crimea.

Material: one incomplete specimen (no. 7/378) from the eastern Crimea (Ordzhonikidze Settlement outskirts, Dvuyakornaya Bay).

DISCUSSION

Sediments under consideration belong to the Dvuyakornaya Formation. In recent works (Permyakov et al., 1984, 1991), the formation is dated back to the late Tithonian–Berriasian, while the underlying Khutoran Formation is considered as the early–middle Tithonian in age. In fact, the Dvuyakornaya Formation age has never been substantiated by descriptions and figures of characteristic fossils except for foraminifers (Kuznetsova and Gorbachik, 1985). Lists of ammonites from these sediments included the middle Tithonian taxa (*Richterella richteri*) in addition to the upper Tithonian and Berriasian forms. Our data call for a revision of the Dvuyakornaya Formation age and its relations with underlying sediments.

The lowest of the examined fossiliferous levels yielded *Euvirgalithacoceras* cf. *tantalus* (Herbich) and *Subplanites* sp. *Pseudowaagenia gemmellariana Olóriz* was found slightly higher, and *Lingulaticeras* cf. *procurvum* (Ziegler) was identified above the last form. Despite some uncertainty in the stratigraphic position of *P. gemmellariana* type specimens, the entire ammonite assemblage indicates a narrow stratigraphic interval within the upper Kimmeridgian *beckeri* Zone. The Crimean specimen of *L.* cf. *procurvum* slightly differs from the holotype and characterizes probably the close though not identical level of the upper Kimmeridgian. The *Euvirgalithacoceras* and *Subplanites* forms are most important for dating the sediments. *E. tantalus* [M] is characteristic of the lower part of the *beckeri* Zone in Germany and insignificant quantity of *Subplanites* [m] forms appear first in the same unit (Schweigert, private communication). With due account for the most important element of the assemblage, we propose to rank the interval between 8 and 12 m above the base of Member 1 in Section 1 as the *Euvirgalithacoceras* cf. *tantalus* Beds of the *beckeri* Zone.

The assemblage of *?Lingulaticeras efimovi, Phylloceras consanguineum*, and *Lytoceras* sp. was found at the higher level. While close species *P. consanguineum* and *P. praeposterium* occur in the Kimmeridgian–basal Tithonian, *?L. efimovi* enables a more exact dating. In the Volga region, this species characterizes the *efimovi* faunal horizon (upper part of the *klimovi* Zone–basal part of the *sokolvi* Zone of the lower Volgian Substage) that is correlated with the upper part of the lower Tithonian *hybonotum* Zone (Rogov, 2004a, 2004b). Data sufficient for identification of *?L. efimovi* subspecies are unavailable so far. Nevertheless, it should be noted that ammonites from the *sokolovi* Zone are usually characterized by more evolute shells. Sediments containing the last assemblage can be considered as the *?Lingulaticeras efimovi* Beds of the *hybonotum* Zone.

Middle Tithonian ammonites are unknown in the eastern Crimea (except for the never figured *Kossmatia richteri*). Therefore, we attribute the sequence between the *?Lingulaticeras efimovi* and *Oloriziceras* cf. *schneidi* Beds to the middle Tithonian arbitrarily.

The significantly greater stratigraphic range determined for the Dvuyakornaya Formation means a necessity to revise the former viewpoint on its conformable contact with the underlying Khutoran Formation (Permyakov et al., 1984, 1991). Since the moment of discrimination, the last unit was considered as the early–middle Tithonian in age. The upper age limit of the Khutoran Formation was likely determined based on its position below the overlying Dvuyakornaya Formation, and the Tithonian age of the former was substantiated by cited fossils. For example, *Phylloceras ptychostoma* (Benecke) present among fossils from this formation (Permyakov et al., 1991) is unknown from sediments older than the Tithonian (Joly, 2000; Checa, 2002b), and corals *Montivaltia nattheimensis* Milachewitsch

(Permyakov, 1980, p. 104, Plate 26, fig. 8) is dated back to the early Tithonian. According to I.Yu. Bugrova (private communication), the corals are undoubtedly not the Early Tithonian in age. If the ammonite identification is correct, the contact between the Khutoran and Dvuyakornaya formations is tectonic but not stratigraphic. This assumption seems correct in the light of recent data on the intricate nappe structure of Tithonian sediments in the westerly areas of the Crimean Mountains (Mileev et al., 1995, 2004). We do not exclude as well that the Dvuyakornaya Formation is present in tectonic nappes of the eastern Crimea, boundaries between which cannot be observed because of poorly exposed sequences of a uniform mainly clayey lithology.

CONCLUSIONS

Based on ammonite finds, presence of upper Kimmeridgian sediments in the Crimean Mountains is substantiated for the first time. The Kimmeridgian–Tithonian boundary is recognized in the continuous section and placed inside the uniform, largely clayey Dvuyakornaya Formation. The upper Kimmeridgian–Tithonian ammonite assemblage (8 species) is described. The *Euvirgalithacoceras* cf. *tantalus* and *?Lingulaticeras efimovi* beds are discriminated in the upper Kimmeridgian and lower Tithonian, respectively. The first subdivision is correlated with the *beckeri* Zone and the second one with the lower Tithonian *hybonotum* Zone of the Submediterranean Province and with *klimovi* and, partly, *sokolovi* zones of the lower Volgian in the Russian platform. Representatives of the genus *Lingulaticeras* first defined in the Crimea, though in the open nomenclature, are of great significance, because they point to connections of the Crimean basin with seas of the Russian platform, where the *efimovi* faunal horizon is established (Rogov, 2004).

It is proposed to define the middle Tithonian as spanning the *fallauxi* Zone (with *richteri* and *admirandum/biruncinatum* subzones) and (preliminarily) *semiforme* Zone.

The *Oloriziceras* cf. *schneidi* and *Paraulacosphinctes* cf. *transitorius* beds are distinguished in the upper Tithonian. They are correlated with the *simplisphinctes* and *transitorius* subzones of the *microcanthum* Zone of Spain, respectively. Based on new ammonite finds, the Dvuyakornaya Formation is dated back to the late Kimmeridgian–Berriasian. The Dvuyakornaya Formation is most likely in tectonic contact with underlying Khutoran Formation.

ACKNOWLEDGMENTS

The work was supported by the Ministry of Education of the Russian Federation (grant E02-9.0-111) and by the Russian Foundation for Basic Research, project no. 03-05-64297.

Reviewers E.D. Kalacheva and E.Yu. Baraboshkin

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