

Integrated stratigraphy of the reference sections for the Callovian-Oxfordian boundary in European Russia

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Key words: Callovian/Oxfordian boundary, Russian Platform, Northern Caucasus, reference section, integrated stratigraphy, GSSP.

Abstract. The most complete succession of the Callovian-Oxfordian boundary recorded in European Russia is the Dubki section, where the authors have carried out integrated paleontological and magnetostratigraphical studies. A continuous sequence of the West-European biostratigraphic units in the interval from the Lamberti to the Cordatum Zones is present in this section, and 10 ammonite biohorizons have been recognized. Additional data concerning nanofossil assemblages, foraminifers, ostracods, belemnoids and the paleomagnetic polarity for the Dubki section are also presented. The Callovian-Oxfordian boundary, marked by FAD of the genus *Cardioceras*, is placed at the base of the *scarburgense* biohorizon. The paleontological richness and continuity of the succession make the Dubki section a possible GSSP candidate for the Callovian/Oxfordian boundary. Correlation of the Dubki ammonite succession with those of the other GSSP candidates, Redcliff Point and Thuoux, is proposed. Other sections studied in Russia have yielded some additional observations on the Callovian-Oxfordian boundary beds. Although in the Dubki section the *praemartini* biohorizon is not found, its existence is proved, however, in Orenburg region (Khanskaya Gora). In the Datchovskaya section (Northern Caucasus) the *paucicostatum* biohorizon is characterized by an unusual combination of Subtethyan and Boreal ammonites, including *Kosmoceras*, which is not typical of the *paucicostatum* biohorizon outside the Northern Caucasus.

INTRODUCTION

During the last decades several sections have been proposed as possible GSSP candidates for the base of the Oxfordian Stage (Fortwengler *et al.*, 1997, 2012; Page, 2004; Kiselev *et al.*, 2006; Page *et al.*, 2009a, b, among others). One of the criteria for GSSP determination is good traceability throughout the World, within the different bio-

choremas (bioprovinces) and (if possible) on the basis of different fossil groups. Therefore study of reference sections (especially in regions with mixed Boreal, Subboreal and Submediterranean faunas as discussed below) in terms of micro- and macrofossil biostratigraphy and magnetostratigraphy has a special significance. Additionally important in connection with the investigation of the reference sections for the Callovian-Oxfordian boundary is the problem of the

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wide distribution of condensed facies and gaps around this boundary, accompanied by suggested sharp changes in climate of the northern hemisphere (Dromart *et al.*, 2003, but see Wierzbowski, Rogov, 2011, Alberti *et al.*, 2012 for evidence of the local development of this cooling) as well as a presumed impact event (Brochwicz-Lewinski *et al.*, 1984; Díaz-Martínez *et al.*, 2002; Díaz-Martínez, 2005). In the sections of European Russia the Callovian-Oxfordian boundary interval is represented mainly by a monotonous clayey member with a common stratigraphical gap (usually covering a few biohorizons), in many cases marked by phosphorite concretions or marly bands. At present in European Russia, we know of only one section rich in ammonites with a relatively continuous succession of biohorizons around the boundary under discussion – the Dubki section. Significantly, this section contains through all the levels of the Upper Callovian – Lower Oxfordian (in different proportions) ammonoids of Boreal, Subboreal and Submediterranean affinities.

Several schemes for the infrasubzonal subdivision of the Callovian–Oxfordian boundary beds of the Russian Platform have been proposed recently. Mitta (2001) recognized the *lamberti* and *paucicostatum* faunal horizons in the Tarkhanovskaya Pristan' section (Tatar Republic, Ulyanovsk Volga area) and subsequently supported this view by a description of the ammonite faunas (Mitta, 2003). In 2002 Kiselev and Rogov (presented during the Jurassic Symposium held in Palermo, Italy, but published two years later in the abstract volume of the Geological Congress, see Kiselev, Rogov, 2004) demonstrated for the uppermost Callovian of the Russian Platform the same succession of faunal horizons as in Western Europe with two exceptions: the *messiaeni* horizon of the Henrici Subzone remains unknown on the Russian Platform, and between the *lamberti* and *paucicostatum* horizons a new unit, the *mojarowskii* horizon, has been proposed. This succession of Upper Callovian ammonites, including *Quenstedtoceras lamberti*, *Q. paucicostatum* and *Gulielmiceras (Mojarowskia) mojarowskii*, was described and figured by Mitta (2003). For the Dubki section Mitta also proposed two faunal horizons for the basal Oxfordian – *scarburgense* and *renggeri*, but Mitta's (2003) interpretation of the horizons around Callovian-Oxfordian boundary in this section differs strictly from that proposed by the present authors. For example, the *paucicostatum* horizon sensu Mitta (*in*: Keupp, Mitta, 2004) corresponds to the *paucicostatum*, *scarburgense*, *alphacordatum* and *praecordatum* horizons of the Dubki section in our interpretation. Simultaneously with appearance of the paper of Mitta (2003), the oppeliid assemblage from the Oxfordian of the Dubki section was described briefly by Rogov and Egorov (2003). The marls

with *Creniceras* and a few metres of underlying clay were referred to the Praecordatum Subzone on the basis of the record of badly preserved *Cardioceras* ex gr. *praecordatum* occurring 1.05–2.05 m below the marls (some of these ammonoids were lately re-determined as *C. bukowskii*). Kiselev and Rogov (2004) proposed the Dubki section as a possible GSSP for the Callovian-Oxfordian boundary and gave a short list of the biohorizons with characteristic ammonites. Above the *scarburgense* biohorizon they distinguished the *woodhamense* biohorizon, but in the present paper this unit is abandoned due to re-interpretation of the records of *Cardioceras woodhamense* as representing other species of *Cardioceras*. The successions of biohorizons around the Callovian-Oxfordian boundary in the Russian Platform were also reviewed by Kiselev and Rogov (2005) and Seltzer (2005) (for the Callovian of the Saratov Volga area only). In the Lower Oxfordian of the Russian Platform, on the basis of the study of numerous sections, the following succession of faunal horizons was proved: *scarburgense*, *praemartini*, *alphacordatum*, *bukowskii*, *baccatum* (Kiselev, Rogov, 2005). The Callovian part of this succession remains chiefly the same as in the study of Gulyaev *et al.* (2002), apart from the newly introduced *angulatum* horizon between the *lamberti* and *mojarowskii* horizons as suggested by Seltzer (2005). The latter unit could not be recognized by our studies, because only rare *Vertumniceras angulatum* were collected by us, all within the range of *G. (M.) mojarowskii*, in the Dubki section.

The ostracod assemblages of the Dubki section have been studied recently in detail by Tesakova (2008). Some unusual oscillations in density and diversity of the ostracodes through the section studied, in comparison with changes in the ammonite assemblages, were shown in a brief publication (Pimenov *et al.*, 2009). This section is also rich in foraminifera and nannofossils. These were preliminarily investigated by Glinskikh (2010) and Matveev (2007), and are described in detail here. Belemnoids are rare but occur throughout the section. Phragmocones of *Belemnotheutis* (= *Acanthoteuthis*) were studied earlier by Fuchs *et al.* (2007), and by Rogov and Bizikov (2006, published 2008). The ontogeny and sexual dimorphism in some *Hibolithes* from the Dubki section were considered by Ippolitov (2006a,b). Well-preserved belemnite and ammonite records provide the possibility for the study of carbon and oxygen isotope values through this section and enable comparison of the oscillations of palaeotemperature derived from the interpretation of the oxygen isotope ratios in belemnite rostra with changes in the ammonite assemblages (Wierzbowski, Rogov, 2011).

MATERIAL

Detailed study of the Callovian-Oxfordian boundary was undertaken in various areas of European Russia and the Northern Caucasus (Fig. 1). Among the sections studied there are three which are most interesting and complete: Dubki (the Saratov region) (Figs 2, 3), Khanskaya Gora (Orenburg region) (Fig. 5), and Dachovskaya (N. Caucasus) (Fig. 4), but observations from other sections have been taken into account also when defining the particular biostratigraphic horizons (see below).

Dubki section (Figs 2, 3). This is located a few kilometers northeastwards from Saratov (Fig. 1A) and it was originally founded as a temporary excavation for nearby road-building. The oldest part of the succession (Henrici Subzone) is now flooded and only sometimes available for

sampling, while the Callovian/Oxfordian boundary (base of the Mariae Zone) is situated at a height of *ca.* 4 m above water-level. Since the year 2008, by decision of the government of the Saratov region, this section became a geological heritage of regional significance, and unauthorized fossil sampling here is prohibited. Recently this section and ammonites from the section were briefly described by Seltzer (1999), Mitta (Mitta, 2003; Keupp, Mitta, 2004) and by the authors (Rogov, Egorov, 2003; Rogov, 2004). Moreover, this section was proposed as a possible candidate for the Callovian/Oxfordian GSSP (Kiselev, Rogov, 2004). Precise ammonite sampling (especially of cardioceratids and kosmoceratids) undertaken during the summer of 2004 allowed the construction of a consistent scale of the faunal horizons and determined the age of some levels. For example, the stratigraphical interpretation of the 'renggeri horizon' of Mitta (2003), distinguished on the base of oppeliid and cardioceratid ammonites, gradually changed from Scarbur-

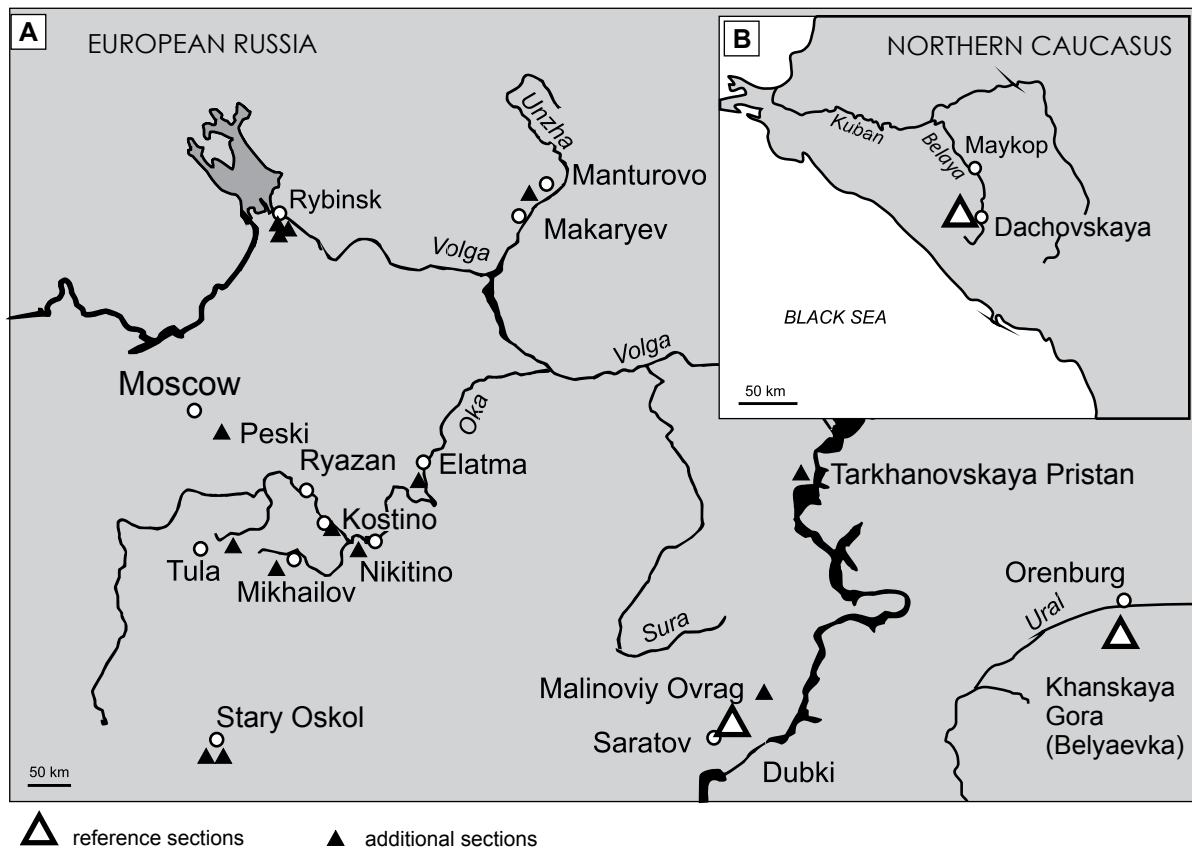


Fig. 1. Location of the studied sections in European Russia (A) and the Northern Caucasus (B)



Fig. 2. Sampling of the Dubki section during the All-Russian Jurassic meeting in the year 2009 held in Saratov

gense Subzone (Mitta, 2003) via Praecordatum Subzone (Rogov, Egorov, 2003; Kiselev, Rogov, 2004) to Bukowskii Subzone of the Cordatum Zone (this work). A lithological description of the section made by M. Rogov is given in the article by Tesakova (2008). Preliminary data on the nanofossil assemblages of the Dubki section were published by Matveev (2007). The isotope stratigraphy and climate oscillations in the studied section were described by Wierzbowski and Rogov (2011), who also analyzed the patterns of change in the relative abundances of ammonites of different paleobiogeographical affinities. They recognized significant oscillations in Boreal/Subboreal/Submediterranean ammonite ratios and indicated the absence of a direct correlation between the stable isotope record and the relative abundances of cardioceratid ammonites in the Dubki section, which could be explained by the different depth habitats of ammonites and belemnites.

Dachovskaya section (Figs 1B, 4) is located in the middle part of the Belaya River basin (western part of the Northern Caucasus). The Callovian and Oxfordian sections in the Belaya River basin extending from Kamennomostsky up to Guseripl have been described repeatedly by many authors

subsequent to Nikshich (1915). The last and most full description of the section near to the settlement of Kamennomostsky was made by Lominadze (1982). He distinguished six layers, of which four belonged to the Callovian (terrigenous beds), and two (limestones) – to the Lower Oxfordian. In spite of the fact that numerous ammonites were found in each layer, they were never described and illustrated. The ammonite assemblages of the Dachovskaya section (Fig. 4) are characterized by the presence of Tethyan (Oppeliidae, Perisphinctaceae, Phyllo- and Lytoceratidae) and Boreal/Subboreal (Cardioceratidae and Kosmoceratidae) faunal elements. Among the cardioceratids, the index-species of the West-European zones, subzones and biohorizons of the Callovian-Oxfordian boundary beds are found. On the basis of the occurrence of *Gulielmiceras (Mojarowskia) mojarowskii* (Nik. et Rozhd.) in bed 1 and

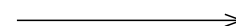


Fig. 3. Range chart of the ammonite and belemnite species of the Dubki section

For explanation of the lithological symbols see Figure 4

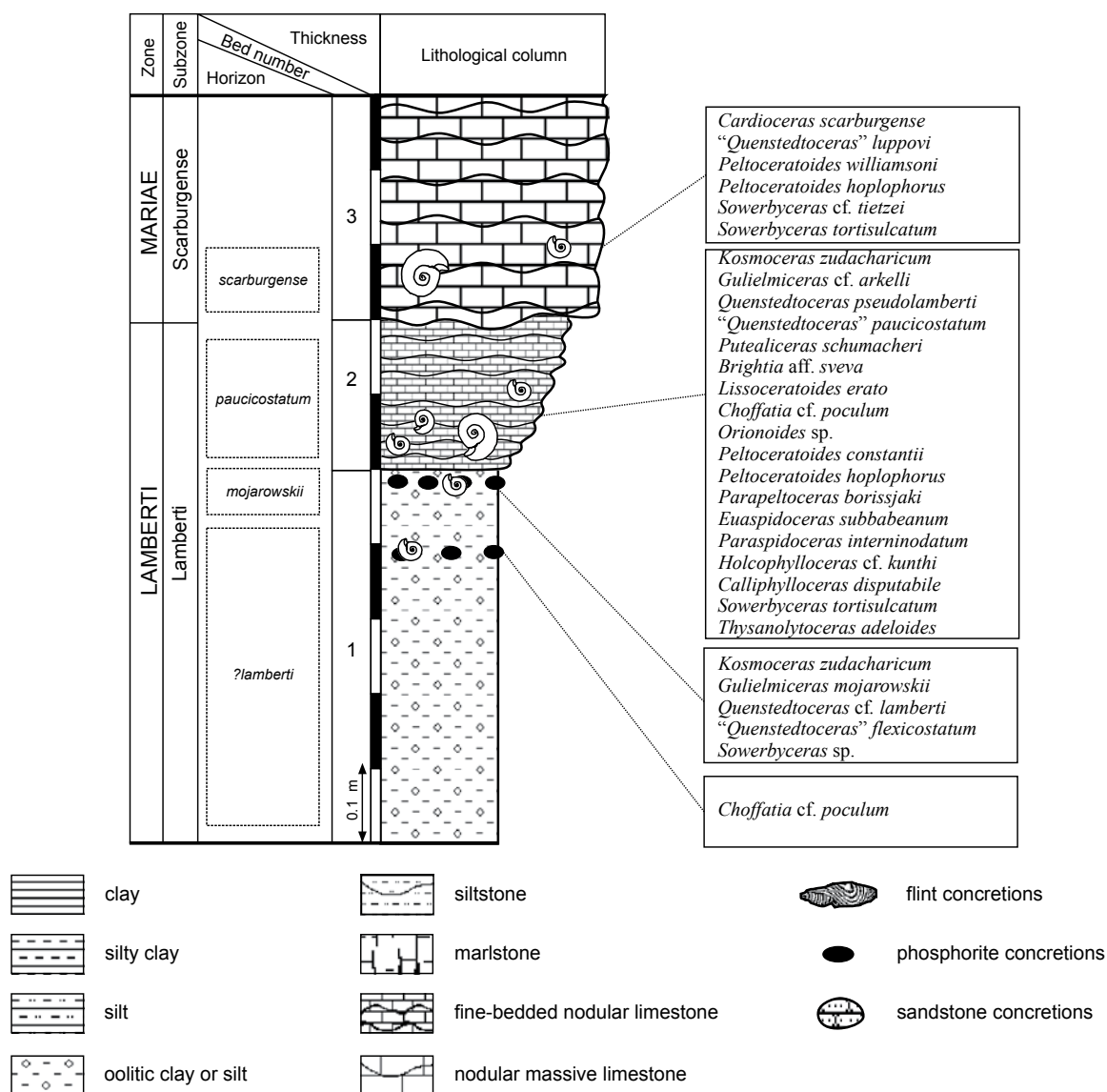


Fig. 4. Ammonite succession in the Dachovskaya section (Northern Caucasus)

“Quenstedtoceras” paucicostatum (Lange) in bed 2 it is possible to distinguish the two uppermost biohorizons of the Lamberti Zone – *mojarowskii* and *paucicostatum*. The presence of *Cardioceras scarburgense* (Young et Bird) in bed 3 indicates the lowermost Oxfordian biohorizon (*scarburgense* biohorizon). Thus, despite the essential lithological changes near the top of the Callovian, the Dachovskaya section shows a continuous succession of biohorizons across the Callovian-Oxfordian boundary.

Khanskaya Gora section (Figs 1A, 5). The Callovian and Oxfordian deposits on the Berdyanka river bank at Khanskaya Gora, between Belyaevka and Mikhailovskoe villages, have been studied by many authors (Sokolov, 1908; Ilvaysky, Florensky, 1941; Meledina, 1987; Mesezhnikov *et al.*, 1989). In the last two papers, primary attention was given to the Callovian (Meledina, 1987) and Middle–Upper Oxfordian (Mesezhnikov *et al.*, 1989) parts of the section.

The ammonite zonation is summarized in Figure 5.

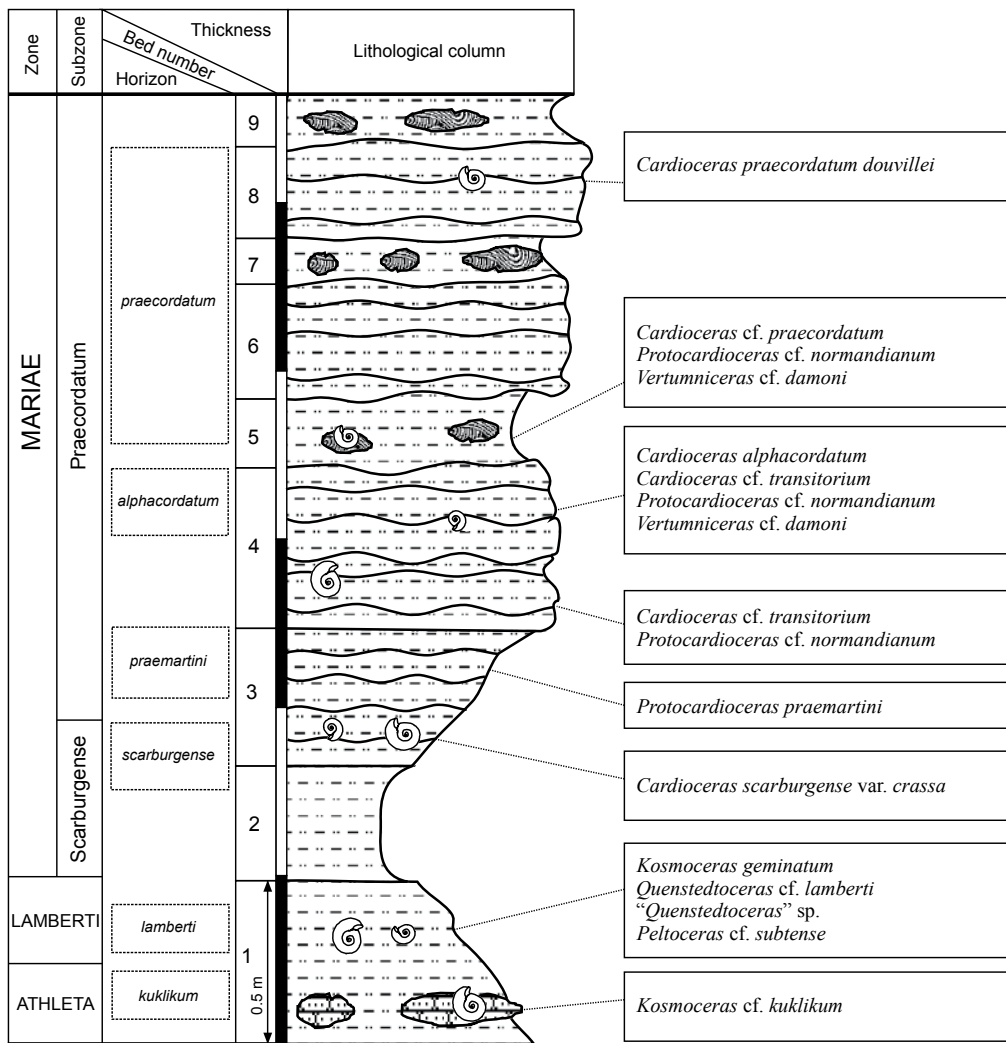


Fig. 5. Ammonite succession in the Khanskaya Gora section

For explanation of the lithological symbols see Figure 4

AMMONITE BIOSTRATIGRAPHY (D. Kiselev and M. Rogov)

Nowadays detailed ammonite biostratigraphy is based upon the recognition of biohorizons. In spite of attempts to make clear errors in the determination and naming of such units (Page, 1995; Rogov *et al.*, 2012) it is still the common situation to have biohorizons within a single succession based on different events in different ammonite lineages. Usages of non-Linnean symbols for the marking of transients of the species (for example, *enodatum* α - γ) also complicate recognition of the biohorizons and their tracing (Kiselev, 2001). The best way of constructing the succession

of biohorizons in our opinion lies in the independent creation of parallel scales based on the development of the different lineages (families), including phylogenetic and migrational events. This procedure should be followed by the integration of the separate scales and the construction of a more detailed synthetic scale. A parallel scale based on the aspidoceratid lineage has been proposed recently by Bonnot *et al.* (2002) for the Callovian/Oxfordian boundary beds of France and by Bert (2004) for the whole Oxfordian Stage. Our preliminary data shows the probable recognition of some of the aspidoceratid biohorizons in the succession studied in Russia.

While using biohorizons, we are following the simple hierarchical principles of the priority for these units (*cf.* Rogov *et al.*, 2012):

1. Minuteness (the smallest biohorizon has priority).
2. Continuity (the biohorizon determined within a single lineage has priority, if it does not contradict (1)).
3. Priority (the oldest name has priority if it does not contradict (1) and (2)).

Reasoning from the fact that a biohorizon is the smallest palaeontologically *correlatable* unit (Page, 1995), use of a species, widely ranging in space, could be accepted as a 4th principle.

A synthetic scheme of biohorizons, based upon the Boreal cardioceratid, Subboreal kosmoceratid and Submediterranean oppeliid ammonoids and their correlation with units of local schemes and a composite West European scheme is shown in Figure 6. Some of the biohorizons recognized at Dubki and in other sections of European Russia and the Northern Caucasus belong to well-known units. Therefore we concentrate here mostly on the characteristics of less well known and/or more recently proposed biohorizons.

Before description of the stratigraphic units, some remarks on the ammonite taxonomy used herein should be

Western Europe				European Russia			
Substage	Zone	Subzone	Biohorizon		Subzone	Biohorizon	
			England	France			
LOWER OXFORDIAN	CORDATUM	Cordatum	<i>cordatum</i>		Cordatum	<i>cordatum</i>	
		Costicardia	<i>costicardia</i>		Costicardia	<i>costicardia</i>	
		Bukowskii	<i>bukowskii</i>		Bukowskii	<i>baccatum</i> <i>bukowskii</i>	
	MARIAE	Praecordatum		<i>praecordatum</i>	Praecordatum	<i>praecordatum</i>	
				<i>alphacordatum</i>		<i>alphacordatum</i>	
				<i>praemartini</i>		<i>praemartini</i>	
		Scarburgense	<i>aff. scarburgense</i>	<i>woodhamense</i>	Scarburgense	<i>scarburgense</i>	
	<i>scarburgense</i>		<i>scarburgense</i>				
	<i>woodhamense</i>						
			<i>redcliffense</i>	<i>thuouensis</i>			
UPPER CALLOVIAN	LAMBERTI	Lamberti	<i>pauci. γ, Peltomorphites</i>		Lamberti	<i>paucicostatum</i>	
			<i>paucicostatum γ</i>				
			<i>paucicostatum β</i>	<i>paucicostatum</i>			
			<i>paucicostatum α</i>				
			<i>Quenstedtoceras</i> sp. 1				
		<i>lamberti</i>	<i>lamberti</i>				
		<i>praelamberti</i>			<i>mojarowskii</i>		
	Henrici		<i>henrici</i>	Henrici	<i>henrici</i>		
			<i>messiaeni</i>				
	ATHLETA	Spinsum	<i>spinsum</i>		"Spinsum"	<i>kuklikum</i>	
		Proniae			Proniae	<i>owlstonense</i>	<i>funiferus</i>
						<i>proniae</i>	<i>patruus</i>
							<i>allae compressum</i>
Phaeinum	<i>phaeinum</i>		Phaeinum	<i>phaeinum</i>	<i>allae allae</i>		

Fig. 6. Biostratigraphical subdivisions of the uppermost part of the Upper Callovian and Lower Oxfordian of European Russia and their correlation with the biostratigraphical subdivisions of England (Callomon, 1964; Page, 2004, Page *et al.*, 2009 a, b) and South-East France (Fortwengler, Marchand, 1994; Fortwengler *et al.*, 1997, 2012; Thierry *et al.*, 1997; Cariou *et al.*, 1997)

provided. Micro- and macroconchs are considered as belonging to different morphospecies and morphogenera. Such an approach is caused by the still unclear problems of the direct correspondance of dimorphs to each other, and by the differences in the rates of morphological evolution within dimorph successions. It should be noted that the sexual or non-sexual nature of ammonite dimorphism remains still under discussion, and the grouping of micro- and macroconchs within a single species is mainly based on their co-occurrences within the section rather than on detailed studies of their ontogeny and adult morphologies. This is the case with the cardioceratid assemblages of the sections studied, which usually show several separate morphological groups within both micro- and macroconchs without overlapping ranges in their morphologies. The co-occurrence of closely related cephalopod species is also well-known with in modern taxa: for example, up to 7 species of Pacific gonatid squids can be caught within a single sample (Nesis, 1996). In other cases, a depth segregation of close species was shown (Arkhipkin, Laptikhovskiy, 2006), but such a segregation can not be recognized in fossil assemblages.

The full list of the names of the ammonite genera and subgenera used in the present study is given in the appendix at the end of the text (see p. 84).

UPPER CALLOVIAN

Lamberti Zone Hebert 1857

Henrici Subzone Callomon 1964

In the West European ammonite succession two biohorizons (*messiaeni* and *henrici*) have been established, whereas in the area studied only the *henrici* biohorizon can be recognized.

henrici biohorizon Callomon 1964

Characteristic ammonites: *Quenstedtoceras henrici* R. Douv. (Pl. 1: 1, 2), *Parapeltoceras pratti* (Spath) and *Sublunuloceras nodosulcatum* (Lahusen) (ranges are restricted to this horizon); some species of wider range also occur, such as *Q. subflexicostatum* Sintzow, *Eichwaldiceras carinatum* (Eichw.), *Eboraciceras dissimile* (Brown), "*Quenstedtoceras*" *intermissum* Buckman, *Vertumniceras vertumnum* (Bean in Leck.), *Kosmoceras (Kosmoceras) spinosum* (Sow.) (Pl. 2: 6, 7), *Kosmoceras (Lobokosmoceras) geminatum* (Buckman) (Pl. 2: 8–10), *Gulielmiceras (Gulielmiceras) ex gr. arkelli* (Mak.), *Peltoceratoides subtense* (Bean in Leck.), *Rursiceras pratti* (Spath), *R. cf. caprinum* (Quenst.), *Choffatia poculum* (Leck.), *Choffatia trina* (Buckm.), *Alligaticeras rotifer* (Brown), *Putealicerias ex gr. puteale* (Bean in Leck.).

Geographic range. European Russia: Dubki, Malinovijskij Ovrage (Saratov region); Mikhailov, Nikitino, Kostino (Ryazan region); Stary Oskol (Kursk region); Peski (Moscow region); Tula region (presumably); Rybinsk district (Yaroslavl region). England, France, Poland (Łuków).

Lamberti Subzone Callomon 1964

praelamberti biohorizon Marchand 1986

Characteristic ammonites: *Quenstedtoceras praelamberti* R. Douv. (Pl. 1: 5, 6), "*Quenstedtoceras*" *intermissum* (Buckm.), "*Q.*" *macer* (Quenstedt) (Pl. 1: 9, 10), *Vertumniceras vertumnum* (Bean in Leck.) (Pl. 1: 12, 13), *Kosmoceras (Kosmoceras) transitionis* (Nikitin) (Pl. 2: 1), *Peltoceratoides subtense* (Bean in Leck.) (Pl. 3: 10), *Rursiceras annulosum* (Quenstedt) (Pl. 3: 8, 9) and bulk of the assemblage from the lower horizon.

Geographic range. European Russia: Dubki, Malinovijskij Ovrage (Saratov region); Mikhailov, Nikitino, Kostino (Ryazan region); Stary Oskol (Kursk region); Peski (Moscow region); Tula region. England, France, Poland (Łuków).

lamberti biohorizon Buckman 1925 emend. Callomon 1964

Characteristic ammonites: *Quenstedtoceras lamberti* (Sow.) (Pl. 1: 3, 4), *Q. subflexicostatum* Sintzow, *Quenstedtoceras zietenii* Maire, *Eboraciceras dissimile* (Brown)/*ordinarium* (Brown), "*Quenstedtoceras*" *flexicostatum* (Phill.), "*Q.*" *cf. paucicostatum* (Lange), *Vertumniceras vertumnum* (Bean. in Leck.), *Kosmoceras (Lobokosmoceras) geminatum* (Buckman), *Gulielmiceras (Gulielmiceras) ex gr. arkelli* (Mak.), *Peltoceratoides schroederi* (Prieser), *P. subtense* (Bean in Leck.), *P. athletoides* (Lahusen), *Rursiceras cf. caprinum* (Quenst.), *Choffatia poculum* (Leck.). Near the top of the range of *Q. lamberti* some species of the successive *mojarowskii* horizon also occur: *Gulielmiceras (Mojarowskia) mojarowskii* (Nikolaeva et Rozhd.), *Eichwaldiceras williamsoni* (Buckman), *Putealicerias douvillei* (Jeannot), *Sublunuloceras discoides* Spath, *Brightia (B.)* sp. nov. (= *B. sveva* (Bonar.) auct.).

Remarks. In the Dubki section the ranges of *Q. lamberti* and *G. (M.) mojarowskii* slightly overlap, therefore the *lamberti* and *mojarowskii* biohorizons as interpreted herein must be separated by an inclined boundary to show their interrelations. Despite the overlap, the ammonite assemblages of the *lamberti* and *mojarowskii* biohorizons differ in both the list of ammonite species and in the relative abundance of the genera.

Geographic range. European Russia: Dubki, Malinovijskij Ovrage (Saratov region); Tarkhanovskaya Pristan (Tatar Republic); Tula region; Oka River basin (Ryazan region);

Peski (Moscow region). England, Scotland, northern and southeast France, Poland.

mojarowskii biohorizon Kiselev, Rogov 2004

Index species. *Gulielmiceras (Mojarowskia) mojarowskii* (Nikolaeva et Rozhdestvenskaya). Holotype: Nikolaeva, 1956, pl. 17: 9, 10. Upper Callovian of the Saratov region near Razboyschina Village.

Stratotype: Dubki section, Bed 1 (ranged from 360 to 475 cm from the visible base of the bed 1).

Characteristic ammonites: *Quenstedtoceras lamberti* (Sow.)/ *pseudolamberti* Sintzow, *Eboracicerias cf. dissimile* (Brown) (only near base of the horizon), *Eichwaldicerias williamsoni* (Buckman), "*Quenstedtoceras*" *flexicostatum* (Phill.), *Vertumnicerias cf. angulatum* (Troizk.), *Kosmoceras (Kosmoceras) transitionis* (Nik.), *K. (K.) zudacharicum* Kazanskii, *Gulielmiceras (Mojarowskia) mojarowskii* (Nikolaeva et Rozhd.) (Pl. 2: 11–13), *Grossouvria sulcifera* (Opp.), *Putealicerias douvillei* (Jeannet) (Pl. 1: 18), *Sublunuloceras discoides* Spath, *Brightia (B.) socini* (Noetling) sensu Gygi, 1990 (Pl. 1: 23), *B. (B.) aff. sveva* (Bonar.), and *B. (B.) cf./aff. thuouxiensis* (Fortwengler *et al.*) (Pl. 1: 21), which differs from the typical *B. thuouxiensis* by its slightly more rectiradiate secondaries.

Correlation of the biohorizon is based on the occurrence of *Q. lamberti* with the first *G. (Mojarowskia)* and the appearance of the species "*Q.*" *paucicostatum* above the last records of *G. (Mojarowskia)*. Unfortunately, the bulk of the horizon in the stratotype section yields only non-characteristic cardioceratids (*E. williamsoni*) and precise correlation of this horizon with the cardioceratid succession remains unclear.

Remarks. It is possible that the *mojarowskii* biohorizon may occur in some areas of Western Europe, *e.g.* in the Haute-Saône (France), where a record of *Kosmoceras (= Mojarowskia) authoisonense* Maire, 1938, a species very close to *G. (M.) mojarowskii*, is known (Maire, 1938, pl. 2: 5), and in northern Spain, from which "*Kosmoceras spinosum*" figured by Conze *et al.* (1984, pl. III: 5a–c), on the basis of the presence of a third row of tubercles, could also belong to *G. (M.) mojarowskii*.

Geographic range: Central Russia (Saratov area and Ulyanovsk area – see *K. sp. ex gr. mojarowskii* in Mitta, 2003, pl. 2: 5), Northern Caucasus, France, Northern Spain.

paucicostatum biohorizon Marchand
in Debrand-Passard *et al.* 1978

Characteristic ammonites in European Russia: *Quenstedtoceras pseudolamberti* Sintzow, *Q. zietenii* Maire, "*Quenstedtoceras*" *paucicostatum* (Lange) (Pl. 1: 14, 15; Pl. 4: 9), "*Q.*" *orbis* (Maire), *Vertumnicerias mariae* (d'Orb.)

(Pl. 1: 11), *Choffatia poculum* (Bean. in Leck.), *Klematosphinctes perisphinctoides* (Sintzov), *Parapeltocheras borissjaki* (Amanniasov) (Pl. 3: 7), *Euaspidoceras subbabeatum* (Sintzov) sensu Jeannet (Pl. 2: 33), *Mirosphinctes sp.*, *Sublunuloceras cf. deperditum* (Roull.), *Brightia cf./aff. thuouxiensis* (Fortwengler *et al.*).

Characteristic ammonites in the Northern Caucasus: *Quenstedtoceras pseudolamberti* Sintzow (Pl. 1: 7, 8; Pl. 4: 4–5), *Q. zietenii* Maire, "*Quenstedtoceras*" *paucicostatum* (Lange) (Pl. 4: 12–14), *Kosmoceras (Kosmoceras) zudacharicum* Kazanskii (Pl. 2: 2–5), *Gulielmiceras cf. arkelli* (Makowski) (Pl. 4: 21, 22), *Choffatia cf. poculum* (Bean in Leck.), *Orionoides sp.*, *Alligaticeras cf. pseudograciosus* Arkell (Pl. 3: 13, 14), *Peltocheratoides constantii* (d'Orb.), *P. hoplophorus* (Buckman) (Pl. 3: 1–4), *Parapeltocheras borissjaki* (Amanniasov), *Euaspidoceras subbabeatum* (Sintzov) sensu Jeannet, *Paraspidoceras interninodatum* Zeiss (Pl. 3: 11, 12), *Paraspidoceras billodensis* (Loriol), *Putealicerias schumacheri* (Noetl.) (Pl. 1: 24; Pl. 3: 15, 16), *Brightia aff. sveva* (Bonarelli), *Lissoceratoides erato* (d'Orb.) (Pl. 1: 25), *Holcophylloceras cf. kunthii* (Neum.), *Holcophylloceras mediterraneum* (Neum.), *Calliphylloceras disputabile* (Zitt.), *Sowerbyceras tortisulcatum* (d'Orb.), *Thysanolytoceras adeloides* (Kudern.).

Remarks. The ammonite assemblage of the *paucicostatum* biohorizon in the Northern Caucasus (Dachovskaya section) is very important and, remarkably, differs from any other by the presence of the last kosmoceratid (*Kosmoceras (K.) zudacharicum*). Another interesting ammonite in this section is the typical Middle-East *Putealicerias schumacheri* (Noetl.). This record could slightly change the correlation of the Socini Zone of the Levant, considered so far to belong to the lowermost Oxfordian (Hirsch *et al.*, 1998).

Geographic range. European Russia: Dubki (Saratov region); Tarkhanovskaya Pristan (Tatar Republik); Mikhailov (Ryazan region). Northern Caucasus: Dakhovskaya. England, Central and Southeast France, Northern Germany, Switzerland.

LOWER OXFORDIAN

Mariae Zone Douvillé 1881

Scarburgense Subzone Buckman 1920

scarburgense **biohorizon** Buckman 1920
emend. Fortwengler and Marchand 1994

Characteristic ammonites: *Cardioceras (Scarburgiceras) scarburgense* (Young et Bird) (Pl. 3: 17), "*Quenstedtoceras*" *luppovi* (Amanniasov) (Pl. 1: 16, 17), *Vertumnicerias mariae* (d'Orb.), *Subvertebriceras stantoni* (Reeside), *Protocardioceras sp.*, *Properisphinctes bernensis* (Loriol),

Poculisphinctes sp., *Peltoceratoides williamsoni* (Phillips) (Pl. 3: 5, 6), *Rursiceras* cf. *torosus* (Oppel), *Euaspidoceras subbabeanum* (Sintzov) sensu Jeannot, *Sublunuloceras* cf. *deperditum* (Roll.), uncommon ?*Eulunulites bonarellii* (Loriol).

Geographic range. European Russia: Mikhailov, Nikitino, Kostino, Elatma (Ryazan region); Dubki; Khanskaya Gora (Orenburg region). Northern Caucasus (Dachovskaya), England, Scotland, France, Germany, Lithuania, East Greenland.

Praecordatum Subzone Morley-Davies 1916

praemartini biohorizon Fortwengler, Marchand 1994

Stratotype: not designated. The Warboys section (England) could be suggested as a stratotype (lowermost 4.5 m of the bed 4 in Spath, 1939), which is the source of the holotype of the index species, but now this is a waste disposal site, and all but the upper Cordatum Zone strata are hidden (pers. comm. by J. Wright), thus such a choice of the type section for this biohorizon is unsuitable.

Characteristic ammonites. *Protocardioceras praemartini* (Spath) only (Pl. 2: 14, 22, 23).

Remarks. In the Warboys section the range *P. praemartini* is limited in comparison with that of the other species described by Spath (1939). In the Khanskaya Gora section this species also occurs in the narrow interval in a similar stratigraphic position in the sequence of cardioceratid/species (between *Cardioceras* cf. *scarburgense* var. *crassa* Spath and *Cardioceras* cf. *transitorium* Spath). It is remarkable, that in the *praemartini* biohorizon of the Khanskaya Gora section, as well as in the Warboys section, only microconchs were found, and even the mode of preservation of the Orenburg specimens is similar to that of those from England. The detailed position of the *praemartini* biohorizon in France is unclear. The ammonites coming from that horizon in France have not been illustrated or described except for the juvenile macroconch (?) figured by Cariou *et al.*, 1997 (pl. 21: 8).

Geographic range. European Russia: Khanskaya Gora (Orenburg region); Manturovo area (Unzha River, Kostroma region). England, ?France.

alphacordatum biohorizon Callomon 1993
emend. Fortwengler and Marchand 1994

Stratotype: not designated. The holotype of the index-species has been found at Warboys section.

Characteristic ammonites: *Cardioceras* (*Scarburgiceras*) *alphacordatum* Spath (Pl. 2: 16, 28, 29), *Goliathiceras* (*Pachycardioceras*) *nikitini* (Lahusen), *Pavlovi-*

ceras pavlowi (Douville), *Vertumniceras mariae* (d'Orb.), *Protocardioceras russiense* (Sasonov) (Pl. 2: 26, 27), ?*Subvertebriceras subcordatum* (Pavlow), *Properisphinctes bernensis* (Loriol), *Peltoceratoides arduennense* (d'Orb.), *P. hoplophorus* Buckm. "*Parapeltoceras*" *subeugenii* (Buckm.), *Euaspidoceras douvillei* (Collot).

Geographic range. European Russia: Dubki (Saratov region); Mikhailov, Nikitino, Kostino (Ryazan region); Khanskaya Gora (Orenburg region); Rybinsk (Yaroslavl region), England, France, Germany, Mangyshlak (Kazakhstan), East Greenland, Arctic Canada, Northern and Northeast Siberia.

praecordatum biohorizon Buckman, 1920

Stratotype: not designated. In Warboys section (England) the biohorizon occupies presumably bed 6, 7 (Callomon, 1968).

Characteristic ammonites. *Cardioceras* (*Scarburgiceras*) *praecordatum praecordatum* R. Douv. (Pl. 2: 17–19), *C. (S.) praecordatum douvillei* Maire (Pl. 2: 15), *Goliathiceras* (*Pachycardioceras*) *borissjaki* (Sasonov), *G. (P.) acutum* (Sasonov), *G. (Korythoceras)* *fluctuans* (Pavlow), *G. (K.) rotundatum* (Nikitin), *Pavloviceras pavlovi* (R. Douv.), *Protocardioceras russiense* (Sasonov), *Vertumniceras* cf. *mariae* (d'Orb.), *V. mangyschlakense* Repin, *Properisphinctes bernensis* (Loriol), *Peltoceratoides intertextus* (Buckman), *Peltomorphites hoplophorus* Buckman, *Peltoceratoides arduennense* (d'Orb.), *Rursiceras* cf. *torosus* (Oppel).

Geographic range. European Russia: Dubki (Saratov region); Nikitino, Kostino (Ryazan region); Khanskaya Gora (Orenburg region); Rybinsk (Yaroslavl region). England, France, Germany, Switzerland, Poland, Lithuania, Mangyshlak (Kazakhstan), Turkmenia (Tuarkyr, Kugitang-Tau), East Greenland, Northern and Northeast Siberia.

Cordatum Zone d'Orbigny 1852

Bukowskii Subzone Arkell 1941

Characteristic ammonites: *Cardioceras* (*Scarburgiceras*) *bukowskii* Maire (Pl. 2: 20, 21), *Cardioceras* (*S.*) *gloriosum* Arkell, *Goliathiceras* (*G.*) *goliathum* (d'Orb.), *G. (G.) nalivekini* (Borissjak) (Pl. 2: 32), *G. (G.)* cf. *subgoliath* (Maire), ?*Subvertebriceras subcordatum* (Pavlow), *Euaspidoceras nikitini* (Borissjak), *Taramelliceras sublaevipictum* (Sintzov).

Geographic range. European Russia: Dubki (Saratov region), Mikhailov (Ryazan region); Khanskaya Gora (Orenburg region); Peski (Moscow region). England, Scotland, France, Germany, Poland, Switzerland.

baccatum biohorizon Rogov 2005 (in Kiselev and Rogov 2005)
(= *renggeri* horizon Seltzer in Mitta, 2003 non
Renggeri Zone Loriol 1898 nec *renggeri* hemera Buckman 1913)

Index species. *Taramelliceras baccatum* Bukowski 1887.

Stratotype. Dubki section, bed 5.

Characteristic ammonites. *Creniceras renggeri* (Opp.) (Pl. 1: 22), ?*Coryceras petitclerci* Gygi, *Taramelliceras baccatum* (Buk.) morph *baccatum* (Buk.) (Pl. 1: 19, 20), *Taramelliceras baccatum* (Buk.) morphe “*dentostriatum*” (Quenst.), *T. sublaevipictum* (Sinzov), *Peltoceratoides arduennense* (d’Orb.), *Goliathiceras (G.) nalivkini* (Borissjak).

Remarks. Initially the level under discussion in the Dubki section was recognized as the *renggeri* biohorizon (Mitta, 2003) and placed within the Scarburgense Subzone. In the present paper the name *renggeri* is replaced by *baccatum* due to a change of the stratigraphical interpretation of the level in question from the Scarburgense Subzone to the Bukowskii Subzone and also because of the wide range of *C. renggeri*, which is used for the designation of different stratigraphic levels from the basal Oxfordian up to correlatives of the Cordatum Zone by different authors. Thus a new index-species of the biohorizon, *Taramelliceras baccatum* instead of *Creniceras renggeri*, has been proposed recently by the authors Kiselev and Rogov (2005), but without the designation of a stratotype and detailed description. The name ‘*baccatum*’ also has been used as a zonal index by Tarkowski (1990). His Baccatum Subzone has a slightly wider stratigraphical range than the *baccatum* biohorizon of Russia. The Renggeri Zone of Sapunov (1979) and Caracuel *et al.* (2000) also partially corresponds to the *baccatum* biohorizon of Central Russia. The relative position of the *baccatum* biohorizon within the zonal succession could be based on oppeliid occurrences and on indirect information from the cardioceratid succession. The absence of the characteristic cardioceratids in bed 5 of the Dubki section (only some pieces of *Goliathiceras* are present), and records of *C. bukowskii* 0,5 m below bed 5, allow us to conclude that equivalents of the *baccatum* biohorizon are situated within the Bukowskii or Costicardia Subzones. This opinion is also strongly supported by comparison with the Mediterranean Baccatum Subzone. Due to the total absence of cardioceratids with tubercles at the point of furcation in this biohorizon there are more reasons to correlate it with the upper part of the *bukowskii* biohorizon. An additional argument for this correlation is provided by the records of *Taramelliceras sublaevipictum* and *Creniceras renggeri* with *Cardioceras bukowskii* in the Mangyshlak peninsula (Repin and Rashvan, 1996, pls. XLVIII–L – the cardioceratids originally recognized as *C. praecordatum*). Mitta’s opinion (Mitta, 2003; Keupp, Mitta, 2004) about the recognition of the so-called

‘*renggeri*’ biohorizon within the Scarburgense Subzone was based on the incorrect determination of cardioceratids from this level as “*Cardioceras (Scarburgiceras)*”. Surprisingly, the relative abundance of the *Taramelliceras-Creniceras* group in the *baccatum* horizon of Dubki (up to ~90%) significantly exceeds their abundance in European sites. Only recently a similar *Taramelliceras*-dominated assemblage has been recognized in the Cordatum Subzone of South-eastern France (Quereilhac *et al.*, 2009), but these ammonites are not so numerous.

Geographic range. Central Russia (Saratov region). On the basis of records of the contemporaneous oppeliids (*C. petitclerci*, *C. renggeri*, *T. sublaevipictum*) we suggest the presence of the biohorizon in Belorussia (Prip’at area), Moscow Region and Mangyshlak (Kazakhstan).

Costicardia Subzone Arkell 1941

Characteristic ammonites: *Cardioceras (Cardioceras) costicardia* Buckman (Pl. 2: 24, 25), *C. (C.) laqueum* Arkell, *C. (C.) percaelatum* Pavlow, *C. (Scoticardioceras) gallicum* Maire, *C. (?S.) excavatiforme* (Maire), *Goliathiceras (G.) goliathum* (d’Orb.), *G. nalivkini* (Borissjak), *G. (Korythoceras) cf. rotundatum* (Nikitin), *G. (Pachycardioceras) anacanthum* (Buckman), *Vertebriceras quadrarium* (Buckman), *Subvertebriceras costellatum* (Buckman), *S. comprimatum* (Buckman), *Perisphinctes* sp., *Peltoceratoides constantii* (d’Orb.), *P. eugenii* (Raspail), *P. arduennense* (d’Orb.), *Euaspidoceras babeatum* (d’Orb.), *Mirosphinctes* sp., *Neocampylites helveticus* Jeannot (Rogov, 2003, fig. 4: 2).

Geographic range. European Russia: Mikhailov, Oka river basin (Ryazan region); Khanskaya Gora (Orenburg region); Peski (Moscow region); Rybinsk district (Yaroslavl region). England, Scotland, France, Germany, Poland, Lithuania (presumably), Switzerland, Greenland, Northern Siberia.

Cordatum Subzone Buckman 1925 emend. Arkell 1941

Characteristic ammonites: *Cardioceras (Cardioceras) cordatum* (Sowerby) (Pl. 2: 30,31), *C. (C.) cordatiforme* (Buckman), *C. (Scotiardioceras) stella* Arkell, *Goliathiceras (G.) goliathum* (d’Orb.), *G. (Pachycardioceras) elatum* (Maire) (Pl. 4: 17–20), *G. (Pachycardioceras) pavlovoides* Arkell, *Vertebriceras* aff. *tumescens* (Arkell), *Properisphinctes bernensis* (Loriol), *P. orbignyi* Tarkowski (Pl. 4: 1–3).

Geographic range. European Russia: Mikhailov, Nikitino, Kostino (Ryazan region); Khanskaya Gora (Orenburg region); Peski (Moscow region); Rybinsk district. England, Scotland, France, Germany, Poland, Lithuania, Switzerland, Northern Siberia, Arctic Canada.

BELEMNOID DISTRIBUTION (O. Dzyuba)

Among the Belemnoidea there are two big groups occurring in the Dubki section: the belemnotheutids and the true belemnites (belemnitids) (Fig. 3). Belemnotheutids range from the Lamberti Subzone (Upper Callovian) to the Praecordatum Subzone (Lower Oxfordian), but are not numerous. These fossils hitherto were not known from the Russian Platform except for *Belemnotheutis antiquus* Pearce described recently by Fuchs *et al.* (2007) from the Lamberti Zone of the Dubki section. Simultaneous wide distribution of the belemnotheutids within the Middle Jurassic–Lower Cretaceous deposits of the Russian Platform and adjacent areas has been shown by Rogov and Bizikov (2006). It has been established that the Upper Callovian–Lower Oxfordian belemnotheutids with a good mode of preservation are close in all characters to *Acanthoteuthis polonica* (Makowski), but there are some problems in the comparison of this taxon with *A. antiqua* (Pearce) of the same age, preserved typically as crushed shells, in contrast to the non-crushed *A. polonica* (Makowski) (*cf.* Bandel, Kulicki, 1988; Doyle, Shakides, 2004). Fuchs *et al.* (2007) regarded *Belemnotheutis polonica* Makowski as a synonym of *B. antiquus* Pearce.

Belemnitids (Pl. 3: 18–33) are represented mainly by species of the Tethyan *Hibolithes* (Mesohibolitidae), which differ from the European Submediterranean/Mediterranean forms by their smaller size (Gustomesov, 1976). All species of *Hibolithes* found in the Dubki section seem to be endemic to the Russian Platform Basin. Their exact stratigraphic ranges are presented here for the first time (Fig. 3). The initial state of study of the Upper Callovian–Lower Oxfordian *Hibolithes* in the Russian Platform does not allow us to propose a belemnite zonation for the Dubki section. Boreal belemnitids (Cylindroteuthididae) are uncommon and are restricted to the Praecordatum Subzone and a part of the Lamberti Subzone only. The taxa *Holcobeloides beaumontianus* (d'Orb.) and *Cylindroteuthis spicularis spicularis* (Phill.) were identified. These two taxa have a wide geographic (Europe and Western Siberia) and stratigraphic (Middle Callovian–Lower Oxfordian) distribution (Dzyuba, 2004).

NANNOFOSSIL ASSEMBLAGES (A. Matveev)

Jurassic calcareous nannofossils still are little-known, especially from the Russian Platform, where they have been studied in few sections. Definitions of the zonal successions and the validities of the zones are also far from the desirable.

We have studied 25 samples from the Upper Callovian–Lower Oxfordian of the Dubki section (Fig. 7). Nannofossils occur through the whole part of the section studied with relatively high abundance. They are especially numerous in the uppermost part of the Oxfordian above the marly band (bed no. 5). Nannofossils are well-preserved and do not show any traces of re-deposition or dissolution. In spite of their high abundance in all samples, the diversity remains low through the whole studied interval, and there are no significance changes observed in the nannofossil assemblages. Three species, *Watznaueria britannica* (Stradner) (Fig. 7: 1, 2), *W. barnesae* (Black) (Fig. 7: 3) and *Zygodiscus erectus* (Deflandre) (Fig. 7: 7) occur in high abundance through the section. Other taxa are also known through the whole interval studied but are not numerous. These are *Stephanolithion bigoti bigoti* (Deflandre) (Fig. 7: 4–6), *Staurolithites stradneri* (Rood, Hay et Barnard) (Fig. 7: 9) and *Cyclagelosphaera margerelii* (Noel) (Fig. 7: 8). Other taxa were found in the some samples only and in small amounts. Analysis of nannofossil ranges through the section studied has revealed only two nannofossil events which could be useful for its stratigraphical subdivision:

1. *Stephanolithion bigoti bigoti* (Deflandre) below the boundary between the Scarburgense and Praecordatum ammonite subzones is uncommon, becoming more numerous above.
2. FAD of *S. bigoti maximum* Medd (only one partially preserved specimen has been found) fixed in the uppermost part of the section studied, within the Cordatum ammonite Zone. In the French sections this species also appears in the Cordatum Zone (S. Gardin, pers. comm. July 2013).

The nannofossil assemblage of the Dubki section is very close to the recently described coeval assemblages of the French Subalpine Basin (Giraud *et al.*, 2009) and Dorset (Page *et al.*, 2009a), but differs in the much higher FAD of *Stephanolithion bigoti maximum* Medd. In the Ukraine (Matveev, Bondarev, 2011) *Stephanolithion bigoti maximum* records are also unknown from the Callovian, and the base of NJ14 zone in this region, as well as in the Dubki section, lies within the Lower Oxfordian.

OSTRACOD DISTRIBUTION (E. Tesakova)

Ostracods are numerous (up 100 and more valves per sample) and diverse (*ca.* 30 species, 1–14 per sample). The usual presence of a few dominant species within the ostracod paleocommunities, together with frequent changes in population structure and density, were determined by oscillations in the salinity, temperature and sediment types,

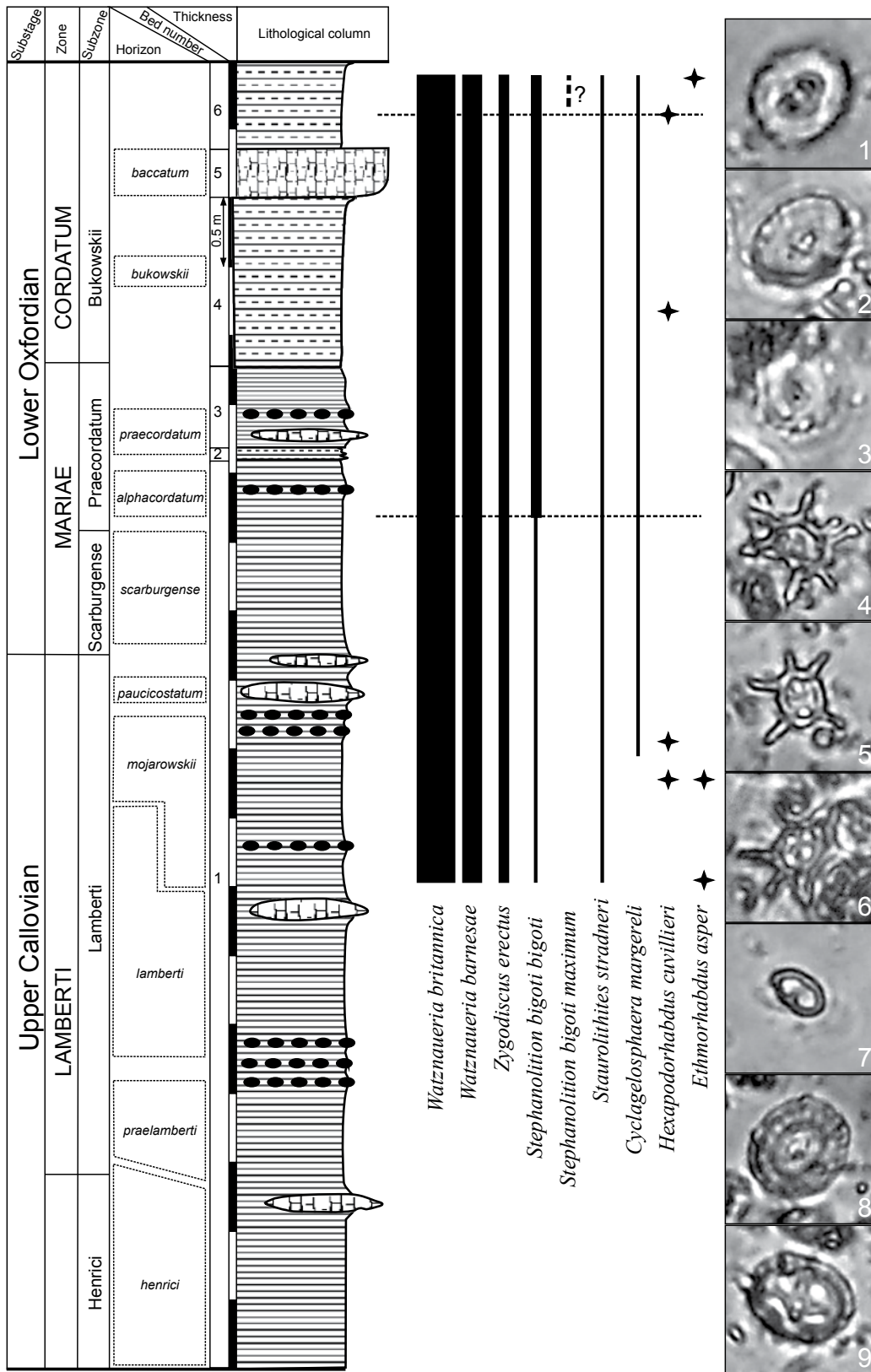


Fig. 7. Range chart of the nannofossil species of the Dubki section

1, 2 – *Watznaueria britannica* (Stradner); 3 – *W. barnesae* (Black); 4–6 – *Stephanolithion bigoti bigoti* (Deflandre); 7 – *Zygodiscus erectus* (Deflandre); 8 – *Cyclagelosphaera margerelii* (Noel); 9 – *Staurolithites stradneri* (Rood, Hay, Barnard). Magnification $\times 1600$ for all the figures. For explanation of the lithological symbols see Figure 4

←

which possibly reflected sea-level changes. Due to the good mode of preservation and the absence of size differentiation in the sampled ostracods, as well as due to the joint occurrence of larval and adult shells, we conclude that the fauna of the section studied was autochthonous. The trends in the diversity of the ostracod assemblages through the Dubki section differ markedly from the diverse ammonite pattern (Pimenov *et al.*, 2009) in the Callovian part of the succession, while Oxfordian changes in diversity are close within these groups. This phenomenon possibly could reflect sea-level fluctuations, which are generally related to changes in the ammonite assemblages which showed the highest diversity during sea level rise (O'Dogherty *et al.*, 2000; Sandoval *et al.*, 2001 among others). The reverse situation occurred possibly during sea level rise when enhanced eutrophication lead to decreasing of ostracod diversity.

Previously within the ostracod succession of the Dubki section 8 assemblages has been recognized (Tesakova, 2008). Recognition of these assemblages primarily was based on the relative abundance of taxa as well as oscillations in diversity of ostracod fauna. Nevertheless, taxonomic changes in ostracod assemblages permit to recognize 3 ostracod zones in the Dubki section (Fig. 8) now accepted as standard for the whole Russian Platform (Mitta *et al.*, 2012). These are *Sabacothere sudorocostata* Zone (assemblages I–III in Tesakova, 2008), *Neurocythere dulcis* Zone (assemblages IV–V in Tesakova, 2008) and *Sabacothere attalicata–Eucytherura costaeirregularis* Zone (assemblages VI–VIII in Tesakova, 2008). Base of each successive zone in the studied section is marked by FAD of its index-species, i.e. *N. dulcis* at the base of the *N. dulcis* Zone and *S. attalicata* at the base of the *Sabacothere attalicata–Eucytherura costaeirregularis* Zone. Ostracod zonal boundaries do not coincide with those based on ammonites or foraminifers, and the Callovian-Oxfordian boundary determined by ammonites lies in the middle of the *Neurocythere dulcis* Zone. Earlier, when incomplete sections with widely distributed gaps around the Callovian-Oxfordian boundary were studied, the coincidence of this boundary with that between the *N. dulcis* and *S. attalicata–E. costaeirregularis* beds has been proposed (Tesakova, 2003), but as clearly visible on the base of the analysis of ostracod ranges of the Dubki section in fact it lies somewhere higher.

FORAMINIFERAL DISTRIBUTION (L. Glinskikh)

The clays of the Callovian-Oxfordian boundary beds in the Dubki section are rich in foraminifers represented by calcareous benthonic species only. Planktonic forams still remain unknown from the Lower Oxfordian of the Volga area. The foraminiferal distribution permits recognition of 2 successive zones, the boundary of which nearly coincides with the Callovian–Oxfordian boundary defined by ammonites and ostracods (Fig. 8). The foraminifers studied were derived from the same samples which had been previously used for extraction of ostracod shells in the study by Tesakova (2008).

The Upper Callovian *Lenticulina tumida–Epistomina elschankaensis* Zone (Grigelis, 1982) of total thickness at least ca. 4.5 m is characterized by *Lenticulina tumida* Mjatl., *L. uhligi* (Wisn.) (Pl. 5: 1), *L. polonica* (Wisn.), *L. compressaeformis* (Paalz.), *L. subtilis* (Wisn.), *L. parainflata* Grig., *Astacolus colligatum* (Brueckm.) (Pl. 5: 3), *Planularia deekei* (Wisn.) (Pl. 5: 4), *Saracenaria engelsensis* Kosyreva in Chabarova (Pl. 5: 5), *S. cornucopia* (Schwag.), *Epistomina elschankaensis* Mjatl., *E. mosquensis* Uhlig (Pl. 5: 13), *E. parastelligera* (Hofker), *E. rjasanensis* (Umansk. et Kuzn.) (Pl. 5: 11, 12), *Pseudolamarckina rjasanensis* (Uhlig) (Pl. 5: 16, 17), *Citharina heteropleura* (Terq.), *Citharinella nikitini* (Uhlig) (Pl. 5: 6), *C. moelleri* (Uhlig) (Pl. 5: 7), *Marginulinopsis folium* (Wisn.), *Vaginulina dimidia* Grig., *Nodosaria mutabilis* Terq., *N. minuta* Cordey, *Pseudonodosaria lahuseni* (Uhlig), *Ophthalmidium areniforme* (E. Byk.) (Pl. 5: 8), *Ichthyolaria suprajurensis* (Mjatl.) (Pl. 5: 10), *Vaginulinopsis* sp., *Dentalina* sp., *Globularina* sp., and (in the upper part of the zone) *Epistomina paralimbata* Grig.

The Lower Oxfordian *Ophthalmidium sagittum–Epistomina volgensis* Zone (Grigelis, 1982) is characterized by *Lenticulina breuckmanni* (Mjatl.) (Pl. 5: 2), *Marginulinopsis primaformis* (Mjatl.), *Epistomina volgensis* Mjatl. (Pl. 5: 14, 15), *E. radiata* Grig., *E. paralimbata* Grig., *Ophthalmidium sagittum* (E. Byk.) (Pl. 5: 9) as well as some transitional species, known from the underlying zone: *Lenticulina tumida* Mjatl., *L. uhligi* (Wisn.), *L. compressaeformis* (Paalz.), *Citharinella nikitini* (Uhlig), *C. moelleri* (Uhlig), *Epistomina mosquensis* Uhlig, *E. parastelligera* (Hofker), *Ichthyolaria suprajurensis* (Mjatl.), *Pseudonodosaria lahuseni* (Uhlig). In addition to the species mentioned above *Lenticulina tympana* Grig., *L. belorussica* (Mitjan.), *Planularia angustissima* (Wisn.), *P. flexuosa* (Brueckm.), *Astacolus erucaeformis* (Wisn.), *Citharina chanika* (Mjatl.), *Saracenaria cornucopia* (Schwag.), *Spirillina kuebleri* Mjatl., *Dentalina* sp., *Lagena* sp., *Nodosaria* sp. were also encoun-

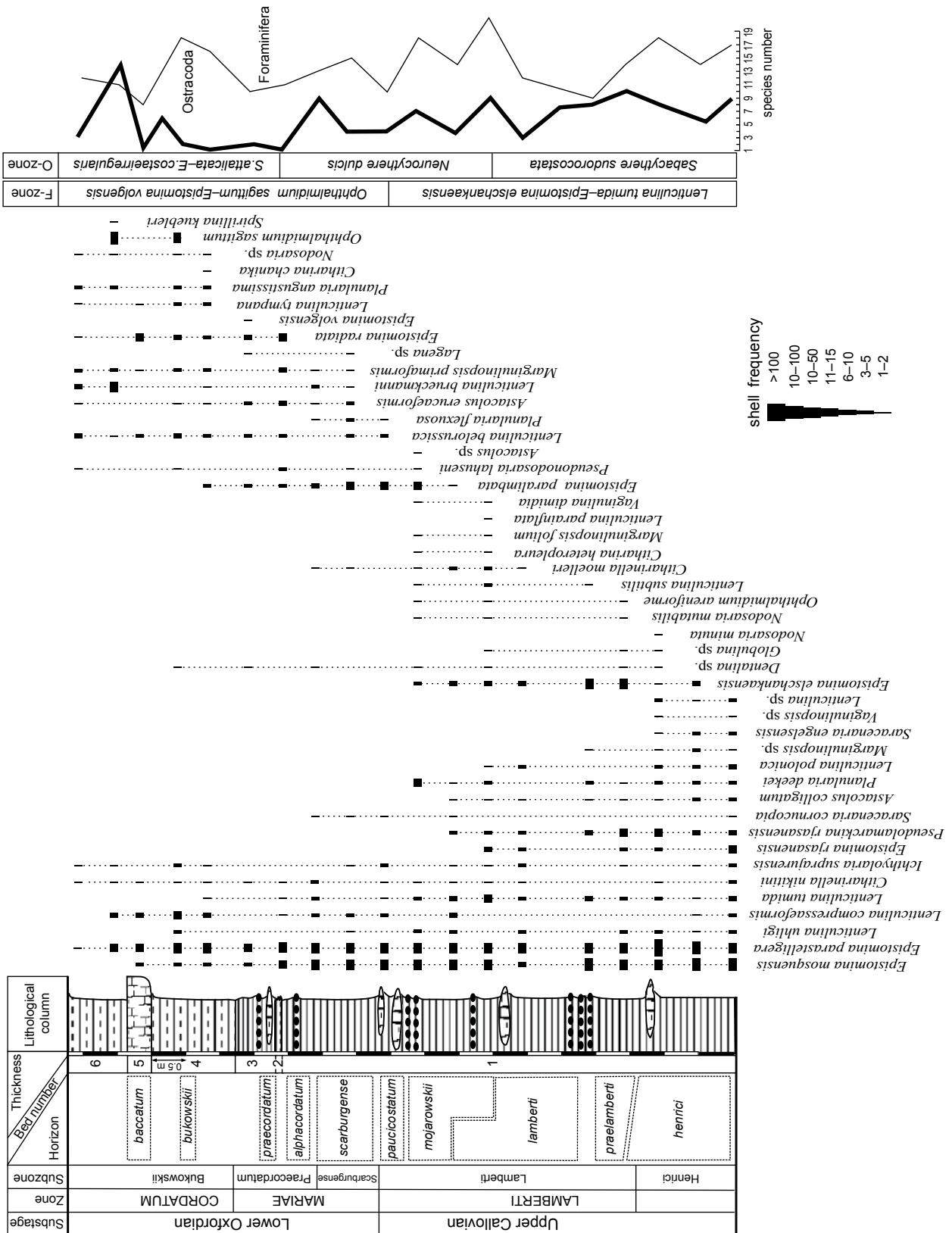


Fig. 8. Range chart of the foraminifer species of the Dubki section (on the left) and diversity diagram of the microfossils (on the right)

Ostracod diversity diagram and the position of the ostracod zonal boundary are given after Tesakova (2008). For explanation of the lithological symbols see Figure 3



tered in this zone. Its lower boundary is marked by remarkable changes in the foraminiferal assemblages. The change in species diversity and relative abundance of foraminifers nearly coincides with similar oscillations in ostracods (Fig. 8), reflecting sea-level rise during the Callovian-Oxfordian transition.

MAGNETOSTRATIGRAPHY (A. Guzhikov, M. Pimenov, A. Mikhailov)

Paleomagnetic sampling through the Callovian-Oxfordian boundary beds of the Dubki section was first undertaken in the year 2001, but no reliable data on magnetic polarity were obtained at that time due to the very weak remanent magnetization (NRM) of the samples (from 0.05 to 0.3×10^{-5} SI), comparable with the spinner-magnetometer JR-4 threshold sensitivity. Nevertheless, a preliminary paleomagnetic scale created on the basis of these data permitted the recognition of the prevalence of normal polarity in the part of the Dubki section studied (Kiselev *et al.*, 2006). In the year 2008, the Dubki section was sampled again for paleomagnetism, and samples were analyzed using more sensitive tools, such as a spinner-magnetometer JR-6 and demagnetizer LDA-3AF. Results of the component analysis have shown that the samples studied are paleomagnetically stable (Fig. 9), and reveal characteristic remanent magnetization (ChRM) corresponding to normal polarity.

The whole paleomagnetic column in the part of the Dubki section studied is characterized by normal polarity (Fig. 9). The angular distance between the ChRM and the direction of remagnetization by the modern field is compared with the error (\pm), determined by the statistics of these vectors, to test the statistical significance of the difference between them (Fig. 9). When the angle exceeds an error, vectors differ significantly; when the angle is lower, vectors statistically coincide with each other (Debiche, Watson, 1995). The amplitude of the 1200-year secular geomagnetic variation of 8° (Bakmutov, 2006) was accepted as representing a radius of the confidence circle (a_{95}) of the modern geomagnetic field. The maximum angle deviation was accepted as representing a radius of the confidence circle (a_{95}) of ChRM. The greatest number of coincidences of the ChRM and the direction of remagnetization is fixed in the uppermost part of the section which is changed by hypergenesis the most. Therefore the magnetic polarity characteristic of the *praecordatum* horizon and the Cordatum Zone cannot be obtained.

All samples from the site 2800 (Callovian) were extracted from fresh rock. The ChRM in these samples is significantly different from the direction of remagnetization, and corresponds to normal polarity. The magnetic polarity characteristic of the Callovian and lowermost Mariae Zone is stable if the polarity determinations on the levels of site 2560, where the ChRM statistically coincides with the direction of remagnetization, are excluded (Fig. 9). Different versions of sample rejection have practically no effect on the average of the paleomagnetic vector (Fig. 10, Table 1). The paleomagnetic structure of the Dubki section remains contradictory, thus, with the international paleomagnetic scale (Ogg, Hinnov, 2012) and the recently published results from the Ham Cliff section, because these latter reveal alternating polarity. It should be remembered, however, that the

Test of the statistical significance of the coincidence of virtual geomagnetic poles

Table 1

Callovian-Oxfordian standard virtual geomagnetic poles for Europe (Besse, Courtillot, 2002)				Angular separation between average ChRM on stereo-projections (numbers 1–3 on Fig. 10) and directions from standard poles for Dubki section (51.7°N , 46.0°E) with errors (\pm) (Debiche, Watson, 1995) [$^\circ$]		
M.Y.	Lat $^\circ$	Long $^\circ$	A_{95}	number 1	number 2	number 3
160	72.5	144.0	5.0	3.5 ± 5.4	2.1 ± 5.0	2.8 ± 5.3
165	70.6	149.5	9.7	5.2 ± 7.0	3.3 ± 6.7	4.9 ± 6.9
170	69.7	112.5	6.0	1.9 ± 5.4	4.2 ± 5.0	3.5 ± 5.4

M.Y. – million years ago, Lat – latitude pole, Long – longitude pole, A_{95} – radius of the confidence circle for pole

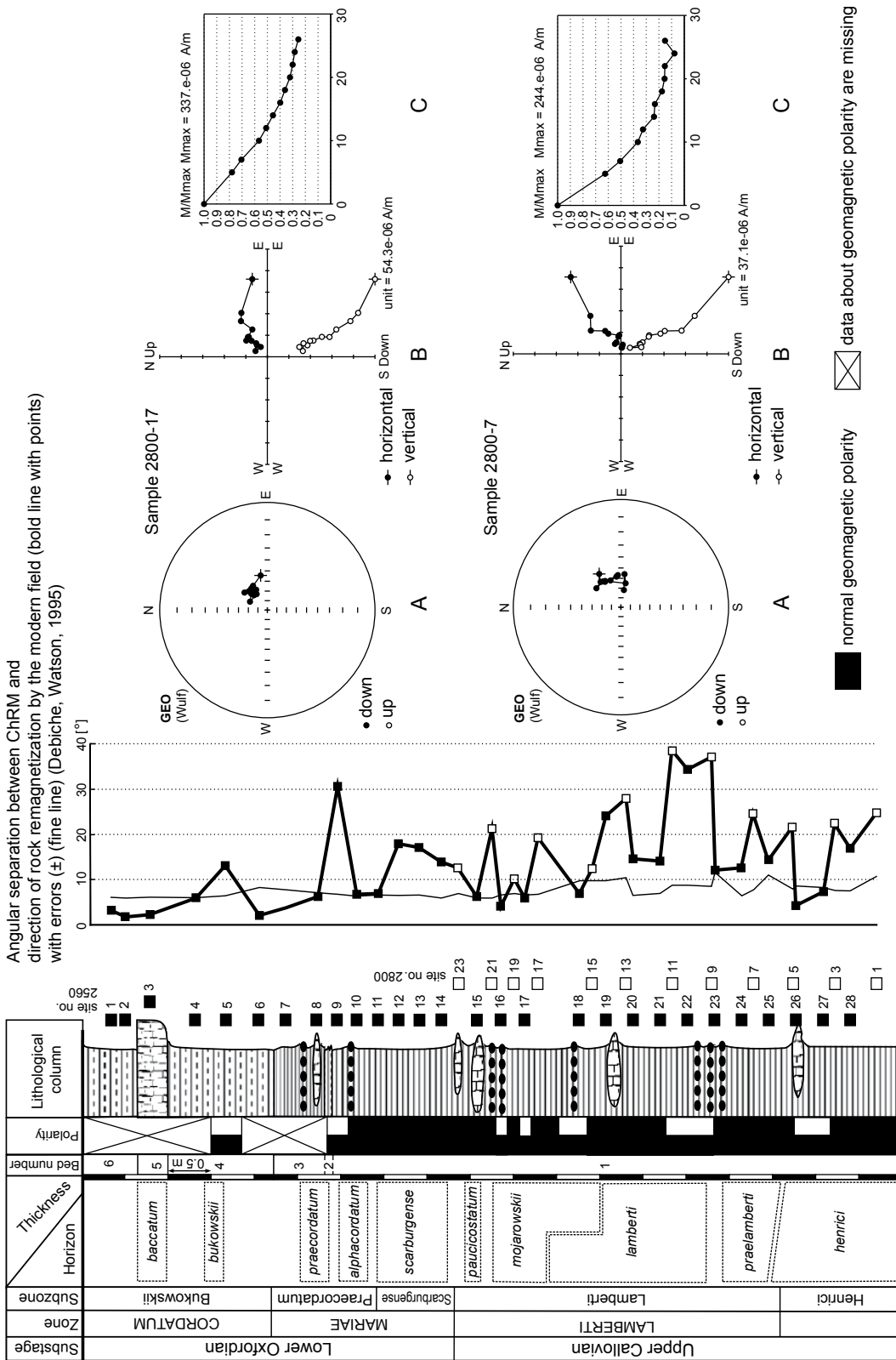


Fig. 9. Results of the magnetostratigraphical studies of the Dubki section, derived from analysis of samples, collected at two sites (no. 2560 and no. 2800)

Relative position of samples and paleomagnetic scale are given on the right. Results of AF demagnetization of the selected samples from the Dubki section are shown on the left. **A** – stereographic projection of NRM vector variations during AF demagnetization, solid and open circles denote projections of NRM vectors on the lower and upper hemispheres respectively; **B** – Zijderveld diagram, solid circles denote projection on horizontal plane (XZ), open circles on the N–S vertical plane (XY), **C** – NRM module (M) as dependent on AF intensity.

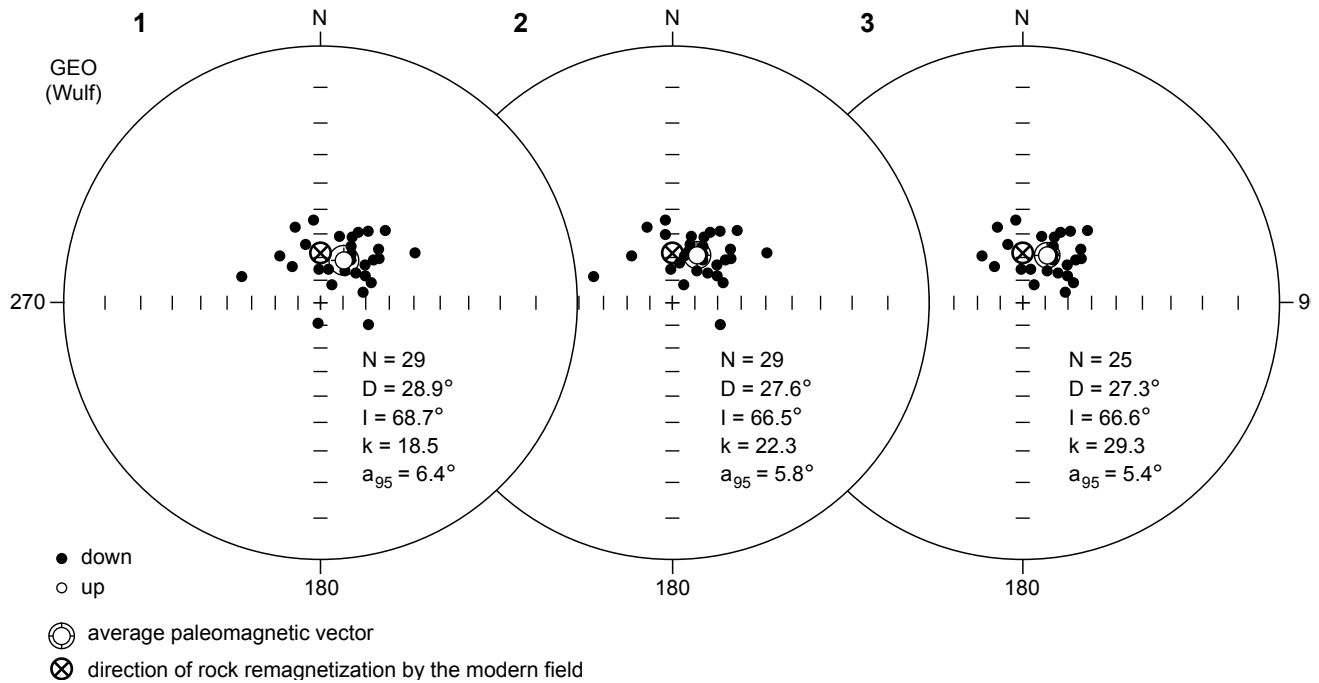


Fig. 10. Stereographic projections of ChRM

A – excluded ChRM, which statistically coincides with directions of remagnetization; **B** – excluded ChRM from the uppermost part of the section (site 2560, samples 1–11); **C** – excluded ChRM, that are at a maximum distance ($>30^\circ$) from average paleomagnetic vector

Callovian-Oxfordian boundary beds are generally poorly studied in their paleomagnetism, and the relevant paleomagnetic scale could be supplemented taking into account our new data from the Dubki section. The Dubki section shows a complete succession well characterized by macro- and microfossils and it was densely sampled when compared with sections in other regions. Suspected sliding, and the small number of samples taken around the Callovian-Oxfordian boundary in the Ham Cliff section (Ogg *et al.*, 2010) make it difficult to use this section as a reference one for paleomagnetic studies. On the other hand, the Jurassic nature of the ChRM of the Dubki section is indicated by the coincidence of the estimated virtual geomagnetic poles with the standard data (Besse and Courtillot, 2002) on the Callovian-Oxfordian poles for Europe (Table 1).

In the Dubki section, the angle between recent magnetization and ChRM gradually decreased upwards from $10\text{--}20^\circ$ at the top of the Lambert Zone to $<5^\circ$ in the Cordatum Zone. Perhaps the slightly weathered upper part of the section studied was partially influenced by the modern magnetic pole, and due to the impossibility of splitting the directions of the modern pole from ChRM in the samples from the Cordatum Zone, the results were excluded from the final figure (Fig. 9).

DISCUSSION (D. Kiselev, M. Rogov)

In spite of general agreement concerning the base of the Oxfordian Stage, which coincides with the transition in the cardioceratid lineage from *Quenstedtoceras* to *Cardioceras*, the precise position of this level in terms of biohorizons as well as the definition of a GSSP section remains a matter of discussion. All proposed GSSP candidates (Ham Cliff at Redcliff Point, Thuoux-Savournon and Dubki) are characterized by mixed ammonite faunas coming from different realms, providing the possibility of subglobal correlation, but their ammonite successions are slightly different, and all these sections more or less equally meet the requirements for GSSP candidates, but their advantages and disadvantages are also different (see Table 2). Only the ammonite faunas of all these sections are well-studied, while other fossil groups and non-biostratigraphical requirements are hardly comparable. Thus here we provide brief remarks on the correlation of the Dubki ammonite succession with those of Redcliff Point (Page *et al.*, 2009 b) and Thuoux (Fortwengler *et al.*, 2012) and discuss ammonite criteria for the Callovian-Oxfordian boundary.

Table 2

Comparison of GSSP candidates in terms of geological, biostratigraphic and other requirements

Requirement (Remane <i>et al.</i> , 1996)	Dubki (this paper; Tesakova, 2008; Wierzbowski, Rogov, 2011)	Redcliff Point (Page <i>et al.</i> , 2009 a, b ; Price, Page, 2008; Ogg <i>et al.</i> , 2010)	Thuoux (Fortwengler, Marchand, 1994; Fortwengler <i>et al.</i> , 2012)
1. Exposure over an adequate thickness of sediments	Yes	Yes	Thickness much bigger compared with those in Redcliff Point and Dubki
2. Continuous sedimentation	Yes	Yes	Yes
3. Absence of synsedimentary and tectonic disturbances	Yes? Some landslides are present	Some landslides are present	Yes
4. Absence of metamorphism and strong diagenetic alteration	Yes	Yes	Yes
5. Abundance and diversity of well-preserved fossils throughout the critical interval.	Yes	Yes	Yes
5.1. Ammonites	Yes (this article)	Yes (Page <i>et al.</i> , 2009 b), most continuous succession of cardioceratid ammonites	Yes (Fortwengler <i>et al.</i> , 2012)
5.2. Belemnites	Yes (this article)	Not described and/or figured	Not described and/or figured
5.3. Foraminifers	Yes (this article)	Not described and/or figured	Not described and/or figured
5.4. Ostracods	Yes (Tesakova, 2008)	Not described and/or figured	Not described and/or figured
5.5. Calcareous nannoplankton	Yes (this article)	Not described and/or figured	Yes (Fortwengler <i>et al.</i> , 2013)
5.6. Dinoflagellate cysts	No	No	Yes (Fortwengler <i>et al.</i> , 2013)
6. Absence of vertical facies changes at or near the boundary	Yes	Yes	Yes
7. Favourable facies for long-range biostratigraphic correlations	Yes	Yes	Yes
8. Magnetostratigraphy	Yes (this article)	Yes (Ogg <i>et al.</i> , 2010)	No detailed data
9. Sequence stratigraphy	No	No	Studied in nearby sections (Boulila <i>et al.</i> , 2008, 2010)
10. Cyclostratigraphy	No	No	Studied in nearby sections (Boulila <i>et al.</i> , 2008, 2010)
11. Analysis of stable isotopes	Yes (Wierzbowski, Rogov, 2011)	Yes (Price, Page, 2008)	Yes (Pellenard <i>et al.</i> , 2013)
12. Radioisotopic dating	No	No	No

The key importance for the decision of the question on the position of the Callovian-Oxfordian boundary has to be the *paucicostatum* biohorizon. In recent years, the problem of its recognition has become a matter of discussion, however.

Significant changes were introduced in the English scale (Page *et al.*, 2009a, b) where three successive biohorizons characterized by “transient species” of “*Q*”. *paucicostatum*, labeled by non-linnean symbols, are recognized (Fig. 6). The terminal Callovian biohorizon was marked by two index-species, including “transient species” “*Q*”. *paucicostatum* γ and *Peltomorphites*. All these units are treated by us

as equivalents of our *paucicostatum* biohorizon due to the following reasons:

Practice shows that usage of transient names marked by non-linnean symbols leads to many inconveniences and confusions, as such transients usually are not described in detail but only mark the relative position of records within the succession (Kiselev, 2001; Rogov *et al.*, 2012).

In the article (Page *et al.*, 2009b) where the new biohorizons are described there is no detailed description of the “*Q*”. *paucicostatum* transients.

Ammonites of the Callovian-Oxfordian boundary interval in the Redcliff Point section are relatively badly pre-

served as crushed clayey moulds, which prevents the precise definition of transients, distinguished by the smallest morphological differences.

The practice of the use of the biohorizon double name combining taxons of different taxonomical rank and the different nature (“*Q*”. *paucicostatum* γ , *Peltomorphites*) is considered by us as inappropriate due to its small correlational potential and problems with recognition in other sections (cf. Rogov *et al.*, 2012).

Above the *paucicostatum* α , β , γ biohorizons in the Redcliff Point section the *redcliffense* biohorizon is recognized. As its index-species was referred by its authors to the genus *Cardioceras*, this horizon was placed at the base of the Oxfordian Stage. However, as indicated by Page *et al.* (2009b), this species is recognized only by means of statistics: “Cardioceratid species transitional between *Q*. ex gr. *paucicostatum* (Lange) and *C. (Pavloviceras) ex gr. scarburgense* (Young and Bird) in which around 20% of the assemblage contains variants or morphologies (“morphs”) resembling the typical *C. scarburgense*... The remainder of the assemblage, has a more *paucicostatum* style”. Thus, the diagnosis of the species is uncertain and obviously it is closer to “*Q*.” *paucicostatum*, than to *C. scarburgense*. This species is considered by us as synonymous with “*Q*.” *paucicostatum*, therefore the *redcliffense* biohorizon is included herein in the *paucicostatum* biohorizon. This opinion agrees with the conclusions of the French authors (Fortwengler *et al.*, 2012). It should be noted that *C. redcliffense* has been identified by J.K. Wright from the Dubki section in the same interval that “*Q*.” *paucicostatum*.

Using of the base of the *thuouxensis* horizon as the base of the Oxfordian Stage, as proposed by our French colleagues (Fortwengler *et al.*, 1997, 2012), leads to some other problems with wide correlation, because its index-species has a local spatial distribution, being known from South-eastern France and possibly from England (Fortwengler *et al.*, 2012), whereas changes in the cardioceratid lineage occurred within or above this horizon. On the other hand, very similar *Brightia* are also recorded in the Dubki section from the Upper Callovian significantly below the Callovian-Oxfordian boundary (*mojarowskii* horizon, see Pl. 1: 21). The *thuouxensis* horizon is considered by us as a partial equivalent of the *paucicostatum* biohorizon, because in the Thuoux section “*Q*.” *paucicostatum* was recorded from this unit (Fortwengler *et al.*, 2012, fig. 5). Unfortunately, figured cardioceratid ammonites from the *thuouxensis* horizon are extremely rare (Fortwengler *et al.*, 2012, pl. 2: 1), and their precise determination is ambiguous. Thus in our opinion the Callovian-Oxfordian boundary, recognized by changes in the cardioceratid lineage and marked by FAD of the genus *Cardioceras*, should be placed in the base of the *scarburgense* horizon.

CONCLUSIONS

Study of the reference sections for the Callovian-Oxfordian boundary in the Russian Platform and North Caucasus shows abundant data, easy comparable with those in Europe. Ammonite assemblages, including Boreal, Subboreal and Submediterranean taxa, as a whole are close to those of North-Western Europe. Belemnites also were represented by mixture of taxa with Boreal and Tethyan affinities. The integrated study of the Dubki section could serve as a bridge for correlation between the Boreal and Submediterranean provinces. This section corresponds well to requirements for the candidate GSSP section (Table 2, see Remane *et al.*, 1996).

The base of the Oxfordian Stage, determined by FAD of ammonite genus *Cardioceras*, is also well-recognized in the Dubki section by changes in ostracods and foraminifers, providing further possibilities for its recognition in drill cores poor in ammonites.

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LIST OF AMMONITE GENERA AND SUBGENERA USED IN THE STUDY

- Quenstedtoceras* Hyatt, 1877 (type species *Ammonites leachi* Sowerby, 1819)
 “*Quenstedtoceras*” [m] – group of microconch species of *Quenstedtoceras*
Eboracicerias Buckman, 1918 (type species *Ammonites dissimilis* Brown, 1849)
Eichwaldicerias Buckman, 1920 (type species *Ammonites carinatus* Eichwald, 1868)
Vertumnicerias Buckman, 1918 [m] (type species *Ammonites vertumnus* Leckenby, 1859)
Cardioceras Neumayr et Uhlig, 1881 (type species *Ammonites cordatus* Sowerby, 1813)
Scarburgicerias Buckman, 1924 (type species *Ammonites scarburgense* Young et Bird, 1828)
Scoticardioceras Buckman, 1925 (type species *Ammonites excavatus* Sowerby, 1815)
Pavlovicerias Buckman, 1920 (type species *Quenstedticeras pavlowi* R. Douville, 1912)
Goliathicerias Buckman, 1919 (type species *Nautilus ammonoides* Young et Bird, 1828)
Pachycardioceras Buckman, 1926 (type species *Pachycardioceras robustum* Buckman, 1926)
Vertebricerias Buckman, 1920 [m] (type species *Vertebricerias dorsale* Buckman, 1920)
Korythoceras Buckman, 1920 (type species *Korythoceras korys* Buckman, 1920)
Protocardioceras Schirardin, 1958 [m] (type species *Cardioceras martini* Reeside, 1919)
Subvertebricerias Arkell, 1941 [m] (type species *Cardioceras densiplicatum* Boden, 1911)
Kosmoceras Waagen, 1869 (type species *Ammonites spinosus* Sowerby, 1829)
Lobokosmoceras Buckman, 1923 (type species *Cosmoceras proniae* Teisseyre, 1887)
Gulielmiceras Buckman, 1920 [m] (type species *Ammonites gulielmi* Sowerby, 1821)
Mojarowskia Nikolaeva et Rozhdestvenskaya, 1956 [m] (type species *Mojarowskia mojarowskii* Nikolaeva et Rozhdestvenskaya, 1956)
Parapeltoceras Schindewolf, 1925 (type species *Nautilus annularis* Reinecke, 1818)
Peltoceratooides Spath, 1924 (type species *Peltoceras semirugosum* Waagen, 1875)
Rursicerias Buckman, 1919 [m] (type species *Rursicerias reversum* Leckenby, 1859)
Euaspidoceras Spath, 1930 (type species *Ammonites perarmatus* Sowerby, 1822)
Paraspidoceras Spath, 1931 (type species *Ammonites meriani* Opper, 1863)
Choffatia Siemiradzki, 1898 (type species *Perisphinctes cobra* Waagen, 1875)
Grossouvria Siemiradzki, 1898 [m] (type species *Ammonites sulciferus* Opper, 1857)
Alligaticeras Buckman, 1921 [m] (type species *Ammonites alligatus* Leckenby, 1859)
Properisphinctes Spath, 1931 [m] (type species *Perisphinctes bernensis* Loriol, 1898)
Brightia Rollier, 1922 (type species *Ammonites hecticus nodosus* Quenstedt, 1849)
Corycerias Ziegler, 1958 [m] (type species *Ammonites microdomus* Opper, 1863)
Creniceras Munier-Chalmas, 1892 [m] (type species *Ammonites renggeri* Opper, 1863)
Eulunulites Elmi, 1967 [m] (type species *Lunuloceras pompekyi* Parona et Bonarelli, 1895)
Neocampylites Callomon, 1973 (nom. nov. pro *Campylites* Rollier, 1922 non *Campylites* Eichwald, 1856, type species *Ammonites delmontanus* Opper, 1863)
Putealicerias Buckman, 1922 (type species *Ammonites putealis* Leckenby, 1859)
Sublunuloceras Spath, 1928 (type species *Harpoceras lairensis* Waagen, 1875)
Taramelliceras Del Campana, 1904 (pro *Taramellia* Del Campana, 1903 non *Taramellia* Seguenza, 1903, type species *Ammonites trachinotus* Opper, 1862)

PLATES

All specimens whitened with ammonium chloride. Plates 1–4: all specimens $\times 0.8$.

Localities are marked as DU – Dubki, DA – Dachovskaya, B – Khanskaya Gora (Belyaevka), K – Kostino, M – Mikhailov, SO – Stary Oskol, N – Nikitino

PLATE 1

- Fig. 1, 2. *Quenstedtoceras henrici* Douville. D1-4. DU, bed 1, 130 cm above bottom. Lamberti Zone, Henrici Subzone;
- Fig. 3, 4. *Quenstedtoceras lamberti* (Sowerby). MK408. DU, bed 1, 290 cm above bottom. Lamberti Zone, Subzone and biohorizon
- Fig. 5, 6. *Quenstedtoceras praelamberti* Douville. D1-95. DU, bed 1, 200 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 7, 8. *Quenstedtoceras pseudolamberti* Sintzow. BD2-2. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 9, 10. "*Quenstedtoceras*" *macer* (Quenstedt). D1-33. DU, bed 1, 180 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 11. *Vertumnicerias mariae* (d'Orbigny). D1-121. DU, bed 1d. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 12, 13. *Vertumnicerias vertumnum* (Bean-Leckenby). D1-45. DU, bed 1, 130 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 14, 15. "*Quenstedtoceras*" *paucicostatum* (Lange). MK453. DU, bed 1d. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 16, 17. "*Quenstedtoceras*" *luppovi* (Amanniazov). BD3-7. DA, bed 3. Mariae Zone, Scarburgense Subzone
- Fig. 18. *Putealicerias douvillei* (Jeannet). MIV817. DU, bed 1, 410 cm above bottom. Lamberti Zone and Subzone, *mojarowskii* biohorizon
- Fig. 19, 20. *Taramelliceras baccatum* (Bukowski) morphe *baccatum*; DU, bed 5. Cordatum Zone, Bukowskii Subzone, *baccatum* biohorizon. **19** – MIV791-1. **20** – MIV541
- Fig. 21. *Brightia* cf./aff. *thuouxensis* (Fortwengler *et al.*). MIV819. DU, bed 1, 450 cm above bottom. Lamberti Zone and Subzone, *mojarowskii* biohorizon
- Fig. 22. *Creniceras renggeri* (Oppel). MIV565. DU, bed 5. Cordatum Zone, Bukowskii Subzone, *baccatum* biohorizon
- Fig. 23. *Brightia socini* (Noetling) sensu Gygi. MIV576. DU, bed 1, 300 cm above bottom. Lamberti Zone and Subzone, *mojarowskii* biohorizon
- Fig. 24. *Putealicerias schumacheri* (Noetling). BD2-19. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 25. *Lissoceratoides erato* (d'Orbigny). BD2-63. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon



PLATE 2

- Fig. 1. *Kosmoceras (Kosmoceras) transitionis* (Nikitin). MK334. DU, bed 1, 175 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 2–5. *Kosmoceras (K.) zudacharicum* Kazanskii. **2, 3** – BD2-12; **4, 5** – BD2-10. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 6, 7. *Kosmoceras (K.) spinosum* (Sowerby). D1-136. DU, bed 1, 50 cm above bottom. Lamberti Zone, Henrici Subzone
- Fig. 8–10. *Kosmoceras (Lobokosmoceras) geminatum* (Buckman). **8, 9** – D1-148. DU, bed 1, 100 cm above bottom. Lamberti Zone, Henrici Subzone. **10** – SO-7. SO. Lamberti Zone and Subzone
- Fig. 11–13. *Gulielmiceras (Mojarowskia) mojarowskii* (Nikolaeva et Rozhd.). D1-164. DU, bed 1, 450 cm above bottom. **13** – BD1-8. DA, bed 1. Lamberti Zone and Subzone, *mojarowskii* biohorizon
- Fig. 14, 22, 23. *Protocardioceras praemartini* (Spath). BB6-13. BA, bed 3. **22, 23** – M12-1. Nikitino. Mariae Zone, Praecordatum Subzone, *praemartini* biohorizon
- Fig. 15. *Cardioceras (Scarburgiceras) praecordatum douvillei* Maire. BB11-4. BA, bed 8. Mariae Zone, Praecordatum Subzone and biohorizon
- Fig. 16. *Cardioceras (Scarburgiceras) alphacordatum* Spath. BB7-27. BA, bed 4. Mariae Zone, Praecordatum Subzone, *alphacordatum* biohorizon
- Fig. 17–19. *Cardioceras (Scarburgiceras) praecordatum* Douville. **17, 18** – N-5. Nikitino. **19** – D1-124. DU, bed 1, 670 cm above bottom. Mariae Zone, Praecordatum Subzone and biohorizon
- Fig. 20, 21. *Cardioceras (Scarburgiceras) bukowskii* Maire. M14-16. M. Cordatum Zone, Bukowskii Subzone
- Fig. 24, 25. *Cardioceras (Cardioceras) costicardia* Buckman. M13-1. M. Cordatum Zone, Costicardia Subzone
- Fig. 26, 27. *Protocardioceras russiense* (Sasonov). D1-126. DU, bed 1, 650 cm above bottom. Mariae Zone, Praecordatum Subzone, *alphacordatum* biohorizon
- Fig. 28, 29. *Cardioceras (Scarburgiceras) alphacordatum* Spath. D1-125. DU, bed 1, 635 cm above bottom. Mariae Zone, Praecordatum Subzone, *alphacordatum* biohorizon
- Fig. 30, 31. *Cardioceras (Cardioceras) cordatum* (Sowerby). K-6. K. Cordatum Zone and Subzone
- Fig. 32. *Goliathiceras nalivkini* (Borissjak). MIV536-2. DU, bed 5. Cordatum Zone, Bukowskii Subzone
- Fig. 33. *Euspidoceras subbabeatum* (Sinzov) sensu Jeannet. MK1571. DU. Lamberti Zone and Subzone, *paucicostatum* biohorizon

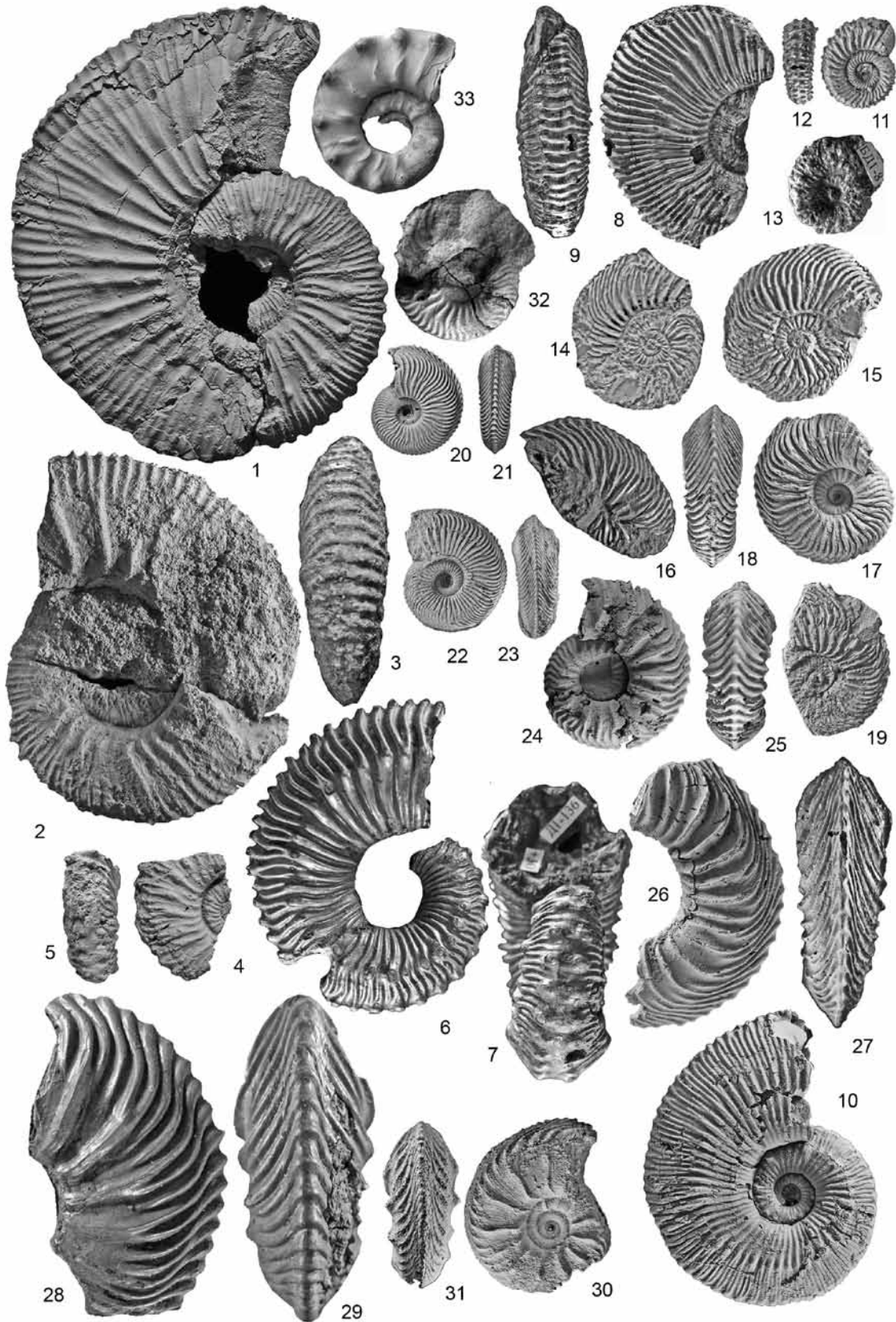


PLATE 3

- Fig. 1–4. *Peltoceratoides hoplophorus* (Buckman). **1, 2**. BD2-52. **3, 4**. BD2-41. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 5, 6. *Peltoceratoides williamsoni* (Phillips). BD3-9. DA, bed 3. Mariae Zone, Scarburgense Subzone
- Fig. 7. *Parapeltoceras borissjaki* (Amanniasov). BD2-54. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 8, 9. *Rursiceras annulosum* (Quenstedt). D1-180. DU, bed 1, 150 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 10. *Peltoceratoides subtense* (Bean in Leck.). D1-174. DU, bed 1, 150 cm above bottom. Lamberti Zone and Subzone, *praelamberti* biohorizon
- Fig. 11, 12. *Paraspidoceras interninodatum* Zeiss. BD2-37. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 13, 14. *Alligaticeras* cf. *pseudograciosus* Arkell. BD2-58. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 15, 16. *Putealicerias schumacheri* (Noetling). BD2-26. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 17. *Cardioceras* (*Scarburgiceras*) *scarburgense* (Young et Bird). N-1. N. Mariae Zone, Scarburgense Subzone
- Fig. 18, 19, 22, 29, 30. *Hibolithes* (*Hibolithes*) *girardoti* (Loriol). No. 898/1. **18** – ventral view, **19** – lateral view, venter to the left. Upper Callovian, in talus. No. 898/2. **22** – ventral view. DU, bed 1, 210 cm above bottom. Lamberti Zone and Subzone. No. 898/3. **29** – ventral view, **30** – lateral view, venter to the left. DU, bed 1, 380 cm above bottom. Lamberti Zone and Subzone
- Fig. 20, 21. *Hibolithes* (*Hemihibolites*) *orlovi* Gustomesov. No. 898/6. **20** – ventral view, **21** – lateral view, venter to the left. DU, bed 4, 90 cm above bottom. Cordatum Zone, Bukowskii Subzone
- Fig. 23–26. *Hibolithes* (*Hibolithes*) *shimanskyi* Gustomesov. No. 898/5. **23** – ventral view, **24** – lateral view, venter to the left. DU, bed 1, 545 cm above bottom. Mariae Zone, Scarburgense Subzone. No. 898/4. **25** – ventral view, **26** – lateral view, venter to the left. DU, Lower Oxfordian, in talus
- Fig. 27, 28. *Hibolithes* (*Hibolithes*) cf. *hastatus* (Blainville). No. 898/8. Fig. **27** – ventral view, fig. **28** – lateral view, venter to the left. DU, bed 5, near bottom. Cordatum Zone, Bukowskii Subzone
- Fig. 31–33. *Holcobeloides beaumontianus* (d'Orbigny). No. 898/9. **31** – ventral view, **32** – lateral view, venter to the left, **33** – alveolar section. DU, bed 1, 280 cm above bottom. Lamberti Zone and Subzone

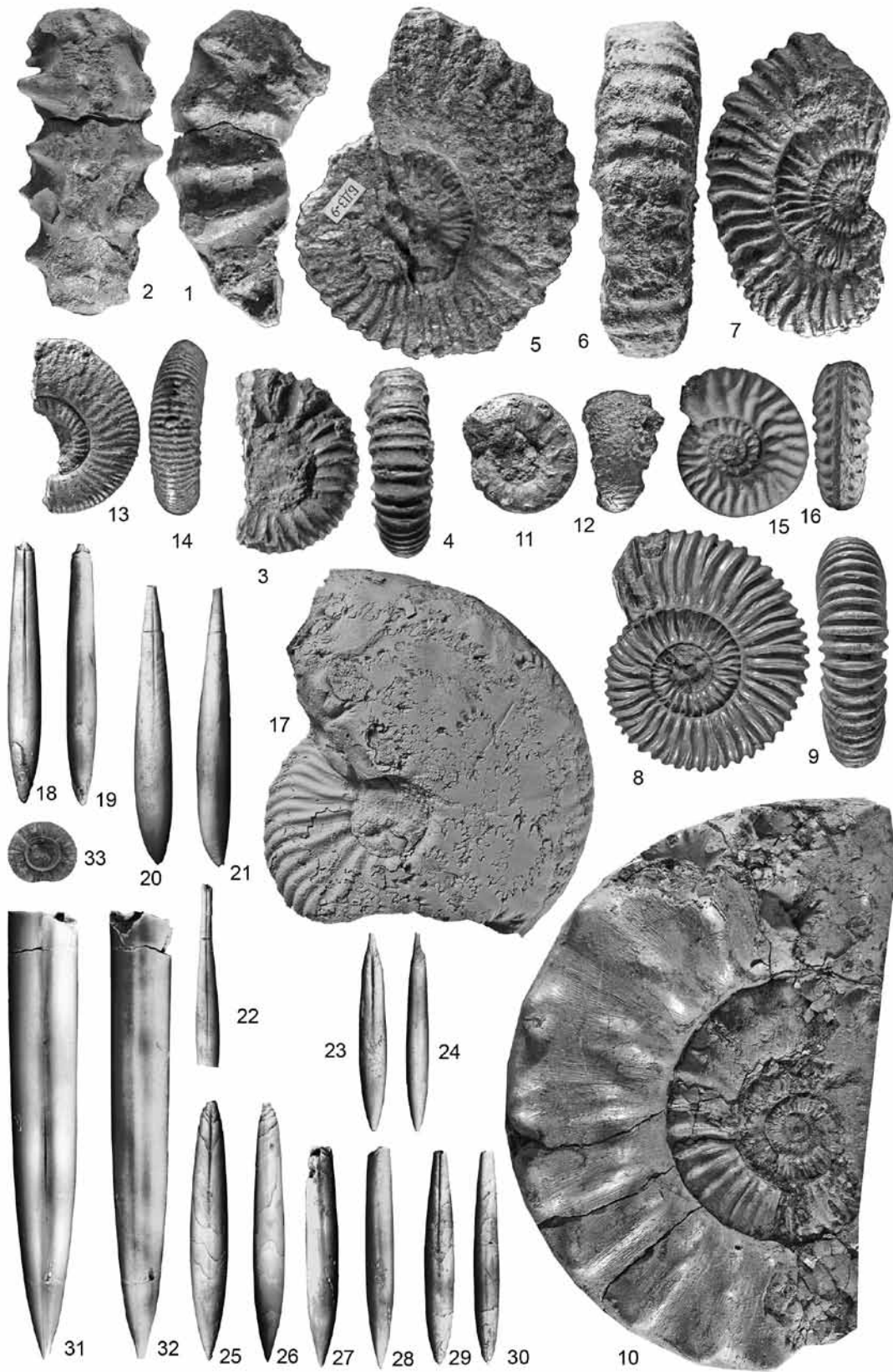


PLATE 4

- Fig. 1–3. *Properisphinctes* cf. *orbignyi* Tarkowski. M, bed 12, upper part. 1 – no number, 2, 3 – MK1503. Cordatum Zone and Subzone
- Fig. 4, 5. *Quenstedtoceras pseudolamberti* Sintzow. BD2-1. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 6, 7. *Sublunuloceras nodosulcatum* (Lah.). MIV551. DU, bed 1, 380 cm above bottom. Lamberti Zone and Subzone, *mojarowskii* biohorizon
- 8, 10, 11. “*Quenstedtoceras*” aff. *paucicostatum* (Lange), **8** – D1-50. DU, bed 1, 450 cm above bottom, **10, 11** – MK-348. DU, bed 1, 380 cm above bottom. Lamberti Zone, *mojarowskii* biohorizon
- Fig. 9, 12–14. “*Quenstedtoceras*” *paucicostatum* (Lange); **9**. MK-331. DU, bed 1, 470 cm above bottom. **12** – BD2-7. DA, bed 2, **13, 14** – BD2-6. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon
- Fig. 15, 16. *Cardioceras praecordatum* Maire. D1-127. DU, bed 3. Mariae Zone, Praecordatum Subzone and biohorizon
- Fig. 17–20. *Goliathiceras (Pachycardioceras) elatum* (Maire). **17, 18** – MK324. **19, 20** – MK325. M, bed 12, upper part. Cordatum Zone and Subzone
- Fig. 21, 22. *Gulielmiceras* cf. *arkelli* (Makowski). BD2-17. DA, bed 2. Lamberti Zone and Subzone, *paucicostatum* biohorizon

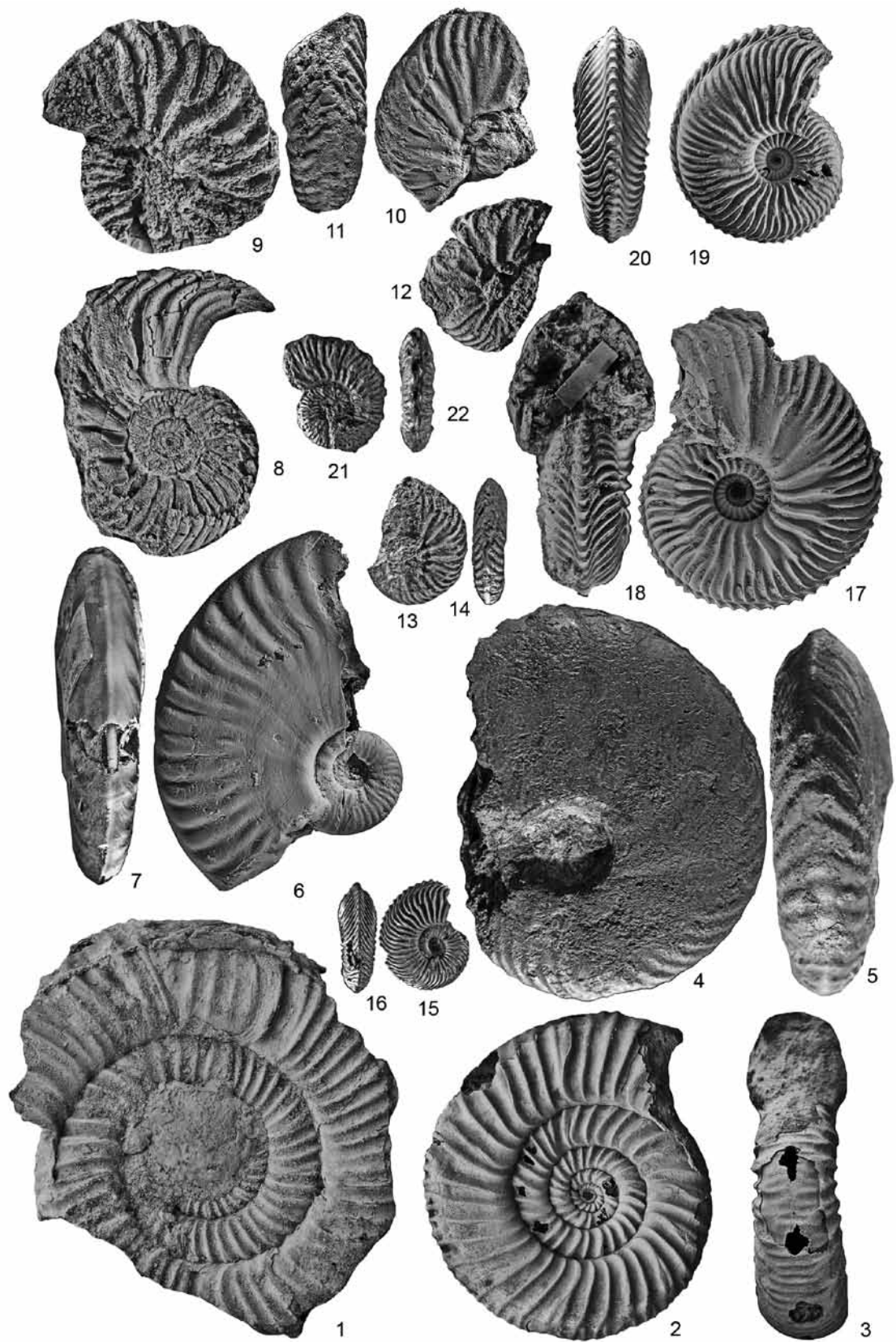
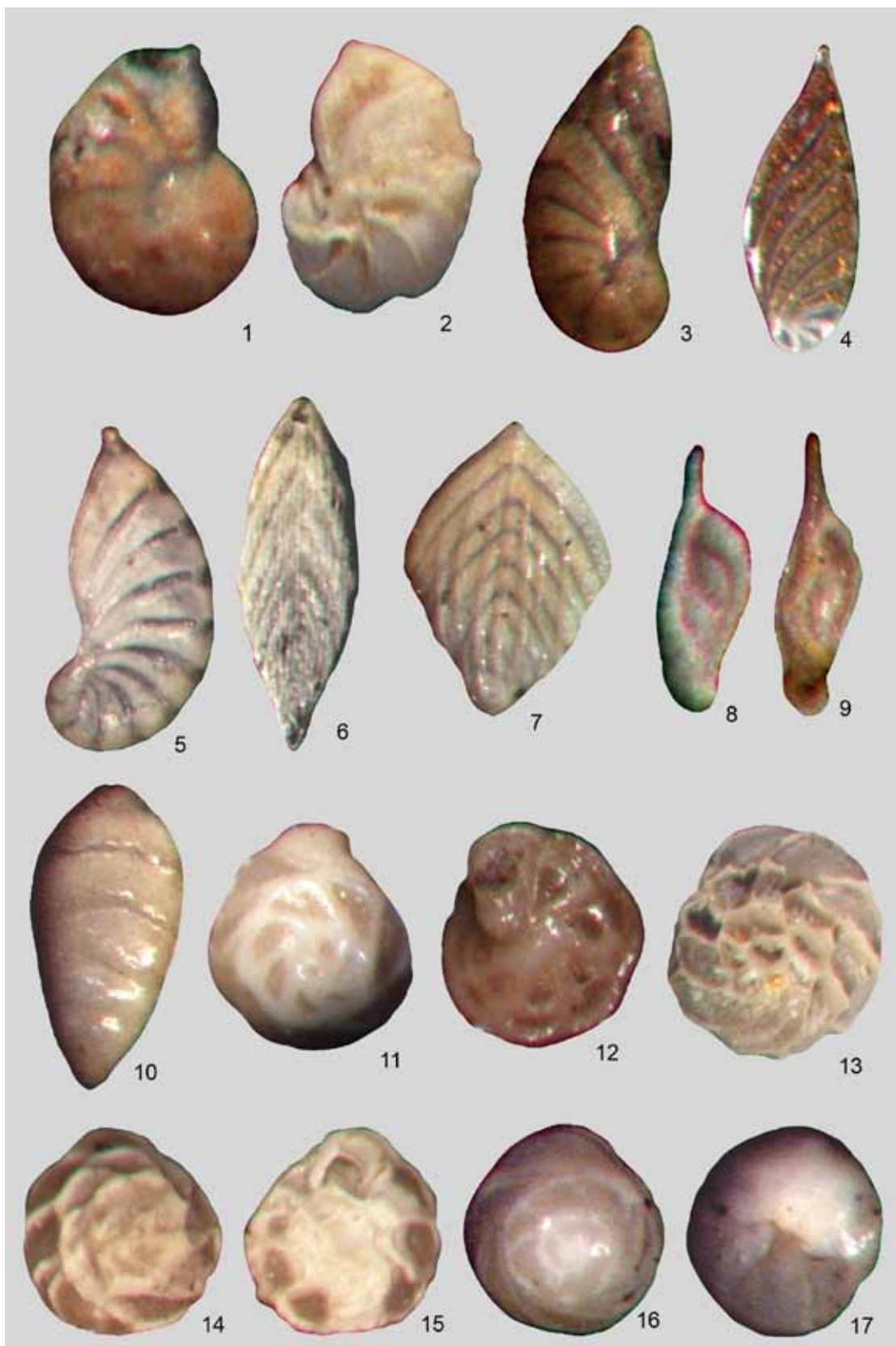


PLATE 5

- Fig. 1. *Lenticulina uhligi* (Wisniowski), $\times 103$. No. 750RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 2. *Lenticulina brueckmanni* (Mjatliuk), $\times 55.2$. No. 100RM. Lateral view. DU, bed 6, Lower Oxfordian, *Epistomina volgensis*–*Ophthalmidium sagittum* Zone
- Fig. 3. *Astacolus colligatum* (Brueckmann), $\times 97.3$. No. 750RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 4. *Planularia deeckei* (Wisniowski), $\times 81.4$. No. 400RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 5. *Saracenaria engelsensis* Kosyreva in Chabarova, $\times 54.6$. No. 850RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 6. *Citharinella nikitini* (Uhlig), $\times 39.1$. No. 550RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 7. *Citharinella moelleri* (Uhlig) $\times 51.3$. No. 450RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 8. *Ophthalmidium areniforme* (E. Bykova), $\times 167.5$. No. 700RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 9. *Ophthalmidium sagittum* (E. Bykova), $\times 93.6$. No. 50RM. Lateral view. DU, bed 4, Lower Oxfordian, *Epistomina volgensis*–*Ophthalmidium sagittum* Zone
- Fig. 10. *Ichthyolaria suprajurensis* (Mjatliuk), $\times 54.7$. No. 100RM. Lateral view. DU, bed 4, Lower Oxfordian, *Epistomina volgensis*–*Ophthalmidium sagittum* Zone
- Fig. 11, 12. *Epistomina rjasanensis* (Umanskaja et K. Kuznetsova) $\times 71.4$. **11** – dorsal view, **12** – ventral view. No. 850RM. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 13. *Epistomina mosquensis* Uhlig, $\times 69.7$. No. 750RM. Dorsal view. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone
- Fig. 14, 15. *Epistomina volgensis* Mjatliuk, $\times 49.2$. **14** – dorsal view, **15** – ventral view. No. 150RM. DU, Lower Oxfordian, *Epistomina volgensis*–*Ophthalmidium sagittum* Zone
- Fig. 16, 17. *Pseudolamarckina rjasanensis* (Uhlig), $\times 83$. **16** – dorsal view, **17** – ventral view. No. 700RM. DU, bed 1. Upper Callovian, *Lenticulina tumida*–*Epistomina elschankaensis* Zone



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