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

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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 nannofossil 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 biochoremas (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 correction 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; Diaz-Martinez et al., 2002; Diaz-Martinez, 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 infrastratigraphical 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 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 Quenstedtocers lamberti, Q. paucicostatum and Guielmiceras (Mojarowska) 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 oppellid 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 later 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 Vertumniniceras 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 nanofossils. 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 Belemnotheriites (= 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 roadbuilding. 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 Mariæ 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-
gende 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 nannofossil assemblages of the Dubki section were published by Matveev (2007). The isotope stratigraphy and climate oscillations in the studied section were described by Wierzbowński 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 Kosmoceratiidae) 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. 2. Sampling of the Dubki section during the All-Russian Jurassic meeting in the year 2009 held in Saratov](image)

![Fig. 3. Range chart of the ammonite and belemnite species of the Dubki section](image)

For explanation of the lithological symbols see Figure 4
Integrated stratigraphy of the reference sections for the Callovian-Oxfordian boundary in European Russia.
“Quenstedtoceras” *paucicostatum* (Lange) in bed 2 it is possible to distinguish the two uppermost biohorizons of the Lambert 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; Ilovaisky, 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.
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 immigrational 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.

**AMMONITE BIOSTRATIGRAPHY**  
(D. Kiselev and M. Rogov)

For explanation of the lithological symbols see Figure 4

![Fig. 5. Ammonite succession in the Khanskaya Gora section](image)
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 Bo- real cardioceratid, Subboreal kosmoceratid and Submedi terranean 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 biohori zons.

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

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**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 correspondence 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 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 within 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, Laptikhovsky, 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 *Sublumuloceras 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, *Vertunniceras vertumnum* (Bean in Leck.), *Kosmoceras* (*Kosmoceras*) *spinosum* (Sow.) (Pl. 2: 6, 7), *Kosmoceras* (*Lobokosmoceras*) *geminatum* (Buckman) (Pl. 2: 8–10), *Gulielmiceras* (*Gulielmiceras*) ex *gr. arcelli* (Mak.), *Peltoceratoides subtense* (Bean in Leck.), *Rursiceras pratti* (Spath), *R. cf. caprinum* (Quenst.), *Choffatia plocum* (Leck.), *Choffatia trina* (Buckm.), *Alligaticeras rotifer* (Brown), *Putealliceras* ex *gr. puteale* (Bean in Leck.).

**Geographic range.** European Russia: Dubki, Malinoviy Ovrag (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, Malinoviy Ovrag (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 zieteni* 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. arcelli* (Mak.), *Peltoceratoides Schroederi* (Prieser), *P. subtense* (Bean in Leck.), *P. athletoides* (Lahusen), *Rursiceras* cf *caprinum* (Quenst.), *Choffatia plocum* (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), *Putealliceras douvillei* (Jeannet), *Sublumuloceras discoides* Spath, *Brightia (B.)* sp. nov. (= *B. svena* (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, Malinoviy Ovrag (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, Eboracitoceras cf. dissimile (Brown) (only near base of the horizon), *Eichwaldiceras williamsoni* (Buckman), “*Quenstedtoceras*” *flexicostatum* (Phil.), *Vertumniceras cf. angulatum* (Troizk.), *Kosmoceras (Kosmoceras) transitionis* (Nik.), *K. (K.) zudacharicum* Kazanski, *Gulielmiceras (Mojarowskia) mojarowskii* (Nikolaeva et Rozh.) (Pl. 2: 11–13), *Grossouvria sphecoides* Spathe, *Sublunuloceras discoides* Spathe, *Brightia (B.) sociini* (Noetling) sensu Gygi, 1990 (Pl. 1: 23), *B. (B.) aff. sveva* (Bonarelli, and *B. (B.) cf. aff. thuouxensis* (Fortwengler et al.) (Pl. 1: 21), which differs from the typical *B. thuouxensis* 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 spino- sum” 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), *Vertumniceras mariae* (d’Orb.), *Choffatia poculum* (Bean, in Leck.), *Klemtosphinctes perisphinctoides* (Sintzov), *Parapeltoceras borissjaki* (Amanniasov) (Pl. 3: 7), *Euaspidoceras subbabeum* (Sintzov) sensu Jeannet (Pl. 2: 33), *Mirospinctes sp.*, *Sublunuloceras cf. depeditum* (Roull.), *Brightia cf. aff. thuouxensis* (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* Kazanski (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), *Peltoceratoides constantii* (d’Orb.), *H. hoplophorus* (Buckman) (Pl. 3: 1–4), *Parapeltoceras borissjaki* (Amanniasov), *Euaspidoceras subbabeum* (Sintzov) sensu Jeannet, *Paraspidoceras internodatum* Zeiss (Pl. 3: 11, 12), *Paraspidoceras billedensis* (Loriol), *Putealiceras schumacheri* (Noetl.) (Pl. 1: 24; Pl. 3: 15, 16), *Brightia aff. sveva* (Bonarelli), *Lissoceratoides erato* (d’Orb.) (Pl. 1: 25), *Holocylphiloceras cf. kunthii* (Neum.), *Holocylphiloceras mediterraneum* (Neum.), *Calliphylloceras disputabile* (Zitt.), *Sowerbyceras tortisulcatum* (d’Orb.), *Thys- anothyloceras 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 *Putealiceras 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 Pritska (Tatar Republic); Mikhailov (Razan 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 (Scarburgi- ceras)* scarburgense (Young et Bird) (Pl. 3: 17), “*Quensted­toceras*” *luppovi* (Amanniasov) (Pl. 1: 16, 17), *Vertumni­ceras mariae* (d’Orb.), *Subvertebriceras stantoni* (Reeside), *Protocardioceras sp.*, *Properisphinctes bernensis* (Loriol),
Poulispinctes sp., Peltoceratoides williamsoni (Phillips) (Pl. 3: 5, 6), Rursiceras cf. torosus (Oppel), Euaspidoiceras subbabeanaum (Sintzov) sensu Jeannet, Subulilococeras cf. deperditum (Roll.), uncommon ?Eulunulites bonarellii (Loriol).

Geographic range. European Russia: Mikhailov, Nikitino, Kostino (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.

Characteristics ammonites. Protocardioceras praemartini (Spach) (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/speleoceratid 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 this 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

demend. Fortwengler and Marchand 1994

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

Characteristics ammonites. Cardioceras (Scarburgiceras) alphacordatum Spath (Pl. 2: 16, 28, 29), Goliathiceras (Pachycardioceras) nikitinianum (Lahusen), Pavloviceras pavlovi (Douvillé), Vertumniceras mariae (d’Orb.), Protocardioceras russiense (Sasonov) (Pl. 2: 26, 27), ?Subvertebriceras subcordatum (Pavlov), Properisphinctes bernensis (Loriol), Peltoceratoides arduennense (d’Orb.), P. hoplophorus Buckman. “Parapeltoceras” subeugenii (Buckm.), Euaspidoiceras 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, Artic Canada, Northern and Northeast Siberia.

Praecordatum Subzone Morley-Davies 1916

praedatum biohorizon Buckman, 1920

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

Characteristics 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 (Pavlov), G. (K.) rotundatum (Nikitin), Pavloviceras pavlovi (R. Douv.), Protocardioceras russiense (Sasonov), Vertumniceras cf. mariae (d’Orb.), V. munguschlakens Epinn, Properisphinctes bernensis (Loriol), Peltoceratoides intertextus (Buckman), Peltomorphites hoplophorus Buckman, Peltoceratoides arduennense (d’Orb.), Rursiceras cf. torosus (Oppel).

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

Cordatum Zone d’Orbigny 1852

Bukowski Subzone Arkell 1941

Characteristics ammonites. Cardioceras (Scarburgiceras) bukowski Maire (Pl. 2: 20, 21), Cardioceras (S) gloriosum Arkell, Goliathiceras (G.) goliathum (d’Orb.), G. (G.) nalivkini (Borissjak) (Pl. 2: 32), G. (G.) cf. subgoliath (Maire), ?Subvertebriceras subcordatum (Pavlov), Euaspidoiceras nikitini (Borissjak), Taramelliceras sublaevipictum (Sinzov).

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.) morph “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 oppellid 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. praeecdudatum). 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 (Quereuilhac et al., 2009), but these ammonites are not so numerous.

Geographic range. Central Russia (Saratov region). On the basis of records of the contemporaneous oppellids (C. petitclerci, C. renggeri, T. sublaevipictum) we suggest the presence of the biohorizon in Belorusussia (Prip’at area), Moscov 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 Pavlov, C. (Scoticardioceras) babeanum Maire, C. (?) excavatiforme (Maire), Goliathiceras (G.) goliathum (d’Orb.), G. nalivkini (Borissjak), G. (Korythoceras) cf. rotundatum (Nikitin), G. (Pachycardioceras) ancanthum (Buckman), Vertebriceras quadrarium (Buckman), Subvertebriceras costellatum (Buckman), S. comprimatum (Buckman), Perisphinctes sp., Peltoceratoides constantii (d’Orb.), P. eugenii (Raspail), P. arduennense (d’Orb.), Euspidioceras babeum (d’Orb.), Mirosphinctes sp., Neocampylites helveticus Jeannet (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.) cordatumformae (Buckman), C. (Scoticardioceras) 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, Greenland, Northern Siberia, Arctic Canada.
BELEMNOID DISTRIBUTION
(O. Dzyuba)

Among the Belemnoidea there are two big groups occurring in the Dubki section: the belemnotheriids and the true belemnites (belemnids) (Fig. 3). Belemnotheriids 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 Belemnotheriutis antiquus (Pearce) described recently by Fuchs et al. (2007) from the Lamberti Zone of the Dubki section. Simultaneous wide distribution of the belemnotheriids 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 belemnotheriids with a good mode of preservation are close in all characters to Acanthotethus 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 Belemnotheriutis polonica Makowski as a synonym of B. antiquus Pearce.

Belemnids (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 belemnids (Cylindroteuthidae) are uncommon and are restricted to the Praecordatum Subzone and a part of the Lamberti Subzone only. The taxa Holcobeloides beaconianus (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 redeposition 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 stradergeri (Rood, Hay et Barnard) (Fig. 7: 9) and Cyclagelo sphera magerellei (Noel) (Fig. 7: 8). Other taxa were found in the same 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,
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 Sabacythere sudorocostata Zone (assemblages I–III in Tesakova, 2008), Neurocythere dulcis Zone (assemblages IV–V in Tesakova, 2008) and Sabacythere 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 Sabacythere 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 Neocythere 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 (Wisz.) (Pl. 5: 1), L. polonica (Wisz.), L. compressaeformis (Paalz.), L. subtilis (Wisz.), L. parainflata Grig., Astacolus colligatum (Bruckm.) (Pl. 5: 3), Planularia dekeei (Wisz.) (Pl. 5: 4), Saracenaria engelsensis Kosyrev in Chabarova (Pl. 5: 5), S. cornucopia (Schwag.), Epistomina elschankaensis Mjatl., E. mosquensis Uhlig (Pl. 5: 13), E. parastelligera (Hofker), E. rjasanensis (Umsansk. 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 (Wisz.), Vaginulina dimidia Grig., Nodosaria mutabilis Terq., N. minuta Cordey, Pseudonodosaria lahuseni (Uhlig), Ophthalmidium areniforme (E. Byk.) (Pl. 5: 8), Ichthyolariola suprajurensis (Mjatl.) (Pl. 5: 10), Vaginulopsis sp., Dentalina sp., Globulina sp., and (in the upper part of the zone) Epistomina paralimbata Grig.

The Lower Oxfordian Ophthalmidium sagittatum–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 sagittatum (E. Byk.) (Pl. 5: 9) as well as some transitional species, known from the underlying zone: Lenticulina tumida Mjatl., L. uhligi (Wisz.), L. compressaeformis (Paalz.), Citharinella nikitini (Uhlig), C. moelleri (Uhlig), Epistomina mosquensis Uhlig, E. parastelligera (Hofker), Ichthyolariola suprajurensis (Mjatl.), Pseudonodosaria lahuseni (Uhlig). In addition to the species mentioned above Lenticulina tympana Grig., L. belorussica (Mitjan.), Planularia angustissima (Wisz.), P. flexuosa (Bruckm.), Astacolus erucaeformis (Wisz.), Citharina chanika (Mjatl.), Saracenaria cornucopia (Schwag.), Spirillina kuebleri Mjatl, Dentalina sp., Lagena sp., Nodosaria sp. were also encoun-
Dmitry Kiselev et al.

Lenticulina tumida–Epistomina elschankaensis
Ophthalmidium sagittum–Epistomina volgensis

F-zone

Ostracoda
Foraminifera

Neurocythere dulcis
S.attalicata–E.costaeirregularis

O-zone
Sabacythere sudorocostata

1–2
6–10
11–15
10–50
10–100
>100

Epistomina mosquensis
Epistomina parastelligera
Epistomina rjasanensis
Pseudolamarckina rjasanensis
Lenticulina tumida
Lenticulina uhligi
Lenticulina compressaeformis
Saracenaria engelsensis
Saracenaria cornucopia
Citharinella nikitini
Astacolus colligatum
Planularia deekei
Ichthyolaria suprajurensis
Marginulinopsis sp.
Nodosaria mutabilis
Nodosaria minuta
Ophthalmidium areniforme
Citharina heteropleura
Citharinella moelleri
Marginulinopsis folium
Lenticulina subtilis
Lenticulina parainflata
Vaginulina dimidia
Pseudonodosaria lahuseni
Planularia flexuosa
Astacolus erucaeformis
Lenticulina brueckmanni
Marginulinopsis primaformis
Lenticulina belorussica
Epistomina radiata
Epistomina volgensis
Citharina chanika
Planularia angustissima
Lenticulina tympana
Nodosaria sp.
Ophthalmidium sagittum
Spirillina kuebleri

Globulina sp.
Lenticulina sp.
Dentalina sp.
Lenticulina polonica
Lagena sp.
Epistomina paralimbata
Astacolus sp.
Shell frequency
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 (±), 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° (Bakhmutov, 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

### 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 \(\times 10^{-5}\) 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 paleomagnetics, 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.

### Table 1

<table>
<thead>
<tr>
<th>M.Y.</th>
<th>Lat°</th>
<th>Long°</th>
<th>(A_{95})</th>
<th>number 1</th>
<th>number 2</th>
<th>number 3</th>
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<td>149.5</td>
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<td>3.3 ±6.7</td>
<td>4.9 ±6.9</td>
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<tr>
<td>170</td>
<td>69.7</td>
<td>112.5</td>
<td>6.0</td>
<td>1.9 ±5.4</td>
<td>4.2 ±5.0</td>
<td>3.5 ±5.4</td>
</tr>
</tbody>
</table>

M.Y. – million years ago, Lat – latitude pole, Long – longitude pole, \(A_{95}\) – radius of the confidence circle for pole
Angular separation between ChRM and direction of rock remagnetization by the modern field (bold line with points) with errors (±) (fine line) (Debiche, Watson, 1995)

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 (XY), open circles on the N–S vertical plane (XZ); C – NRM module (M) as dependent on AF intensity.
Callovian-Oxfordian boundary beds are generally poorly studied in their paleomagnetics, 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 10–20° at the top of the Lamberti Zone to 5° 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.
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-

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**Table 2**

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

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>1. Exposure over an adequate thickness of sediments</td>
<td>Yes</td>
<td>Yes</td>
<td>Thickness much bigger compared with those in Redcliff Point and Dubki</td>
</tr>
<tr>
<td>2. Continuous sedimentation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Absence of synsedimentary and tectonic disturbances</td>
<td>Yes? Some landslides are present</td>
<td>Some landslides are present</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Absence of metamorphism and strong diagenetic alteration</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5. Abundance and diversity of well-preserved fossils throughout the critical interval.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5.1. Ammonites</td>
<td>Yes (this article)</td>
<td>Yes (Page <em>et al.</em>, 2009 b), most continuous succession of cardioceratid ammonites</td>
<td>Yes (Fortwengler <em>et al.</em>, 2012)</td>
</tr>
<tr>
<td>5.2. Belemnites</td>
<td>Yes (this article)</td>
<td>Not described and/or figured</td>
<td>Not described and/or figured</td>
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<tr>
<td>5.3. Foraminifers</td>
<td>Yes (this article)</td>
<td>Not described and/or figured</td>
<td>Not described and/or figured</td>
</tr>
<tr>
<td>5.4. Ostracods</td>
<td>Yes (Tesakova, 2008)</td>
<td>Not described and/or figured</td>
<td>Not described and/or figured</td>
</tr>
<tr>
<td>5.5. Calcareous nannoplankton</td>
<td>Yes (this article)</td>
<td>Not described and/or figured</td>
<td>Yes (Fortwengler <em>et al.</em>, 2013)</td>
</tr>
<tr>
<td>5.6. Dinoflagellate cysts</td>
<td>No</td>
<td>No</td>
<td>Yes (Fortwengler <em>et al.</em>, 2013)</td>
</tr>
<tr>
<td>6. Absence of vertical facies changes at or near the boundary</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Favourable facies for long-range biostratigraphic correlations</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8. Magnetostratigraphy</td>
<td>Yes (this article)</td>
<td>Yes (Ogg <em>et al.</em>, 2010)</td>
<td>No detailed data</td>
</tr>
<tr>
<td>12. Radioisotopic dating</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
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 (mizarowski 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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REFERENCES


DZYUBA O.S., 2004 — Belemnites (Cylindroteuthidae) and biostratigraphy of the Middle and Upper Jurassic of Siberia. Publishing House of SB RAS, Department “Geo”, Novosibirsk [in Russian].


IPPOLITOV A.P., 2006a — On the possible expression of sexual dimorphism in *Hibolites* Montfort, 1808 from the Middle and Upper Jurassic of European Russia. *In: Contributions to current cephalopod research: morphology, systematics, evolution, ecology and biostratigraphy* (eds I.S. Barskov, T.B. Leonova): 57–60. Paleontological Institute of RAS, Moscow [in Russian].


MELEDINA S.V., 1987 — Ammonites and zonal stratigraphy of the Callovian of subboreal regions of the USSR. Nauka, Moscow [in Russian].


OGG J.G., COE A.L., PRZYBYLSKI P.A., WRIGHT J.K., 2010 — Oxfordian magnetostratigraphy of Britain and its correla-


PAGE K.N., 2004 — The Callovian-Oxfordian boundary in Britain: a review of key sections and their correlation with the proposed global stratotype section and point for the Oxfordian in Haute Provence, France. *Rivista Italiana di Paleontologia e Stratigrafia*, **110**: 201–208.


TESAKOV E., 2008 — Late Callovian and Early Oxfordian ostracods from the Dubki section (Saratov area, Russia): implications for stratigraphy, paleoecology, eustatic cycles and palaeobiography. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **249**: 25–45.

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

Eboraciceras Buckman, 1918 (type species Ammonites dissimilis Brown, 1849)

Eichwaldiceras Buckman, 1920 (type species Ammonites carinatus Eichwald, 1868)

Vertumniceras Buckman, 1918 [m] (type species Ammonites vertumnus Leckenby, 1859)

Cardioceras Neumayr et Uhlig, 1881 (type species Ammonites cordatus Sowerby, 1813)

Scarburgiceras Buckman, 1924 (type species Ammonites scarburgense Young et Bird, 1828)

Scoticardioceras Buckman, 1925 (type species Ammonites excavatus Sowerby, 1815)

Pavloviceras Buckman, 1920 (type species Quenstedticeras pavlowi R.Douville, 1912)

Goliathiceras Buckman, 1919 (type species Nautilus ammonoides Young et Bird, 1828)

Pachycardioceras Buckman, 1926 (type species Pachycardioceras robustum Buckman, 1926)

Vertebriceras Buckman, 1920 [m] (type species Vertebriceras dorsale Buckman, 1920)

Korythoceras Buckman, 1920 (type species Korythoceras korys Buckman, 1920)

Protocardioceras Schirardin, 1958 [m] (type species Cardioceras martini Reeside, 1919)

Subvertebriceras Arkell, 1941 [m] (type species Cardioceras densiplicatum Boden, 1911)

Kosmoceras Waagen, 1869 (type species Ammonites spinosus Sowerby, 1829)

Lobokosmoceras Buckman, 1923 (type species Cosmoceras pronia Teisseyre, 1887)

Guliemiceras 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)

Peltooceratoides Spath, 1924 (type species Peltooceras semirugosum Waagen, 1875)

Rursiceras Buckman, 1919 [m] (type species Rursiceras reversum Leckenby, 1859)

Euaspidoceras Spath, 1930 (type species Ammonites perarmatus Sowerby, 1822)

Paraspidoceras Spath, 1931 (type species Ammonites meriani Oppel, 1863)

Choaffia Siemiradzki, 1898 (type species Perisphinctes cobra Waagen, 1875)

Grossouvria Siemiradzki, 1898 [m] (type species Ammonites sulciferus Oppel, 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)

Coryceras Ziegler, 1958 [m] (type species Ammonites microdomus Oppel, 1863)

Creniceras Munier-Chalmas, 1892 [m] (type species Ammonites renggeri Oppel, 1863)

Euhumalites Elmi, 1967 [m] (type species Lunuloceras pompeckyi Parona et Bonarelli, 1895)

Neocampylites Callomon, 1973 (nom. nov. pro Campylites Rollier, 1922 non Campylites Eichwald, 1856, type species Ammonites delmontanus Oppel, 1863)

Putealiceras Buckman, 1922 (type species Ammonites putealis Leckenby, 1859)

Sublunuloceras Spath, 1928 (type species Harpoceras lairense Waagen, 1875)

Taramelliceras Del Campana, 1904 (pro Taramellia Del Campana, 1903 non Taramellia Seguenza, 1903, type species Ammonites trachinotus Oppel, 1862)
PLATES

All specimens whitened with ammonium chloride. Plates 1–4: all specimens ×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. _Vertumniceras mariae_ (d’Orbigny). D1-121. DU, bed 1d. Lamberti Zone and Subzone, _paucicostatum_ biohorizon

Fig. 12, 13. _Vertumniceras vertumnum_ (Bean-Leckensby). 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. _Putealiceras 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. _Putealiceras 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
Dmitry KISELEV et al. — Integrated stratigraphy of the reference sections for the Callovian-Oxfordian boundary in European Russia
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) prae cordatum 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) prae cordatum* 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.  *Euaspidoceras subbabe anum* (Sinzov) sensu Jeannet. MK1571. DU. Lamberti Zone and Subzone, *paucicostatum* biohorizon
Dmitry KISELEV et al. — Integrated stratigraphy of the reference sections for the Callovian-Oxfordian boundary in European Russia
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 annulatum* (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. *Putealiceras 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 (Hemihibolithes) orlovi* Gustomessov. 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* Gustomessov. 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
Dmitry KISELEV et al. — Integrated stratigraphy of the reference sections for the Callovian-Oxfordian boundary in European Russia
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. *Sublumuloceras nodosulcatum* (Lah.). MIV551. DU, bed 1, 380 cm above bottom. Lamberti Zone and Subzone, *mojarowski* 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, *mojarowski* 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
Fig. 1. *Lenticulina uhligi* (Wisniowski), ×103. No. 750RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 2. *Lenticulina brueckmanni* (Mjatliuk), ×55.2. No. 100RM. Lateral view. DU, bed 6, Lower Oxfordian, *Epistomina volgensis–Ophthalmidium sagittum* Zone

Fig. 3. *Astacolus colligatum* (Brueckmann), ×97.3. No. 750RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 4. *Planularia deeckei* (Wisniowski), ×81.4. No. 400RM. Lateral view. DU, bed 1, Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 5. *Saracenaria engelsensis* Kosyreva in Chabarova, ×54.6. No. 850RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 6. *Citharinella nikitini* (Uhlig), ×39.1. No. 550RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 7. *Citharinella moelleri* (Uhlig) ×51.3. No. 450RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 8. *Ophthalmidium areniforme* (E. Bykova), ×167.5. No. 700RM. Lateral view. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 9. *Ophthalmidium sagittum* (E. Bykova), ×93.6. No. 50RM. Lateral view. DU, bed 4, Lower Oxfordian, *Epistomina volgensis–Ophthalmidium sagittum* Zone

Fig. 10. *Ichthyolaria suprajurensis* Mjatliuk, ×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) ×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, ×69.7. No. 750RM. Dorsal view. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone

Fig. 14, 15. *Epistomina volgensis* Mjatliuk, ×49.2. **14** – dorsal view, **15** – ventral view. No. 150RM. DU, Lower Oxfordian, *Epistomina volgensis–Ophthalmidium sagittum* Zone

Fig. 16, 17. *Pseudolamarckina rjasanensis* (Uhlig), ×83. **16** – dorsal view, **17** – ventral view. No. 700RM. DU, bed 1. Upper Callovian, *Lenticulina tumida–Epistomina elschankaensis* Zone