

Biostratigraphy and ammonites of the Middle Oxfordian to lowermost Upper Kimmeridgian in northern Central Siberia¹

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Abstract

The Middle Oxfordian to lowermost Upper Kimmeridgian ammonite faunas from northern Central Siberia (Nordvik, Chernokhrebetnaya, and Levaya Boyarka sections) are discussed, giving the basis for distinguishing the ammonite zones based on cardioceratid ammonites of the genus *Amoeboceras* (Boreal zonation), and, within the Kimmeridgian Stage, faunas—for distinguishing zones based on the aulacostephanid ammonites (Subboreal zonation). The succession of Boreal ammonites is essentially the same as in other areas of the Arctic and NW Europe, but the Subboreal ammonites differ somewhat from those known from NW Europe and Greenland. The Siberian aulacostephanid zones—the *Involuta* Zone and the *Evoluta* Zone—are correlated with the *Baylei* Zone (without its lowermost portion), and the *Cymodoce* Zone/lowermost part of the *Mutabilis* Zone (the *Askepta* Subzone) from NW Europe. The uniform character of the Boreal ammonite faunas in the Arctic makes possible a discussion on their phylogeny during the Late Oxfordian and Kimmeridgian: the succession of particular groups of *Amoeboceras* species referred to successive subgenera is revealed by the occurrence of well differentiated assemblages of typical normal-sized macro and microconchs, intermittently marked by the occurrence of assemblages of pedomorphic “small-sized microconchs” appearing at some levels preceding marked evolutionary modifications. Some comments on the paleontology of separate groups of ammonites are also given. These include a discussion on the occurrence of Middle Oxfordian ammonites of the genus *Cardioceras* in the Nordvik section in relation to the critical review of the paper of Rogov and Wierzbowski (2009) by Nikitenko et al. (2011). The discussion shows that the oldest deposits in the section belong to the Middle Oxfordian, which results in the necessity for some changes in the foraminiferal zonal scheme of Nikitenko et al. (2011). The ammonites of the *Pictonia involuta* group are distinguished as the new subgenus *Mesezhnikovia* Wierzbowski and Rogov.

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Keywords: northern Central Siberia; Oxfordian; Kimmeridgian; ammonites; phylogeny; taxonomy; zonal schemes; correlations

Introduction

Northern Central Siberia provides a number of fossiliferous sections important for recognition of the Upper Jurassic stratigraphy of the area (e.g., Shurygin et al., 2011, and earlier papers cited therein). The sections of the Khatanga Trough: of the Urdyuck-Khaya Cape of the Nordvik Peninsula situated on the Laptiev Sea (Voronets, 1962; Rogov and Wierzbowski, 2009, and earlier papers cited therein), of the Chernokhrebetnaya River (Mesezhnikov, 1984; Aleynikov and Meledina, 1993), and of the Kheta River Basin (especially of the Levaya Boyarka River—Saks et al., 1969a,b; Mesezhnikov, 1967, 1969a, 1984) are crucial for the elaboration of the detailed

ammonite succession, and thus the basis for founding the biostratigraphical scheme of the Middle Oxfordian to Kimmeridgian in northern Central Siberia (Fig. 1). In this respect, the last paper of Nikitenko et al. (2011) giving a critical analysis of the Oxfordian–Kimmeridgian interpretation of the Nordvik Peninsula section by Rogov and Wierzbowski (2009) needs special comment. This is also a good opportunity to summarize the results of the stratigraphical analysis carried out on the sections and to consider the implications for the biostratigraphical interpretation of the Middle Oxfordian to lowermost Upper Kimmeridgian deposits not only in northern Central Siberia but also in other areas of the NW Europe and the Arctic.

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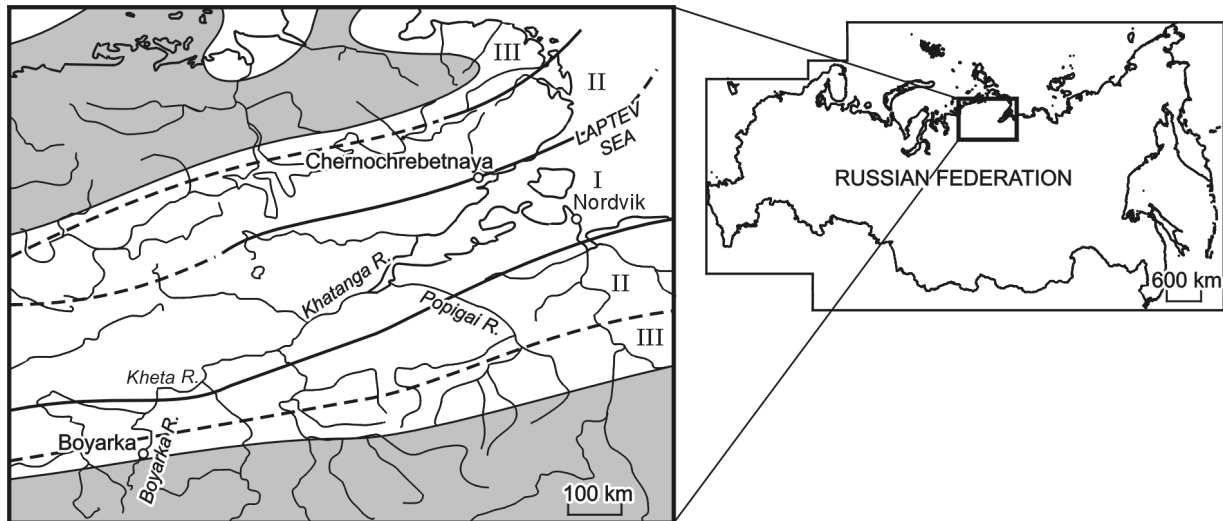


Fig. 1. Upper Jurassic paleogeography of the north of Central Siberia and location map showing the position of the sections studied. Paleogeography is given after Zakharov and Shurygin (1983): land area is marked in gray; I–III indicate the bionomic zones: I, deep; II, relatively deep; and III, shallow.

Stratigraphy

Middle Oxfordian

The Middle Oxfordian deposits have been identified by ammonites and subdivided into the Densiplicatum Zone and the Tenuiserratum Zone in the Chernokhrebetnaya River section of the eastern Taimyr by Aleynikov and Meledina (1993). However, the uppermost part of the Middle Oxfordian succession have yielded only fragmentarily preserved ammonites of the genus *Cardioceras*.

The stratigraphical interpretation of unit 1 (beds 1–3) of the Nordvik Peninsula differs markedly depending on the attribution of the ammonites occurring here to particular genera by various authors: either to the genus *Cardioceras*, which gives the basis for distinguishing the Middle Oxfordian (cf. Voronets, 1962; cf. Saks et al., 1963; Rogov and Wierzbowski, 2009), or to the genus *Amoeboceras* which results in recognition of the Upper Oxfordian (Basov et al., 1970; Nikitenko et al., 2011). The following ammonites were reported from unit 1 of the Nordvik section: “*Cardioceras* sp. indet.” (by Voronets, 1962, p. 17—not illustrated); “*Cardioceras* cf. ex gr. *zenaidae* Ilv.” (by Voronets, 1962, not illustrated; see also Saks et al., 1963)—the specimen is preserved in the Voronets’s collection in CNIGR Museum (Saint Petersburg), but as it represents a fragment of a whorl with its ornamentation poorly seen—its affiliation to the genus *Cardioceras* may be given with some reservation; “*Amoeboceras* sp.” (by Basov et al., 1970—not illustrated). Recently, Rogov and Wierzbowski (2009, plate 1, fig. 1) presented a specimen referred to as “*Cardioceras* (*Cawtoniceras*) ex gr. *blakei* Spath” coming from the uppermost part of unit 1 (bed 3), and reported the occurrence of fragmentarily preserved ammonites belonging to the Middle Oxfordian genus *Cardioceras* from the lowermost part of bed 3. These specimens, however, were neither illustrated nor studied in detail at that time. Concerning this fauna Nikitenko et al.

(2011, p. 967) interpreted the illustrated specimen as belonging to the genus *Amoeboceras* because of the “presence of a distinct near-keel area on the latter whorl and distinct ribbing, which is also observed on the earlier whorls”. It should be noted that the inner whorls of the specimen in question are not visible, and the ribbing of the outer whorl shows a high secondary/primary rib ratio which is very typical for *Cardioceras* (*Maltoniceras* and *Cawtoniceras*) but not encountered in early *Amoeboceras*. On the other hand, Nikitenko et al. (2011, plate 1, figs. 1–3, pp. 975–976) illustrated and described a single specimen referred to as “*Amoeboceras* (*Amoeboceras*) ex gr. *alternoides* (Nikitin, 1887)” coming from the lowermost part of unit 1 (base of bed 1). In conclusion, Nikitenko et al. (2011) stated that “the paleontologic evidence for the presence of the upper Middle Oxfordian (Rogov and Wierzbowski, 2009) at the bottom of the Jurassic section of the Nordvik Peninsula (upper unit 1) seems wrong”.

Our interpretation of nearly all these specimens from unit 1 as given herein differs markedly from that proposed by Nikitenko et al. (2011), because the overall affinities of the ammonites coming from unit 1 of the Nordvik section are certainly with the genus *Cardioceras*. Here belongs: *Cardioceras* (*Cawtoniceras*) ex gr. *blakei* Spath of Rogov and Wierzbowski (2009, plate 1, fig. 1) which clearly shows the continuation of the secondary ribs onto the keel, and in opposition to the opinion of Nikitenko et al. (2011), this specimen cannot be placed in the genus *Amoeboceras* (see also comments given above). This is also the case with the specimens referred to herein as *Cardioceras* (*Subvertebriceras*) and *C. (Scoticardioceras)*, coming from the lower and middle parts of bed 3 of unit 1, and illustrated for the first time (Fig. 2; Plate 1, figs. 3a, b, 5–6), and showing the well developed continuation of the secondary ribs onto the keel typical of the genus *Cardioceras*. Also about ten other fragmentarily preserved ammonites belong to the genus *Cardioceras*. These were mentioned by Rogov and Wier-

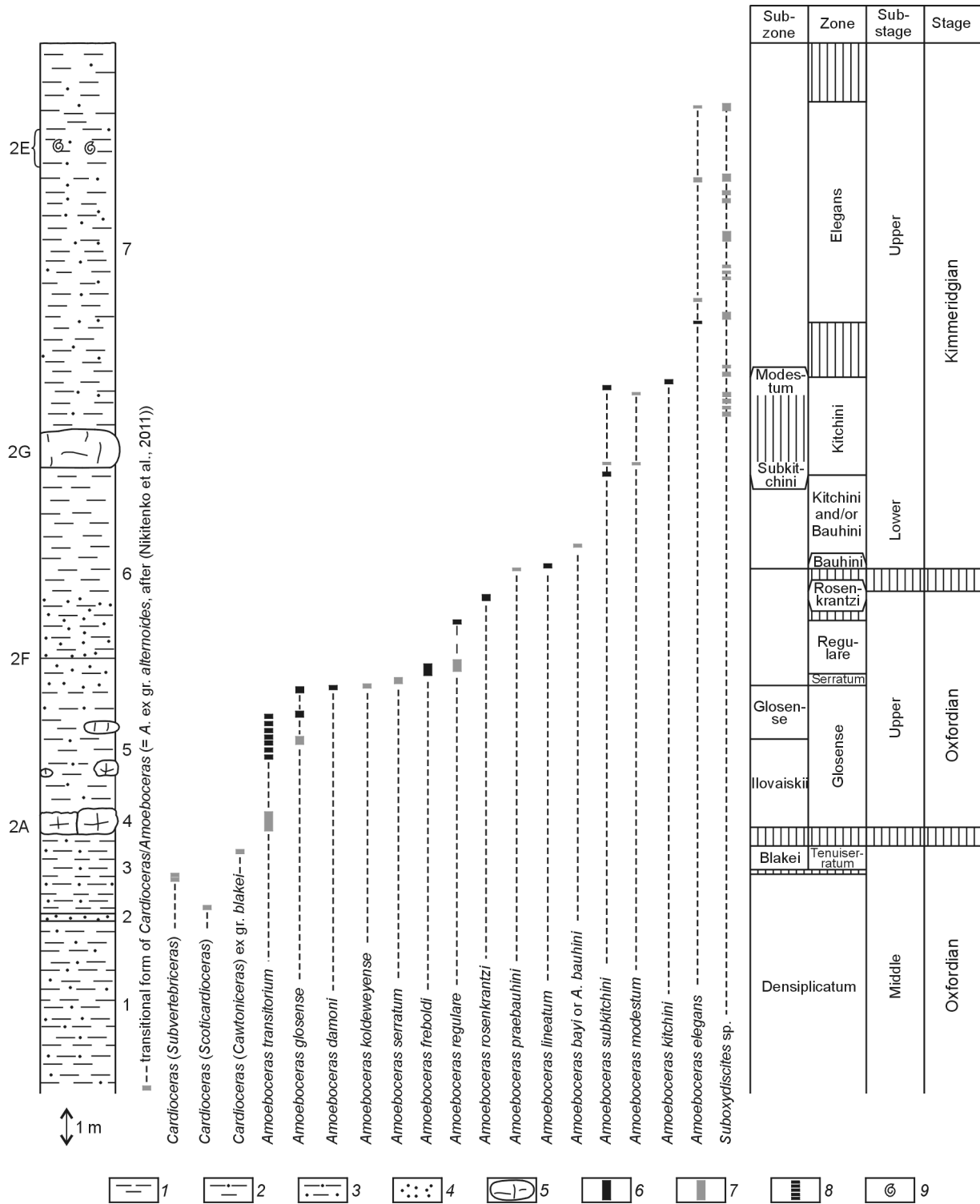


Fig. 2. Ammonite distribution in the Nordvik section (after Rogov and Wierzbowski, 2009), supplemented with new data from the Middle Oxfordian: 1, clays; 2, silty clays; 3, clayey siltstones; 4, silty clayey sandstones; 5, calcareous concretions; 6, precise range of specimens referred to the species; 7, precise range of specimens referred to as cf. or ex gr. species; 8, approximate range of specimens referred to the species; 9, bed with numerous ammonites used as correlation level 2E.

zowski (2009), and come from the whole of bed 3, plus the uppermost part of bed 1 of unit 1. Also possibly included here is “*Cardioceras* cf. ex gr. *zenaidae* Ilov.” from Voronet’s own collection.

On the other hand, the assemblage from unit 1 contains a form showing a weakening of the ribbing at the ventral side, represented by the specimen figured by Nikitenko et al. (2011, plate 1, figs. 1–3) which resembles early representatives of

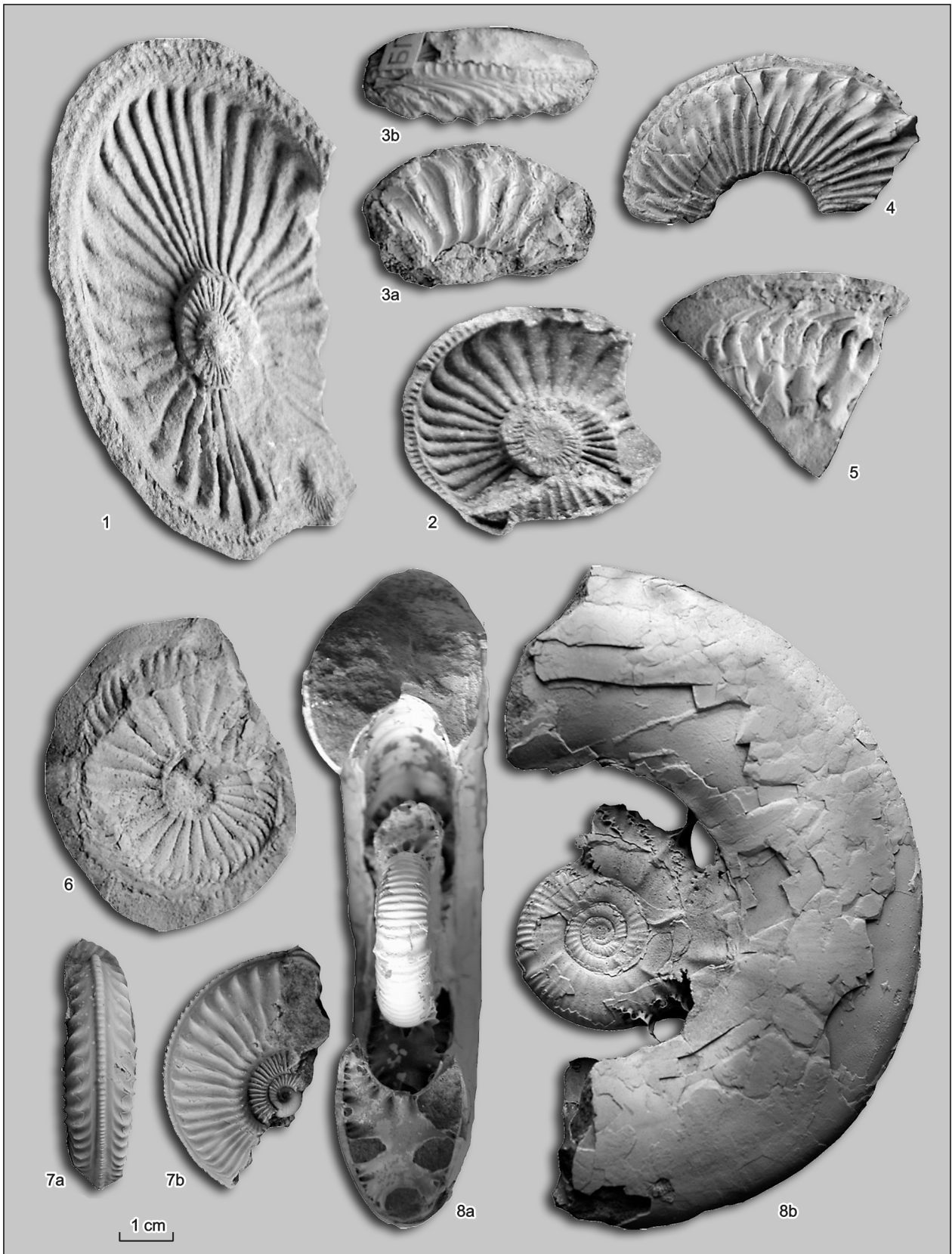


Plate 1. Middle Oxfordian ammonites of the genus *Cardioceras* from the Nordvik section and Lower Kimmeridgian *Pictonia* (*Mesezhnikovia*) and *Amoeboceras* (*Amoebites*) from the Levaya Boyarka and Chernokhrebetnaya sections. Figures 1, 2, 4, 8 in natural size, other $\times 2$.

1, 2. *Amoeboceras* (*Amoebites*) *mesezhnikovi* (Sykes & Surlyk), Lower Kimmeridgian, Kitchini Zone, Subkitchini Subzone; 1, Chernokhrebetnaya River, no label, VNIGRI R41; 2, Chernokhrebetnaya River, section 22, bed 20 (collected by M.S. Mesezhnikov, 1962), VNIGRI R35; 3a, b, 5. *Cardioceras* (*Subvertebriceras*) sp., Nordvik, Middle Oxfordian, Densiplicatum Zone; 3, 1.2 m below 2A, SGM BP-09614; 5, 1.05 m below 2A, GGM-1129-44; 6. *Cardioceras* (*Scoticardioceras*) sp. Nordvik, Middle Oxfordian, Densiplicatum Zone—1.82 m below 2A, specimen lost; 4. *Amoeboceras* (*Amoebites*) *subkitchini* (Spath), Chernokhrebetnaya River, section 44, bed K-10 (collected by M.S. Mesezhnikov), Lower Kimmeridgian, Kitchini Zone, Subkitchini Subzone, VNIGRI R33; 7. *Amoeboceras* (*Amoebites*) ex gr. *subkitchini* Spath, Levaya Boyarka, section 22, bed 3, Lower Kimmeridgian, Involuta Zone (collected by M.S. Mesezhnikov), VNIGRI coll., no number; 8a, b. *Pictonia* (*Mesezhnikovia*) *ronkinae* Mesezhnikov, Levaya Boyarka, section 22, bed 3 (collected by N.I. Shulgina, 1967), VNIGRI.

the genus *Amoeboceras*. This resemblance is only superficial, for the ribbing of the inner whorls of this ammonite is not typical of that of early *Amoeboceras*, but is common in late *Cardioceras*. The ammonite, as figured by Nikitenko et al. (2011), shows smooth inner whorls with secondaries appearing first at a diameter of 10 mm, but a keel is well-developed at even earlier stages of shell growth. All the *Amoeboceras* from the Glosense Zone (lowermost zone of the Upper Oxfordian) show the primaries appearing either earlier or at the same time as the secondaries at a fairly small shell diameter of less than 5 mm. Only younger *Amoeboceras* from the Serratum Zone, such as *A. serratum* and especially *A. koldeweyense*, are characterized by smooth inner whorls, sometimes up to a diameter of 30 mm. The inner whorls of the ammonite in question (Nikitenko et al., 2011, plate 1, fig. 2) are somewhat similar to those of *Cardioceras* (*Maltoniceras*) *kokeni* Boden (Mesezhnikov et al., 1989, plate II, fig. 14; plate III, figs. 2, 3, 11; Aleynikov, Meledina, 1993, plate 1, fig. 6; Repin et al., 2006, plate 35, figs. 7, 18); that species has been often placed in the subgenus *Cawtoniceras*—but more probably it belongs to the subgenus *Maltoniceras*. The specimen in question from the Nordvik section is characterized, however, by relatively thick ribs, which became thinner and numerous in the outer whorl.

The occurrence of forms transitional between the genera which follow each other in a succession is often the case in stratigraphical intervals, e.g., at the Callovian–Oxfordian boundary where transitional forms between the older genus *Quenstedtoceras* and the younger *Cardioceras* are normally encountered (e.g., Page et al., 2009). The situation at the Middle/Upper Oxfordian boundary in many European sections is different in most cases—the youngest representatives of the genus *Cardioceras* (subgenus *Cawtoniceras*) typical of the uppermost Middle Oxfordian, differ markedly from the oldest representatives of the genus *Amoeboceras* like *A. ilovaiskii* and its allies occurring at the base of the Upper Oxfordian. It was, however, indicated by Sykes and Callomon (1979, pp. 847, 848) that already in some *Cardioceras* of the Densiplicatum Zone of the Middle Oxfordian in England, the secondary ribs tend to be separated from the serrated keel by smooth margins, marking some similarity to *Amoeboceras*. Possibly the same phenomenon has been observed in the section at the Anabar River in northern Siberia (Mesezhnikov in: Meledina et al., 1976, p. 67) where in a single bed, not showing any signs of condensation, have been reported *Amoeboceras* sp., together with several forms of *Cardioceras*—like *C. (Subvertebriceras) densiplicatum* Boden, *C. (S.) sowerbyi* Arkell, *C. (Scoticardioceras) excavatum* (Sowerby)

and *C. (Plasmaticeras)* indicative of the Densiplicatum Zone of the Middle Oxfordian. The occurrence of a special fauna of cardioceratids in the Alaskan Northern Slope was also recognized by Callomon (1984, fauna D9, p. 167): “hard to place closely; the macroconch still resembles late *Cardioceras* (*Maltoniceras*) in the crenulation of the keel, but *Amoeboceras* (*Prionodoceras*) in ribbing and coiling, whereas the microconch resembles *Amoeboceras* s.s. in its keel but *Cardioceras* (*Vertebriceras*) in ribbing”. This fauna was tentatively placed by Callomon (1984) in the lowermost Upper Oxfordian, but it could be older. Thus, no contradiction exists between the occurrence of ammonites of the genus *Cardioceras* along with some specimens transitional to *Amoeboceras* as stated in unit 1 of the Nordvik sections; according to the character of the former these deposits should be placed still in the Middle Oxfordian.

The presence of *Cardioceras* (*Scoticardioceras*) and *C. (Subvertebriceras)* is typical of the Densiplicatum Zone (Sykes and Callomon, 1979; Wright and Page, 2006), and this age should be accepted for the middle and lower parts of bed 3 of the Nordvik section. The specimen referred to as *Amoeboceras* (*Amoeboceras*) ex gr. *alternoides* (Nikitin) by Nikitenko et al. (2011) in accordance to that has been discussed above is in fact intermediate in character between *Cardioceras* (*Maltoniceras*) and *Amoeboceras* (*Paramoeboceras*). The occurrence of this form in the lowest part of bed 1 suggests still the presence of the Densiplicatum Zone of the Middle Oxfordian.

In accordance with the reinterpretation of ammonites from unit 1 of the Nordvik section some critical comments should be given on the stratigraphical position of the dinocysts and foraminifers recognized in this unit and considered by Nikitenko et al. (2011) as diagnostic of the Upper Oxfordian. According to Nikitenko et al. (2011, pp. 969, 971) the distribution of foraminifers “does not preclude that lowermost unit 1 (lower bed 1) may belong to the *Recurvoides disputabilis* JF37 f-Zone”, whereas the middle and upper parts of unit 1 and the higher units up to bed 7a of the lower part of unit 4 “contains foraminiferal assemblages of the *Haplophragmoides? canuiformis* JF40 f-Zone”. Whereas the JF 37 f-Zone was correlated with the lower part of the Upper Oxfordian, the JF40 f-Zone was considered as corresponding to the upper part of the Upper Oxfordian and a bulk of the Lower Kimmeridgian (Nikitenko, 2009; Nikitenko et al., 2011, fig. 5). Such a stratigraphical interpretation of the deposits differs markedly, however, from that based on ammonites as described by Rogov and Wierzbowski (2009). It should be remembered that the type section of the *Haplophragmoides?*

canuiformis JF40 f-Zone was distinguished by Nikitenko (2009, pp. 254–255, fig. 32) on the Nordvik Peninsula (the Urdyuk Khaya Cape), and the zone included originally units 2–3 and the lowermost part of unit 4 (lower part of bed 7a) of the section. Later, Nikitenko et al. (2011) placed into this zone also the upper and middle parts of unit 1 (beds 2–3). The ammonite faunas described by Rogov and Wierzbowski (2009; and discussion herein) show that the part of the section corresponding to the *Haplophragmoides* ? *canuiformis* JF40 f-Zone spans a stratigraphical interval at least from the Middle Oxfordian up to the end of the Kitchini Zone (may be also the Sokolovi = Kochi Zone of the Upper Kimmeridgian), and there is no place to distinguish therein the *Recurvoides disputabilis* JF37 f-Zone, if its stratigraphical range had to be limited to a lower part of the Upper Oxfordian.

Unit 1 of the Nordvik Peninsula section was referred also to the Upper Oxfordian on the basis of its organic dinocyst assemblage by Nikitenko et al. (2011). This assemblage yielded the dinocysts *Aldorfia dictyota* (Cookson et Eisenack), and *Nannoceratopsis pellucida* Deflandre (index species of beds with dinocysts) together with an Arctic species *Paragonyaulacysta borealis* (Brideaux et Fischer); Nikitenko et al. (2011, pp. 973–974) stated that these dinocysts had to “appear for the first time in various Boreal realm sections only in the Upper Oxfordian”. In fact, all these forms are known from the Lower/Middle Oxfordian, and the characteristic low diversity *P. borealis* assemblage typical of the high latitude Arctic occurs already at the turn of the Callovian and Oxfordian (Århus, 1988; Smelror, 1993). It should be remembered also that the local *Paragonyaulacysta borealis* Zone is distinguished in the Lower Oxfordian of the Brooks–Mackenzie Basin of Arctic Canada (Poulton et al., 1992, fig. 4.3B). The statement of Nikitenko et al. (2011, p. 974) that *P. borealis* appears in high latitude Arctic areas in the Upper Oxfordian is evidently erroneous, because it is based on data from a few sections from the Canadian Arctic (Brideaux and Fischer, 1976; for stratigraphy see also Harrison et al., 1999), which did not yield any older dinocyst assemblage than the Late Oxfordian one. Similarly, the occurrence of *Paragonyaulacysta borealis* in the oldest cored deposits attributed to the Upper Oxfordian in the Barents Sea area (Wierzbowski and Århus, 1990) does not indicate that the cyst in question has appeared in this area for the first time during the Late Oxfordian. Taking into account the well known differences in stratigraphical ranges of the dinocyst species between the particular areas, it may be noticed, moreover, that the stratigraphical range of another dinocyst—*Nannoceratopsis pellucida* in the Russian Platform and northern Siberia should not range much higher than the Middle Oxfordian—the ammonite *Tenuiserratum* Zone (Riding et al., 1999). Hence, the assemblage of dinocysts recorded from unit 1 of the Nordvik section by Nikitenko et al. (2011) cannot be treated in any case as indicative of the Late Oxfordian, because it may as well be Middle Oxfordian in age.

Upper Oxfordian

The standard Boreal Upper Oxfordian ammonite zones (Sykes and Callomon, 1979) have been distinguished in the Chernokhrebetnaya River section in eastern Taimyr (Aleynikov and Meledina, 1993; see also Shurygin et al., 2000; 2011). The ammonites of the genus *Amoeboceras* (subgenera: *Paramoeboceras* and *Amoeboceras*, see paleontological chapter herein) enable the recognition of the following zones and subzones: the Glosense Zone with the Ilovaikii Subzone below and the Glosense Subzone above, the Serratium Zone, the Regulare Zone and the Rosenkrantzi Zone (Aleynikov and Meledina, 1993, fig. 3, plate 1).

Upper Oxfordian ammonites are recorded also from the Kheta River Basin—in the Levaya Boyarka sections—where the Ravni Zone has been established by Mesezhnikov (1967, 1969a, 1984). The ammonite assemblage in question has been found in carbonate or phosphatized sandstone concretions in the glauconitic sands (beds 1 and 2 in Mesezhnikov, 1967) which are about 2.8 m in thickness. At the base of the unit occurs *Amoeboceras regulare* Spath, whereas other ammonites (*A. freboldi* Spath, *A. leucum* Spath, *A. pectinatum* Mesezhnikov and *A. schulginiae* Mesezhnikov, including “*A. ravni*” of Mesezhnikov, 1967, plate I, fig. 1; see Matyja et al., 2006, pp. 399, 401) occurring higher in the section have not been localized precisely in the unit (Mesezhnikov, 1967). The assemblage is typical of the Regulare Zone plus the Rosenkrantzi Zone of the standard Boreal Upper Oxfordian (see Mesezhnikov et al., 1989; Aleynikov and Meledina, 1993; Shurygin et al., 2000), but possibly also of the lower part of the Bauhini Zone of the lowermost Boreal Kimmeridgian, as proved by occurrence of *A. schulginiae* whose stratigraphical range in Skye, Scotland, and at Unzha River, Russian Platform, corresponds just to this stratigraphical interval (Matyja et al., 2006; Glowniak et al., 2010; see also Fig. 3 herein). Additional evidence that the Ravni Zone in Mesezhnikov’s interpretation also includes the lowermost part of the Lower Kimmeridgian in the Russian Platform came from records of *Amoeboceras (Plasmatites)* from this zone (Mesezhnikov et al., 1989).

In the Nordvik Peninsula section the first described ammonite referred to as “*Amoeboceras (Amoeboceras) cf. alternans* (von Buch)” by Voronets (1962, plate XXX, fig. 6) was recorded from the lowermost part of unit 2. This poorly preserved ammonite is difficult for to interpret unequivocally, being either a late *Cardioceras* transitional to *Amoeboceras*, possibly still of Middle Oxfordian age (Rogov and Wierzbowski, 2009, p. 147), or an early representative of *Amoeboceras* close to *A. ilovaikii* (Sokolov) (see Mesezhnikov, 1967, p. 112), or *A. koldeweyense* Sykes et Callomon (Mesezhnikov et al., 1989, table 5). In any case, the specimen in question cannot be compared with the true *A. alternans* (von Buch) which occurs in generally younger deposits of the Upper Oxfordian from the Serratium Zone upwards (cf. Sykes and Callomon, 1979; Mesezhnikov et al., 1989). Fortunately, other ammonites found in unit 2 (beds 4 and 5) make possible its closer stratigraphical interpretation. These are: *A. transitio-*

rium Spath (Rogov and Wierzbowski, 2009, plate 1, figs. 2–4; see also Fig. 2 herein) at the base of the unit; *A. glosense* (Bigot et Brasil) (Rogov and Wierzbowski, 2009, plate 1, fig. 5) in its middle part; and *A. cf. koldeweyense* Sykes et Callomon (Rogov and Wierzbowski, 2009, plate 1, fig. 6), *A. damoni* Spath (Rogov and Wierzbowski, 2009, plate 1, fig. 7) and *A. cf. serratum* (Sowerby) (Rogov and Wierzbowski, 2009, plate 1, fig. 8) in upper part of the unit. Moreover, *A. regulare* Spath and *A. freboldi* Spath have been recognized in the topmost part of unit 2 (Rogov and Wierzbowski, 2009, plate 1, fig. 9). These ammonites unequivocally indicate the presence of the Glosense Zone, the Serratum Zone, and possibly a lowermost part of the Regulare Zone in unit 2 of the Nordvik Peninsula section corresponding to the lower and middle parts of the Upper Oxfordian (Rogov and Wierzbowski, 2009, fig. 2; see also Figs. 2–3 herein). Any more detailed biostratigraphical data are not available from the interval studied because the records of “*Amoeboceras* ex gr. *alternans* and *Amoeboceras* (*Prionodoceras*) sp.” “without illustrations—as reported by Saks et al. (1963) and Basov et al. (1970) are of limited stratigraphical value. Nevertheless, it may be noticed that a single level with numerous *A. transitorium* Spath in the Nordvik Peninsula section as recorded by Mesezhnikov et al. (1989, p. 68) could possibly be correlated with a lower part of unit 2 (bed 4–lower part of bed 5) where ammonites of this species have been encountered fairly commonly in the section studied (Rogov and Wierzbowski, 2009, fig. 2; Fig. 2 herein). A younger ammonite assemblage occurring in a lower part of bed 6 (unit 3) in the Nordvik section consists of *A. regulare* Spath and *A. rosenkrantzi* Spath and is indicative of the upper part of the Upper Oxfordian—the Regulare Zone and the Rosenkrantzi Zone (Rogov and Wierzbowski, 2009, fig. 2; plate 2, fig. 1; plate 2, fig. 2).

Numerous detailed objections were given by Nikitenko et al (2011) against the paleontological interpretation of the ammonites from the Nordvik section by Rogov and Wierzbowski (2009), but these authors also make general statements on the difficulties in the interpretation of the *Amoeboceras* species “for lack of clear idea about the morphogenesis” of the genus “whose evolution is observable only in a big collection of well preserved specimens” (Nikitenko et al., 2011, p. 969). Thus, the collection studied by Rogov and Wierzbowski, 2009, consisting of about 60 specimens of which about 20 were illustrated, appeared too small for Nikitenko et al. (2011). Moreover, Nikitenko et al (2011, p. 969) neglected indirectly the stratigraphical value of the ammonites described by Rogov and Wierzbowski (2009): because “the specimens illustrated are crushed and deformed”, and this “precludes objective reconstructions of the whorl cross-section, which is one of the characteristics used in distinguishing *Amoeboceras* subgenera and species”; as well as “an objective species assignment of ammonoids is possible for specimens with the terminal body chamber”. The only comments which can be given in that matter are as follows: the phylogeny of the genus *Amoeboceras* is not so poorly recognized as suggested by Nikitenko et al. (2011), and several papers have been devoted to this topic. General comments on

the phylogeny of the genus are given below in the chapter on paleontology. The specimens of the genus *Amoeboceras*, although flattened and not complete, are taxonomically identifiable. This is well proved by the studies of similarly or even more poorly preserved specimens coming from the many clay successions in other Boreal sections. For example, ammonites from the Flodigarry section of the Isle of Skye, Scotland, which have been used for the definition of the primary standard for the Oxfordian/Kimmeridgian boundary and the only candidate for its GSSP (Matyja et al., 2006; Wierzbowski, 2010) as well as for the establishment of the Boreal standard zonation of the Middle and Upper Oxfordian by Sykes and Callomon (1979), have a similar mode of preservation. The cross-section of whorls is not such an important feature in the recognition of *Amoeboceras* subgenera and species as suggested by Nikitenko et al. (2011)—in fact, for example three very close forms of the subgenus *Plasmatites*, possibly even representing the same “biological species” according to the horizontal classification, show quite different whorl sections (see Matyja and Wierzbowski, 1988). It should be remembered also that the stratigraphical interpretation of the Nordvik section as accepted by Nikitenko et al. (2011, fig. 2) appears to be based in fact on a few specimens from older collections plus additionally single newly determined specimen.

An additional reservation is given by Nikitenko et al. (2011, p. 969) in their taxonomical interpretation of the ammonite species to the specimen referred to as *Amoeboceras* cf. *serratum* by Rogov and Wierzbowski (2009, plate 1, fig. 8). The species *A. serratum* according to Nikitenko et al. (2011, p. 969) is “marked by smoothed early whorls ($D = 30$ mm)“ which has not been stated in the specimen studied, and “this casts doubt on its species assignment and the corresponding zonal stratigraphic unit”. It should be remembered, however, that the species *A. serratum* shows a short smooth stage which never attains 30 mm diameter when compared with *A. koldeweyense* where such long smooth stage, including the inner and locally middle, whorls does occur (Sykes and Callomon, 1979, pp. 876–880). Nevertheless, the specimen studied from the Nordvik section and referred to as *A. cf. serratum* shows smooth inner whorls up to about 5 mm, whereas that referred to as *A. cf. koldeweyense* from the same section shows this stage up to about 10 mm diameter (cf. Rogov and Wierzbowski, 2009, plate 1, figs. 6 and 8). The smooth stage on the inner whorls is very short (if really occurs) in specimens referred to as *Amoeboceras serratum* (Sowerby) by Mesezhnikov et al. (1989, plate 17, figs. 2–3; plate 18, fig. 6) from the faunistically well documented Serratum Zone of the Upper Oxfordian at the Adzhva River section in the Petchora River Basin. Thus, the objections of Nikitenko et al. (2011) related to *A. cf. serratum* identification by Rogov and Wierzbowski (2009) seem unjustified.

Lower and lowermost Upper Kimmeridgian

The *Amoeboceras* zonation of the Boreal Kimmeridgian is based mostly on the studies of Mesezhnikov (1968, 1984), Birkelund and Callomon (1985), Wierzbowski and Smelror

(1993), and Matyja et al. (2006). The lower zone of the Lower Kimmeridgian, the Bauhini Zone, is defined by the stratigraphical range of a special small-sized group of species referred to the subgenus *Plasmatites* (Matyja et al., 2006); see also Wierzbowski and Smelror (1993)—where, however, the base of the Bauhini Zone was placed somewhat higher as the zone was restricted that time to the stratigraphical range of *A. bauhini*. The higher zone is the Kitchini Zone defined by the stratigraphical range of ammonites of the subgenus *Amoebites* (see Mesezhnikov, 1968; Wierzbowski and Smelror, 1993). It is subdivided into three subzones (Wierzbowski et al., 2002; Matyja et al., 2006). The lowermost is the Bayi Subzone, distinguished herein for the first time and treated previously as a biohorizon at the base of the Subkitchini Subzone. It is characterized by the incoming of the first small sized *Amoebites* grouped around *Amoeboceras* (*Amoebites*) *bayi* Birkelund and Callomon, as well as *A. (A.) cricki* (Salfeld) and corresponds to the full range of *A. bayi*. The middle Subkitchini Subzone is characterized by the occurrence of closely allied forms/species grouped around *A. subkitchini* Spath (cf. Birkelund and Callomon, 1985, pp. 19–23), whereas the Modestum Subzone above is characterized by the occurrence of *A. modestum*, *A. kitchini* and their allies (cf. Wierzbowski and Smelror, 1993). The top of the Kitchini Zone is marked by the appearance of the subgenus *Euprionoceras* (Mesezhnikov, 1984; Wierzbowski and Smelror, 1993) which marks the Sokolovi = Kochi Zone—the next zone of the Boreal Kimmeridgian.

The occurrence of the Bauhini Zone in North Siberia was recognized for the first time in the Nordvik section—in the middle part of bed 6 of the unit 3 which yielded two specimens of the subgenus *Plasmatites*—*A. (P.) cf. praebauhini* and *A. (P.) lineatum* (Rogov and Wierzbowski, 2009, fig. 2; plate 2, figs. 3–4; see also Fig. 2 herein). This finding is remarkable because it indicates the wide distribution of the subgenus in the Arctic—known before from the Barents Sea, the Norwegian Sea and Svalbard (e.g., Erschova, 1983; Århus et al., 1989; Wierzbowski and Smelror, 1993; Wierzbowski et al., 2002), and thus shows its large correlation potential. The zone has not been recognized so far in other areas of northern Siberia—but this may be explained by stratigraphical gaps and/or lack of the ammonite fauna in the corresponding intervals. In the Chernokhrebetnaya River section the cross-bedded sandstones of bed 14, possibly representing this interval, are mostly barren except for their lowermost part which yielded *A. ex gr. rosenkrantzi* indicating the uppermost Upper Oxfordian (Aleynikov and Meledina, 1993, fig. 3); one badly preserved ammonite resembling *Amoeboceras* (*Plasmatites*) was found in Mesezhnikov's collection from Chernokhrebetnaya, but its position in the section is unknown. In the Levaya Boyarka sections, the record of *A. schulginae* in bed 1 suggests the occurrence of the lower part of the Bauhini Zone (see above). It should be also remembered that a single specimen referred to as *Amoeboceras cf. bauhini* (Oppel) was reported, but not illustrated, from glacial drift deposits at the Bolshaya Romanikha River in the Kheta River Basin (Safonov, 1959).

The Kitchini Zone is well established in the Nordvik section, in the upper part of bed 6 of unit 3 where ammonites indicative of the upper part of the Bauhini Zone/lowermost part of the Kitchini Zone—the Bayi Subzone (*A. bayi* Birkelund and Callomon or *A. bauhini* (Oppel); Rogov and Wierzbowski, 2009, plate 2, fig. 5), and the Subkitchini Subzone above (*A. (Amoebites) subkitchini* Spath; Rogov and Wierzbowski, 2009, plate 2, figs. 6–7) were recognized. A single specimen referred to as *A. (Amoebites) ex gr. cf. modestum* Mesezhnikov and Romm was found also in the Subkitchini Subzone. A higher assemblage of ammonites composed of *A. (Amoebites) kitchini* (Salfeld) (Rogov and Wierzbowski, 2009, plate 2, fig. 8), together with forms referred to as *A. (A.) modestum*, and directly above the last specimen of *A. subkitchini*, was found in a lower part of bed 7, from about 0.9 m to about 1.2 m above its base, and it was interpreted as belonging to the Modestum Subzone of the Kitchini Zone. The stratigraphical interval below, ranging down to the first occurrence of *A. ex gr. cf. modestum* in the section studied was marked as an interval of uncertain correlation corresponding to the Subkitchini Subzone and/or the Modestum Subzone (Rogov and Wierzbowski, 2009, fig. 2; see also Figs. 2–3 herein). Thus, the statement of Nikitenko et al. (2011) on the difficulties in the recognition of the Subkitchini Subzone and the Modestum Subzone as defined by Rogov and Wierzbowski (2009) because “their taxonomic composition is identical”, seems unsubstantiated.

The Nordvik Peninsula section has yielded also a few Kimmeridgian ammonites illustrated and described by Voronets (1962). The lowest one referred to as “*Amoeboceras* (*Amoebites*) *ex gr. kitchini* Salfeld” (Voronets, 1962, plate XXIX, fig. 1) is closely comparable with *A. (A.) subkitchini* Spath (cf. Rogov and Wierzbowski, 2009) and this indicates the Subkitchini Subzone. The specimen comes from bed 6—unit 3 of the section of Basov et al. (1970)—most probably from the uppermost part of the unit—which yielded the similar specimens described by Rogov and Wierzbowski (2009, plate 2, figs. 6–7). Another specimen of Voronets (1962, plate XXIX, fig. 3) originally referred to as “*Amoeboceras* (*Euprionoceras* ?) *cf. aldingeri* Spath” seems close to *Amoeboceras* (*Euprionoceras*) *sokolovi* (Bodylevsky)—*kochi* Spath which suggests the presence of the Sokolovi = Kochi Zone (Rogov and Wierzbowski, 2009—see also Fig. 3 herein; cf. Wierzbowski and Smelror, 1993). On the other hand, as indicated by Voronets (1962, fig. 3), all the Kimmeridgian cardioceratids were found below the base of the bed 7, i.e., they are not younger than the Subkitchini Subzone, which casts some doubts on the stratigraphical position of the specimen in question. Unfortunately, the specimen under consideration is not preserved in the Voronets's collection which makes its closer study impossible. As suggested by one of us (M.R.), this record even could be an Upper Oxfordian *Amoeboceras*, as this ammonite bears very weak ribbing in the body chamber. Above the records of *A. (Amoebites) kitchini*, a still younger assemblage of ammonites composed of *A. (Hoplocardioceras) elegans* Spath occurs (Rogov and Wierzbowski, 2009, figs. 2–3; see also Fig. 3 herein)—it is indicative of the

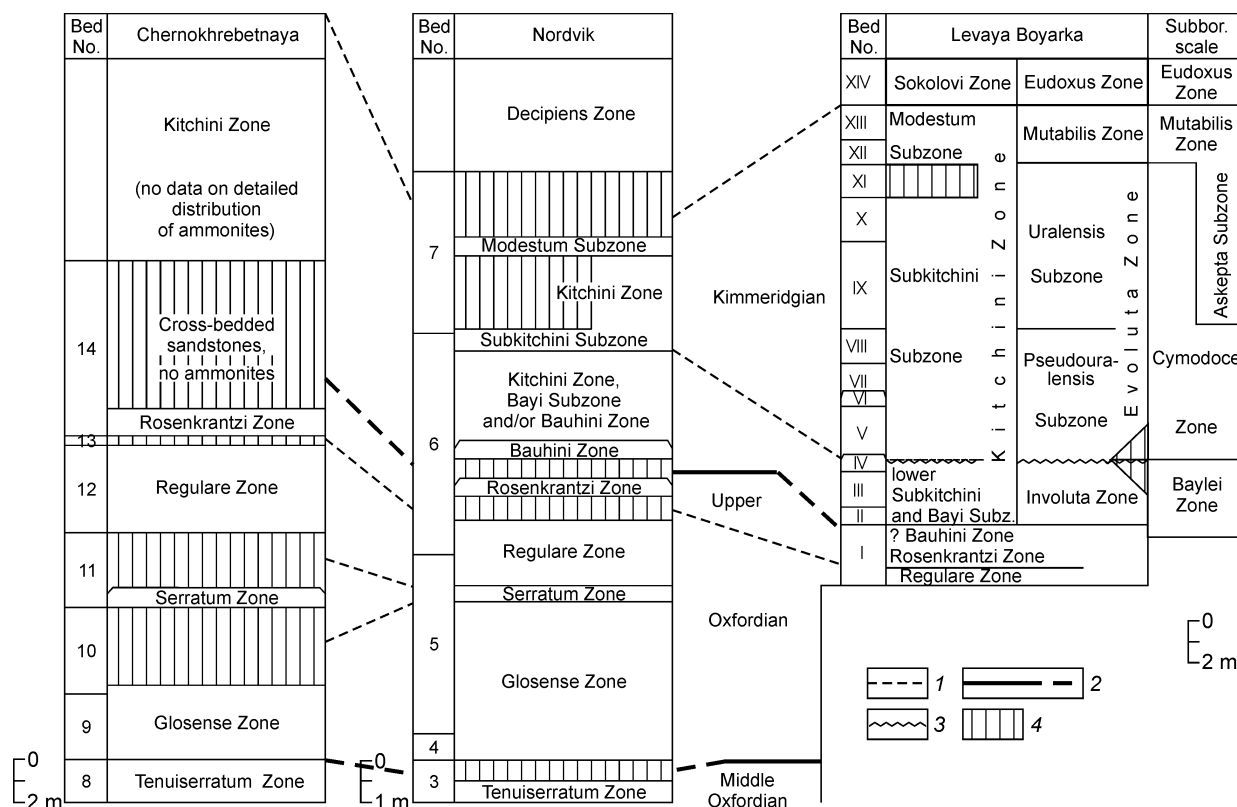


Fig. 3. Stratigraphical interpretation of the sections from northern Central Siberia discussed: the Chernokhrebetnaya River (interpretation and number of beds after Aleynikov and Meledina, 1993) supplemented with Kimmeridgian ammonite data (after Kaplan et al., 1974); the Nordvik section after Rogov and Wierzbowski (2009) supplemented with some ammonite data after Voronets (1962; revised, herein); the Levaya Boyarka sections (number of beds after Mesezhnikov, 1967, 1984; and Saks et al., 1969a,b; stratigraphical interpretation partly modified); the interpretation shows the chronostratigraphical interval from the uppermost Middle Oxfordian to the Kimmeridgian and it is based both on cardioceratid ammonites (Boreal subdivision) and aulacostephanids (Subboreal subdivision): 1, approximate correlation of the chronozones; 2, approximate correlation of the stage and substage boundaries; 3, suggested marked stratigraphical discontinuities in the sections; 4, intervals of the sections of unclear zonal/subzonal affiliations.

Elegans Zone (Spath, 1935) (= Decipiens Zone of Shulgina, 1960)—the youngest *Amoeboceras* zone of the Kimmeridgian in the Arctic.

The Chernokhrebetnaya River section in eastern Taimyr offers a thick succession of Kimmeridgian deposits, whose lower part, about 30–40 m in thickness, yielded Lower Kimmeridgian ammonites (Kaplan et al., 1974; Meledina and Kaplan, 1976; Mesezhnikov, 1984; Fig. 3 herein). These include representatives of *Amoeboceras* (*Amoebites*) corresponding to the *A. subkitchini* (Plate 1, Fig. 4) as treated by Birkelund and Callomon (1985, p. 22), who considered a number of forms described from northern regions of Russia such as *A. spathi*, *A. kitchini*, *A. pulchrum*, *A. altericarinatum* as “very closely related, if not identical with *A. subkitchini*”. Additionally, specimens of *Amoeboceras* (*Amoebites*) *mesezhnikovi* have been recognized recently in Mesezhnikov’s collection coming from the Chernokhrebetnaya River section (Plate 1, Figs. 1–2).

Markedly different Kimmeridgian ammonite faunas come from the Levaya Boyarka sections of the Kheta River Basin. The succession here has been divided into beds I to XIV (Mesezhnikov, 1969a, 1984; Saks et al., 1969a,b)—see Fig. 3. Ammonite from here comprise both representatives of the family Cardioceratidae—the genus *Amoeboceras*, as well as

the members of the family Aulacostephanidae—genera *Pictonia*, *Rasenia* and others (Mesezhnikov, 1967, 1969a, 1984; Saks et al., 1969a,b). This makes possible the distinguishing here both the Boreal ammonite zones based on the succession of *Amoeboceras* faunas, and the Subboreal Zones based on the succession of aulacostephanids (Fig. 3).

The lowermost fauna is found in a lower part of bed II and it is composed of nonillustrated *Pictonia* sp. indet. (Mesezhnikov, 1967; Saks et al., 1969a,b; this form was not mentioned by Mesezhnikov, 1984), and a few representatives of the genus *Amoeboceras*—including two specimens referred to as “*Amoeboceras* (*Amoebites*) *spathi* Schulgina” (Mesezhnikov, 1984, plate III, figs. 3–4; and precisely located in the section by Mesezhnikov, 1967; and Saks et al., 1969b). However, these ammonites differ from the bulk of the specimens attributed by Shulgina (1960) and Mesezhnikov (1984) to *A. spathi* in their having a weak accentuation of the secondary ribs at the ventrolateral shoulders, and the continuation of the secondary ribs onto the keel; such a feature is shown also by one of the specimens of Shulgina (1960, plate 1, figs. 7a, b). These specimens, from lower part of bed II of Levaya Boyarka section and attaining about 40–45 mm in diameter, are possibly fully grown as shown by some uncoiling of the umbilical seam, and predominance of single ribs on the

last part of the outer whorl. These specimens differ also from typical representatives of *A. subkitchini* and its allies in the character of the ventral side, and show similarity to weakly ornamented, involute, early representatives of *Amoebites*—such as some specimens of *A. (A.) bayi* (see Birkelund and Callomon, 1985, plate 1, figs. 2, 7–8, 11–12; see also Wright, 1989, fig. 4A, B).

A higher ammonite fauna coming from the upper part of bed II consists of numerous specimens of *Pictonia (Mesezhnikovia) ronkinae* Mesezhnikov and *P. (M.) involuta* Mesezhnikov (see Mesezhnikov, 1969a, 1984; Saks et al., 1969b; also the chapter on paleontology herein), and rare, nonillustrated specimens referred to as “*Amoeboceras (Amoebites) ex gr. kitchini*” or “*A. (A.) pulchrum*”. A similar ammonite fauna comes from beds III and IV where specimens of both species of the genus *Pictonia* (Mesezhnikov, 1969a, plates I–IX) still dominate, but these were found along with representatives of *Amoeboceras (Amoebites)* (more common in bed IV) referred by Mesezhnikov to *A. spathi* and *Amoeboceras (Amoebites) ex gr. kitchini* or *A. (A.) pulchrum* (Saks et al. 1969b; Mesezhnikov, 1984). Because the bulk of the specimens in question of the genus *Amoeboceras* were neither illustrated nor described, any detailed discussion on their specific affiliation is not possible; the only suggestion is that they could represent some early forms of the subgenus *Amoebites*—possibly related to *A. bayi* or its direct descendants. Additionally, the three illustrated ammonites of the genus *Amoeboceras* were referred to a stratigraphical interval corresponding to beds II–IV of the Levaya Boyarka section. These include: (1) “*Amoeboceras (Amoebites) subkitchini* Spath” illustrated by Mesezhnikov (1984, plate I, fig. 5) which is really close to *A. subkitchini*, but also resemble some *A. bayi*; the specimen was said to come from bed III, however, both in the detailed description of the section and in the range-chart of the species (Mesezhnikov, 1984, p. 20, figs. 8 and 25) its occurrence in that stratigraphical interval is not indicated, which results in some doubts on the position of the specimen in the section; (2) *Amoeboceras (Amoebites) pingueforme* Mesezhnikov, illustrated by Mesezhnikov (1984, plate I, fig. 4) and coming from bed IV, which shows some similarity to the type of *A. pingueforme* from bed V, but differs in its extremely coarse ribbing; (3) the paratype of *Amoeboceras (Amoebites) simplex* Mesezhnikov et Romm (= *A. (A.) mesezhnikovi* Sykes et Surluk), illustrated by Mesezhnikov and Romm (1973, plate IV, figs. 3a, b) but without precise location in the section, only with the general statement that it comes from the Involuta Zone (beds II–IV); this specimen differs, however, from the holotype of the species in its more robust ornamentation with strong development of the mid-lateral tubercles, and a distinct separation of the primary ribs from short and strongly tuberculate secondary ribs. It bears a close resemblance to *Amoeboceras schulginae* Mesezhnikov, and the most likely interpretation is that it should be treated as belonging to that species. In Mesezhnikov’s collection we have found an additional specimen of *Amoeboceras (Amoebites)* from bed III (Plate 1, Fig. 7 herein), which we consider to be as *A. (A.) ex gr. subkitchini* Spath. It differs from *A. (A.) bayi* in its

longer primary ribs and more involute coiling. Similar *A. (A.) subkitchini* are known from fauna 15 of Milne Land, representing the lowest occurrence of the species recognized in this area and correlated with the lowest Cymodoce Zone (Birkelund and Callomon, 1985).

The stratigraphical position of beds II–IV from the Levaya Boyarka sections was discussed by Mesezhnikov (1968, 1984; see also Saks et al., 1969a) who recognized this stratigraphical interval as corresponding to his Involuta Zone. Its index species *Pictonia involuta* Mesezhnikov occurs from the upper part of bed II up to the top of bed IV, whereas the lower part of the zone yielded only poorly known *Pictonia* sp. indet. On the other hand, the stratigraphical interval possibly already from the upper part of bed I, and surely covering beds II to IV, is characterized by Boreal faunas of Kimmeridgian *Amoeboceras*: that from upper part of bed I may correspond to the Bauhini Zone—the only argument is, however, the alleged occurrence of *A. schulginae* (in fact mentioned together with uppermost Oxfordian ammonites without precise location in the bed—see Mesezhnikov, 1967). The occurrence of ammonites close to *A. schulginae* in the Involuta Zone, i.e., from beds II–IV, and the occurrence of *A. bayi* already in a lower part of bed II, and following a poorly recognized assemblage representing some early forms of the subgenus *Amoebites*—possibly related to *A. bayi* or its direct descendants, suggests the presence of a lower part of the Kitchini Zone—possibly the Bayi Subzone and, if the interpretation of *A. subkitchini* in this part of section is correct, also to the lowermost part of the Subkitchini Subzone (Fig. 3 herein).

Younger ammonite faunas occur in beds V to XI of the Levaya Boyarka sections. They are composed of different representatives of the family Aulacostephanidae—*Rasenia* and, occurring above, *Zonovia/Zenostephanus*, as well as of the family Cardioceratidae—*Amoeboceras (Amoebites)*.

The base of bed V shows a marked change in the aulacostephanid ammonites. Ammonites of the genus *Pictonia*, so abundant in lower beds, completely disappear and are replaced by a quite new fauna with ammonites of the genus *Rasenia*. It should be remembered that many sections in the Subboreal/Boreal provinces show the “intermediate” intervals characterized by the occurrence of early *Rasenia* (such as *R. inconstans*), showing sometimes in one horizon a continuous variation in the spectrum of forms ranging from those with nonbullate ribs typical of *Pictonia* and those with bullate ribs of the *Rasenia* type; such an interval, recognized in central East Greenland and other NW European sections (Birkelund and Callomon, 1985), is correlated with the lowermost part of the beds with *Rasenia*—the Cymodoce Zone. The absence of such interval in the sections of the Levaya Boyarka River studied suggests according to one of the authors (AW) a stratigraphical gap at the boundary of the beds with *Pictonia* (Involuta Zone) and beds with *Rasenia* (Evoluta Zone), i.e., at the boundary of bed IV and V (Fig. 3). On the other hand (opinion of M.R.), the presence of a continuous succession of cardioceratids may suggest that the biostratigraphical gap in fact does not exist, and that the absence of earliest *Rasenia* has resulted from paleoenvironmental and/or paleobio-

geographical reasons. According to that interpretation, the cardioceratid ammonites from beds III–IV of the Levaya Boyarka section could belong to a younger species than *A. bayi*, and consequently the beds in question should correspond to a lower part of the Subkitchini Subzone which correlates with the lowermost part of the Cymodoce Zone, well above the *A. bayi* range. Such correlation is supported additionally by the co-occurrence of early *Rasenia* and *Amoeboceras (Amoebites) bayi* as reported recently on the Russian Platform (Glowniak et al., 2010).

The most common representatives of *Amoeboceras* include such forms as “*A. (A.) spathi* Schulgina” from bed V and bed VII (Mesezhnikov, 1984, plate II, fig. 5; plate III, fig. 1); “*A. (A.) pulchrum* Mesezhnikov and Romm” (Mesezhnikov, 1984, plate I, fig. 3) from bed VII; as well as “*A. (A.) subkitchini* Spath” (Mesezhnikov, 1984, plate II, fig. 4)—“*A. (A.) alticarinatum* Mesezhnikov and Romm” (Mesezhnikov, 1984, plate III, fig. 2)—“*A. (A.) pulchrum* Mesezhnikov and Romm” (Mesezhnikov, 1984, plate III, fig. 5) from bed X. All these forms are closely related to *Amoeboceras (Amoebites) subkitchini* Spath (see Birkelund and Callomon, 1985), and generally may be treated as indicative of the middle part of the Kitchini Zone—the Subkitchini Subzone (Fig. 3). Other representatives of the genus *Amoeboceras* include *Amoeboceras (Amoebites) pingueforme* Mesezhnikov (Mesezhnikov, 1969a, plate XXI, fig. 5) and the holotype of *A. (A.) mesezhnikovi* Sykes et Surlyk (see Mesezhnikov and Romm, 1973, plate IV, fig. 4)—both coming from bed V (Saks et al., 1969b; Mesezhnikov, 1984). These two ammonite species were described by Wierzbowski (1989, plate 16, figs. 4, 5; plate 17, figs. 1, 2) from Sassenfjorden in Spitsbergen—from the stratigraphical interval directly above the oldest ammonite fauna with *Amoeboceras (Amoebites) subkitchini* Spath, and directly below and together with an ammonite fauna with *Rasenia cymodoce* (d’Orbigny); this observation was confirmed recently by Rogov (2010a) in other successions of Spitsbergen. This suggests that *A. pingueforme* and *A. mesezhnikovi* could be treated as indicative of the lower (but not the lowest) part of the Subboreal Cymodoce Zone, and the corresponding Subkitchini Subzone of the Kitchini Zone. Their occurrence in bed V of the Levaya Boyarka sections seems to be in accordance with the presumed stratigraphical gap at the boundary between beds IV and V, as postulated above, which possibly encompasses some lower parts the Subkitchini Subzone.

Beds XII–XIII of the Levaya Boyarka sections have yielded representatives of *Aulacostephanoides mutabilis*—*A. cf. mutabilis* (Sowerby) indicative of the Mutabilis Zone *sensu stricto* of the lowermost Upper Kimmeridgian (Mesezhnikov, 1969a, plate XXI, fig. 1; Mesezhnikov, 1984). Only one cardioceratid ammonite—“*A. (A.) kitchini* (Salfeld)” (Mesezhnikov, 1984, plate III, fig. 6) from bed XII was figured. This ammonite resembles *A. (A.) modestum* Mesezhnikov et Romm, but differs from this species in the presence of distinct lateral tubercles at the rib furcation point. An additional illustrated specimen of *Amoeboceras* referred to as “*Amoeboceras (Amoebites) elegans* Spath” by Mesezhnikov (1984, pp. 94–95,

plate V, fig. 4) comes from bed XIII. The specimen in question is small, attaining about 25 mm, but nevertheless it differs from *A. elegans* Spath which already at this diameter shows the presence of short ventrolateral clavi (cf. Birkelund and Callomon, 1985, plate 5, figs. 1–7; plate 6, figs. 1–8). It seems that the specimen is close to late representatives of *Amoeboceras (Amoebites)* such as *A. (A.) modestum* Mesezhnikov and Romm (1973, plate III, figs. 1–3) or “*Amoeboceras (Amoebites) cf. A. (A.) beugrandi* (Sauvage)” of Birkelund and Callomon (1985, plate 4, figs. 6–8). Similar forms from the Barents Sea area were compared with *A. (A.) modestum* by Wierzbowski and Smelror (1993, plate 2, figs. 1, 2). All these forms show the common presence of biplicate ribs on the inner whorls, as well as often on the outer whorl, whereas the ventrolateral nodes are weakly developed. When occurring along with the small, heavy-ribbed group of specimens with ventrolateral nodes and clavi of the *Amoeboceras (Amoebites) kitchini* (Salfeld) type,—all these forms may be treated as indicative of the upper part of the Kitchini Zone—the Modestum Subzone (Wierzbowski and Smelror, 1993; Wierzbowski et al., 2002). Thus, it may be suggested that beds XII and XIII of the Levaya Boyarka sections correspond to the Modestum Subzone (Fig. 3). It should be remembered, however, that “biplicate forms” including *A. modestum* appear already in the Subkitchini Subzone representing the middle part of the Kitchini Zone, where they occur, however, along with typical representatives of the *Amoeboceras (Amoebites) subkitchini* group.

A younger *Amoeboceras* fauna was discovered in bed XIV of the Levaya Boyarka sections (Mesezhnikov, 1969a, plate XI, figs. 1–2; Mesezhnikov, 1984, plate V, fig. 1) together with *Aulacostephanus* ammonites indicative of the Eudoxus Zone of the Upper Kimmeridgian. These ammonites have been referred to as *Amoeboceras (Euprionoceras) sokolovi* (Bodylevsky)—*kochi* Spath by Mesezhnikov (1969a, 1984) and although fragmentarily preserved they seem to indicate the presence of the Sokolovi = Kochi Zone (Fig. 3). A possible close relation between *A. kochi* and *A. sokolovi* was first pointed out by Birkelund and Callomon (1985, pp. 26–27). Additional records of *A. (Euprionoceras) sokolovi* from its type region (Spitsbergen) by Wierzbowski (1989) and Rogov (2010a), after Callomon and Birkelund (1985), clearly show that this species has the same range and is close in all aspects of ribbing, size and shell outline to *A. kochi*. Thus, the name *A. (Euprionoceras) sokolovi* should be considered as a senior synonym of *A. (Euprionoceras) kochi*, and the Sokolovi Zone becomes the valid name for the former Kochi Zone.

Stratigraphical correlations and conclusions

The standard Middle and Upper Oxfordian ammonite zones of the Boreal zonal scheme used in NW Europe and the European Arctic (Sykes and Callomon, 1979) are well recognizable in the Barents shelf and northern Central Siberia (e.g., Aleynikov and Meledina, 1993; Wierzbowski and Smelror,

1993; Rogov and Wierzbowski, 2009; and earlier papers cited therein). The Lower and lowermost Upper Kimmeridgian Boreal zonation as proposed by Wierzbowski and Smelror (1993) on the base of the detailed ammonite succession from central East Greenland described by Birkelund and Callomon (1985; see also Callomon and Birkelund, 1980), and cores from the Barents shelf and Norwegian shelf (Wierzbowski and Århus, 1990; Wierzbowski et al., 2002), seems to be also readily correlated with the ammonite succession of *Amoeboceras* faunas from northern Central Siberia (Rogov and Wierzbowski, 2009; and comments herein). Thus, the only problem for discussion is the correlation of the Lower and lowermost Upper Kimmeridgian Boreal zones based on cardioceratids with those based on aulacostephanids, which is followed herein by comments on the differences between the aulacostephanid zonation of NW Europe and that of northern Siberia (see Fig. 3).

The standard NW European zonation of the Lower Kimmeridgian (Birkelund et al., 1983; Birkelund and Callomon, 1985; Matyja et al., 2006) includes the following ammonite zones and subzones (from the bottom): the Baylei Zone with the Densicostata Subzone below, and the Normandiana Subzone above, as well as the Cymodoce Zone with four informal ammonite horizons: *inconstans*, *cymodoce*, *involuta*, and *evoluta*. The lowest northern Siberian zone of the Kimmeridgian was characterized by the stratigraphical range of *Pictonia* ammonites by Mesezhnikov (1968, 1969a, 1984) and defined as the Involuta Zone. The most characteristic elements of this zone are ammonites of the *Pictonia involuta* group showing some number of features which distinguished them from other ammonites of the genus *Pictonia* from NW Europe and European Arctic (Mesezhnikov, 1969a). This group is defined herein as the new subgenus *Mesezhnikovia* Wierzbowski et Rogov (see chapter on paleontology). The Involuta Zone in its type section, recognized by Mesezhnikov (1968; see also Saks et al., 1969a) at the Levaya Boyarka River includes, however, not only the deposits in which ammonites of the *Pictonia involuta* group occur, but also some deposits below (lowermost part of the bed II) with a poorly defined assemblage of *Pictonia* sp. indet. The interval of the section covering the stratigraphical range of *Pictonia* corresponds to a lower part of the Boreal Kitchini Zone—possibly the Bayi Subzone and, perhaps, also to the lowermost part of the Subkitchini Subzone. If these assumptions are correct, the Siberian Involuta Zone, in its type section, should correspond at least to the Baylei Zone of NW Europe except in its lowermost part (Fig. 3; see also Mesezhnikov, 1984; cf. Matyja et al., 2006). The stratigraphical interval characterized by the occurrence of ammonites of the *Pictonia involuta* group (beds II, except its lowermost part—bed IV) could correspond approximately to the NW European Normandiana Subzone of the Baylei Zone, but may be also to a lowermost part of the Cymodoce Zone as interpreted by one of the authors (M.R.).

On the other hand, in the Subpolar Ural (Lopsiya River section), the Involuta Zone is characterized by *Pictonia involuta* Mesezhnikov (Mesezhnikov, 1969a) as well as *Pic-*

tonia of the *densicostata* group—“*Pictonia* aff. *gracilis* Tornquist” (Mesezhnikov, 1984, p. 96, plate 7, fig. 2). The latter species shows a similarity to the densely ribbed *Pictonia densicostata* Buckman, from the lower part of the Baylei Zone in NW Europe—the Densicostata Subzone. It should be remembered, however, that Mesezhnikov (1984, pp. 11–12, figs. 4, 5) found ammonites of the genus *Ringsteadia* as well as *Rasenia incostans* Spath and *Prorasenia* in stratigraphically condensed deposits of the lowermost Kimmeridgian together with the ammonites of the genus *Pictonia* discussed here in the Lopsiya River section of the Subpolar Ural. The section was recognized as an auxiliary section of the Involuta Zone (Mesezhnikov, 1968), and along with other sections of the Subpolar Urals became the basis for subdivision of the Zone (Mesezhnikov, 1984, p. 57) into a lower part characterized by *Pictonia* and *Amoebites*, and an upper part characterized by the occurrence of *Pictonia*, *Prorasenia* and *Amoebites* together with the first representatives of the genus *Rasenia* (including *R. inconstans*). This subdivision of the Involuta Zone remains tentative, because the proposed lower and upper members of this zone were recognized in different sections. Such an interpretation of the Involuta Zone results in the correlation of the upper part of the Zone with a lower part of the Cymodoce Zone. This was indicated already by Mesezhnikov (1984), who correlated the upper part of the Involuta Zone with the fauna 15 in East Greenland, commonly placed in the lowermost part of the Cymodoce Zone (Birkelund and Callomon, 1985, fig. 5; see also Wierzbowski, 1989, fig. 7). Should this definition of the Involuta Zone be accepted, however, the top of the zone would be drawn much higher than the NW European Baylei Zone, which is inconvenient for wider correlations. Beside some formal problems with the original definition of the Involuta Zone, there exists also the problem related to the generic affiliation of some of the ammonites from the Lopsiya section figured by Mesezhnikov (1984, plate XIII, fig. 1) as *Rasenia inconstans* which appear close to *Pictonia* in their type of ribbing.

The ammonites of the genus *Rasenia* in the Levaya Boyarka section in beds V to XI were treated as indicative of the Evoluta Zone (Mesezhnikov, 1984; earlier the Borealis Zone of Mesezhnikov, 1969a; Saks et al., 1969a). The Evoluta Zone was subdivided into a lower part—the Pseudouralensis Subzone (beds V to VIII), as well as an upper part—the Uralensis Subzone where representatives of the *Zonovia–Zenostephanus* group (Mesezhnikov, 1984) become especially common. The appearance of the first true *Zenostephanus* (formerly *Xenostephanus*, see Callomon et al., 2009, for details) was stated to occur in England “well above the Cymodoce Zone but still well down in the Mutabilis Zone”, and the fauna was said to be similar to that from northern Siberia (Birkelund et al., 1983, p. 296). Nearly at the same level, *Zenostephanus* appears in the Franz-Josef Land (Repin et al., 2007). It may be suggested that beds V–VIII from the Levaya Boyarka yielding the typical faunas of *Rasenia* and corresponding to the Pseudouralensis Subzone can be correlated with the NW European Cymodoce Zone *sensu stricto* (see also below), whereas some beds from this section, from

the base of the Uralensis Subzone, are in fact younger than the upper part of the Cymodoce Zone, and may correspond to a lower part of the Mutabilis Zone from NW Europe (cf. Birkelund and Callomon, 1985, fig. 5; see also Wierzbowski, 1989, fig. 7). It should be remembered that the latter interval (beds IX–XI) could correspond to the *askepta* horizon originally distinguished in the uppermost part of the Cymodoce Zone (Birkelund et al., 1978), but later (Birkelund et al., 1983) treated as the Askepta Subzone recognized as the basal subzone of the Mutabilis Zone *sensu lato* (Fig. 3).

The twofold definition of the lower boundary of the Subboreal Mutabilis Zone—either at the base of the Askepta Subzone (Birkelund et al., 1983), or at the base of the Mutabilis Subzone (Hantzpergue, 1989), results in the recognition of the Lower–Upper Kimmeridgian boundary at different levels depending on the Subboreal subdivision accepted. So far, the problem cannot be resolved unequivocally because correlation of the Submediterranean Acanthicum Zone with the Subboreal zonal schemes is still unclear (e.g., Matyja and Wierzbowski, 2000a). It should be remembered that the Acanthicum Zone is treated usually as the lowermost zone of the Upper Kimmeridgian in the Submediterranean zonal scheme. On the other hand, the problem of the correlation of the Lower and Upper Kimmeridgian boundary in the Subboreal zonal schemes with the Boreal scheme—although somewhat vague in detail, may be partly clarified by stratigraphical information in the Levaya Boyarka sections. If the Mutabilis Zone is drawn at the base of the Mutabilis Subzone (= base of Mutabilis Zone *sensu stricto*), the corresponding boundary in the Boreal scheme should be placed near the base of the Modestum Subzone of the Kitchini Zone. If it is drawn at the base of the Askepta Subzone (base of Mutabilis Zone *sensu lato*), the corresponding boundary should be placed somewhere in upper part of the Subkitchini Subzone of the Kitchini Zone.

Summarizing the facts, the sections from northern Central Siberia discussed here show marked differentiation of the coeval ammonite assemblages into: (1) ones composed entirely of ammonites of the family Cardioceratidae represented by the genus *Cardioceras* in the Middle Oxfordian, and the genus *Amoeboceras* in the Upper Oxfordian and Lower Kimmeridgian, and occurring in the Nordvik section and the Chernokhrebetnaya section, and (2) ones composed of ammonites of the family Aulacostephanidae (genera: *Pictonia*, *Rasenia*, *Zonovia/Zenostephanus* and *Aulacostephanoides*) and the Cardioceratidae (genus *Amoeboceras*)—well represented in the Kimmeridgian of the Levaya Boyarka sections. The former is the typical Boreal assemblage recognized also by Mesezhnikov (1969b) to as representative of the Taimyr–Canadian Province. The latter has a Subboreal character and was recognized by Mesezhnikov (1969b) as representative of his Greenland–Khatanga Province.

It should be remembered that the ammonites of the family Cardioceratidae were confined originally to the circum-polar Boreal Sea representing the Boreal Realm (Province) of more stable conditions. They expanded markedly southwards, however, especially during the Oxfordian, co-occurring with

ammonites of the Submediterranean and Subboreal provinces. On the other hand, the ammonites of the family Aulacostephanidae which appeared in the Late Oxfordian showed a generally more patchy distribution, being confined mostly to what was called the Subboreal Realm (Province) in Europe—the area of unstable environmental, often shallow-water conditions of the so-called “European Archipelago” (Fürsich and Sykes, 1977). The Subboreal Realm (Province) stretches in Siberia from the Subpolar Ural where at the Lopsiya River uppermost Oxfordian ammonites of the genus *Ringsteadia* followed by Lower Kimmeridgian *Pictonia* and *Rasenia* are known (Mesezhnikov, 1967, 1984), and further east into northern Siberia including the sections placed at the southern edge of the Khatanga Trough where ammonites of the family Aulacostephanidae occur commonly. Also these Siberian areas were possibly characterized by rather unstable environmental conditions during the Early Kimmeridgian as a result of the paleogeography and related sea current system (Zakharov et al., 2005).

A special role in the development of the environmental conditions promoting the occurrence of particular groups of ammonites was played by the appearance of new land areas and the related changes in sedimentation which influenced the successions at the turn of the Oxfordian and Kimmeridgian in Europe (e.g., Enay, 1980; see also Fürsich and Sykes, 1977). Related phenomena could be also recognized in the Siberian sections. They seem responsible for example for: a marked stratigraphical discontinuity and erosion at the Oxfordian/Kimmeridgian boundary in the Lopsiya River section in the Subboreal Ural (see Mesezhnikov, 1984, fig. 4); and the appearance of barren, cross-bedded sandstones sandwiched in between sandy siltstones with ammonites of the genus *Amoeboceras* (*Amoeboceras*) indicative of the Regulare and Rosenkrantzi zones of the Upper Oxfordian below, and siltstones and sands with *Amoeboceras* (*Amoebites*) indicative of the Kitchini Zone of the Lower Kimmeridgian above, in the Chernokhrebetnaya River section. All these observations suggest a close relation between the changes of the physical conditions and the development of ammonite faunas: these possibly resulted in the sudden appearance at the turn of the Oxfordian and Kimmeridgian of the representatives of the family Aulacostephanidae—of the genus *Pictonia*, which replaced an older assemblage consisting entirely of *Amoeboceras* (*Amoeboceras*) in the Levaya Boyarka sections (Mesezhnikov, 1967, 1969a, 1984). In the northern Siberia the Nordvik section only shows an undisturbed, continuous succession of deposits and of ammonites of the genus *Amoeboceras* from the Middle–Late Oxfordian to the Kimmeridgian—and thus it is a good candidate for a reference section for the Oxfordian/Kimmeridgian boundary in Siberia.

Evolutionary history of ammonites of the genus *Amoeboceras*

When considering the phylogeny of ammonites of the genus *Amoeboceras* some general comments in relation to their

taxonomy have to be made. Specific names are used in sense of “morphospecies” having vertical ranges as opposed to isochronous “horizontal” assemblages thought to represent the variable “biospecies members”, representing in fact the phyletic transients in an evolving lineage (see Callomon, 1985). This taxonomical approach results mostly from a stratigraphical approach because retention of the well known names of “morphospecies”, deeply entrenched in the literature and having well recognized vertical ranges, is undoubtedly useful in general consideration of the evolutionary history of the group. In addition, an important element of the ammonite taxonomy is the differentiation of final sizes and morphology of ammonite shells, commonly interpreted as dimorphism, resulting in the appearance of large macroconchs, and small microconchs. In fact, however, in relation to the genus *Amoeboceras*, the problem appears more complicated because in some stratigraphical intervals in addition to normally-sized macro and microconchs, there occur “small-sized microconchs”, and the relationship between them and normally-sized morphs is not always clear in detail. The “small-sized microconchs” represent sometimes extreme lateral counterparts of particular members of the main *Amoeboceras* lineage, especially well represented by invasional forms in the Submediterranean Realm (Province). Miniaturization of these ammonites was caused by their relatively slow growth rate, as shown by crowding of the septae in most of the last whorl of the phragmocone (Matyja and Wierzbowski, 2000b). This phenomenon resulted from the displacing of representatives of the genus into more peripheral areas having a specially stressed environmental conditions in relation to the “home areas” inhabited by *Amoeboceras* of the Boreal Realm.

The generic names as used herein are generally confined to successive members of the *Amoeboceras* lineage as discussed below, and the distinction of “morphosubgenera” as based on the dimorphic status of the shells (as e.g., *Amoeboceras* and *Prionodoceras* for Upper Oxfordian micro- and macroconchs) is avoided. The special feature of the main stock of the *Amoeboceras* lineage is the common occurrence at some stratigraphical levels of smaller forms (including “small microconchs”) which are preceded and followed by normally-sized macroconchs and microconchs (Fig. 4). Some of these small-sized forms show a prolonged stage of development of dense, poorly differentiated ribbing usually continuing onto the keel (sometimes replaced by weakly developed ribblets and even distinguished as a “smooth stage” of the shell). The development of such a stage of ornamentation has probably a paedomorphic character because it resembles the ornamentation of some *Cardioceras* ancestors like, e.g., *Plasmatoceras*. The diminution of the final size of ammonites in the lineage is often encountered in large areas of the Boreal Province, and marks particular stages in the evolutionary history of the genus making possible the distinction of successive *Amoeboceras* faunas in the succession. The appearance of such small-sized faunas precedes major evolutionary innovations in the *Amoeboceras* lineage except the latest “small-sized” fauna (*Nannocardioceras*) which appeared just before the total extinction of the cardioceratids. The diminution of shell size may be

interpreted as of a paedomorphic character, and at least some of these forms show the features of progenetic forms (cf. Matyja and Wierzbowski, 2000b), but some possibly also of neotenic forms. This suggests that the final size of the ammonite shell could be controlled by environmental factors which strongly favours the hypothesis of developmental polymorphism in ammonites proposed by Matyja (1986).

The youngest *Cardioceras* fauna composed of small-sized *Miticardioceras*—*Cawtoniceras* of the small-sized microconch type precedes the appearance of the first *Amoeboceras* fauna of the *A. glosense* group (Sykes and Callomon, 1979; Wright and Page, 2006) represented both by normally sized macro and microconchs: *A. ilovaiskii* (Sokolov), *A. alternoides* (Nikitin emend. Mesezhnikov et al., 1989), *A. transitorium* Spath, *A. newbridgense* Sykes and Callomon, *A. nunningtonense* Wright, *A. glosense* (Bigot and Brasil) and *A. damoni* Spath. The group has been distinguished originally as subgenus *Paramoeboceras* by Gerasimov (Mesezhnikov et al., 1989; this subgeneric name was used also earlier by Mesezhnikov et al., 1986, but without any diagnosis given) with type species *A. (Paramoeboceras) ilovaiskii* (Sokolov)—but the wider scope of this subgenus as proposed by Mesezhnikov et al. (1989) is difficult for to accept because it covers all the Upper Oxfordian larger-sized *Amoeboceras* like those of the *A. regulare* and *A. rosenkrantzi* groups which do not show the most characteristic feature of *Paramoeboceras*—the presence of secondaries strongly projected forward. On the other hand, the presence or not of a smooth outer whorl, and/or uncoiling of the umbilical seam on the outer whorl, cannot be treated as features important in taxonomy making distinction possible between *Paramoeboceras* and *Prionodoceras* (cf. Mesezhnikov et al., 1989) because these are the features of large, fully grown macroconchs. The ammonites of the subgenus *Paramoeboceras* are typical of the Glosense Zone of the lowermost Upper Oxfordian.

The next stage of evolutionary history was marked by appearance at a beginning of the Serratum Chron of small to medium-sized *Amoeboceras koldeweyense* Sykes and Callomon—which showed prolonged stage of “smooth” inner whorls (in fact covered by dense ribblets). The normal-sized macro- and microconchs of the *A. serratum* and *A. regulare* groups such as *A. serratum* (Sowerby), *A. regulare* Spath and *A. frebaldi* Spath were developed in the Serratum Chron and the Regulare Chron of the middle part of the Late Oxfordian (Sykes and Callomon, 1979). These forms evolved smoothly (Fig. 4) into representatives of the *A. rosenkrantzi* group, such as *A. rosenkrantzi* Spath, *A. leucum* Spath, *A. marstonense* Spath, *A. pectinatum* Mesezhnikov and *A. schulginae* Mesezhnikov. This part of the lineage was known in the Rosenkrantzi Chron of the latest Oxfordian, but the youngest forms, represented by large-sized macroconchs of *A. schulginae*, occur in the Bauhini Chron of the earliest Kimmeridgian (Matyja et al., 2006), while poorly known macroconchs close to *A. schulginae* are also known from the earliest Kitchini Chron (Bayi Subchron).

It should be remembered that the bulk of the stratigraphical interval in question shows the appearance of “small-sized

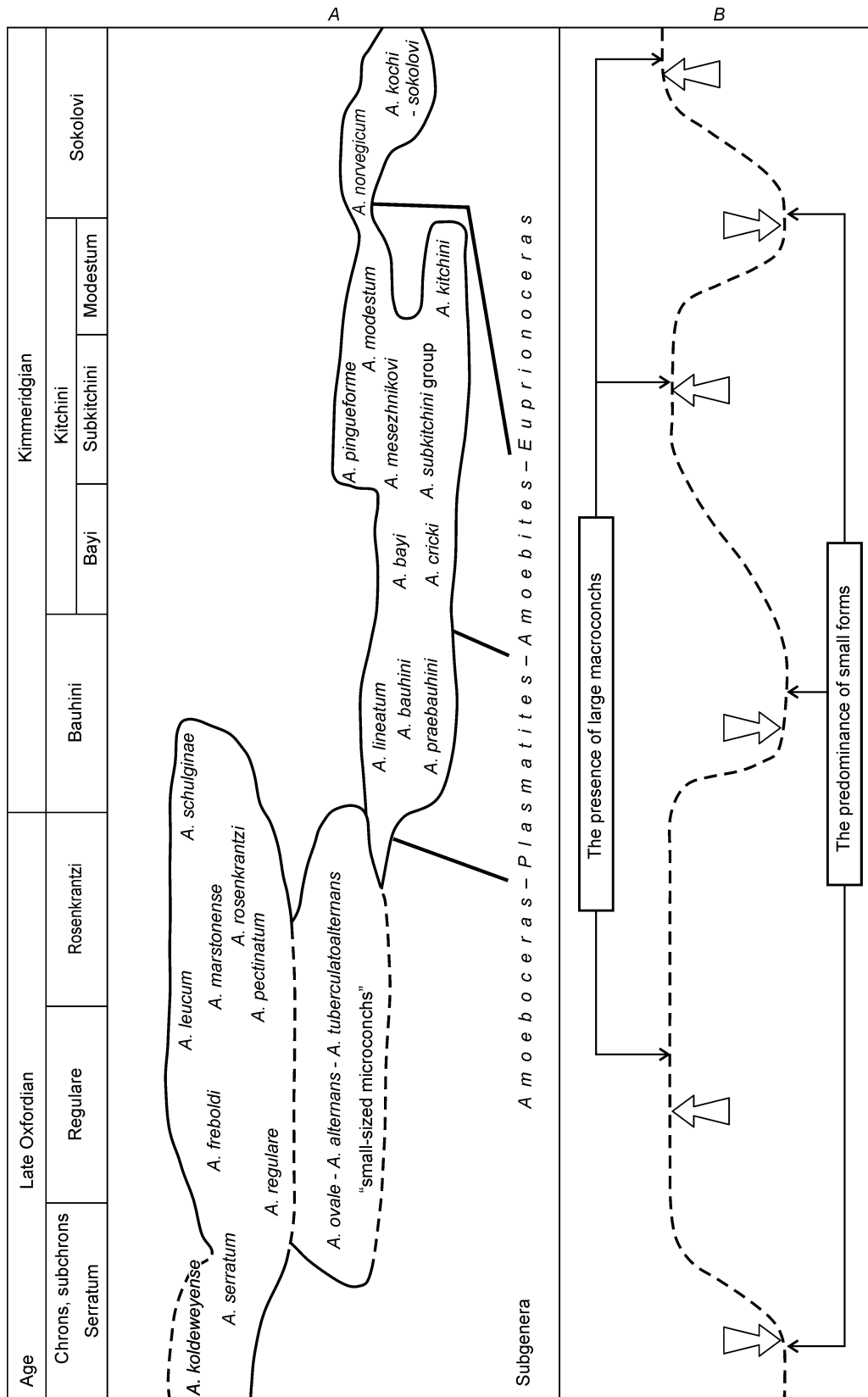


Fig. 4. Phylogeny of cardioceratid genus *Amoebocheras* from mid Late Oxfordian to mid Late Kimmeridgian: A. Relative position of the *Amoebocheras* species discussed here within the lineage; B. The relative changes of sizes of ammonite shells within the lineage (arrows indicate the maximal and minimal sizes); the names of subgenera are given in relation to the evolutionary history of the group.

microconchs” such as *Amoeboceras ovale* (Quenstedt)—*A. alternans* (von Buch)—*A. tuberculatoalternans* (Nikitin) already during the Serratum Chron. These appear later slightly changed, in the Regulare and the Rosenkrantzi Chrons in many Submediterranean areas like Central Poland, southern Germany and Switzerland (e.g., Klieber, 1981; Matyja and Wierzbowski, 1988, 1994; Atrops et al., 1993). It is worth noting that *A. ovale* has been described also by Mesezhnikov et al. (1989, plate 8, figs 2, 4–5, 7–11; plate 10, figs. 3–5, plate 26, figs. 9, 10) from the northern part of the Russian Platform in the Adzhva River section of the Petchora River Basin where it attains, however, a larger final size when compared with that from the Submediterranean Realm (Province). About 2/3 of total number of illustrated specimens from the Adzha River section are from 35–45 mm in diameter; on the other hand, the median-size of specimens of *A. ovale* in Submediterranean Realm (Province) is from about 20 mm in final diameter in southern Germany (Klieber, 1981), to about 35 mm in central Poland. This shows the general tendency in enlargement of shell-size of *A. ovale* from the southern part of the Submediterranean Realm (Province) to the Boreal Realm (Province) in the north (see also Matyja and Wierzbowski, 2000b, fig. 3).

The species *Amoeboceras alternans* (von Buch) was recognized as the type species of the nominative genus (and subgenus) of *Amoeboceras*, and this subgeneric name was often accepted for small-sized microconchs. Although there exists a considerable variability of corresponding micro- and macroconchs (originally grouped under the name *Prionodoceras*) in the Upper Oxfordian, all of them show features in common, such as “tabulate venter, and minutely serrated keel flanked by smooth bands or shallow sulci” (Arkell et al., 1957, p. L 306). Because the general affiliation of corresponding micro- and macroconchs to a single species does not present serious difficulties (e.g., Sykes and Callomon, 1979), the distinction between subgenera *Amoeboceras* and *Prionodoceras* seems unnecessary. All the corresponding forms can be thus easily accommodated in the nominative subgenus *Amoeboceras* (see also Matyja et al., 2006).

A marked turn-over in the *Amoeboceras* lineage took place at the beginning of the Bauhini Chron of the earliest Kimmeridgian. It was marked by the appearance of small-sized representatives of the subgenus *Plasmatites* represented by closely related forms such as *A. (P.) bauhini* (Opper), *A. (P.) praebauhini* (Salfeld) = ? *A. (P.) crenulatus* (Buckman), and *A. (P.) lineatum* (Quenstedt), sometimes with the addition of somewhat larger forms referred to as *Amoeboceras schulginiae*—*A. aff. schulginiae* (see Matyja et al., 2006; Wierzbowski and Smelror, 1993; Schweigert and Callomon, 1997; see also Callomon, 1985). These ammonites, although showing marked variability in ornamentation and whorl-section, represent, however, very closely related forms (Matyja and Wierzbowski, 1988), as often encountered in laterally differentiated assemblages of the genus *Amoeboceras* for which “intraspecific variability seems to be unusually large” (Sykes and Callomon, 1979, p. 858). The remarkable fact is, however, the similarity in ornamentation of *Plasmatites* to that of Early–Middle

Oxfordian *Plasmatoceras* as shown for example by the continuation of the secondary ribs onto the crenulated keel: this similarity was treated as of homoeomorphic type (Sykes and Callomon, 1979) but it could be interpreted as well as of pedomorphic character. These ammonites are known deep in the Boreal Realm (Province), but they range southwards into the Submediterranean Province—in a similar manner to earlier “small-sized microconchs” of the *A. ovale*—*A. alternans* group (e.g., Matyja and Wierzbowski, 1988; Atrops et al., 1993; Schweigert and Callomon, 1997; see also Matyja and Wierzbowski, 2000b).

The transition between the subgenera *Plasmatites* and *Amoebites* is marked by the development of strongly accentuated secondaries and the appearance of looped ribs on the outer whorl. The strong accentuation of the secondary ribs occurs already in late representatives of the subgenus *Amoeboceras* (e.g., in *A. rosenkrantzi*, see Sykes and Callomon, 1979, p. 888), where at larger diameters looped ribs may even appear (in *A. schulginiae*, see Mesezhnikov, 1967, p. 123). The next stage, marked by the development of a smooth spiral band separating long primary and short secondary ribs, appears in representatives of the subgenus *Plasmatites*—being especially well developed in *A. (P.) bauhini* (see Birkelund and Callomon, 1985, p. 12). The first small-sized *Amoebites* is, however, *A. (A.) bayi* Birkelund and Callomon which shows the presence of looped ribs on the outer whorl, and which is joined by transitional forms with older *Plasmatites* (Birkelund and Callomon, 1985; Matyja et al., 2006). The occurrence of *A. (A.) bayi* is indicative of the Bayi Subzone (as distinguished herein) of the Kitchini Zone.

There is then observed a fairly rapid increase in shell size in the lineage (Fig. 4). The ammonites are grouped around *A. (A.) subkitchini* Salfeld and include, according to Birkelund and Callomon (1985, pp. 19–23), a number of closely related forms like *A. aldingeri* Spath, *A. irregulare* Spath, *A. prorsum* Spath, *A. spathi* Shulgina, *A. pulchrum* Mesezhnikov and Romm, *A. alticarinatum* Mesezhnikov and Romm, but also many larger-sized specimens referred to as “*A. kitchini* Salfeld”. The ammonites are represented by macroconchs attaining considerable sizes (up to 80–90 mm in diameters) with strong ribbing and well developed ventrolateral clavi or nodes, and by smaller-sized microconchs. This assemblage is diagnostic of the Subkitchini Subzone representing the middle part of the Kitchini Zone. It should be remembered, however, that in the same stratigraphical interval there occur relatively small-sized forms showing similar strong ornamentation but with fairly common simple and biplicate ribs and weakly developed ventrolateral nodes on outer whorl—like *A. (A.) mesezhnikovii* Sykes and Surlyk, and *A. (A.) pingueforme* Mesezhnikov (see Mesezhnikov, 1969a, plate 21, fig. 5; Mesezhnikov and Romm, 1973, plate 4, fig. 4; see also Wierzbowski, 1989, plate 16, fig. 5; plate 17, figs. 1, 2; Plate 1, Figs. 1–2 herein). Here may also belong *A. (A.) modestum* Mesezhnikov and Romm (see Mesezhnikov and Romm, 1973, plate 3, figs. 1–3). It is an open question whether these forms represent a lateral offshoot of the main lineage or if they are only extreme lateral variants of the *A. subkitchini* group.

The upper part of the Kitchini Zone called the Modestum Subzone shows once more the diminution in shell-size of the *Amoeboceras* species. The characteristic species appears to be *A. (A.) kitchini* (Salfeld) whose lectotype, designated by Birkelund and Callomon (1985, fig. 6), is a fully grown small-sized specimen about 45 mm in diameter. As stated by Birkelund and Callomon (1985, p. 22): “...the principal differences between *A. subkitchini* and *A. kitchini* lie in a rather smaller size, smaller umbilical width, coarser ribbing, heavier and more strongly differentiated nodes and clavi and deeper ventral sulci in the latter. The relation between them appears to be phyletic, showing an evolutionary change from finely to coarsely ribbed, strongly tuberculate forms”. Similar small, heavily ribbed forms are commonly encountered in the upper part of the Kitchini Zone (e.g., Rogov and Wierzbowski, 2009, plate 2, fig. 8; Wierzbowski et al., 2002, figs. 3g, h). On the other hand, in the upper part of the Kitchini Zone there occur small, less strongly ornamented forms showing the common occurrence of biplicate ribs—these seem very close to *A. (A.) modestum* (see e.g., Wierzbowski and Smelror, 1993, plate 2, figs. 1, 2). A stratigraphical interval dominated by small-sized microconchs (“*A.cf./aff. beaugrandi*”) is the Modestum Subzone, well recognized through the different Boreal and Subboreal areas, such as England (Birkelund et al., 1983), East Greenland (Birkelund and Callomon, 1985) and the Russian Platform.

A new ammonite fauna of *Amoeboceras* is represented by small to medium-sized *A. (Euprionoceras) norvegicum* Wierzbowski showing the inner whorls covered with vestigial striations replaced by stronger and more distant single and biplicate ribs on the outer whorl (Wierzbowski and Smelror, 1993, plate 2, figs. 4, 5). The lineage (Fig. 4) continues up into larger-sized macroconchs and corresponding microconchs of typical representatives of the subgenus *Euprionoceras*—the species *A. (E.) sokolovi* (Bodylevsky)—*A. (E.) kochi* Spath. The occurrence of simple secondary ribbing with poorly developed tubercles is essential feature of the subgenus *Euprionoceras* when compared with earlier heavy-ribbed *Amoebites* (see Birkelund and Callomon, 1985). The occurrence of the subgenus *Euprionoceras* is indicative of the Sokolovi = Kochi Zone.

A still younger part of the lineage is represented by the appearance once more of heavily ornamented ammonites (macro and microconchs) referred to the subgenus *Hoplocardioceras*—these are the trituberculate *A. (H.) decipiens* and the very close but less strongly tuberculate *A. (H.) elegans* Spath. These are indicative of the Decipiens (= Elegans) Zone (Wierzbowski and Smelror, 1993). The ammonites of the subgenus *Hoplocardioceras* emerged gradually from forms similar to the older *Euprionoceras* with transitional forms resembling *Amoeboceras uralense* Mesezhnikov as interpreted by Birkenmajer and Wierzbowski (1991). It should be remembered, however, that these ammonites resemble *A. uralense*, but differ in their less regular ribbing. *A. uralense* remain poorly known species of unclear stratigraphical position, because only one immature specimen from a drill core at Tolya River in the Subpolar Ural was figured by Mesezhnikov

and Romm (1973), and later by Mesezhnikov (1984) from Lopsiya River. This species has not been considered here.

A special position in the *Amoeboceras* lineage is occupied by the miniature fauna of *Nannocardioceras*. It is treated sometimes as the youngest *Amoeboceras* fauna which marks the end of the lineage (Callomon, 1985), but it is practically unknown in the high-latitude Arctic, being widely distributed in more southerly located areas like Britain, Russian Platform and central and northern Poland. The fauna of *Nannocardioceras* occurs in the stratigraphical interval corresponding at least partly to that of the subgenus *Hoplocardioceras* (e.g., Gallois and Cox, 1976). This may suggest that the fauna represents in fact one of a kind of “small-sized microconchs” developed mainly at the more peripheral areas having a special environmental conditions in relation to the “home areas” of *Amoeboceras* in the Boreal Realm.

In the Subboreal areas (including the Pechora region) the last cardioceratids are known in the lowermost part of the Autissiodorensis Zone (*volgae* horizon of the Subborealis Subzone, Rogov, 2010b) but disappear below the Kimmeridgian/Volgian boundary. The uppermost Kimmeridgian in a high-latitude Arctic areas is either poorly exposed and/or poorly fossiliferous (East Greenland, Spitsbergen and Western Siberia), or mainly dominated by the Boreal oppeliid genus *Suboxydiscites* (Khatanga Trough and Taimyr) making possible the distinction of the Taimyrensis Zone. Mesezhnikov (1984, and earlier papers) recorded cardioceratids from the Taimyrensis Zone representing the uppermost zone of the Boreal Kimmeridgian, but these ammonites have neither been figured nor described. The precise ranges of cardioceratids through the Taimyrensis Zone are unknown, though as indicated by Mesezhnikov (1984, fig. 25a) in the Khatanga depression cardioceratids disappear before the top of the Kimmeridgian. Moreover, in all the cases when the Taimyrensis Zone is overlain by Volgian deposits, a significant gap is present at this boundary. The occurrence of *Suboxydiscites* in the uppermost subzone of the Subboreal Kimmeridgian (Fallax Subzone, see Rogov, 2010b) indicates that the upper boundary of the Taimyrensis Zone should be very close to the Kimmeridgian/Volgian boundary.

Systematic position of the Siberian ammonites of the genus *Pictonia*

Siberian ammonites of the genus *Pictonia* are especially well known in the Levaya Boyarka section (Mesezhnikov, 1967, 1969a, 1984). These ammonites are represented mostly by the species *Pictonia involuta* Mesezhnikov and *Pictonia ronkinae* Mesezhnikov. They constitute together a special group of *Pictonia* ammonites called the *Pictonia involuta* group which is characterized by fading of the ornamentation in the inner side of the outer whorls with retention of the ornamentation in the ventrolateral side (Mesezhnikov, 1969a). This feature, together with more involute coiling, differentiates Siberian representatives of the genus *Pictonia* from those of NW Europe (Wright, 2010). From the foregoing, and taking into account the well known paleogeographical differentia-

tion of the Aulacostephanidae, it seems necessary to separate the Siberian representatives of the genus on the subgeneric level from the main stream of *Pictonia* (*Pictonia*), with its type species *Pictonia* (*Pictonia*) *baylei* Salfeld, 1913.

Subgenus Mesezhnikovia Rogov and Wierzbowski, 2013

Type species: Pictonia (*Mesezhnikovia*) *involuta* Mesezhnikov, 1969; holotype: specimen illustrated by Mesezhnikov (1969a, plates 1, 2) from bed IV of the Levaya Boyarka section.

Derivation of the name: in honour of M.S. Mesezhnikov (1931–1989) an outstanding student of the Boreal Jurassic and Cretaceous ammonites.

Diagnosis: Macroconchs—on inner whorls moderately evolute, on outer whorls moderately evolute to involute, specimens attain about 150 to 180 mm in diameter, but even up to 120–130 mm represent phragmocones; only some largest of them about 160–180 mm in diameter show fragments of body chamber preserved. Whorls section oval, in some on outer whorl—oval tapering towards venter. Ribbing of inner whorls consists of single, biplicate and triplicate ribs of “perisphinctoidal” type with commonly occurring swollen ribs (flared ribs) bordering constrictions as commonly in *Pictonia*. Ribbing in inner side of whorls disappears already at 60–70 mm diameter, but ribbing in outer side of whorls continues up to 100–120 mm diameter; final part of last whorl becoming smooth. Microconchs are unknown.

Species composition: *Pictonia* (*Mesezhnikovia*) *involuta* Mesezhnikov, 1969; *Pictonia* (*Mesezhnikovia*) *ronkinae* Mesezhnikov, 1969 (Plate 1, Fig. 8a, b).

Stratigraphical range: Lowermost Kimmeridgian (the *Involuta* Zone).

Geographical range: North of Central Siberia, Subpolar Urals.

Remarks: Mesezhnikov (1969a, plate 10, fig. 1) described as *Pictonia involuta uralensis* a large specimen represented by a phragmocone, about 160 mm in diameter, with poorly visible inner whorls showing very sparsely placed ribs; according to Mesezhnikov (1969a) that specimen came from the Tolya River section of the Subpolar Ural (and by analogy the one not illustrated from the Lopsiya River section). It can be placed within intraspecific variability of *P. involuta*. It should be remembered, however, that the other specimen of *Pictonia* referred to as “*P. aff. gracilis* Tornquist” by Mesezhnikov (1984, plate 7, fig. 2) from the Lopsiya River section differs markedly from the representatives of *Pictonia* (*Mesezhnikovia*) described in retention of the primary ribs on the body chamber up to about 85 mm diameter, as well as in the generally thinner ribs and less common occurrence of constrictions. The specimen in question shows some similarity to densely ribbed early *Pictonia* of the *P. densicostata* group from NW Europe (cf. Matyja et al., 2006; Wright, 2010) but it differs in its more involute coiling.

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References

- Aleynikov, A.N., Meledina, S.V., 1993. Ammonite biostratigraphy of the Middle and Upper Oxfordian in East Taimyr, East Siberia. *Acta Geol. Pol.* 43 (3–4), 183–192.
- Århus, N., 1988. Palynostratigraphy of some Bathonian–Hauterivian sections in the Arctic, with emphasis on the Janusfjellet Formation type section, Spitsbergen. Unpublished IKU report no. 23.1252. 11/01/88.
- Århus, N., Birkelund, T., Smelror, M., 1989. Biostratigraphy of some Callovian and Oxfordian cores off Vega, Helgeland, Norway. *Norsk Geologisk Tidsskrift* 69, 39–56.
- Arkell, W.J., Kummel, B., Wright, C.W., 1957. Mesozoic Ammonoidea, in: Moore, R.C. (Ed.), *Treatise on Invertebrate Paleontology*, part L, Mollusca 4, Cephalopoda–Ammonoidea, L80–L490. Geological Society of America & University of Kansas Press, Boulder, Colorado and Lawrence, Kansas.
- Atrops, F., Gygi, R., Matyja, B.A., Wierzbowski, A., 1993. The *Amoeboceras* faunas in the Middle Oxfordian–lowermost Kimmeridgian, Submediterranean succession, and their correlation value. *Acta Geol. Pol.* 43 (3–4), 213–227.
- Basov, V.A., Zakharov, V.A., Ivanova, E.F., Saks, V.N., Shulgina, N.I., Yudovny, E.G., 1970. Zonal subdivision of Upper Jurassic and Lower Cretaceous deposits of the Urduk-Khaya Cape (Paksa Peninsula, Anabar Bay), in: *Scientific Reports of the Institute of Arctic Geology, Paleontology and Biostratigraphy* (Uchenye Zapiski NIIGA. Paleontologiya i Biostratografiya) [in Russian]. NIIGA, Leningrad, Issue 29, pp. 14–31.
- Birkelund, T., Callomon, J.H., 1985. The Kimmeridgian ammonite faunas of Milne Land, central East Greenland. *Grønlands Geologiske Undersøgelse* 153, 1–56.
- Birkelund, T., Thusu, B., Vigran, J., 1978. Jurassic–Cretaceous biostratigraphy of Norway, with comments on the British *Rasenia cymodoce* Zone. *Palaeontology* 21 (1), 31–63.
- Birkelund, T., Callomon, J.H., Clausen, C.K., Hansen, H.N., Salinas, I., 1983. The Lower Kimmeridgian Clay at Westbury, Wiltshire, England. *Proc. Geol. Assoc.* 94 (4), 289–309.

- Birkenmajer, K., Wierzbowski, A., 1991. New Kimmeridgian ammonite fauna from East Spitsbergen and its phyletic significance. *Polar Res.* 9 (2), 169–179.
- Brideaux, W.W., Fischer, M.J., 1976. Upper Jurassic–Lower Cretaceous dinoflagellate assemblages from Arctic Canada. *Geol. Surv. Canada Bull.* 259, 1–53.
- Callomon, J.H., 1984. A review of the biostratigraphy of the post-Lower Bajocian Jurassic ammonites of western and northern North America, in: Westermann, G.E.G. (Ed.), *Jurassic–Cretaceous biochronology and paleogeography of North America*, *Geol. Assoc. Canada Spec. Papers* 27, 143–174.
- Callomon, J.H., 1985. The evolution of the Jurassic ammonite family *Cardioceratidae*. *Special Papers in Palaeontology* 33, 49–90.
- Callomon, J.H., Birkelund, T., 1980. The Jurassic transgression and the mid-late Jurassic succession in Milne Land, central East Greenland. *Geol. Mag.* 117, 211–226.
- Callomon, J.H., Donovan, S.K., Van den Hoek Ostende, L.W., 2009. *Zenostephanus*, a new name for the genus *Xenostephanus* Arkell & Callomon, 1963 (Mollusca, Cephalopoda), preoccupied by *Xenostephanus* Simpson, Minoprio and Patterson, 1962 (Mammalia). *Palaeontology* 52, 671–672.
- Enay, R., 1980. Indices d'émersion et d'influences continentales dans l'Oxfordien supérieur–Kimmeridgien inférieur en France. *Interprétation paléogéographique et conséquences paléobiogéographiques*. *Bull. Soc. Geol. France* 22, 4, 581–590.
- Fürsich, F.T., Sykes, R.W., 1977. Palaeobiogeography of the European Boreal Realm during Oxfordian (Upper Jurassic) times: a quantitative approach. *Neues Jhb. Geol. Paläont. Abh.* 155 (2), 137–161.
- Gallois, R.W., Cox, B.M., 1976. The stratigraphy of the Lower Kimmeridge Clay of Eastern England. *Proc. Yorkshire Geol. Soc.* 41 (2), 13–26.
- Głowniak, E., Kiselev, D.N., Rogov, M., Wierzbowski, A., Wright, J.K., 2010. The Middle Oxfordian to lowermost Kimmeridgian ammonite succession at Mikhalenino (Kostroma District) of the Russian Platform, and its stratigraphical and paleobiogeographical importance. *Volumina Jurassica* 8, 5–48.
- Hantzpergue, P., 1989. Les ammonites kimmeridgiennes du haut-fond d'Europe occidentale: biochronologie, systématique, evolution, paléobiogéographie. Centre National de la Recherche Scientifique, Paris.
- Harrison, J.C., Wall, J.H., Brent, T.A., Poulton, T.P., Davies, E.H., 1999. Rift-related structures in Jurassic and Lower Cretaceous strata near the Canadian polar margin, Yukon Territory, Northwest Territories and Nunavut, Current Research 1999-E, *Geol. Surv. Canada*, 47–58.
- Kaplan, M.E., Knyazev, V.G., Meledina, S.V., Mesezhnikov, M.S., 1974. Jurassic deposits of the Cape of Tsvetkov and Chernokhrebetnaya River (eastern Taimyr), in: *Trans. Inst. Geol. Geophys.*, SB AS USSR [in Russian]. Nauka, Novosibirsk, Vol. 136, pp. 66–83.
- Klieber, D., 1981. Zum Problem der Abgrenzung von *Amoeboceras alternans* (v. Buch 1831) und *Amoeboceras ovale* (Quenstedt 1849). *Geologische Blätter für Nord-Ost Bayern* 31, 271–284.
- Matyja, B.A., 1986. Developmental polymorphism in Oxfordian ammonites. *Acta Geol. Pol.* 36, 1–3, 37–68.
- Matyja, B.A., Wierzbowski, A., 1988. Two *Amoeboceras* invasions in Submediterranean Late Oxfordian of Central Poland, in: Rocha R.B., Soares A.F. (Eds.), *2nd International Symp. on Jurassic Stratigraphy*. Lisboa, Vol. 1, pp. 421–432.
- Matyja, B.A., Wierzbowski, A., 1994. On correlation of Submediterranean and Boreal ammonite zonations of the Middle and Upper Oxfordian: new data from Central Poland, *Geobios Mém. Spéc.* 17, 351–358.
- Matyja, B.A., Wierzbowski, A., 2000a. Biostratigraphical correlations between the Subboreal Mutabilis Zone and the Submediterranean Upper Hypselocyclum—Divisum Zones of the Kimmeridgian: new data from northern Poland. *GeoResearch Forum* 6, 129–136.
- Matyja, B.A., Wierzbowski, A., 2000b. Biological response of ammonites to changing environmental conditions: an example of Boreal *Amoeboceras* invasions into Submediterranean Province during Late Oxfordian. *Acta Geol. Pol.* 50, 1, 45–54.
- Matyja, B.A., Wierzbowski, A., Wright, J.K., 2006. The Sub-Boreal/Boreal ammonite succession at the Oxfordian/Kimmeridgian boundary at Flodigarry, Staffin Bay (Isle of Skye), Scotland, *Trans. Roy. Soc. Edinburgh, Earth Sci.* 96, 387–405.
- Meledina, S.V., Kaplan, M.E., 1976. Chernokhrebetnaya River and Cape of Tsvetkov, in: Saks, V.N. (Ed.), *Stratigraphy of the Jurassic System of the North of the USSR* [in Russian]. Nauka, Moscow, pp. 91–98.
- Meledina, S.V., Nalnjaeva, T.I., Kaplan, M.E., Shurygin, B.N., 1976. Anabar River, in: Saks V.N. (Ed.), *Stratigraphy of the Jurassic System of the North of the USSR* [in Russian]. Nauka, Moscow, pp. 57–67.
- Mesezhnikov, M.S., 1967. A new ammonite zone of the Upper Oxfordian and the position of Oxfordian and Kimmeridgian boundary in northern Siberia, in: Saks, V.N. (Ed.), *Problems of Paleontological Substantiation of Detailed Stratigraphy of Siberia and Far East* [in Russian]. Nauka, Leningrad, pp. 110–130.
- Mesezhnikov, M.S., 1968. Zonal subdivisions of the Lower Kimmeridgian of Arctic. *Dokl. Akad. Nauk SSSR* 178 (4), 912–915.
- Mesezhnikov, M.S., 1969a. Kimmeridgian ammonites, in: Saks, V.N. (Ed.), *Fundamental Section of the Upper Jurassic of Kheta River Basin* [in Russian]. Nauka, Leningrad, pp. 99–124.
- Mesezhnikov, M.S., 1969b. Zonal stratigraphy and zoogeographical subdivision of the marine basins. *Geologiya i Geofizika* 10 (7), 45–53.
- Mesezhnikov, M.S., 1984. Kimmeridgian and Volgian of the North of the USSR [in Russian]. Nedra, Leningrad.
- Mesezhnikov, M.S., Romm, G.M., 1973. A contribution to the systematic of the genus *Amoebites* (Ammonoidea, Cardioceratidae). *Paleontologicheskii Zh.*, No. 7, 314–325.
- Mesezhnikov M.S., Kalacheva E.D., Rotkyte L.M., 1986. Ammonite distribution in the Middle Oxfordian deposits of Unzha River (Makariev reference section), in: Mesezhnikov M.S. (Ed.), *Jurassic of the Russian Platform* [in Russian]. VINGRI, Leningrad, pp. 145–154.
- Mesezhnikov, M.S., Azbel, A.J., Kalacheva, E.D., Rotkyte, L.M., 1989. The Middle and Upper Oxfordian of the Russian Platform [in Russian]. Academy of Sciences of USSR, Stratigraphical Committee Transactions, Vol. 19, pp. 1–158.
- Nikitenko, B.L., 2009. Jurassic Stratigraphy, Paleobiogeography and Biofacies of Siberia, Based on Microfauna (Foraminifers and Ostracodes) [in Russian with English summary]. Novosibirsk.
- Nikitenko, B.L., Knyazev, V.G., Lebedeva, N.K., Peshchevitskaya, E.B., Kutugin, R.V., 2011. Problems of Oxfordian and Kimmeridgian stratigraphy in northern Central Siberia (Nordvik Peninsula section). *Russian Geology and Geophysics (Geologiya i Geofizika)* 52 (9), 963–978 (1222–1241).
- Page, K.N., Melendez, G., Wright, J.K., 2009. The ammonite faunas of the Callovian–Oxfordian boundary interval in Europe and their relevance to the establishment of an Oxfordian GSSP. *Volumina Jurassica* 7, 89–99.
- Poulton, T.P., Detterman, R.L., Hall, R.L., Jones, D.L., Peterson, J.A., Smith, P., Taylor, D.G., Tipper, H.W., Westermann, G.E.G., 1992. Regional geology and stratigraphy—Western Canada and United States, in: Westermann, G.E.G. (Ed.), *The Jurassic of the Circum-Pacific*. Cambridge University Press, Cambridge, pp. 29–92.
- Repin, Yu.S., Zakharov, V.A., Meledina, S.V., Nalnyaeva, T.I., 2006. Atlas of the Mollusks of the Pechora Jurassic [in Russian]. *Byul. VNIGRI*, No. 3, 1–262.
- Repin, Yu.S., Fedorova, A.A., Bystrova, V.V., Kulikova, N.K., Polubotko, I.V., 2007. Mesozoic of the Barents sea sedimentological basin, in: Kirichkova, A.V., Dmitrieva, T.V. (Eds.), *Stratigraphy and Its Role in Development of the Oil and Gas Complex of Russia* [in Russian]. VNIGRI, St. Petersburg, pp. 112–161.
- Riding, J.B., Fedorova, V.A., Ilyina, V.I., 1999. Jurassic and lowermost Cretaceous dinoflagellate cyst biostratigraphy of the Russian Platform and northern Siberia. *A.A.S.P. Contribution Series* 36, 1–183.
- Rogov, M., 2010a. New data on the Kimmeridgian ammonite biostratigraphy of Spitsbergen. *Earth Science Frontiers, Special Issue* 17, 94–95.
- Rogov, M., 2010b. A precise ammonite biostratigraphy through the Kimmeridgian–Volgian boundary beds in the Gorodischi section (Middle Volga area, Russia), and the base of the Volgian Stage in its type area. *Volumina Jurassica* 8, 103–130.
- Rogov, M., Wierzbowski, A., 2009. The succession of ammonites of the genus *Amoeboceras* in the Upper Oxfordian–Kimmeridgian of the Nordvik section in northern Siberia. *Volumina Jurassica* 7, 147–156.

- Safronov, V.N., 1959. On the findings of the Mesozoic deposits in the north of the Siberian platform in the upper reaches of Bol'shaya Romanikha River [in Russian]. Inform. Byul. Inst. Geol. Arktiki, Leningrad, Issue 14, pp. 9–13.
- Saks, V.N., Ronkina, Z.Z., Shulgina, N.I., Basov, V.A., Bondarenko, N.M., 1963. Jurassic and Cretaceous Stratigraphy of the Northern Soviet Union [in Russian]. Izd. AN SSSR, Moscow–Leningrad.
- Saks, V.N., Basov, V.A., Mesezhnikov, M.S., Ronkina, Z.Z., Shulgina, N.I., 1969a. Stratigraphical conclusions and correlations, in: Saks, V.N. (Ed.), Fundamental Section of the Upper Jurassic of Kheta River Basin [in Russian]. Nauka, Leningrad, pp. 64–92.
- Saks, V.N., Ronkina, Z.Z., Basov, V.A., Zakharov, V.A., Mesezhnikov, M.S., Shulgina, N.I., Yudovny, E.G., 1969b. Description of strata of reference section, in: Saks, V.N. (Ed.), Fundamental Section of the Upper Jurassic of Kheta River Basin [in Russian]. Nauka, Leningrad, pp. 14–62.
- Schweigert, G., Callomon, J.H., 1997. Der *bauhini*—Faunenhorizont und seine Bedeutung für die Korrelation zwischen tetyalem und subborealem Oberjura. Stuttgarter Beitr. Naturk., Ser. B, 247, 1–69.
- Shulgina, N.I., 1960. Ammonites of Franz Josef Land and the Taimyr and their importance for zonal correlation of the Kimmeridgian in the Arctic, in: Paleontology and Biostratigraphy of the Soviet Arctic [in Russian]. Trans. NIIGA, Vol. 111, pp. 136–149.
- Shurygin, B.N., Nikitenko, B.L., Devyatov, V.P., Ilyina, V.I., Meledina, S.V., Gaideburova, E.A., Dzyuba, O.S., Kazakov, A.M., Mogucheva, N.K., 2000. Stratigraphy of the Siberian Petroliferous Basins: Jurassic System [in Russian]. Izd. SO RAN, Filial "Geo", Novosibirsk.
- Shurygin, B.N., Nikitenko, B.L., Meledina, S.V., Dzyuba, O.S., Knyazev, V.G., 2011. Comprehensive zonal subdivisions of Siberian Jurassic and their significance for Circum-Arctic correlations. Russian Geology and Geophysics (Geologiya i Geofizika) 52 (8), 825–844 (1051–1074).
- Smelror, M., 1993. Biogeography of Bathonian to Oxfordian (Jurassic) dinoflagellates: Arctic, NW Europe and circum-Mediterranean regions. Palaeogeogr., Palaeoclimatol., Palaeoecol. 102, 121–160.
- Spath, L.F., 1935. The Upper Jurassic invertebrate faunas of Cape Leslie, Milne Land. I. Oxfordian and Lower Kimmeridgian. Medd. om Gronland 99 (2), 1–78.
- Sykes, R.M., Callomon, J.H., 1979. The *Amoeboceras* zonation of the Boreal Upper Oxfordian. Palaeontology 22 (4), 839–903.
- Voronets, N.S., 1962. Stratigraphy and Cephalopods of the Jurassic and Lower Cretaceous Deposits of the Lena–Anabar Area. Memoires of the Institute of Arctic Geology (Trudy Instituta Geologii Arktiki) [in Russian]. NIIGA, Leningrad, Vol. 110.
- Wierzbowski, A., 1989. Ammonites and stratigraphy of the Kimmeridgian at Wimanfjellet, Sassenfjorden, Spitsbergen. Acta Palaeont. Polonica 34 (4), 355–378.
- Wierzbowski, A., 2010. On the Oxfordian/Kimmeridgian boundary and its GSSP—current state of knowledge. Volumina Jurassica 8, 177–181.
- Wierzbowski, A., Århus, N., 1990. Ammonite and dinoflagellate cyst succession of an Upper Oxfordian–Kimmeridgian black shale core from the Nordkapp Basin, southern Barents Sea. Newsl. Stratigr. 22, 1, 7–19.
- Wierzbowski, A., Smelror, M., 1993. Ammonite succession in the Kimmeridgian of southwestern Barents Sea, and the *Amoeboceras* zonation of the Boreal Kimmeridgian. Acta Geol. Pol. 43, 3–4, 229–248.
- Wierzbowski, A., Smelror, M., Mørk, A., 2002. Ammonites and dinoflagellate cysts in the Upper Oxfordian and Kimmeridgian of the northeastern Norwegian Sea (Nordland VII offshore area): biostratigraphical and biogeographical significance. Neues Jahr. Geol. Paläontol. Abh. 226 (2), 145–164.
- Wright, J.K., 1989. The early Kimmeridgian ammonite succession at Staffin, Isle of Skye. Scottish J. Geol. 25 (3), 263–272.
- Wright, J.K., 2010. The Aulacostephanidae (Ammonoidea) of the Oxfordian/Kimmeridgian boundary beds (Upper Jurassic) of southern England. Palaeontology 53 (1), 11–52.
- Wright, J.K., Page, K.N., 2006. The cardioceratid ammonite fauna of the Upware Limestone and Dimmock's Cote Marl (Upper Jurassic) in Cambridgeshire, England. Proc. Yorkshire Geol. Soc. 56 (2), 65–75.
- Zakharov, V.A., Shurygin, B.N., 1983. Geographical differentiation of the marine bivalves of the Jurassic and Early Cretaceous Arctic Zoogeographical Realm, in: Trans. Inst. Geol. Geophys. Sib. Branch Acad. Sci. USSR. Novosibirsk, Vol. 555, pp. 72–88.
- Zakharov, V.A., Baudin, F., Dzyuba, O.S., Daux, V., Zverev, K.V., Renard, M., 2005. Isotopic and faunal record of high paleotemperatures in the Kimmeridgian of Subpolar Urals. Geologiya i Geofizika (Russian Geology and Geophysics) 46 (1), 3–20 (1–19).

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