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Problems of Oxfordian and Kimmeridgian stratigraphy in northern Central Siberia (*Nordvik Peninsula section*)

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Abstract

The Oxfordian–Lower Hauterivian section of the Nordvik Peninsula (northern Central Siberia) is a reference for developing zonal scales for various fossil groups and improving the Boreal zonal standard. In the middle 1950s–late 1980s, it was studied extensively by geologists, stratigraphers, lithologists, and experts on various fossil groups. These studies yielded rich fossil and microfossil collections and a set of parallel zonal scales for various faunal groups. Recently, a new detailed ammonite zonation of the Oxfordian and Kimmeridgian units of this section has been proposed. These results contradict the previous biostratigraphic data on ammonites, foraminifers, and palynomorphs. In the present paper, all the biostratigraphic data on the Oxfordian and Kimmeridgian units of the Nordvik Peninsula (Cape Urdyuk-Khaya) and northern Central Siberia undergo a comprehensive analysis and comparison with those on the Boreal Realm. The ammonite-constrained stratigraphic position of the lower Upper Jurassic in the Cape Urdyuk-Khaya section is interpreted as Upper Oxfordian or Middle Oxfordian. In our view, this difference in the understanding is due to the misidentification of some Oxfordian ammonite forms. The zones based on other fossil groups (foraminifers, dinocysts) which were distinguished in the Upper Oxfordian and Kimmeridgian sections of the Nordvik Peninsula are well traceable circumarctically. Their stratigraphic position in various regions of the Northern Hemisphere is constrained by ammonites and bivalves. However, if we use the last alternative ammonite zonation of this section part, hardly explicable contradictions will appear in interregional foraminiferal and dinocyst correlations.

Keywords: Oxfordian; Kimmeridgian; reference section; stratigraphy; ammonites; foraminifers; dinocysts; zonal scales; Nordvik Peninsula; Central and East Siberia

Introduction

A set of parallel zonal scales for various fossil groups was based on reference sections (the completest ones) containing ammonites, bivalves, belemnites, foraminifers, ostracods, and marine and terrestrial palynomorphs. Such sections include the Upper Jurassic and Neocomian outcrops on the Nordvik Peninsula (Anabar Bay, northern Central Siberia) (Fig. 1). Near Capes Urdyuk-Khaya (Fig. 1) and Paksa, the predominant Upper Oxfordian–Lower Valanginian argillaceous rocks crop out almost continuously (Basov et al., 1970; Resolutions, 1981; Saks et al., 1963; Zakharov et al., 1983).

These sections were studied extensively by geologists, stratigraphers, lithologists, and experts on various fossil groups in the middle 1950s–late 1980s (Basov et al., 1970; Gerke, 1953; Kaplan and Yudovnyi, 1973; Resolutions, 1981; Saks, 1976; Saks et al., 1958, 1963; Zakharov et al., 1983). The 1967 field studies (Basov et al., 1970) yielded a division of the Upper Jurassic and Lower Cretaceous section on the Nordvik Peninsula into beds and units, which was used as a standard afterward in nearly all papers (sometimes with minor specifications) (Nikitenko, 2009; Nikitenko et al., 2008; Saks, 1976; Zakharov, 1981; Zakharov et al., 1983) (Fig. 2). The previous biostratigraphic data and fossil finds (Saks et al., 1963; Voronets, 1962) were also tied with this lithostratigraphic division.

Vast collections of Upper Oxfordian–Lower Cretaceous ammonites, bivalves, belemnites, and microfossils have been assembled over many years; this permitted developing a set of parallel zonal scales for these fossil groups. The bivalve, foraminiferal, palynomorph, and, most importantly, ammonite

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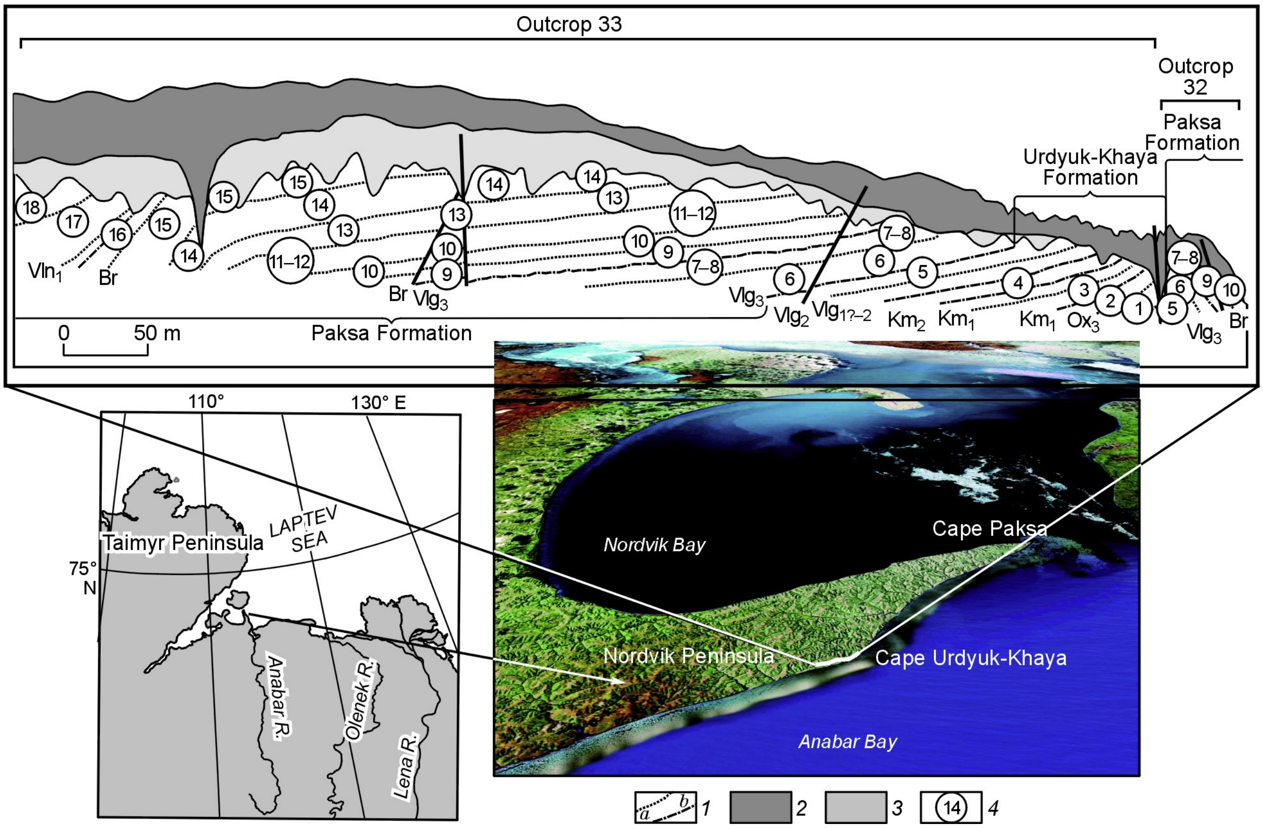


Fig. 1. Position of the Oxfordian and Kimmeridgian reference section on the Nordvik Peninsula, Cape Urdyuk-Khaya (northern Central Siberia) and geologic section of outcrops 32 and 33 (Nikitenko et al., 2008; Saks, 1972). *1*, unit (*a*), stage, and substage (*b*) boundaries; *2*, tundra; *3*, rockslide; *4*, unit no. Ox_3, Upper Oxfordian; Km_1, Lower Kimmeridgian; Km_2, Upper Kimmeridgian; $Vlg_{1?–2}$, Lower?–Middle Volgian; Vlg_2, Middle Volgian; Vlg_3, Upper Volgian; Br, Boreal Berriasian; Vln_1, Lower Valanginian.

collections were studied and discussed at numerous colloquia by M.S. Mesezhnikov, N.I. Shul'gina, E.D. Kalacheva, S.V. Meledina, and other leading ammonite experts; afterward the most reliable identifications of ammonites and other fossils were incorporated into the official stratigraphic charts (Resolutions, 1981) (Fig. 2). The zonal scales developed for these groups were tested repeatedly in publications and at conferences. Afterward a set of zonal scales for various fossil groups was suggested as the Boreal zonal standard (Zakharov et al., 1997) and the type sections of some standard zones were found in outcrops on the Nordvik Peninsula.

The bivalve, foraminiferal, and palynomorph scales in the Boreal zonal standard were calibrated against the standard (ammonite zonal scale) and one another. Correspondingly, the ammonite zonal scale is tied with all the other scales. As a rule, the zonal boundaries on the scales do not coincide; this ensures mutual biostratigraphic control in sectional division and correlation and reduces the likelihood of error. Changes in the ammonite scale and the ammonite redating of the well-studied reference sections necessitate a recalibration of the entire set of zonal scales. Therefore, such changes have to be justified.

The Jurassic and Cretaceous sections on the Nordvik Peninsula are quite well-studied biostratigraphically and remain references for the further improvement, refinement, and development of zonal scales. More than a decade has passed since the publication of the Mesozoic Boreal zonal standard (Zakharov et al., 1997), where the most complete stratigraphic coordinate system was created for the first time for all geologic purposes. Over this time experts on the Boreal Mesozoic have obtained completely new data, which have transformed our view of the stratigraphy of individual Jurassic and Cretaceous intervals. The Jurassic–Cretaceous boundary in the upper Upper Volgian has been located on the basis of magnetostratigraphic data (Houa et al., 2007), and this level has been recorded reliably on the ammonite Boreal zonal scales; an entirely new zonal scale has been developed for the Upper Bathonian and Lower Callovian of the East European craton and northern Siberia on the basis of cardioceratids (ammonites) (Kiselev and Rogov, 2007; Knyazev et al., 2010); the Jurassic stratigraphy and microfaunal zonal scales for the Barents shelf based on foraminifers and ostracods have been improved (Basov et al., 2008, 2009); a scale for the Volgian–Hauterivian terrestrial and marine palynomorphs has been suggested as part of the Boreal zonal standard (Nikitenko et al., 2008; Pestchevitskaya, 2007a,b), with the type sections of some zones on the Nordvik Peninsula, and many others.

Innovations also include the results of the recent study (Rogov and Wierzbowski, 2009) devoted to the ammonite zonation of the Oxfordian and Kimmeridgian units on the

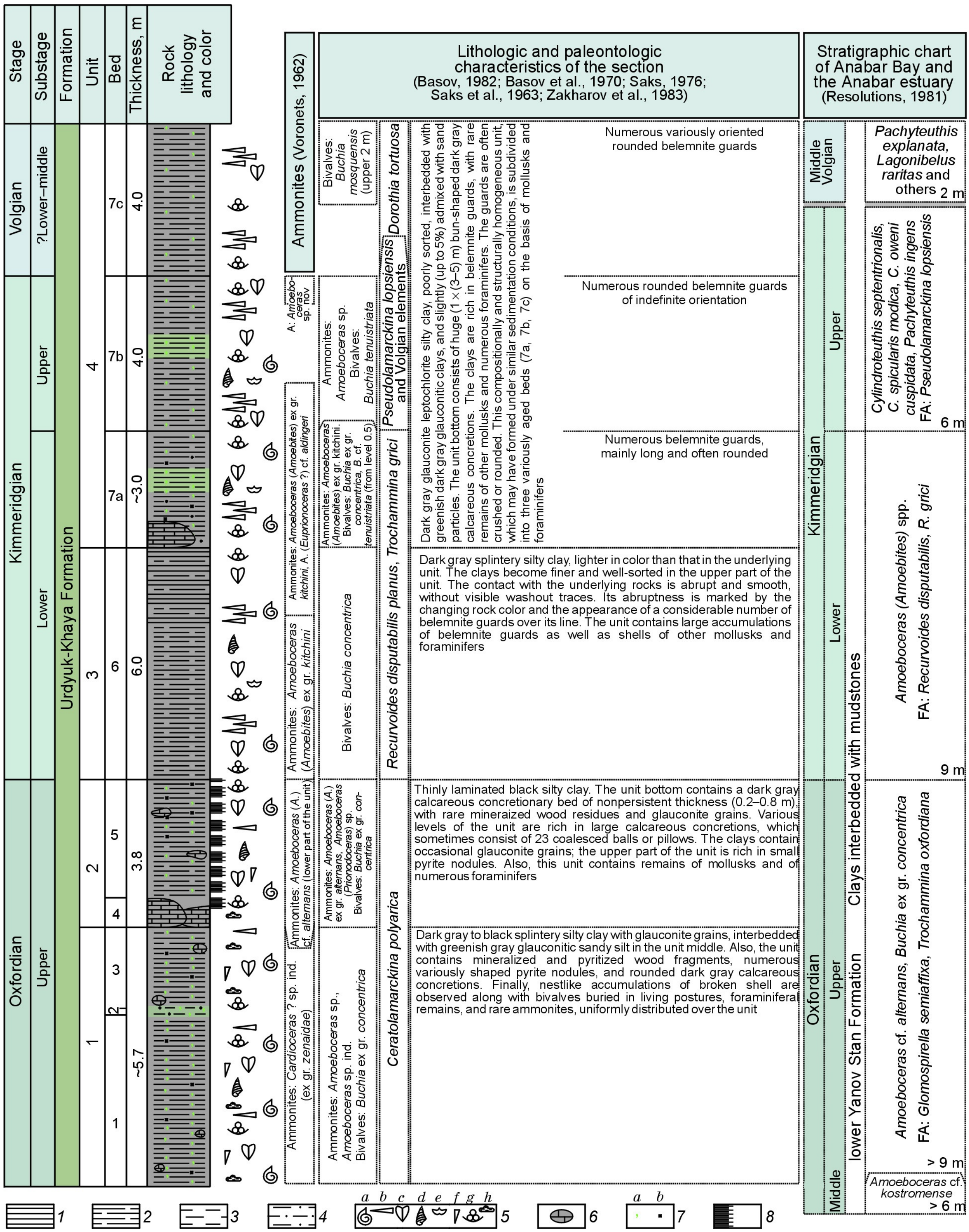


Fig. 2. Stratigraphic studies of the Oxfordian and Kimmeridgian reference section on the Nordvik Peninsula, Cape Urdyuk-Khaya, in the late 1950s–1980s. Bed and unit division is after (Basov et al., 1970). *1*, clay; *2*, silty clay; *3*, silt; *4*, sandy silt; *5*, fossils: *a*, ammonites; *b*, belemnites; *c*, bivalves; *d*, gastropods; *e*, brachiopods; *f*, Dentalium tubes; *g*, foraminifers; *h*, wood; *6*, concretion; 7, glauconite (*a*), pyrite (*b*); *8*, horizontal bedding.

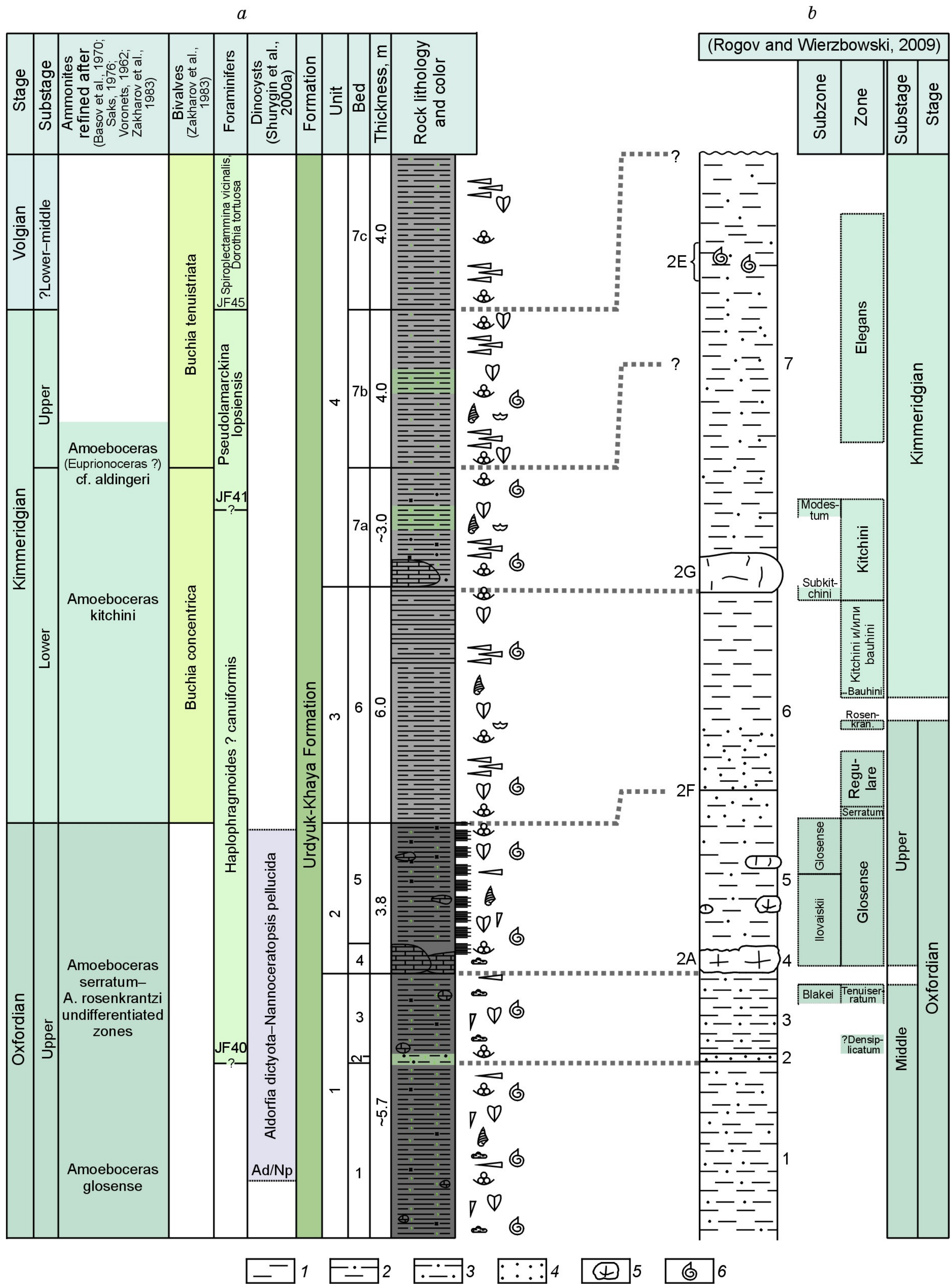


Fig. 3. Biostratigraphic (ammonites, foraminifers, dinocysts) studies of the Oxfordian and Kimmeridgian section on the Nordvik Peninsula, Cape Urdyuk-Khaya, and comparison with the latest ammonite zonation (Rogov and Wierzbowski, 2009). *a*, See legend in Fig. 2; *b*, *1*, clay; *2*, silty clay, *3*, clayey siltstones; *4*, silt–clay sandstones; *5*, calcareous concretions; *6*, *Amoeboceras*-rich bed, correlation level 2E.

Nordvik Peninsula (Cape Urdyuk-Khaya), northern Siberia. The most radical changes have affected the lowermost Upper Jurassic, which was dated as Upper Oxfordian on the basis of the ammonites *Amoeboceras* sp. (Basov et al., 1970; Saks, 1976; Saks et al., 1963; Voronets, 1962; Zakharov et al., 1983). According to (Rogov and Wierzbowski, 2009), this section part (upper half of unit 1, upper bed 3) corresponds only to the Middle Oxfordian Cardioceras tenuiserratum Zone, and lower bed 3 may correspond to the Cardioceras densiplicatum Zone (Fig. 3).

The results obtained in (Rogov and Wierzbowski, 2009) contradict the previous biostratigraphic data on ammonites (Basov et al., 1970; Resolutions, 1981; Saks, 1976; Saks et al., 1963; Voronets, 1962; Zakharov et al., 1983), foraminifers (Basov, 1982; Basov et al., 1970; Nikitenko, 2009; Saks, 1976), and palynomorphs (Shurygin et al., 2000a; Zakharov et al., 1997) (Figs. 2, 3). Thus, the present study is devoted to a comprehensive analysis of all the biostratigraphic data on the Oxfordian–Kimmeridgian part of the Nordvik Peninsula (Cape Urdyuk-Khaya) section and other sections in northern Siberia and comparing them with those on the Boreal Realm.

The biostratigraphic analysis is based on ammonite collections from the lower Oxfordian section of the Nordvik Peninsula (Cape Urdyuk-Khaya) (Fig. 1); the microfaunal collections of 1967, tied reliably with the standard lithostratigraphic division of the section and expanded by later field studies; all the known published data. Note that one of the authors took part in the 1967 field studies, when the section was divided into the beds and units used as standards afterward (Basov et al., 1970).

Biostratigraphic data

Ammonites. Ammonites are quite rare and usually poorly preserved in the Oxfordian and Kimmeridgian units of the Nordvik Peninsula; therefore, their images and descriptions have hardly been published (Zakharov et al., 1983). The Upper Oxfordian ammonites *Amoeboceras* sp. indet. and *Amoeboceras* sp. (Basov et al., 1970; Resolutions, 1981; Saks, 1976; Saks et al., 1963; Zakharov et al., 1983) are recorded at the bottom of the Upper Jurassic section (unit 1) of the Nordvik Peninsula (Cape Urdyuk-Khaya). Previously *Cardioceras*? sp. indet. (ex gr. *zenaidae*) (Voronets, 1962) (Fig. 2) was recorded in this section part; it was shown in an unpublished paper of N.S. Voronets as a compressed whorl fragment of a small shell. In our view, the poor state of this specimen precludes precise species identification, but it must belong to the genus *Amoeboceras*, judging by the presence of distinct near-keel areas.

In the same section, V.G. Knyazev found a specimen of *Amoeboceras* (*Amoeboceras*) ex gr. *alternoides* (Plate 1, Figs. 1–3) at the bottom of bed 1 (unit 1), which suggests the Late Oxfordian age of the host sediments. Thus, our data agree well with the previous results (Basov et al., 1970; Resolutions, 1981; Saks, 1976; Saks et al., 1963; Voronets, 1962; Zakharov et al., 1983) (Figs. 2, 3).

According to other data (Rogov and Wierzbowski, 2009, Fig. 2), a *Cardioceras* (*Cawtoniceras*) ex gr. *blakei* shell was found 47 cm below datum 2a (apparently, near the top of unit 1, upper bed 3); this is why the host sediments were assigned to the upper Middle Oxfordian. What is more, poorly preserved *Cardioceras* ammonites (no images) were recorded in lower bed 3 (unit 1), suggesting the possible presence of the underlying Middle Oxfordian Cardioceras densiplicatum Zone (Fig. 3) (Rogov and Wierzbowski, 2009, p. 151).

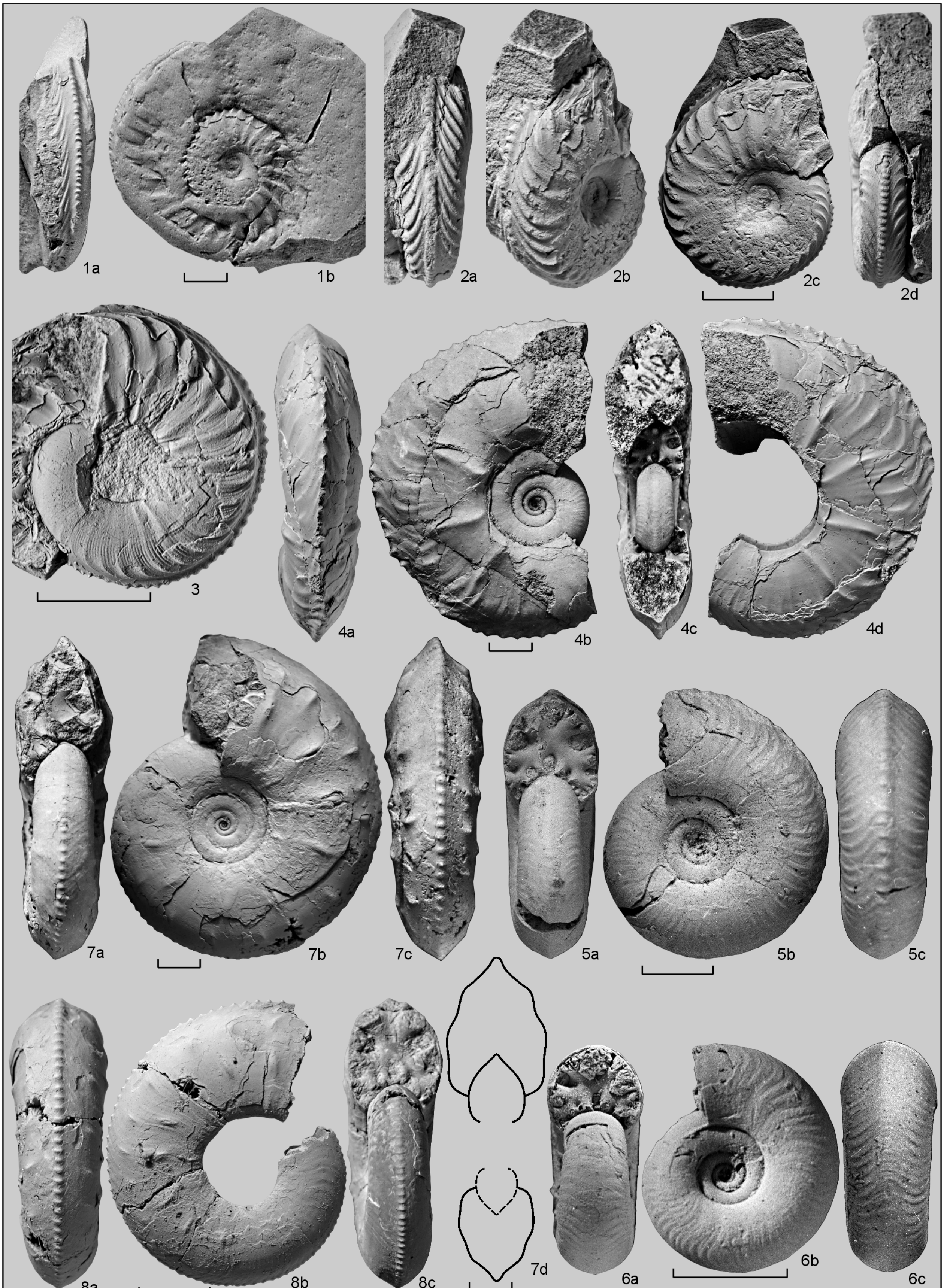
The state of the specimen identified as *Cardioceras* (*Cawtoniceras*) ex gr. *blakei* (Rogov and Wierzbowski, 2009, Table 1, Fig. 1) casts doubt not only upon its species assignment but also on its generic assignment. This considerably complicates its use for detailed stratigraphic studies. The small specimen of *Cardioceras* (*Cawtoniceras*) ex gr. *blakei* (Rogov and Wierzbowski, 2009, Table 1, Fig. 1) has distinct dense ribs, not typical of this species, at the beginning of the later whorl. It seems more correct to assign it to the genus *Amoeboceras*; this is confirmed by the presence of a distinct near-keel area on the later whorl and distinct ribbing, which is also observed on the earlier whorls.

The upper Middle Oxfordian (Cardioceras tenuiserratum Zone, C. blakei Subzone) is constrained by the last *Cardioceras* specimens, comprising species of the subgenera *Cawtoniceras*, *Maltoniceras*, and *Miticardioceras.* The index species *Cardioceras blakei* has widely spaced primary ribs, separated from the more numerous secondary ones. Without going into the debate about the subgenus assignment of this species (Arkell, 1935–1948; Spath, 1935), note that its morphology is marked by quite a long "smoothed shell' stage, spanning the early and middle whorls (D < 20 mm); the whorls at this stage are covered with fine transverse waves. This is well exemplified by *Cardioceras ex gr. blakei* (Plate 1, Figs. 4–6) and *C. schellwieni* (Plate 1, Figs. 7, 8) from the upper Middle Oxfordian in the lower reaches of the Anabar River.

Thus, the paleontologic evidence for the presence of the upper Middle Oxfordian (Rogov and Wierzbowski, 2009) (Cardioceras tenuiserratum Zone, C. blakei Subzone, let alone C. densiplicatum Zone) at the bottom of the Jurassic section on the Nordvik Peninsula (upper unit 1) (Fig. 3) seems wrong.

In the overlying part of the Oxfordian section (unit 2), *Amoeboceras* cf. *alternans* (Voronets, 1962), *Amoeboceras* cf. *alternans,* and *Amoeboceras* (*Prionodoceras*) sp. (Basov et al., 1970; Saks, 1976; Saks et al., 1963; Zakharov et al., 1983) were recorded; this allows us to assign units 1 and 2 to the upper Upper Oxfordian (Amoeboceras alternans and Amoeboceras ravni Zones) (Zakharov et al., 1983). The Kimmeridgian part of the section (units 3 and 4) (Figs. 2, 3) contained *Amoeboceras* sp., *Amoeboceras* sp. nov., *A.* ex gr. *kitchini*, and *A.* (*Euprionoceras*?) *aldingeri* (Basov et al., 1970; Saks, 1976; Saks et al., 1963; Voronets, 1962; Zakharov et al., 1983).

Note that some previously identified Oxfordian and Kimmeridgian ammonites from the Nordvik Peninsula section were not included (Fig. 2) in the official Upper Jurassic


1a
1b
2a
2b
2c
2d
3
4a
4b
4c
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7a
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7c
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5b
5c
8a
8b
8c
7d
6a
6b
6c

Plate 1. Oxfordian ammonites from the Anabar River and Anabar Bay.
Figs. 1–3. *Amoeboceras* (*Amoeboceras*) ex gr. *alternoides* (Nikitin, 1887): *1*, specimen no. 181/500 (×1.5): *1a*, ventral view; *1b*, lateral view; Nordvik Peninsula, Cape Urdyuk-Khaya, outcrop 33, unit 1, bottom of bed 1; Upper Oxfordian, Amoeboceras glosense Zone; collected by V.G. Knyazev, field specimen no. 33/1-2003; *2*, the same (×2.5): *2a*, ventral view; *2b*, ventrolateral view; *2c*, lateral view; *2d*, view from the river mouth; *3*, the same (×4), lateral view.
Figs. 4–6. *Cardioceras* ex gr. *blakei* Spath, 1935: *4*, specimen no. 181/372 (×1.5): *4a*, ventral view; *4b*, *4d*, lateral view; *4c*, view from the river mouth; lower reaches of the Anabar River, right bank, opposite Agrafena Island, outcrop 1, bed 6; upper Middle Oxfordian; collected by L.R. Stolyarova, field specimen no. 12/2-2003; *5*, the same (×2.5): *5a*, view from the river mouth; *5b*, lateral view; *5c*, ventral view; *6*, the same (×4): *6a*, View from the river mouth; *6b*, lateral view; *6c*, ventral view.
Figs. 7, 8. *Cardioceras schellwieni* Boden, 1911: *7*, specimen no. 181/371 (×1.5): *7a*, view from the river mouth; *7b*, lateral view; *7c*, ventral view; *7d*, cross-section; lower reaches of the Anabar River, right bank, 1.5 km downstream of the Polovinnaya River mouth, outcrop 6, bed 1; upper Middle Oxfordian; collected by V.G. Knyazev, specimen no. 6/1-2003; *8*, specimen no. 181/371-1 (×2.5): *8a*, ventral view; *8b*, lateral view; *8c*, view from the river mouth; the same locality, age, and field no.
All the scale bars are 5 mm long.

stratigraphic chart of northern Central Siberia (Resolutions, 1981), probably after a revision at an expert colloquium.

The detailed zonation suggested for the overlying part of the Oxfordian and Kimmeridgian section on the Nordvik Peninsula (Rogov and Wierzbowski, 2009) (Fig. 3) is based on *Amoeboceras* species. Note that the species assignment of this genus is still quite difficult for lack of a clear idea about its morphogenesis. This is especially evident with the Late Oxfordian *Amoeboceras* species, whose evolution is observable only in a big collection of well-preserved specimens. Therefore, representative samples are crucial in solving taxonomic and biostratigraphic problems (Sykes and Callomon, 1979). Also, according to many ammonite experts (Callomon, 1985; Kiselev and Rogov, 2007; Mesezhnikov et al., 1989; Sykes and Callomon, 1979), an objective species assignment of ammonoids is possible for specimens with the terminal body chamber.

The ammonite collection from the Upper Oxfordian and Kimmeridgian of the Nordvik Peninsula (Rogov and Wierzbowski, 2009) numbers ~60 specimens (from eight zones and four subzones), 18 of which are illustrated. Six of them were identified in the open nomenclature. The specimens illustrated are crushed and deformed shells embedded in rock. Such material precludes objective reconstructions of the whorl cross-section, which is one of the characteristics used in distinguishing *Amoeboceras* subgenera and species. Finally, four illustrated specimens from this collection are juvenile.

The species assignment of some illustrated forms seems questionable. For example, in (Rogov and Wierzbowski, 2009, Table 2, Fig. 4) *Amoeboceras* cf. *serratum* (index species of one of the proposed zones) is shown. It (Sykes and Callomon, 1979) is marked by smoothed early whorls ($D \approx 30$ mm), which give way to distinct, almost radial, ribs. The specimen identified as *A.* cf. *serratum* in (Rogov and Wierzbowski, 2009) does not show the smoothed stage; this casts doubt on its species assignment and the corresponding zonal stratigraphic unit.

Thus, the quality and representativeness of the illustrated ammonite collection (Rogov and Wierzbowski, 2009) from the Oxfordian and Kimmeridgian units of Cape Urdyuk-Khaya are not enough for it to serve as the basis for such detailed Oxfordian and Kimmeridgian zonation of this section (Fig. 3). Also, it is not always clear how some zones and subzones are distinguished. For example, in the Kimmeridgian Amoeboceras kitchini Zone, the A. subkitchini and A. modestum Subzones are distinguished, though their taxonomic composition is identical (Rogov and Wierzbowski, 2009).

Foraminifers. The Oxfordian and Kimmeridgian units in northern Siberia are divided into the following f-zones and beds: Ammobaculites tobolskensis, Trochammina oxfordiana JF34 (Lower Oxfordian), Ammodiscus thomsi, Tolypammina svetlanae JF35 (Middle Oxfordian and bottom of Upper Oxfordian), T. oxfordiana JF36 (Lower Oxfordian and bottom of Upper Oxfordian), Recurvoides disputabilis JF37 (middle Upper Oxfordian), Haplophragmoides? canuiformis JF40 (upper Upper Oxfordian–lower half of Lower Kimmeridgian), Trochammina omskensis, Verneuilinoides graciosus JF38 (upper Upper Oxfordian–lower Lower Kimmeridgian), H.? canuiformis JF39 (middle Lower Kimmeridgian), and Pseudolamarckina lopsiensis JF41 (upper Lower and Upper Kimmeridgian). The foraminiferal zones were calibrated against the ammonite zonal scale and bivalve scale for numerous sections in Siberia, Barents Sea region, Arctic Canada, and northern Alaska (Grigyalis, 1982; Nikitenko, 2009; Shurygin et al., 2000a; Vyachkileva et al., 1990) (Figs. 4, 5).

The Oxfordian, Kimmeridgian, and lower Volgian sections on Cape Urdyuk-Khaya (Nordvik Peninsula) contain the following zones: H.? canuiformis JF40 (unit 1, bed 2–unit 4, middle bed 7a), Pseudolamarckina lopsiensis JF41 (unit 4, upper bed 7a–unit 4, bed 7b), Spiroplectammina vicinalis, and Dorothia tortuosa JF45 (unit 4, bed 7c; unit 5, lower bed 9) (Fig. 3).

The first foraminifers from the assemblage of the Haplophragmoides? canuiformis JF40 f-Zone were found in bed 2 (unit 1), consisting of greenish gray glauconitic sandy siltstones. Occasional specimens of *Conorboides* cf. *polyarica* and *Astacolus* ex gr. *subrusticus* appear at this level. Unit 1 also contains rare specimens of *Ichthyolaria suprajurensis*, *Lenticulina ocunjovensis*, and *L. diserta* (Nikitenko, 2009). According to V.A. Basov (Basov, 1982; Basov et al., 1970; Saks, 1976), unit 1 in this section contains larger and more diverse assemblages with *Conorboides poliarica*, *Pseudonodosaria* ex gr. *tutkowskii*, *Geinitzinita* cf. *praenodulosa*, *A.* aff. *subrusticus*, *Lenticulina* spp., *Globulina topagorukensis*, and other species typical of f-zone JF40. The distribution of some typical foraminiferal taxa does not preclude that lowermost unit 1 (lower bed 1) may belong to the Recurvoides disputabilis JF37 f-Zone. Unit 1 contains the Upper Oxfordian ammonites *Cardioceras*? sp. indet. (ex gr. *zenaidae*) (Voro-

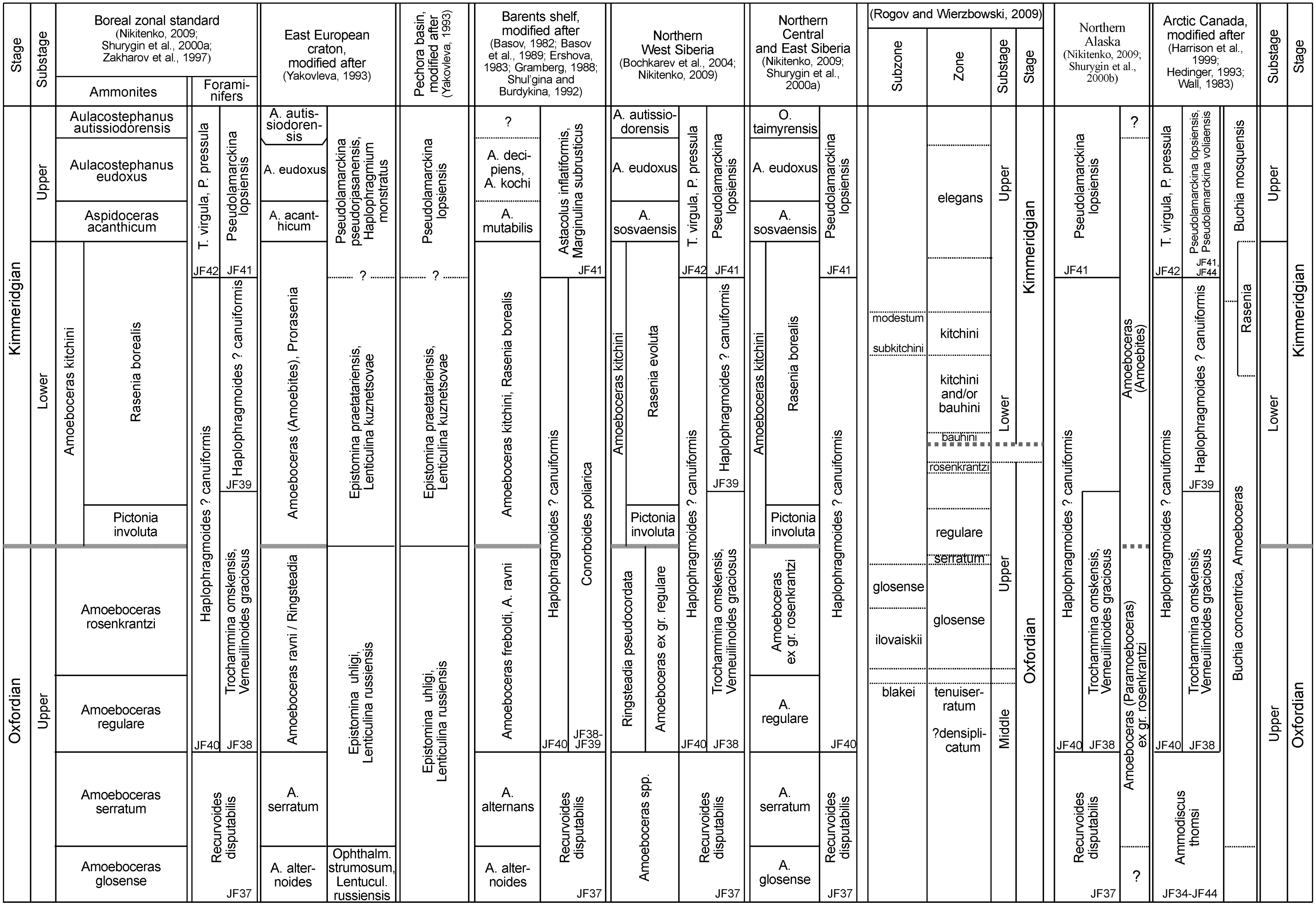

Fig. 4. Circumboreal interregional correlations of the Oxfordian and Kimmeridgian units on the basis of ammonites and foraminifers and comparison with the ammonite zonation of the Nordvik Peninsula section (northern Central Siberia) (Rogov and Wierzbowski, 2009).

nets, 1962) (in modern view, *Amoeboceras* sp. indet.), *Amoeboceras* sp. indet., and *Amoeboceras* sp. (Basov et al., 1970; Saks, 1976; Zakharov et al., 1983); at the very bottom of the unit, Knyazev found specimens of *A.* ex gr. *alternoides* (Plate 1, Figs. 1–3) and the bivalves *Buchia* ex gr. *concentrica* (Zakharov et al., 1983) (Figs. 2, 3). Other authors (Rogov and Wierzbowski, 2009) assign the upper half of unit 1 to the Middle Oxfordian.

The interval from the bottom of unit 2 to lower unit 4 (lower half of bed 7a) (Fig. 3) contains the following, often large, foraminiferal assemblages of f-zone JF40: *Conorboides poliarica*, *Ammodiscus thomsi*, *Bojarkaella firma*, *Geinitzinita praenodulosa*, *Saracenaria subsuta*, *Recurvoides* ex gr. *disputabilis*, *R.* ex gr. *sublustris*, *Pseudonodosaria brandi*, *P. tutkowskii*, *Vaginulina infida*, *Ammobaculites* sp., *Lenticulina* ex gr. *darbyellaformis*, *L. ocunjovensis*, *L. semipellucida*, *L. diserta*, *L. mikhailovi*, *L. greisli, L. initabilis*, *Dentalina* sp., *D.* ex gr. *gracilis*, *Astacolus nobilissimus*, *Anmarginulina* ex gr. *suprajurensis*, and others (Nikitenko, 2009). They coexist in unit 2 with the ammonites *Amoeboceras* cf. *alternans* (lower part of the unit) (Saks, 1976; Voronets, 1962), *Amoeboceras* ex gr. *alternans*, and *Amoeboceras* (*Prionodoceras*) sp. (Basov et al., 1970; Saks, 1976) as well as the bivalves *Buchia* ex gr. *concentrica* (Zakharov et al., 1983) (Figs. 2, 3). Other authors (Rogov and Wierzbowski, 2009) distinguish the following ammonite zones: Amoeboceras glosense, A. serratum, and the lower A. regulare Zone.

Unit 3 contains the Lower Kimmeridgian ammonites *A.* ex gr. *kitchini* (Saks, 1976; Voronets, 1962) and the bivalves *Buchia concentrica* (Zakharov et al., 1983). Rogov and Wierzbowski (2009) assign the unit to the upper Upper Oxfordian (upper Amoeboceras regulare Zone, A. rosenkrantzi Zone) and lower Kimmeridgian (Amoeboceras bauhini Zone, lower A. kitchini Zone). Apparently, *Amoeboceras* ex gr. *kitchini* and *A.* (*Euprionoceras* ?) cf. *aldingeri* (Saks, 1976; Voronets, 1962) were previously found in upper unit 3 and lower unit 4 (bed 7a, lower bed 7b) (Figs. 2, 3).

In middle bed 7a (lower unit 4), the foraminiferal assemblages change. Upper bed 7a and bed 7b contain the foraminifers from the Pseudolamarckina lopsiensis JF41 f-Zone. Along with them, the ammonites *Amoeboceras* ex gr. *kitchini* and the bivalves *Buchia* ex gr. *concentrica* and *B.* cf. *tenuistriata* were found (unit 4, bed 7a) (Basov et al., 1970; Saks, 1976; Zakharov et al., 1983) (Figs. 2, 3). The ammonites from the Amoeboceras kitchini and A. elegans Zones (Rogov and Wierzbowski, 2009) were identified at approximately the same level.

The foraminifers from the assemblage of f-zone JF40 coexist with the uppermost Oxfordian and Lower Kimmeridgian ammonites in northern Central and East Siberia. In the sections of the Boyarka River basin (Saks, 1969), these are the ammonites from the Upper Oxfordian Amoeboceras regulare and A. rosenkrantzi Zones: *Amoeboceras regulare*, *A. ravni*, *A. freboldi*, *A. leucum*, *A. schulginae*, and *A. pectinatum* (bed 1). The upper (Lower Kimmeridgian) part of f-zone JF40 (beds 2–9) is constrained by *Amoeboceras* (*Amoebites*) *spathi*, *A.* (*A.*) *kitchini*, *A.* (*A.*) *ingueforme*, *Pictonia* spp., *Rasenia* spp., *Zonovia subelshamensis*, *Z. subinconstans*, and other species. The bivalves *Buchia concentrica* are typical of this section part (Saks, 1969). Along with the Lower Kimmeridgian ammonites from the Rasenia borealis Zone (beds 10–11) and the Upper Kimmeridgian ammonites from the Aulacostephanus mutabilis, Aulacostephanus eudoxus, and Oxydiscytes taimyrensis Zones, beds 10–16 contain foraminiferal assemblages with *Pseudolamarckina lopsiensis*, *Geinitzinita praenodulosa*, *Astacolus subrusticus*, *A. inflatiformis*, *Astacolus* spp., *Lenticulina initabilis*, *L. gerkei*, *Lenticulina* spp., and many others (Pseudolamarckina lopsiensis JF41 f-Zone).

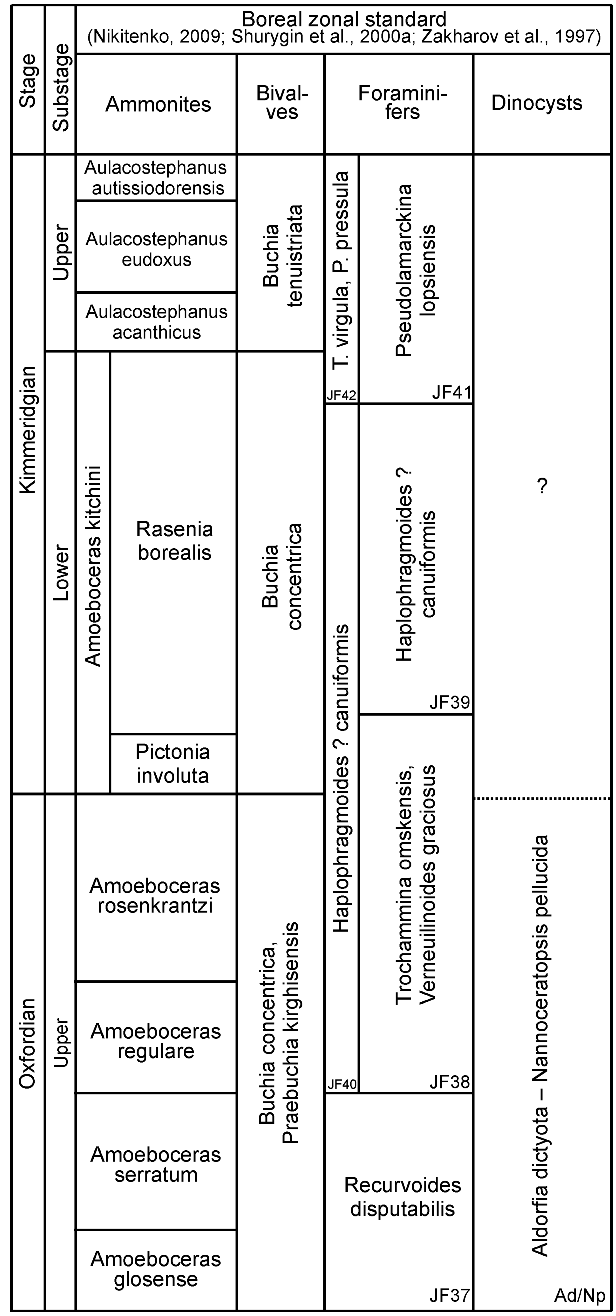

Fig. 5. Boreal Oxfordian and Kimmeridgian zonal standard (Nikitenko, 2009; Shurygin et al., 2000a; Zakharov et al., 1997).

The Oxfordian type section of Siberia is located by the Chernokhrebetnaya River (eastern Taimyr), where all three substages and almost all the ammonite zones making up the Oxfordian Stage were stripped in natural exposures (Shurygin et al., 2000a). In the upper part of the sand unit, the ammonites from the zones and beds with *Amoeboceras regulare* and *A. rosenkrantzi*, as well as the bivalves *Buchia concentrica* (Aleynikov and Meledina, 1993; Saks, 1976), coexist with the assemblages containing *Recurvoides disputabilis*, *R. sublustris*, *Conorboides poliarica*, *Lenticulina ocunjovensis*, *Ammodiscus thomsi*, and other foraminifers typical of f-zone JF40. Numerous *R. disputabilis* (R. disputabilis JF37 f-Zone) coexist with *A. serratum*. The Lower Oxfordian sandstones and siltstones with *Cardioceras* spp. (Saks, 1976) are constrained by the foraminifers from the Trochammina oxfordiana JF36 f-Zone, with *T. oxfordiana*, *Astacolus nobilissima*, *Saracenaria carzevae*, *Recurvoides scherkalyensis*, and others (Lutova, 1981). Such assemblages are also found in the clays of the Urdyuk-Khaya Formation on the western shore of Anabar Bay (Lutova, 1981). The following Lower Oxfordian ammonites are present at this level: *Cardioceras arcticum*, *C. percaelatum*, and *C. excavatum* (Saks, 1976; Voronets, 1962).

A thin condensed section of the Oxfordian and Kimmeridgian sandstones of the Sigovskaya Formation, probably with numerous inner washouts, is stripped by the Anabar River. Nevertheless, almost the entire sequence of the Lower and lower Upper Oxfordian ammonite zones and the Oxfordian and Kimmeridgian foraminiferal zones is found here (Knyazev, 1975; Nikitenko, 2009; Saks, 1976). The foraminiferal assemblages of the T. oxfordiana JF36 f-Zone were distinguished in units 40 and 41 and at the bottom of unit 42 along with the ammonites from the Lower, Middle, and the bottom of the Upper Oxfordian. Unit 41 and the bottom of unit 42 with the ammonites from the Middle and the bottom of the Upper Oxfordian (*Cardioceras* (*Plasmatoceras*) spp., *C.* (*Vertebriceras*) *densiplicatum*, *Amoeboceras* spp.)) (Saks, 1976) contain abundant *Ammodiscus thomsi*, *Glomospira oxfordiana*, *Glomospirella semiaffixa*, and *Tolypammina svetlanae*, typical of f-zone JF35. The foraminiferal assemblages of zone JF40 were found in uppermost sand unit 42 and the greenish gray oolitic glauconitic sands of unit 43. Unit 42, probably its upper part, contains Upper Oxfordian *Amoeboceras* spp., and the outcrop strip of unit 43 contains the Lower Kimmeridgian ammonites *Rasenia* cf. *orbignyi* and *R.* cf. *coronata* (Lutova, 1981; Nikitenko, 2009; Saks, 1976). The level of zone JF37 was not determined here, but it may correspond to a washout or middle unit 42, not sampled for micropaleontologic analysis.

The foraminiferal assemblages of f-zone JF40 are also found in core samples from Central and East Siberian boreholes. For example, an assemblage from this zone was found in the Syndasskaya 201 borehole in dark gray greenish glauconitic silty clays (Gerke, 1953; Voronov, 1961).

The Oxfordian and Kimmeridgian sections of West Siberia, stripped by numerous boreholes and in natural exposures, show a similar sequence of foraminiferal zones, often ammonite- and bivalve-constrained (Fig. 4). The Lower Oxfordian contains the Ammobaculites tobolskensis and Trochammina oxfordiana JF34 Zones; *Cardioceras* ex gr. *cordatum*, *Cardioceras* sp., *C.* (?*Scarburgiceras*) ex gr. *gloriosum*, and Cardioceratinae gen. et sp. indet. were identified along with the foraminiferal assemblages (Bulynnikova, 1972; Glinskikh et al., 1999; Komissarenko and Tylkina, 1977; Nikitenko et al., 2002; Resolution, 1991; Vyachkileva et al., 1990). The foraminiferal assemblages of the Ammodiscus thomsi and Trochammina svetlanae JF35 Zones were constrained by *Cardioceras* (*Plasmatoceras*) *salymensis* and other Middle Oxfordian ammonites (Resolution, 1991; Vyachkileva et al., 1990). However, the sediments with foraminiferal assemblage JF35 contain Middle Oxfordian (*Cardioceras* (sp. indet.) *zenaidae*, *Cardioceras* spp., *C.* (*P.*) *salymensis*) and lower Upper Oxfordian ammonites (*Amoeboceras alternoides*, *A.* sp. indet. cf. *glosense*, *A.* ex gr. *alternans*, *Amoeboceras* spp.) (Bulynnikova, 1972; Dain, 1972; Komissarenko and Tylkina, 1977; Levina, 1968; Resolution, 1991; Shurygin et al., 2000a; Vyachkileva et al., 1990). The overlying Recurvoides disputabilis JF37 f-Zone is dated on the basis of the Upper Oxfordian ammonites *A. alternoides* and *Amoeboceras* spp. found in the corresponding beds (Bochkarev et al., 2004; Vyachkileva et al., 1990). Eastern West Siberia and the Yenisei–Khatanga trough feature the isolated T. oxfordiana JF36 f-Zone (stratigraphic equivalent of zones JF34 and JF35). Lower Oxfordian ammonites were found in f-zone JF36 only in the Ust'-Yenisei district (Bulynnikova, 1972).

In most of West Siberia, foraminiferal zone JF40 can be subdivided into the Trochammina omskensis and Verneuilinoides graciosus JF38 f-Zones and the beds with *Haplophragmoides*? *canuiformis* JF39. Lowermost f-zone JF38 contains the ammonites *Amoeboceras* cf. *alternans* and *Amoeboceras* spp. (Mesezhnikov, 1959, 1984). Upper f-zone JF38 contains the Lower Kimmeridgian ammonites from an assemblage of the Rasenia evoluta Zone in the Lopsiya River (Subpolar Urals) sections and ?*Pictonia*, *Prorasenia* sp. indet., and *Amoeboceras kitchini* in other sections (Bulynnikova, 1972; Komissarenko and Tylkina, 1977; Shurygin et al., 2000a; Vyachkileva et al., 1990). The beds with *H.*? *canuiformis* JF39 in western West Siberia (Ob' profile) contain the ammonites *A.* (*A.*) cf. *spathi* juv. In other parts of West Siberia, the Lower Kimmeridgian position of the beds was confirmed by the presence of a typical foraminiferal assemblage along with the ammonites *A. kitchini*, *Zonovia* ex gr. *uralensis*, and *Rasenia* (*Zonovia*?) sp. indet. (Bulynnikova, 1972; Mesezhnikov, 1959, 1984). Beds JF39 in the Lopsiya River key section contain the ammonites *A. kitchini*, *Amoeboceras* spp., *Zonovia ilovaiskii*, and *Rasenia* spp. (Mesezhnikov, 1959, 1984). In some special facies sections, only f-zone JF40, corresponding to f-zone JF38 and beds JF39, is identifiable. The following ammonites were identified in the Lower Kimmeridgian part of West Siberia: *A.* (*A.*) cf. *spathi* juv., *A. kitchini*, *Amoeboceras* spp., *Z.* ex gr. *uralensis*, *Z. ilovaiskii*, *Rasenia* (*Zonovia*?) sp. indet., *Rasenia inconstans*, and *R. laevigata* (Bulynnikova, 1972; Dain, 1972; Kravets, 1959; Mesezhnikov, 1959, 1984; Resolution, 1991). The bottom of the overlying P. lopsiensis JF41 f-Zone also contains the ammonites from the R. evoluta Zone (Kravets, 1959; Mesezhnikov, 1959, 1984); higher upsection, Upper Kimmeridgian *Aulacostephanus* spp. were found.

In the Oxfordian and Kimmeridgian sections of the Barents shelf, ammonites and foraminiferal assemblages coexist much more seldom. However, a similar zonal sequence of biostratigraphic units is also distinguished here (Fig. 4). The foraminiferal assemblages of the Recurvoides disputabilis JF37 Zone on Spitsbergen and Franz Josef Land are constrained by Upper Oxfordian *Amoeboceras* spp. (Klubov, 1965; Meledina et al., 1979; Pchelina, 1980; Sokolov, 1981). The overlying section part contains foraminiferal assemblages typical of f-zone JF40 along with the Upper Oxfordian and Lower Kimmeridgian ammonites *Amoeboceras* cf. *ravni* and *A. kitchini*. An interval containing *Ceratobulimina* (=*Conorboides*) *polyarica* was found in the upper Upper Oxfordian–Lower Kimmeridgian of the West Kola saddle (Basov et al., 1989; Gramberg, 1988). In stratigraphic volume and taxonomic composition, the assemblage is closest to those of f-zone JF40 from the upper Upper Oxfordian–Lower Kimmeridgian of the Nordvik Peninsula and Subpolar Urals (Nikitenko, 2009). An assemblage of beds with *Astacolus inflatiformis* and *A. subrusticus* was found in the upper Lower–Upper Kimmeridgian sections of Spitsbergen. Such assemblages were first found in the Kheta River basin and corresponded to the P. lopsiensis JF41 f-Zone (Grigyalis, 1982) (Fig. 4).

The upper Oxfordian and Kimmeridgian sections of Arctic Canada (Fig. 4) feature almost the same sequence of foraminiferal zones as the Siberian one. The Upper Oxfordian and Lower Kimmeridgian bivalves *Buchia concentrica* and poorly preserved *Amoeboceras* ammonites (Balkwill et al., 1977; Hedinger, 1993; Poulton et al., 1982; Wall, 1983) coexist with numerous *Verneuilinoides graciosus*, more rare *Bulbobaculites pokrovkaensis*, *Cancrisiella ambitiosa*, *Recurvoides sublustris*, *Conorboides brauni* (=*C. polyarica*) (Hedinger, 1993), and many other species making up the Trochammina omskensis and Verneuilinoides graciosus JF38 f-Zone (upper Upper Oxfordian, lower Kimmeridgian) (Nikitenko, 2009). The overlying section part contains assemblages of beds with *Haplophragmoides*? *canuiformis* JF39, the P. lopsiensis JF41 f-Zone, and probably beds with *P. voliaensis* JF44 (Hedinger, 1993; Nikitenko, 2009).

The Pliensbachian and Aalenian strata in northern Alaska (Arctic Platform) are overlain unconformably by the greenish gray sandstones, sandy siltstones, and mudstones of the upper Kingak Formation (Oxfordian–Kimmeridgian). The lower part of the Kingak section is rich in foraminiferal assemblages typical of the Trochammina oxfordiana JF36 f-Zone (Lower–bottom of Upper Oxfordian). In some sections the Ammobaculites tobolskensis, Trochammina oxfordiana JF34 f-Zone (Lower Oxfordian) and the overlying Ammodiscus thomsi and Tolypammina svetlanae JF35 f-Zone (Middle–bottom of Upper Oxfordian) are identifiable (Nikitenko, 2009). The lower part of these biostratigraphic units is constrained by the bivalves from the beds with *Meleagrinella ovalis* and *Praebuchia kirghisensis* and Lower Oxfordian ammonites (Shurygin, 2005; Shurygin et al., 2000b). The overlying part of the Kingak Formation is rich in the foraminifers typical of the Recurvoides disputabilis JF37 f-Zone (Fig. 4). Many of the taxa known in the Lower and Middle Oxfordian of northern Alaska are absent from this level. The upper part of the zone contains *Amoeboceras* specimens (Shurygin, 2005; Shurygin et al., 2000b).

The lower boundary of f-zone JF40 (Fig. 4) is marked by a considerable assemblage renewal and a change of the dominant taxa. The stratigraphic range of some species allows tracing the T. omskensis and V. graciosus JF38 f-Zone in some sections (Nikitenko, 2009). This and the overlying section part consist of greenish gray glauconitic sandstones, sandy siltstones, and dark gray greenish mudstones. The overlying parts of the Kingak Formation contain foraminiferal assemblages of the P. lopsiensis JF41 f-Zone (Nikitenko, 2009). This section part is usually constrained by the bivalves *B. concentrica* and the Upper Oxfordian *Amoeboceras* (*Paramoeboceras*) and Kimmeridgian *A.* (*Amoebites*) ammonites (Shurygin, 2005; Shurygin et al., 2000b).

The Oxfordian foraminiferal assemblages from the East European craton and northern Western Europe differ considerably from the Siberian ones, almost not overlapping with them. Unlike the ones from northern Siberia, they are rich in *Epistomina*, *Ophthalmidium*, *Lenticulina*, *Globuligerina*, and other foraminifers. These groups usually dominate the assemblages even in the sections of the Pechora River basin. *Recurvoides disputabilis*, *Spiroplectammina* ex gr. *tobolskensis*, *Geinitzinita* ex gr. *nodulosa*, and other Siberian species appear only in the Upper Oxfordian sections of the Pechora River (Grigyalis, 1982). However, despite the differences in the generic and species composition and structure, the upper Upper Oxfordian–lower Kimmeridgian foraminiferal assemblages in the East European craton and Siberia show a structural turnover and a change of the dominant taxa (Nikitenko and Khafaeva, 2000; Nikitenko et al., 2005). This interval with renewed foraminiferal assemblages, found in various regions, has great correlation significance. Siberian species become more abundant in the lower Lower Kimmeridgian of the Pechora basin, whereas typical European species appear in the West Siberian sections (Shurygin et al., 2000a). Migrants from European basins are found in the upper Lower Kimmeridgian assemblages from the foraminiferal zones of northern Siberia. *Pseudolamarckina dainae* (=*P. lopsiensis*), *Epistomina tatariensis*, *Saracenaria subsuta*, *Citharinella* spp., *Tristix* spp., and many others appear in the northern Siberia sections; this allows correlating the P. lopsiensis JF41 Zone from northern Siberia and the East European P. pseudorjasanensis–Haplophragmoides monstratus Zone, which is also present in the West European sections (Kuznetsova, 1979) (Fig. 4).

Dinocysts. In units 1 and 2 of the Upper Oxfordian section of Cape Urdyuk-Khaya (Fig. 1), beds with the dinocysts *Aldorfia dictyota–Nannoceratopsis pellucida* (Shurygin et al., 2000a; Zakharov et al., 1997) (Figs. 3, 5) were distinguished on the basis of FAD on the Arctic species *Paragonyaulacysta borealis* and the last finds of *N. pellucida*. The species from the assemblage of these beds appear for the first time in various Boreal Realm sections only in the upper Upper Oxfordian. For example, the first Arctic *P. borealis* in the northern Canada sections were found in the strata (natural exposures and core samples) assigned to the Upper Oxfordian–Lower Kimmeridgian and constrained by the bivalves from the Buchia concentrica Zone (Brideaux and Fisher, 1976; Harrison et al., 1999).

The index species of the beds with *A. dictyota* is widespread in northwestern Europe; it thrived in the second half of the Late Oxfordian–early Early Kimmeridgian (Poulsen and Riding, 2003). In southern North America, *A. dictyota* is recorded starting from the Kimmeridgian bottom (the interval containing *L. subtile*, *O. balios*, and *A. dictyota*) (Olmstead, 1999). In English sections and in the potential stratotype section of the Oxfordian–Kimmeridgian boundary, it was recorded directly near this boundary (Wierzbowski et al., 2006). In more northerly (North Sea) and the Subarctic areas (Pechora basin), specimens of *A. dictyota* were first found in the lower Lower Kimmeridgian units (Duxbury et al., 1999; Riding et al., 1999). The late Oxfordian and Kimmeridgian dinocyst assemblages of the Boreal Realm are rich in well traceable cosmopolitan taxa (Poulsen and Riding, 2003; Riding et al., 1999).

The stratigraphic position (Upper Oxfordian) of the dinocyst beds in this section is constrained by the ammonites *Amoeboceras* sp., *A.* sp. indet., *A.* ex gr. *alternans*, *A.* (*Prionodoceras*) sp., *A.* ex gr. *alternoides*, the bivalves *Buchia* ex gr. *concentrica* (Basov et al., 1970; Saks, 1976; Zakharov et al., 1983) (Fig. 3), and interregional dinocyst correlations with other parts of the Boreal Realm, where the dinocyst assemblages are also tied with the ammonite zones. In another interpretation (Rogov and Wierzbowski, 2009), the beds with *Aldorfia dictyota–Nannoceratopsis pellucida* should belong to the Middle and bottom of the Upper Oxfordian.

Ammonites Desciption

Family Cardioceratidae Siemiradzki, 1891
Subfamily Cardioceratinae Siemiradzki, 1891
Genus *Cardioceras* Neumayr et Uhlig, 1881

The genus *Cardioceras* is divided into ten subgenera, which remain under animated discussion.

Subgenus *Cawtoniceras* Buckman, 1923

The later whorls and body chamber are more ornamented owing to coarse primary ribs, which are widely spaced and end with distinct lateral tubercles. In passing to the venter, the second row of ventral tubercles forms, which are, as a rule, isolated from the lateral ones. Two–four secondary ribs originate from the ventral tubercles and form a slightly serrated keel. The near-keel area is poorly isolated.

Cardioceras (*Cawtoniceras*) *schellwieni* Boden, 1911
Plate 1, Figs. 7, 8

A detailed synonymy is given in (Mesezhnikov et al., 1989, p. 78).

Holotype. Described in (Boden, 1911, Table 2, Fig. 3). Papilë, Lithuania. Middle Oxfordian, Cardioceras tenuiserratum Zone.

Description. The shells are medium-sized (Table 1), of discone shape, and with a moderately narrow concave umbo. The whorl cross-section is highly oval and ornamented (keel, knobs) (Plate 1, Fig. 7d). The venter is narrow and pointed; it has ill-defined near-keel areas, changing abruptly into the wide, slightly flattened lateral sides at the apices of the ventrolateral tubercles. The umbonal walls are narrow, flattened, and sloping. In specimen no. 181/371, the body chamber occupies half a whorl ($D \approx 33$ mm); in specimen no. 181/371, it has not been preserved.

At $D = 38$ mm, *surface ornamentation* is manifested in two rows of transversely elongated tubercles (lateral, ventrolateral), which are bulges of ill-defined (reduced) primary and secondary ribs. The lateral tubercles, located in the middle of the lateral sides, are long and sparse (six on one side of the terminal half-whorl). The ventrolateral tubercles are considerably shorter and thinner; they are relicts of the bifurcating secondary ribs. Each lateral tubercle corresponds to two ventrolateral ones. The surface of the shell layer in the near-umbonal part features 6–7 fine ribs between the lateral tubercles; they form a gentle sinus and smooth out up to the middle of the lateral side. Fine ribs (three or, less often, four per tubercle) are split off from the ventrolateral tubercles; they bend far forward near the keel and thicken on the keel itself, forming ~40 keel tubercles on the terminal half-whorl. The keel is relatively high, narrow, and serrated.

On the earlier whorls, the shell surface is covered with finest dense transverse streaks, which form a shallow lateral sinus and a moderately high, slightly angular, ventral projection. At $D \approx 10$ mm, they turn into fine ribs, forming keel tubercles. At $D = 13–14$ mm, very short fine sparse (6–7 per half-whorl) primary ribs appear on the near-apertural half of the lateral side. During the ontogeny the ribs rapidly shorten, thicken, and turn into transversely elongated lateral tubercles. At $D = 16$ mm, very short and ill-defined secondary ribs

Table 1. Sizes (mm) and percentages for *Cardioceras* (*Cawtoniceras*) *schellwieni* Boden, 1911

Specimen no.	*D*	*W*	*H*	*U*	*W/D*	*H/D*	*U/D*	*W/H*
181/371	37.5	11.0	17.0	10.5	29.3	45.3	28.0	64.7
	26.6	8.5	11.3	8.2	32.0	42.5	30.8	75.2
181/371-1	27.5	8.5	11.5	8.8	30.9	41.8	32.0	73.9
	20.0	6.9	8.2	6.5	34.5	41.0	32.5	84.1
	15.8	5.5	6.3	5.2	34.8	39.9	32.9	87.3

Note. Here and in what follows: *D*, diameter; *W*, width; *H*, height; *U*, umbilicus.

Table 2. Sizes (mm) and percentages for *Cardioceras* (*Cawtoniceras*) ex gr. *blakei* Spath, 1935

Specimen no.	*D*	*W*	*H*	*U*	*W/D*	*H/D*	*U/D*	*W/H*
181/372	25.0	8.2	10.0	8.1	32.8	40.0	32.4	82.0
	19.2	6.6	7.6	6.2	34.4	39.6	32.3	86.8
	10.2	4.3	3.8	3.5	42.2	37.3	34.3	113.2

appear. During the ontogeny they rapidly strengthen and turn into ventrolateral transverse tubercles.

Comparison. This species differs from other *Cawtoniceras* species in the presence of two isolated rows of primary and secondary ribs (rib ratio 2), ending with transversely elongated tubercles.

Geologic age and geographic range. The species is widespread in Western Europe, European Russia, and northern Siberia. Middle Oxfordian, Cardioceras tenuiserratum Zone.

Material. Two well-preserved specimens, right bank of the Anabar River, 1.5 km below the Polovinnaya River mouth, outcrop 6, bed 1.

Cardioceras (*Cawtoniceras*) ex gr. *blakei* Spath, 1935
Plate 1, Figs. 4–6

Description. The shell is medium-sized (Table 2), of discone shape, and with a moderately narrow concave umbo. The whorl cross-section is highly oval. The venter is narrow and pointed. The body chamber occupies six tenths of a whorl.

Ornamentation. The terminal half-whorl ($D \sim 38$ mm) features six short thick primary ribs, beginning abruptly on the umbilical shoulder and ending abruptly in the middle of the lateral side. The ribs cross the umbonal half of the whorl radially, with a hardly visible frontal whorl in the middle. The ventral half of the whorl features the secondary ribs, which are finer and denser. They bend slightly backward and form a very high ventral projection; their ratio to the primary ones is 3–4. The venter, between the secondary ribs, sometimes features short intercalary ribs of similar thickness and shape. The secondary and intercalary ribs, when crossing the keel, form well-defined tubercles on it, and the keel is serrated owing to them.

The juvenile shell is covered with fine transverse streaks, forming a wide rounded lateral sinus and a high angular ventral projection (Plate 1, Figs. 5, 6). At $D = 11$–13 mm, the streaks become sparser and turn into fine ribs, forming thick keel tubercles on the venter (Plate 1, Fig. 5). At $D > 20$ mm, primary ribs appear.

Comparison and remarks. This species differs from the similar *C.* (*C.*) *kokeni* in the coarser ornamentation of the body chamber.

Note that the holotype *C.* (*C.*) *blakei* is represented by a small shell and considered by some researchers to be a microconch (Sykes and Callomon, 1979). The absence of images of larger specimens with a whole body chamber complicates its subgeneric assignment (Arkell, 1935–1948; Spath, 1935). However, all the researchers agreed that juvenile shells of this species (up to $D \approx 20$ mm) were smoothed.

Geologic age and geographic range. This species has a narrower geographic range than *C.* (*C.*) *schellwieni*. It was recorded only in the upper Middle Oxfordian (upper C. tenuis-erratum Zone) of Western and Eastern Europe, European Russia, and northern Siberia.

Material. One well-preserved specimen, right bank of the Anabar River, opposite Agrafena Island, outcrop 1, bed 6.

Genus *Amoeboceras* Hyatt, 1900

Identification. Cardioceratinae with a completely isolated keel, which has smooth near-keel areas and furrows on the edges. The secondary rib apices only seldom join the keel tubercles, the shell layer being well-preserved. The main characteristic of the genus *Amoeboceras* is absent connection between the secondary ribs and keel tubercles; note that the keel has smooth strips (grooves) and furrows on the sides and the keel tubercles considerably outnumber the secondary ribs.

Subgenus *Amoeboceras* s.s. Hyatt, 1900

The shells are small or medium-sized, with a gently growing spiral, subrectangular whorls, and an ornamented body chamber. Upper Oxfordian. The Late Oxfordian *Amoeboceras* s.s. are similar to the Early Kimmeridgian representatives of the subgenus *Amoebites*. The latter have fibulated ribs and a relatively coarsely serrated keel.

Amoeboceras transitorium group. Medium-sized shells with subrectangular whorl cross-sections and secondary ribs extending far along the venter. According to (Mesezhnikov et al., 1989), this group comprises *A.* (*Amoeboceras*) *transitorium* and *A.* (*A.*) *alternoides*.

Amoeboceras (*Amoeboceras*) ex gr. *alternoides* (Nikitin, 1887)
Plate 1, Figs. 1–3

Description. The shell is small and moderately wide, with a moderately narrow umbo, wide flattened lateral sides, and a flattened narrow venter, complicated by a high keel and smooth near-keel grooves.

Ornamentation. The juvenile shell ($D \leq 8$ mm) is covered with finest dense ribs, which cross the lateral side subradially and bend far forward on the venter. A wide serrated keel is pronounced already at $D = 7$–8 mm. The ventrolateral part of the whorl features fine sparse crescent-shaped ribs, whose extensions on the lateral side look like hardly visible transverse wrinkles. These ribs thicken rapidly and coarsen at $D > 10$ mm (~12 per half-whorl) (Table 3). They cross the lateral side subradially and form an elbow bend on the ventrolateral edge; afterward they bend abruptly forward, thinning and ending near the keel. Well-defined tubercles form

Table 3. Sizes (mm) and percentages for *Amoeboceras* (*Amoeboceras*) ex. gr. *alternoides* (Nikitin, 1887)

Specimen no.	*D*	*W*	*H*	*U*	*W/D*	*H/D*	*U/D*	*W/H*
181/500	14.7	5.5	6.6	3.8	37.4	44.9	25.9	83.3
	10.0	4.0	4.3	2.8	40.0	43.0	28.0	93.0

at the intersection of their extensions with the keel. Intercalary ribs are observed between the primary ones on the ventral part of the whorl and replicate their shape. The keel is high, narrow, serrated, and flanked by finest smooth grooves, which widen during further ontogeny.

Comparison and remarks. Considering the doubts about the holotype *A.* (*A.*) *alternoides* and its stratigraphic correlations, some researchers assigned this species to Lower–Middle Oxfordian *Cardioceras* (Sykes and Callomon, 1979). However, the thorough study of this species in (Mesezhnikov et al., 1989) revealed its most typical features: strong straight ribs, bending very sharply forward on the ventral whorl and extending far along the keel; the absence of isolated lateral and ventrolateral tubercles on the middle and adult whorls; ornamented body chamber. Significantly, already at D = 7–8 mm, a wide serrated keel is pronounced; over time it becomes narrow, serrated, and flanked by finest smooth grooves, which widen at the later stages. The features listed characterize the genus *Amoeboceras*, more specifically, the subgenus *Amoeboceras* s.s.

Geologic age and geographic range. This species is widespread in Western and Eastern Europe, European Russia, West Siberia, on the eastern Taimyr Peninsula, in the lower reaches of the Anabar River and Anabar Bay, and in northeastern Greenland. Upper Oxfordian, Amoeboceras glosense Zone.

Material. One well-preserved specimen; Nordvik Peninsula, Cape Urdyuk-Khaya, outcrop 33, unit 1, bottom of bed 1.

Conclusions

Although the Nordvik Peninsula reference outcrops have long been studied, it should be admitted that the level of the biostratigraphic knowledge of the Oxfordian–Kimmeridgian part of this section is not high enough. The ammonite-constrained stratigraphic position of the lower Upper Jurassic in the Cape Urdyuk-Khaya section is interpreted in two ways. According to many-year studies and our data, the lowermost Upper Jurassic section belongs to the Upper Oxfordian; other researchers (Rogov and Wierzbowski, 2009) assign it only to the Middle Oxfordian. The state of the illustrated ammonites (Rogov and Wierzbowski, 2009) casts doubt upon the identification of some species; this precludes explaining the changed stratigraphic position in the Oxfordian part of the Nordvik Peninsula section and such a detailed division into ammonite zones and subzones. The foraminiferal zones distinguished in the Upper Oxfordian and Kimmeridgian sections of the Nordvik Peninsula are well traceable circumarctically. Their stratigraphic position in various parts of the Northern Hemisphere is constrained by ammonites, bivalves, and palynomorphs. According to publications and our data, the foraminiferal assemblages of zones JF40 and JF41 in the Nordvik Peninsula section coexist with Upper Oxfordian and Kimmeridgian ammonites, bivalves, and palynomorphs; this agrees well with the data on the entire Boreal Realm. In the dinocyst assemblages from units 1 and 2 on the Nordvik Peninsula, some species first appear in various Boreal sections in the upper Upper Oxfordian, as evidenced by ammonite and bivalve finds. On the other hand, if we use the alternative ammonite zonation (Rogov and Wierzbowski, 2009) of this section part, hardly explicable contradictions will arise in interregional dinocyst correlations.

Thus, according to the above analysis, the latest ammonite zonation of the Oxfordian and Kimmeridgian sections on the Nordvik Peninsula (Rogov and Wierzbowski, 2009) contradict the previous and our ammonite data as well as biostratigraphic data on microfauna and palynomorphs. The Oxfordian and Kimmeridgian zonation of the Nordvik Peninsula can be improved provided that new field studies of this section are conducted, with the detailed bed-by-bed collection of all the fossils associated not only with selected datums but also with the standard bed boundaries.

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