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Zonal stratigraphy and biogeography of the West Siberian Oxfordian based on ammonites

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Abstract

The Oxfordian Stage of West Siberia contains Boreal ammonites Cardioceratidae. The authors' bank of paleontological data includes ~500 definitions of Cardioceratinae, permitting a considerable refinement of the official Oxfordian regional zonal scale. The lower substage is divided into the Cardioceras (Scarburgiceras) obliteratum, C. (S.) scarburgense, and C. (S.) gloriosum Zones instead of beds with *C. (S.)* spp., whereas the C. (Cardioceras) percaelatum and C. (C.) cordatum Zones are recognized instead of beds with *C.* (*C.*) spp. We have found new ammonites typical of the Middle Oxfordian C. (Subvertebriceras) densiplicatum and C. (Miticardioceras) tenuiserratum Zones. The first of these zones is divided into two subzones. The Upper Oxfordian includes the Amoeboceras glosense and A. serratum Zones instead of beds with *A.* spp., and the A. regulare Zone and beds with *A. rosenkrantzi* are recognized instead of the A. ex gr. regulare Zone. The genus *Ringsteadia* (Aulacostephanidae) is observed only in the northwestern part of the region, along the eastern slope of the North Urals; therefore, two upper units of the biostratigraphic scale correspond to beds with *Ringsteadia marstonensis*.

In the Oxfordian, West Siberia and northern Siberia belonged to the North Siberian province of the Arctic realm. Only in the latest Oxfordian did the northwestern West Siberian basin become part of the Boreal–Atlantic realm, as evidenced by the distribution of *Ringsteadia* on the eastern slope of the Cis-Polar Urals.

Keywords: biostratigraphy; ammonites; biogeographic realms; Oxfordian; West Siberia

Introduction

The authors' bank of paleontological data for wells drilled into the territory of West Siberia includes ~500 finds of Oxfordian ammonites. They all belong to the genera *Cardioceras* and *Amoeboceras*, the family Cardioceratidae. The indexes of the Lower and Middle Oxfordian are the subgenera *Cardioceras* (*Scarburgiceras*), *C.* (*Cardioceras*), *C.* (*Scoticardioceras*), *C.* (*Subvertebriceras*), *C.* (*Plasmatoceras*), *C.* (*Maltoniceras*), *C.* (*Cawtoniceras*), and *C.* (*Miticardioceras*), whereas the indexes of the Upper Oxfordian are the species of the genus *Amoeboceras* sensu stricto.

Oxfordian marine sediments are widespread throughout the West Siberian Plate. The Oxfordian Stage is part of marine formations which occur from west to east: Mauryn'ya in the Urals structure-facies zone (SFZ), Danilovskoe in the Yamal–Tyumen' SFZ, Abalak in the Kazym–Konda and Frolovskii–Tambei SFZs, Vasyugan in the Purpe–Vasyugan SFZ, and Gol'chikha in northwestern and northern West Siberia (the Nurma subzone of the Frolovskii–Tambei zone). In the Taz–Kheta region and on the northern margin of the Siberian Platform, the Oxfordian Stage belongs to the Sigovoe Formation. Owing to finds of Upper Oxfordian ammonites, part of the Barabinsk Member at the base of the Kimmeridgian Georgievka Formation was assigned to the Oxfordian. In southern West Siberia, within the transition from marine to continental sediments of the Om'–Chulym facies region, the Oxfordian sediments are part of the Naunak, Tatarskaya, and Tyazhin Formations, which consist of shallow-water marine, lagoonal, and deltaic sandstones with numerous plant remnants, carbonized plant detritus, thin coal seams, and rare marine bivalves and foraminifers (Fig. 1, Table 1) (Gurari, 2004; Shurygin et al., 2000).

Most of the Oxfordian ammonites are from the Danilovskoe, Abalak, and Vasyugan Formations.

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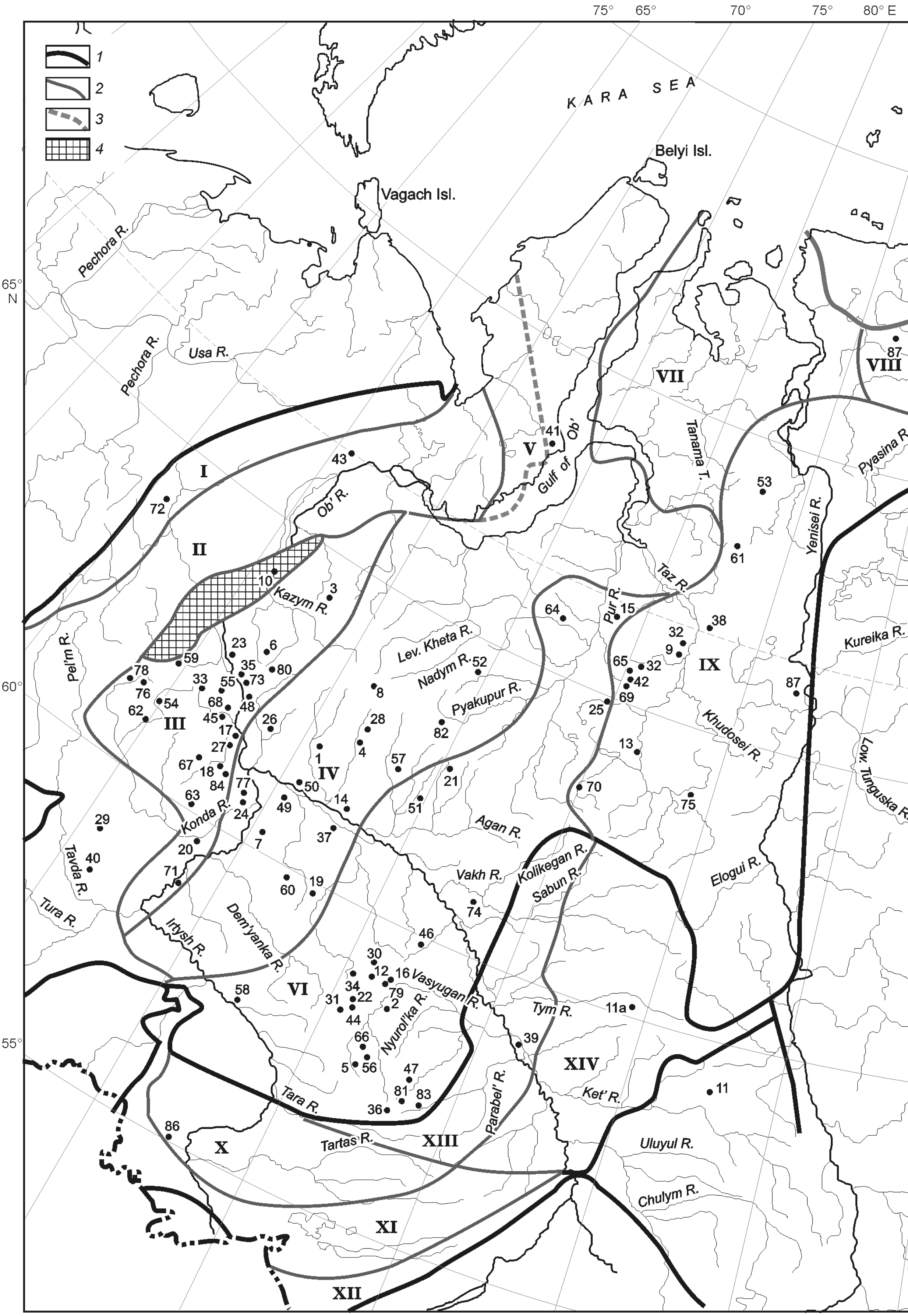
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Vagach Isl.
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Usa R.
Ob' R.
Gulf of Ob'
Kazym R.
Tanama T.
Pyasina R.
Yenisei R.
Taz R.
Pur R.
Lev. Kheta R.
Nadym R.
Pyakupur R.
Kureika R.
Khudosei R.
Low. Tunguska R.
Pel'm R.
Konda R.
Agan R.
Tavda R.
Tura R.
Vakh R.
Kolikegan R.
Sabun R.
Elogui R.
Irtysh R.
Dem'yanka R.
Vasyugan R.
Nyurol'ka R.
Tym R.
Parabel' R.
Ket' R.
Tara R.
Tartas R.
Uluyul R.
Chulym R.
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II
III
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XI
XII
XIII
XIV

Fig. 1. Structure-facies zonation of the Callovian and Upper Jurassic of West Siberia (Gurari, 2004) and the sites of the wells from which the Oxfordian ammonites mentioned in the text were defined. *1–3*, boundaries: *1*, of facies regions of marine (northern), transitional (intermediate), and continental (southern) sediment genesis; *2*, of structure-facies zones; *3*, of structure-facies subzones; *4*, pinchout of Callovian–Upper Jurassic sediments in western West Siberia. I–XIV, structure-facies zones; 1–87, wells: 1, Aipimskaya 15; 2, Aipolovskaya 1; 3, Aitorskaya 7-R; 4, Vachimskaya 8; 5, Verkhnezayach'ya 80; 6, Verkhnenazymskaya 289; 7, Verkhnesalymskaya 21; 8, Verkhnetrom"eganskaya 2008; 9, Verkhnechasel'skaya 153; 10, Voikarskaya 2; 11a, Vostok 1; 11, Vostok 3; 12, Vostochno-Ledyanaya 1; 13, Vostochno-Ninel'skaya 2; 14, Vostochno-Surgutskaya 156; 15, Vostochno-Tarkosalinskaya 72; 16, Duklinskaya 2; 17, Elizarovskaya 25, 27; 18, Em"egovskaya 4, 517; 19, Zabolotnaya 2-R; 20, Zaozernaya 2; 21, Zapadno-Kotukhtinskaya 147; 22, Zapadno-Moiseevskaya 21; 23, Zapadno-Tugrovskaya 18; 24, Zapadno-Frolovskaya 4-R, 35; 25, Iokhturskaya 527, 528; 26, It'yakhskaya 302; 27, Kamennaya 3, 11, 21-R; 28, Kamynskaya 50; 29, Karabashskaya 3; 30, Katyl'ginskaya 102; 31, Krapivinskaya 194; 32, Kynskaya 211, 216; 33, Lazarevskaya 10132; 34, Larlomkinskaya 13, 17, 18, 19; 35, Maloatlymskaya 4; 36, Maloichskaya 9; 37, Mamontovskaya 10; 38, Mangazeiskaya 5, 9; 39, Nalim'ya 1, 5; 40, Nizhnesortymskaya 208, 231; 41, Novoportovskaya 88, 82; 42, Novochasel'skaya 220; 43, Obskoi profil' 12; 44, Pavlovskaya 5; 45, Pal'yanovskaya 23, 418, 43; 46, Poselkovaya 9; 47, Puglalymskaya 90; 48, Rogozhnikovskaya 711; 49, Salymskaya 1, 11, 138; 50, Semeyarovskaya 18; 51, Srednevat'eganskaya 88; 52, Srednenadymskaya 80; 53, Sredneyarovskaya 3; 54, Symor'yakhskaya 10261, 106036; 55, Talinskaya 113; 56, Talovaya 4; 57, Tevlinsko-Russkinskaya 116; 58, Tevrizskaya 4; 59, Tugrovskaya 15, 18-R; 60, Tukanskaya 54; 61, Tukolando-Vadinskaya 320; 62, Ubinskaya 324; 63, Uraiskaya 10904; 64, Urengoiskaya 414; 65, Ust'-Chasel'skaya 198; 66, Fedyushkinskaya 2; 67, Filippovskaya 6-R; 68, Khangokurtskaya 827; 69, Kharampurskaya 308, 323, 324, 329, 332, 370; 70, Kholmistaya 328, 654, 664; 71, Cherkashinskaya 1; 72, Chuel'skaya 86; 73, Sherkalinskaya 131, 132-R; 74, Shirotnaya 53; 75, Shirtovskaya 309; 76, Shukhtungortskaya 303, 332; 77, Erginskaya 20, 28; 78, Esskaya 2; 79, Yuzhno-El'tsovaya 1; 80, Yuzhno-Ol'khovskaya 264; 81, Yuzhno-Poselkovaya 1; 82, Yuzhno-Pyakutinskaya 15; 83, Yuzhno-Tabaganskaya 135; 84, Yuzhno-Talinskaya 324; 85, Turukhanskaya 1-R; 86, Omskaya 1; 87, Dzhangodskaya 1, 2.

The Oxfordian Stage in the Danilovskoe Formation consists of finely washed mudstone-like glauconitic clays; in the Abalak Formation, of dark gray to siltstone clays with pyrite concretions; and in the Vasyugan Formation, of alternating sandstones, siltstones, and clays saturated with carbonized plant detritus. The lower (Oxfordian) part of the Sigovoe Formation and the Upper Vasyugan Subformation show lithologic similarity and correlation. It was found that the sandstone beds within the Vasyugan Formation (the group J_1), which are of interest as a hydrocarbon reservoir, have clear stratigraphic assignment. The Upper/Middle Oxfordian boundary passes beneath the bed J_1^1; the bed J_1^2 is mainly of Middle Oxfordian age; the bed J_1^3 is Early Oxfordian; and the bed J_1^4 occupies the position between Middle and Upper Callovian (Shurygin et al., 2000; Vyachkileva et al., 1990).

The collections are dominated by Lower and Middle Oxfordian subgenera and species; Upper Oxfordian ones occur considerably more rarely and are often, owing to the poor integrity of *Amoeboceras* shells, hardly distinguishable from the Kimmeridgian species of this genus.

The ammonite shells in core samples are preserved to different extents: Numerous specimens of satisfactory integrity often coexist with those definable to the species level but predominantly in open nomenclature. The currently available abundant ammonite definitions can serve as a reliable basis for the development of a zonal scale for the West Siberian Oxfordian.

Ammonite zonal scale for the West Siberian Oxfordian

The considerable similarity of the Oxfordian genera, subgenera, and species of Cardioceratidae in West Siberia and northern Siberia determined significant similarity between the zonal scales for these regions, though the official West Siberian scale is less detailed than that for East Siberia (Shurygin et al., 2000). The Oxfordian zonal scale for West Siberia is derived from the East Siberian scale, based on paleontological data from outcrops of northern Siberia and the subsequent targeted study of ammonite collections.

Isolated finds of ammonites in core samples do not make it possible to estimate the thickness of individual biostratigraphic units but only show their presence and succession in the section. Species from adjacent zones rarely coexist in the same wells; therefore, the zonal boundaries are usually tentative.

The zonation of the Oxfordian Stage within its stratotype sections in Southern England was based on ammonites from three families: Cardioceratidae for the lower substage, Perisphinctidae for the middle and upper substages, and Aulacostephanidae for the upper part of the upper substage (Krymgol'ts, 1982).

Table 1. Structure-facies zones, after (Gurari, 2004), and distribution of formations in which the Oxfordian Stage was detected

Number of the structure-facies zone	Zone; local stratigraphic unit
I	Urals; Mauryn'ya Formation
II	Yamal–Tyumen'; Danilovskoe Formation
III, IV	Kazym–Konda, Frolovskii–Tambei; Abalak Formation
V	Nurma (subzone); Nurma Formation
VI	Purpe–Vasyugan; Vasyugan Formation
VII	Gydan; Gol'chikha Formation
VIII	Taz–Kheta; Sigovoe Formation, Barabinsk Member
IX, X, XI	Omsk, Tebisskaya, Bagan; Tatarskaya Formation
XII, XIII	Sil'ga, Azharma; Naunak Formation
XIV	Chulym–Taseeva; Tyazhin Formation

However, the dramatic predominance of cardioceratidae in boreal regions, an Oxfordian zonal scale based exclusively on Cardioceratidae ammonites was developed for the sections of Scotland (isle of Skye) and East Greenland (Sykes and Callomon, 1979). This scale turned out to be applicable to the sections of Eastern Europe, northern Siberia, and West Siberia owing to similarity between ammonite subgenera and species. The latter was due to extensive Oxfordian transgression in the Northern Hemisphere and the expansion of the range of the family (Meledina and Aleinikov, 2003; Mesezhnikov et al., 1984, 1989; Vyachkileva, 1987).

The first zonal scheme for the West Siberian Oxfordian was developed with the sufficient accumulation of paleontological data (Mesezhnikov et al., 1984). The Lower Oxfordian was divided into beds with *Cardioceras* (*Scarburgiceras*), based on finds of the species *C.* (*S.*) *gloriosum* and *C.* (*S.*) *obliteratum*, and beds with *C.* (*Cardioceras*), based on the species *C.* (*C.*) *cordatum* and *C.* (*C.*) *percaelatum*.

The succession of ammonite subgenera and species in the wells coincided with that detected in the Anabar region, in which a zonal scale was developed for the Lower Oxfordian of Siberia (Knyazev, 1975). These zones were as follows (in ascending order): Cardioceras (Scarburgiceras) obliteratum, C. (S.) gloriosum, C. (Cardioceras) percaelatum, and C. (C.) cordatum.

The Middle Oxfordian in the West Siberian zonal scale included two zones: C. densiplicatum and C. tenuiserratum, whereas the Upper Oxfordian was defined as beds with *Amoeboceras* spp. (at the bottom) and the A. ravni Zone (at the top). The Kimmeridgian stage began with the Pictonia involuta Zone. In fact, the Oxfordian zonal scale for West Siberia was derived from that for northern Siberia.

The Oxfordian regional zonation was refined as the Oxfordian biostratigraphic chart was supplemented by definitions of ammonites from new wells.

Abundant additional evidence appeared for the presence of the lower part of the Lower Oxfordian, which was, as previously, defined as beds with *Cardioceras* (*Scarburgiceras*), which correspond to a sum of the C. (Scarburgiceras) obliteratum, C. (S.) scarburgense, and C. (S.) gloriosum Zones in the Siberian scale (Gurari, 2004; Shurygin et al., 2000). The lower boundary of the Oxfordian Stage is marked by the appearance of *Cardioceras* (*Scarburgiceras*), *Pavloviceras*, and *Goliathiceras*, which replace the Upper Callovian genera of Cardioceratidae: *Longaeviceras*, *Eboraciceras*, and *Quenstedtoceras*.

Judging by ammonites from different wells, the section contains analogs of both *Scarburgiceras* zones (Fig. 2). **The C. (S.) obliteratum—C. (S.) scarburgense Zone** is indicated by definitions of index species, though tentative, in the following wells: Urengoiskaya 414 (depth 3571 m), Talinskaya 113 (depth 2518.9 m), Vachimskaya 8 (depth 2688.88 m (Vyachkileva et al., 1990, Plate 46, fig. 1)), Zapadno-Tugrovskaya 18 (depths 2165.6 and 2166.6 m (Meledina, 1998, Plate 2, fig. 9)), Novoportovskaya 82 (interval 2039–2049 m), and Srednenadymskaya 80 (depth 3464.5 m). Also, the species *C.* (*S.*) *alphacordatum* Spath is typical of the lower Oxfordian in northern Siberia and West Siberia: the Zapadno-Frolovskaya 4-R (depth 2799.2 m (Vyachkileva et al., 1990, Plate 46, fig. 3)), Urengoiskaya 414 (depth 3571 m), Vostochno-Surgutskaya 28 (depth 2870.05 m (Vyachkileva et al., 1990, Plate 46, fig. 5)), Nizhnesortymskaya 231 (depth 2991.5 m (Braduchan et al., 1984, Table I)), Mezhdurechenskaya 10 (depth 2652.1 m), Zaozernaya 2 (depth 2752 m), Yuzhno-Pyakutinskaya 15 (depth 2652.1 m), and Srednevat'eganskaya 88 (depth 3131.35 m (Vyachkileva et al., 1990, Plate 46, fig. 6)) wells.

The C. (Scarburgiceras) gloriosum Zone, which overlies the lowermost Oxfordian, is defined from finds of the following species: *Cardioceras* (*S.*) *praecordatum* (Douv.) in the Urengoiskaya 414 (depth 3571 m), Kamennaya 11 (depth 2406.8 m), Tugrovskaya R-18 (depth 2165.1 m (Levchuk et al., 2000, Plate, fig. 9), depth 2168.71 m (Levchuk et al., 2000, Plate, fig. 2)), Talinskaya 113 (depth 2518.9 m (Vyachkileva et al., 1990, Plate 46, fig. 2)), Uraiskaya 10904 (depth 2135.1 m) wells and *C.* (*S.*) *gloriosum* Arkell in the Em"egovskaya 4 (depth 2331.9 m (Vyachkileva et al., 1990, Plate 46, fig. 7)), Em"egovskaya 517 (depth 2414 m (Vyachkileva et al., 1990, Plate 46, fig. 8)), Pal'yanovskaya 43 (depth 2477.5 m (Vyachkileva et al., 1990, Plate 46, fig. 4)), Yuzhno-Pyakutinskaya 15 (depth 2652.3 m) wells. Along with the genus *Cardioceras*, the presence of the C. (S.) gloriosum Zone in the beds with *C.* (*Scarburgiceras*) spp. is also indirectly evidenced by *Goliathiceras* (*Korythoceras*) cf. *rotundum* Nik. in the Elizarovskaya 25 well (depth 2459 m (Vyachkileva et al., 1990, Plate 46, fig. 21)) and *Goliathiceras* sp. ind. in the Yuzhno-Talinskaya 324 (depth 2576.75 m), Tevlinsko-Russkinskaya 116 (depth 2880.2 m) wells and in the Khanty-Mansiiskaya, Urengoiskaya, and Novoportovskaya areas (in the East European Platform, *Goliathiceras* occur throughout the Lower Oxfordian).

The lower Lower Oxfordian can be clearly divided into two zones in the Yuzhno-Konitlorskaya 101 well: The interval 2967.35–2971 m at different levels contains *Cardioceras* (*Scarburgiceras*) cf. *scarburgense* (Y.et B.) (Plate 1, fig. 4), *C.*(*S.*) sp. ind., and *Pavloviceras* ex gr. *omphaloides* (Sow.) (Plate 1, fig. 11), i.e., genera and species from the lowermost Oxfordian, whereas from 2966.5 to 2964 m, only *C.* (*Scarburgiceras*) cf. and ex gr. *gloriosum* Arkell (Plate 1, fig. 3) are observed. Although part of the definitions of the Lower Oxfordian ammonites do not permit species identification, the beds with *C.* (*Scarburgiceras*) can be divided into two zones analogous to those in the Lower Oxfordian of northern Siberia: **the C. (Scarburgiceras) obliteratum—C. (S.) scarburgense** and **the C. (S.) gloriosum Zones**. The same zones are present in the Boreal standard (Nikitenko et al., 2013).

A more detailed division is possible for a higher part of the Lower Oxfordian—beds with *Cardioceras s. str.*, which correspond to two Siberian zones: **the C. (Cardioceras) percaelatum** and **C. (C.) cordatum Zones.** The number of species definitions is enough for detecting individual zones which should be included in the regional scale.

The definitions often include the easily identifiable zonal index species *C.* (*C.*) *percaelatum*: the Lazarevskaya 10132

<table>
<tr><th>Stage</th><th>Substage</th><th>Boreal ammonite standard (Nikinenko et al., 2013; Shurygin et al., 2013)</th><th colspan="2">Northern Siberia (Nikitenko et al., 2013)</th><th colspan="2">West Siberia (Gurari, 2004)</th><th colspan="2">West Siberia, authors' version</th></tr>
<tr><td>Kimmer.</td><td>Lower</td><td>Amoeboceras (Amoebites) kitchini</td><td colspan="2">Amoeboceras (Amoebites) kitchini</td><td colspan="2">Amoeboceras (Amoebites) kitchini</td><td colspan="2">Amoeboceras (Amoebites) kitchini</td></tr>
<tr><td rowspan="10">Oxfordian</td><td rowspan="4">Upper</td><td>Amoeboceras rozenkrantzi</td><td rowspan="2">Amoeboceras ravni</td><td>Amoeboceras rozenkrantzi</td><td rowspan="2">Ringsteadia pseudocordata</td><td rowspan="2">Amoeboceras ex gr. regulare</td><td rowspan="2">Beds with Ringsteadia marstonensis</td><td>Beds with Amoeboceras rozenkrantzi</td></tr>
<tr><td>Amoeboceras regulare</td><td>Amoeboceras regulare</td><td>Amoeboceras regulare</td></tr>
<tr><td>Amoeboceras serratum</td><td colspan="2">Amoeboceras serratum</td><td colspan="2" rowspan="2">Beds with Amoeboceras spp.</td><td colspan="2">Amoeboceras serratum</td></tr>
<tr><td>Amoeboceras glosense</td><td colspan="2">Amoeboceras glosense/ Amoeboceras alternoides</td><td colspan="2">Amoeboceras glosense</td></tr>
<tr><td rowspan="2">Middle</td><td>Cardioceras tenuiserratum</td><td colspan="2">Cardioceras tenuiserratum</td><td colspan="2">Cardioceras tenuiserratum</td><td colspan="2">Cardioceras tenuiserratum</td></tr>
<tr><td>Cardioceras densiplicatum</td><td colspan="2">Cardioceras densiplicatum</td><td colspan="2">Cardioceras densiplicatum</td><td>Cardioceras densipli-catum</td><td>C. (Maltoniceras) maltonense
C. (Vertebriceras) vertebrale</td></tr>
<tr><td rowspan="4">Lower</td><td>Cardioceras cordatum</td><td colspan="2">Cardioceras cordatum</td><td colspan="2" rowspan="2">Beds with Cardioceras (Cardioceras) spp.</td><td colspan="2">Cardioceras cordatum</td></tr>
<tr><td>Cardioceras percaelatum</td><td colspan="2">Cardioceras percaelatum</td><td colspan="2">Cardioceras percaelatum</td></tr>
<tr><td>Cardioceras gloriosum</td><td>Cardioceras gloriosum</td><td>C. gloriosum
C. praecordatum</td><td colspan="2" rowspan="2">Beds with Cardioceras (Scarburgiceras) spp.</td><td colspan="2">Cardioceras (Scarburgiceras) gloriosum</td></tr>
<tr><td>Cardioceras obliteratum, Cardioceras scarburgense</td><td colspan="2">Cardioceras obliteratum, Cardioceras scarburgense</td><td colspan="2">Cardioceras (Scarburgiceras) obliteratum – scarburgense</td></tr>
</table>

Fig. 2. Zonation of the West Siberian Oxfordian and correlation with the Boreal standard.

(depths 2051.2, 2051.1, and 2052.7 m), Aitorskaya 7-R (depth 2413 m (Vyachkileva et al., 1990, Plate 46, fig. 9)), Elizarovskaya 25-R (depth 2459.4, 2460 (Biostratigraphic, 1977, Table X), Salymskaya 1 (depth 2888.6 m), Salymskaya 11-R (depth 2886.4 m (Vyachkileva et al., 1990, Plate 46, fig. 10)), Yuzhno-Ol'khovskaya 264 (depth 2772.39 m, Plate 1, fig. 1), Filippovskaya 6-R (depth 1970.5 m (Biostratigraphic, 1977, Table X)), Fedyushkinskaya 2 (depth 2874 m), Chuel'skaya 86-R (interval 1633.1–1636.6 m (Biostratigraphic, 1977, Table X)), Krapivinskaya 199 (depth 2667.6 m), Zaozernaya 2 (depths 2752.4 and 2752 m, Plate, fig. 8), Shukhtungorskaya 303 (depth 1785.7 m), and Shukhtungorskaya 332 (depth 1785.75 m) wells. The species *C.* (*C.*) *cordatum* (Sow.), which characterizes the following zone, is described in the Zapadno-Moiseevskaya 21 (depth 2689.4 m), Aipimskaya 15 (depth 2941.8 m (Vyachkileva et al., 1990, Plate 46, fig. 20)), Elizarovskaya 27 (interval 2450.6–2458 m), Zabolotnaya 2-R (interval 3006–3017 m (Biostratigraphic, 1977, Table X)), Kamennaya 3 (depth 2392.9 m (Vyachkileva et al., 1990, Plate 46, fig. 12)), Karabashskaya 3 (depth 1872.5 m (Vyachkileva et al., 1990, Plate 46, fig. 14)), Erginskaya 20 (depth 2790.7 m), Sherkalinskaya 131 (depth 2206.9 m (Vyachkileva et al., 1990, Plate 46, fig. 16)), Verkhnenazymskaya (central) 13 (depth 2617 m), Semeyarovskaya 18 (depth 2846.8 m), Tykanskaya 54 (depth 2923.45 m (Vyachkileva et al., 1990, Plate 46, fig. 15)), Yuzhno-Poselkovaya 1 (depth 2821.8 m (Vyachkileva et al., 1990, Plate 46, fig. 13)), Larlomkinskaya 13 (depth 2535.9 m), 18 (depth 2526.6 m), Nalim'ya 5 (depth 2896 m), Pal'yanovskaya 418 (depth 2349.1 m (Vyachkileva et al., 1990, Plate 46, fig. 18)), and Ubinskaya 10052 (depth 1874.6 m) wells.

The current zonation of the Middle and Upper Oxfordian in the Boreal Jurassic was developed under the influence of the biostratigraphic views of English authors on sections of Scotland and East Greenland (Birkelund and Callomon, 1985; Sykes and Callomon, 1979). Actually, the sections in Scotland (Isle of Skye) and East Greenland were acknowledged as stratotype sections of two upper substages of the Boreal Oxfordian, and the zonal scale of the Middle and Upper Oxfordian, developed by R.M. Sykes and J.H. Callomon, was

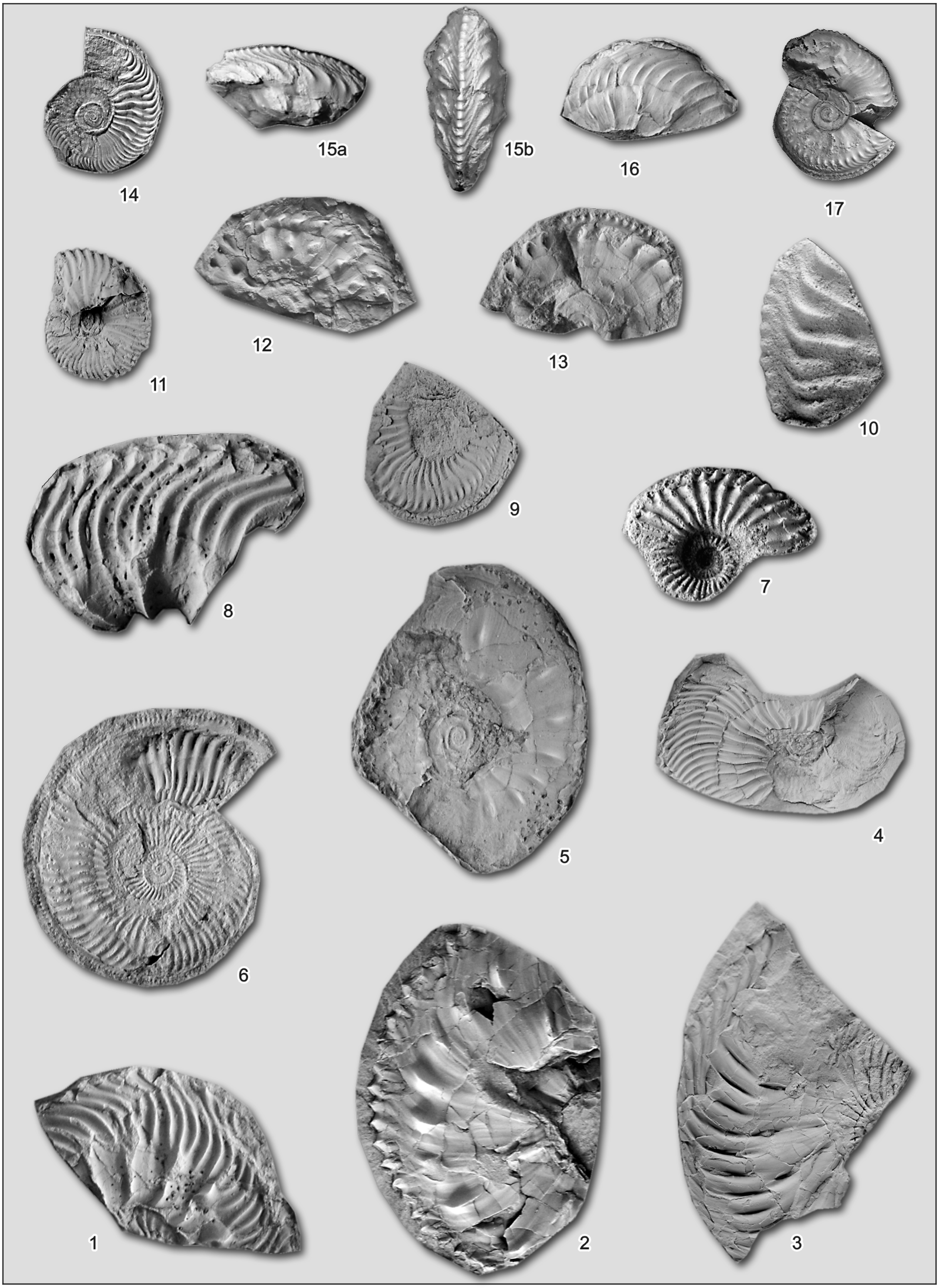
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Plate 1.

Fig. 1. *Cardioceras* (*Cardioceras*) *percaelatum* Pavlow. Specimen no. 2050-1, the Yuzhno-Ol'khovskaya 264, interval 2770–2778 m, depth 2772.39 m, Lower Oxfordian, the Cardioceras percaelatum Zone.

Fig. 2. *Cardioceras* (*Maltoniceras*) cf. *maltonense* (Yong et Bird). Specimen no. 2050-2, the Zaozernaya 2 well, interval 2740–2751.5 m, depth 2747.1 m, Middle Oxfordian, the Cardioceras densiplicatum Zone.

Fig. 3. *Cardioceras* (*Scarburgiceras*) cf. *gloriosum* Arkell. Specimen no. 2050-3, the Yuzhno-Konitlorskaya 101 well, interval 2964–2971 m, depth 2966.5 m, Lower Oxfordian, the Cardioceras gloriosum Zone.

Fig. 4. *Cardioceras* (*Scarburgiceras*) cf. *scarburgense* (Yong et Bird.). Specimen no. 2050-4, the Yuzhno-Konitlorskaya 101 well, interval 2964–2971 m, depth 2967.35 m, Lower Oxfordian, the Cardioceras obliteratum—scarburgense Zone.

Fig. 5. *Cardioceras* (*Maltoniceras*) cf. *bodeni* Maire. Specimen no. 2050-5, the It'yakhskaya 302 well, interval 2724–2732 m, depth 2725.2 m, Middle Oxfordian, the Cardioceras tenuiserratum Zone.

Fig. 6. *Amoeboceras* cf. *rosenkrantzi* Spath. Specimen no. 2050-6, the Mangazeiskaya 9 well, interval 3465–3479 m, depth 3467.6 m, Upper Oxfordian, beds with *Amoeboceras rosenkrantzi*.

Fig. 7. *Cardioceras* (*Subvertebriceras*) *densiplicatum* Boden. Specimen no. 2050-7, the Duklinskaya 2 well, interval 2614.6–2620.5 m, depth 2616.6 m, Middle Oxfordian, the Cardioceras densiplicatum Zone.

Fig. 8. *Cardioceras* (*Cardioceras*) *percaelatum* Pavlow. Specimen no. 2050-8, the Zaozernaya 2 well, interval 2751.5–2756.5 m, depth 2752 m, Lower Oxfordian, the Cardioceras percaelatum Zone.

Fig. 9. *Amoeboceras* cf. *rosenkrantzi* Spath. Specimen no. 2050-9, the Symor'yakhskaya 10636 well, interval 2025–2035 m, depth 2034.7 m, Upper Oxfordian, beds with *Amoeboceras rosenkrantzi*.

Fig. 10. *Cardioceras* sp. ind. Specimen no. 2050-10, the Puglalymskaya 90 well, interval 2451.9–2456.2 m, depth 2554.4 m, Lower–Middle (the densiplicatum Zone) Oxfordian.

Fig. 11. *Pavloviceras* ex gr. *omphaloides* (Sowerby). Specimen no. 2050-11, the Yuzhno-Konitlorskaya 101 well, interval 2964–2971 m, depth 2969.9 m, Lower Oxfordian, the Cardioceras obliteratum—scarburgense Zone.

Fig. 12. *Cardioceras* (*Maltoniceras*) cf. *schellwieni* Boden. Specimen no. 2050-12, the It'yakhskaya 302 well, interval 2724–2732 m, depth 2728.9 m, Middle Oxfordian, the Cardioceras tenuiserratum Zone.

Fig. 13. *Cardioceras* (*Cawtoniceras*) cf. *kokeni* Boden. Specimen no. 2050-13, the Rogozhnikovskaya 711 well, interval 2571–2585 m, depth 2575.4 m, Middle Oxfordian, the Cardioceras tenuiserratum Zone.

Fig. 14. *Cardioceras* (*Scoticardioceras*) cf. *exavatum* (Sowerby). Specimen no. 2050-14, the Kaimysovskaya 1 well, interval 2662.2–2669.2 m, depth 2668.9 m, Middle Oxfordian, the Cardioceras densiplicatum Zone.

Fig.15. Cardioceras (Subvertebriceras) ex gr. densiplicatum Boden. Specimen no. 2050-15: 15a, side view; 15b, ventral view; the Larlomkinskaya 19 well, interval2513.72521.4m, depth2517.7m, Middle Oxfordian, the Cardioceras densiplicatum Zone.

Fig.16. Cardioceras cf. bodeni Maire. Specimen no.2050-16, the Kaimysovskaya 1 well, interval2669.22675.4m, depth2669.45m, Middle Oxfordian, the Cardioceras densiplicatum Zone, the ?C. (Maltoniceras) maltonense Subzone.

Fig.17. Cardioceras (Subvertebriceras) ex gr. zenaidae Ilovaisky. Specimen no. 2050-17, the Larlomkinskaya 19 well, interval2513.72521.4m, depth2514.6m, Middle Oxfordian, the Cardioceras densiplicatum Zone, the ?C. (Maltoniceras) maltonense Subzone—the C. tenuiserratum Zone.

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included in the Boreal standard (Shurygin et al., 2011; Zakharov et al., 1997, 2005). The West Siberian zonal scale for the Middle Oxfordian was developed owing to data from core studies (predominantly from western and southeastern areas). It was shown that the same zones can be recognized in West Siberia as in northwestern Europe, and even tentative subzonation was carried out (Mesezhnikov et al., 1984; Nesterov, 1991; Vyachkileva, 1987).

The Cardioceras densiplicatum and **C. tenuiserratum Zones** were distinguished in the Middle Oxfordian. The first one contains the species *C.* (*Subvertebriceras*) and *C.* (*Plasmatoceras*) (in the upper part, *C.* (*Maltoniceras*)), and the upper zone contains *C.* (*Maltoniceras*) and *C.* (*Miticardioceras*), transferred from the lower zone. The C. densiplicatum Ammonite Zone is divided into two parts corresponding to subzones in English publications: C. (Vertebriceras) vertebrale and C. (M.) maltonense. The upper zone has recently been confirmed by numerous finds of ammonites in some wells.

It was noticed (Vyachkileva, 1987) that fine-ribbed and fine-streaked *Plasmatoceras* shells are more often observed in the clayey rocks of the Abalak Formation than coarse-ribbed *Vertebriceras* and *Subvertebriceras* shells. Also, Sykes and Callomon (1979) pointed out the predominance of *Plasmatoceras* in clayey facies and that of *Vertebriceras* and *Subvertebriceras* in sandy facies.

By the presence of the index species *C.* (*Subvertebriceras*) *densiplicatum*, the C. (Subvertebriceras) densiplicatum Zone was defined in the following wells: Yuzhno-Talinskaya 324 (depth 2558.3 m), Tugrovskaya 15 (depth 2207.9 m (Levchuk et al., 2000, Plate, fig. 14)), Khangokurtskaya 827 (interval 2266–2271 m (Vyachkileva, 1987)), Nizhnesortymskaya 208 (depth 2931 m (Vyachkileva et al., 1990, Plate 47, fig. 6)), Poselkovaya 9 (depth 2673.4 m), Duklinskaya 2 (2614–2620.5 m, Plate 1, fig. 7), Duklinskaya 1 (depths 2592.5 and 2533.5 m), Glukharinaya 2 (depth 2579 m), Larlomkinskaya 19 (depth 2517.7 m, Plate, fig. 15), and Esskaya 2 (interval 1691–1694.5 m (Biostratigraphic, 1977, Table X)). This zone is considerably more often detected from finds of the subgenus *Plasmatoceras*, including the species *C.* (*P.*) *tenuicostatum* Nik. in the following wells: Tukolando-Vadinskaya 320 (depth 4249.2 m), Nalim'ya 1 (depth 2885.8 m), Elizarovskaya 25 (interval 2452–2458 m (Vyachkileva, 1987)), Elizarovskaya 30 (interval 2525–2533 m (Vyachkileva, 1987)), Maloatlymskaya 4 (depth 2449 m), Tugrovskaya 15 (depth 2209.6 m (Levchuk et al., 2000, Plate, fig. 15), depth 2207.9 m (Levchuk et al., 2000, Plate, fig. 16)), Sherkalinskaya 132-R (interval 2134–2141 m (Vyachkileva, 1987)), and Aipolovskaya 1 (depth 2810.3 m). Also, *C.* (*Plasmatoceras*) *salymensis* Popl. was found in the Salymskaya 11-R (depth 2886.1 m (Biostratigraphic, 1977, Table X)), Elizarovskaya 25 (depth 2452.6 m), and Ubinskaya 324-R (depth 1880.25 m (Vyachkileva, 1987)) wells; *C*. (*P*.) cf. *bodylevskii* Knjazev, in the Erginskaya 20 (depth 2790.2 m) and Tugrovskaya 15 (depths 2209.6 and 2207.9 m (Levchuk et al., 2000, Plate, figs. 12, 13)) wells; *C*. (*P*.) *tenuistriatum* Boris., in the Tugrovskaya 15 (depth 2209.6 m (Levchuk, 2000, Plate, figs. 11, 17)) and Sherkalinskaya 131-R (depth 2205.9 m (Vyachkileva et al., 1990, Plate 47, fig. 11)) wells.

According to N.P. Vyachkileva (1987), who tentatively divided the C. densiplicatum Zone in West Siberia into two parts, the lower part of the zone (the C. vertebrale Subzone) is indicated by the presence of Lower Oxfordian *C*. (*Scoticardioceras*) species, including *C*. (*S*.) *excavatum* (Sow.): the Kamennaya 21-R (interval 2407–2411 m), Kamennaya 3 (interval 2407–2414 m), Verkhnetrom"eganskaya 2008 (depth 3102.5 m), Sherkalinskaya 23 (interval 2842–2849 m), Sherkalinskaya 132-R (interval 2134–2141 m), Erginskaya 28 (interval 2815–2825 m), Mamontovskaya 10 (interval 2899–2909 m), Kamynskaya 50 (depths 2892.6 and 2892.8 m), and Kaimysovskaya 1 (depth 2668.9 m, Plate 1, fig. 14).

The presence of the subgenus *C*. (*Maltoniceras*), which appears in the upper part of the lower zone and persists in the upper Middle Oxfordian, can be viewed as an index of the upper part (the C. maltonense Subzone) in the C. densiplicatum Zone if the subgenus coexists with other species typical of this zone. The fact that the vertical range of *Maltoniceras* goes beyond one zone reduces the importance of the subgenus for accurate age determination if core samples contain only *Maltoniceras*. The upper subzone of the C. densiplicatum Zone was detected in the following wells from finds of *C*. (*Maltoniceras*) close to *C*. (*M*.) *highworthensis* Arkell: Symor'yakhskaya 10261 (depth 2063.1 m), Katylginskaya 102 (depth 2650.8 m), Em"egovskaya 517 (depth 2409.05 m (Vyachkileva et al., 1990, Plate 47, fig. 1)), Elizarovskaya 30 (interval 2525–2533 m (Vyachkileva, 1987)), and Erginskaya 28 (interval 2815–2825 m). The species *C*. (*M*.) cf. *bodeni* Maire was defined in the Severo-Danilovskaya 10009 (depths 1752.7 and 1753 m), Tugrovskaya 15 (depth 2209.6 m (Levchuk et al., 2000, Plate, fig. 10)), Kaimysovskaya 1 (depth 2669.45 m), and Maloatlymskaya 4 (depth 2444.1 m) wells. The species *C*. (*M*.) *schellwieni* Boden was found in the Larlomkinskaya 18 (depth 2526 m), Nalim'ya 1 (depth 2885.4 m), and Yuzhno-El'tsovskaya 1 (depth 2572 m) wells, whereas *C*. (*M*.) cf. *maltonense* (Y. et B.) was observed in the Vostochno-Ledyanaya 1 (depth 2706 m) well.

The possibility of dividing the C. densiplicatum Zone into two subzones was confirmed by the vertical distribution of some species in the It'yakhskaya 302 well, interval 2729.3–2730.7 m: *C*. (*Subvertebriceras*) cf. *densiplicatum* Boden, C. (S.) sp., *C*. (*Plasmatoceras*) cf. *tenuistriatum* Boris., and *C*. (*P*.) cf. *subtenuicostatum* Nik. (the vertebrale Subzone); higher, within the interval 2728.9–2725.2 m: *C*. (*Maltoniceras*) cf. *schellweni* Boden (Plate 1, fig. 12), *C*. (*M*.) cf. *bodeni* Maire (Plate 1, fig. 5), and *C*. (*M*.) sp. *C*. (*Scoticardioceras*) cf. *excavatum* (Sow.) (the maltonense Subzone). The maltonense Subzone was detected in the Zaozernaya 2 well (interval 2740–2751.5 m) from *C*. (*M*.) cf. *maltonense* (Y. et B.) (depth 2747.1 m, Plate 1, fig. 2), *C*.(*M*.) cf. *schellweni* Boden (depth 2747.6 m), and *C*. (*M*.) sp. ind. (depth 2747 m) and in the Pal'yanovskaya 418 well from *C*. (*M*.) ex gr. *schellweni* Boden (depth 2347.1 m). In the same well, the lower part of the densiplicatum Zone with *C*. (*Plasmatoceras*) cf. *popilaniense* Boden (depth 2349.1 m; previously (Vyachkileva et al., 1990, Plate 46, fig. 18), the specimen was erroneously defined as *C*. ex gr. *cordatum*). Specimens of *C*. (*Maltoniceras*) of uncertain species assignment were recorded in the Kamynskaya 48 (interval 2870–2878 m (Vyachkileva, 1987)) and Pal'yanovskaya 418 (interval 2343–2360 m (Vyachkileva, 1987)) wells.

The C. tenuiserratum Zone was detected in few wells. Its lower boundary in the Middle Oxfordian can be determined from finds of *Cardioceras* (*Miticardioceras*). Of the subgenera and species which characterize this zone in Scotland and European Russia, the West Siberian wells contain only a small number of specimens of *Miticardioceras* and *Maltoniceras* and some specimens of *C*. (*Subvertebriceras*) *zenaidae* Ilov., which occur mainly in the lower part of the zone. Paleontologic evidence for the presence of this zone is provided by the following wells: Yuzhno-Tabaganskaya 135 (depth 2610 m (Vyachkileva et al., 1990, Plate 47, fig. 12)), Kamennaya 201 (depth 2455.01 m (Vyachkileva et al., 1990, Plate 47, fig. 7)), Verkhnesalymskaya 21 (depth 2946.2 m (Vyachkileva et al., 1990, Plate 47, fig. 4]), Katylginskaya 102 (depth 2650.8 m (Vyachkileva et al., 1990, Plate 47, fig. 2)), Tevrizskaya 4 (depth 2365.25 m (Vyachkileva et al., 1990, Plate 47, fig. 3)), and Erginskaya 28 (depth 2817.2 m (Vyachkileva et al., 1990, Plate 47, fig. 4)). Reliable finds of *C*. (*Cawtoniceras*), which determine the appearance of the upper subzone in the C. tenuiserratum Zone, Scotland, are rare in West Siberia.

Additional data have recently been obtained on the composition of ammonites and their distribution in the upper Middle Oxfordian. The species *C*. (*Cawtoniceras*) *kokeni* Boden (depth 2579.6 m) was found in the Severo-Tambaevskaya 2 well, whereas *C*. sp. (cf. *kokeni*) was observed in the Em"egovskaya 517 and Erginskaya 28 wells (intervals 2409–2421 and 2818.3 m, respectively). In the Rogozhnikovskaya 711 well, *C*. (*Cawtoniceras*) cf. *kokeni* Boden (Plate 1, fig. 13) and *C*. (?*Cawt*., ?*Malt*.) (depth 2575.4 m) were defined, which characterize the upper part of the C. tenuiserratum Zone, whereas its lower part was confirmed by finds of *C*. (*Scoticardioceras*) cf. *excavatum* (Sow.) (depth 2579.5 m) and *C*. (?*Subvert*.) sp. (depth 2580.2 m). Also, the following species were found at different levels: *C*. (*Subvert*.) ex gr. *densiplicatum* (depth 2579.65 m), *C*. (*Scoticard*.) cf. *popilaniense* Boden, sp. juv. (depth 2578.3 m), and *C*. (*Cawtoniceras*) cf. *intercalatum* Arkell (depth 2578.45 m). The species *C*. (*Subvertebriceras*) *zenaidae* Ilov., widespread in the East European Platform in the upper part of the C. densiplicatum Zone—lower part of the C. tenuiserratum Zone, was defined from the following wells: Zapadno-Kotukhtinskaya 147 (depth 2982 m), Kamennaya 201 (depth 2455.1 m (Vyachkileva et al., 1990, Plate 47, fig. 7)), Larlomkinskaya 19 (depth 2514.6 m, Plate 1, fig. 17), Larlomkinskaya 17 (depth 2501.3 m), and Maloatlymskaya 4 (depth 2443 m).

Thus, abundant evidence has been obtained for the presence not only of the C. tenuiserratum Zone as a whole but also, sometimes, of its upper and lower parts. *Cardioceras* subgenera and species and the pattern of their distribution in the tenuiserratum Zone of the Middle Oxfordian show almost total coincidence in West Siberia and Scotland.

The Middle/Upper Oxfordian boundary is characterized by the disappearance of *Cardioceras* and the appearance of the genus *Amoeboceras* of the *A. glosense* group, which marks off an important stage in the evolution of cardioceratids. In Southern England (Subboreal Oxfordian standard), the genus *Amoeboceras* appears already in the upper part of the pumilis Zone of the Middle Oxfordian (Sykes and Callomon, 1979). Therefore, the correlation between the Middle/Upper Oxfordian boundary and the appearance of *Amoeboceras*, which is accepted for the Boreal Oxfordian, is somewhat tentative in the case of correlation with the standard. This boundary was detected in the Abalak and Vasyugan Formations in the Kamynskaya and Zaozernaya areas (Vyachkileva, 1987). The lower Upper Oxfordian was defined in the West Siberian zonal scale as beds with *Amoeboceras* spp., because reliable species definitions were rare and isolated. The beds with *A.* spp. correspond to the A. glosense and A. serratum Zones in the Boreal standard and to the A. alternoides and A. serratum Zones in the regional scale for the East European Platform (Mesezhnikov et al., 1989) (or, in a more recent version, to the A. glosense and A. serratum Zones (Glowniak et al., 2010)).

As one can see, the zonal indices used in the regional charts are not always the same, but zonal correlations, including those with the Boreal standard, which reflects the zonal succession for Scotland, are usually not problematic. The A. regulare Zone and beds with *A. rosenkrantzi* (Meledina and Aleinikov, 2003) were found higher than the A. serratum Zone in the type section of the Siberian Oxfordian (on the eastern Taimyr Peninsula). Also, both biostratigraphic units were detected on the Nordvik Peninsula (Nikitenko et al., 2013; Rogov and Wierzbowski, 2009). Finally, there are reasons to recognize two zones—**the A. glosense** and **A. serratum**—in West Siberia instead of beds with *A.* spp.

The Amoeboceras glosense Zone (Upper Oxfordian) is detected from the species *A. glosense* (Bigot et Brasil) in the Novoportovskaya 88 (depth 2008.8 m (Vyachkileva et al., 1990, Plate 48, fig. 4)) and Salymskaya 138 (depth 2887.2–2894.0 m) wells; *A.* cf. *alternoides* (Nik.) in the following wells: Sredneyarovskaya 3 (depth 3251.8 m (Vyachkileva et al., 1990, Plate 48, fig. 1)), Kharampurskaya 324 (depth 2980.5 m (Vyachkileva et al., 1990, Plate 48, fig. 2)), Kharampurskaya 344 (depth 2967.6 m), Verkhnezayach'ya 80 (depth 2684.9 m), Krapivinskaya 194 (depth 2692.95 m), Cherkashinskaya 1 (depth 2318.45 m (Vyachkileva et al., 1990, Plate 48, fig. 2)); *A.* ex gr. *alternans* (Buch) in the Maloichskaya 9 well (depth 2529.6 m (Vyachkileva et al., 1990, Plate 48, fig. 6)); and *A.* ex gr. *glosense* in the following wells: Kharampurskaya 328, Kharampurskaya 329, Kharampurskaya 323 (depths 2872.2, 2949.5, and 2862.8 m, respectively), Kholmistaya 654, Kholmistaya 664 (depths 3004.8 and 2911.5 m), Iokhturskaya 527 (depth 3005.5 m), and Puglalymskaya 90 (interval 2451.9–2456.2 m, Plate 1, fig. 10). The glosense and alternoides Zones are detected from the species *A. ilovaiskii* (M. Sok.), which is the index species of the lower subzone of the glosense Zone. This species was also found in West Siberia in the Severo-Yulzhavskaya 2 (depth 2685.2 m), Vostochno-Ninel'skaya 2 (depth 2928 m), Pavlovskaya 5 (depths 2604.2 and 2604.1 m), and Shirotnaya 53 (depth 2642.8 m) wells.

The Amoeboceras serratum Zone (Upper Oxfordian) in Scotland is defined by few *Amoeboceras* species. It includes the index species *A. koldeweyense* Sykes et Call., *A. mansoni* Prinle, *A.* cf. *schulginae* Mesezhn., and *A. freboldi* Spath (Sykes and Callomon, 1979). In the East European Platform, along with the first three species, it includes *A. ovale* (Qu.) and *A. tuberculatoalternans* (Nik.) (Mesezhnikov et al., 1989), though the presence of the last species at this stratigraphic level has not been confirmed (Glowniak et al., 2010).

In West Siberia, **the A. serratum Zone** was detected only in the Kharampurskaya 308 well (depth 2914 m (Vyachkileva et al., 1990, Plate 48, fig. 11)) from the species *A.* sp. cf. *serratum* (Sow.). Also, some species are observed which occur outside the serratum Zone. For example, *A. damoni* Spath is found from the upper part of the glosense Zone to the lower part of the serratum Zone, whereas *A. leucum* Spath is found in the upper half of the serratum Zone—the lower part of the higher A. regulare Zone. The presence of only these species in core samples, not confirmed by coexistence with species typical of the adjacent zones, might be interpreted as an index of the serratum Zone. The first of these species (and only this species) was defined in the Kharampurskaya 370 (depth 3065 m) and Kharampurskaya 329 (depth 2947.4 m) wells. The species *A.* ex gr. *leucum* Spath was found in the Vostochno-Tarkosalinskaya 72 well (depth 3407.65 m), 5.6 m lower than *A.* cf. *rosenkrantzi*.

The upper Upper Oxfordian was recognized both in northern Siberia and West Siberia as the single Amoeboceras ravni Zone (Nesterov, 1991; Shurygin et al., 2000). Later, it was decided to recognize beds with *A.* ex gr. *regulare* in West Siberia, because the species *A. ravni* Spath is unknown in this region, whereas *A. regulare* Spath and similar species were repeatedly present among definitions from wells (Gurari, 2004). The A. ravni Zone, detected near the Boyarka River (Mesezhnikov, 1967), was correlated with the Ringsteadia pseudocordata Zone on the eastern slope of the Cis-Polar Urals (Mesezhnikov et al., 1989).

Abundant definitions of species typical of some zones were obtained from wells, and this permitted showing **the A. regulare Zone** and beds with ***A. rosenkrantzi*** on the regional scale. The Regulare Zone in the type sections of Scotland is characterized by the following species: *A. regulare* Spath, *A. leucum* Spath, *A. freboldi* Spath, and *A. schulginae* Mesezhn. In West Siberia, the zone was confirmed by definitions of the index species, predominantly in open nomenclature, in the following wells: Kharampurskaya 332 (depths 2954 and 2957 m) and Kharampurskaya 315 (depth 2236.2 m), Symor'yakhskaya 10636 (depth 2034.7 m, Plate 1, fig. 9), Shirtovskaya 309 (bed J_1^0), Kynskaya 201 (depth 2841.45 m), Ust'- Chasel'skaya 198, Ust'-Chasel'skaya 220 (depth 2725.2 m (Vyachkileva et al., 1990, Plate 48, fig. 16), depth 2890.5 m), Vostok 1 (depths 2281.9 and 2284.8 m), Iokhturskaya 528 (depth 2948.15 m), and Mangazeiskaya 5 (depth 3494.1 m). In the Vostochno-Tarkosalinskaya 72 well, the zone is characterized by the species *A.* cf. *regulare* Spath and *A.* ex gr. *leucum* Spath (depths 3417.5 and 3407.65 m). The presence of *A.* cf. *leucum* Spath suggests that of the Regulare Zone in well 12 of the Ob' profile (interval 327–329 m (Vyachkileva et al., 1990, Plate 48, fig. 14)) and that of *A.* cf. *freboldi* in the Vostok 3 (depths 2511.1 and 2512.2 m), Vostok 1 (depths 2282.05 and 2509.3 m), Voikarskaya 2 (depth 403.5 m (Vyachkileva et al., 1990, Plate 48, fig. 15)), and Talovaya 4 (depth 2801.8 m) wells.

Beds with *A. rosenkrantzi* are distinguished in the terminal part of the Oxfordian Stage. The species *A. rosenkrantzi* Spath was defined in the Zapadno-Frolovskaya 35 well (depth 2794.4 m (Vyachkileva et al., 1990, Plate 48, fig. 18)), the Vostochno-Tarkosalinskaya 72 well (depths 3413.3 and 3414.35 m), in which ammonites from both Upper Oxfordian zones were found, in the Mangazeiskaya 9 well (depth 3467.6 m, Plate 1, fig. 6), and in the Symor'yakhskaya 10636 well (depth 2034.7 m).

The Ringsteadia pseudocordata Zone in the North Urals part of West Siberia is characterized only by specimens of the family Aulacostephanidae in the absence of Cardioceratidae. The evolution of the local *Ringsteadia* facies was related to localization in the shallowest and warmest zone of Trans-Urals Bay in the West Siberian sea basin (Mesezhnikov et al., 1989; Jurassic..., 1988). It is proposed to show beds with *Ringsteadia marstonensis* on the biostratigraphic chart of West Siberia for the North Urals part of the region, because the unit is of uncertain biostratigraphic extent in Siberia and the species *R. pseudocordata* has not been recorded here. For the rest of the region, we propose the independent A. regulare Zone and beds with *A. rosenkrantzi* instead of the beds with *A.* ex gr. *regulare*. The *Ringsteadia* species, which determine the paleontologic appearance of the biostratigraphic unit in Siberia, were described by M.S. Mesezhnikov (1967, 1984). Aulacostephanidae become a usual component of Kimmeridgian zonal assemblages both in northern Siberia and West Siberia (Meledina, 2005). The Kimmeridgian Stage of West Siberia based on Cardioceratidae is detected from the appearance of the subgenus *Amoeboceras* (*Amoebites*)—*A.* ex gr. *kitchini* and other species.

In some sections (Scotland, Barents Sea shelf), the Oxfordian/Kimmeridgian boundary is localized between A. rosenkrantzi Zone and A. bauhini Zone, which is replaced by the A. kitchini Zone (Birkelund and Callomon, 1985; Matyja et al., 2006). Originally, the species *A.* (*Plasmatites*) *bauhini* was mentioned as an index of the upper subzone of the A. rosenkrantzi Zone (Sykes and Callomon, 1979). Owing to finds of *Pictonia* ammonites in the A. bauhini Subzone, this subzone, elevated to the rank of a zone, was transferred to the lower Kimmeridgian. The uncertain taxonomic status and geographic range of the subgenus *Plasmatites* have already been mentioned in (Nikitenko et al., 2013). This casts doubt on the recognition of a separate biostratigraphic unit based on this subgenus in the Boreal Oxfordian scale. No reliable finds of the species *A. bauhini* are known for West Siberia. The Oxfordian/Kimmeridgian boundary is marked by the appearance of *Amoeboceras* (*Amoebites*).

Oxfordian biogeography of the West Siberian sea basin

Most of the West Siberian territory in the Oxfordian Age was occupied by a sea basin inherited from the Callovian (Fig. 3). The Oxfordian sediments are almost ubiquitous and make up a considerable part of the Upper Jurassic marine series. In the southeast and east, the sea basin was adjoined by a coastal plain which changes to a low aggradation plain and is sometimes flooded by the sea.

The North Sos'va land, which separated a shallow embayment in the Callovian, turned into an isle or a chain of isles in the Oxfordian. Therefore, the sea waters along the Urals in the northwest of the West Siberian Sea freely communicated with the main water area. The sediments contained ammonites, bivalves, and foraminifers. On the eastern slope of the Cis-Polar Urals (the Tol'ya and Yany-Man'ya Rivers), brownish gray clays (up to 60 m thick) were observed with carbonaceous detritus, siderite concretions, and ammonite remnants in the upper part. Farther south (the Lopsiya River), there was a member (up to 14 m thick) with thin coal lenses, accumulations of Trigoniidae shells, and Upper Oxfordian ammonites (Jurassic..., 1983).

East of the insular shoal, a deep sea zone (the lower sublittoral zone, from 25 to 100 m) was localized in the inner part of the sea displaced westward. Most of the eastern half of the sedimentary basin was covered with a shallow sea (the upper sublittoral zone, up to 25 m). The main finds of Oxfordian ammonites are confined to these parts of the basin. The lacustrine alluvium in southeastern West Siberia (the Chulym–Yenisei region) consists of variegated silt–sand–clayey sediments. The average thickness of the Oxfordian sediments in West Siberia is 30–50 m.

The Urals, Kazakhstan, Altai–Sayan, and Central Siberian lands, which bordered on the West Siberian basin, were low denudation highlands or mountains. This is evidenced by the very fine-grained character of the sediments which accumulated in these regions. In the lower reaches of the Yenisei River, the Oxfordian sedimentation took place in the upper sublittoral zone, with the accumulation of alternating sands and siltstones with clay interbeds. Oblique bedding is typical of this region. The Oxfordian sediments are up to 153 m thick (Jurassic..., 1983).

In the Early Oxfordian, sands containing numerous ammonites, bivalves, brachiopods, gastropods, belemnites, and foraminifers accumulated in the eastern part of the Yenisei–Khatanga interfluve. On the bathymetric profile through the Boyarka and Anabar Rivers, Paksa Peninsula, and Chernokhrebetnaya River, reconstructed from the character of the

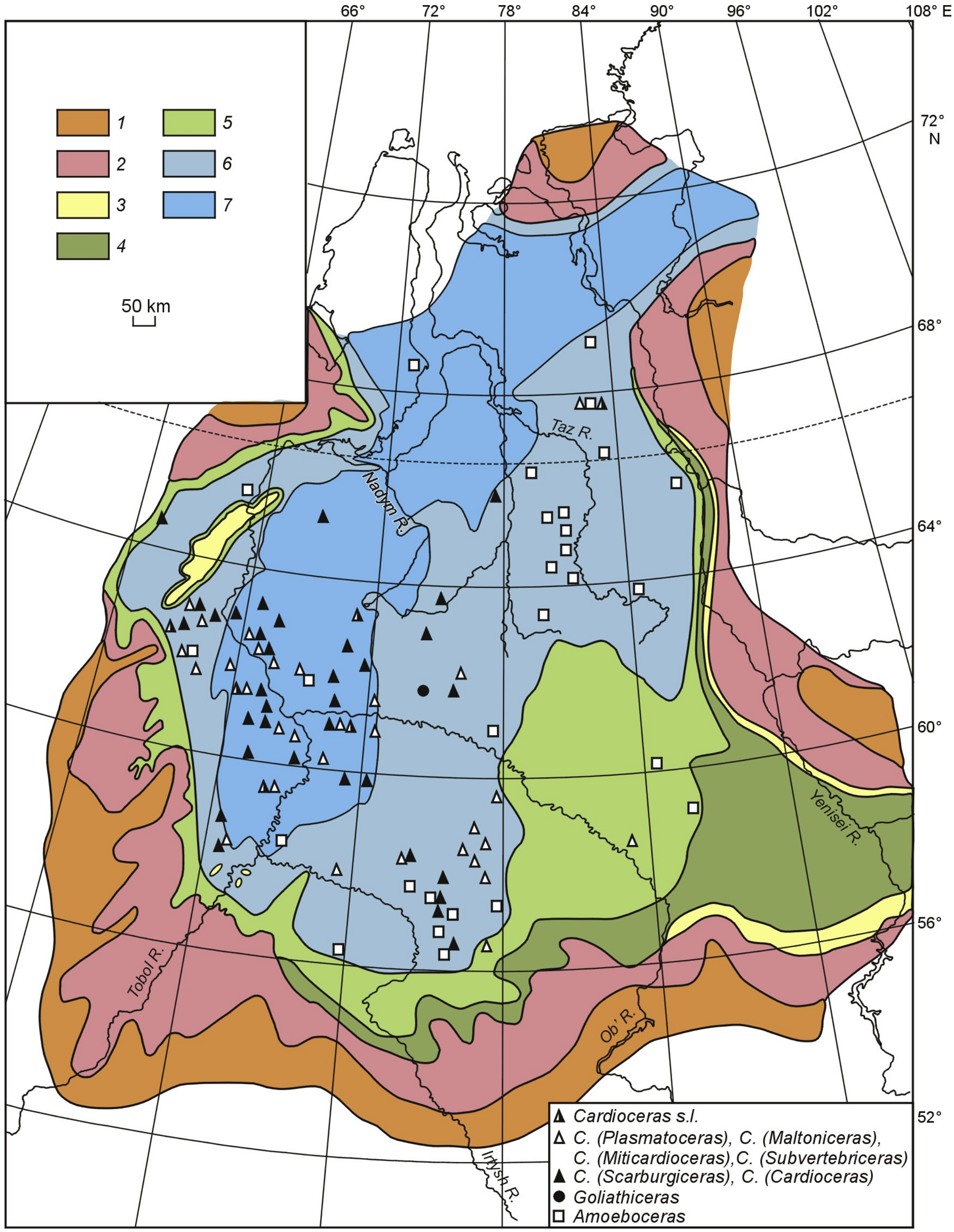

Fig. 3. Distribution of Oxfordian ammonite genera detected in the wells of West Siberia. The simplified paleogeographical base is from (Nesterov, 1976), modified after (Kontorovich et al., 2013). *1*, plateau, upland; *2–5*, plains: *2*, high; *3*, denudation–aggradation; *4*, low, aggradation (sediments of riverbeds, floodplains, lakes, etc.); *5*, coastal, which was sometimes flooded by the sea (sediments of riverbeds, deltas, beaches, etc.); *6*, sea shore, depth less than 25 m; *7*, sea, depth 25–100 m.

sediment and fossil fauna, the Oxfordian sea depths in that region were no more than 150 m (Jurassic..., 1983, Fig. 25).

The vast range of the Boreal family Cardioceratidae in the Northern Hemisphere permitted the demarcation of the boundary of the Panboreal superrealm. The latter is divided in the Oxfordian into the following realms: Arctic, absolutely dominated by Cardioceratidae (Fig. 4), except the peripheral regions; Boreal–Atlantic, in which Cardioceratidae coexist with widespread genera from the Subboreal family Aulacostephanidae and different portions of specimens of genera from the Peri-Tethyan families Oppeliidae, Haploceratidae, and Aspidoceratidae; and Boreal–Pacific, with no Cardioceratidae and predominant Perisphinctidae and Phylloceratidae (Meledina, 2001; Meledina et al., 2001; Zakharov et al., 2003).

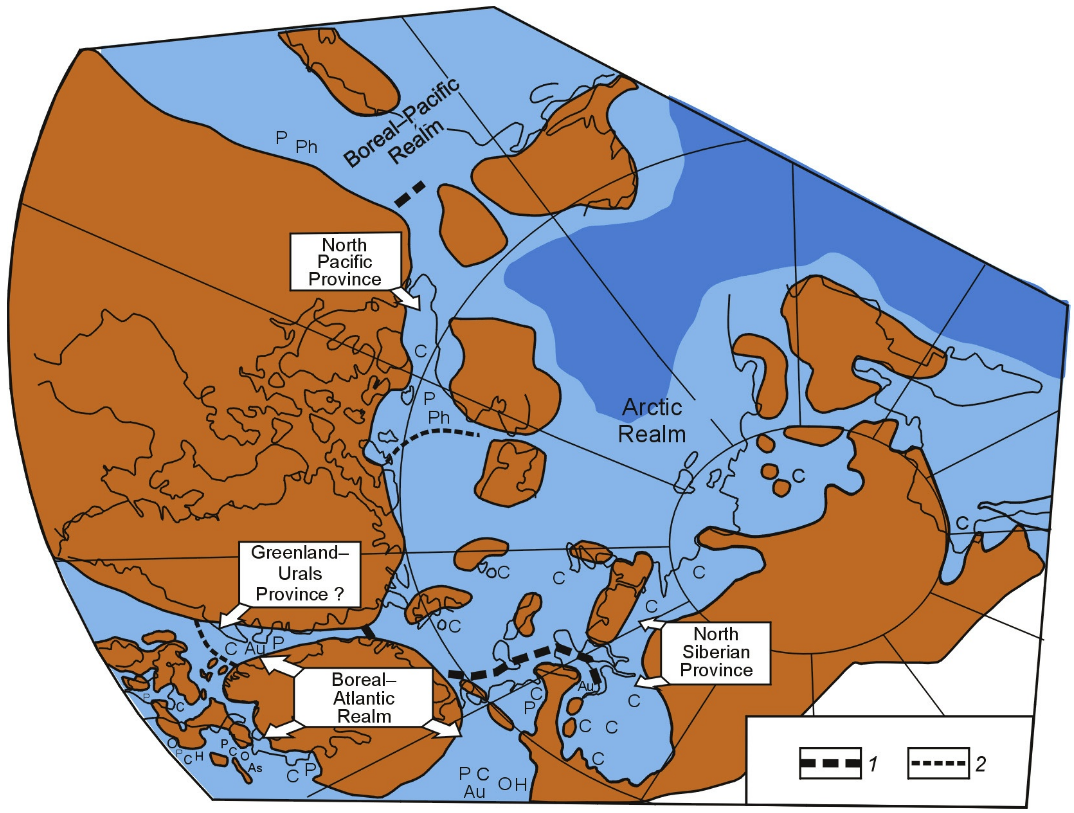

Fig. 4. Oxfordian biogeographic zonation of the Arctic basin on ammonites. The palinspastic base is after (Golonka and Scotese, 1995); the paleogeographical reconstructions are from (Jurassic..., 1983), specified after (Nikitenko, 2009). Au, Aulacostephanidae; C, Cardioceratidae; P, Perisphinctidae; O, Oppeliidae; H, Haploceratidae; As, Aspidoceratidae; Ph, Phylloceratidae. *1*, *2*, boundaries: *1*, of realms; *2*, of provinces.

The Arctic realm is bounded by the area of mass occurrence of Cardioceratidae. It included the Circum-Polar water areas of northern Siberia, the Far East, Arctic isles, Alaska, and, probably, British Columbia and Arctic Canada. The Arctic realm in the Oxfordian was dominated by the Boreal genera *Cardioceras* and *Amoeboceras*. The Lower Oxfordian sediments contain *Cardioceras* (*Scarburgiceras*), C. (*Cardioceras*), *Vertumniceras*, *Pavloviceras*, and *Goliathiceras*; the Middle Oxfordian ones contain *C.* (*Subvertebriceras*), *C.* (*Plasmatoceras*), *C.* (*Scoticardioceras*), *C.* (*Maltoniceras*), and C. (*Cawtoniceras*); and the Upper Oxfordian ones contain *Amoeboceras*. The realm included the North Siberian province, which reflected the specific features of the realm in the most complete way, and the North Pacific province, in which the composition of ammonites was influenced by the Boreal–Pacific realm.

The North Siberian province spanned northern Siberia and the Arctic islands in the Early Oxfordian. Undoubtedly, it also included West Siberia, as evidenced by similar taxonomic composition in this region and in northern Siberia. The type sections for the province (chorotype) are Lower Oxfordian outcrops in the basin of the Anabar River and on the eastern Taimyr Peninsula (Meledina et al., 2001; Zakharov et al., 2003). Alaska, Arctic Canada, and the Russian Far East, aligned along the boundary between Arctic and Boreal–Pacific realms, make up the North Pacific province. This is because this province, despite the presence of the genera *Cardioceras* and *Amoeboceras*, as in the Arctic province, was marked by the highly endemic character of their species and the presence of Phylloceratidae and Perisphinctidae, which were typical of the Boreal–Pacific realm. In the middle and early Late Oxfordian, the assemblages of cardioceratid subgenera and species became uniform within the Panboreal superrealm.

Northwestern Europe, the southern Baltic region, Poland, East Greenland, and central and northern regions of European Russia, northern Siberia, and North America have many *Subvertebriceras*, *Maltoniceras*, *Plasmatoceras*, *Cawtoniceras*, and *Amoeboceras* species in common.

Realm differences were expressed in the fact that Cardioceratidae coexisted in the Boreal–Atlantic realm with Perisphinctidae (*Dichotomoceras* and others), Aulacostephanidae (*Decipia*, *Rasenoides*, *Eurasenia*, *Microbiplices*, and *Ringsteadia*), Oppeliidae (*Taramelliceras* and *Ochetoceras*), Haploceratidae (*Glochiceras*, *Coryceras*, and *Lingulaticeras*). By the relationship of Boreal, Subboreal, and Sub-Tethyan taxa in faunal assemblages, the Boreal–Atlantic realm is divided into three or four provinces through the Middle and Late Oxfordian (Zakharov et al., 2003). The area near the interrealm boundary was populated by Perisphinctidae, which are not typical of Arctic seas. This part of the former North Siberian province is defined as the Greenland–Urals province, considered within the boundaries of the Boreal–Atlantic realm in the Late

Oxfordian (Meledina, 2001; Saks et al., 1971). The latest paleontological data indicate the nonuniform taxonomy of this biochore. Its western part (East Greenland) is closer to the Boreal–Atlantic realm, whereas the shelf of the Norwegian and Barents Seas and Spitsbergen are characterized by exclusively Arctic ammonites. Probably, it wil be reasonable to make more precise the boundaries and nomenclature of this province.

In the latest Oxfordian, the genus *Ringsteadia* penetrated the West Siberian Sea from the west and populated that area, and that was the reason to assign the eastern Cis-Polar Urals to the Boreal–Atlantic realm, whereas most of the West Siberian basin, as before, belonged to the North Siberian province of the Arctic realm.

The areal distribution of ammonites from different climate zones was determined by the configuration of the seas and land and the directions of currents: Some branches of cool currents reached Scotland and Southern England, spreading Boreal species, whereas the warm current, which brought Aulacostephanidae to Siberia, was related to the Central Russia Sea, whose influence persisted in the Kimmeridgian (Meledina, 2005; Rogov, 2012).

Conclusions

Owing to abundant definitions of ammonites in core samples from wells drilled by now into the West Siberian territory, some Lower and Upper Oxfordian zones have received a reliable paleontological substantiation. The Lower Oxfordian includes the Cardioceras (Scarb.) obliteratum, C. (S.) scarburgense, and C. (S.) gloriosum Zones. In the official regional zonal scale, this Jurassic interval was defined as beds with *C.* (*Scarburgiceras*) spp. The overlying beds with *C.* (*Cardioceras*) spp. are divided into the C. (C.) percaelatum and C. (C.) cordatum Zones. The Middle Oxfordian in West Siberia includes the C. (Subvert.) densiplicatum and C. (Miticard.) tenuiserratum Zones, the first of which is divided ito subzones: lower, with C. (Vertebr.) vertebrale, and upper, with C. (Maltonic.) maltonense. In the Upper Oxfordian, the beds with *Amoeboceras* spp. on the current chart can be replaced by the A. glosense and A. serratum Zones, whereas the A. ravni Zone should be replaced on the biostratigraphic scale by the A. regulare Zone and beds with *A. rosenkrantzi*.

The Oxfordian ammonites of West Siberia belong to the Boreal family Cardioceratidae; therefore, all the zonal subdivisions are based on the genera, subgenera, and species of this family. Only the uppermost Oxfordian sediments on the eastern slope of the Cis-Polar Urals contain the genus *Ringsteadia* (Aulacostephanidae). Therefore, the upper Upper Oxfordian of West Siberia includes parallel units for ammonites from both families. All the Oxfordian zones on the regional scale are substantiated by definitions of ammonites from specific wells.

The similarity of cardioceratid genera and species for West Siberia and northern Siberia ensures consistency between the Oxfordian zonal scales for both regions: Actually, the West Siberian scale is derived from, and copies, that for northern Siberia.

The taxonomic similarity of the Oxfordian ammonites served as a basis for assigning West Siberia through the Oxfordian Age to the North Siberian province of the Arctic realm. In the latest Oxfordian (the regulare and rosenkrantzi phases), the northwestern West Siberian basin became part of the Boreal–Atlantic realm owing to the genus *Ringsteadia* which penetrated from the west. The appearance of the latter might have been due to the influence of the Central Russian Sea, analogous to that presumed for the Kimmeridgian and Volgian Ages (Rogov, 2012). However, most of the West Siberian Sea remained part of the North Siberian province of the Arctic realm.

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