Lower and Middle Jurassic foraminiferal and ostracod biostratigraphy of the eastern Barents Sea and correlation with northern Siberia

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The Barents Sea shelf and adjacent areas comprise one of the important petroleum-bearing provinces of the world. During the last three decades, these areas have received considerable interest in the exploration for petroleum, resulting in the discovery of several new gas and oil fields. This has necessitated large-scale geological mapping and evaluation studies based on detailed biostratigraphy and high-resolution stratigraphy. Apparently synchronous microfauna assemblages of Lower and Middle Jurassic age are characterized by closely similar taxonomic composition in both the Barents Sea shelf and northeastern Siberia, allowing the recognition of the Siberian zonal successions in Barents Sea region. Detailed biostratigraphic analysis of foraminiferal and ostracod zonal subdivisions, together with lithostratigraphic data, have provided the basis for a more detailed determination of the stratigraphic position and extent of lithostratigraphic units and seismic sequence in the Barents Sea shelf. The results show that the Lower and Middle Jurassic sections of Barents Sea shelf and northern Siberia have a very similar lithostratigraphic structure. Taking into consideration the microbiotic similarity and lithostratigraphic development of these regions, a high degree of regional homogenity of depositional conditions can be assumed in the Early and Middle Jurassic.

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Introduction

The Barents Sea shelf and adjacent areas comprise one of the more important petroleum-bearing provinces of the world. During the last three decades, these regions (Fig. 1) have been subjected to considerable activity of petroleum exploration, resulting in the discoveries of new gas and oil fields, e.g. Shtokmanovskaya, Arcticheskaya. This has necessitated large-scale geological mapping and evaluation studies based on detailed biostratigraphy and high-resolution stratigraphic interpretations. Abundant ditch-cuttings and, more rare, core material recovered from Jurassic and Cretaceous sections in these areas have been used for micropaleontological studies. Microfaunal assemblages in these sections are often characterized by irregular distribution due to the sporadic sampling of core and ditch cuttings. The results of these studies are summarized in a biostratigraphic subdivision based on foraminifers from the Lower and Middle Jurassic of the Barents Sea area (Gramberg 1988; Basov et al. 1989). Local successions of foraminiferal assemblages have been defined and correlated with coeval microfaunal successions in northeastern Siberia. This research has demonstrated a considerable taxonomic similarity between the Siberian and Barents Sea Lower and Middle Jurassic microfaunas.

Recently, a set of parallel and independent zonal schemes based on the main fossil groups have been developed for the Jurassic and Cretaceous of northeastern Siberia. The schemes are a result from many years of comprehensive study of continuous sections in the region. The schemes are based on ammonites, bivalves, foraminifers and ostracods have been proposed as a Boreal Zonal Standard (Zakharov et al. 1997; Riding et al. 1999; Shurygin et al. 2000; Nikitenko & Mickey, 2004; Nikitenko 2008) (Fig. 2). Based on these standards zonal subdivisions based on foraminifers and ostracods have been developed for northeastern and northwestern Siberia (Figs. 1, 2). The microfossil schemes are based on the recovery of rich microfaunal assemblages, and are biostratigraphically constrained by ammonite recoveries (Nikitenko 1992; 1994; 2008; Shurygin et al. 2000; Nikitenko & Mickey 2004). It should be noted that zones according to General Stratigraphic Scale (Hardenbol et al. 1998), there has been a recalibration of the stratigraphic position of certain of ammonite zones. This has also resulted in changes of the stratigraphic position of zones based on other fossil groups (Fig. 2) (Shurygin et al. 2000).

As mentioned earlier, contemporaneous Lower and Middle microfaunal assemblages of the Barents Sea shelf and northeastern Siberia are have quite
Fig. 1. Location map of Lower and Middle Jurassic key sections of northeastern Siberia, northwestern Siberia and Barents Sea region.

Fig. 2. Boreal zonal standard and zonal subdivision of the Lower and Middle Jurassic in the Barents Sea region.
similar taxonomic compositions. This mean that the northeastern Siberian zonal scheme is applicable in the Barents Sea region. Since the microfaunal assemblages in the Lower and Middle Jurassic succession of the Barents Sea shelf contain only rare ammonites, their stratigraphic range and position is best constrained by correlation with the northern Siberian foraminifera and ostracod zones (Nikitenko 1992, 1994, 2008; Zakharov et al. 1997; Nikitenko & Mickey 2004). This has provided a basis for revision and improvement of the Jurassic biostratigraphic zonal subdivisions based on foraminifers and ostracods in the Barents Sea area, and consequently a better validation of the stratigraphic extent and position of the lithostratigraphic units in the Barents Sea area.

Biostratigraphy

A combined set of foraminiferal zones is used as the basis for the biostratigraphic subdivision: 1) concurrent-range zones, 2) ecological zones, 3) a set of parallel phylozones. The lower boundaries of foraminiferal zones have been defined by the first occurrences of new assemblages and important taxa, as well as by acme of characteristic taxa.

The oldest foraminiferal assemblages (Upper Pliensbachian, *Trochammina lapidosa* foraminiferal Zone JF4), which includes *Ammodiscus siliceus, Trochammina lapidosa, Glomospira* ex gr. *gordialis, Saccammina* sp., *Ichthyolyarina brizaeformis, Gaudryina* sp., *Textularia areoplecta, Saracenaria* ex gr. *sublaevis* and *Recurvoides taimyrensis*, is defined in the lower part of the Wilhelmya Formation (Svalbard Archipelago), in the upper part of the Tegetthoff and Vasilevka formations (Franz Josef Land), and in sections from wells of the Murmanskaia and Arcticheskaya fields (Figs. 3, 4). The dominance of *Recurvoides taimyrensis* indicates that the assemblage is correlative with the *Recurvoides taimyrensis* JF9 Zone in upper part of the Tegetthoff Formation (Franz Josef Land). Characteristic Lower Jurassic species, such as *Ammodiscus* spp., *Haplophragmoides* spp. and undetermined *Textularia* (Løfaldli & Nagy 1980), are recovered from silts and clays of the Wilhelmya Formation.

Foraminifers from the lowermost Toarcian have not been found. This may be explained by rare core sampling. The assemblage of the *Astacolus praefoliaceus, Lenticulina multa* JF12 foraminiferal Zone (uppermost Lower Toarcian – lowermost Lower Aalenian) (Figs. 2-4) includes the species *Lenticulina multa, L. aff. asteroidae*, L. ex gr. *d’Orbignyi, Astacolus praefoliaceus, Ammodiscus glumaceus, Dentalina aff. torta, Saccammina inanis, S. ampullacea, Verneuilinoides sindascensis, Trochammina sp., Evolutinella sp., and Kutsevella* ex gr. *indistincta* (Fig. 5). The zone is recognized in several sections on the Barents Sea shelf (i.e. the Severo-Kildinskaya, Murmanskaia, Arcticheskaya fields) and in the Pechora Basin (middle part of Sysola Formation in the Pomorskaya field).

The distribution of ostracods is very irregular in the Lower and Middle Jurassic successions. The Lower Jurassic is almost devoid of ostracods; only rare specimens are recovered from several samples, mostly from the Arcticheskaya field. The occurrences of *Ogmoconcha* ex gr. *longula* indicate the presence of the *Ogmoconcha longula* JO2 ostracod Zone (uppermost Hettangian–?the base of Toarcian) (Figs. 2; 5, q). In northern Siberia assemblages of the JO2 Zone are recovered together with the ammonites *Psiloceras planorbis* and *Amaltheus* spp., and together with *Amaltheus* spp. and *Tiltoniceras antiquum* in NE Russia (Nikitenko & Mickey 2004). Rare occurrences of *Camptocythere* (Camptocythere) *mandelstani*, which indicate the *Camptocythere mandelstani* JO4 Zone (lower part of the Lower Toarcian) (Fig. 2), are recorded in central areas of the Barents Sea shelf. The occurrences of *Camptocythere* (Camptocythere) ex gr. *oculata* from the *Camptocythere oculata* JO6 Zone in the Arcticheskaya field (Fig. 5, r) indicate here the presence of upper Lower Toarcian – lower Upper Toarcian strata (Fig. 2). From the uppermost Bajocien ostracods become abundant in the microfaunal assemblages.

A reliable marker zone identified in almost all areas of the Barents shelf is the *Verneuilinoides syndascensis* JF14 Zone (lower part of the Lower Aalenian) (Fig. 2). The foraminiferal assemblage is usually dominated by abundant specimens of the index-species (Fig. 5, f), while other species (especially calcareous forms) are more rare.

Assemblages with *Saccammina compacta, S. ampullacea, Recurvoides anabarenis, Ryadhella sibirica, Trochammina praesquamata, Astacolus aff. costulaus, Lenticulina aff. interrumpa, Verneuilinoides tertia, Lenticulina* ex gr. *asteroidae, Ammodiscus arangastachienis, Kutsevella* sp., and *Pseudonodosaria ex gr. glandulinoides (Trochammina praesquamata* JF15 Zone, upper part of the Lower Aalenian – lowermost Bajocian) (Fig. 2) are recovered from the lower part of Fiume Formation on Franz Josef Land), the upper part of Sysola Formation in the Pechora Basin (Pomorskaya field), and in sections at the Severo-Kildinskaya, Murmanskaia and Arcticheskaya fields (Figs. 3, 4).

Foraminiferal zones of short stratigraphic extend are recognized in the lower part of the Fiume Formation in several sections on Franz Josef Land. The local development of the *Lenticulina nordvikensis* JF16-JF17 Zone (uppermost Lower Aalenian – Upper Aalenian) (Fig. 2) is characterized by a specific foraminiferal assemblage which include *Trochammina praesquamata, Kutsevella memorabilis, Dentalina* ex gr. *communis, Astacolus* ex gr. *protracta (?)=A. zwetkovi, Globulina* ex gr. *oolithica, Lenticulina nordvikensis, L. ex gr. mironovi* and *Verneuilinoides tertia*. The assemblage of the *Ammodiscus arangastachienis* JF18 Zone (lower part of the Lower Bajocian) (Fig. 2) is dominated by the index-species.
The assemblages of the *Riyadhella sibirica* JF19 Zone (upper part of the Lower Bajocian – base of the Bathonian) are recovered from almost all sections of the Barents Sea shelf and adjacent areas (Figs. 2-4), including northern Pechora Basin (uppermost Sysola Formation and lowermost Churkino Formation), Franz Josef Land (middle part of the Fiume Formation), Svalbard Archipelago (uppermost Wilhelmøya Formation and base of Agardfjellet Formation), and in sections of some offshore wells in this areas. The assemblages are often typified by abundant occurrences of the index-species (Fig. 5, k, l). Other species in this zone include: *Lenticulina incurvare, Marginulinopsis pseudoclara, Dentalina scharovskaja, Guttulina tatarensis, Recurvoides anabarensis, Trochammina praesquamata, Vaginulinopsis koczevnikovi, Globulina oolithica, G. praecircumphlua* and *Astacolus protracta*.

The local *Ammodiscus arangastachiensis, Recurvoides anabarensis* JF20-JF24 Zone has a relatively wide
stratigraphic extent, and corresponds in range to the JF20-JF24 Zones (the uppermost Lower Bajocian – the lowermost Upper Bajocian) of northeastern Siberia (Fig. 2). The zone is often characterized by depleted microfaunal assemblages. Middle and Upper Bathonian ammonites, together with the foraminifers Ammobaculites suprajurassicum, A. aff. alaskaensis, Haplophragmoides spp. and Recurvoides spp., are recovered from the base of the Agardfjellet Formation on Kong Karls Land. Slightly higher up in the section, Callovian ammonites and the foraminifers Recurvoides scherkalyensis and Haplophragmoides spp. and are recovered (Lofaldli & Nagy 1980). These are typical for the Dorothis insperata, Trochammina rostovzevi JF25 Zone (uppermost Bathonian – Callovian) (Fig. 2).

The foraminiferal assemblages (Fig. 5) of the Trochammina aff. praesquamata JF22 Zone (uppermost Bajocian – lower part of the Upper Bathonian) (Fig. 2) are recognized in the northern part of the Pechora...
Basin (upper part of Sysola Formation and lower part of Churkino Formation). It should be pointed out that there is a considerable reduction in taxonomic diversity of the assemblages in the upper part of the JF22 Zone, and that taxa of wide stratigraphic range are dominant. A similar situation is observed in the sections of Siberia, where only species-depleted assemblages are recognized at this stratigraphic level (Nikitenko et al. 2000).

The common occurrence of uppermost Bajocian ostracods in micropaleontological samples is used to define the Camptocythere arangastachiensis JO13 Zone (uppermost Lower Bajocian – Upper Bajocian) and Camptocythere scrobiculatoformis JO14 Zone (Lower Bathonian – lowermost Upper Bathonian) (Figs. 2-4) in the Barents sea area and Pechora Basin.

The described sedimentary succession is overlain by deposits containing contrasting, more rich and abundant foraminiferal assemblages typical for the uppermost Bathonian – Callovian Dorothea insperata, Trochammina rostoffevi JF25 Zone or the Kutsevella membrabilis, Guttulina tatarensis JF28 Zone (Figs. 2-4).

Conclusions

The stratigraphic position of previous defined Lower and Middle Jurassic microfaunal assemblages of the Barents Sea shelf has been considerably better defined by calibration against contemporaneous northeastern Siberian assemblages which are dated by ammonites and bivalves (Figs. 1, 3, 4). For example, the Trochammina lapidosa assemblage (Gramberg 1988; Basov et al. 1989) was previously regarded as Pliensbachian. From the new, revised zonal subdivision, it is now known to correspond to the uppermost Pliensbachian – basal Lower Toarcian (Fig. 2). The beds with Trochammina aff. lapidosa were previously regarded as Upper Pliensbachian – Toarcian (Gramberg 1988; Basov et al. 1989), but now the position of this assemblage (Recurvoides taimyrensis JF9 Zone) is restricted to the uppermost Pliensbachian – base of the Toarcian (Fig. 2). The well-known stratigraphic marker beds with Riyadhella sibirica was previously interpreted as Upper Bathonian or Upper Bathonian – Lower Callovian (Grigelis 1982; Gramberg 1988; Basov et al. 1989; Repin et al. 2007). From the present zonal subdivision it is known to correspond to the upper part of Lower Bajocian – lowermost Bathonian (Nikitenko & Shurygin 1994) (Fig. 2).

On the Barents Shelf the presence of the Lower Jurassic Ogmocorona longula JO2, Camptocythere mandelstami JO4 and Camptocythere ocalata JO6 zones are recognized by rare occurrences of ostracods. Ostracods become common components of micropaleontological assemblages in the upper part of the Lower Bajocian, where they are used to define the Camptocythere arangastachiensis JO13 Zone and Camptocythere scrobiculatoformis JO14 Zone (Fig. 2).

Detailed biostratigraphic analysis of foraminifers and ostracods, in association with with lithostratigraphic studies of the sections, provides the basis for refinement of the stratigraphic position and extent of lithostratigraphic units and seismic sequences in the Barents Sea shelf (Figs. 265).
3, 4). It turns out that the Lower and Middle Jurassic sections of the Barents Sea shelf and northern Siberia have a very similar lithostratigraphic development. Taking into consideration the microbiotic similarity and lithostratigraphic features of the successions in these regions, a closely similar sedimentary facial development during the Early and Middle Jurassic can be assumed (Figs. 3, 4) (Basov et al. 2009). The Lower and Middle Jurassic sections of the Barents sea shelf, northwestern and northeastern Siberia show similar changes lithological changes, which are caused by eustatic sea-level changes. In these regions, the stratigraphic position of the various sandy and clayey lithological units, and especially their lower boundaries, are essential similar as confirmed by the macro- and microfaunas.

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