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Devonian–Permian sedimentary basins and paleogeography of the Eastern Russian Arctic: An overview

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ABSTRACT

The Arctic basins attract broad international interest because of the region's potentially significant undiscovered hydrocarbon resources. The Russian High Arctic is mostly represented by broad shelves, with a few wells drilled only in its western part (Kara and Barents shelves). This contribution provides an overview of the geological setting, stratigraphy, paleogeography, and tectono-sedimentary evolution of the middle–late Paleozoic basins of the Eastern Russian Arctic, including: Severnaya Zemlya, the New Siberian Islands, northern Siberia, the Taimyr and Chukotka peninsulas, and Wrangel Island. Reconstructing the geological evolution of the Eastern Russian Arctic during the middle–late Paleozoic is very difficult because the region was overprinted by a number of late Paleozoic to early Mesozoic tectonic events.

1. Introduction

The Arctic basins have attracted an increasing amount of international interest in recent years because of the potential for containing a significant proportion of the world's undiscovered hydrocarbon (principally gas) resources. The Russian High Arctic is mostly represented by broad shelves, with a few wells drilled in the Barents and Kara seas penetrating Mesozoic strata. No deep wells have been drilled in the Eastern Russian Arctic shelves within the Laptev, east Siberian and Chukchi seas. Despite the importance of the middle–late Paleozoic sedimentary basins of the Russian High Arctic, the study of Paleozoic strata in this region has been limited to the remote archipelagoes and coastal areas of the adjacent mainland, which offer snapshots into their Paleozoic history. This paper provides an overview of the Devonian–Permian stratigraphy, depositional environments and available provenance studies across Severnaya Zemlya, the New Siberian Islands, northern Siberia, the Taimyr and Chukotka peninsulas, and Wrangel Island (Fig. 1). Our overview is based on all available published data, the majority of which was acquired during geological mapping in the 1960s, 1970s and 1980s. The level of detail varies significantly among these geological investigations across different parts of the study area, due to remote locations and brief periods of time for field work. The compilation of a correlative stratigraphic framework also is complicated by the overprinting of younger tectonic and magmatic events, and associated metamorphism. Here, we also analyze the available detrital zircon data from the Eastern Russian Arctic.

1.1. Severnaya Zemlya

1.1.1. Stratigraphy

The Severnaya Zemlya Archipelago comprises four big islands (Pioneer, October Revolution, Komsomolets and Bol'shevik), along with several smaller islets and island groups. Pioneer, October Revolution and Komsomolets islands are mainly composed of Cambrian to Upper Devonian deposits, while Cambrian–Ordovician rocks with a few exposures of Upper Carboniferous–Permian and Mesozoic deposits crop out on Bol'shevik Island (Makariev, 2013).

1.1.1.1. Devonian. Lower Devonian strata exposed on Pioneer, October Revolution and Komsomolets islands are very similar in composition and sedimentary facies, and overlie Upper Silurian rocks with an erosional unconformity (Fig. 2). The depth of erosion varies significantly, reaching a maximum of a few hundred meters on October Revolution Island (Matukhin and Menner, 1999). The basal part of the Lochkovian deposits is usually represented by gravelly to pebbly conglomerate and coarse-grained sandstone, with the pebbles reworked from Silurian limestone and chert. The conglomerate and sandstone are overlain by alternating grayish argillite, marl and limestone of Early Lochkovian age. Upper Lochkovian strata comprise grayish sandstone and siltstone in the lower part of succession, and reddish argillite and siltstone with subordinate layers of dolomite and marl with celestine and barite concretions in the upper part. The Lochkovian age is substantiated by the

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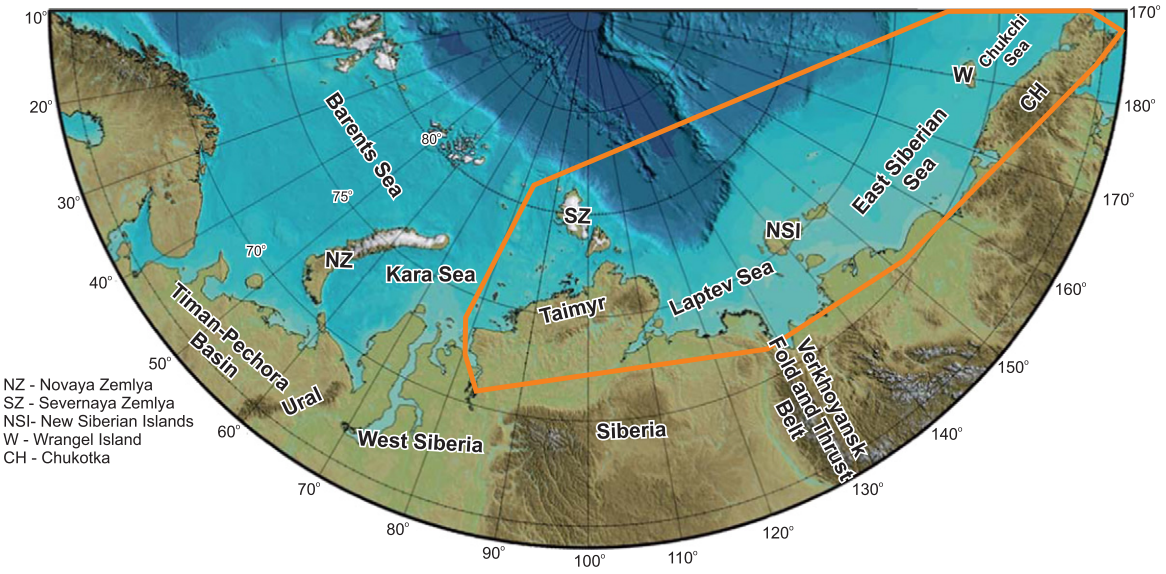

Fig. 1. Regional setting of the study area (orange outline shows the study area).

occurrence of ostracods and vertebrates throughout the succession (Matukhin and Menner, 1999). The thickness varies from 200 to 580 m.

The 100–300 m thick Lower–Upper Pragian succession comprises varicolored sandstone, siltstone and argillite in the lower part, and grayish dolomitic marl with beds of dolomite and local gypsum layers in the upper part of the succession. The fossil assemblages mainly contain bivalves and vertebrates.

The uppermost Pragian–Lower Emsian strata are represented by a 80–300 m thick shallowing upward succession, comprising grayish bioclastic and stromatolitic limestone grading upwards to gypsum with subordinate marl layers (Menner et al., 1982). The limestone contains diverse marine fossils, including brachiopods, bivalves, ostracods, bryozoans, crinoids and corals.

The Upper Emsian strata on October Revolution Island comprise interbedded stromatolitic dolomite, marl, and bioclastic and stromatolitic limestone, with interbedded red sandstone and siltstone with ironstones at the top of succession. On Komsomolets Island, the Upper Emsian strata comprise alternating marl, stromatolitic limestone, bioclastic limestone and dolomite in the lower part of the succession, and argillite in the upper part. The Upper Emsian succession of Pioneer Island is represented by interbedded marl, micritic and bioclastic limestone. Ostracods and vertebrates have been recorded from October Revolution Island, while brachiopods and bivalves have been described from Pioneer Island (Matukhin and Menner, 1999). The thickness of Upper Emsian strata varies from 40 to 150 m.

The Eifelian–Givetian succession of October Revolution Island comprises 340–400 m of alternating red sandstone, siltstone and clay. Locally, beds of dolomite, dolomitic marl and limestone have been described from the upper part of the succession. The coeval strata of Komsomolets Island are represented by 40–625 m of varicolored sandstone and siltstone. Red Eifelian–Givetian sandstone, siltstone and clay up to 100 m thick crop out on Pioneer Island.

Frasnian strata of October Revolution Island comprise alternating red sandstone, siltstone and argillite, with numerous vertebrates described from within the succession. Thin limestone beds with marine fossils occur in the upper part of the succession. The Frasnian deposits of Komsomolets Island are represented by intercalated reddish sandstone, siltstone and clay with rare vertebrates. Thin layers of limestone and marl occur in the upper part of the succession. The Frasnian strata of Pioneer Island comprise red sandstone, argillite and siltstone (Markovsky and Kulyasheva, 1993; Matukhin and Menner, 1999). The thickness of Frasnian sandstone reaches 1000 m.

Lower Famennian deposits have only been described from the northern part of October Revolution Island and are represented by varicolored sandstone with lenses of conglomerates intercalated with siltstone and argillite (Khanin, 1982). The Devonian 220–260 m thick black argillite and siltstone, with rare layers of limestone and coalified plant detritus, mapped in the northern part of Bol'shevik Island, have been tentatively dated as Late Devonian–Early Carboniferous in age based on sparse palynological data, and overlie Cambrian deposits with a pronounced angular unconformity (Makariev, 2013; Markovsky et al., 1988).

1.1.1.2. Carboniferous–Permian. Carboniferous–Permian strata have been described from a few small exposures across the archipelago, but precise determination of their stratigraphic age is difficult and based on sparse palynological data (Dibner, 1982a,b; Makariev, 2013). In the western part of Bol'shevik Island, they are described as Lower Carboniferous based on spores and pollen (Dibner, 1982b).

Upper Carboniferous–Lower Permian deposits are exposed in the northeastern part of Bol'shevik Island, where they overlie Middle Cambrian folded strata with an angular unconformity. Plant spores and pollen indicate that the strata broadly span Late Carboniferous to Early Permian time (Dibner, 1982b; Gramberg and Ushakov, 2000; Makariev, 2013; Sobolev et al., 2013). The succession is mainly represented by an alternation of weakly cemented sandstone, siltstone and argillite, with lenses and layers of coal and coalified plant detritus with thickness up to 300 m. Lenses and beds of quarzitic conglomerate occur throughout the succession (Ershova et al., 2015d).

Scattered exposures of Upper Carboniferous–Permian deposits up to 30 m thick have been described from October Revolution Island, where intercalated siltstone, sandstone and argillite with lenses and beds of conglomerate with coalified plant detritus commonly overlie Cambrian rocks with angular unconformity (Dibner, 1982a; Markovsky et al., 1984).

A thin succession of Guadalupian (?) deposits has been described from the western part of Komsomolets Island. This succession varies in thickness from 20 to 80 m and comprises intercalated sandstone and siltstone with subordinate beds of argillite and coal-bearing argillite lying with angular unconformity on Middle Devonian deposits (Markovsky and Kulyasheva, 1993) (Fig. 2).

1.1.2. Paleogeography

In general, sedimentary facies within the Devonian sedimentary basin of the Severnaya Zemlya Archipelago are indicative of a marine

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