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Mineralogy of low grade metamorphosed manganese sediments of the Urals: Petrological and geological applications

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ABSTRACT

The paper describes mineralogy of the low grade metamorphosed manganese sediments, which occur in sedimentary complexes of the Pai Khoi Ridge and the Polar Urals and volcanosedimentary complexes of the Central and South Urals. The degree of metamorphism of the rocks studied corresponds to PT conditions of the prehnite–pumpellyite (deposits of Pai Khoi and Polar and South Urals) and green schist (deposits of the Central Urals) facies. One hundred and nine minerals were identified in the manganese-bearing rocks on the basis of optical and electron microscopy, X-ray diffraction, and microprobe analysis. According to the variations in the amount of major minerals of the manganese rocks of the Urals, they are subdivided on carbonate (I), oxide–carbonate–silicate (II), and oxide–silicate (III) types. Carbonates, various Mn^{2+}-bearing silicates associated with oxides and carbonates, and braunite (Mn^{3+}-bearing silicate) are the major Mn hosts in types I, II, and III, respectively. Because of the different oxidation state of Mn, the rocks of types I and II are termed as "reduced" and the rocks of type III, as "oxidized". The formation of a certain mineralogical type of metamorphic assemblage is controlled by the content of organic matter in the primary sediments. The sequence type I → type II → type III reflects the decrease in the amount of organic matter in metalliferous sediments. Mineralogical data indicate that manganese in the primary sediments accumulated in a silicate form (Mn—Si gel, glass, etc). During diagenesis, the Mn–Si phase was transformed to neotokite with subsequent formation of caryopilite and further crystallization of pyroxmangite, rhodonite, tephroite, and other silicates due to reactions involving caryopilite. The hydrated Mn-silicates (caryopilite and/or friedelite) and the spatially associated parsettensite, stilpnomelane, and other minerals are the index minerals of the low grade metamorphism. Under PT conditions of prehnite–pumpellyite facies, nearly 70% of silicate minerals are hydrous. The metamorphosed Mn-bearing sediments are characterized by the low-temperature caryopilite (or tephroite-caryopilite-pyroxmangite ± rhodonite) and the high-temperature caryopilite-free (or tephroite-pyroxmangite ± rhodonite) facies. Their PT conditions correspond to zeolite and prehnite-pumpellyite (the low-temperature) and green schist and higher grade (the high-temperature) facies.

1. Introduction

Several tens of small stratiform Mn deposits of the Urals are confined to the sedimentary and volcanosedimentary complexes (Betekhtin, 1946; Rabinovich, 1971; Mikhaylov and Rogov, 1985; Mikhaylov, 1993, 2001, 2011; Shishkin and Gerasimov, 1995; Magadeev et al., 1997; Ovchinnikov, 1998; Kontar et al., 1999; Kostyuk et al., 2000; Starikova and Zavileisky, 2010; Brusnitsyn and Zhukov, 2005, 2012; Brusnitsyn, 2013a; Kuleshov et al., 2014; Starikova, 2014). Most researchers suppose that Mn-bearing ores were formed in marine basins and are syngenetic to host sediments. As known, in the contemporary oceans, Mn is deposited in oxide form and, during diagenesis, catagenesis, and metamorphism, the Mn oxides are transformed into carbonates and silicates. Numerous Mn deposits of the Urals are metamorphosed under conditions of low-grade prehnite-pumpellyite or green schists facies. Under such conditions, Mn rocks are characterized, on the one hand, by the relics of sedimentary protolith and sedimentary-diagenetic textures and structures and, on the other hand, by the presence of typical metamorphic minerals (rhodonite, tephroite, spessartine, and other minerals). The study of these "transitional" rocks provides a unique opportunity to identify the

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transformation of the phase composition during the gradual increase in temperature and pressure, i.e., during transition of sedimentary rock to metamorphic one.

>30 deposits have been studied and the following deposits are chosen for the detailed mineralogical studies (Fig. 1): (i) the deposits, which were metamorphosed under conditions of prehnite-pumpellyite facies: Parnok (Polar Urals) and Kozhaevo, Urazovo, Bikkulovo, Kazgan-Tash, Kusimovo, Kyzyl-Tash and South, Middle, and North Fayzuly (South Urals); (ii) those, which were metamorphosed under conditions of prehnite-pumpellyite to green schists facies: Kheyakha, Sibirchatayakha, Karsk, Nadeiyakha-1 and -2, Lower Silova, Silovayakha (Pai Khoi) and Sob River basin (Polar Urals); and (iii) the deposits, which were metamorphosed under conditions of green schists facies: Malosedelnikovo, Kurganovo, and Borodulino (Central Urals).

The results of studies of the deposits have previously been published in (Brusnitsyn, 1998, 2000, 2006, 2010, 2013a, 2015; Brusnitsyn and Zhukov, 2005, 2012; Starikova and Zavileisky, 2010; Starikova, 2011, 2012, 2014; Brusnitsyn et al., 2000, 2009, 2014, 2016). The aim of this paper is to summarize mineralogy of low-grade metamorphosed Mn-bearing sediments of the Urals and to interpret these data according to the geological and physico-chemical conditions of formation and transformation of metalliferous sediments.

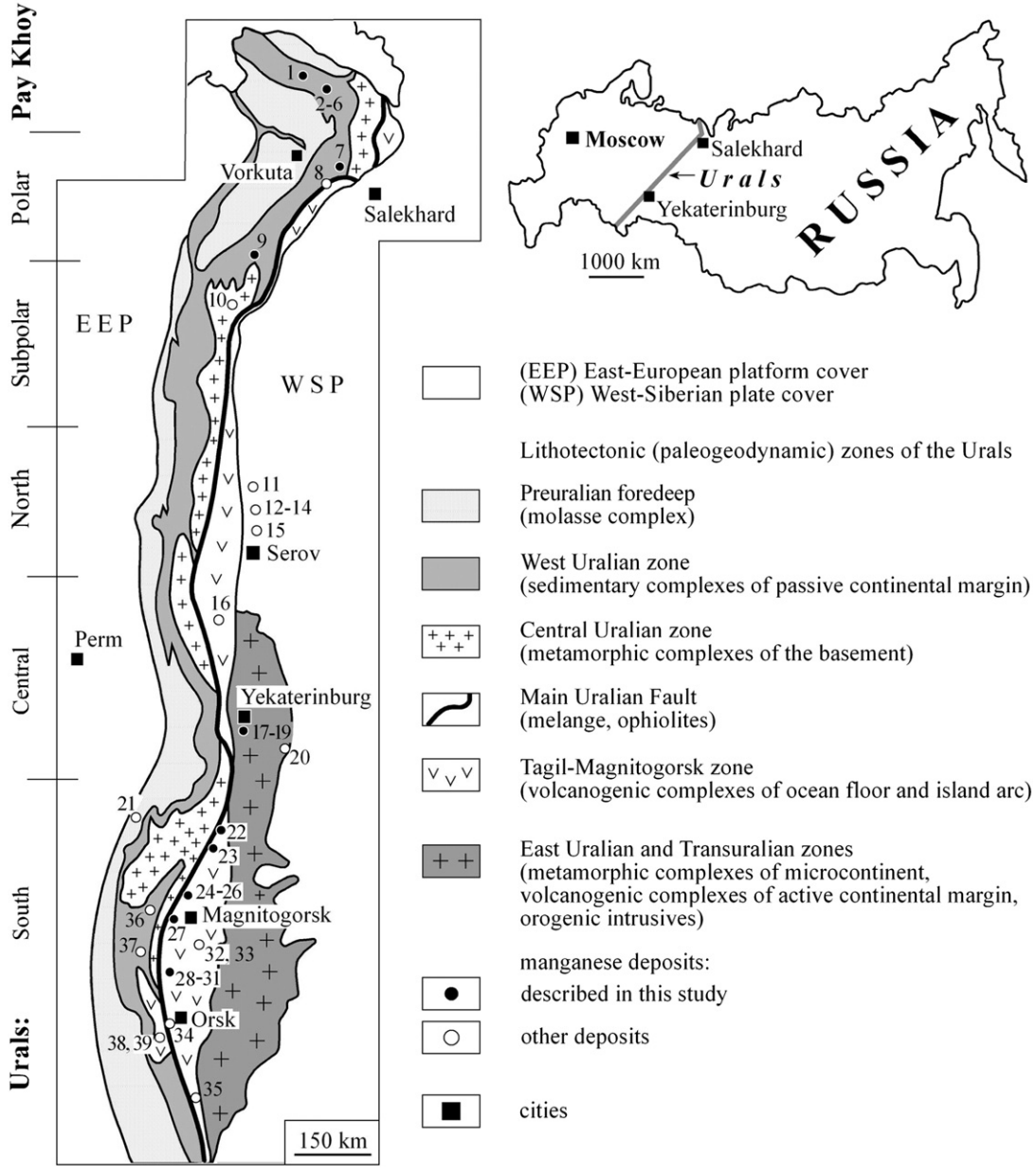

Fig. 1. Location of main manganese deposits of the Urals, after (Mikhaylov and Rogov, 1985; Mikhaylov, 1993, 2001, 2011; Kontar et al., 1999; Puchkov, 2010; Brusnitsyn, 2013a; Starikova, 2014). Manganese deposits: 1 - Kheyakha, Sibirchatayakha (Late Devonian); 2 - Lower Silova (Late Devonian); 3 - Karsk (Late Devonian); 4 - Silovayakha (Late Devonian); 5 - Nadeiyakha-1 (Late Devonian); 6 - Nadeiyakha-2 (Late Devonian); 7 - Sob River basin (Late Devonian to Early Carboniferous); 8 - Upper Tyshor (Proterozoic); 9 - Parnok (Middle to Late Ordovician or Middle Devonian); 10 - Verayu (Proterozoic); 11 - Burmantovskoe (Late Cretaceous to Paleocene); 12 - Pokunochnoe (Late Cretaceous to Paleocene); 13 - Tyn'ynskoe (Late Cretaceous to Paleocene); 14 - Berezovo (Late Cretaceous to Paleocene); 15 - Yekaterino (Late Cretaceous to Paleocene); 16 - Sapal (Late Silurian to Early Devonian); 17 - Malosedelnikovo (Early Silurian); 18 - Kurganovo (Early Silurian); 19 - Borodulino (Early Silurian); 20 - Klevakino (Late Devonian); 21 - Ulutelyak (Permian); 22 - Kozhaevo (Middle to Late Devonian); 23 - Urazovo (Middle Devonian); 24 - Bikkulovo (Middle to Late Devonian); 25 - Kazgan-Tash (Middle to Late Devonian); 26 - Kusimovo (Middle Devonian); 27 - Kyzyl-Tash (Middle to Late Devonian); 28 - South Fayzuly, souther part (Middle Devonian); 29 - South Fayzuly, norther part (Middle Devonian); 30 - Middle Fayzuly (Middle Devonian); 31 - North Fayzuly (Middle Devonian); 32 - Bakhtino (Devonian); 33 - Kipchara (Early Carboniferous); 34 - Akkerman (Early Carboniferous); 35 - Shuuldak (Middle Devonian); 36 - Shigrysh (Early Carboniferous); 37 - Zilair (Middle Devonian); 38 - Guberlya (Middle to Late Ordovican); 39 - Kharkovo (Middle to Late Ordovican).