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Composition and characteristics of the ferromanganese crusts from the western Arctic Ocean

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ABSTRACT

Layered ferromanganese crusts collected by dredge from a water depth range of 2770 to 2200 m on Mendeleev Ridge, Arctic Ocean, were analyzed for mineralogical and chemical compositions and dated using the excess ^{230}Th technique. Comparison with crusts from other oceans reveals that Fe-Mn deposits of Mendeleev Ridge have the highest Fe/Mn ratios, are depleted in Mn, Co, and Ni, and enriched in Si and Al as well as some minor elements, Li, Th, Sc, As and V. However, the upper layer of the crusts shows Mn, Co, and Ni contents comparable to crusts from the Atlantic and Indian Oceans. Growth rates vary from 3.03 to 3.97 mm/Myr measured on the uppermost 2 mm. Mn and Fe oxyhydroxides (vernadite, ferroxyhyte, birnessite, todorokite and goethite) and nonmetalliferous detrital minerals characterize the Arctic crusts. Temporal changes in crust composition reflect changes in the depositional environment. Crust formation was dominated by three main processes: precipitation of Fe-Mn oxyhydroxides from ambient ocean water, sorption of metals by those Fe and Mn phases, and fluctuating but large inputs of terrigenous debris.

1. Introduction

The economic interest in oceanic ferromanganese (Fe-Mn) crusts and nodules results from high grades of base, critical, and rare metals (Anikeeva et al., 2002; Hein et al., 2000; Muiños et al., 2013). Hydrogenetic Fe-Mn crusts have gained recognition as a potential future resource for a wide variety of elements such as Co, Ti, Mn, Ni, Pt, Zr, Nb, Te, Bi, Mo, W, Th, and rare earth elements plus yttrium (REY; Hein and Koschinsky, 2014). The Fe and Mn oxides form from the direct precipitation from ambient seawater and are deposited mostly on the flat tops and flanks of seamounts where oceanic currents prevent sedimentation (Anikeeva et al., 2002; Hein and Koschinsky, 2014; Melnikov, 2005).

Fe-Mn deposits are distributed globally with the largest fields in the Pacific Ocean, and smaller fields in the Atlantic and Indian Oceans. The Arctic Ocean remains a poorly explored region for deep-ocean mineral deposits. Fe-Mn deposits within the western Arctic Ocean were reported by a number of scientists (e.g., Baturin et al., 2014). In 2014, fragments of Fe-Mn crusts were sampled southwest of the study area via submersible (Fig. 1A) (Bazilevskaya and Skolotnev, 2015). Mainly 1–2 mm-thick crusts and two 30 mm-thick crusts were collected on that cruise. In 2008, 2009, and 2012, US scientists collected Fe-Mn crusts from the Chukchi Borderland that are similar in appearance and composition to those reported here (Fig. 1A) (Hein et al., 2012).

We present here data for Fe-Mn crusts collected from the western Arctic Ocean. Crusts were sampled on Mendeleev Ridge and studied in terms of morphology, mineralogy, and chemical composition, and a genetic model is proposed based on these characteristics. Our study includes a considerable number of samples containing thick (up to 50 mm) crusts. An integrated approach based on the application of different analytical techniques (i.e. ICP, ICP-MS, XRD, ED, SEM-EDX, EPMA) was used to better determine the chemical and mineral compositions of the crust samples, which then can be related to regional geological and oceanographic conditions.

2. Material and methods

Geological and geophysical studies at Mendeleev Ridge were carried out using the Russian ice breaker Kapitan Dranitzyn within the

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