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Geochemical Features of Major and Rare-Earth Element Behavior in the Paratunka and Bol'shebannyi Hydrothermal Systems of Kamchatka

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Abstract—This paper presents original data on the content and distribution of major and rare-earth elements in the modern hydrothermal systems of the Paratunka and Bol'shebannyi thermal water deposits. In spite of the similar geochemical type of the waters, the individual sites of the hydrothermal systems differ in the major component composition, which is caused by the time of water–rock interaction, temperature control, and the possible influence of seawater intrusions. The REE concentrations in the studied thermal waters are extremely low (a few tenths of ppb). A distinctive feature of these thermal waters is the presence of a positive Eu anomaly. The possible reasons for its appearance are discussed. Calculation of REE speciation shows that the main parameters controlling the formation of the REE complexes in the Paratunka and Bol'shebannyi hydrothermal systems are their individual chemical properties, as well as pH, Eh, and temperature of the aqueous solution.

Keywords: nitric thermal waters, rare-earth elements, water–rock interaction, Kamchatka

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INTRODUCTION

The geochemical characteristics of modern hydrothermal vents provide insight into their formation and evolution by water–rock interaction. In addition to the main cations and anions (Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}), attention has recently focused on the rare-earth elements, which are considered as sensitive indicators of geochemical processes proceeding in modern hydrothermal systems [9, 22, 27, 29, 31–33, 37–39]. The determination of the rare-earth elements is made possible owing to the development of new methods of mass-spectrometric analysis (ICP-MS and high-resolution ICP-MS instrumentation HR-ICP-MS). The study of the REE behavior in the natural waters of the Far East began more than 15 years ago [19, 21, 22, 26, 27, 34, 35, 40, 42]. Unique data were obtained on the CO_2-rich mineral waters, mineralized acid waters in the regions of active volcanism, and fresh groundwaters and river waters. At the same time, nitric alkaline thermal vents remained weakly studied, in spite of their enormous resources, especially in Kamchatka. We have attempted to fill this gap by presenting the REE data on the Paratunka and Bol'shebannyi thermal water deposits, which are located within the Paratunka geothermal area. The main difficulty in studying this type of water is related to the extremely low REE contents (tenths of μg/L). Methodical approaches have recently been developed to minimize this problem [9]. In addition, a technique was developed to determine the REE content in suspended particulate matter remaining on a filter after obtaining of a filtrate from small aliquots [3]. This procedure allows reliable REE measurement not only in the filtrate but also in the suspended particulate matter.

The aim of the current work is to establish the REE contents and fractionation in the nitric thermal waters of the Paratunka geothermal area using modern techniques. In addition to REE, the waters were also analyzed for major elements, which determine the geochemical image of alkaline thermal springs. The nitric thermal waters of the Paratunka geothermal area were compared with other nitric thermal waters of Kamchatka and Sikhote Alin.