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Volcano–hydrothermal system of Ebeko volcano, Paramushir, Kuril Islands: Geochemistry and solute fluxes of magmatic chlorine and sulfur

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ABSTRACT

Ebeko volcano at the northern part of Paramushir Island in the Kuril island arc produces frequent phreatic eruptions and relatively strong fumarolic activity at the summit area ~1000 m above sea level (asl). The fumaroles are characterized by low-temperature, HCl- and S-rich gas and numerous hyper-acid pools (pH < 1) without drains. At ~550 m asl, in the Yurieva stream canyon, many hot (up to 87 °C) springs discharge ultra-acidic (pH 1–2) SO_4–Cl water into the stream and finally into the Sea of Okhotsk. During quiescent stages of degassing, these fumaroles emit 1000–2000 t/d of water vapor, <20 t/d of SO_2 and <5 t/d of HCl. The measurement of acidic hot Yurieva springs shows that the flux of Cl and S, 60–80 t/d each, is independent on the volcanic activity in the last two decades. Such high flux of Cl is among the highest ever measured in a volcano–hydrothermal system. Oxygen and hydrogen isotopic composition of water and Cl concentration for Yurieva springs show an excellent positive correlation, indicating a mixing between meteoric water and magmatic vapor. In contrast, volcanic gas condensates of Ebeko fumaroles do not show a simple mixing trend but rather a complicated data suggesting evaporation of the acidic brine. Temperatures calculated from gas compositions and isotope data are similar, ranging from 150 to 250 °C, which is consistent with the presence of a liquid aquifer below the Ebeko fumarolic fields. Saturation indices of non-silicate minerals suggest temperatures ranging from 150 to 200 °C for Yurieva springs. Trace elements (including REE) and Sr isotope composition suggest congruent dissolution of the Ebeko volcanic rocks by acidic waters. Waters of Yurieva springs and waters of the summit thermal fields (including volcanic gas condensates) are different in Cl/SO_4 ratios and isotopic compositions, suggesting complicated boiling–condensation–mixing processes.

1. Introduction

Ebeko volcano on Paramushir Island is one of the best studied active volcanoes of the Kurilian Island Arc. Its eruptive history in details has been traced by Melekestsev et al. (1993). Geological structure as well as petrology and geochemistry of the eruptive products of Ebeko has been studied by many authors (Markhinin, 1967; Gorshkov, 1970; Fedorchenko et al., 1989; Avdeiko et al., 1992, and references therein). There were several attempts for measuring the heat output by fumaroles and hydrothermal system of the volcano (Nekhoroshev, 1960; Menyailov et al., 1988; Kotenko and Kotenko, 2006). Menyailov et al. (1985, 1988) and Kotenko et al. (2007) reported chemical composition of fumarolic gases during different stages of the volcanic activity. Menyailov et al. (1985, 1988) have measured isotopic composition of the volcanic gas condensates and isotopic ratios of noble gases in two Ebeko fumaroles. Geochemistry of thermal waters has been studies in Nikitina (1978), Markhinin and Stratula (1977), Fazlullin (1999), Bortnikova et al. (2006) and Kalacheva and Kotenko (2013). Solute discharge by acidic thermal waters of the volcano–hydrothermal system has been measured by Zelenov (1972) and Fazlullin (1999). One of the two deep wells drilled in the vicinity of the volcano found hot water (90 °C). Rychagov et al. (2002) have used core and cuttings from these wells for a detailed mineralogical description of the geological cross-section near Ebeko.

The volcano is attractive for volcanologists and geochemists for several reasons. Frequent phreatic eruptions are hazards to several thousand people living in a small town of Severo-Kurilsk in the vicinity of the volcano (10–12 km from the crater). Secondly, the volcano is characterized by strong fumarolic and hydrothermal activity with abundant manifestations which are easily accessible. A geochemical monitoring program, including systematic sampling of fumarolic gases, was conducted by Igor Menyailov's group in 1960–1980 (e.g., Menyailov et al., 1985, 1988) and the program was partially re-started after almost a 20 year break (Kotenko et al., 2007, 2012; Bortnikova et al., 2006; Kalacheva and Kotenko, 2013; Kotenko and

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