

Variations in Mercury Concentrations at the Thermal Fields of the Kambalny Range as a Consequence of the Kambalny Volcano Eruption (Kamchatka, Russia)

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ABSTRACT

Kambalny volcanic range (Southern Kamchatka, Russia) represents a group of highly eroded volcanic structures elongated in the submeridional direction, their age is defined as from the Pleistocene to the Holocene (Belousov et al., 1976). The Kambalny volcano is located in the southern part of that structure. Its last eruption occurred in March-April of 2017 (Girina, 2017; Rychagov, 2017). Hydrothermal activity in the form of individual water-mud pots and steam-gas jets are observed over almost the entire area of the Kambalny range with three groups of hydrothermal fields being the most active: Severo-, Uzhno- and Centralno-Kambalny thermo anomalies (Belousov et al., 1976). In the period from 2010 to 2018 steam-gas jets of Severo-, Uzhno- and Centralno-Kambalny geothermal fields were subjected to mercury concentration testing (Rychagov, 2014). The comparison of results on mercury concentration obtained through 2010-2018 shows noticeable increase in mercury content in 2017 (i.e. straight after eruption). These data suggest that the Kambalny range hydrothermal system is a powerful modern source of mercury intake and accumulation. It also shows the connection of the modern hydrothermal system with active volcanism.

1. INTRODUCTION

There are numerous studies that have been devoted to the behavior of mercury at hydrothermal systems and active volcanoes (Ferrara et al., 2000; Bagnato et al., 2009, 2014; Nriagu, Becker, 2003; Blum et al., 2014). In the course of present study we have observed an increase of mercury content in hydrothermal solutions of thermal fields associated with the Kambalny Range (Southern Kamchatka, Russia) that followed the eruption of the Kambalny volcano in 2017.

2. GEOLOGICAL STRUCTURE OF THE KAMBALNY RANGE

The Kambalny volcanic range is a series of volcanic structures elongated from the South to the North that are of varying degree of erosion and unknown age (Fig. 1). The Kambalny volcano (active) is located at the Southern part of the range. Its historical eruption occurred in 2017 (Girina et al., 2017; Rychagov et al., 2017) being the only known historical eruption. The volcano is a slag cone with a height of 2161 m. There two craters 1) having dimensions 620 x 570 m and located in the apex part; 2) the small crater having diameter of 200 m is adjacent to the main one. The volcano is divided into several structures, the formation of which occurred at different times. The evolution of volcano is characterized by a transition from highly explosive eruptions of the central type to fissure-type eruptions and further to the extrusive stage at the final steps of the ridge formation. The decrease in explosiveness was reflected in a decrease in the amount of pyroclastic material in volcanic structures, mainly basalt composition composed of small lava flows (Dolgozhivushiy tsentr ..., 1980).

3. THERMAL FIELDS OF KAMBALNY VOLCANIC RANGE

The large hydrothermal system is located underneath Kambalny Range (Structure of Hydrothermal System, 1993). It is represented on the surface by three groups of hydrothermal fields, each of which differs by its geological structure and morphostructure (Belousov et al., 1976): Severo-Kambalny, Centralno-Kambalny and Uzhno-Kambalny. Manifestations of hydrothermal activity are in the form of separate boilers and steam jets and observed practically over the entire area of the Kambalny range. It is considered that thermal fields are associated with magma chambers of the Kambalny volcano (Structure of Hydrothermal System, 1993). It has been shown recently that low-temperature salts are represented by hydrated sulphates with high proportion of ammonium minerals (Zhitova, et al., 2018). In this work we have studied the mercury content in the natural waters and gas condensate from the Severo-Kambalny and Uzhno-Kambalny thermal fields.

3.1. Uzhno-Kambalny Central thermal field

The Uzhno-Kambalny Central thermal field is localized in a ring structure with a diameter of 500-600 m, which is a crater of the Upper Quaternary andesitic volcano (Fig. 2 a) (Structure of Hydrothermal System, 1993). Geochemical data indicate the presence of deep fluid involved in the formation of a term. Hydrothermally altered rocks and clays from this field are also characterized by high concentrations of Au, Ag, Hg, and alkali metals (Structure of Hydrothermal System, 1993). The main discharge is represented by steam-gas jets, mud-water, water boiling pots, steaming soils (Fig. 2 b, c). The rocks forming thermal anomaly are strongly argillitized and converted to clay. A specific feature of this geothermal field is the presence of sulfur mounds, the formation of which is associated with boiling pots having high content of H₂S in the vapor (Belousov et al., 1976).

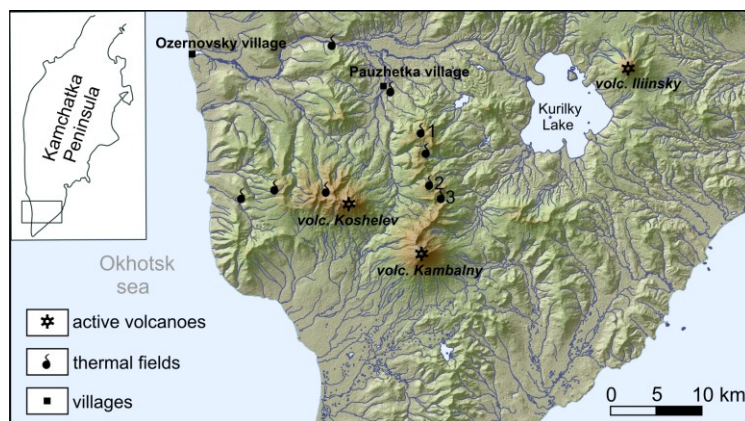


Figure 1: Geography of Kambalny volcanic range: 1 – Severo-Kambalny; 2 – Uzhno-Kambalny Centralny and 3 – Uzhno-Kambalny Dalny thermal fields.

3.2. Uzhno-Kambalny Dalny thermal field

The Uzhno-Kambalny Dalny is the largest thermal manifestation of the Kambalny Range. Hydrothermal activity is represented by a large number of boiling pots and steam-gas jets. The characteristic feature of this thermal anomaly is large amount of water on its surface in a form of various mud and water pots, thermal lakes and steaming soils.

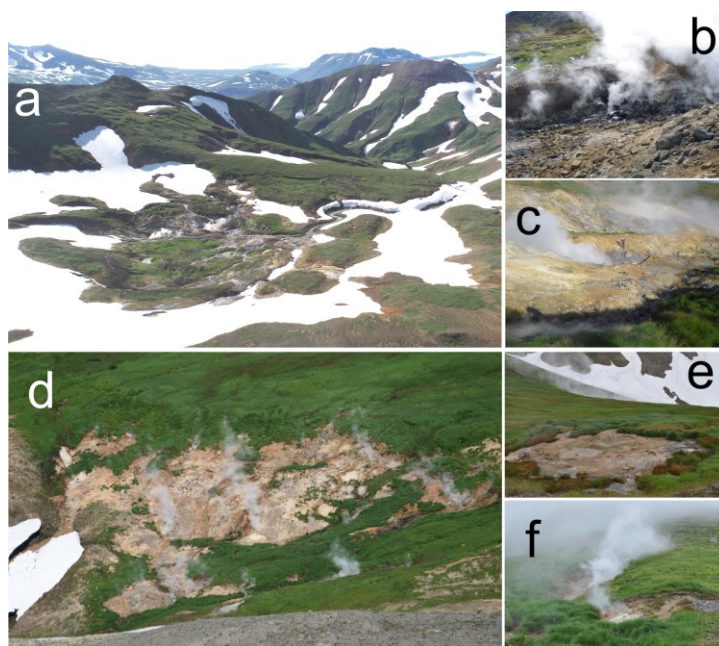


Figure 2: The general views and hydrothermal manifestations of Severo- and Uzhno-Kambalny thermal fields.

3.3. Severo-Kambalny thermal field

The Severo-Kambalny thermal field is located in the upper part of stream Trudny (Fig. 2 d). The discharge of hydrothermal solutions occurs on the slopes and is represented by steam jets and steaming soils, mud and water pulsating pots (Fig. 2 e, f). In the area of the main discharge the ground temperature is in the range 70 to 97 °C. In the area of less active hydrothermal manifestation (individual boilers, steaming soils and wetlands) the ground temperature is 20 to 50 °C (Belousov et al., 1976). In general, all thermal fields of the Kambalny range have similar indicators of heat removal and gas composition (Belousov et al., 1976).

4. MERCURY AT GEOTHERMAL FIELDS OF KAMBALNY VOLCANIC RANGE

Recently we have studied the mercury content at geothermal systems associated with Koshchelev volcano (Southern Kamchatka, Russia) (Rychagov et al., 2009, 2010, 2014). Then the study has been extended to the nearby Kambalny volcano and reported here.

4.1. Gas condensate.

The mercury content in gas condensate has been studied at three thermal fields: Uzhno-Kambalny Dalny, Uzhno-Kambalny Centralny and Severo-Kambalny. The concentration of mercury in condensate from the Severo-Kambalny thermal field was 2.73–4.95 µg/l with the average value 3.55 µg/l before the eruption. After the eruption, the value was 4.53–24.79 µg / l, with an average value of 10.63 µg/l.

The mercury content in gas condensate of Uzhno-Kambalny Dalny was 5.36-25.37 mg/l with the average value of 13.56 $\mu\text{g/l}$ in 2012. At the condensate taken from Uzhno-Kambalny Centralny the mercury contents in 2017 and 2018 were 8.99–29.28 $\mu\text{g/l}$ with an average of 16.87 $\mu\text{g/l}$ and 10.50-47.36 $\mu\text{g/l}$ with an average of 21.71 $\mu\text{g/l}$, respectively (Fig. 3). Again showing an increase of mercury content after eruption of Kambalny volcano.

4.2. Natural waters.

Thermal waters on the Kambalny Range were tested on three fields in different years: the Uzhno-Kambalny Dalny (2012), Uzhno-Kambalny Centralny (2017, 2018) and Severo-Kambalny (2011, 2014 and 2017). The mercury concentration in thermal waters of Uzhno-Kambalny Dalny field was in the range of 0.02-3.52 $\mu\text{g/l}$ with the average value of 0.7 /l (before eruption). After the eruption, in 2017, the mercury concentration in the thermal waters of the Uzhno Kambalny Centralny field was 0.01-1.14 $\mu\text{g/l}$, the average value of 0.4 $\mu\text{g/l}$. The obtained values of mercury concentration remained nearly identical before and after eruption for Uzhno-Kambalny thermal fields. The same situation was characteristic for Severo-Kambalny thermal fields. The absence in mercury concentrations in thermal waters is due to dilution of hydrothermal solutions by meteoric waters on the surface thermal fields.

5. CONCLUSION

The study of mercury content in gas condensate shows the increase of its concentration after eruption of Kambalny volcano. However the changes of mercury concentration in thermal water are not detectable. It is worth noting that Uzhno- and Severo-Kambalny thermal fields reacted at the eruption differently. The obtained here results can be considered as an indicator of connection between the hydrothermal system and the magma system of the Kambalny volcano. The increase in the mercury concentration in the vapor may occur due to the following reasons: (i) mercury release by magma which is transferred to deep fluid and results in an enrichment of hydrothermal solution (vapor) by mercury or (ii) mercury release from rocks as a result of temperature increase (because of magma approach) followed by mercury migration including its getting into hydrothermal solutions.

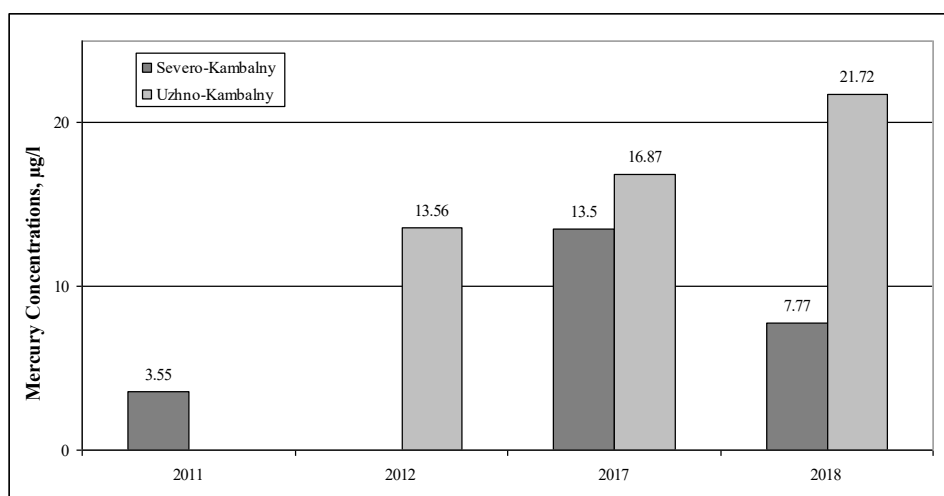


Figure 3: Average values of mercury concentration in gas condensates.

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