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# Hydrological and geochemical change related to volcanic activity of Usu volcano, Japan

Tomo Shibata [a,*], Fujio Akita [a], Wataru Hirose [a], Ryuji Ikeda [b]

[a] *Geological Survey of Hokkaido, Kita-ku, Sapporo, Hokkaido, 060-0819, Japan*
[b] *Department of Natural History Science, Faculty of Science, Hokkaido University, Kita-ku, Sapporo, Hokkaido, 060-0810, Japan*

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**Abstract**

Mt. Usu is a stratovolcano located on the southern side of the Toya caldera in Hokkaido, Japan. In historical times it emitted dacitic products associated to remarkable crustal deformations. Usu volcano erupted on March 31st 2000 after 23 yr of dormancy and this eruption was the fourth in the 20th century. Secular variations in water levels, temperature and chemical compositions of thermal water have been observed around Usu volcano. The water levels decreased since October 1999, 6 months prior to the eruption. The decrease in water levels is a precursory change and is probably due to leakage of thermal water from the shallow aquifer hosting it. No variations in temperature and chemical composition of thermal water were evident prior to the eruption. However, in a few wells, the temperature of the thermal water increased by up to 15 °C with respect to the pre-eruptive values. Moreover, the concentration of some solutes (Na, K, Cl and $SO_4$) became higher after the eruption. These thermal and chemical changes are ascribable to increased input of a deep hydrothermal liquid into the shallow groundwater aquifer.


*Keywords:* Thermal water; Volcanic eruption; Eruption monitoring; Volcanic activity; Usu volcano

## 1. Introduction

Chemical and isotopic compositions of volcanic gases and hydrothermal waters provide insights into volcanic mechanisms and critical information for evaluating volcanic hazards, because volcanic gases contain a substantial proportion of volatiles released directly from magmas. Successive variations in volcanic gas chemistry could be useful to evaluate the present state of volcanic activity and to understand the behavior of magmatic fluids in geothermal systems. Considerable physical and chemical changes in volcanic gases and hydrothermal waters have been reported before, during, and after volcanic eruptions (Hirabayashi and Kusakabe, 1985; Matsubaya, 1985; Carapezza et al., 2004; Capasso et al., 2005), and some of the first type are recognized as precursors of the eruptions.

Many studies of volcanic gases like noble gases, $CO_2$, $H_2S$ and so on have been carried out in recent year (e.g., Giggenbach, 1990; Sano et al., 1995, Capasso et al., 1999). Since volcanic gases are directly sampled from fumaroles and plumes, gas sampling inevitably involves serious risks. Moreover, gas sampling is impossible during volcanic eruptions, when we would like to know most information from volcanic gases. Alternatively, thermal waters may represent the subject of geochemical monitoring. Thermal waters are commonly originated by injection of gases degassed from magma into meteoric waters, which circulate in shallow aquifers beneath the volcano, and they typically emerge at the surface around the foot of the volcano. Thermal waters give us some important scents of volcanic activity, although it is sometimes difficult to assess the geochemical meaning of changes in the concentrations of relevant components and species (Capasso et al., 2000; Inguaggiato et al., 2005). The chemical composition, pH and temperature of the thermal waters may vary in response to variable interactions of coexisting water and/or rocks in the

* Corresponding author. Geological Survey of Hokkaido, N19 W12, Kita-ku, Sapporo, Hokkaido 060-0819, Japan. Tel.: +81 11 747 2473; fax: +81 11 737 9071.
*E-mail address:* tomo@gsh.pref.hokkaido.jp (T. Shibata).

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hydrothermal system. Therefore, the precursors may reveal very different changes at different types of volcanic eruptions and in distinct geological settings (Giggenbach, 1988).

Usu volcano, which is located in northern Japan, is one of the most turbulent volcanoes in Japan. Therefore, we monitored water levels, temperature and the chemical composition of thermal waters at Usu volcano. Here, we will present, discuss and interpret anomalous changes in the water level, temperature and chemical composition of thermal waters. These changes are closely associated with the variations in volcanic activity occurred during the 2000 eruption.

## 2. The thermal system of Usu volcano and its recent activity

Thermal waters first emerged at the northern foot of Usu volcano (42.53° N, 140.83° E) during the 1910 eruptive activity (Omori, 1911), which included phreatic explosions and extrusion of cryptodomes around the northern foot of the volcano. Meiji–Shinzan is one of these cryptodomes, and a number of hot springs emerged around Meiji–Shinzan. The thermal system of Usu volcano was probably initiated by an intrusion of magma at shallow depth. Consequently, an aquifer of thermal water was formed at 80–350 m depth into permeable strata around Meiji–Shinzan (Akita et al., 2001; Yahata, 2002). This region has been developed as a Spa resort since the 1910 activity, and some wells have been drilled to exploit thermal waters for commercial purpose. The discharged water has a temperature of 30–60 °C and the total amount of extracted water is of 3000–4000 $m^3$/day at present.

Usu volcano is situated on the southern side of the Toya caldera (Fig. 1), which formed during the late Pleistocene (0.13±0.03 Ma) (Okumura and Sangawa, 1984). Its highest peak is at 731 m above sea level and its base is about 6 km in diameter. In the early Holocene (~10 ka), the main stratovolcano formed with alternations of lava flows and scoriae of tholeiitic basalt and basaltic andesite composition (Oba et al., 1983). About 7000–8000 yr ago, dacitic domes were extruded and the northern side of the summit formed. After that, the collapse of the summit area

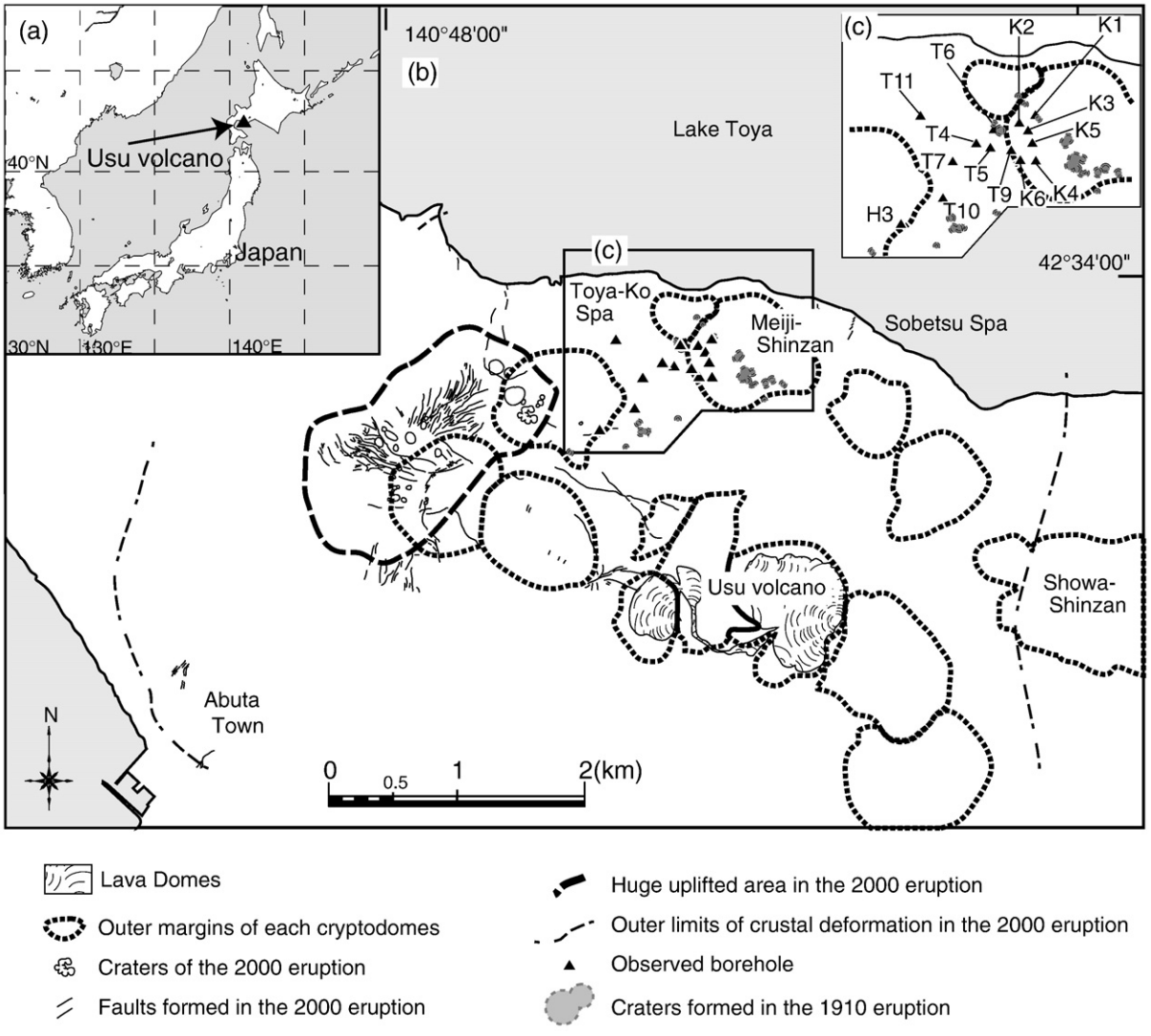


Fig. 1. Simplified map of Usu volcano together with schematic of the 2000 eruption and observed wells.