

Secular variation of sulfur isotope ratio dissolved in the lake water of Yugama crater, Kusatsu-Shirane volcano, Japan

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1. Introduction

The chemical monitoring at Yugama crater lake located on Mt. Kusatsu-Shirane volcano, Gunma, Japan has been carried out since 1966 (Ossaka et al., 1997, Ohba et al., 2008). The sulfur isotope ratio ($\delta^{34}\text{S}$) of sulfate dissolved in the lake water was previously measured by Ohsawa et al. (1993) and Kusakabe et al. (2000), and the variation in 1955 to 1995 was revealed. In this study, the lake waters stored in Kusatsu-Shirane volcano observatory were analyzed, and the variation since 1988 to 2007 was determined.

2. Result and Discussion

The period since 1966 to 2007 was divided into the following four periods.

Period-I (1966-1981)

The number of earthquake observed by Japan Meteorological Agency was low relative to the following period. In general the volcanic activity in this period was stable. Although a small phreatic eruption took place in 1976 in a crater adjacent to Yugama crater, no change was observed in $\delta^{34}\text{S}$. The variation in $\delta^{34}\text{S}$ is small and the value was stable keeping a high level of +20 to +21 permil to CDT over the period.

Period-II (1982-1988)

Five phreatic eruptions occurred in Yugama crater in 1982 and 1983. A large number of earthquakes were observed. After the first eruption in 1982, the concentration of sulfate in lake water started to increase. The concentration reached the maximum in 1984 then turned to decrease. The $\delta^{34}\text{S}$ was +19 permil in the early stage and it decreased to +17 permil gradually. The pattern of change in $\delta^{34}\text{S}$ was not similar to that of sulfate concentration.

Period-III (1989-1999)

A faint eruption occurred in Yugama crater in 1989. The number of earthquakes increased significantly in 1990. The number of earthquakes in 1995 to 1999 was low. The lake water temperature in 1990 to 1992 in summer season was 10 degree C higher than that of air temperature in Kusatsu town. The temperature difference in Period-I and II was about 6 degree C, suggesting the increase of heat supply to Yugama crater lake. On the point of view of seismicity and heat discharge, the volcanic activity in this period was higher than the other periods, in spite of no significant eruption such as those in 1982 and 1983. The trend of the decrease in $\delta^{34}\text{S}$ following the former period continued until 1990. The $\delta^{34}\text{S}$ reached the lowest value, +13 permil on Nov. 1990. No corresponding change was detected in $\delta^{34}\text{S}$ coinciding the faint eruption in 1989. The $\delta^{34}\text{S}$ started to increase in the late of 1990. The value increased up to +20 permil until 1994. Although the high value was kept until 1989, it turned to a quick decrease in 1999. The sulfate concentration in lake water was stable over the period despite the large variation in $\delta^{34}\text{S}$. According to Ohba et al. (1994), the flux of fluid supplied to Yugama lake was increased over the period in 1988 to 1990. The factor of the increase could be ten times as maximum. In 1988 and 1990, no significant change was observed in the lake volume. The increase in the influx to Yugama lake leads the increase in the flux of seeping lake water. According to Takano et al. (1997) the sulfate in Yugama lake water originates in two sources, one is a magmatic sulfate with high $\delta^{34}\text{S}$ and another is a biogenic sulfate with a low $\delta^{34}\text{S}$ dissolved in surface water supplied to Yugama lake flowing over the ambient soil. The increase in $\delta^{34}\text{S}$ with stable sulfate concentration can be explained by the increase in contribution of magmatic sulfate relative to the biogenic sulfate.

Period-IV (2000-2007)

The number of earthquake was very low before 2001. The number shows a slight increase after 2002. The volcanic activity in this period was stable. The decrease in $\delta^{34}\text{S}$ following the former period continued until 2007. The sulfate concentration in lake water was also stable. The $\delta^{34}\text{S}$ in this period was generally low relative to other period suggesting the limited supply of magmatic fluid.