Temporal Variation in Controlled Source Electromagnetic Response at Inferno Crater Lake, New Zealand

Norihiro Kitaoka[1], Yasuo Ogawa[2], T. Grant Caldwell[3], Alison Kirkby[4], Keiichi Ishizu[5] and Takuto Minami[6]
[1]Tokyo Institute of Technology, kitaoka.n.aa@m.titech.ac.jp
[2]Tokyo Institute of Technology; Tohoku University, oga@ksvo.titech.ac.jp
[3]GNS Science, g.caldwell@gns.cri.nz
[4]GNS Science, a.kirkby@gns.cri.nz
[5]University of Hyogo, k.ishizu@sci.u-hyogo.ac.jp
[6]Kobe University, tminami@port.kobe-u.ac.jp

SUMMARY

To reduce the risk of phreatic or hydrovolcanic eruptions, it is crucial to monitor the temporal variation of high-resistivity vapor layers in the hydrothermal systems of volcanoes. However, the development of methods to detect temporal changes in resistivity structures with high temporal resolution remains incomplete. To address this issue, a frequency-domain controlled source electromagnetic (CSEM) survey was conducted at Inferno Crater Lake in New Zealand from May to November 2023. The lake exhibits a 40-day cycle in temperature and water level, with water level fluctuations of up to 7 meters and temperature changes of around 40°C, suggesting fluctuations in a resistive two-phase layer within its hydrothermal system. The calculation of electric fields and currents at signal frequencies was performed using the Fast Fourier Transform (FFT) on one-hour data segments. Error values were determined based on the median amplitude of surrounding frequencies. Signal-to-noise ratios ranging from 10 to 100 were obtained. Subsequently, apparent resistivity and phase were calculated from the observed electric fields and transmitted currents. Deviations in these values exhibited frequency dependence and spatial distribution, and were correlated with changes in water level and temperature. A forward modeling of the effect of lake level fluctuations demonstrated that the deviations represent the temporal change in the subsurface structure. The results indicate that frequency-domain CSEM methods are effective for monitoring temporal changes in resistivity structures, offering valuable insights into dynamic subsurface processes in volcanic hydrothermal systems.

Keywords: Controlled source electromagnetics (CSEM), monitoring, Volcanic hazards and risks