Continuous heat accumulation beneath Tokachi-dake volcano, northern Japan, as inferred from magnetic total field changes

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Tokachi-dake is an active volcano in the central Hokkaido, northern Japan. In historic age, it experienced phreatomagmatic to magmatic eruptions in 1926, 1962, and 1988-89. Recent major geothermal anomalies and fumaroles have been concentrated on Taisho and 62-II craters. Geodetic monitoring based on GPS has revealed continuous inflation localized at 62-II crater since 2007 (Japan Meteorological Agency, 2012). In contrast, seismicity and fumarolic activity at 62-II crater were considerably low in this period. Most recently, after 2010, micro-seismicity beneath the crater area has gradually revived and thermal activity at Taisho crater has measurably elevated. We have performed magnetic repeated surveys since 2008 aiming for better understanding of ongoing subsurface processes beneath the craters.

Numerous studies have reported magnetic changes associated with volcanic activity. In many cases, such changes are attributed to the thermo-magnetic effect in which heating/cooling causes decrease/increase in magnetization of volcanic rocks. If the localized ground inflation at Tokachi-dake accompanies thermal processes beneath the crater, it should be detected as magnetic field changes.

In each survey, we recorded the magnetic total field at about 30 sites for 2 minutes on each with every 5 seconds around the craters. Repeatability of the sensor position was typically several cm in a typical field gradient of 10 nT/m (but occasionally 100 nT/m). During the survey, another magnetometer was operated at a temporary reference station that was located approximately 8 km north from the target area. Simple difference reduction was applied between each site and the reference in order to remove the variations of extra-terrestrial origins.

The first and second campaigns revealed a distinct dipolar pattern in magnetic changes, indicating magnetization loss at a depth of roughly 200 m beneath the 62-II crater. Subsequent repeat surveys suggested the continuous demagnetization at almost the same position with an approximately constant rate. The maximal cumulative change exceeded 150 nT for the four years by 2012. The equivalent change in the magnetic moment amounted to 1.3×10^{6} Am^{2}/yr. The most likely explanation of this demagnetization is the thermo-magnetic effect due to heating beneath the crater. This result implies that heat supply from depth is larger than discharge from the vent. Through several approximations and assumptions, we obtain an equivalent thermal accumulation as an order of $10^{14\text{-}15}$ J/yr; corresponding to several tens of MW. This thermal demagnetization accompanying the ground inflation may be a part of the preparation process to forthcoming surface manifestation, although the estimated thermal energy may also be accounted for the fluctuation of heat discharge from the vent. Further accurate measurements of surface heat loss may be a key to a better evaluation of the supply from depth.