Volcanic Rocks Evaluation Using Magnetic Susceptibility

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In the field of geology, magnetic susceptibility is often used to understand rock magnetic behavior. Susceptibility value is proportional to ferromagnetic minerals content (Ishihara 1979), whether it is volume-specific (κ; dimensionless) or mass-specific (χ m^3/kg). Magnetic susceptibility is affected by various parameters such as mineral phase, mineral size distribution, and measurement temperature. Magnetite is known to have a very high susceptibility in several tens nanometer size (Maher, 1988). A recent study found that crystallization of magnetite nanolite (30 nm –1 μm in width) and ultrananolite (< 30 nm in diameter) reflects residence time and pressure in the shallow part of the conduit during magma ascent (Mujin & Nakamura 2014; Mujin *et al*. 2017). Magnetite nanolites and ultrananolites presumably will increase magnetic susceptibility. Magnetic susceptibility of the volcanic ejecta is expected to change as the residence time and pressure in the shallow conduit even for the same eruption event. In other words, magnetic susceptibility has a potential to be a tool for near-real-time monitoring of volcanic activity in the shallow conduit. This study aims to understand the fundamental of magnetic susceptibility behaviors in volcanic rocks by using various variables. We have investigated (1) the difference of several susceptibility meters, (2) the instrument reproducibility, (3) the difference in κ and χ due to pyroclast grain size effect, (4) the additivity of magnetic susceptibility, (5) magnetite content dependence, (6) oxidation effect, and (7) sample from different volcanoes and eruption types.

Magnetic susceptibility measurement was conducted using SM-30 (ZH Instruments) which is the handy type and MS3-MS2B and MS3-MS2G (Bartington Instruments Ltd.) which are laboratory instruments. All the samples were pulverized using a Multi-Beads Shocker (Yasui Kikai, Co.) with 3000 rpm in 10 seconds, then stored in the standard box. The measurement using SM-30 requires ~150 g samples packed into circle plate (96.25 cm^3), while MS2B sensor requires ~20 g samples packed into the circle box (10 ml volume) and MS2G sensor requires ~2 g packed into the cylinder tube (1 ml volume). MS3 meter connected to Bartsoft software during the measurement process which can measure both κ and χ, whereas SM-30 is only κ. The MS2B sensor records low-frequency (κ_{LF}) and high-frequency (κ_{HF}) which are considered to find frequency dependence of the samples (κ_{FD}). The measurement processes conducted in the same place.

Relative tendencies of susceptibility of samples were similar in SM-30 and MS3. Compared to MS3, susceptibility measured with SM-30 is ~30 % lower. Instrumental reproducibility (2σ) of MS2B and MS2G are ~5 x 10^{-6} and ~7 x 10^{-6} (κ; dimensionless), respectively. When different grain size measured, volume susceptibility (κ) varied, but mass susceptibility (χ) shows the same value. Thus, mass-specific correction must be acceptable for volcanic rocks powder measurement because the correction rectifies the error by density variance. Mass susceptibility value from mixing andesite (8.6 x 10^{-6} m^3/kg) and rhyolite (0.3 x 10^{-6} m^3/kg) with equal amounts resulted in roughly intermediate (4.2 x 10^{-6} m^3/kg) between them. Mass susceptibility value shows proportional dependency to the Fe-oxides mass. When the andesite heated in the air, susceptibility decreased with the increase of heating time accompanied by increasing its frequency dependence. The changes of mineral structure, from ferromagnetic to paramagnetic due to the heating process may cause a drop in susceptibility. The susceptibility decreased as the order of andesite (Sakurajima-Taisho pumices), basalt (Fuji-Hoei scoria) and rhyolite (Wadatoge obsidian). It is necessary to clarify the influence on the magnetic susceptibility of magnetite nanolite and ultrananolite.

Keywords: nanolite, pyroclast, magnetite

