Magnetization of oceanic lithosphere: Rock magnetism for characterization of submarine volcanism in the Okinawa Trough

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The Okinawa Trough is an initial back-arc rifting basin located behind the Ryukyu arc-trench system, and has a unique key to understand oceanic lithosphere formation, continent splitting, and hydrothermal systems. In order to understand comprehensive tectonic background of the Okinawa Trough, information of volcanic activity such as location, volume, timing, and type is essentially needed. Magnetic data can provide clues to modern and past volcanic activity because rich ferromagnetic minerals (mainly titanomagentite) within volcanic body carry strong magnetization, which is caused to acquire from the Earth's field when they cool, and produce magnetic anomaly. However, linkage between crustal magnetization and material processes in volcanic activity is still poorly understood. In order to establish a useful benchmark for interpreting magnetic anomalies, we performed comprehensive rock magnetic analysis and petrological studies of abyssal rock samples collected in the Okinawa Trough. The measurements were conducted for basalt from the Yaeyama Ridge (YYR), Irabu knolls (IRKs) and axial rift knolls off Kumejima Island (ARKs), dacite from the Hatoma knoll (HTK), and rhyolite and pumice from the Tarama Knoll (TRK), and Daisan-Kume Knoll (DSK).

The natural remanent magnetization (NRM) intensity varies over two orders of magnitude from <0.1A/m to >200A/m. The magnetic susceptibility of all samples is too low to induce magnetic field under geomagnetic field intensity comparing with NRM intensity. The NRM intensity of volcanic rocks may vary in relation to several factors such as the geomagnetic field strength at the timing of remanence acquisition, amount and type of magnetic minerals, grain chemistry such as Ti content of titanomagnetite, magnetic domain state controlled by grain size distribution, and the degree of low-temperature oxidation. Therefore, we carefully examined magnetic properties, petrography, and geochemical signatures for understanding rock-to-rock NRM variation.

Thermomagnetic curves of volcanic rocks with low NRM (<1 A/m) from the YYR, IRKs, and HTK show irreversible and complex Curie temperatures, suggesting these samples have been affected by hydrothermally alteration and/or low-temperature oxidation which considerably decreases the NRM. Low NRM of pumice from the TRK and DSK is likely explained by low amount of titanomagnetite grains. The large difference of NRM between rhyolite and basalt is certainly explained by difference of magma iron content, which is diluted by the silica content through magma evolution. A rhyolite sample from the TRK contains titanomagnetite as the magnetic carrier with a Curie temperature of 490°C and shows magnetic domain state of pseudo single domain (PSD). This sample was compared with one basaltic rock from the IRKs with similar Curie temperature and PSD signature. Both samples show reversible thermomagnetic curves, suggesting that they have not been affected by low-temperature oxidation. The titanomagnetite amount of this TK’s rhyolite (0.9 wt.%) is about one-third that of IKs’s basalt (3.1 wt.%). This result is consistent with the bulk rock geochemistry data. The NRM intensity is also about one-third (3.1 A/m to 9.4 A/m). These results indicate that lower NRM intensity of rhyolite was caused mainly by a smaller titanomagnetite content due to low iron content diluted by silica content.

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