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Precise determination of Fe species in plagioclase crystals: a preliminary study
Precise determination of Fe species in plagioclase crystals: a preliminary study

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Silicate minerals such as plagioclase and pyroxene sometimes contain fine-grained magnetite crystals; such silicates are called magnetic silicates. Magnetic silicates are ubiquitous in mafic and intermediate plutonic rocks [Dunlop and Ozdemir, 1997; Gee and Kent, 2007]. As the middle and lower crust have greater mafic composition than the upper crust [Rudnick and Gao, 2004], magnetic silicates should play an important role in controlling the magnetic properties of deep crustal rocks. For understanding the sources of magnetic anomalies, which are often originated from thick magnetized layers within the crust [Shive et al., 1992 and reference therein], it is crucial to investigate the condition of exsolution of magnetite in silicate minerals.

In this study, to precisely determine the chemical species of Fe in the plagioclase crystals, magnetic measurements combined with microscopic observation and synchrotron radiation study were conducted for single grain plagioclase crystals. We prepared the two types of plagioclase crystals from (1) the basalt (Ofunato scoria) from the Miyakejima volcano [Ushioda et al., 2014] and (2) the gabbro from the Oman ophiolite [Sato et al., submitted]. The plagioclase crystals were collected under a stereoscopic microscope and used for the measurements after a hydrochloric acid (HCl) leaching for several days.

The main series of measurements for the single grain plagioclase crystals were as follows. (1) To estimate a content of magnetic mineral in the plagioclase crystals, magnetic hysteresis loop was measured using an Alternating Gradient Magnetometer (MicroMag 2900, Princeton Measurements Corporation) and magnetic hysteresis parameters (saturation magnetization M_s, saturation remanence M_{rs}, coercivity B_c, and coercivity of remanence B_{cr}) were calculated. (2) To investigate chemical compositions of the plagioclase crystals, microscopic observation was conducted using a field emission electron microprobe (JXA-8530, JEOL). (3) To investigate valence state of Fe, K-edge X-ray absorption near edge structure (XANES) spectra were measured at BL-4A of Photon Factory (PF).

The M_s value for the plagioclase crystals of the basalt and gabbro samples were $<5 \times 10^{-4}$ Am^2/kg and ca. 1×10^{-2} Am^2/kg, respectively. Therefore, the plagioclase crystal of the gabbro contained substantial amount of magnetic minerals, while that of the basalt contained no or little magnetic mineral. Taking into account the Curie temperature of 548 ^{o}C [Sato et al., submitted], the ulvospinel content for the plagioclase crystal of the gabbro was estimated to be x = 0.047 [Hunt et al., 1995] and the magnetite content was estimated to be 0.011wt%.

The microscopic observation showed that the FeO contents for the plagioclase crystals of the basalt and gabbro samples were 0.45wt% and 0.18wt%, respectively. The XANES analysis showed that the valence state of Fe for the plagioclase crystals of the basalt and gabbro samples were ca. 2.54 (Fe^{3+}/Fe^{2+} = 1.17) and ca. 2.59 (Fe^{3+}/Fe^{2+} = 1.44), respectively. In the case of the basalt sample, all Fe was contained in the plagioclase crystal, which is consistent with the thermal history of the Miyakejima basalt [Ushioda et al., 2014]. In the case of the gabbro sample, about 95% of Fe was contained in the plagioclase crystal and the remaining 5% of Fe was exsolved as magnetite crystals. The presence of magnetite was also suggested by the linear combination fitting of XANES spectra.

Now, our plan is to conduct high temperature heating experiment for the plagioclase crystals with varying the oxygen fugacity. On the basis of the measurements results for the samples before and after heating, we will discuss the high temperature heating effect on the Fe chemical species in the plagioclase crystals.

Keywords: Plagioclase, Magnetic silicate, Rock-magnetism, XANES