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High temperature oxidation of lherzolite xenolith from Oku district, Oki-Dogo Island, Japan: evidence in olivine

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Ejima et al. (2011) reported Fe^{3+} from olivine in lherzolite xenolith from Oku-district, Oki-Dogo Island, Shimane Prefecture, and pointed out two possibilities of generation of Fe^{3+} in olivine: 1) Olivine was incorporated Fe^{3+} at upper mantle condition; 2) Fe^{3+} was generated in olivine by high temperature oxidation in host basalt magma. In order to solve this problem, we investigated a brown zone (about 0.3 mm) distributed at the rim of olivine in the margin of the xenolith in touch with host basalt, using methods of electron probe microanalysis (EMPA), high resolution transmission electron microscopy (HRTEM) and Raman spectroscopy.

The brown zone consisted of forsterite with Fo_{69} (mol%), which is Fe-rich than that at the core part (Fo_{81}) of the xenoliths. No impurity was detected by EMPA, although the Fe-O vibration peaks of hematite and magnetite were detected by Raman spectroscopic analysis. HRTEM observation revealed existence of dislocation cores parallel to (001) of olivine structure, and electron diffraction spots of olivine consisting of the brown zone showed weak streak along the c-axis. However no precipitate such as hematite or magnetite was detected by HRTEM observation. Thus, the Fe-O vibrations observed in Raman spectra can be attributed to very short-range hematite and magnetite structure clusters in olivine, but not to hematite and magnetite phases.

On the basis of the results of the present study, genetic process of hematite and magnetite structure clusters at the rim of olivine in the margin of the Oku lherzolite xenolith in touch with host basalt is considered as follows: 1) a part of Fe^{2+} on the rim of olivine was changed to Fe^{3+} by high temperature oxidation, and vacant octahedral sites were generated; 2) Fe^{3+} in olivine increased with high temperature oxidation, and hematite and magnetite structure clusters were formed in olivine structure; 3) in the region of hematite structure clusters, vacant layers (dislocation cores) parallel to (001) of olivine structure were formed. Therefore, crystallization of hematite and magnetite along the dislocation cores by further high temperature oxidation is expected.

Previous studies by annealing experiments of olivine in air reported crystallization of laihunite. However, in the olivine of the Oku lherzolite xenolith, laihunite was not detected, and existence of hematite and magnetite structures clusters in olivine are considered instead. Thus, two ways of crystallization of precipitates by high temperature oxidation can be proposed: 1) crystallization of laihunite -> hematite -> magnetite with increasing temperature; 2) crystallization of magnetite -> hematite with decreasing temperature, where the crystallization of laihunite is quite difficult. The latter case corresponds to olivine in the Oku lherzolite xenolith.

We conclude that Fe^{3+} within olivine from the Oku lherzolite xenolith (Ejima et al., 2011) was generated by high temperature oxidation underwent during the transportation from the upper mantle to the surface.

Keywords: olivine, lherzolite xenolith, oxidation state of Fe, high temperature oxidation