Hydrogen in Olivines From the Colorado Plateau: Implications for Water in the Mantle and the Alpe Arami Controversy

Identifier T32B-07

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Abstract

Petrological, geochemical and geophysical data indicate that portions of the upper mantle beneath the Colorado Plateau are highly hydrated, which has important implications for mantle viscosity and geodynamics (e.g. [1]). One line of evidence for this comes from the study of H in nominally anhydrous minerals. It has been shown that mantle garnets from the Plateau have higher H contents than those from other continental areas. Recently, we began a reinvestigation of H in olivines from the Buell Park (Arizona) and Green Knobs (New Mexico) diatremes, using polarized IR spectroscopy. Two varieties of olivine have been described [2] at these localities: green-colored crystals containing trace amounts of H, and brown olivines that contain substantially more H in the form of lamellae of Ti-clinohumite (Ti-cl). Our new observations show that there is a continuum between these two varieties. H concentrations range from 50 to 530 wt ppm H_2O. The olivine with the lowest H content exhibits strong absorption bands in the 3400 to 3650 cm^{-1} wavenumber region that closely resemble (in location and pleochroism) those found in olivines hydrated in our laboratory and by Kohlstedt and co-workers. The olivines with higher H contents contain these same bands as well as additional peaks at 3571, 3524, 3402, 3319, and 3230 cm^{-1} that are attributed to the Ti-cl lamellae. The 3402 cm^{-1} band is the strongest absorber both in these olivines and in spectra of Ti-cl single crystals. In addition to the nm-scale Ti-cl lamellae, these olivines contain oriented, micrometer-scale inclusions of chromite and cr-diopside. These precipitates are indicative of cooling and high silica activity [3]. This contrasts with assertions [4,5] that the high-wavenumber peaks in olivine are related to low silica activity, whereas low-wavenumber peaks indicate high silica activity. The specific attribution of the 3230 cm^{-1} peak to high silica activity [5] may also be in error. This peak is present in olivines in this study as well as olivines from several other localities (Zabargad Island, Egypt; Vesuvius, Italy; Monastery Farm, South Africa). In all of these cases it is correlated with a peak at 3402 cm^{-1} that suggests the presence of Ti-cl inclusions or lamellae [6]. The dominance of low wavenumber peaks at nominally low silica activity in some experimental studies [4,5] may be related to other factors such as oxygen fugacity, Fe-content, or the presence of unidentified hydrous inclusions. Some olivines from the Alpe Arami garnet peridotite contain oriented ilmenite chromite inclusions, and the inferred high TiO_2 content of the precursor olivines has been attributed to ultra-high pressure metamorphism at 10 GPa or more (e.g. [7]). Our observations support an alternative view [8] that the ilmenite exsolution is related to breakdown of Ti-cl lamellae in the olivine, not necessarily at such high pressures. Further work is underway using analytical TEM

to investigate the structures and chemistry of these lamellae, and further elucidate the mechanisms by which mantle olivine may incorporate both Ti and H.

References: [1] Dixon (2004) EPSL 222: 451-467 [2] Kitamura (1987) Nature 328: 143-145 [3] Markl (2001) Am Min 86: 36-46 [4] Matveev (2001) J Petr 42: 721-729 [5] Lemaire (2004) CMP 147: 48-57 [6] Miller (1987) PCM 14:461-472 [7] Bozhilov (2003) Am Min 88: 596-603 [8] Risold (2001) CMP 140: 619-628

Cite as: Author(s) (2004), Title, *Eos Trans. AGU, 85*(47), Fall Meet. Suppl., Abstract T32B-07