

VIS-NIR SPECTRAL PROPERTIES OF OLIVINE IN A BASALTIC GLASS: IMPLICATIONS FOR OLIVINE-RICH TERRAINS ON MARS. M. Nicholis, R. E. Milliken, J. F. Mustard, and M. Rutherford. Dept. Geological Sciences, Brown University, Providence RI 02912 USA. Email: mike_nicholis@brown.edu

Introduction: Results from the Mars Global Surveyor TES and Mars Express OMEGA spectrometers suggest some regions on Mars have an increased abundance of olivine relative to surrounding terrains [1,2]. Most recently, OMEGA spectra acquired near the Isidis basin have been interpreted to represent areas of preserved olivine-rich impact melt [3]. Olivine and pyroxene are easily identifiable in near-infrared (NIR) spectra by the presence of strong electronic transition absorptions caused by Fe held in the M1 and M2 sites [4]. Pyroxenes have absorptions centered near 1 and 2 μm , whereas olivine has only the 1 μm feature, allowing the latter to be easily identified when the former is not present. Previous spectral studies have focused primarily on particulate mixtures derived from mineral separates or rock samples, though Minitti et al. [5] examined unaltered and oxidized glasses of SNC composition. Here, we examine the effects of an experimentally generated glassy matrix containing olivine crystals to determine 1) changes in NIR spectra due to the presence of a glassy basaltic matrix instead of crystallized basaltic matrix, 2) the amount of olivine required to uniquely identify a glass as containing olivine crystals, 3) whether it is possible to distinguish an olivine-rich glass from an olivine-rich basalt or Fe-rich glass using VIS-NIR reflectance spectroscopy. We present the results in the context of OMEGA data, with implications for the origin of "olivine-rich" terrains on Mars.

Methods: Olivine-rich basalt from Kilauea Iki lava lake was melted and quenched to a glass with various amounts of olivine. The starting material was a natural, porphyritic, olivine-rich basalt containing phenocrysts of olivine and plagioclase in order of decreasing abundance. The olivine (Fo₇₅₋₈₁) is typically found in clots of multiple grains on the order of 0.5-1 cm in diameter with individual grains ranging from 0.1-0.5 mm in size. The groundmass is variably vesiculated with phases of olivine, plagioclase, clinopyroxene, and Fe-Ti oxides. The basalt was ground and sieved to <125 μm , then hand picked to produce aliquots of basalt + olivine with ~50, 10, and <2% olivine by volume. Each sample was placed in an Au₈₀Pd₂₀ alloy capsule and run in a TZM (Tungsten-Zirconium-Molybdenum) pressure vessel. The pressurizing medium was a CH₄-Ar gas mixture, the ratio of which has been calibrated with the breakdown of fayalite to pin down the Quartz-Fayalite-Magnetite (QFM) oxygen fugacity. We chose an fO₂ of QFM because it falls in the middle of the wide range of oxygen fugacity values for Mars [6,7,8]. All experiments were pressurized to 400 bars and then raised to their final pressure of 500 bars at 1185°C. These P-T conditions melt grains of the basaltic matrix while leaving the olivine crystals intact. Samples were held at final conditions for 1 hour and then quenched, producing glasses of basaltic composition with varying amounts of olivine crystals.

Back scatter electron images (BSE, Figure 1) reveal that the samples are basaltic glasses with ~50%, 10%,

and <2 vol. % olivine crystals (ranging in size from 10-400 μm). The sharp edge textures of olivines found in our experiments, along with very small compositional zoning features on the BSE images, suggest that there was minimal interaction (assimilation) between the melt and olivine. This is supported by the similarity in composition of the glass component for all 3 experiments: (wt. %) 53.33% SiO₂, 14.01% Al₂O₃, 2.27% TiO₂, 8.65% FeO, 8.13% MgO, 10.69% CaO, 0.17% MnO, 0.40% K₂O, 2.10% Na₂O, 0.44% P₂O₅.

Each of the three glass samples, and a sample consisting solely of olivine phenocrysts, was ground and sieved to <45 μm for spectral analysis. Reflectance spectra were acquired from 0.3 – 2.5 μm with an ASD Field Spectrometer at Brown University.

Results: The glass and olivine spectra show several key features (Figure 2), including strong absorptions in the visible wavelength range due to charge transfer, and a broad, strong absorption centered near ~1 μm indicating the presence of Fe. Olivine is known to have three distinct absorptions centered near 0.86, 1.06, and 1.33 μm , caused by electronic transitions of Fe located in specific crystallographic sites in the olivine structure. The sidebands are weaker and appear as shoulders on the stronger center band. These features are clearly visible in the spectrum of the pure olivine as well as the glass with ~50% olivine crystals. The two glasses with lesser amounts of olivine, however, show a symmetrical band centered near 1 μm , with a long wavelength edge near ~1.5 μm , and a weak absorption centered near 2 μm . The 2 μm feature was also observed in glasses by [9] and is attributed to crystal field transitions in a glassy matrix.

The similarity between the two low-olivine glasses suggests that the symmetrical 1 μm band is caused by Fe in the glass structure, not by the small olivine crystals. OMEGA spectra of an olivine-rich terrain, divided by a spectrum of bright dust, reveal a strong, broad absorption centered near 1 μm with a long wavelength edge near 1.6 μm , similar to some spectra of pure olivine (Figure 3) [2]. The broadness of this band may be indicative of Fe-rich olivine (fayalite) or olivine with a large particle size [REF]. The olivine shoulder near 1.3 μm , however, is not evident in the OMEGA ratio spectrum. Instead, the general shape of the 1 μm band is more similar to that of our glass spectra with <50% olivine.

Conclusions: Preliminary results suggest that it is difficult to distinguish between fayalitic olivine, large olivine grains, Fe-rich glass, or glass with minor amounts of olivine crystals, all of which may exhibit a broad, symmetrical absorption centered near 1 μm . This is similar to the 1 μm feature observed in OMEGA data for "olivine-rich" areas, suggesting that these regions may represent ol-rich basalt or glass (impact or volcanic). Putting these observations in their

geological context will help to further constrain the interpretation. Future work will focus on a wider range of olivine compositions, ol/glass ratios, and glass grain sizes.

References: [1] Hoefen et al. (2003) *Science*, 302, 627 – 630; [2] Mustard et al. (2005) *Science*, 307, 1594-1597; [3] Mustard et al. (2005) *Eos Trans. AGU*, 86(52), Fall Meeting; [4] Burns, R. *Min. Appl. Cryst Field Theory*, Cambridge Press, 575 pp.; [5] Minitti et al. (2002) *JGR*, 107, 5030; [6] Delaney et al. (1998) *LPSC 29*, 1241-1242; [7] Ghosal et al. (1998) *Contrib. Min. Pet.*, 130, 346-357; [8] Herd, C. and Papike, J. (1998) *Geol. Soc. Am. Abstr. Prog.*, 31, 44-45; [9] Pieters, C. and P. Englert (1993) *Remote Geochemical Analysis*, 594 pp.; [10] Pieters et al. (2004) *LPSC 35*, #1840.

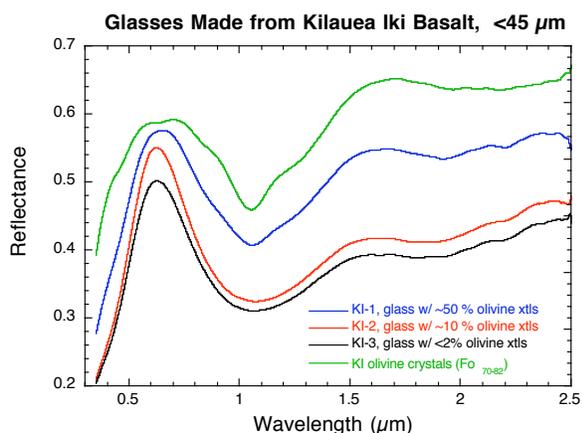


Figure 2. Reflectance spectra of experimental glasses with ~50, 10, and <2% olivine and a spectrum of the ground olivine phenocrysts. Three distinct absorptions are present near 1 μm in the pure olivine and ol-rich glass. The band is more symmetrical for the ol-poor glasses, similar to what is observed in OMEGA data (Figure 3).

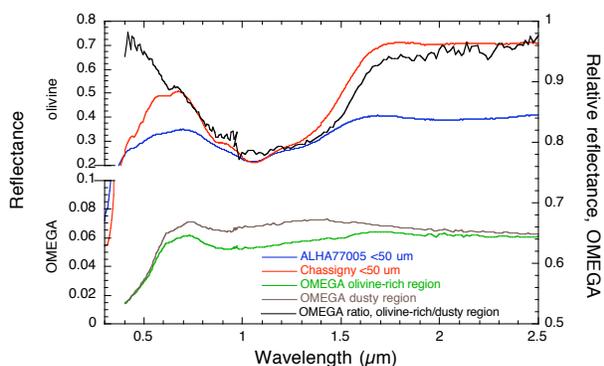


Figure 3. Reflectance spectra of olivine separates from SNC meteorites (RELAB database, [10]) compared to an OMEGA ratio spectrum for an olivine-rich area (Orbit 0394). The OMEGA ratio spectrum shows a broad, symmetric band centered at 1 μm that is similar in width to olivine, but is more symmetrical, similar to our glass spectra (Figure 2). Original OMEGA spectra are also shown.

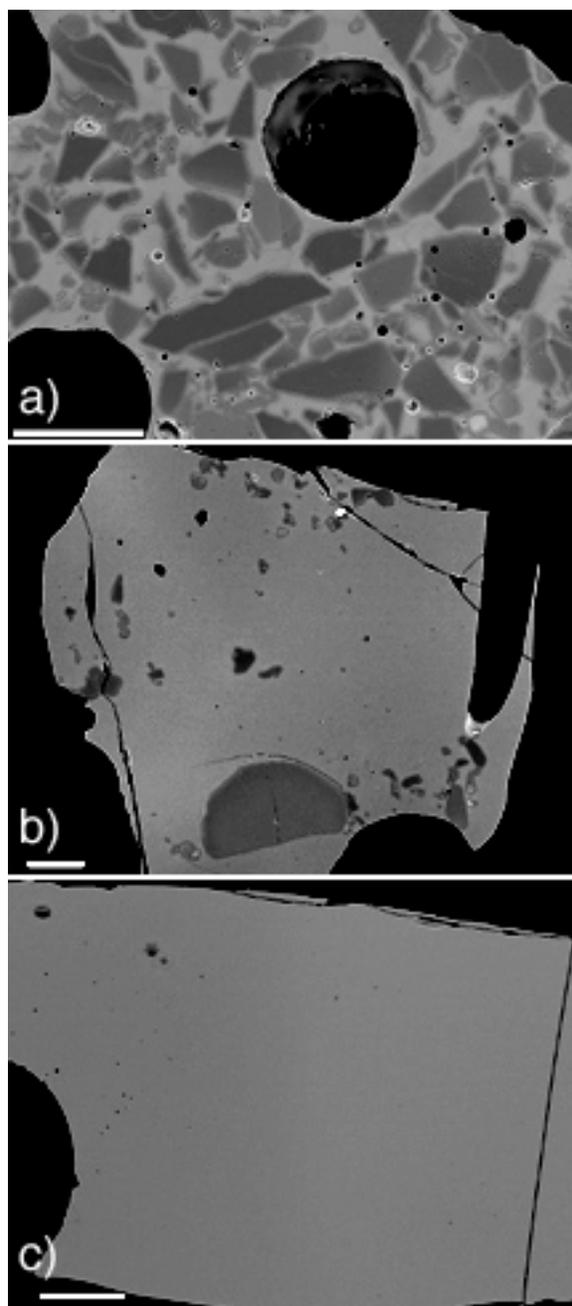


Figure 1. Back scatter images of glasses with a) ~50% olivine, b) ~10% olivine, and c) <2% olivine by volume. Gray areas are the glassy matrix, dark gray areas are olivine crystals, and black areas are epoxy or bubbles. All scale bars are 200 μm