

FORMATION MECHANISM OF IRON-RICH OLIVINE: EXPERIMENTAL CONSTRAINTS INTO EARLY FLUID-ASSISTED HYDRATION AND DEHYDRATION PROCESSES ON ASTEROIDS.

E. Dobrică¹, J. A. Nuth² and A. J. Brearley¹, ¹Department of Earth and Planetary Sciences, MSC03-2040, 1 University of New Mexico, Albuquerque, NM 87131-0001, USA (edobrica@unm.edu); ²Solar System Exploration Division, Code 690, NASA Goddard Space Flight center, Greenbelt MD 20771 USA..

Introduction: Iron-rich olivine is one of the major minerals in the matrices of unequilibrated ordinary (UOCs) and carbonaceous (CV, CK, CO) chondrites whose petrologic type is >3.1 [1-3]. There has been an extensive discussion in the literature as to the formation mechanism of these olivines; however, their origin is poorly understood. The formation of ferroan olivine during hydrothermal alteration has been demonstrated to be thermodynamically viable [4]. The stability of ferroan olivine is highly dependent on several variables, including temperature, water/rock (W/R) ratio, pressure, oxygen fugacity, and bulk rock composition. So far, hydrothermal alteration experiments have not been successful at forming FeO-rich olivines with the compositions and textures observed in the matrices of chondrites [5-7]. Therefore, understanding the formation conditions of FeO-rich olivines remains a key problem to explain the effects of hydrothermal alteration on chondrite matrices.

Methods and results: We performed three new experiments in an attempt to synthesize FeO-rich olivine. We conducted two experiments to investigate the effects of hydration and one hydration-dehydration experiment to understand if FeO-rich olivine could form during dehydration of phyllosilicates, as described by previous studies [1]. We modified the procedure used by Dobrică et al. [8], by using (1) thicker gold tubes (0.2 mm wall), (2) sharper pencil graphite (0.7 mm) for welding to avoid leaks and (3) one experiment was performed on iron foil (thickness 0.25 mm) instead of iron powder. The welding process was faster, which limited the evaporation of water from the gold tube during welding and no leaks were observed.

In the first hydration experiment, we used amorphous silicate that was deposited on top of an homogeneous iron foil (thickness 0.25 mm). Additionally, deionized water was added to cover these materials, which were placed inside a Parr bomb (reactor vessel) for 8 days. We chose amorphous silicates as the precursor material since they are ubiquitous fine-grained materials in almost all primitive solar system materials (chondritic meteorites and interplanetary dust particles) and in most astrophysical environments [9]. The amorphous silicate grains were synthesized experimentally by disequilibrium condensation [10]. The composition of the silicate grains, which condense from the Fe-SiO₂-H₂ vapor, cluster at the pure oxide (FeO_y, SiO_x) end members and at intermediate compositions [11]. We used an iron film, instead of an iron powder, to understand how the alteration proceeded from the surface in contact with the amorphous silicate, down towards the depth of the iron film. For the second hydration experiment, we used a similar amorphous silicate and iron metal powder (spherical particles, $<10 \mu\text{m}$), as the starting material for the experiment. We loaded the materials in gold (Au) capsules ($\sim 5 \text{ mg}$ - amorphous silicate, $\sim 10 \text{ mg}$ - iron powder and $\sim 2 \mu\text{l}$ water to simulate a W:R ratios of 1) in a sealed glove compartment, purged with N₂. We carried out the experiment for a period of 8 days. For the third experiment, we hydrated an iron-rich amorphous silicate and iron metal powder mixture in a Parr bomb for 6 days (Fig. 1a). A few months after the hydration of materials, about half of the hydrated products were replaced back in the oven for 13 days for the dehydration experiments (Fig. 1b). All the experiments were placed inside Parr bombs and heated in a low temperature furnace (Fisher Scientific, Isotemp 500 Series) at a temperature of 220°C. Three transmission electron microscopy (TEM) sections of the experimental run products were prepared using the FIB technique with a FEI Quanta 3D Dualbeam® FIB instrument. Using quantitative energy dispersive X-ray spectroscopy (EDS) analysis and electron diffraction, we identified the formation of fayalite by dehydration in the third experiment. This study shows that fayalite could form on the parent body of asteroids at low temperature during hydration-dehydration processes.

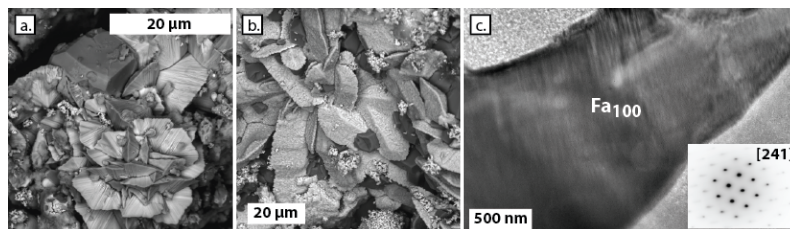


Figure 1. Backscattered electron images of the hydration (a) dehydration (b) experiments. c) Dark-field STEM image of the fayalite (diffraction pattern indexed as [241] zone axis) identified in the dehydration experiment.

Acknowledgements: This work was funded by NASA grant NNX15AD28G to Brearley (PI).

References: [1] Krot A. N. et al. (1997) *Meteorit. Planet. Sci.* 32:31-49. [2] Dobrică E. and Brearley A. J. (2014) *Meteorit. Planet. Sci.*

49:1323-1349. [3] Doyle P. M. et al. (2015) *Nature Communications* 6:1-10. [4] Zolotov M. Y et al. (2006) *Meteorit. Planet. Sci.* 41:1775-1796. [5] Chizmadia L. J. et al. (2006) *LPSC 37:#2187*. [6] Nakamura-Messenger K. et al. (2011) *Meteorit. Planet. Sci.* 46:843-856. [7] Le Guillou C. et al. (2015) *Chemical Geology* 412:179-192. [8] Dobrică E. et al. (2017) *LPSC 38:#2865*. [9] Brearley A. J. (1993) *Geochim. Cosmochim. Acta* 57:1521-1550. [10] Nuth III J. A. et al. (2002) *Meteorit. Planet. Sci.* 37:1579-1590. [11] Nuth III J. A. et al. (1983) *Proceedings of the 13th Lunar and Planetary Science Conference, part 2, Journal of Geophysical Research* 88 (Suppl.):A847-A852.