

during the experiment, consistent with an increase in volume due to oxidation.

Raman Results. Raman spectra of unaltered olivines show only the characteristic doublet at ca. 822

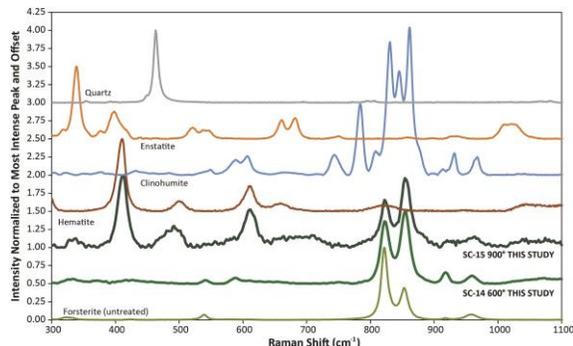


Figure 2. Raman spectra of oxidized olivines SC-14 and SC-15 (bold green lines) compared against untreated San Carlos olivine (light green line at bottom) and other phases that are potential oxidation products. The sample treated at 600° resembles untreated olivine, even after 625 hours of heating. The SC-15 sample treated at 900° contains significant hematite and a suggestion of enstatite. Other heat-treated samples may contain clinohumite or quartz.

and 854 cm^{-1} [17] along with other minor peaks that are also present in numerous examples of forsteritic olivine on the ruff.info web site. There is no detectable alteration in the unaltered crystals. At 600 °C altered crystals show evidence for peaks associated with hematite as the dominant alteration mineral with potentially minor magnetite, and clinohumite as well, but the olivine peaks still dominate the spectra even after 625 hours of oxidation. For the 900 °C experiments, alteration minerals including hematite and possibly magnetite dominate the spectra. There is potentially clinohumite as well, and forsterite is still present in the spectra, though to a much lesser extent. After 625 hours, there is minimal evidence for enstatite and quartz, as would be expected from oxidation of olivine to Fe-oxides [11]. Raman spectra of these minerals are shown in **Fig. 2**, with forsterite samples SC-14 and SC-15 heat treated at 600°C and 900°C, respectively, for 625 hours.

VSM results. Before oxidation, olivine showed a paramagnetic signature and had no detectable ferromagnetic signal. For the 900 °C experiments, there was a change to a ferromagnetic signature after only 12 minutes (our shortest run time). For the 600 °C experiments, the change to a ferromagnetic signature did not occur until oxidation occurred between 125 and 625 minutes. Further, when hysteresis data is compiled into a Day et al. [16] plot (**Fig. 3**), the nucleation of high-coercivity hematite causes most samples to exhibit more single-domain like behavior with increased heating times and temperatures. The

magnetic hysteresis loops, show a combination of ferromagnetic contributions from a ‘soft’ magnetic mineral (magnetite) and a ‘hard’ magnetic mineral (hematite).

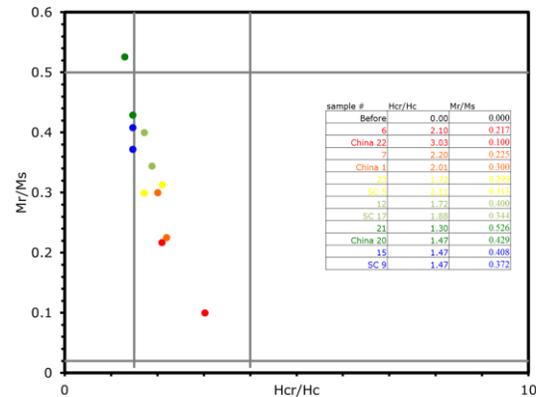


Figure 3. Day et al. [16] plot for the 900 °C experiments. Hcr/Hc is the remanent coercivity divided by coercive force. Mr/Ms is the isothermal remanent magnetization divided by the saturation magnetization.

Implications: Hematite dominates the alteration products seen in the Raman spectra; however, the minor amount of magnetite that is also being produced by oxidation dominates the magnetic properties. Olivine oxidation on the surface should be dominated by hematite; however, small amounts magnetite should also be present and can contribute to a magnetic signature. Additional further characterization of these samples will include Mössbauer spectroscopy to better understand the distribution and mineralogy of the altered samples.

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