PROGRESS TOWARDS DETERMINING THE TEMPERATURE OF LUNAR GLASS BEADS

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Introduction: Lunar glass beads, thought to have formed during pyroclastic fountaining events, have been used to constrain lunar heat flow, magma temperatures, volcanic processes and also volatile diffusion processes [1-4]. Orange glass beads from the Apollo 17 site include largely crystal-free beads that are inferred to have erupted above their liquidus temperature (≥1400 °C [4]), and crystal-bearing beads that may have formed under unusual thermal conditions in the lunar eruption column (e.g. with gases or heat-radiating particles [4]). The conditions during eruption, degassing and quench are important for constraining volatile diffusion processes because diffusion coefficients depend on temperature [5]. In this contribution, we evaluate the usefulness of micro-reflectance thermal IR (TIR) spectroscopy for determining the temperature of lunar orange glass beads.

Basis for using TIR: Our previous work [summarized in 6] shows that, in general, the SiO_2 content of glasses is related to the wavenumber position of the major band in TIR spectra (Fig. 1), although Na_2O+K_2O may also play a role. The shift in band position is ~+4cm^{-1} per 1 wt% SiO_2 for glasses with similar Na_2O+K_2O contents.

TIR is sensitive to the overall glass composition and structure because the major band position (~10 µm or ~1000 cm^{-1}) is related to asymmetric stretching of Si-O-Si. However, TIR spectra are strongly influenced by temperature also [7]. Glasses that are cooled rapidly commonly retain a structural configuration representative of the glass transition temperature (T_g) and this is reflected in the position of the TIR major band. However, if glasses are annealed at temperatures $\leq T_g$ long enough to rearrange the glass structure, and then the glass structure, and subsequently the TIR band position, reflects a lower temperature, known as the fictive temperature, T_f [e.g., 8].

Methods: Johnson Space Center provided lunar "orange glass" beads (Apollo 74220). Glasses were analyzed with the electron probe and the same locations were analyzed using micro-FTIR specular reflectance spectroscopy (µR-FTIR) on a Nicolet Nexus 670 FTIR and a Continuµm microscope with a Globar source, XT-KBr beamsplitter and an MCT-A detector over 30x30 to 100x100µm areas.

Results. Glass beads were group into those that were entirely glassy in cross-section, those with low amounts of crystals (<10 modal%), and those with a moderate amount of crystals (~20-60 modal%). The major element chemistry of each group is within error of the other groups, indicating that any changes in IR spectra should not be due to the glass chemistry. The beads with no or few crystals had TIR band positions and shapes within error. Glass beads with moderate crystals had TIR band positions ~+5-10cm^{-1} relative to those with no or few crystals, suggesting they formed at lower temperatures. We plan to calibrate the TIR shift using glasses heated over a range of temperatures.

Conclusions. The µR-FTIR band position may be used to probe the thermal history of glasses; creating an opportunity to better understand lunar volcanic processes.

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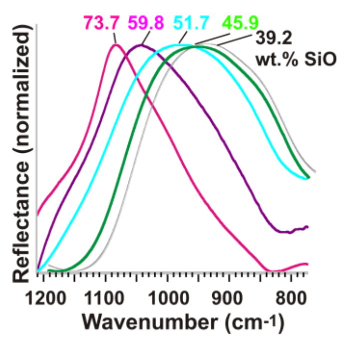

Figure 1. µR-FTIR reflectance versus wavenumber for representative glasses: rhyolite (green), andesite (purple), basalt (cyan) and lunar "orange" glass (red). The SiO_2 contents are given in wt. %.

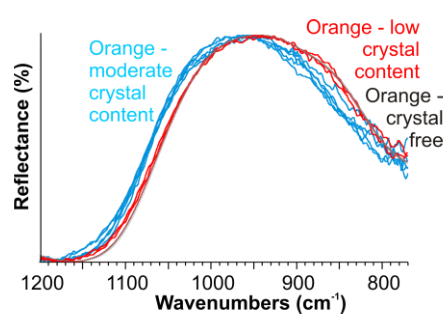

Figure 2. µR-FTIR reflectance versus wavenumber for orange glasses (Apollo 74220. From left to right - Blue: glasses with moderate crystal content. Red: glasses with low crystal content. Grey: glasses with no crystals in the two-dimensional cross-section.