

Fe-BEARING GLASSY MATERIALS: SPECTRAL REFLECTANCE PROPERTIES. E. A. Cloutis¹, ¹Dept. of Geography, Univ. of Winnipeg, 515 Portage Ave., Winnipeg, MB, Canada R3B 2E9; e.cloutis@uwinnipeg.ca.

Introduction: Poorly crystalline/amorphous silicate-dominated materials (hereafter glassy materials) are expected to occur on many planetary surfaces as the result of processes such as rapid cooling of volcanically erupted lavas and liquified impact ejecta (impact melts), and hydrothermal alteration. As iron is ubiquitous on most planetary surfaces, it is expected that Fe-bearing glassy materials would be present on many planetary surfaces. The presence of amorphous materials has been confirmed on Mars [1], Fe-bearing volcanic glasses have been found on the Moon [2], and Fe-bearing impact melts are present in meteorites [3].

The presence of Fe-bearing glassy materials can provide insights into processes operating on planetary surfaces. To better determine how and whether such materials can be detected by reflectance spectroscopy, we have conducted a spectroscopic survey of a variety of such materials.

Methodology: A suite of Fe-bearing glassy materials were included in this study (Table 1) and have been spectrally characterized at both RELAB [2] and the PSF [3]. These materials have been characterized by XRF and wet chemistry for total iron and $\text{Fe}^{2+}/\text{Fe}^{3+}$ ratios [4] and by X-ray diffractometry (XRD) or back-scattered electron (BSE) imaging to roughly constrain their crystallinity. XRD was used to determine the presence of an amorphous "hump" and to search for any mineral specific diffraction peaks, while BSE imaging was used to assess compositional homogeneity. It should be noted that we did not use the XRD (and BSE) to provide a quantitative measure of "glassiness". Here we present some of the major findings from this ongoing study.

Sample ID & description	Fe^{2+}O (wt. %)	$\text{Fe}^{3+}_2\text{O}_3$ (wt%)
SIL003, SIL004: obsidian	0.51, 0.80	0.41, 0.70
IMP001: Darwin glass	2.38	0.25
SIL130: Libyan desert glass	0.12	0.02
SIL131: Dakhleh glass	0.56	4.59
TEK001, 003, 004: tektites	4.67, 4.10, 4.21	0.42, 0.64, 0.35
ICE170: glassy basalt	8.39	1.64
BAS101 & BSB101: glassy basalts	10.60, 8.84	1.07, 2.66
G3, G4, G10, G11, G12: Lunar analogue glasses	9.96, 15.34, 12.17, 5.84, 6.10	10.97, 9.81, 13.49, 6.99, 4.79

Results: The presence of Fe^{2+} in a silicate matrix appears to lead to the appearance of one or two weak absorption bands in the 1 and/or 2 micron region that is likely attributable to Fe^{2+} in a roughly octahedral coordination environment bound to oxygens associated with silica tetrahedra or silica networks.

Grain size effects: As with most Fe-bearing glassy materials, powdered samples of a basaltic flow from Kilauea caldera, HI, USA (BAS101) show two weak Fe^{2+} absorption bands: a stronger one near 1.05 μm and a weaker one near 2.00 μm (Fig. 1). With increasing grain size, reflectance decreases, but the overall red slope remains. The red slope is likely attributable to $\text{Fe}^{2+}\text{-O}$ and $\text{Fe}^{3+}\text{-O}$ charge transfers that occur in the ultraviolet region shortward of 0.3 μm [4]. It is likely that the red slope is more attributable to $\text{Fe}^{3+}\text{-O}$ which is approximately two orders of magnitude more intense than $\text{Fe}^{2+}\text{-O}$ charge transfers [5,6]. Band depths also initially increase with increasing particle size, as expected, until the bands become saturated at the largest grain size examined (250-500 μm).

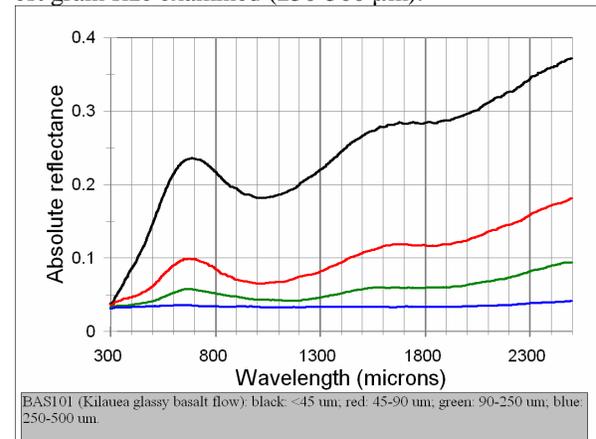


Fig. 1. Reflectance spectra of different grain sizes of a glassy basalt (BAS101).

Crystallinity effects: Reflectance spectra of different portions and grain sizes of a glassy pillow basalt from Iceland (ICE170) are shown in Fig. 2. The major difference between spectra of powders of the exterior glassy surface and crystalline interior portion are in terms of the 1 μm region Fe^{2+} absorption band: it is wider and at longer wavelength in the glassy spectra than the crystalline spectra. All the powder spectra are red-sloped, as expected. The whole rock surface spectrum has an overall blue slope, consistent with other whole rock spectra.

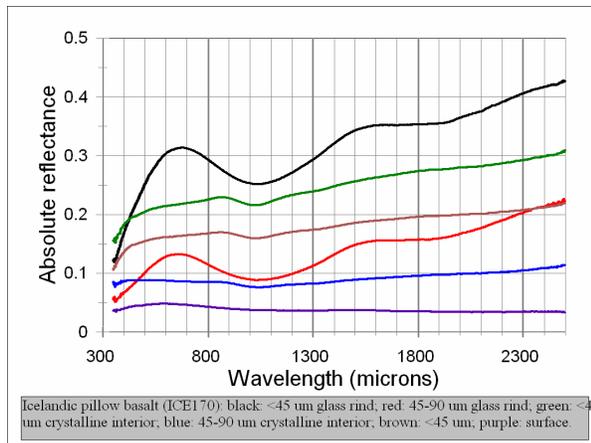


Fig. 2. Reflectance spectra of different fractions of an Icelandic pillow basalt (ICE170).

Fe²⁺ content effects: In general we would expect increasing Fe²⁺ content to lead to increasing band depth in the 1 μm region for a constant grain size, and this is generally the case. In Fig. 3, Darwin glass has the highest Fe²⁺ content and deepest 1 μm absorption feature. Overall reflectance is not expected to exhibit a trend with Fe²⁺ content, as other transition series cations (e.g., Fe³⁺, Ti, Cr) can affect overall reflectance. Also noteworthy is the fact that the Dakhleh glass has the highest Fe³⁺ content, which likely accounts for its lowest reflectance, overall red slope, and strong UV downturn. For Fe²⁺ embedded in a largely transparent silica-rich matrix, even small amounts of Fe²⁺ will result in a weak but detectable absorption band; e.g., SIL130: 0.12 wt.% Fe²⁺O.

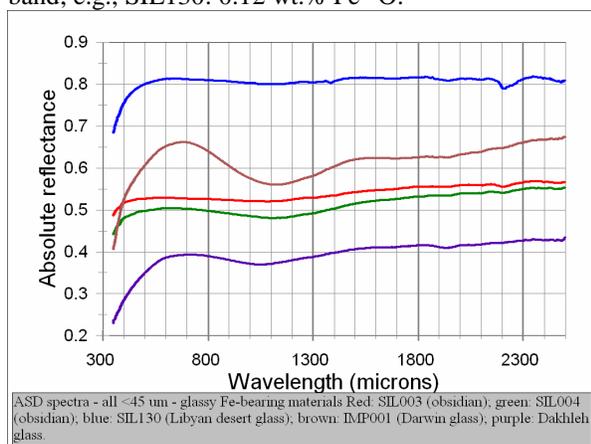


Fig. 3. Reflectance spectra of <45 μm powders of various Fe-bearing glassy materials.

Impact products (tektites): Fig. 4 shows reflectance spectra of <45 μm powders of tektites (indochinites). They all exhibit a broad 1 μm band as well as a weaker 2 μm band. Band depths and slopes are variable in spite of similar Fe²⁺ and Fe³⁺ contents, illustrat-

ing the fact that other factors besides Fe content can affect Fe-bearing glassy spectra.

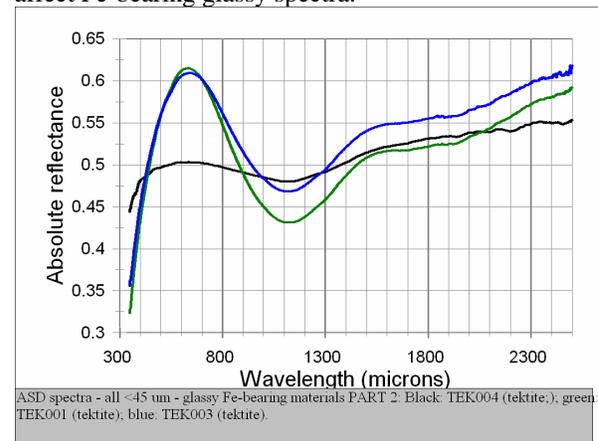


Fig. 4. Reflectance spectra of <45 μm tektite powders.

Fe³⁺ content effects: As mentioned, Fe³⁺ content can affect Fe-bearing glassy material spectra. The overall appearance of such spectra will be a function of Fe²⁺ and Fe³⁺ contents. Because Fe³⁺ has such a strong and wide absorption feature in the UV, reflectance of the glasses are all similar below ~0.5 μm. The reddest spectra, i.e., those that are brightest in the IR are those with the lowest Fe³⁺ contents (G11, G12). However, even high Fe³⁺ contents are not able to fully suppress the Fe²⁺ absorption bands in the 1 and 2 μm regions.

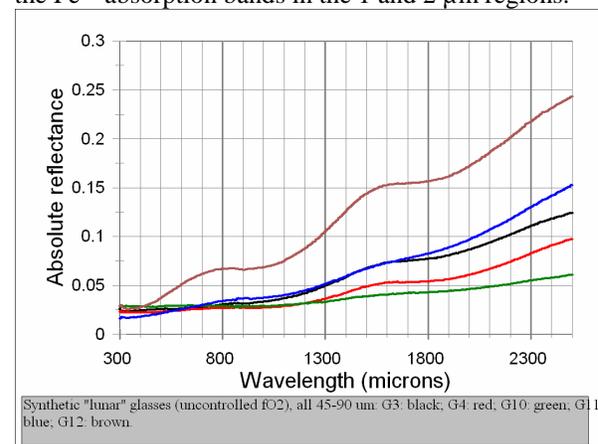


Fig. 5. Reflectance spectra of 45-90 μm powders of synthetic silica-rich glasses [7].

References: [1] Bish D. et al. (2014) *IUCrJ*, 1, 514-522. [2] http://www.lpi.usra.edu/publications/books/lunar_sourcebook/. [3] Reddy V. et al. (2014) *Icarus*, 237, 116-130. [4] Cloutis E. A. et al. (2008) *Icarus*, 197, 321-347. [5] Soshea R. W. et al. (1958) *J. Phys. Chem. Solids*, 5, 23-33. [6] Blazey K. W. (1977) *J. Phys. Chem. Solids*, 38, 671-675. [7] Cloutis E. A. et al. (1990) *Icarus*, 86, 383-401.

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