IDENTIFYING BASALTIC GLASS IN COMPLEX SAMPLES WITH BLIND ENDMEMBER NON-LINEAR UNMIXING. K. M. Cannon[1] and J. F. Mustard[1], [1]Brown University, Department of Earth, Environmental and Planetary Sciences, Providence RI, USA, kevin_cannon@brown.edu

Introduction: Basaltic glass is present on many planetary bodies and is particularly significant on Mars because it can preserve biosignatures [1,2] and could act as a substrate for microbial life [3,4]. There is thus a need to reliably distinguish basaltic glass in remotely sensed data from other mafic materials that also have broad Fe^{2+} crystal field absorptions.

Experiments have demonstrated that non-linear unmixing of visible/near-infrared (VNIR) reflectance data is viable using both the Hapke [5] and Shkuratov [6] models [7,8]. However these experiments were tightly controlled with simple pure endmember mixtures, and both endmember spectra and particle sizes known. The much harder case is real planetary surfaces where there may be many mineral components present, the choice of appropriate endmembers is difficult, particle sizes can only be guessed at, and instrument effects may complicate modeling. Here we try to bridge this gap with blind endmember unmixing of natural mafic/ultramafic samples spiked with basaltic glass.

Materials and Methods: We used four natural rocks: (1) An olivine-rich basalt from Cyprus, (2) San Carlos dunite, (3) A medium-grained pyroxenite from the Bushveld Complex, and (4) A coarse-grained norite, also from Bushveld.

These rocks were crushed and dry sieved to a 45-75 μm size fraction. Each rock powder then had 0, 5.0 and 10.53 wt.% synthetic basaltic glass added to it, to total 12 samples thus far. We measured these powder samples at the Reflectance Experiment Laboratory (RELAB) facility at Brown University using the custom-built UV-VIS-NIR spectrometer with a 0.3-2.6 μm spectral range and 5 nm sampling. Spectra were clipped between 1-2.5 μm for unmixing because many planetary spectrometers have a detector join at 1 μm (e.g., CRISM, OMEGA, Dawn VIR). We used a suite of 7 synthetic and natural mineral endmembers (Fig. 1): 3 pyroxenes, 2 olivines, 1 basaltic glass, and 1 smectite. Importantly, none of these spectral endmembers were derived from the material used in the physical mixtures. We used the Hapke model [5] to convert all endmember and mixture spectra to single-scattering albedo, and then inverted the mixtures into endmember spectral fractions using least squares inverse modeling.

In theory a planetary spectrum can be inverted to both endmember abundances and particle sizes using optical constants. However, the resulting mineral "abundances" are completely dependent on the particle size, which is also output by the model. Without ground truth on particle sizes, why should these absolute abundances be trusted? Here we are more concerned with reliable detection and *relative* spectral fractions of basaltic glass, a material that is not obvious to the naked eye in a mixed spectrum, and one that does not lend itself to spectral parameterization unless it is the dominant phase in a mixture [9].

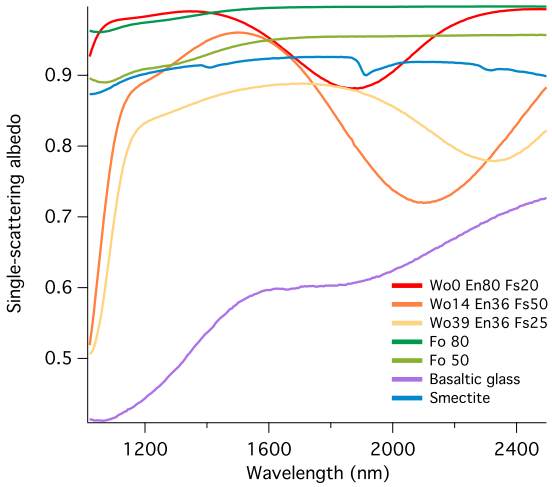

Figure 1. Endmembers used in the unmixing model. RELAB IDs: DL-CMP-002; DL-CMP-011; DL-CMP-073; DD-MDD-087; DD-MDD-093; BE-JFM-062; SA-EAC-059.

Results: Mixture spectra are shown in Figure 2. We explored many permutations of the unmixing model, including constraints (sum-to-one, non-negativity), and addition of albedo-modifying (w=0 and w=1) and slope-modifying endmembers. Major findings are:

(1) Basaltic glass is never modeled above 0% for any of the pure rock samples as long as a w=0 endmember is included (glass is the darkest endmember); this demonstrates that false positive detections of glass are not an issue for the suite of materials and the parameter space explored here.

(2) With 7 endmembers, 10 wt.% glass is barely detectable (modeled >0% in 1 of the 4 mixture suites).

(3) However, basaltic glass *is modeled* when including the pure rock spectrum as an additional endmember for the 5 and 10% mixtures, and the relative amount of glass added is detected very accurately: a mean increase in modeled abundance of 207±23 (1σ) % versus an actual increase of 211% in the 10.53 vs. 5.0 wt.% mixtures. This is in spite of differences in particle size between the mixtures and endmembers,

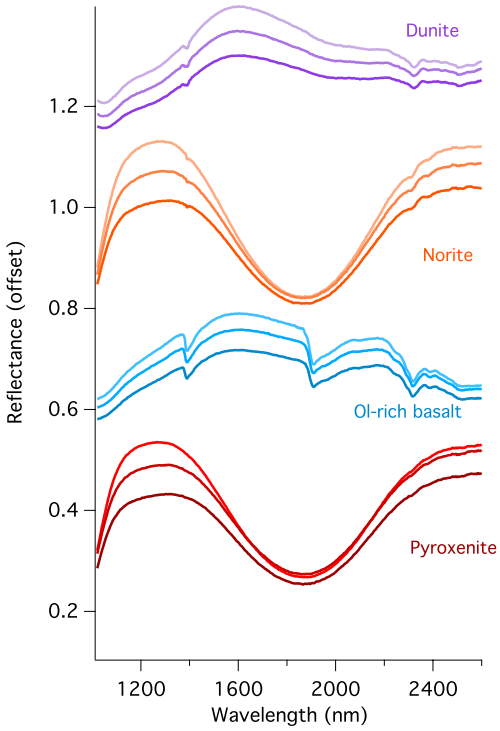

Figure 2. Physical mixture spectra: top = 0% glass; middle = 5% glass; bottom = 10.53% glass in each set.

and the fact that the glass spectral endmember is different from the actual glass in the mixtures.

(4) Using full constraints (sum-to-one and non-negativity) gives more realistic endmember fractions at the cost of increased root mean square error (RMSE).

(5) Bright endmembers have little effect: using anorthite, w=1, neither, or both does not change the RMSE or the modeled mineralogy significantly, even though plagioclase is in both the Bushveld rocks.

Application to Spacecraft Data: We applied the same unmixing model to remotely acquired CRISM data for Mars, and in another contribution explore the astrobiological implications of martian impact glass [10]. A neutral in-scene endmember was used to capture the instrument effects and general spectral shape of the data: this is akin to using the pure rock spectrum as an endmember in the laboratory experiments, which greatly improves the RMSE and accuracy of the modeled mineralogy. A similar technique was used successfully to model halloysite on Mars [11].

Figure 3a shows an example of a modeled mineralogy map for the central uplift of Alga Crater [12]. Modeled olivine and pyroxene deposits (in red and blue, respectively) correspond excellently to previous mineral mapping of Alga [12] and to standard CRISM spectral parameters (Fig. 3b). Basaltic glass (in yellow) maps as scattered but coherent deposits that correspond to dark, brecciated units in HiRISE imagery.

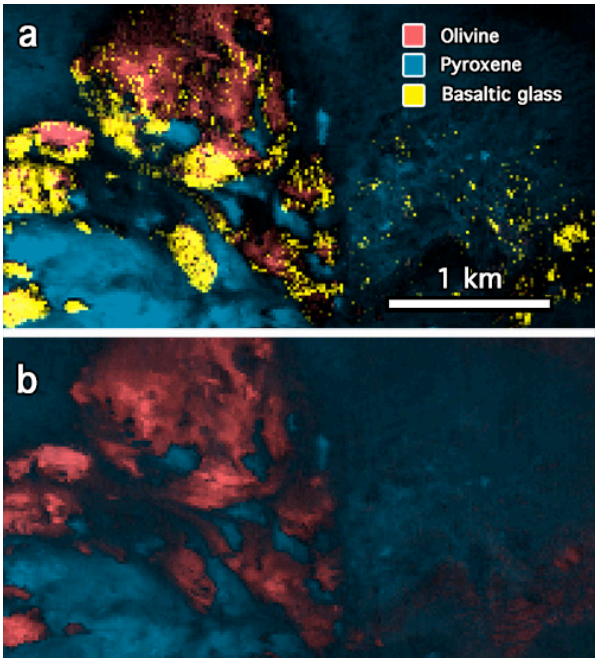

Figure 3. Alga Crater, CRISM scene FRT00006415 (a) Modeled mineralogy with total olivine in red, total pyroxene in blue, and basaltic glass in yellow. (b) CRISM parameters OLINDEX3 in red and (LCPINDEX2 + HCPINDEX2) in blue.

Conclusions: Basaltic glass is unique in that it shows no definitive spectral features when mixed with olivine/pyroxene. It is difficult to detect this glass with spectral parameters, but we have shown here that this glass can be detected and mapped with no false positives, using non-linear Hapke modeling of VNIR data with a small set of blind endmembers.

Future work will apply these techniques to different planetary datasets including M^3 for the Moon and Dawn VIR for 4 Vesta.

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