LINEAR DECONVOLUTION OF MARTIAN METEORITES USING MARTIAN MINERALOGY.

K. J. Orr[1], L. V. Forman[1], M. J. Hackett[2], V. E. Hamilton[3] and G. K. Benedix[1]. [1]Space Science and Technology Centre, School of Earth and Planetary Sciences, Curtin University, GPO Box 1987, Perth, Western Australia 6845, Australia (kenneth.orr@postgrad.curtin.edu.au), [2]School of Molecular and Life Sciences, Curtin University, GPO Box 1987, Perth, Western Australia 6845, Australia, [3]Southwest Research Institute, 1050 Walnut St. #300, Boulder, Colorado 80302, USA.

Introduction: Thermal infrared spectroscopy of the Martian surface in the mid-infrared (5-50 µm) relies largely on a terrestrial spectral library for the linear deconvolution process [1-2]. While this has proven highly successful in unravelling Martian geology, the terrestrial mineral spectra do not totally match the mineralogy of the Martian meteorites, specifically shergottites. Shergottites are mafic to ultramafic rocks mostly composed of pyroxene, olivine and plagioclase (in many cases shocked to maskelynite). Olivine and plagioclase are well represented in the spectral library. On the other hand, shergottite pyroxene compositions are of 'inter-endmember' augite and pigeonite. While there are numerous pyroxene spectra in the terrestrial library, they do not cover the shergottite pyroxene compositional range. This is important as the spectral profile of pyroxene changes based on composition and crystal structure.

To address this issue, we produced a number of augite and pigeonite spectra from Martian meteorite thin-sections [3]. By using a number of non-destructive techniques, we ensured all the spectra were randomly oriented with a known geochemistry. The Martian pyroxene spectra are quite different to the terrestrial pyroxene spectra. This is significant, as using the most accurate spectral end members in linear deconvolution provides the best results. Similar work has been done by synthesizing pigeonite [4]. The synthetic pigeonite spectra have a closer spectral profile (and composition) to the Martian pyroxene spectra, but do not fully represent the range in Martian pyroxene compositions.

To test the significance of varying composition in pyroxene spectra, we linearly deconvolved a number of shergottite spectra using the available spectra libraries. Both a Martian and a terrestrial (including synthetic) spectral library were utilized. To provide a thorough comparison, basaltic, olivine-phyric and poikilitic shergottite spectra were deconvolved.

Methods: The Institute of Meteoritics at the University of New Mexico supplied ~0.5 g chips of the following meteorites: Dhofar 019, Los Angeles, NWA (Northwest Africa) 856, NWA 6963, NWA 8686, NWA 10441, NWA 10818, NWA 11043, NWA 12335 and Zagami. ANSMET (The Antarctic Search for Meteorites) supplied <0.4 g chips of the following: ALH (Alan Hills) 77005, LAR (Larkman Nunatak) 06319, LAR 12011 and RBT (Roberts Massif) 04262. NIPR (National Institute of Polar Research) supplied <0.2 g chips of the following samples: Y- (Yamato) 002192 and Y-002712. All chips made into either thin-sections or 1-inch epoxy rounds. These were then polished and carbon coated.

To determine modal abundance of the mineralogy, the samples were analyzed with a Tescan Integrated Mineral Analyser (TIMA) at the John de Laeter Centre, Curtin University. Using four EDS (Energy Dispersive) X-ray detectors, the TIMA rapidly semi-quantitatively mapped the samples at high resolution producing element maps. These maps were combined to create RGB images using Adobe Photoshop and modal abundances calculated using the pixel counting method. Analytical conditions were 70 nm spot size, 3 µm step size, 15 mm working distance and at 25 kV accelerating voltage.

Infrared spectra of the shergottites were acquired with micro-Fourier Transform Infrared Spectroscopy (µ-FTIR). Mapping was conducted using a Thermo Scientific Nicolet iN10MX infrared imaging microscope with a liquid-nitrogen cooled MCT/A (Mercury Cadmium Telluride) detector, at Curtin University. Operating in the 5-15 µm (4000-675 cm^{-1}) wavelength range, maps were acquired with a 400 µm step and spot size, 2 scans and at 4 cm^{-1} spectral resolution. Background acquisition of a gold reflectance standard occurred prior to every analysis. Maps were averaged to provide a single infrared spectrum of each sample meteorite.

For linear deconvolution, we used the non-negative least squares algorithm (NNLS) [5]. This ensures no end members are removed during the iterative process until a final non-negative solution is found. Each meteorite was deconvolved using both Martian and terrestrial libraries. The focus of this study is to evaluate pyroxene spectra, therefore only major mineralogy were used for end members (pyroxene, olivine and maskelynite). To keep the emphasis on pyroxene, the same terrestrial olivine and Martian maskelynite end members were used in both Martian and terrestrial runs. The only parameter that differed between Martian and terrestrial were the pyroxene end members. Martian pyroxene end members included augite, pigeonite and pyroxferroite.

Terrestrial pyroxene end members included augite and synthetic pigeonite. Orthopyroxene was not used, as in these samples, it does not constitute a major mineral. Blackbody was included in all runs to account for any changes in spectral contrast.

Results and Discussion: Each meteorite spectrum was deconvolved using Martian then terrestrial mineral spectra. The results show some significant differences between which library was used, and which meteorite was deconvolved.

The basaltic shergottites, composed of pyroxene and maskelynite, are the 'simplest' group of shergottites to deconvolve. As maskelynite is featureless in the mid-infrared, the pyroxene grains likely produced the band centers in the meteorite spectra. Therefore, modelling basaltic shergottites puts all the emphasis on the pyroxene spectra. The Martian modelling closely resembles that of the spectra of the basaltic shergottites, matching all the major band centers and Christensen Features (CF) (Fig. 1). On the other hand, terrestrial modelling does not closely resemble the meteorite spectra. Leading to significant discrepancies between the true modal mineralogy and the modal mineral suggested by the deconvolution run.

The olivine-phyric and poikilitic shergottites show a different story. The band centers of olivine in the mid-infrared are very dominant, and therefore can overshadow other mineral band centers. Poikilitic shergottites contain a large proportion of olivine (on average >40%), which has more of a pronounced effect than in olivine-phyric shergottites (olivine abundance of ~20%). The Martian and terrestrial models for both groups of shergottite quite precise (the modelled spectrum is close to the measured spectrum) but are not as accurate. The Martian runs tend to over-predict olivine while the terrestrial runs under-predict pyroxene and maskelynite. Further work is required to evaluate the effect of including olivine.

Overall, while modelling of the olivine-bearing shergottites suggests evaluating the impact of single mineral spectra becomes difficult even in a rock with only three major minerals. The basaltic shergottite modelling clearly demonstrates using Martian pyroxene spectra significantly improves the deconvolution result. This study fills in a compositional hole in the terrestrial library and provides the first example of using mid-infrared mineral spectra sourced from another planetary body.

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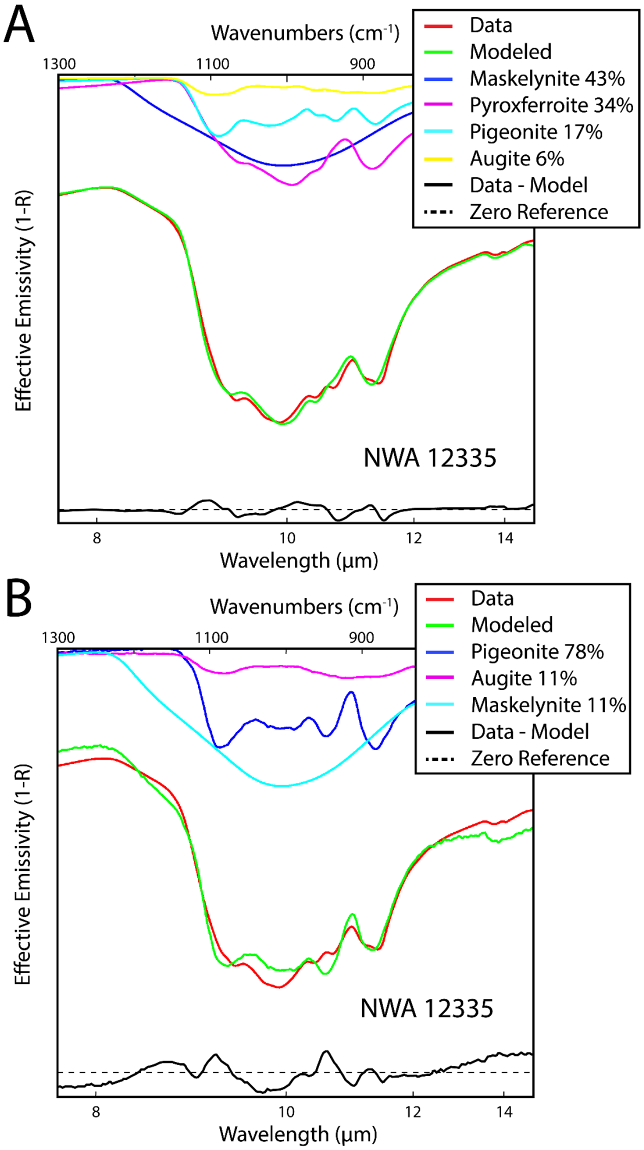

Figure 1. Linear deconvolution of basaltic shergottite NWA 12335. A: Martian deconvolution. B: terrestrial deconvolution. The Martian run clearly models the meteorite spectrum closer than the terrestrial run.