

THE EFFECT OF COMPOSITION AND ZONING ON INFRA-RED SPECTRA OF THE MARTIAN SILICATE MINERALS N. R. Stephen^{1,2}, G. K. Benedix¹ & M. Genge². ¹Department of Mineralogy, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK, ²Department of Earth Science & Engineering, Imperial College London, South Kensington, London, SW7 2AZ, UK (n.stephen@nhm.ac.uk).

Introduction: Spectral un-mixing of TES and THEMIS data from Mars currently uses a series of databases and libraries containing various synthetic and terrestrial analogues alongside a few lunar samples to provide reference spectra. At present, there are no Martian samples within these spectral libraries to act as a reference when analysing data from the Martian surface. Whilst we do not at present have sample return from Mars, the growing collection of Martian meteorites provides us with the only in-situ opportunity to study Martian material on Earth [1].

Previous micro-FTIR studies [2-5] have assessed the viability of the mid-IR spectra from meteorite sections being used as a reference, and others have shown using terrestrial samples that bulk-rock spectra can be theoretically mixed from and/or compared to synthetic analogues where actual samples are not available [6]. However, individual mineral spectra for Martian-specific compositions are not presently available within these libraries.

In this study, we isolate the mid-IR spectral characteristics of the individual, Martian-specific primary minerals most abundant in the Shergottite meteorites; pyroxene (both augite and pigeonite) and olivine where present. We aim to illustrate that the often variable compositions within their Shergottite hosts are reflected in their spectra, particularly with respect to Fe/Mg and Ca, due to the typical zoning patterns seen in these meteorites when compared to those used from library references. Variability in Martian spectra, at least at cm-m scales, might also shed light on mineralogical variations.

Samples & Analytical Techniques: Individual spectra have been determined by Micro-FTIR analysis of five Shergottites; three basaltic Shergottites; EETA79001 lith. B (loan), Zagami, (BM1966, 54) and Los Angeles, (BM2000, M12), alongside two olivine-phyric Shergottites; DAG476, (BM2000, M7), and SAU005, (BM2000, M40). Two thin sections of Los Angeles and two from DAG476 were analysed alongside one thin section from each of SAU005 and EETA79001. 3 thin sections in total were analysed from Zagami. For the purposes of this abstract we are focusing on the Zagami meteorite however full results will be presented at the meeting.

Mineral spectra were collected using a Perkin Elmer SpectrumOne[®] Fourier Transform Infra-Red spectrometer with an AutoIMAGE[®] microscope at-

tachment at the Natural History Museum (NHM) in London, UK. The mid-IR wavelength range was used; $\lambda=3\text{-}30\mu\text{m}$ ($4000\text{-}600\text{cm}^{-1}$), with 20 scans at an aperture size of $100\mu\text{m}$. The data were processed in the Perkin Elmer Spectrum[®] software.

The geochemical data were collected on the Cameca SX-100 electron microprobe within the EMMA Unit at the NHM, London. Operating parameters were: 20kV accelerating voltage, 20nA current and a $5\mu\text{m}$ spot size.

Results & Discussion: Vibrational spectra from the Shergottite meteorites exhibit the typical features that one would expect of the associated primary minerals. The most abundant mineral in the Shergottite meteorites are clinopyroxenes and these have two distinct absorptions between 1200cm^{-1} and 800cm^{-1} , with the absence of the characteristic orthopyroxene 'V' at $\sim 600\text{cm}^{-1}$, [6]. Within the meteorites however there are two clinopyroxenes present in the samples; a high-Ca pyroxene (augite) and a low-Ca pyroxene (pigeonite), in almost equal proportions, [7], and their spectra are readily distinguishable from one another due to structural differences.

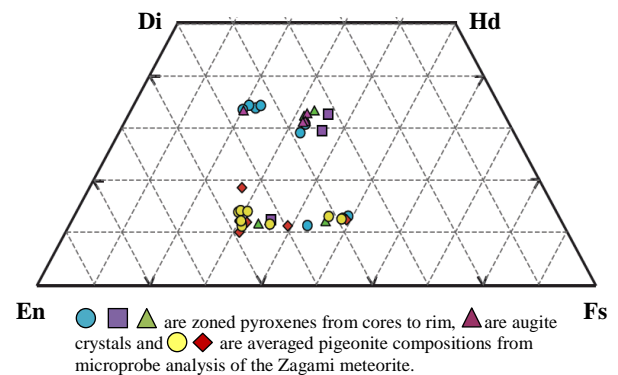


Figure 1: Example pyroxene compositions from the Zagami meteorite used in this study; the separation between high-Ca clinopyroxene (augite) and low-Ca clinopyroxene (pigeonite) is clearly apparent.

Preliminary results from this study indicate that whilst the spectra display a general trend compatible with the library entries for the primary phases, Martian-specific spectra show a larger variability in the prominence of the features observed related to the composition of that phase. E.g., with respect to the

pyroxene phases in Zagami, plotting band depth [8] against their composition (Fe/Mg+Ca wt% oxide) allows the high-Ca (augite) and low-Ca (pigeonite) pyroxenes to be distinguished from their zoning profiles, fig 2a. Band depth calculations plot a broadly similar relationship to composition irrespective of the band selected.

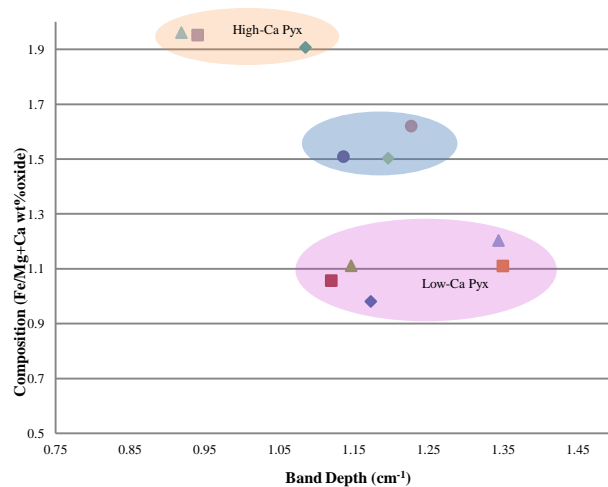


Figure 2a: Separation of high-Ca (augite) and low-Ca (pigeonite) phases indicated from composition versus band depth in their mid-IR spectrum. Points 1-11 are different pyx crystals within the Zagami meteorite.

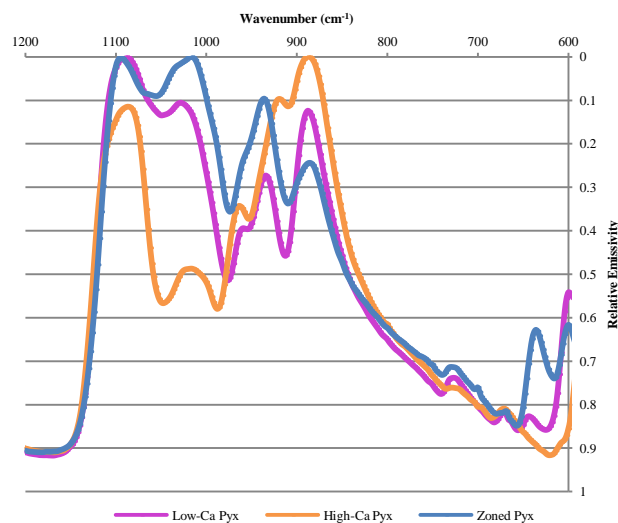


Figure 2b: Averaged mid-IR spectrum from high-Ca (augite) and low-Ca (pigeonite) phases as seen in fig. 2a with the zoned region discussed above for comparison.

Whilst the pyroxene (augite and pigeonite) phases can be broadly resolved in terms of their spectra, band depth varies with Ca content sufficiently to allow high-

Ca and low-Ca pyroxenes to be distinguished, however, intermediate compositions of high temperature pyroxenes have overlapping band depth. Variability in band depth may be due to Fe/Mg content and warrants further investigation. The results presented may not aid in spectral un-mixing of global TES data on the whole due to a different wavelength range but they should be applicable for deconvolution of THEMIS data over a range of mineral compositions far broader than those previously seen within library spectra.

Spectroscopic surface measurements from orbital data of both visible and near infra-red reflectance spectra indicate that much of the Martian surface is likely to be basaltic in composition [9] and where available, rover data [10] support this understanding. The nature of remote thermal emission spectra only allows for sampling of the outermost 10-100 μ m of the crust and therefore unlikely to sample true igneous material unaffected by surface alteration. However, in regions of the Martian surface where spectral signatures are considered to be more likely to represent unaltered Martian crust such as Meridiani and Bounce Rock [11], their spectral signatures are more in agreement with those seen in the unaltered Shergottite meteorites, and plot in the tholeiitic basalt field [12].

Further spectra need to be obtained on a wider range of compositions before Martian meteorites can be used to deconvolve global spectral map data, however the far-reaching implications of this study and the affect of zoned compositions on phase spectra could begin to suggest as to why the FeO/MgO ratio of TES or THEMIS-derived compositions differ from those of global distribution maps from other spectrometers, i.e. the gamma-ray spectrometer (GRS) where spectral measurements are taken at a far greater depth and therefore sampling a less altered composition.

References: [1] McSween, H.Y. (2003) in *Meteorites, Comets and Planets* (ed. A.M. Davis), Vol 1 *Treatise on Geochemistry* (eds H.D. Holland and K.K. Turekian). [2] Palomba et al (2006) *Icarus* 182:68-79. [3] Klima R. and Pieters C. (2006) *JGR* 111:E01005. [4] Morlok A. et al. (2006) *Meteoritics and Planet. Sci.* 41:773-784. [5] Benedix G. & Hamilton V. (2007) Abstract #1805, 38th Lunar & Planetary Science Conference. [6] Hamilton, V.E. (2000) *Journal of Geophysical Research* 105:9701-9716. [7] N.R. Stephen et al. (2010) Abstract #2367 LPSC XLI [8] Michalski, J.R. et al. (2006) *Earth & Planetary Science Letters* 248:822-829 [9] J.P. Bibring, et al. (2005) *Science*, 10.1126 [10] Ashley, J.W. et al. (2009) Abstract #2468, 40th Lunar & Planetary Science Conference [11] Zipfel, J. et al. (2004) *Meteoritics & Planetary Science* 39:A118 [12] McSween, H.Y. Jnr. et al. (2009) *Science* 324:736-739