

**A MARTIAN METEORITE SPECTRAL LIBRARY BASED ON IN SITU PYROXENE AND BULK MARTIAN METEORITE SPECTRA.** K. J. Orr<sup>1</sup>, L. V. Forman<sup>1</sup>, G. K. Benedix<sup>1</sup>, M. J. Hackett<sup>2</sup> and V. E. Hamilton<sup>3</sup>. <sup>1</sup>Space Science and Technology Centre (SSTC), School of Earth and Planetary Sciences, Curtin University, Perth, Western Australia, Australia (kenneth.orr@postgrad.curtin.edu.au), <sup>2</sup>School of Molecular and Life Sciences, Curtin University, Perth, Western Australia, Australia, <sup>3</sup>Southwest Research Institute, 1050 Walnut St. #300, Boulder, CO 80302 USA.

**Introduction:** Thermal infrared spectrometers have been on board every major space mission to Mars. The Thermal Emission Spectrometer (TES) and the Thermal Emission Imaging System (THEMIS), on board Mars Global Surveyor and Mars Odyssey, respectively, have globally mapped the Martian surface in the mid-infrared (MIR). In the MIR, spectra can be linearly deconvolved to determine modal mineralogy and the MIR also allows for differentiation between various silicates and their constituent phases [1]. This is commonly done by deconvolving the Mars acquired spectra using known terrestrial spectra of rocks and minerals. While this has proven a successful method to map the surface geology of Mars e.g., [2-4], mineral compositions in the Martian meteorites, especially pyroxene, are not well represented in the current spectral library. This is due to the inherent difficulty using traditional techniques to extract specific phases when they are complexly zoned. Most mineral spectra in the current library are particulate samples, which ensures the resulting spectra have a random orientation. This approach isn't suitable for Martian meteorites due to the destructive nature of the process. By combining non-destructive techniques, we can spectrally analyse Martian meteorite minerals and produce spectra with a known geochemistry and a random orientation. All meteorites analysed here are shergottites (basaltic, olivine-phyric and poikilitic), as these represent the most diverse compositional range of Martian meteorites.

**Methods:** The Institute of Meteoritics at the University of New Mexico supplied ~0.5 g chips of 14 meteorites for analysis: Dhofar 019, Northwest Africa (NWA) 856, NWA 6963, NWA 7034, NWA 8159, NWA 8161, NWA 8686, NWA 10441, NWA 10818, NWA 11043, NWA 12335, Los Angeles, Tissint, and Zagami. The National Institute of Polar Research supplied ~0.15 g chips of 6 further meteorites: Yamato (Y)-793605, Y-984028 and paired Y-980459/980497 and Y-002192/002712.

All samples were initially analysed using a Tescan Integrated Mineral Analyser (TIMA) at the John de Laeter Centre in Curtin University to map mineralogy and locate regions of interest for further analyses. The TIMA semi-quantitatively maps sec-

tions using four energy dispersive x-ray (EDS) detectors which allows phase, back-scattered electron (BSE) and element x-rays maps to be collected simultaneously. The analyses were run with a 70 nm spot size, 3  $\mu\text{m}$  step size, 15 mm working distance and at 25 kV accelerating voltage.

Electron back-scattered diffraction (EBSD) analyses were carried out on the sections using a Tescan Mira3 VP-FESEM (variable pressure field emission scanning electron microscope) with an Oxford Instruments Symmetry CMOS detector at the John de Laeter Centre in Curtin University. This technique was used to determine the crystallographic orientations of the mineral grains. The analyses were conducted with the sample tilted at 70°, 1.5-2  $\mu\text{m}$  step size, 20 mm working distance and at 20 kV accelerating voltage.

*In situ* major and minor elements were analysed using a JEOL 8530F Plus electron probe microanalyser (EPMA) at the Centre for Microscopy, Characterisation and Analysis in the University of Western Australia. This allowed quantitative mapping of specific regions of interest at 2  $\mu\text{m}$  pixel size, 40 ms pixel time, 40 nA beam current and at 15 kV accelerating voltage.

Lastly, the sections were spectrally mapped using micro-Fourier transform infrared ( $\mu\text{FTIR}$ ) spectroscopy with a Thermo Scientific Nicolet iN10MX infrared imaging microscope at Curtin University. The sections were analysed with a nitrogen-cooled (MCT/A (Mercury Cadmium Telluride) detector with an operating wavelength range of 5 – 15  $\mu\text{m}$ . The analyses were conducted with 50  $\mu\text{m}$  step and spot size, 64 scans and at 4  $\text{cm}^{-1}$  spectral resolution. A gold reflectance standard was used as background. The acquired spectral maps were used to target specific mineral grains and by averaging, we then produced bulk Martian meteorite spectra.

**Results and Discussion:** We present bulk spectra 20 Martian meteorite samples (Fig. 1). Our results show there are significant differences in bulk spectral profile between the different groups of shergottites, which is primarily based on the relative abundances of the major minerals pyroxene, olivine and maskelynite (Fig. 1). Pigeonite and augite spectra are also present-

ed with ‘artificially’ created random orientations and known geochemistry. These Martian pigeonite and augite spectra show shifts in band positions and minima compared to current library pyroxenes, largely dependent on geochemical composition. We also observe variations in spectra based on the specific crystallographic orientation of the grains. By using EBSD, we not only can create randomly orientated spectra, but also spectra that are specifically orientated, which could then be applied to rocks with a preferred orientation [5,6]. By combining spectra from different grains, with different orientations and all with known geochemistry, we can supplement current spectral libraries with these Mars-specific mineral compositions.

This is the largest spectral survey of Martian min-

erals and meteorites to date, and will provide a comprehensive benchmark to map the surface geology of Mars using infrared spectroscopy. This will initially be utilized in combination with TES and THEMIS IR bulk data to constrain the locations of the source craters of the Martian meteorites e.g., [8].

**References:** [1] Ramsey M. S. and Christensen P. R. (1998) *JGR*, 103, 577-596. [2] Bandfield J. L. et al. (2000) *Science*, 287, 1626-1630. [3] Bandfield J. L. (2002) *JGR*, 107, E6, 9: 1-20. [4] Christensen P. R. et al. (2001) *JGR*, 106, 23873-23885. [5] Daly L. et al. (2019) *EPSL*, 520, 220-230. [6] McCoy T. J. et al. (1992) *GCA*, 56, 3671-3582. [7] Hamilton V. E. et al. (1997) *JGR*, 102, 25593-25603. [8] Hamilton V. E. et al. (2003) *MAPS*, 38, 871-885.

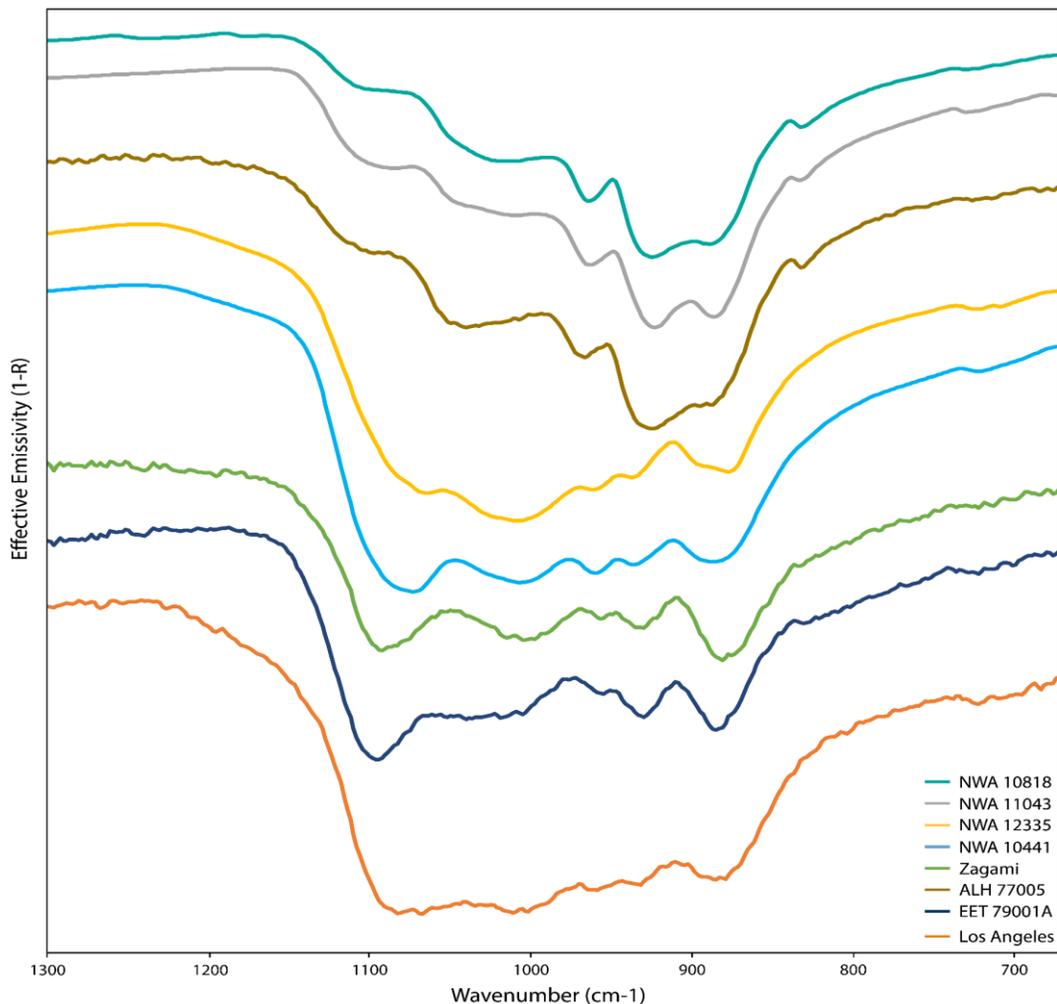


Figure 1. Martian meteorite bulk spectra. Comparing new bulk spectra data of NWA 10441, NWA 10818, NWA 11043 and NWA 12335 against previous bulk spectra data from [7] (ALH 77005, EET 79001A, Los Angeles and Zagami). NWA 10818, NWA 11043 and ALH 77005 are poikilitic shergottites, showing a spectral profile strongly skewed by olivine. NWA 10441, NWA 12335, Los Angeles and Zagami are basaltic shergottites, with no or little olivine, their spectral profile is governed by their relative abundance of pyroxene and maskelynite. EET 79001A is an olivine-phyric shergottite, however it has a spectral profile similar to that of the basaltic shergottites, suggesting the abundance of olivine is relatively minor.