EPSC Abstracts
Vol. 8, EPSC2013-297, 2013
European Planetary Science Congress 2013

Infrared mapping of silicate minerals in Martian meteorites using a synchrotron light source

N. R. Stephen[1,2], P. F. Schofield[1] & A. J. Berry[1,2,3] (1) Department of Earth Sciences, Natural History Museum, Cromwell Road, South Kensington, London, SW7 2BP (2) Department of Earth Science & Engineering, Imperial College London, South Kensington, London, SW7 2AZ (3) Research School of Earth Sciences, Australian National University, Canberra, ACT 2601, Australia *(Email: n.stephen@nhm.ac.uk)*

Abstract

In addition to the limited number of Martian meteorites available for study, a combination of variable mineral textures, grain sizes and chemical zonation severely reduce the applicability of micro-spectroscopy data to the spectra obtained from orbiting or roving spacecraft. Consequently, the accuracy and precision of remote identifications of Martian mineralogy is reduced while ambiguities in mineral identification and geological interpretation are increased. This study enhances the spectral databases available for remote missions by providing spectra for samples that are well-defined mineralogically and texturally. Better precision within the spectral databases and libraries will help ensure that interpretations of Martian mineralogy are geologically correct.

1. Introduction

The geology of the surface of Mars has been mapped however with the small number of specimens of Martian rocks, (presently 69 confirmed Martian meteorites), our interpretations have been based on the remote observations of satellites and rovers that in turn rely upon the accuracy, relevance and completeness of spectral databases and libraries. The TES (a thermal emission spectrometer on board Mars Global Surveyor orbiter), mini-TES (a miniature version mounted on the Mars Exploration Rovers; Spirit & Opportunity) and THEMIS (thermal emission imaging system on board Mars Odyssey orbiter) instruments are all spectrometers designed to identify Martian silicate minerals on the surface of Mars.

Despite several of these missions to Mars still being in operation, either in orbit or on the surface of the red planet, until we have successful sample return missions to Mars, Martian meteorites provide the best possible in situ opportunity to study true Martian material on Earth. Until actual Martian signatures are entered into the databases and libraries currently used to interpret remotely-collected data sent back from the various missions, our understanding of the geological history of Mars is hampered by various misinterpretations and the lack of precise spectral un-mixing of this data.

Thermal Emission Spectroscopy (TIR) is used to determine an accurate spectrum for individual phases in the laboratory before entering the confirmed spectra into a library for use in global *"deconvolution"* (or spectral un-mixing) of the spacecraft data. Whilst the libraries contain spectra from most mineral species alongside bulk-rock compositions, the majority of these spectra are generated using terrestrial samples or synthetic analogues. This can lead to misidentifications or under/overrepresentation of specific phases in the case of extra-terrestrial datasets, an issue that has been noted on previous occasions, [1, 2].

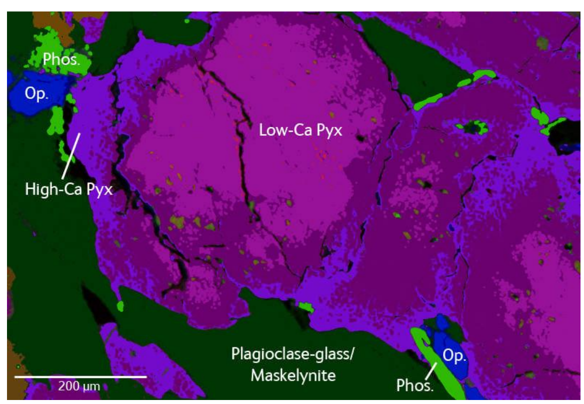

Figure 1: Chemical zonation seen in the pyroxene phases within the Zagami meteorite. Low-Ca pyroxene (pigeonite) in the cores zones to high-Ca pyroxene (augite) towards the rims of the crystals. The same effect is seen throughout all the silicate phases in the Martian meteorites available for study.

Micro Fourier Transform Infrared (micro-FTIR) spectroscopy has been used to quantify Martian-specific mineral spectra in recent studies allowing for targeted analysis of single crystals of known orientation and composition. However, even if the correct phase is identified, mineral spectra are influenced by both crystal orientation [3] and chemical zoning [4] (Fig. 1).

2. Samples & Analytical Technique

Infrared maps were collected from selected areas of a representative number of Martian meteorites using beamline B22 at Diamond Light Source, UK. Spectra were recorded using an 8x8µm beam and are the average of 256 scans. Infrared maps of areas 100 x 100 µm were acquired in 3-4 h. The 13 specimens were polished thin sections and resin-mounted stubs that were prepared for electron microscopy and electron microprobe analyses. The meteorites studied were Zagami, DaG 476, SaU 005, EET 79001, Los Angeles, Tissint, Nakhla and NWA 7034.

3. Results

The data were analysed using various software designed for spectral analysis and interpretation, (IDL, ENVI, Davinci etc.), allowing for the mixing and modelling of these spectra against both terrestrial and synthetic counterparts. This will allow for comparisons to be made between the Martian-specific mineral phases and the previously used spectra. It will also illustrate where advances have been achieved in the accuracy and precision of spectral matching. The finalised spectra will go into spectral databases so that comparisons can be drawn with the spacecraft data and will be presented at the meeting.

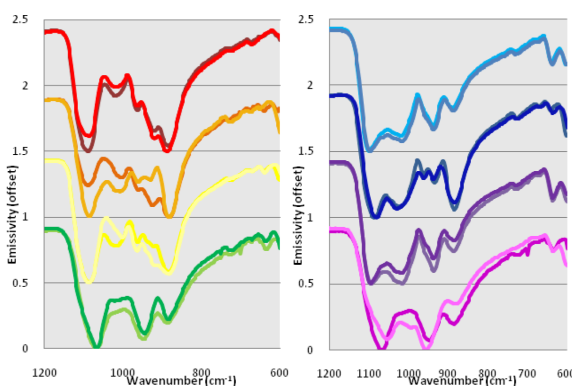

Figure 2: a) FTIR spectra for the pyroxene phases in Martian meteorites converted to emissivity and offset for clarity. The two colour shades for each spectrum represent the max and min variation seen in compositional changes. **b)** Offset spectra for pyroxene phases that represent max and min variation seen due to crystal orientation.

4. Preliminary Conclusions

Prior micro-FTIR work [5] has revealed significant spectral variations across single crystals associated with chemical zoning and between crystals due to crystallographic orientation (Fig. 2). The spot size to make analyses using current techniques is a minimum of 50 µm/pixel, which is larger than many of the single crystals. Furthermore, chemical zoning in the pyroxenes within the Martian meteorites is in the order of 10 µm (Fig. 1). These two issues inherently compromise the accuracy of individual spectra. In order to truly characterise the spectrum for each Martian-specific mineral phase, it was required to reach a spot size that can constrain the zones within a single crystal and also provide a spectrum that can go further than just the mid-IR range currently being used, reaching the lower wavenumbers (>700 cm^{-1}). Synchrotron micro-FTIR has allowed for the characterisation of near-IR wavenumbers with the required, smaller spot size and therefore direct comparisons with the spacecraft data.

Acknowledgements

The authors would like to thank Carl Agee at the University of New Mexico for the loan of additional meteorite specimens and Diamond Light Source for the award of beamtime on beamline B22 to conduct the experiment.

References

[1] Palomba et al. (2006) Icarus 182:68-79 [2] Klima R. and Pieters C. (2006) JGR 111:E01005 [3] Stephen et al. (2010) MetSoc, New York, USA #5008 [4] Stephen et al. (2012) 43rd LPSC, Houston, Texas #2367 [5] Stephen et al. (2011) MetSoc, London, England #5064