Project Title: Imaging the surface geology of Mars using meteorite derived spectra.

Lead Institution: Curtin University

Main Supervisor: Assoc. Prof. Gretchen Benedix, Department of Applied Geology
Co-Supervisor: Dr. Mark Hackett, Department of Chemistry
Co-Supervisor: Dr. Lucy Forman, Department of Applied Geology
Associate Supervisor: Dr. Victoria Hamilton, Southwest Research Institution (Boulder, CO, USA)

Project enquiries: g.benedix@curtin.edu.au

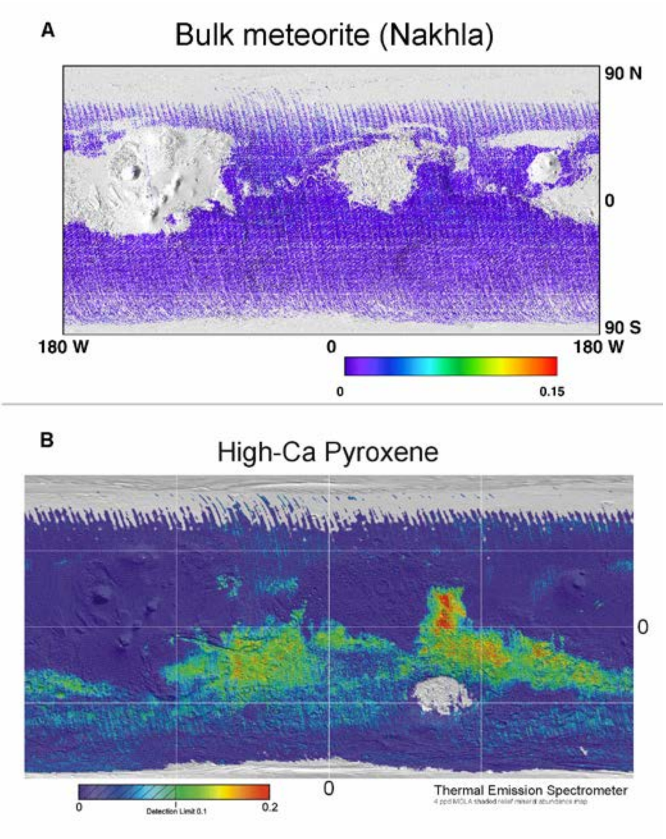

Figure. Thermal emission maps from the Mars Global Surveyor highlighting areas on Mars where spectra are consistent with A) the Nakhla martian meteorite (a clinopyroxenitic rock) and B) 4 different high-ca pyroxene compositions. Color bars indicate abundance of that compositions across the surface (up to 20%). Grey (A) and dark blue (B) denote dust cover.

Project Background

Knowledge of the surface geology of Mars comes from spectral and chemical data acquired remotely by spacecraft orbiting and roving the planet. However, we are missing some basic information needed to correctly deconvolve the remotely collected data. Although Martian mineralogy is similar to terrestrial mineralogy, the elemental and impact-derived structural differences are sufficient to hinder a precise match to current mineral spectra libraries, producing serious issues in interpretation. And although we have Martian meteorites (launched from the surface as ejecta following large impacts), their full potential cannot be realised. Martian meteorites can be thought of as free sample-return missions, but unlike the Apollo missions to the Moon where rocks were returned from specific locations, that context information is missing for Mars. The two principal obstacles to establishing the launch sites for these rocks are: composition - limited sensitivity of the spectral dataset prevents a definitive match to surface rocks (Figure 1); and chronology - lack of consensus on the geochronology of Mars meteorites and uncertainties around surface age. Without context information, interpreting the geologic record that Martian meteorites contain, and using that knowledge to understand the geology of Mars, becomes extremely difficult.

Project Aims and Methods

By combining *in situ* mineralogy and petrology with spectroscopy on Martian meteorites, this project aims to enhance our understanding of Mars formation and evolution by:

1) Replacing terrestrial with Mars-specific mineral spectra and using these on existing orbit-derived bulk spectral datasets in order to unravel the surface mineralogy of Mars.
2) Using advanced characterisation tools to evaluate the impact of mineral structure on spectral features and to understand the geochronology/thermochronology of the meteoritic minerals.

Integrate outcomes from (1) and (2) with results from complementary chronology study to uncover the source craters of the Martian meteorites and provide a geological context for these free sample-return materials.

Candidate

The ideal candidate would have a background in planetary geology, geology, or chemistry, with an interest in Martian geology, mineralogy and geochemistry.

Training

Training will depend on the specific interests and abilities of the PhD candidate, but could include: (a) petrologic analysis of martian meteorites (SEM, EPMA, EBSD, FTIR, Raman, etc..) including presentation interpretration of data; (b) deconvolution of bulk spacecraft derived spectra; (c) image processing; and/or (d) some computational manipulation/modeling.

References / Reading List

Bandfield J. L. (2002) Global mineral distributions on Mars. *J Geophys Res-Planet* **107**, 5042.

Pepin R. O. (1985) Meteorites - Evidence of Martian Origins. *Nature* **317**, 473–475.Platz, T, G Michael, KL Tanaka, JA Skinner Jr., & CM Fortezzo. 2013. Crater-based dating of geological units on Mars: Methods and application for the new global geological map. *Icarus* 225**,** 806–827.

Christensen, PR, JL Bandfield, VE Hamilton, DA Howard, MD Lane, JL Piatek, SW Ruff, and WL Stefanov. 2000. "A Thermal Emission Spectral Library of Rock-Forming Minerals." *Journal of Geophysical Research* 105 (E) (April): 9735–9740. doi:10.1029/1998JE000624.

Ruff, SW, PR Christensen, PW Barbera, and DL Anderson. 1997. "Quantitative Thermal Emission Spectroscopy of Minerals: a Laboratory Technique for Measurement and Calibration." *Journal of Geophysical Research-Solid Earth* 102 (B7): 14899–14913.

Ramsey, MS, and PR Christensen. 1998. "Mineral Abundance Determination: Quantitative Deconvolution of Thermal Emission Spectra." *Journal of Geophysical Research-Solid Earth* 103 (B1): 577–596.

Hamilton, VE, PR Christensen, HY McSween, & JL Bandfield. 2003. Searching for the source regions of martian meteorites using MGS TES: Integrating martian meteorites into the global distribution of igneous materials on Mars. *Meteoritics &Planetary Science* **38,** 871–885.

Ody, A, F Poulet, J-P Bibring, B Gondet, Y Langevin, and C Quantin. 2013. "Search for Spectral Analogue Sites of Martian Meteorites Using NIR Data." *LPI Contributions* 1719 (March 1): 2265.

Hallis, L, GK Benedix, and VE Hamilton. 2006. Constraining The Surface Mineralogy of Mars: Infrared (2.5 to 14 micron) Reflectance Microspectroscopy Of Meteoritic Minerals In Thin Section. AGU Fall Meeting Abstract #P23C-0073.

Benedix, GK and VE Hamilton. 2007. Infrared (2.5 to 14 µm) reflectance microspectroscopy of meteoritic minerals in thin section. *38th Annual Lunar and Planetary Science Conference*, abstr. #1805.

Benedix, GK and VE Hamilton. 2009. Constraints on mapping source regions of Martian meteorites and the distribution of pyroxene on Mars: IR microspectroscopy of pyroxene in shergottites. *Meteoritics and Planetary Science*, 44, abstr. #5082. (72nd Ann. Meeting Meteorit. Soc.).

Benedix G. K., Hamilton V. E. and Reddy S. M. (2015) Assessing Mineral Orientation in Martian Meteorites Using IR Microspectroscopy and EBSD Techniques. *78th Annual Meeting of the Meteoritical Society*, abst# 5202.

Benedix G. K., Hamilton V. E. and Reddy S. M. (2016) µ-FTIR Spectroscopy and Electron Backscatter Diffraction of Martian Shergottite Robert Massif 04262. *47th Lunar and Planetary Science Conference* abstr# 1951.

King, PL. 2010. Micro-reflectance IR spectroscopy as a tool for better understanding remote IR spectra of planetary bodies. Geol. Soc. Am. Abstr. with Prog., 42(5), 630.

Hamilton, VE, and HC Connolly. 2012. "In Situ Microspectroscopy of a Type B CAI in Allende: Mineral Identification in Petrographic Context." *43rd Lunar and Planetary Science Conference* 43 (March): 2495.

Johnson, JR, MI Staid, TN Titus, and K Becker.2006. Shocked plagioclase signatures in thermal emission spectrometer data of Mars. Icarus, 180, 60-74.