MAPPING HYDROTHERMAL SYSTEMS ON MARS USING SHORT WAVE INFRARED REFLECTANCE (SWIR) SPECTROSCOPY

Adrian Brown
Australian Centre for Astrobiology
Department of Earth and Planetary Sciences, Macquarie University, NSW 2109
+61 2 9850 6286
Email: abrown@els.mq.edu.au
Project Website: http://aca.mq.edu.au/abrown.htm

Abstract

Short Wave Infrared Reflectance (SWIR) spectroscopy is a mature, reliable technology that is useful for mineral identification. Here we report on the latest results of a study conducted using a portable SWIR instrument to investigate an Archaean stromatolitic unit associated with hydrothermal activity in the Pilbara Region of Western Australia.

Introduction

Hydrothermal deposits have been suggested as locations of great importance in the search for fossilized forms of ancient biota on Earth (Walter and Des Marais, 1993; Farmer and Des Marais, 1999). They occur where spatially confined warm (50°) to hot (500°) fluids are in disequilibrium with their host rocks (Pirajno, 1992). By the action of such a system, solutes can be concentrated to form ores at certain horizons within or on the surface of a rock body. Such concentrations may be developed where a drop in temperature, pressure, or alteration of the permeability or chemistry of the host rocks created conditions suitable for the solute to be precipitated from the hot fluid.

Hydrothermal vents at mid ocean ridges have been found to harbour a wide variety of life. The energy available due to the chemical disequilibrium around such sites has caused many scientists to wonder whether such deep sea vents may have been the ‘cradle of life’ (Macleod, *et al.*, 1994) on Earth.

Short Wave Infra Red (SWIR) Spectroscopy

Economic geologists and remote sensing specialists have long been interested in hydrothermal deposits for their valuable ore deposits. The distinctive alteration minerals that come about through hot water reacting with rock are easily detectable by satellites or aircraft carrying infrared spectrometers such as the Australian built PIMA II field spectrometer (Thompson, *et al.*, 1999). Such an instrument is proposed to fly with the ExoMars mission in 2009. As part of the preliminary investigation proving the usefulness of this technology at suitable Earth Analogues, an investigation has been carried out at the North Pole Dome (NPD) in the Pilbara region of north western Australia, site of a diverse range of stromatolitic horizons (Hoffman, *et al.*, 1999).

Trendall Locality

The region where this study took place is a stromatolitic outcrop of the Strelley Pool Chert (SPC) member of the Warrawoona Group. The Trendall Locality, as the outcrop is known, is highly silicified sequence, comprised of a lower carbonate sequence, middle black and white chert sequence, and upper clastic sequence. Each sequence is crosscut by massive black chert veins. Previous workers have suggested these veins may have been evidence of hydrothermal activity (Van Kranendonk and Hickman, 2000; Van Kranendonk, *et al.*, 2003). The outcrop covers a 150 sq. m area, and considerable regions are overlain by spinifex grass. The unit dips gently at about 25-30 degrees in this area, placing the stromatolite features roughly in profile.

The sequence is overlain by a subophitic pillow basalt sequence and underlain by a foliated, golden brown weathering clay unit. These units were also sampled during this study.

For a geological map of the area and extensive pictures of the outcrop, the reader is referred to the website:

http://aca.mq.edu.au/AdrianBrown/Trendall/index.htm

Sampling Strategy

In order to assess the possible use of a SWIR type instrument employed by a Rover on a Mars mission, the outcrop was first assessed visually (this may be done on Mars by a panchromatic camera) and then individual SWIR spectra were taken at various locations on visually assessed units of perceived importance in the sequence.

The visually identified units were then assessed for their constituent mineralogy by interpretation of their spectra.

SWIR Instrument and Analysis

The PIMA instrument, manufactured by Integrated Spectronics (http://www.intspec.com) was used to obtain the spectra.

The PIMA instrument measures reflected light from an internal light source in the wavelengths 1300 to 2500 μm. It illuminates a small region of approximately 10mm diameter directly on the surface of a mineral in front of the detector. The bandwidth of the PIMA is approximately 7 μm and it has a spectral sampling interval of 2 μm, though its spectral resolution in the SWIR is closer to 8 μm. It is quoted by the manufacturer to have a Signal to Noise Ratio (SNR) of between 3500 and 4500 to 1. Measurements typically take less than a minute and the instrument must be in direct contact with the sample being analysed. Calibration against a known internal standard is automatically carried out by the instrument prior to spectra collection. Internal temperature and battery status are measured and reported to an attached WinCE palm computer. Spectra from the PIMA instrument can be downloaded to a PC for further analysis.

The spectra were then assessed for mineral matches using "The Spectral Analyst" software produced by CSIRO. The mineralogy was then cross indexed to the unit in which it occurred.

Results

Minerals detected in the SPC Archaean sequence included clinochlore, muscovite/illite, dolomite, kaolinite, halloysite and opal (probably late stage alteration).

The following observations have been made:

1. The overlying basalt layer is rich in magnesium chlorite (clinochlore).
2. The rocks of the overlying clastic sequence contain some evidence for Al rich micas (such as muscovite).
3. The spectra of black cherts within the SPC are relatively featureless, but show some evidence for included water in the mineral structure.
4. The carbonate layer encasing the stromatolites is chiefly composed of dolomite, which can be traced through to progressively more silicified areas of the carbonate layer using the PIMA.

The ability of the SWIR instrument to identify the carbonate as dolomite and then to trace the presence of carbonate into more heavily silicified units was established. Even within visibly silicified units, enough spectral information was presented in the SWIR spectra to enable identification of OH mineralogy, bound and unbound water using bands at 1.4 and 1.9 microns (Aines and Rossman, 1984) and differentiate Mg from Al-OH mineralogy.

Conclusion

This study has highlighted the ability of SWIR technology to differentiate differing mineralogies, even in a highly silicified environment.

For further details, pictures, presentations and continuous updates on the results of this project, the reader is encouraged to visit the project website at http://aca.mq.edu.au/abrown.htm.

References

Aines, R. D. and Rossman, G. R. (1984) Water in mineral? A peak in the infrared. *Journal of Geophysical Research*, 89, 4059-4071.

Farmer, J. D. and Des Marais, D. J. (1999) Exploring for a record of ancient Martian life. *Journal of Geophysical Research-Planets*, 104 (E11), 26977-26995.

Hoffman, H. J., Grey, K., Hickman, A. H. and Thorpe, R. I. (1999) Origin of 3.45 Ga coniform stromatolites in Warrawoona Group, Western Australia. *GSA Bulletin*, 111 (8), 1256-1262.

Macleod, G., McKeown, C., Hall, A. J. and Russell, M. J. (1994) Hydrothermal and Oceanic Ph Conditions of Possible Relevance to the Origin of Life. *Origins of Life and Evolution of the Biosphere*, 24 (1), 19-41.

Pirajno, F., (1992) *Hydrothermal mineral deposits: principles and fundamental concepts for the exploration geologist*, Springer-Verlag, Berlin.

Thompson, A. J. B., Hauff, P. L. and Robitaille, A. J. (1999) Alteration mapping in exploration: application of short-wave infrared (SWIR) spectroscopy. *SEG Newsletter*, 39, 16-27.

Van Kranendonk, M. and Hickman, A. H. (2000) Archaean geology of the North Shaw region, East Pilbara Granite Greenstone Terrain, Western Australia - a field guide, pp. 64, GSWA, Perth, WA.

Van Kranendonk, M., Webb, G. E. and Kamber, B. S. (2003) Geological and trace element evidence for a marine sedimentary environment of deposition and biogenicity of 3.45 Ga stromatolitic carbonates in the Pilbara Craton, and support for a reducing Archaean ocean. *Geobiology*, 1, 91-108.

Walter, M. R. and Des Marais, D. J. (1993) Preservation of Biological Information in Thermal-Spring Deposits - Developing a Strategy for the Search for Fossil Life on Mars. *Icarus*, 101 (1), 129-143.