Remote sensing and spectral investigations in the Western Succession, Mount Isa Inlier: Implications for exploration

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Introduction

Detailed stratigraphic, structural and mineralogical investigations carried out in the northern part of the Leichhardt River Fault Trough (Bull Creek) as part of a Predictive Minerals Discovery Cooperative Research Centre study have identified several areas of intense hydrothermal alteration. These investigations demonstrate the utility of satellite imagery in identifying and discriminating mineral signatures formed through hydrothermal processes.

Satellite data complement geological and geophysical datasets to assist in better target selection in areas of exploration interest. Landsat Thematic Mapper, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Hyperion imaging spectrometer data covering the Bull Creek area of the Mount Isa Block have been used to test the ability of remote sensing methods to map regional geological units and alteration patterns (hydrothermal footprints). ASTER and Landsat investigations were expanded to cover the Termite Range Fault adjacent to the Century Mine. Band ratios and spectral unmixing techniques show promise in being able to discriminate between different mineralogies and lithologies, and can be a useful guide to understanding regional fluid movements when examined in conjunction with structural data. These data also have the potential to improve the spatial accuracy of mapping. Hyperion provides the opportunity to evaluate the capabilities of short-wave-infrared spaceborne hyperspectral data in the Mount Isa Terrain. This capability is especially valuable in remote areas where available geological and other ground truth information is limited.

The use of remotely sensed alteration maps enables exploration companies to gain a good understanding of the distribution of spectrally like materials on a regional scale. This can be important for highlighting areas prospective for mineralisation.

Methodology

Satellite/Sensor	Processing Level	Path Row/Area of Interest	Date of acquisition
Landsat 5	Ortho-corrected	99/73	23/09/89
Landsat 5	Ortho-corrected	100/73	14/09/89
Landsat 7 ETM+	Ortho-corrected	99/73	30/5/2002
Landsat 7 ETM+	Ortho-corrected	100/73	21/5/2002
ASTER	Path oriented	Bull Creek	13/9/2000
ASTER	Path oriented	Termite Range	23/11/2000
Hyperion	Raw image oriented	Bull Creek	21/9/2003

Table 1. A table and description of remote sensing data used in the orientation study.

Various data sets were acquired for the study (table 1). Preprocessing was required to enable the generation of spectral products from satellite image data. The Landsat and ASTER were radiometrically calibrated by converting the image digital number values to top of atmosphere radiance and atmospherically corrected using the dark pixel subtraction method.

The Hyperion preprocessing steps included the replacement of bad lines, elimination of bad bands, illumination correction, and local destreaking (treating VNIR and SWIR bands separately) to remove artifacts associated with the pushbroom sensor. The FLAASH module in ENVI was used to generate a surface reflectance product from the Hyperion data. Spectral polishing was then used to smooth the data.

Technique*s*

The generation of alteration and geologically relevant products utilized three main techniques including: 1. band ratios to isolate significant spectral absorption features for a target mineral from ASTER and Landsat data to highlight clay, iron and silica rich lithologies (figure 1), 2. Decorrelation techniques to highlight spectral variability and reduce data dimensionality, and 3. Spectral unmixing techniques to isolate and identify specific spectral targets.

Band ratios and Relative absorption-Band Depth (RBD, Crowley et al., 1989) images are generated through simple band arithmetic given knowledge of the absorption features of a target mineral. Band ratios provide a good quick pass of possible mineralogy in a given scene. RBD images have the numerator as the sum of the bands representing the shoulders and the denominator as the band located nearest the absorption feature minimum (Crowley et al., 1989).

The decorrelation technique stretches the principal components of an image to display inter-band variance. This method highlights spectral variability and can be a simple way to discriminate lithologies.

Hyperion required the application of spectral unmixing techniques, including 1. Minimum Noise Fraction generation to separate signal from noise (Hyperion has a fairly low signal to noise ratio of around 80:1 in SWIR; Datt et al., 2003), 2. Pixel purity index to highlight areas of spectrally pure pixels, 3. N-dimensional visualiser to select end members, 4. Spectral analysis to identify end members with reference to the USGS mineral spectral library and the Bull Creek PIMA spectral library (figure 2), and 5. Full or partial unmixing functions to map end members back to the data for the production of mineral maps.

Samples were collected over areas of mineral alteration and specific lithologies within the study area. Geological descriptions and spectral signatures, using Portable Infrared Mineral Analyser (PIMA) were compiled for both fresh and weathered surfaces in order to establish a spectral library. The spectral library helped differentiate particular lithological units and alteration mineralogy.

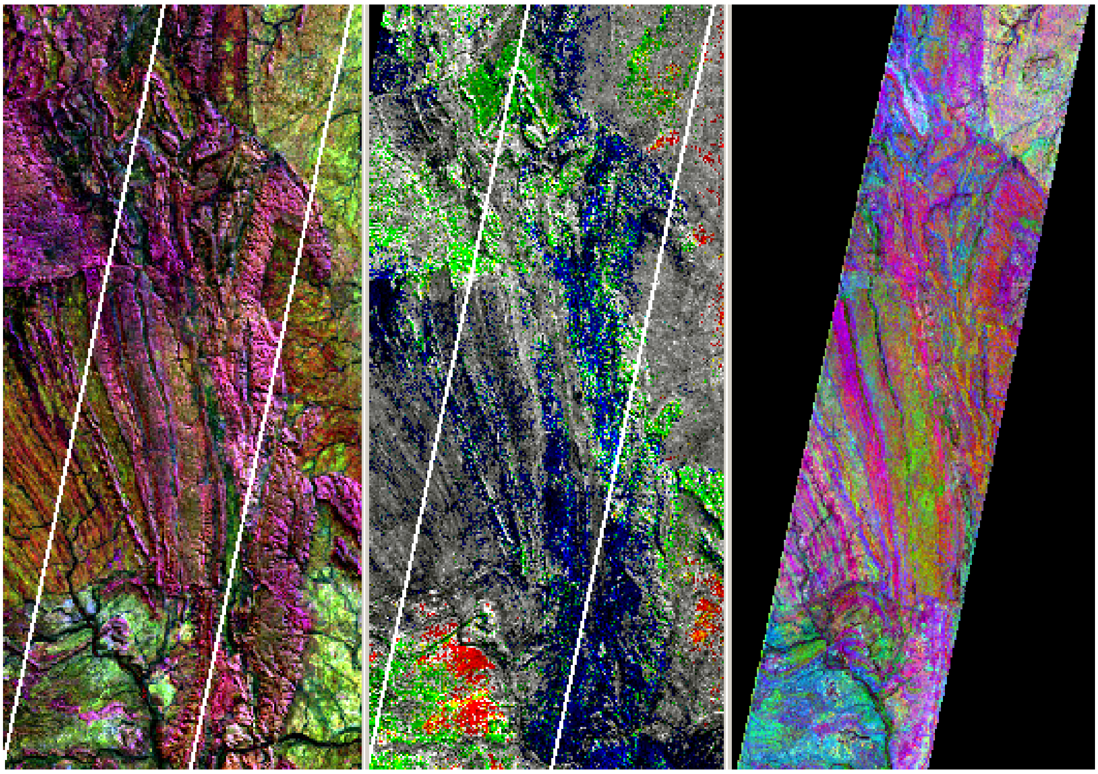
Preliminary Results

Landsat Thematic Mapper data in the Bull Creek area were processed to broadly highlight clay, iron and silica rich units (figure 1). The processing was able to distinguish areas of gossans and silification. ASTER data, with heightened spectral resolution were used to break the broad mineralogical groupings of the Landsat ratio images into smaller more precise groupings. ASTER was able to discriminate between alunite, phengite, kaolinite, and carbonate with varying degrees of success. Phengite was restricted to zones within Leichhardt Metamorphics, basement granites as well as two areas at crystal creek. Alunite showed localized concentration along faults and in preferred stratigraphic horizons. Hyperion data were used to map specific mineralogical targets.

In the Termite Range area, ASTER data were used to map phengite, carbonate and kaolinite mineral occurrences (figure 3). The Kamarga Dome showed diffuse kaolinite alteration that highlighted northeast-southwest trending faults, possibly due to increase weathering of feldspar minerals. The Termite Range Formation showed distinct zoning of phengite-kaolinite mineralogy in areas with little vegetation. No significant alteration was observed along the Termite Range Fault itself.

It is important to note that several factors complicate the ability of remotely sensed data to generate reliable mineral index images. These include vegetation cover and greenness, time of year, weathering, soil moisture and particle size, target size and material brightness (highly reflective materials are more reliably extracted). Producing accurate alteration maps requires a good understanding of the limitations of satellite data as well as knowledge of alteration and geochemical processes.

Figure 1. Bull Creek Target - At left, clay, iron and silica RGB Landsat TM band ratio image. At centre, ASTER Phengite, Muscovite and Alunite RGB thresholded to highlight likely occurrence. At right, Hyperion derived Minimum Noise Fraction image representing MNFs 3,4 and 5 as RGB.



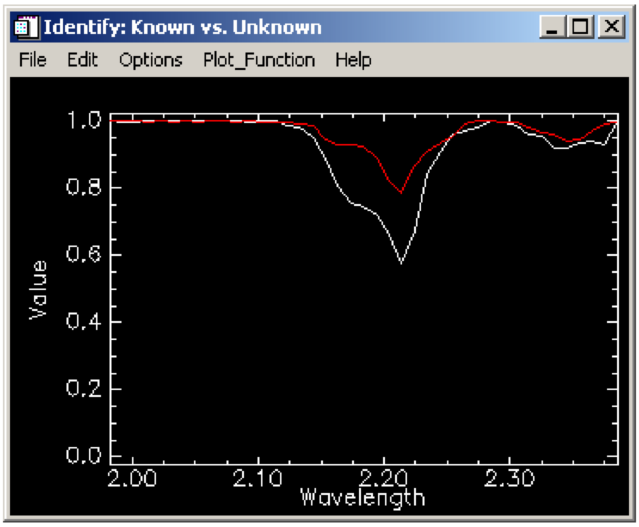


Figure 2. Hyperion end-member compared to PIMA sample 030603J1 (Halloysite) PIMA spectrum white, Hyperion red.

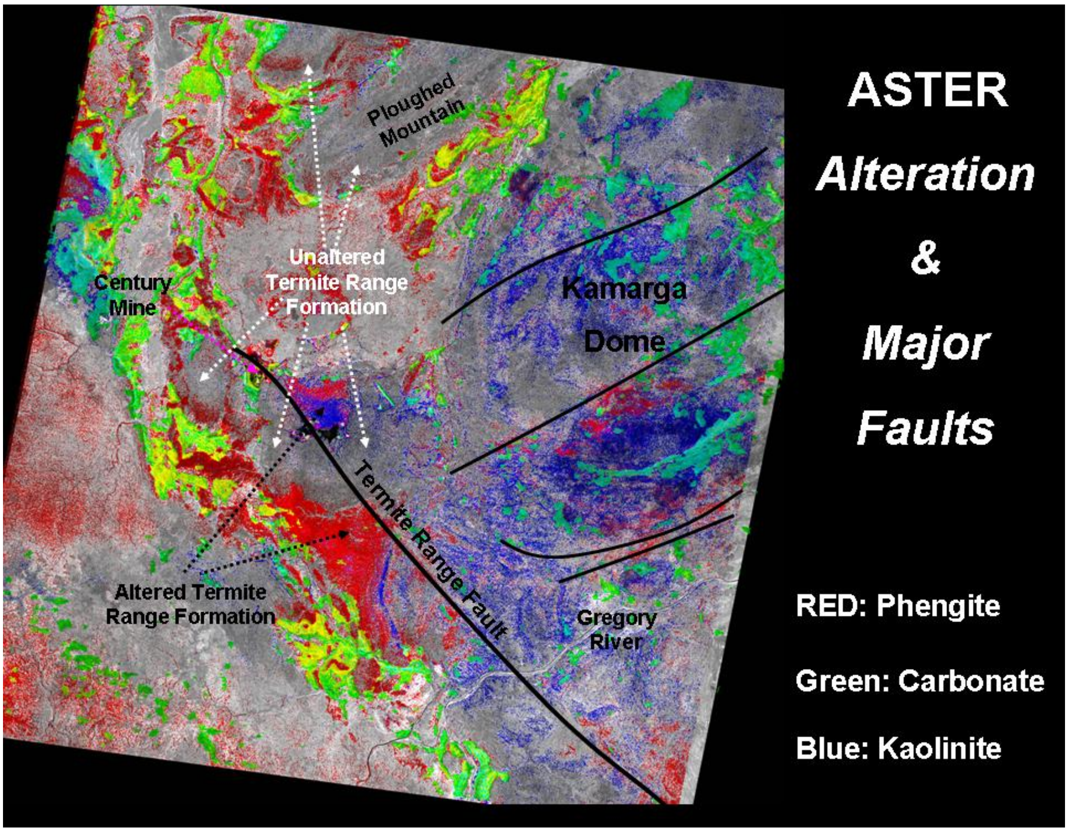


Figure 3. An ASTER derived phengite-carbonate-kaolinite map showing the major structural and alteration features.

Future Work

The next phase of the satellite image investigations will involve field validation of spectral processing methodology used in this study. Investigations will also focus on improving Hyperion data pre-processing. It is anticipated that field validation will be completed during the next 12 months. Successful acquisitions of Hyperion and Advanced Land Imager (ALI) data have been made over the Mount Gordon Fault and are yet to be processed to extract geological information.

The preliminary results have highlighted the usefulness of remote sensing in the production of alteration maps. As there is very good coverage of ASTER data, future work is needed to expand the alteration maps on a regional scale to cover the entire Mount Isa Inlier.

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References

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