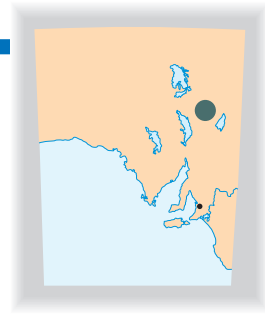


Mount Fitton hyperspectral mineral mapping collaborative project

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Introduction

An international collaborative project is underway in South Australia's northern Flinders Ranges to demonstrate the benefits of mineralogical mapping using air and spaceborne hyperspectral data. The collaboration involves CSIRO Exploration and Mining, the National Remote Sensing Centre (NRSC, UK) and PIRSA, with assistance from De Beers Stockdale Prospecting, Commercial Minerals and Integrated Spectronics.

The project involves Dr Anthony Denniss spending approximately three months in Australia working with staff of CSIRO's Mineral Mapping Technologies Group to process and interpret five flight lines of airborne hyperspectral data provided by De Beers Stockdale and Integrated Spectronics. The project consists of two phases:

- processing and field-checking the airborne hyperspectral data at its maximum 5 m resolution in order to produce a new series of detailed mineral abundance maps
- reprocessing the airborne data after it has been convolved spatially and spectrally to the resolution of the proposed Australian Resources and Environment Satellite (ARIES-1).

The two sets of processed data will then be used in a comparative study of the value of the new hyperspectral-derived mineral maps (Figs 1, 2) and the differences seen at various scales.

Project area and geology

The study area is located in the northern Flinders Ranges, centred on the Mount Fitton Talc deposits ~570 km north of Adelaide and 130 km northeast of Leigh Creek. The area is detailed on the MARREE 1:250 000 and Blanchewater 1:100 000 scale geological maps.

The Mount Fitton area consists of mildly metamorphosed Neoproterozoic Adelaidean sediments of the Umeratana and Wilpena Groups, within the Adelaide Geosyncline (Preiss, 1987). The main rock types are quartzite, sandstone, siltstone, shale and carbonate rocks which, in this region, are flanked to the north and east by exposed Palaeo- and Mesoproterozoic basement of the Mount Babbage and Mount Painter Inliers.

These Adelaidean sediments show a shallow, westerly plunging fold structure as a result of north to south crustal compression during the Cambro-Ordovician Delamerian Orogeny (Thomson, 1969). Folds are gentle in competent strata and tighter in incompetent strata, such as the Balcanoona Formation. The majority of faulting is sub-parallel to the axial plane cleavage.

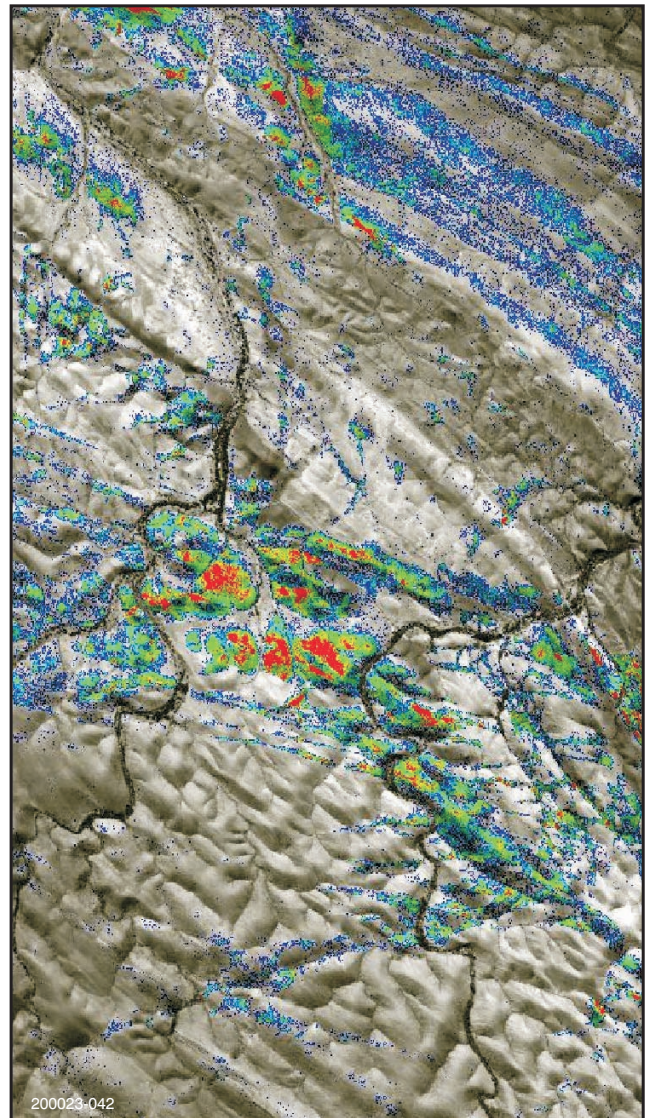


Fig. 1 Extract of the chlorite scene end-member abundance image showing chlorite-rich units within siltstone of the Fortress Hill Formation (top right) and a large chloritised fault zone (centre). Red = high relative abundance, blue = low relative abundance.

Vegetation cover in the area is very sparse, consisting of eucalypts (confined mainly to creek beds), saltbush and spinifex. The most extensive vegetation cover is associated with dolomite of the Balcanoona Formation, which has ~50% cover of mallee.

Hyperspectral data and processing methods

Six flight lines (four north–south and two east–west) of 96 and 128-channel HyMap™ data, spanning the 0.4–2.4 μm

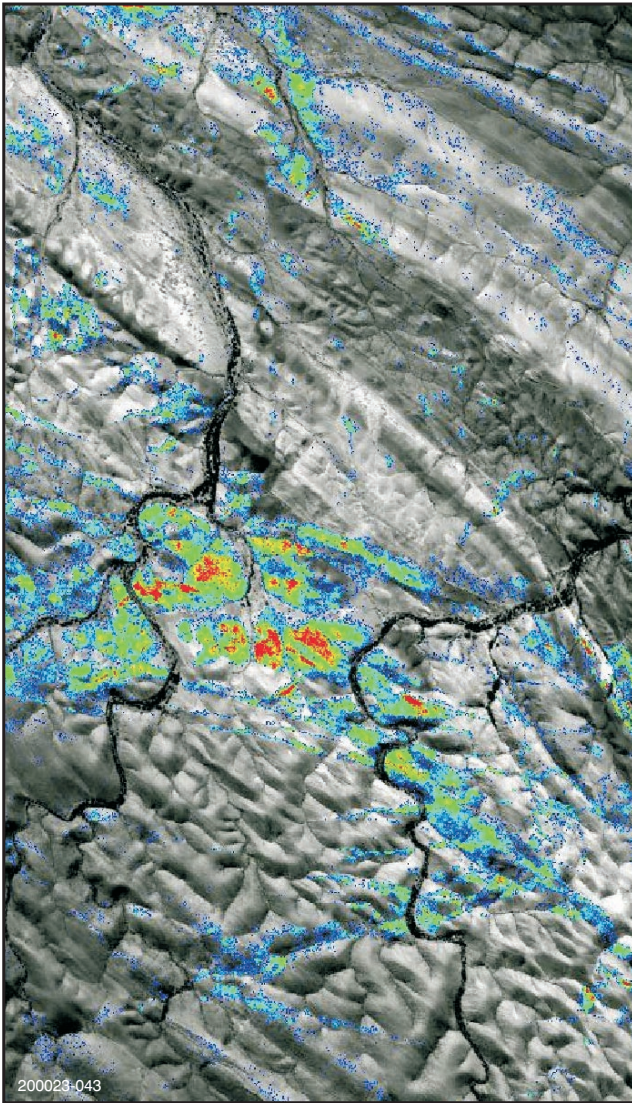


Fig. 2 Relative abundance of the chlorite+Al(OH) (probably mica) scene end member highlighting fault zones rather than the siltstone stratigraphy seen on Figure 1.

wavelength range, were available for the project. These wavelengths are ideal for mapping of stratigraphic units, the regolith or alteration zones containing carbonate, sulphate and hydroxyl-bearing minerals (e.g. sericite, kaolinite, chlorite, talc), as well as iron oxides, and green and dry vegetation.

The data available for most of the area were slightly different from 'conventional' HyMap data, as the shortwave-infrared (SWIR-2) channels between 2.1 and 2.4 μm were re-configured to a finer bandwidth of ~ 10 nm, as opposed to the conventional 18–20 nm. Part of the area was also covered with conventional 18–20 nm resolution HyMap data.

The hyperspectral data were processed using the ENVI image processing package augmented by a series of special tools developed by CSIRO. The data processing consisted of calibrating and atmospherically correcting all channels prior to extracting the SWIR-2 data. To date, only the SWIR-2 data over the most geologically interesting (2.1–2.4 μm) region have been fully processed, but analysis of the visible and near-infrared (VNIR) data (0.4–2.0 μm) has commenced.

Processing consisted of reducing the data volume using the Maximum Noise Fraction transformation (MNF) prior to creating a Pixel Purity Image (PPI) to identify the spectrally

most extreme materials in the area. These pixels were then visually examined using a dynamic n-dimensional scattergram tool to identify spectrally coherent mineralogical groups (clusters) from the regional noisy background. A spectral library of end-member spectra (Figs 3, 4) was then created representing the spectrally purest pixels (i.e., the different mineralogies) within these coherent groups.

Using this end-member library, a whole series of relative abundance images of each mineralogical or other class was then produced using the Mixture Tuned Matched Filtered (MTMF) method. These images show the location of all pixels within all the flight lines with approximately the same spectral characteristics as the end-member training spectra, as well as showing the relative strength (or abundance) of these spectral absorptions. These images were then thresholded, pseudo-coloured and draped onto a base image to produce a series of mineral abundance maps. Such maps can then be taken into the field for verification or combined into a GIS to produce a set of geo-referenced mineralogical map layers along with other geological or geophysical data.

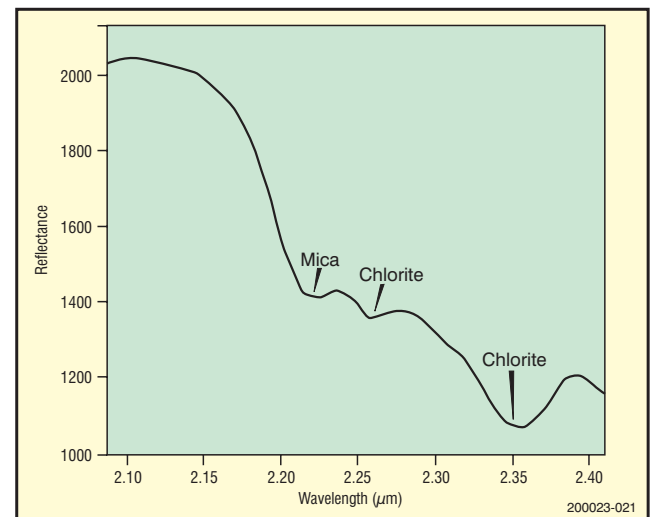


Fig. 3 HyMap reflectance spectrum of a chlorite+Al(OH) mineral (probably mica) showing the diagnostic absorption features of the two minerals.

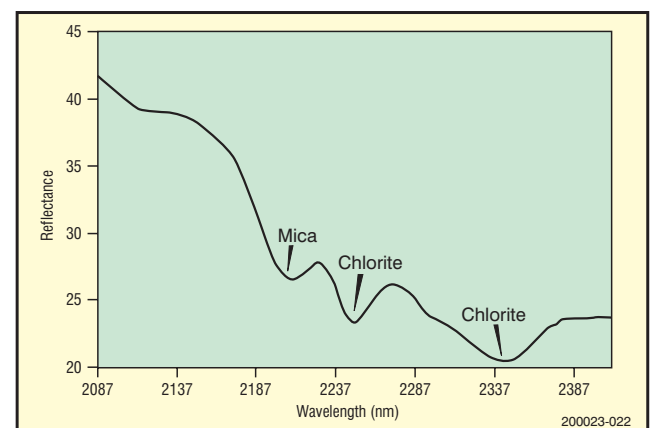


Fig. 4 PIMA-II field spectrum of a sample from the same area as Figure 3, showing similar absorption characteristics confirming the airborne data interpretation. Differences in the relative depths of absorption features are due to variations in the relative abundance of the two minerals between the field and airborne sample sites.

Current results

Mineral abundance images from the initial processing were field checked in July 1999. This showed that the majority of the mineral abundance maps were correctly mapping mineral features that could be located and verified in the field using a PIMA-II™ field portable spectrometer (Figs 3, 4). However, the field visits also indicated that some of the initial mineral abundance images were duplications of each other. This resulted from using two training end members that were only very slightly different. The fieldwork confirmed that a total of 10 mineral abundance maps could be produced with a high degree of confidence. These included chlorite, chlorite+Al(OH) mixture, kaolinite, three different compositions of white mica, three different carbonates (including a carbonate-tremolite mixture), and talc.

Examples of the chlorite and chlorite with Al(OH) abundance images are shown on Figures 1 and 2, respectively. The chlorite image shows the distribution of chlorite-rich units within the Fortress Hill Siltstone (top of image) as well as chlorite associated with late-stage, cross-cutting faults (centre of image). Figure 2 shows the distribution of chlorite+Al(OH) (probably sericitic mica), which tends to be limited to fault zones only.

Future work

This project is on-going and much work remains to be done, including electron microprobe analysis of the mica

and chlorite compositions, and acquisition of additional flight lines of data. However, the preliminary results are extremely encouraging and indicate that the data are clearly mapping distinct mineral assemblages, and demonstrate the power of this new geological mapping tool for refining the geological understanding of this particular area.

Acknowledgements

The assistance of the following colleagues is gratefully acknowledged in making this collaboration possible and contributing to various aspects of the work: Peter Mason, Melissa Quigley and Tom Cudahy (CSIRO Exploration and Mining), Alan Mauger (PIRSA), Simon Powell (Commercial Minerals), Mike Hussey (De Beers Stockdale) and Terry Cocks (Integrated Spectronics Pty Ltd).

For further information contact Steve Hore (ph. 08 8463 3046).

References

- Preiss, W.V., 1987. The Adelaide Geosyncline: late Proterozoic stratigraphy, sedimentation, palaeontology and tectonics. *South Australia. Geological Survey. Bulletin*, 53.
- Thomson, B.P., 1969. The Delarmerian Orogeny. In: Parkin, L.W. (Ed.), *Handbook of South Australian geology*. Geological Survey of South Australia, p.106. ■

DID YOU KNOW?.....

Remote sensing for minerals

For any given material, the amount of solar radiation that it reflects, absorbs or transmits varies with wavelength. This property makes it possible to identify different substances by their spectral signatures, whether it be from a space vehicle, aircraft or a person in the field.

ARIES (Australian Resource Information and Environment Satellite)

- The ARIES-1 project is the outcome of 20 years of collaborative research and development into advanced remote sensing technologies for exploration between CSIRO and the mining industry.
- ARIES-1 is a 400 kg satellite in a 500 km sun-synchronous orbit which will be fully operational in early 2000.
- ARIES-1 will be a commercial operation using a spaceborne imaging spectrometer with visible, VNIR and SWIR capabilities.
- With the volume of data produced from 105 potential output channels in the wavelength region of 400–2500 nm recorded at 30 m resolution over a 15 km swath, it is anticipated that much of the image processing will be performed by the satellite operator. ARIES-1 will also have a 10 m panchromatic co-registered image sharpening band. It is proposed that one of the final products provided to the geoscientific community will be mineral abundance maps.
- The ARIES-1 hyperspectral remote sensing system will provide users with the next generation of data and information services for mineral exploration, geological and resource mapping, and environmental monitoring.

HyMap (airborne platform)

- The HyMap spectral scanner, operated by HyVista, provides 126 bands across the reflective solar wavelength region of 450–2500 nm with contiguous spectral coverage (except in the atmospheric water vapour bands) and bandwidths between 15 and 20 nm.
- The sensor operates in a three-axis gyro-stabilised platform to minimise image distortion due to aircraft motion, and can be adapted to any aircraft with a standard aerial camera port.
- The resolution and swath width are specified by the client but a typical survey might produce a 2.5 km wide strip at 5 m resolution with 126 channels.

PIMA (Portable Infrared Mineral Analyser)

- The PIMA SP field-portable infrared spectrometer was designed to allow field personnel to rapidly and cost effectively measure 'laboratory' standard spectra of rocks and minerals in the field.
- The spectra are of sufficiently high resolution to reveal spectral detail of absorption bands that can provide information on the degree of crystallinity and subtle mineralogical variations.
- PIMA utilises the SWIR, with 601 channels in the 1300–2500 nm wavelength range. Using an inbuilt light source, it can measure parts of the spectrum that, because of atmospheric interference, are not available to instruments relying on reflected solar radiation.

For further information please refer to the following Web pages:

www.syd.dem.csiro.au/research/MMTG/ariesflyer81.html
www.hyvista.com/HyMapSensor
www.intspec.com/PIMA/PIMASP