Airborne and ground-based spectral surveys map surface minerals and chemistries near Duchess, Queensland.

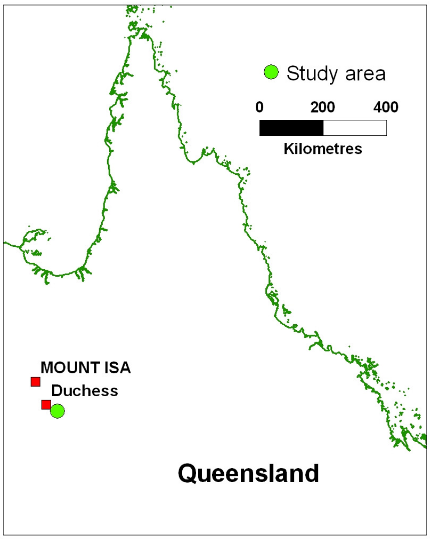
Mal Jones[A], Tom Cudahy[B], Matilda Thomas[C], Rob Hewson[D]

[A] Geological Survey of Queensland. Email Mal.Jones@deedi.qld.gov.au
[B] CSIRO Exploration and Mining. Email Thomas.Cudahy@csiro.au [D]Email Rob.Hewson@csiro.au
[C] Geoscience Australia. Email Matilda.Thomas@ga.gov.au

Abstract
Spectral data from airborne and ground surveys enable mapping of the mineralogy and chemistry of soils in a semi-arid terrain of Northwest Queensland. The study site is a region of low relief, 20 km southeast of Duchess near Mount Isa. The airborne hyperspectral survey identified more than twenty surface components including vegetation, ferric oxide, ferrous iron, MgOH, and white mica. Field samples were analysed by spectrometer and X-ray diffraction to test surface units defined from the airborne data. The derived surface materials map is relevant to soil mapping and mineral exploration, and also provides insights into regolith development, sediment sources, and transport pathways, all key elements of landscape evolution.

Key Words
Hyperspectral; SWIR; XRD; paleochannel; regolith.

Introduction
Geological studies for mapping and mineral exploration routinely use airborne radiometric surveys. Airborne Hyperspectral scanners are a more recent development, with greater spatial resolution and moderate to high spectral resolution. Hyperspectral scanners discriminate a greater number of land surface components, enabling maps of surface cover, minerals, and chemistry to be made. These maps are supported by ground based spectral measurements of soil using a high resolution portable spectrometer and by X-Ray Diffraction analyses for minerals.



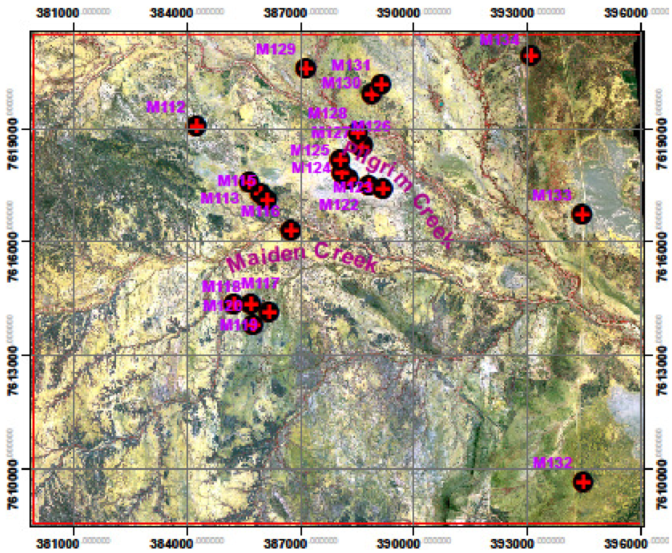
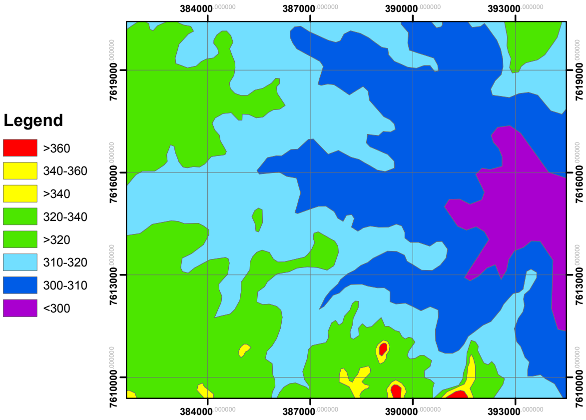


Figure 1. Location Map. Figure 2. False colour image shows limited vegetation, drainage, and sample sites.

The study area of 16 x 13 km lies southeast of Duchess, about 90 km southeast of Mount Isa (Figure 1). The hyperspectral survey was flown in August-September 2006 during very dry conditions when the vegetation cover was sparse (Figure 2) (Cudahy and others 2008). The airborne HyMap scanner measures 126 channels covering wavelengths from visible to short wavelength infra red (SWIR). The 126 data points for each 4.5 m pixel record the radiance at specific wavelengths, enabling reflectance spectra to be constructed for each of the approximately 10 M pixels in the study area. Absorption features in the spectra identify surface components within each pixel. The data were processed by CSIRO in Perth to produce twenty two image maps that show the distribution (abundance) of surface components (e.g. kaolin, Ferrous Fe), and in some instances, the chemical variability of a component (e.g. white mica composition). A subset of eight image maps was used to interpret surface materials across the entire landscape. Surface mineral and chemistry maps can be applied to investigations including soil studies, mineral exploration, and landscape evolution.

Landforms and Geology

The 1 sec Shuttle Radar Topography Mission data record a subdued topography with an elevation range of 280 to 370 m (Figure 3). The bedrock geology forms the foundation of the landscape, and has a major influence on the surface materials. The type of bedrock, and factors including the presence or absence of an in-place weathered mantle, or cover of transported sediments, affect the mineral composition and chemical attributes at the surface. The oldest geology comprises Proterozoic Corella Formation (calcareous lithologies; metamorphosed sediments), intruded by the Proterozoic Saint Mungo Granite (porphyritic hornblende biotite granite). These rocks are overlain by sparsely preserved Cambrian sediments - Mount Birnie Beds, Inca Formation, Thorntonia Limestone, O'Hara Shale. Minor remnants of Mesozoic deposits occur on mesas and rises. Unconsolidated Cenozoic sediments occur on low areas (Figure 4).



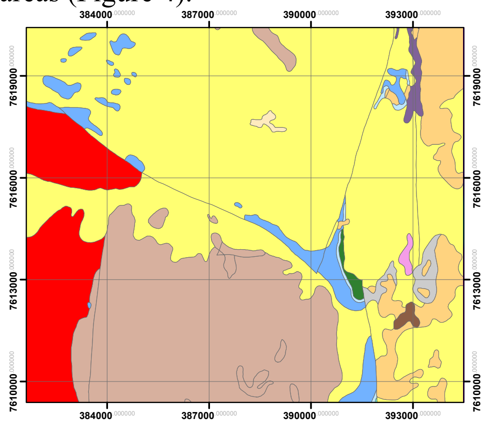


Figure 3. SRTM Topography (elevation in m). Figure 4. Geology map shows extensive Cenozoic cover in the north (yellow) on Proterozoic Corella Formation carbonates and metasediments mainly in the south (pink-brown) and Saint Mungo Granite to the west (red). Cambrian limestone and sediments are blue, green, purple.

Image Maps Derived from Hyperspectral Survey

The hyperspectral data were processed using in-house software at CSIRO. All pixels were classified according to the presence or absence of diagnostic spectral absorption features. These classes indicate presence/absence of specific components of surface materials across the landscape. Within these classes, the depth of spectral absorption features was used to estimate abundance (highest abundance correlates with greatest depth of absorption feature). Variations in mineral composition within specific mineral groups, e.g. white mica, were determined from slight variations in the wavelength of diagnostic features (e.g. the 2200 nm white mica absorption occurs at longer wavelengths with substitution of Fe and Mg cations in the lattice).

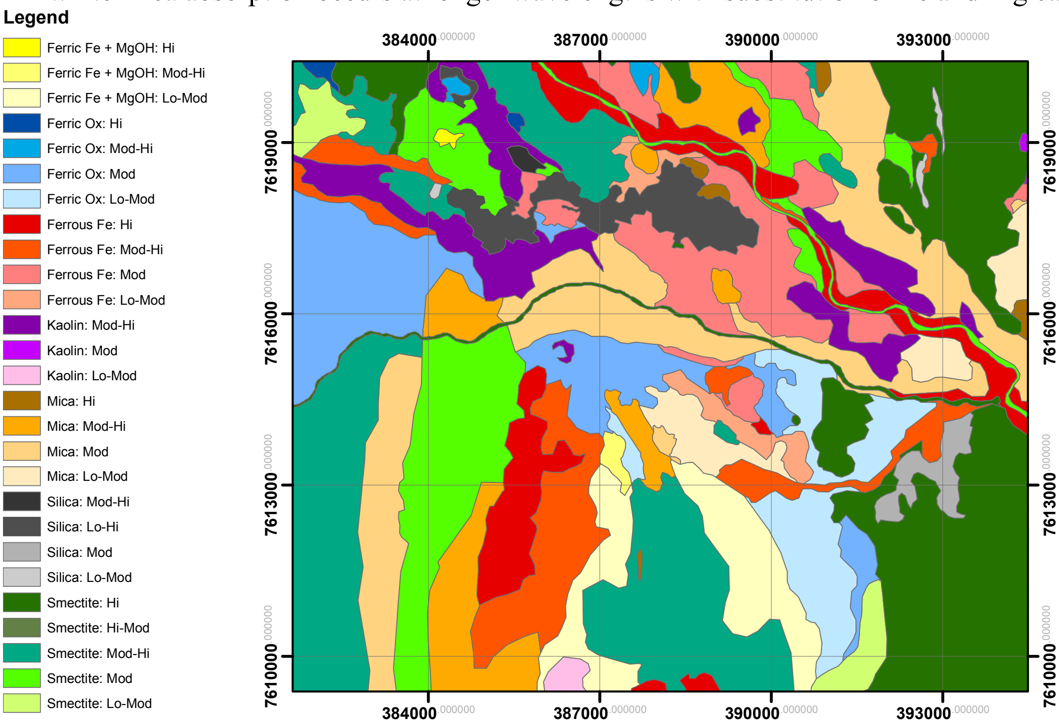


Figure 5. Surface minerals and chemistry map derived from hyperspectral survey.

Eight image maps were used to investigate the surface material characteristics: Aluminium Smectite; White Mica; Kaolin; Ferrous Iron; Ferric Oxide; Ferric Fe and MgOH; Silica (Hydrated); and False Colour. Polygons were constructed to depict areas of dominance or high abundance of components. Some areas rated highly in a number of components, and could be assigned to more than one surface mineral class. Other areas contained low abundances in all mineral and chemical groups (Figure 5).

Soil sampling and analysis

Rock and soil samples were collected at twenty three locations in the study area (Figure 2). The soil samples were measured with an ASD portable spectrometer, which covers wavelengths from 350-2500 nm (visible to short wavelength infra red) at 1 nm increments. TSG software (http://www.ausspec.com/TSG.htm) was used to identify the mineralogy of the soil samples from their spectra (Figure 6). The software identifies up to two major components on the basis of SWIR spectral characteristics. Additionally, the presence of iron oxide is determined by visible wavelength absorption features. The VNIR-SWIR spectral determinations are most sensitive to OH bonds which occur in minerals such as montmorillonite, kaolinite, and white mica (illite-muscovite), and to some carbonates (siderite), and hydrated silica, but are insensitive to other minerals such as silicates (quartz, feldspar).

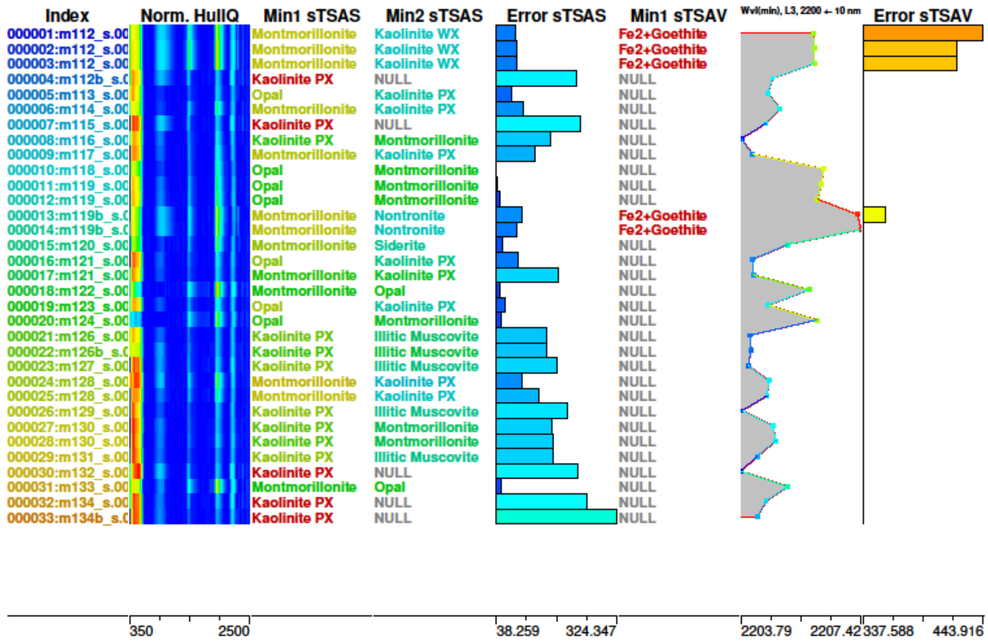


Figure 6. Spectral analyses of soil samples (Column 1=sample no) identify up to two major mineral components from SWIR wavelengths (Columns 3-4) and one from visible wavelengths (Column 6). Variation in the wavelength of the ~2200 nm feature is related to cation substitution in clay lattices and is shown in Column 7. Opal = hydrated silica. PX = poorly crystalline; WX = well crystalline. See Figure 2 for locations.

Further analyses using X-ray diffraction were completed on eighteen soil samples. Minerals such as quartz are highly diffractive of X-rays and so dominate most XRD analyses with high intensity features at 26.68 and 20.9° 2θ (Figure 7). Clay minerals are less diffractive and produce relatively small peaks on the X-ray diffractograms. Identification of the mineralogy of **mixed** samples can be problematic due to the number of peaks, some of which become broad due to overlapping effects from similar minerals. Nevertheless, the analyses show a generally good correlation between the HyMap-based land surface units and the mineralogy of soil samples determined by spectrometer and XRD methods.

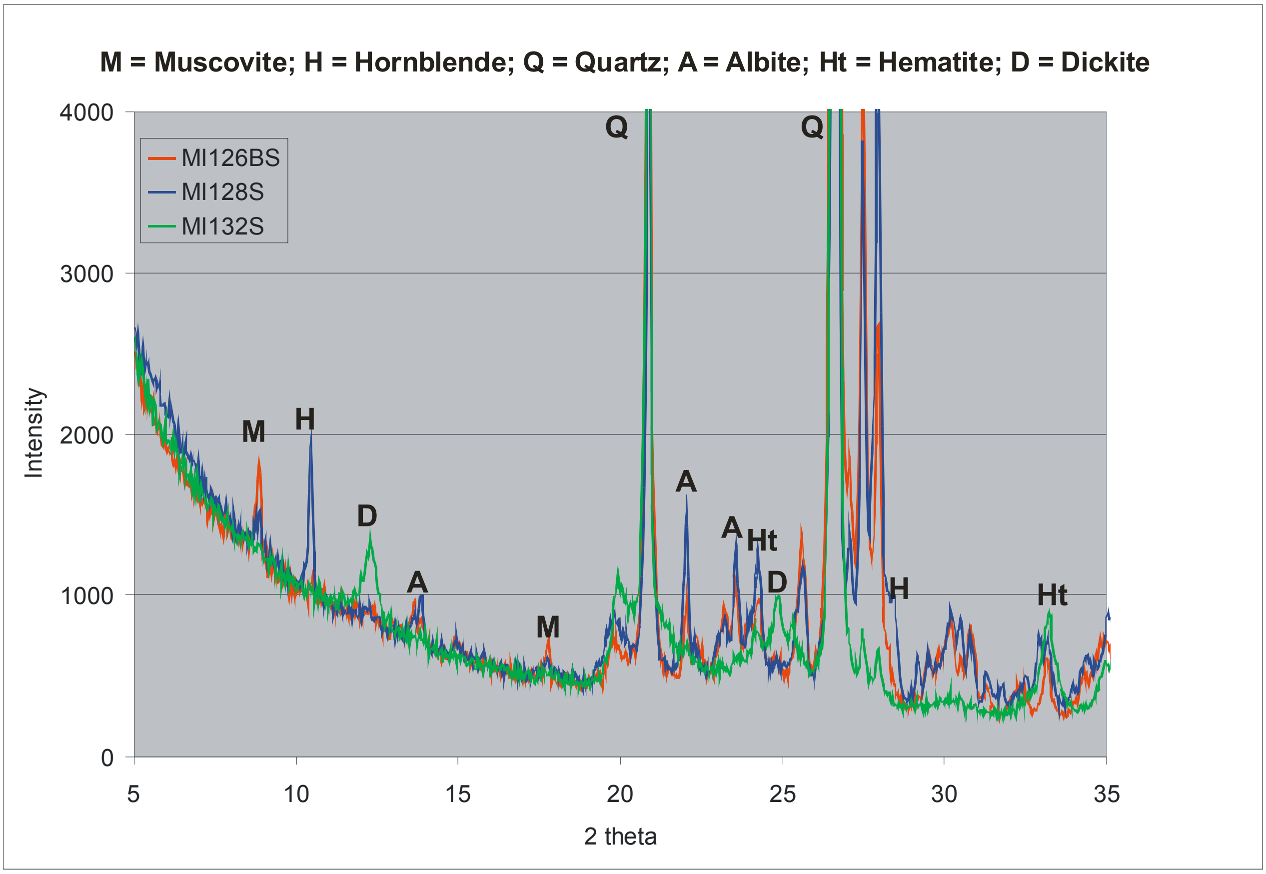


Figure 7. X-ray diffractogram of soil samples from sites 126, 128 and 132. Quartz features dominate in all samples (intensity >4000) whereas other minerals are of much lower intensity. Sample 126 contains muscovite, 128 contains hornblende (edenite) and 132 contains dickite, a form of Kaolinite.

Conclusions

The surface mineral and chemistry map (Figure 5) derived from airborne and ground spectral surveys characterises the entire land surface based on abundance of specific minerals or chemistries. Integrated ground and airborne spectral surveys identify surface components not readily discernable to the naked eye, and provide validated coverage of project areas. Mineral components such as opaline silica can be identified prior to on-the-ground field surveys and flagged for checking and sampling. The surface components can be used to identify sediment sources, transport pathways and depositional areas to assist understanding of landscape evolution. They also reveal areas of outcropping or thinly covered bedrock in apparently uniform terrain, and identify erosional and depositional areas. The combination of airborne and ground spectral surveys provide a level of landscape characterisation not previously achieved, demonstrating proof of concept for surface material mapping over wide areas of Australia.

References

Cudahy T. Jones M. Thomas M. Laukamp C. Caccetta M. Hewson R. Rodger A. Verrall, M. (2008) Next Generation Mineral Mapping: Queensland airborne HyMap and Satellite ASTER Surveys 2006-2008. *CSIRO Exploration and Mining Report* P2007/364.