New airborne HyMap data aids assessment of magnesite resources

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Introduction

Skillogalee Dolomite is the most extensive of the Neoproterozoic carbonates of the Adelaide Geosyncline. The formation varies from a few hundred to 5000 m in thickness, and is characterised by the presence of minor thin magnesite beds typically <0.5 m thick. Northwest of Leigh Creek and extending for ~120 km into the Willouran Ranges, magnesite beds increase in both frequency and thickness, reaching a maximum in the region of Screechowl Creek where individual beds up to 5 m thick have been recorded (Fig. 1). Deposits near Leigh Creek have been mined for pharmaceutical, agricultural and industrial applications but have been regarded as too dolomitic for use in MgO refractories, the single largest market for magnesite. Renewed interest worldwide in magnesite resources is in response to forecasts of strong demand for magnesium metal as a major component in lightweight alloys for the motor vehicle industry. Fine-grained sedimentary magnesite in the Skillogalee Dolomite has a low iron content and is readily leached in concentrated HCl to give a quality magnesium chloride salt suitable for electrolytic production of magnesium metal.

Geological field work during 1997–98 focused on locating closely spaced magnesite beds comprising mineable packages from which individual beds could be selectively mined. This method of mining has been used effectively at Commercial Minerals Ltd's Myrtle Springs Quarry to extract individual magnesite beds averaging 1.2 m in thickness. Identification and detailed mapping of magnesite in the Willouran Ranges have been hampered by limited vehicular access and the necessity for investigations to be largely field based and on foot.

In March 1998, the opportunity was taken to include the Willouran Ranges in trial flights of a new hyperspectral visible–short wave infrared (VIS–SWIR) airborne imaging spectrometer (HyMap™) manufactured in Australia by Integrated Spectronics Pty Ltd. Improved signal to noise ratio, together with the high spatial and spectral resolution capabilities of this spectrometer, offer the possibility of using airborne data to differentiate a wide range of mineral species at the ground surface through recognition of their characteristic absorption spectra.

Geology

The trial HyMap survey was flown over a 30 km strike length of Skillogalee Dolomite outcrop along the western Willouran Ranges, commencing south of Mount Nor West and including the Screechowl Creek magnesite deposit. In the area selected, Skillogalee Dolomite strikes northwest, dips steeply to the southwest at 65–85° and is up to 1.5 km

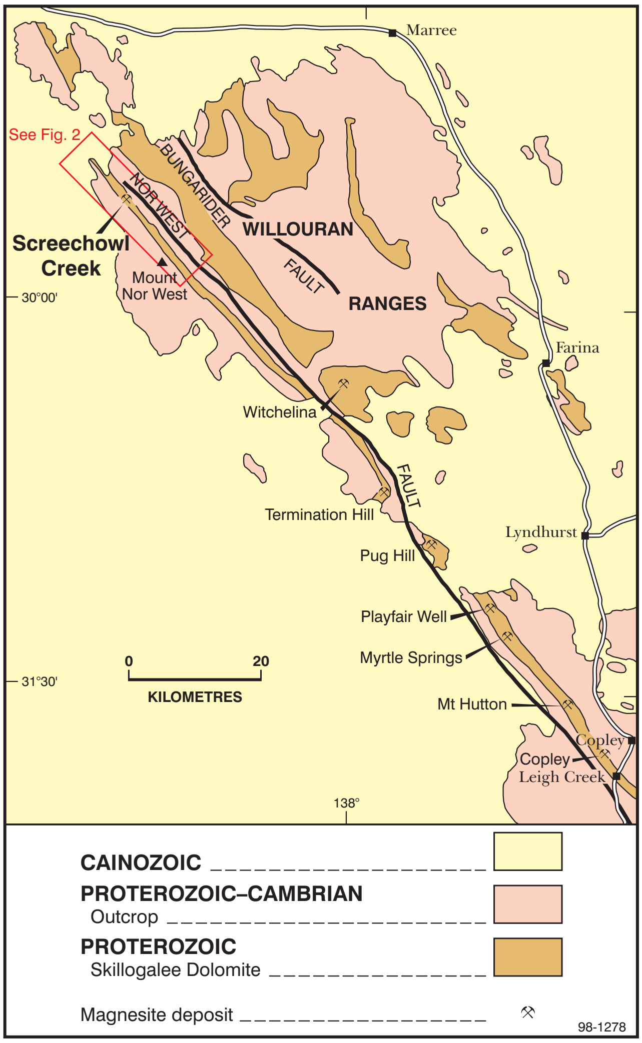
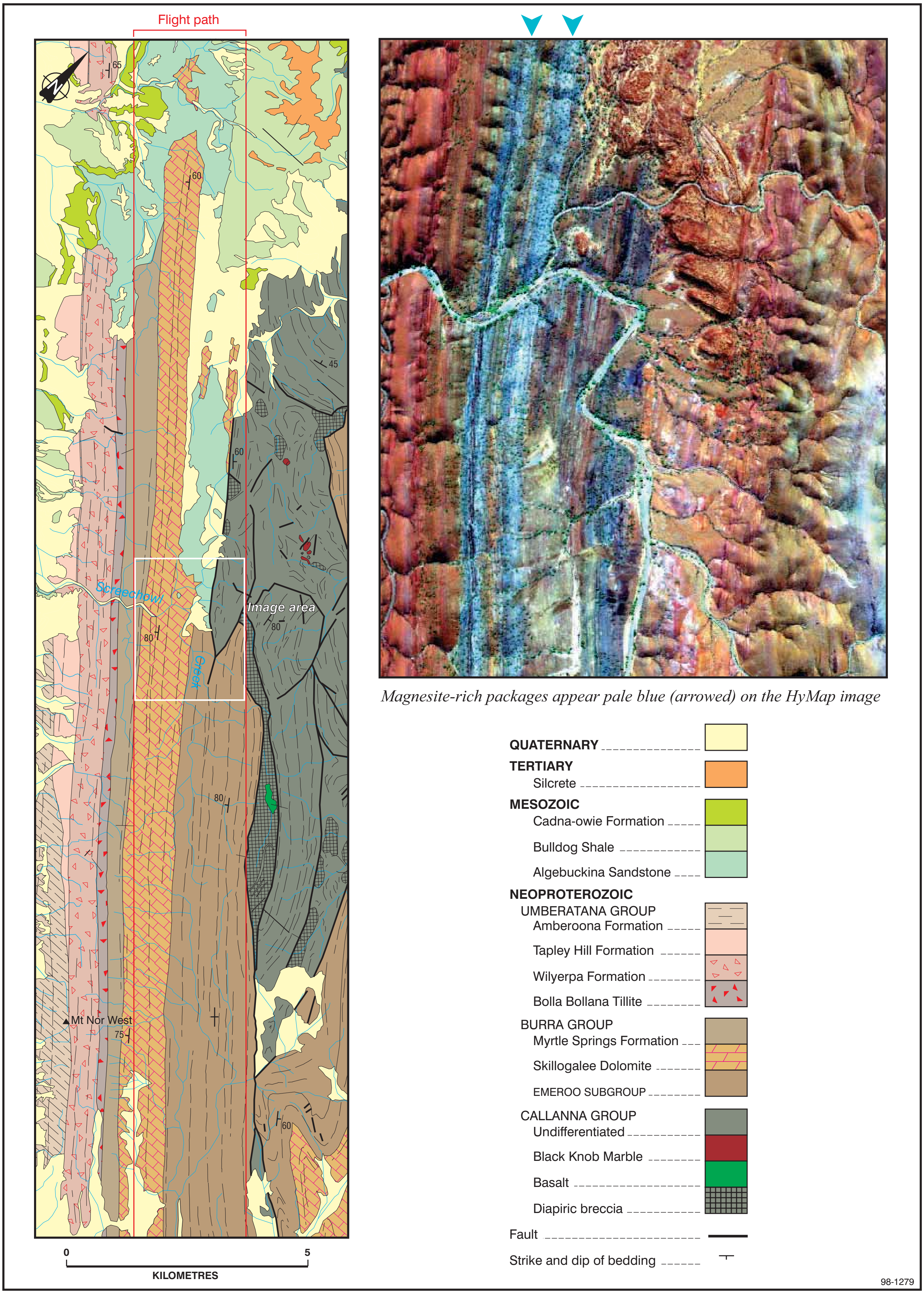


Fig. 1 *Location of sedimentary magnesite deposits to the northwest of Leigh Creek.*

thick (Fig. 2). Other Proterozoic units included in the 2.5 km wide scan path were Emeroo Subgroup medium-grained sandstone below the Skillogalee carbonates, and part of the overlying Myrtle Springs Formation, a laminated siltstone interbedded with thin, siliceous dolomite. To the north of Screechowl Creek, flat-lying medium to coarse sand and clayey siltstone of Jurassic to Cretaceous age infill valleys and blanket low-lying areas of Proterozoic bedrock. The lower 300 m of the Skillogalee comprise shale and sandstone with dolomitic siltstone. Above 300 m, carbonate units are dominant and include predominantly micritic, carbonaceous, dark grey dolomite with occasional stromatolite horizons, interbedded dolomitic arkose, micritic magnesite, magnesite conglomerate, and minor siltstone.



Magnesite-rich packages appear pale blue (arrowed) on the HyMap image

***Fig. 2** Geology of the western Willouran Ranges showing part of the HyMap flight path and false colour HyMap image.*

In a measured section at Screechowl Creek, significant magnesite concentrations were recorded at around 360, 700 and 950 m above the contact with the Emeroo Subgroup (Belperio, 1987). Sedimentary structures and carbon–oxygen isotope studies indicate that the carbonates were deposited as shallow marine sediments (Belperio, 1990). Changes in lithology reflect repeated transgressive and regressive marine cycles. The environment was at times sufficiently restricted to allow elevated pH conditions or salinity changes that triggered magnesite precipitation. This part of the cycle generally progressed through to the drying up of magnesite-precipitating lagoons with exposure and desiccation of newly formed magnesite crusts (Uppill, 1979). Subsequent marine transgression reworked the disrupted magnesite crust to form a distinctive magnesite conglomerate as sheet flood deposits across what must have been extensive areas of low depositional slope. Repetition of the cycle of subsidence, shoaling, exposure and disruption resulted in repetitive deposition of dolomite and thin magnesite beds. Following burial and consolidation, the rocks were folded about northwest–southeast axes to give broad folds with long limbs. Dehydrogenation and alteration of Type 1 kerogens from organic matter in the dolomitic units (McKirdy and Watson, 1986) are consistent with metamorphism to lower greenschist facies.

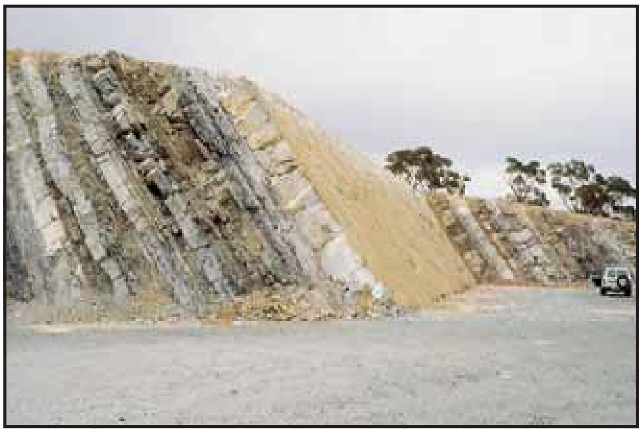
At Screechowl Creek, magnesite beds vary from <0.5 to 5 m in thickness and are remarkably persistent with individual beds being traced along strike for several kilometres, in places exceeding 10 km. Areas of high concentration of magnesite include 50–120 m thick sediment packages where magnesite beds, of >80% magnesite, comprise up to 30% of the sediment.

The region is arid and dominant landforms are parallel strike ridges of rocky outcrop. Vegetation includes sparse, low bluebush shrub and grasses with patchy open woodland of low mulga and eucalypt largely confined to hilly terrains and along dry water courses. The arid climate, rocky outcrop, and sparse vegetation make the area ideally suited to mineral mapping from the air.

Ground survey

In conjunction with the airborne survey, field samples were collected for spectral analysis. This was to determine the range of minerals that could be differentiated spectrally and their relationship to lithology, thereby providing some spectral ground control to aid interpretation of the HyMap data. A section across strike was selected to the south of Screechowl Creek where field mapping provided good stratigraphic control. Twelve sample sites were chosen, broadly representative of the range of lithologies (magnesite, dolomite, dolomitic shale, siltstone and quartzite) and landform variation (elevated land surface, hillslope and valley floor). The sites, of ~1 m^2, typically comprised a mixture of rock fragments (20–80%) in fine-grained clay and silt matrix. Spectra were recorded using PIMA II, a portable infrared analyser with a spectral range of 1300–2500 nm. Spectra were taken of both the silt–clay matrix and the surfaces of dominant rock fragments at each site.

White magnesite rock fragments gave spectra with a high albedo and distinct carbonate absorption (Fig. 3). Interbedded grey dolomite units were characterised by a lower albedo and shallower carbonate absorption feature at slightly higher wavelength when compared to magnesite. Talc and montmorillonite were dominant in the spectra of all weathered carbonate rock fragments and in the soil developed on carbonate units. Rock units with high quartz content were characterised by the presence of chlorite and montmorillonite. In the area sampled, the only significant difference due to terrain variation was the greater accumulation of iron oxide-coated rock fragments on the lower slopes and valley floor. These samples absorbed strongly and gave little useful spectral information on the nature of the underlying rock units. Overall, the results indicated that, where sufficient magnesite rock fragments were present in the soil, differences in the HyMap spectral data should be sufficient to discriminate magnesite-enriched zones within the predominantly dolomitic sequences.



Thin, white magnesite beds in dolomite at Myrtle Springs Quarry. *(Photo 46337)*

HyMap survey

The HyMap airborne survey was flown on 26 March 1998 to specifications summarised in Table 1. Data were provided to PIRSA on CD-ROM in integer format compatible with the ENVI™ image processing system (Fig. 4).

Table 1 *Flight line specifications.*

Start coordinates	Lat. 30°01'42" S Long. 137°48'40" E
End coordinates	Lat. 29°49'30" S Long. 137°35'20" E
Approx. line orientation	311/131° magnetic
Traverse distance	30 km
Ground elevation	130 m (south) to 311 m (Mount Nor West), taken as 200 m
Pixel size	5 m
Flying height	2000 + 200 m = 2200 x 3.28 = 7200 feet AMSL for a 5 m pixel
Ground speed	130 knots

The raw digital data were unprocessed other than being adjusted against the internal dark current image. From this data set, a false colour image was produced using simulated Landsat TM 741 (2080,760,450:RGB). The resulting image clearly showed that areas of high magnesite content could be distinguished from those of predominantly dolomite, largely through the albedo difference in the reflected spectra (Fig. 2). However, this did not distinguish magnesite from other minerals having absorption bands in the region 2080–2500 nm and a high spectral albedo, in particular

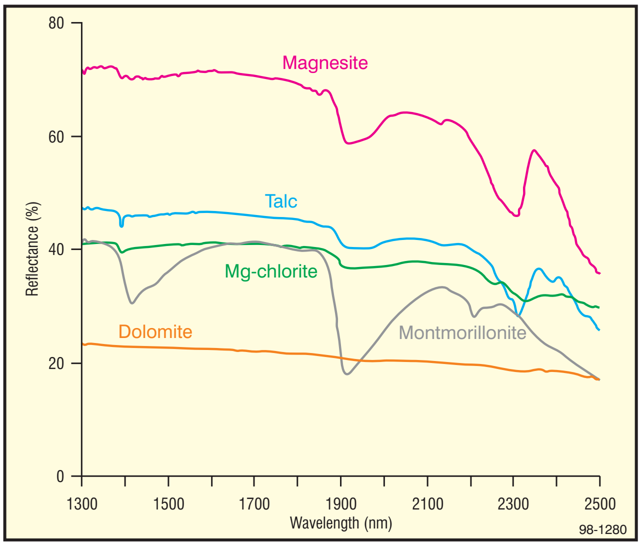


Fig. 3 PIMA II spectra of selected field samples.

kaolin, a common weathering product of both Proterozoic shale and Cretaceous marine sediments.

Technical specifications of the scanner are outlined in Table 2. To maximise the spectral discrimination and mineral identification capabilities of the instrument, it was necessary to isolate those components of the spectra related to mineral absorptions. This required further processing of the data to remove effects due largely to atmospheric absorptions and, to a lesser extent, vegetation.

Processing the HyMap data

Full details of the process methods adopted are given in Keeling *et al*. (1998). In brief, the technique involved firstly producing an image that approximated a radiance image by ratioing each pixel with a halon spectra generated in the laboratory. The dominant effects of atmospheric absorption in the radiance image can be removed to a large degree by algorithms based on the spectral absorption feature at 1140 nm (Boardman *et al*., 1995).

However, the approach taken for this project was to use field data and laboratory HyMap spectra of selected samples of magnesite and dolomite from the Screechowl Creek deposit. Pixels in areas of relatively pure dolomite and magnesite were identified on the HyMap image from field data recorded on enlarged aerial photographs. The selected pixels were forced to match laboratory spectra by subtraction, and the difference regarded as a combination of atmospheric absorption, vegetation and noise. The difference spectrum was then subtracted from all data pixels. Away from areas of 'pure' mineral pixels this produced some processing artefacts, largely confined to the VNIR/NIR/SWIR1 regions of the data. The SWIR2 channels, where the atmospherics would have been at a minimum, most closely matched the spectral response expected from laboratory and field measurements (Fig. 4). This region of the spectra was used to classify the image in terms of mineral abundance. Spectrally significant minimum noise fraction (MNF) bands were identified using MNF transformation. By assigning previously identified pure end members selected from field data, linear spectral unmixing was used to classify the proportions of magnesite, dolomite and kaolin present in each pixel. An image of magnesite–dolomite distribution was produced from these results (Fig. 5).

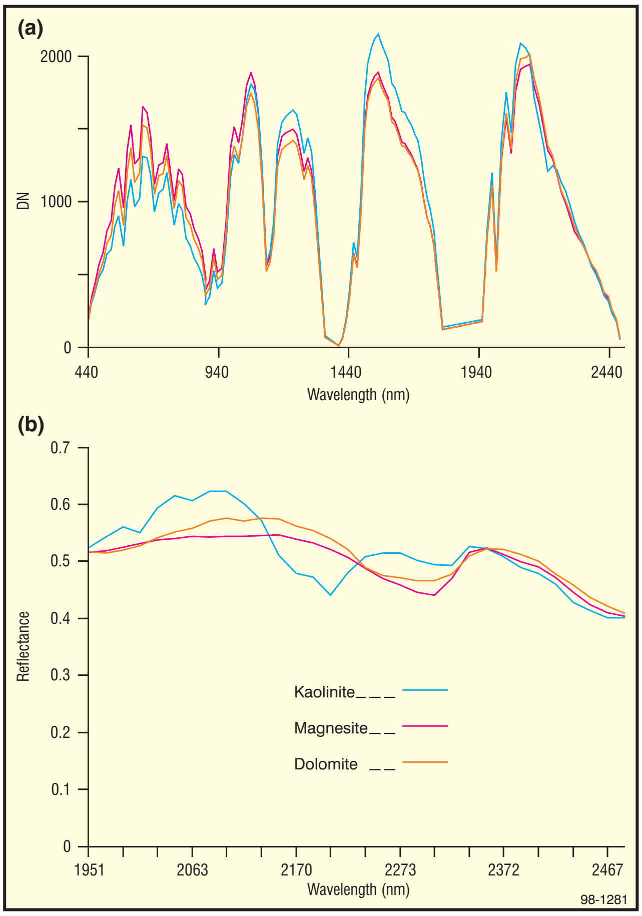


Fig. 4 Selected pixels showing HyMap spectral data **(a)** *as delivered and* **(b)** *after processing (SWIR2 band data only).*

Table 2 *HyMap Airborne Hyperspectral Scanner specifications.*

Spatial				
Instantaneous field of view	2.5 mr (milliradians) along track, 2.0 mr across track ~5 m pixel at 2000 m flying height			
Field of view	60° (512 pixels)			
Spectral				
Signal/noise ratio	200:1 to 900:1 for a 5 m pixel			
Module	**Spectral range** (µm)	**Bandwidth across module** (nm)	**Channels**	**Average spectral interval** (nm)
VIS	0.42–0.88	15–16	32	16
NIR	0.881–1.335	12–14	32	13
SWIR1	1.40–1.81	11–13	32	12
SWIR2	1.95–2.49	15–18	32	16

Interbedded dolomite and magnesite, south of Screechowl Creek. (Photo 46344)

Results

In the Screechowl Creek area, the generated map of magnesite distribution corresponded well with that determined from detailed surface mapping. In particular, the stratigraphic positions of all significant magnesite concentrations recorded from field investigations were identified with confidence on images generated from the HyMap data and the relative significance of each, in terms of overall thickness and lateral continuity, could be rapidly appraised, at least qualitatively. The HyMap data have been used to extend geological mapping for 15–20 km south of Screechowl Creek where the along-strike projection of the main magnesite zone was ambiguous on aerial photography. This has provided additional drilling targets for magnesite in areas of greater accessibility. Processing refinements are still needed to rigorously remove atmospheric effects from the imagery, but the initial indications are that mineral mapping from an airborne platform has become a reality with development of the HyMap instrument.

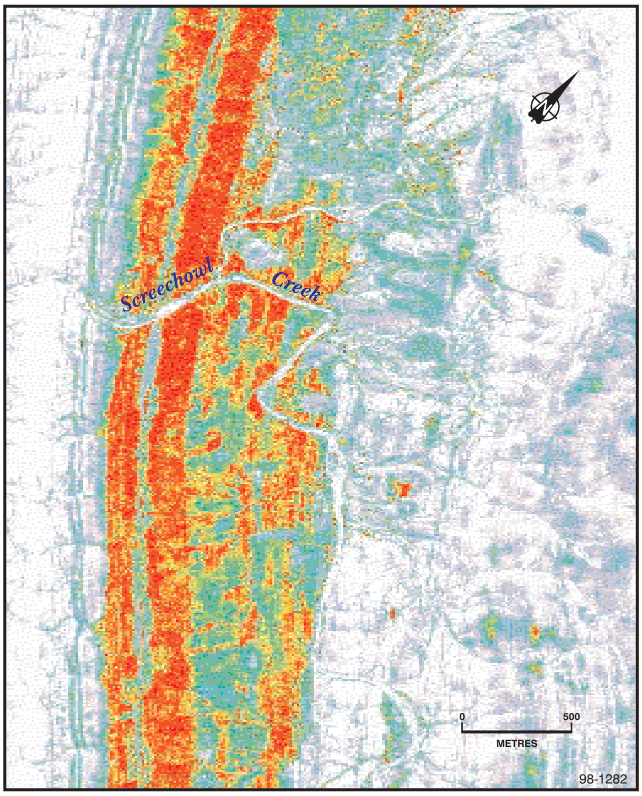


Fig. 5 *Classified HyMap image over the Screechowl Creek deposit showing distribution of magnesite end-member. Red indicates high magnesite content.*

Field mapping of magnesite beds near Screechowl Creek. (Photo 46343)

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