Finding new mineral prospects with HYMAP: early results from a hyperspectral remote-sensing case study in the west Pilbara

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New research conducted in the Pilbara region of Western Australia has demonstrated that high-resolution remote sensing can detect minerals associated with ore deposits. The flat terrain, sparse exposure, and weathering and 'calcretisation' of bedrock in this area hamper the visual identification of hydrothermal alteration minerals. HYMAP (airborne hyperspectral remote sensing) is a rapid and cost-effective exploration tool that provides valuable new information on the geology and the distribution of surface minerals.

Survey area and HYMAP data acquisition

As part of the joint AGSO–GSWA 'North Pilbara' project for the National Geoscience Mapping Accord, an aircraft carrying the hyperspectral HYMAP system (Cocks et al. 1998: 'First EARSEL Workshop on Imaging Spectrometry', University of Zurich, October, 1998) surveyed an area of $\sim$180 km^2 in the west Pilbara. The survey area covered the Indee district, where Resolute Ltd recently discovered zones of gold mineralisation.

The regional geology (Smithies 1998: 'Geology of the Yule 1:100 000 Sheet', Geological Survey of Western Australia) comprises Archaean Mallina Formation metasediments deformed by the east-striking Mallina Shear Zone (Fig. 1a). An

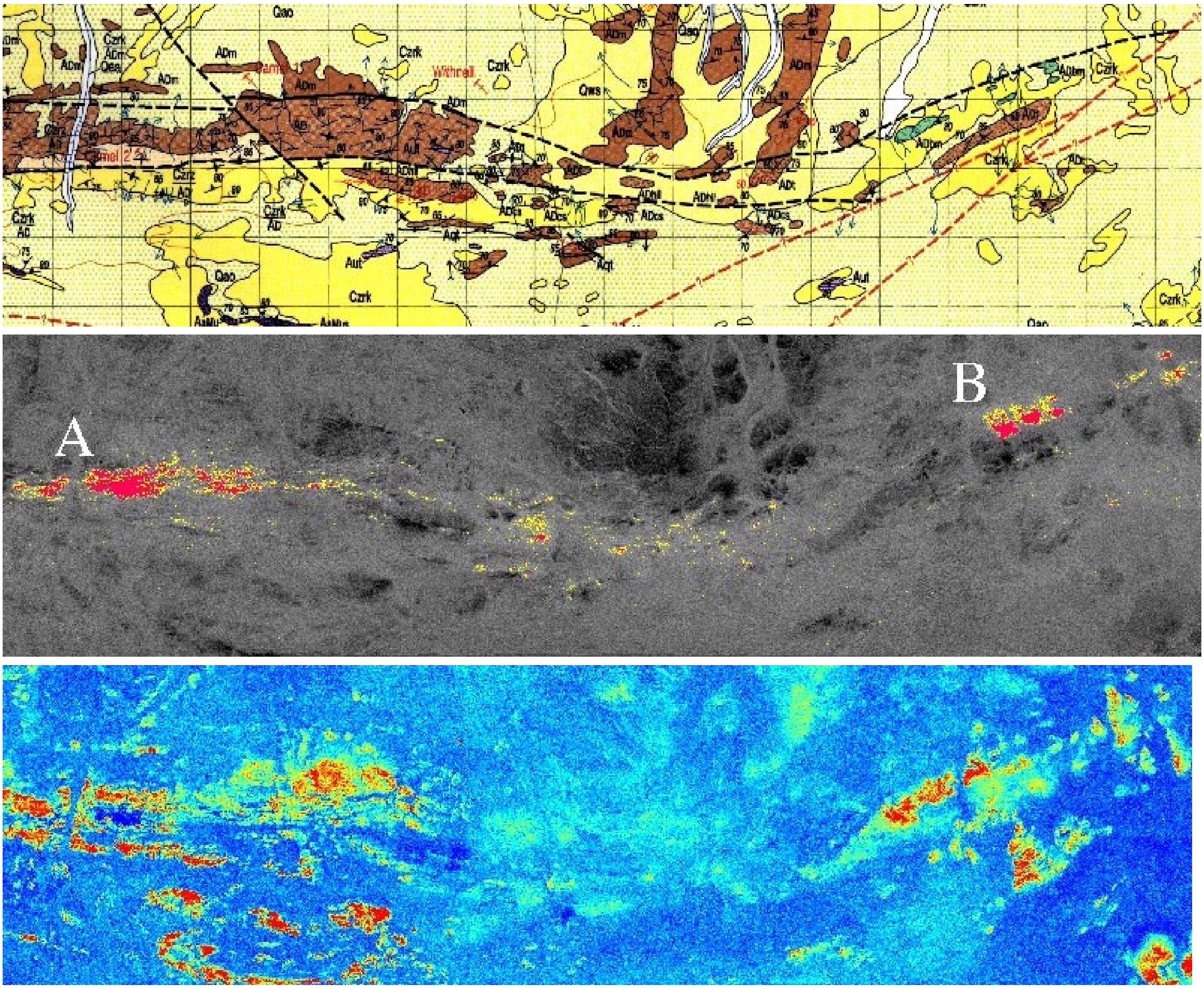

Fig. 1. An 18 × 5-km area of the Indee district, in the Yule 1:100 000 Sheet area. *(a)* Geology (from Smithies 1998: op. cit.): brown (Adm), metasediments of the Archaean Mallina Formation; green (Adbm) and purple (Aut), mafic to ultramafic igneous rocks; bright yellow (Czrk), calcrete; pale yellow (Qac), sand; the dashed and solid black lines distinguish the Mallina Fault Zone; the red dashed lines represent magnetic lineaments. *(b)* Pyrophyllite abundance image derived from mixture-modelling of the airborne HYMAP data: red reflects high concentrations of pyrophyllite; yellow, low but detectable concentrations of pyrophyllite. *(c)* Dolomite abundance image derived from mixture-modelling of the airborne HYMAP data: red reflects high concentrations of dolomite; yellow and green, lower concentrations; blue, no detectable dolomite.

extensive shallow cover of residual sand and calcrete regolith (Figs. 1a and 2) largely conceals outcrop. The gold occurs in a variety of styles associated with hydrothermal quartz veins and breccias with distinctive alteration mineral assemblages.

The HYMAP sensor collects reflected solar radiation in 128 bands covering the 0.44–2.5-µm wavelength range, which includes the visible, near infra-red, and short-wave infra-red regions of the electromagnetic spectrum. For an image pixel size of ~10 × 10 m, our survey sampled a spectrum for every pixel in the area. Each spectrum is a mixture of spectral components — including vegetation and minerals, and atmospheric and illumination effects. Our analysis of the HYMAP data incorporated an atmospheric correction, and modelling of the various component mixtures to produce mineral abundance maps.

HYMAP data presentation, verification, and interpretation

Figure 1b, generated by mixture-modelling of HYMAP data, shows a number of 'bullseye' targets of pyrophyllite distributed along the Mallina Shear Zone, notably areas A and B. Pyrophyllite is a high-temperature hydrothermal mineral and is closely associated with certain styles of gold mineralisation. Pyrophyllite in high abundance (red) at target A is spatially adjacent to an extensively drilled gold prospect returning gold assays >10 m @ ~7–11 g/t (Gold Gazette, November 1998, p. 5). Along strike, target area B (Fig. 2) has been regionally explored only, and, according to the intensity of the pyrophyllite association, represents a new prospect.

A comparison of spectral signatures of pure pyrophyllite and the spectrum measured by the HYMAP data clearly shows a characteristic absorption feature at 2.167 µm (Fig. 3). Ground-checking samples in target areas A and B with a Portable Infrared Mineral Analyser (PIMA) confirmed the presence of pyrophyllite (Fig. 3).

Fig. 2. Sand- and spinifex-covered landscape at target area B.

Comparison of the pyrophyllite image (Fig. 1b) with the geology (Fig. 1a) shows that the new prospect (area B) is partly covered by calcrete and sand (cf. Fig. 2). The target area is flat, largely free of outcrop, and strewn with lag. Here, the pyrophyllite occurrence coincides with the location of the shear zone, and may reflect an along-strike continuation of mineralisation. Assay results on a hand specimen from area B returned anomalous gold (0.34 ppm), confirming the prospectivity of the HYMAP-identified target. PIMA spectral analysis of field samples targeted by the image map identified the carbonate in the calcrete as mainly dolomite (cf. Fig. 1c). Whereas the dolomite image map (Fig. 1c) generally corresponds closely with the mapped geology (Fig. 1a), some areas of calcrete cover have been somewhat generalised on the 1:100 000 geological map, so the image shows a more precise distribution and subdivision of dolomite-bearing calcrete regolith.

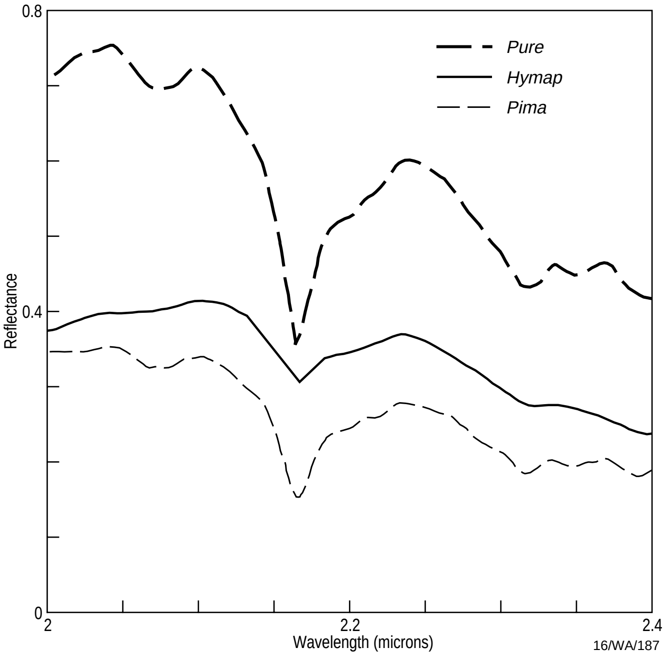

Fig. 3. Pyrophyllite reflectance curves for a pure sample measured in the laboratory, a pyrophyllite-rich pixel measured by HYMAP, and PIMA analysis of a field sample.

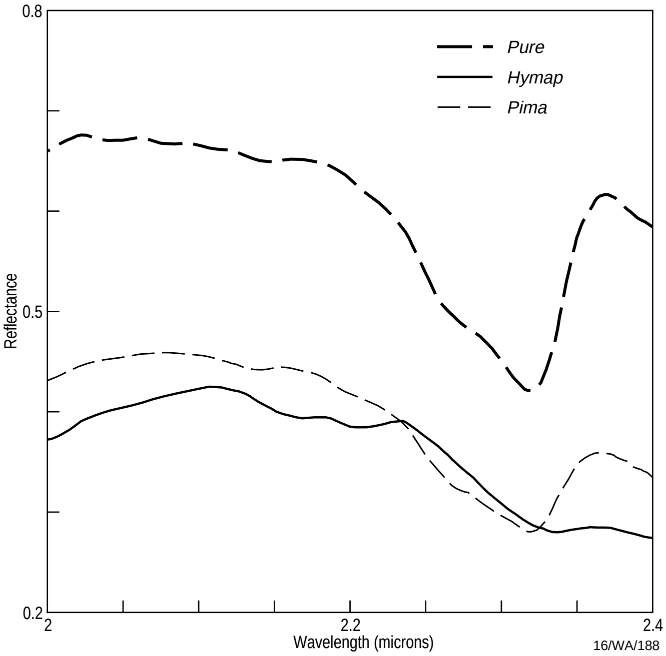

Fig. 4. Dolomite reflectance curves for a pure sample measured in the laboratory, a dolomite-rich pixel measured by HYMAP, and PIMA analysis of a field sample.

Dolomite reflectance curves (Fig. 4) reveal a broad carbonate absorption feature centred at about 2.33 μm in the pure laboratory sample and in the PIMA spectrum of a sample obtained in the field. This feature is also evident in the dolomite pixel in the HYMAP data, but only as a low broad feature. The low reflectance in the HYMAP data beyond 2.35 μm may be due to a problem with the initial conversion of the data to reflectance. This problem of low HYMAP reflectance in this part of the spectrum affects all pixels, and will have to be resolved. However, the mixture-modelling analysis was able to detect the relative influence of the broad feature in the HYMAP spectrum shown in Figure 4.

Conclusions

The preliminary results presented here demonstrate the ability of hyperspectral remote sensing to detect mineral deposits in areas of shallow, residual regolith cover. Thus, the HYMAP identification of the alteration mineral, pyrophyllite (a known associate of gold), defines new exploration targets (which were subsequently confirmed by assay results). Imaging of dolomite abundance, confirmed by PIMA ground-checking, helps to identify groundwater-deposited materials and associations with carbonate alteration in mineralised zones.

Alteration minerals were recognised in this study despite the area's regolith problems such as flat terrain, sparse exposure, 'calcretisation', and extensive bedrock weathering. This is particularly exciting, as HYMAP might be a suitable exploration tool in other prospective areas evincing a similar regolith history (e.g., shallow residual cover).

The accurate, rapid, and cost-effective identification of alteration minerals as vectors to ore (as detected by HYMAP) in this area is largely beyond the geologist in the field. To date, such alteration-mineral identification has applied extensive and time-consuming laboratory work on samples by non-spectral methods.

Although not presented here, HYMAP has successfully identified other hydrothermal alteration minerals (such as sericite, chlorite, kaolinite, calcite, etc.). Analysis of these and other mineral combinations reveals additional geological information not readily acquired from other, traditional mapping techniques.

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