ASTER night-time thermal infrared data: interpreting subsurface features from high resolution data

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Introduction

Night-time thermal infrared (NTIR) data provides an additional and potentially valuable source of information for mineral explorers. This technology is used for locating palaeocoastal heavy mineral sands and palaeochannels for uranium and placer deposits. To date, the most frequently used thermal imagery is derived from the National Oceanic and Atmospheric Administration (NOAA) - Advanced Very High Resolution Radiometer (AVHRR) meteorological satellite. The 1.1 km spatial resolution data is sufficient to delineate the broader features related to palaeochannels, strandlines and sub-surface structural features.

Trial applications of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) NTIR data are providing details previously unrecognised in NOAA data, and stimulating new questions about the role of properties of outcropping units, surface textures and structure that give rise to the observed effects. Improved results are due to the higher resolution of ASTER data. The thermal component is acquired by 5 bands and presented spatially by 90 m pixels. These bands provide information used to identify minerals and allow calculation of temperature and emissivity.

ASTER night-time only scenes were acquired by PIRSA over the Eucla Basin and North Flinders Ranges (Fig. 1), areas with recent discoveries of palaeocoastal heavy mineral sands and channel sand uranium. The aim of the project was to gather new data to assist with production of a more detailed map of palaeodrainage for the state. Presented here are preliminary results from the North Flinders Ranges study.

Night-time thermal data

Research fields using NTIR data include geological, volcanic, coastal erosion and energy flux estimation on land surfaces. NOAA-AVHRR and Landsat TM (Thematic Mapper) data are used in these studies. However, for detailed geological interpretive work NOAA-AVHRR has a low-spatial resolution and Landsat TM offers only a single channel of thermal data. Night-time acquisitions of Landsat TM are not easily available.

One of the early applications of NOAA-AVHRR NTIR data for geological purposes was carried out by Tapley (1989), who recognised three broad principles of thermal imagery pertinent to geological applications:

- differences in daytime reflectance of surface materials (albedo)
- radiant efficiency (emissivity)
- ability to absorb solar heat during the day and emit heat during the night (thermal inertia).

A preference was given to data acquired post wet season because thermal contrasts were enhanced. Stratham-Lee (1995) used NOAA-AVHRR imagery to interpret palaeodrainage of approximately Tertiary age on the western edge of Lake Eyre in South Australia. This concept was applied in recent studies by Hou and Mauger (2005).

NTIR images are presented as positive or negative, with positive (light tones) for regions of warmest radiant temperature and negative (dark tones) representing cooler radiant temperatures. Variation is a record of stored heat being emitted from surface and sub-surface features. Trees

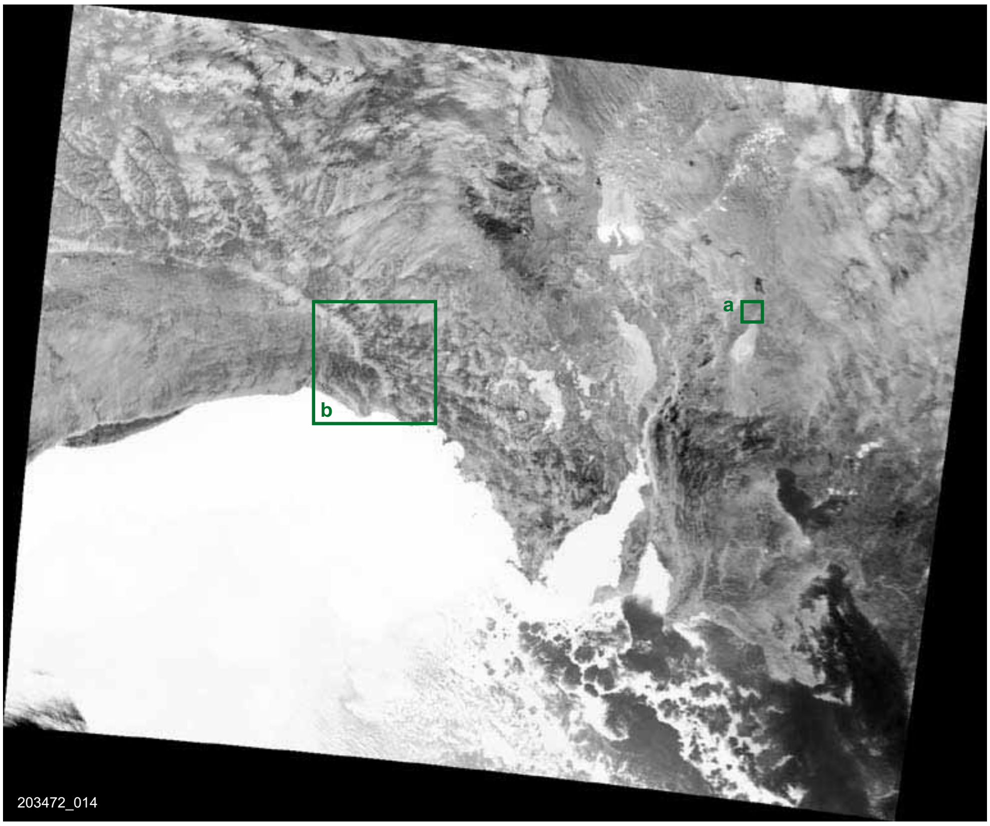

Figure 1 *State NOAA image showing location of trial ASTER NTIR scenes in* ***(a)*** *North Flinders Ranges and* ***(b)*** *Eucla Basin margin. Image is affected by dense pockets of cloud in the SE and windshear and distortion in the east.*

for instance are cooler during the day and warmer at night. Water is cooler than soil and rock during the day, while the reverse is seen at night when claypans and other surface drainage appear as light tones. This later observation helps discriminate surface drainage from buried ancient river systems that continue to act as conduits for groundwater. Other factors also influence positive and negative responses seen in NTIR images, such as soil (or rock) type, density and porosity. An understanding of the interaction and combinations of these factors is required when applied to geological studies.

Figure 2 *Image in North Flinders Ranges (area a, Fig. 1) generated from NOAA NTIR. A disadvantage of NOAA data is the poor resolution. This is the same area seen in Figure 3.*

NOAA-AVHRR

The NOAA-AVHRR satellite provides twice daily coverage for any particular area with a swath width of 2400 km. The entire Earth can be covered in 14 days. At nadir, spatial resolution is 1.1 km but decreases with the increase in the view angle off nadir with a distortion of up to 3.3 km. Poor spatial resolution is a disadvantage (Fig. 2) as is large amounts of pre-processing required and poorly developed methodology. However NOAA data is low cost and the volume of data to cover large areas is also low.

Day and night-time NOAA data (5 bands) used in this study were acquired in August 1991 (Fig. 1). Only night-time bands 4 (10.30–11.30 µm) and 5 (11.50–12.50 µm) are used to identify palaeochannels. Wind shear and sporadic cloud cover affect the image in the eastern and western regions of the state.

ASTER

ASTER comprises three imaging assemblies acquiring data in 14 channels between 0.52 and 11.65 µm and a viewing swath width of 60 km. The multi-spectral aspect of ASTER not only provides information about reflectance properties of materials but also records measurements used to derive land and sea surface temperatures and emissivity. From the visible-near-infrared (VNIR) telescope, an elevation model can be derived with 15 m spatial resolution.

Geological applications reported by Hewson et al. (2004), Fabris (2002), Hou and Alley (2003) and Hou and Mauger (2005) used daytime ASTER scenes with varying degrees of success. Hewson et al. generated a mosaic of mineral maps of spectral end-members derived from a number of ASTER scenes over Olary. Thermal properties of Landsat TM were investigated by Fabris (2002). Hou and Mauger (2005) discussed empirical discrimination achieved through image processing of daytime ASTER to locate palaeochannels. It was also noted that daytime ASTER data was less effective in highlighting palaeochannels than NOAA, as daytime temperature masks emissivity properties.

ASTER NTIR data is underutilised, with no previous geological applications known. ASTER bands 13 (10.25–10.95 µm) and 14 (10.95–11.65 µm) used in this study correlate well with NOAA bands 4 and 5 used in geological applications.

Case study — North Flinders Ranges

ASTER NTIR data over the North Flinders Ranges was flown on 29 May 2000 at 13.41.09 universal time. Temperature and emissivity were calculated using Level 1B (5 band) data. Level 2 pre-processed temperature maps were compared with in-house results. Minimal variations were observed between the two products. Drainage patterns interpreted as palaeochannels were compared to drillhole logs. Traverses across the ASTER NTIR were also used in the interpretation.

Preliminary examination of the data for structural information reveals previously inferred faults can be more confidently defined. Fault C in Figure 3 has truncated a generally N–S trending palaeochannel. Further east, present day drainage overlying an earlier drainage system has also been redirected along the fault for a short distance.

The palaeodrainage evident in the ASTER data, described above, are not visible in the NOAA image. To support this interpretation a schematic cross-section (Fig. 4) of traverse A–B in Figure 3 compares elevation and ASTER NTIR temperature data. Dark patches in ASTER NTIR highlight cool responses of moisture-rich sediments often associated with palaeochannels. In Figure 4 these appear as deep troughs, indicating low temperatures. Furthermore, a thick package of fluvial sediments ending in pyritic carbonaceous sandy gravel (Fig. 5)

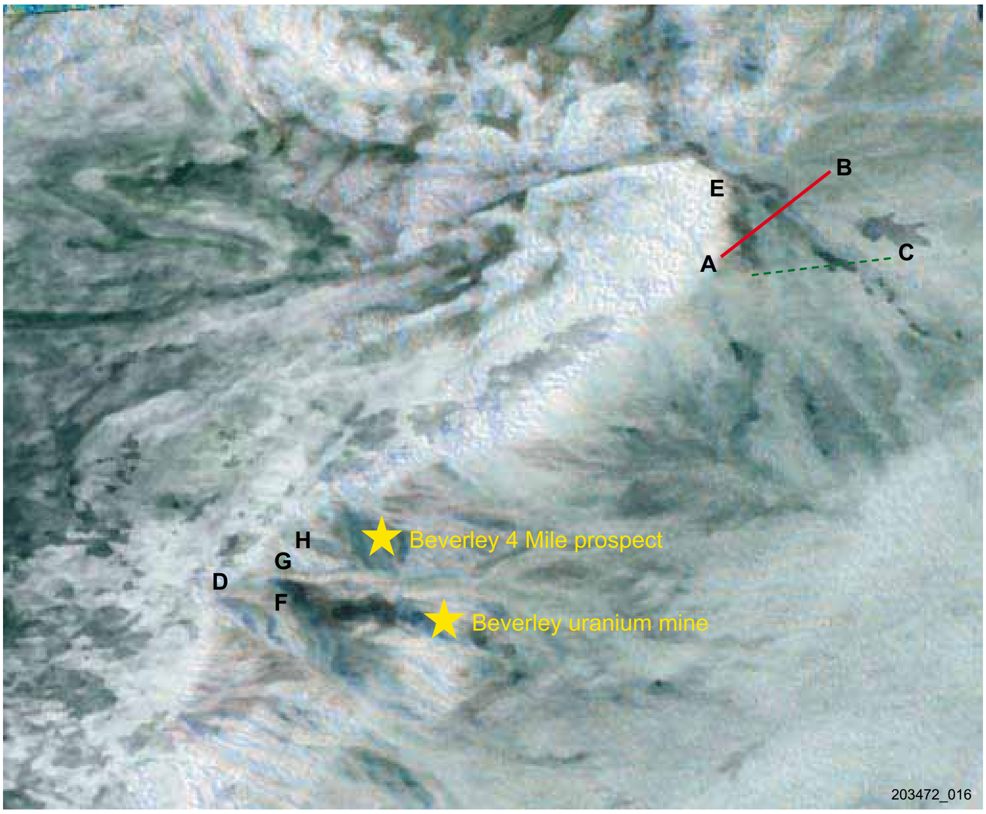

Figure 3 *Image in North Flinders Ranges (area a, Fig. 1) generated from ASTER NTIR. A slight transparency shows the elevation model in the background. This area is extremely complex and detail is lost when using NOAA data for interpretation. Dark areas (cooler temperatures) on the plains are related to sediment moisture retention. On the ranges they are likely to refer to the type of lithology. Further investigations are required to verify this possibility. Traverse shown by red line. Inferred fault C is in green. Location of poorly cemented sandstone located at D.*

properties observed in NOAA NTIR and ASTER NTIR data. High resolution data from the ASTER instrument provided structural, geomorphological and lithological information, very little of which was apparent in NOAA data.

Previous research where NOAA NTIR data was used reported that the time of data acquisition was a critical factor to locate palaeochannels, however, ASTER NTIR is not as readily available as NOAA NTIR. Despite ASTER NTIR data acquired outside preferred acquisition time parameters, results appear to be useful and are substantially better than those from NOAA. In this case, the higher spatial resolution of ASTER NTIR outweighs the need to choose optimal conditions for the acquisition of images.

Elevation data has often proved useful in palaeochannel studies

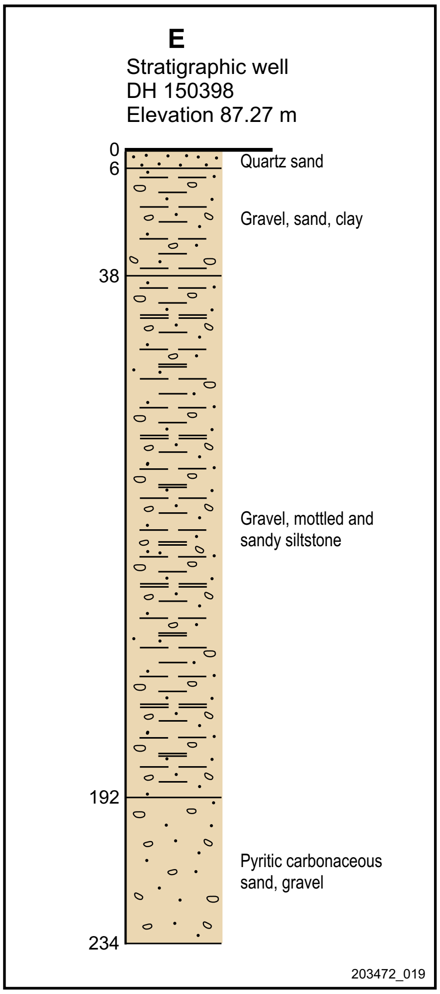

Figure 5 *Geological log, drillhole DH 150398 (E in Fig. 3).*

is reported in the log of stratigraphic well DH 150398 (E in Fig. 3).

During recent fieldwork in the Mt Painter Province to ground truth hyperspectral data, a poorly cemented sandstone was identified at location D. This is interpreted as inverted topography resulting from active tectonism. ASTER NTIR shows a dark cool response produced from a deep channel to the east of location D. A cross-section of drillholes F, G and H (Fig. 6) supports the interpretation of the presence of a palaeochannel from the accumulation of fluvial sediments reported in water well DH 87790 (F). Interconnecting pore space and higher porosity of fluvial sediments in the channels and alluvial fans than adjoining terrain, retain moisture which gives rise to the dark response (cooler sediment temperatures) seen in the ASTER NTIR data at these locations.

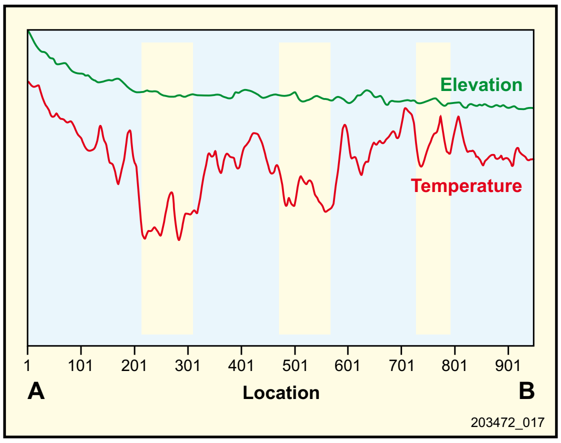

Figure 4 *Traverse A–B, North Flinders Ranges, showing elevation and temperature contrasts. Palaeochannels have been identified and supported by drillhole information. Elevation information is from SRTM data and temperature contrast from the ASTER pre-enhanced temperature map. (Traverse is located in Fig. 3.)*

Discussion

This study highlights the contrast in spatial resolution of surface thermal emissivity

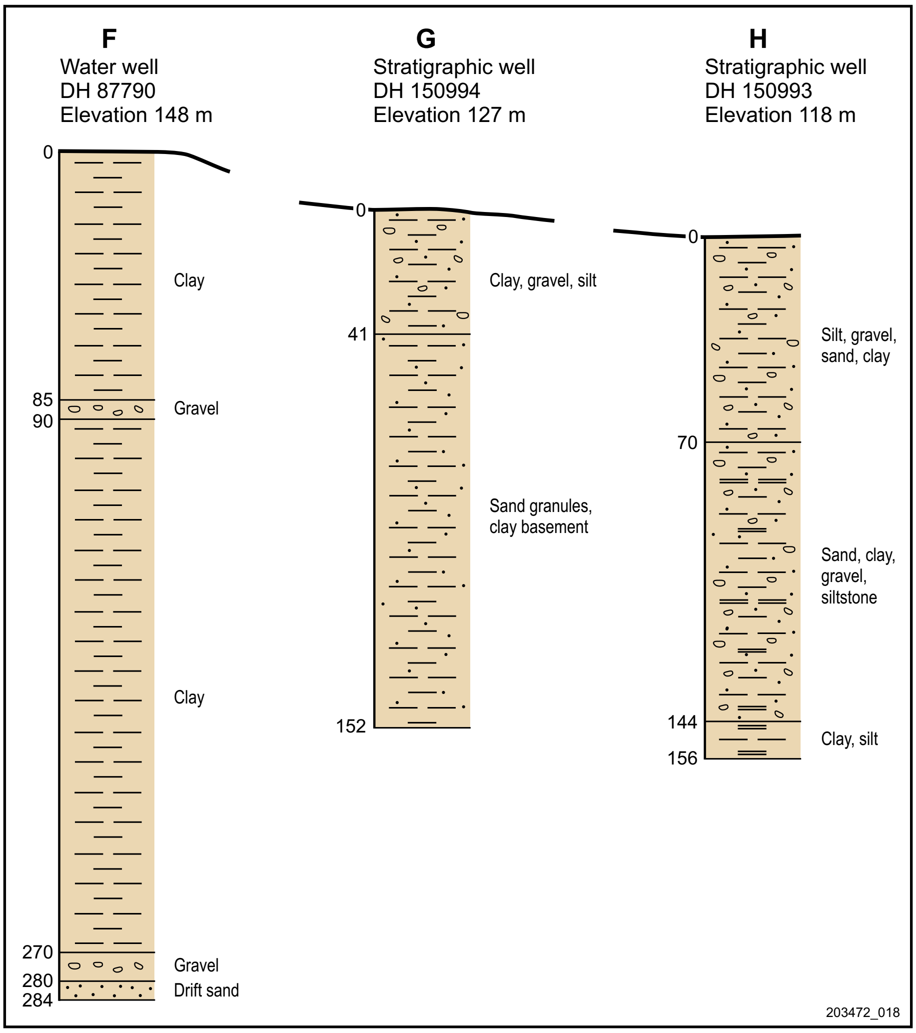

Figure 6 *Geological cross-section, drillholes DH 87790, 150994 and 150993 (F, G and H in Fig. 3).*

as a guide to locating buried channels. It is worth noting in the Mt Painter Province this may not be effective as ongoing tectonic movements appear to have created a disequilibrium between sediment deposition and sediment transport, obscuring older drainage systems and changing the flow direction of alluvial fans, leaving no surface expression of previous drainage patterns.

Conclusion

These trials of ASTER NTIR data, although applied to small highly prospective areas of South Australia, are cost effective showing promising results. Application of these data and interpretations stand to have enormous impact on mineral exploration models, particularly those already relying on coarse resolution NOAA NTIR remotely sensed data.

This is a new application of high resolution ASTER NTIR data related to temperature variation resulting from moisture trapped in sediments. Surface expressions of palaeochannels are not always evident but their presence is supported in this instance by field observations and other data.

Simple processing of ASTER NTIR data provides detail superior to that from NOAA NTIR. The masking effects of daytime temperatures on surface emissivity noted by Hou and Mauger (2005) are overcome with the use of ASTER NTIR data. Temperature maps available as higher end ASTER products require minimal processing and can be integrated with existing data.

Further research can provide important information such as understanding temperature variations and properties of outcropping units. Applying such new knowledge will further improve interpretations where ASTER NTIR data is used and exploration targets will be better defined.

Recommendation

The application of ASTER NTIR data has the potential to assist scientific investigations in many disciplines, including groundwater studies, land surface temperature monitoring, geothermal studies and geology. This is the first study of ASTER NTIR applied to mineral exploration. Results highlight the value of applying this data in exploration programs.

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