Geologic and alteration mapping at Mt Fitton, South Australia, using ASTER satellite-borne data.

R.D. Hewson, T.J. Cudahy
CSIRO Exploration and Mining
Underwood Avenue
Floreat Park, W.A., Australia, 6014

J.F. Huntington
CSIRO Exploration and Mining
Dehli Rd
North Ryde, N.S.W, Australia 2113

Abstract - The Japanese ASTER sensor on board the US Terra satellite was launched in December 1999 to establish a space-borne capability for high spatial, multispectral visible-shortwave infrared and thermal infrared remote sensing data mapping of the Earth’s environment. The Mt Fitton test site in South Australia was chosen to test the ability of the ASTER instrument for geological mapping having been previously surveyed by several visible-shortwave IR and thermal IR airborne remote sensing instruments and several field campaigns collecting relevant spectral measurements. These previous airborne remote sensing surveys and field campaigns successfully mapped a suite of intrusives and sedimentary units with some greenschist metamorphic and localised hydrothermal alteration. Visible-NIR ASTER channels successfully mapped green vegetation and iron oxide information. ASTER SWIR data was spectrally unmixed into four spectrally recognizable endmembers that relate to areas rich in talc, chlorite, white mica and carbonate mineralogies. This result was confirmed using IRIS field spectra resampled to ASTER resolution wavelengths. Quartz, carbonate and talc-tremolite rich units at Mt Fitton were also discriminated using ASTER’s thermal infrared data. These results from low level ASTER data products indicated that ASTER could discriminate mineral groups not achievable from Landsat TM, though more precise mineral species mapping is not possible.

I. INTRODUCTION

The launch of the Japanese ASTER sensor, on board the US Terra satellite, in December 1999 has signaled the start of a new era in mapping the Earth’s surface composition. Although Landsat satellite TM data has proved useful for regional geological studies [1], its coarse spectral resolution precludes detailed mapping of geological composition. It has been shown by several investigators at various test sites that multi-spectral visible-shortwave remote sensing can successfully map areas of prospective geological alteration and key mineral groups [2]. However the limited survey coverage and costs have discouraged widespread use of this airborne data for routine surface mapping. The ASTER sensor offers data from three 15 meter pixel resolution visible-NIR channels, six 30 meter pixel resolution SWIR channels and five 90 meter pixel resolution TIR channels [3]. The ASTER instrument also forms part of the NASA EOS mission, collecting environmental and geological surface information over the next five years. An extensive range of data products will be made available including calibrated radiance to the sensor, presently available and at a later date, surface reflectance and surface emissivity imagery.

The Mt Fitton test site (139° 25’ E, 29° 55’ S) is located in semi-arid hilly terrain approximately 600 km NNE of Adelaide (South Australia). There is wide range of exposed geological units, including Precambrian granites, amphibolite dykes, and tightly folded and faulted tillites, siltstones and carbonates [3] (Fig. 1). Examples of greenschist facies metamorphism and localized hydrothermal alteration also occur at a number of sites. Alteration mineralogy at Mt Fitton is largely controlled by the host rock composition. In particular carbonates (dolomite, magnesite and calcite), including the Balcanoona Formation, have in part been converted or replaced with quartz, muscovite, chlorite, actinolite, tremolite, talc, epidote and scapolite. Talc is actively mined within the survey area at the Flinders Talc Mine (Fig. 1). Sparse vegetation and limited regolith development has enabled good exposure of these various units and mineralized zones. Mt Fitton has been used as a test site for several airborne sensors (AMS, HyMap, TIMS and MIRACO2 LAS) and the Hyperion satellite sensor. Data sets from previous airborne surveys and field spectral measurements provided a foundation for evaluating the georeferenced ASTER radiance at the sensor calibrated data (Level 1B).

II. EVALUATION AND PROCESSING STRATEGY

Visible-shortwave hyperspectral AMS (HyMap) and multispectral TIMS data sets were used to produce simulated ASTER data. The AMS data acquired in 1998 with an instantaneous field of view (IFOV) of 5 m, consisted of 96 bands in the 0.53-2.41 μm region and FWHM spectral resolutions of 12-18 nm. The TIMS data were acquired in 1993 at an IFOV of 4 m, consisting of 6 bands between 8.2-11.8 μm and FWHM’s of 0.3-0.9 μm. The AMS data were corrected for atmospheric effects using an ATREM based algorithm. The TIMS data was calibrated to radiance at the sensor using algorithms described in [4]. The VNIR-SWIR AMS and TIR TIMS data sets were resampled by the same method used by [5] using the FWHMs of each band to yield simulations for the 14 ASTER spectral bands. Spatial resampling of these airborne data sets were undertaken using...
the nearest neighbour method into the respective ASTER spatial resolutions for each band region. The ASTER scene was subset and rotated to facilitate direct comparisons with the AMS and TIMS data.

Several image processing strategies were utilised, including decorrelation stretching (D-stretch) [6], log residuals [7], MNF transformations [8] and spectral unmixing [9]. Log residuals were processed from the ASTER bands 4-9 in the SWIR region to perform an approximate correction for atmospheric effects. MNF processing and Mixture Tuned Matched Filtering were applied to the ASTER SWIR bands to obtain spectrally unmixed endmembers. The derived endmember signatures were then used to unmix the SWIR data of the complete ASTER scene into surface components.

III. EVALUATION AND MINERAL MAPPING RESULTS

The D-stretch product of ASTER bands 3-2-1 (Fig 2) and bands 6-7-9 show a high correlation with the equivalent derived AMS products. The high spatial resolution (15 m) is apparent from the delineation of the drainage and vegetation. The D-stretch of ASTER bands 13-12-10 (Fig. 3a) also compares well with the equivalent IMS D-stretch 5-3-1 (Fig. 3b), as used in previous studies [5, 6]. However the cubic convolution resampling of ASTER Level 1B processing appears to have smoothed the between pixel variation observed in the TIMS simulated D-stretch (Fig. 3b).

Quartz rich areas, indicated in red highlighted the tillites/quartzites of the Mount Curtis Tillite/Fortress Hill Formation and the Bolla Bollana Formation. The clay-rich Bonney Sandstone are highlighted in both D-stretch products by the purple areas to the far west while the talc mine is indicated by the dark blue area to the east.

Log residuals were used on the six SWIR bands (4-9) to compensate for systematic atmospheric multiplicative effects and to enhance pixel-specific mineralogical signatures. These produced SWIR spectral signatures similar in shape to the spectral endmembers with spatially distinct areas (Fig. 4). The derived endmember spectral signatures were similar to the spectral field measurements collected previously (Fig. 5).

Endmembers include the dolomite-rich Balcanoona Formation the white mica rich Amberona Formation and chlorite and talc-rich mineralised areas. However the similarity between these signatures precludes definitive mineral interpretation without the assistance of previous surveys/field campaigns or a priori knowledge. The ability of the infeasibility data, derived from the Mixture Tuned Matched Filter results, proved very useful in removing “false positives” of areas incorrectly matched with endmember spectral signatures. The application of the derived endmember spectral library to the larger ASTER scene proved useful for mapping the extension (and faulting) of the Balcanoona, Mount Curtis Tillite/Fortress Hill, and the Amberona Formations, a possible occurrence of talc to the south, and the delineation of white mica-rich granite – porphyry units.

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REFERENCES


Figure 1 Geology of Mt Fitton test site. Airborne AMS (red) and TIMS (blue) surveys are shown.
Figure 2. Decorrelation stretch of ASTER bands 3-2-1

Figure 3: (a) Decorrelation stretch of ASTER bands 13-12-10 and (b) the equivalent TIMS decorrelation stretch 5-3-1.

Figure 4. MTMF spectral unmixed endmembers of ASTER SWIR bands 4-9 draped over albedo image: carbonate rich Balcanoona Formation (red); Amberoona Formation (purple and cyan); chlorite rich (yellow); white mica rich (blue); talc rich (green).

Figure 5: (a) Spectral endmembers derived from ASTER SWIR channels 4-9 of Mt Fitton test site: carbonate rich Balcanoona Formation (red); Amberoona Formation (purple, cyan); chlorite rich (coral); white mica rich (blue); talc rich (green)

(b) IRIS Field spectra resampled to ASTER SWIR wavelengths: Balcanoona Formation dolomite (red); chlorite rich Balcanoona Formation (dark green); Amberoona Formation (blue); weathered talc (green).