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PRELIMINARY RESULTS FROM AN INVESTIGATION OF AIS-1 DATA OVER AN AREA OF EPITHERMAL ALTERATION: PLATEAU, NORTHERN QUEENSLAND, AUSTRALIA.

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ABSTRACT:

AIS-1 data were acquired over the eastern edge of the Seventy Mile Range, north Queensland, Australia, as part of the US/Australia Joint Scanner Project. The area includes undifferentiated sequences of acid to intermediate volcanics and intrusives; meta-sediments; and a series of partially lateritised sedimentary rocks.

The study area exhibits a considerable spectral variability, after the suppression of striping effects commonly observed in AIS-1 data. Log residual, and Internal Average Relative Reflectance (IARR) analytical techniques were used to enhance mineralogically related spectral features. Both methods produce similar results, but did not visually highlight mineral absorption features due to processing artifacts in areas of significant vegetation cover. The enhancement of mineralogically related absorption features was achieved using a hybrid processing approach based on the relative reflectance differences between vegetated and non-vegetated surfaces at $1.2um$ & $2.1um$. The result is an image with little overall contrast, but which enhances the more subtle spectral features believed to be associated with clays and epidote.

The AIS data was subject to interactive analysis using the SPAM package. Clear separation of clay and epidote (?) related absorption features was apparent, and the identification of kaolinite proved possible despite the presence of spectral effects caused by vegetation and second order overlap.

INTRODUCTION:

As part of the US/Australia Joint Scanner Project, two AIS flight lines were flown over the Plateau site in northern Queensland, Australia. The study area is located approximately 150 km SSW of Townsville (Figure 1). This paper describes some preliminary results arising from the analysis and interpretation of data from one of the two flight lines, which covers part of the Horse Creek Block (Figure 1). Limited ground data were available for this area, enabling us to evaluate a variety of processing techniques for highlighting mineralogically related absorption features.

GEOLOGICAL AND ENVIRONMENTAL SETTING:

The study area experiences a tropical climate, with warm dry winters and hot wet summers. Vegetation consists primarily of open Eucalypt and acacia woodland. Grasses, particularly spear grass (Heteropogon contortus), are the dominant understorey. The vegetation density is varied, and species distribution irregular.

The regional geological setting of the site is reviewed by Wyatt et al. (1971). The geology of the Horse Creek Block itself, is summarised in Figure 1. In the NE the area is dominated by Tertiary sandstones. Isolated mesas of lateritised Tertiary sediments are present throughout this part of the surveyed area. The Cambro-Ordovician Mount Windsor volcanics, of andesitic composition, outcrop in a north-south trend running across the central part of the block. Silicious shales and cherts of an equivalent age (the Cape River Beds) are present to the east of the flight line. Isolated outcrops of late Tertiary/early Quaternary shale and sandstone of the Campse beds are also present.

The Cambro-Ordovician volcanics and meta-sediments are intruded by a small leucogranite and an altered rhyolite body of a similar size. Both these intrusives are believed to be Permo-Carboniferous in age. The rhyolite has a mineralised brecciated margin with pervasive quartz-sericitic and minor kaolinitic and chloritic alteration. Laboratory spectra and corroborative XRD analysis of weathered samples from the rhyolite and the adjacent host volcanics, indicate the presence of kaolinite, sericite, chlorite, carbonate and epidote minerals (Figure 2).

AIS-1 DATA QUALITY AND PREPROCESSING:

Calibrated AIS-1 data from the Plateau site exhibit the effects of a time dependent, non-uniform individual detector response, and a vibrating detector array (Vane 1986). In the imagery these are manifest as vertical and horizontal striping respectively. Two radiometric correction techniques were applied to the data to suppress the striping.

Vertical striping and data "spikes" were removed in two steps. Firstly, the effects of extreme column values, due to dead detector elements, and spectral "spikes" or discontinuities, such as those that occur at boundaries between different grating positions, were removed by averaging in the spectral direction. Secondly, the data were spatially averaged, tying the individual column means to the overall band mean to suppress the vertical striping.

Horizontal stripes in the imagery, arising from a vibrating detector array at the focal plane of the spectrometer, were removed by spatial averaging within a moving window of lines down the image. Residual striping

remained after both techniques had been applied to the data.

The AIS data for the Plateau area also exhibits the effects of spectral contamination in the 1.6 to 2.4μm region due to a second order overlap from shorter wavelengths between 0.8 and 1.2μm. The cause of this problem, as described by Vane (1986), is related to a switch in the position of a blocking filter, and the efficiency of the diffraction grating in second order. The presence of a contribution in second order to that in first order between 1.6 and 2.4 is seen in variations in the CO_2 absorption bands at 2.0 and 2.06μm down the flight line, and as a broad absorption feature around 2.28μm, particularly where vegetation is present. These effects are similar to those described by Huntington et al. (1986) for other Australian AIS-1 data sets.

AIS DATA ANALYSIS FOR THE HORSE CREEK BLOCK SUBSCENE:

1. Data Normalisation and Image Enhancement:

Examination of the raw radiance data for the Horse Creek Block sub-scene revealed no apparent mineralogical information. This has been ascribed to the diminution of mineralogical absorption features due to a combination of atmospheric effects, weathering, and the presence of vegetation cover (Huntington et al. 1986). Several processing methods were examined for the suppression of background and atmospheric effects, and the enhancement of subtle mineral related spectral features. These included the log residual technique (Green and Craig 1985), and the Internal Average Relative Reflectance (IARR) method (Kruse et al. 1985).

Both the log residual and IARR processing methods require the normalisation of the data prior to spectral curve averaging which produces a standard or reference curve for the whole scene. The standard curve is then divided into the the normalised pixel curve to produce a residual relative reflectance curve for each pixel. The results produced from either method are essentially the same. Both have the advantages of :

    i) requiring no ground data for their implementation;
   ii) being computationally simple to implement;
  iii) producing output in the form of relative
       reflectance suitable for use with the SPAM
       package;
   iv) being applicable to different terrains and
       environments.

However, they also exhibit several disadvantages, including:

i) the removal, or even suppression, of the spectral
        response of dominant cover types which may be
        important;
    ii) the creation of spectral "artifacts" which could
        be interpreted as real absorption features and/or
        spectral highs;
   iii) the apparent suppression of more subtle mineral
        absorption features in the 2.2μm wavelength region
        when vegetation is present (Huntington et al 1986,
        & Cocks and Green 1986).

     Although the first two drawbacks mentioned above
cannot be corrected for (only recognised and accepted as
possible sources of error), the third problem can be
overcome.
     Figure 3 shows a fanned set of AIS data (covering
bands 100 to 112, between 2.14 and 2.26μm) for the area
depicted in Figure 1. These images have been processed by
the log residuals method using all 128 bands. The lack of
observable mineral related absorption features around the
2.2μm wavelength region is apparent, particularly in the
area coincident with, and adjacent to, the rhyolite. This
contrasts with what might have been expected given the
nature of the spectral features depicted in Figure 2. A
similar problem was reported by Huntington et al. (1986)
for another Australian AIS data set processed in the same
way.
     Vegetation and rock components within the scene
behave very differently at 1.2μm and 2.1μm. The differences
between these two spectral regions are more marked for a
vegetated surface than for one which is bare. Vegetation
gives a high response at 1.2μm relative to that at 2.1μm.
This contrasts with only a slightly higher response at
1.2μm relative to 2.1μm for bare surface materials.
Normalising the data using log residuals or the IARR
method, forces bare surfaces to give a higher spectral
response in the region around 2.2μm when compared with one
which is vegetated. In effect, subtle spectral features are
masked by sharp contrasts between vegetated and bare
surfaces. In Figure 3, the darker grey levels represent
areas of dense vegetation cover, whilst lighter areas
correspond to partially vegetated and bare surfaces. Subtle
mineral absorption features, whilst being present, are not
very apparent.
     Two alternative methods were utilised in an attempt
to suppress the marked contrasts between different cover
types and to enhance the more subtle spectral features of
interest.
     The first of these has been outlined by Huntington et
al. (1986), and represents an extension of the log
residuals technique. Instead of processing all 128 spectral
bands of the AIS data, those covering the atmospheric water
absorption bands were excluded from the analysis. The
remaining spectral bands in the three atmospheric windows
were then processed separately using the log residuals
method. This approach does remove the relationship between

the 1.2 and 2.1μm regions as described above, to enhance mineral related absorptions. However, absorptions relating to vegetation are still present and although the major mineral absorption features are more apparent, they may still be confused with those corresponding to vegetation.

A second technique, a hybrid approach, known as Ratio Group Normalising (RGN), was also tried which attempts to normalise the data relative to several standard curves rather than one individual curve. Pixels were grouped into ten classes based upon a simple ratio of bands 1 and 97, and then standard curves were generated for each group using the IARR method of Kruse et al. (1985). Grouping was based on a division of the ratio range generated by all pixels, into ten equally spaced increments. The main advantage offered by this approach is that standard curves are generated for pixels with spectral curves of the same general order of magnitude. This has the effect of enhancing the more subtle absorption features contained in the data. However, problems can arise when a particular ratio grouping may contain a single or predominant land cover type. The technique would lead to the suppression of spectral features relating to that cover type.

A fanned AIS data set processed using the RGN method is depicted in Figure 4. The images cover the same spectral bands and the same area as shown in Figure 3. In contrast to the data processed using log residuals on 128 bands, subtle absorption features are more apparent. For example, the area corresponding to the rhyolite shows an absorption centred around 2.2μm (see Fig. 4). Vegetation related spectral features have also been suppressed. It should be noted that the ratio groupings seem to be correlated to varying vegetation/bare surface proportions. Pixels falling in the high ratio value groups correspond to heavily vegetated surfaces, whilst low ratios relate to areas of sparse vegetation cover. The role of dead vegetation in this simple model remains undetermined. Further work is required to confirm the utility of the ratio grouping method.

2. Spectral Feature Analysis:

Output from the data normalising and enhancement processing was analysed extensively using the NASA/JPL SPAM (SPectral Analysis Manager) package configured to run on an I2S Model 75 image processing system running S600 software. The initial phase of analysis involved automatic clustering of IARR processed AIS data over the 2.12 to 2.41μm wavelength range. The intention was to flag areas with more subtle spectral features which might be related to certain mineral groupings. In the subscene covering part of the Horse Creek Block, three main spectral clusters were observed, giving mean class curves as indicated in colour slide 1 (see pocket at the end of proceedings). Two of the three curves show absorption features with minima around 2.2μm (yellow), and 2.3um (purple).

Using the SPAM 'FIND' function, pixels with curves matching (in amplitude terms) those determined by SPAM 'CLUSTER', were flagged in the image. The result is also shown in colour slide 1 (see pocket at the end of proceedings). The rhyolite, and some adjacent areas of altered andesite, are highlighted as having absorptions centred around 2.2 and 2.3μm respectivly, which is as expected. Areas of dense vegetation cover are also flagged (as light blue)in the image (see colour slide 1). These results suggest that a preliminary analysis of AIS data using an unsupervised cluster may identify areas that warrant further more detailed investigation.

Average spectral curves generated from 3 x 3 pixel areas on the rhyolite, and over the altered andesite, were compared with mineral spectra held in the SPAM library. Close correspondence was noted between that for the rhyolite and Kaolinite. ORD (kaolinite), as shown in colour slide 2 (see pocket at the end of proceedings). The rhyolite curve is shown in yellow, and the Kaolinite.ORD curve in blue. A closer match was also noted with Kaolinite.F.1.(kaolinite, mica, quartz) and the rhyolite (not shown). The slight displacement in the position of the rhyolite minima relative to the library spectra may be linked to the vibrating detector array in the AIS spectrometer (see Cocks and Green 1986).

A mean spectral curve for an area mapped as epidote altered andesite was closely tied with a library curve for Calcite.C.2 (Figure 5), rather than one for epidote as might have been expected. However, this apparent mismatch could, in part, be accounted for by spectral contamination due to second order overlap. Much of the andesite is covered by open Eucalypt woodland with a dry grass understory of varying density. The spectral curve shown in Figure 5 is likely to represent a mixture of a first order absorption relating to the mineralogy, a broad cellulose linked absorption feature around 2.25μm commonly found in dry vegetation (Figure 6), and a "pseudo" absorption at about 2.28μm which represents the second order contribution from a water absorption feature in vegetation at 1.14um (see Figure 6). The latter component has been described elsewhere by Huntington et al. (1986). The combined effect of these elements could explain the broad nature of the absorption shown in the AIS data.

CONCLUSIONS:

Although only a preliminary analysis of the AIS data for the Plateau site has been carried out, we can draw several conclusions from this work.

1. The time-varying detector response, a vibrating detector array, and contamination from spectral order overlap severely degrade the radiometric quality of data acquired over the Plateau site.

2. Mineral related absorption features in the 2.0 to 2.4μm region become apparent when background and atmospheric effects are suppressed. Log residuals computed on data for this atmospheric window only, rather than on all 128 bands, are partially effective for such purposes. An alternative, computationally simple approach known as the Ratio Group Normalising method, successfully enhances subtle mineral related absorption features when all 128 bands are utilised.

3. Preprocessed, corrected (normalised) AIS data is effectively analysed using SPAM.

4. Clear separation of major mineral groupings is possible using normalised AIS data. In certain limited cases, the identification of particular clay mineral species (eg. kaolinite) is possible using these data.

5. Second order spectral contamination, combined with absorption features specific to dry vegetation, mask absorptions diagnostic of some minerals. These problems are particularly acute in the case of pixels with appreciable amounts of vegetation cover.

6. Further work is necessary to evaluate various methods designed to suppress the effects of second order spectral contamination. Similarly, additional study is required to elaborate on the spectral mixing processes that occur in the heavily weathered, partially vegetated environment, characterised by the Plateau site.

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        metry: The application of AIS data to the   detection
        of subtle mineral absorption features. Proc.   2nd

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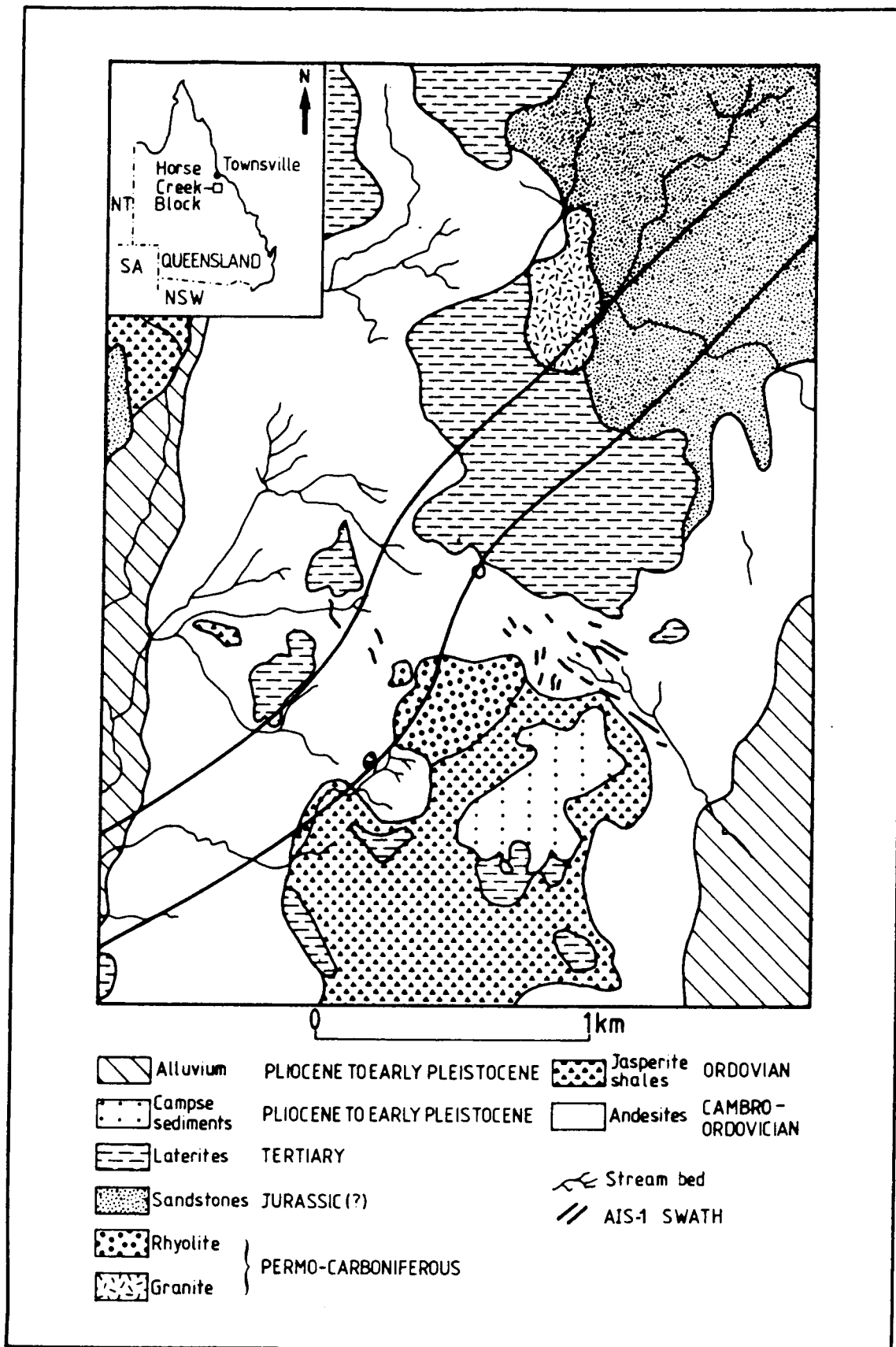
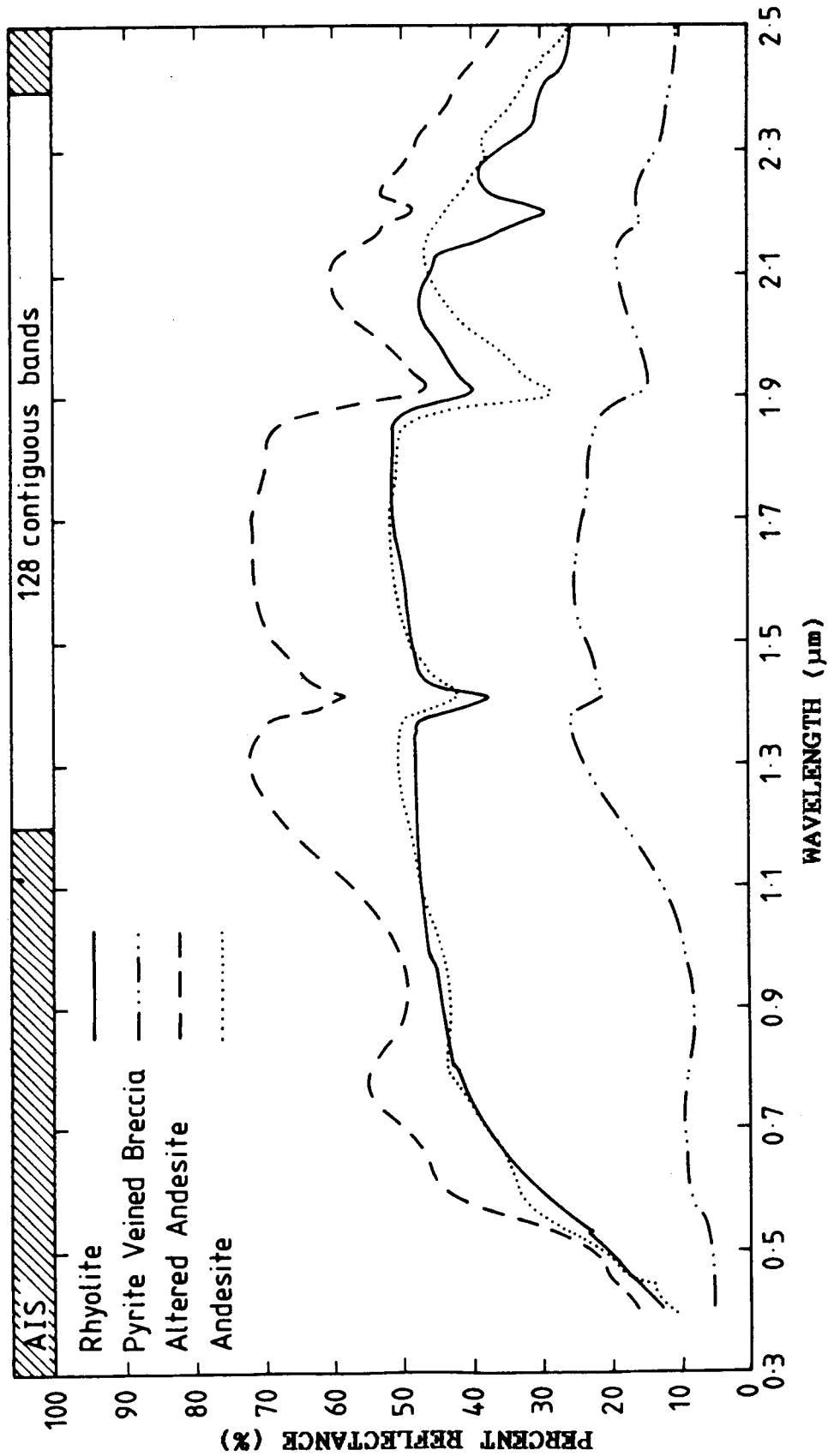Figure 1: Generalised geology of the Horse Creek Block, northern Queensland, Australia.

Figure 2: Laboratory spectra (0.4 – 2.5μm) taken from weathered surfaces of four samples acquired in the Horse Creek Block
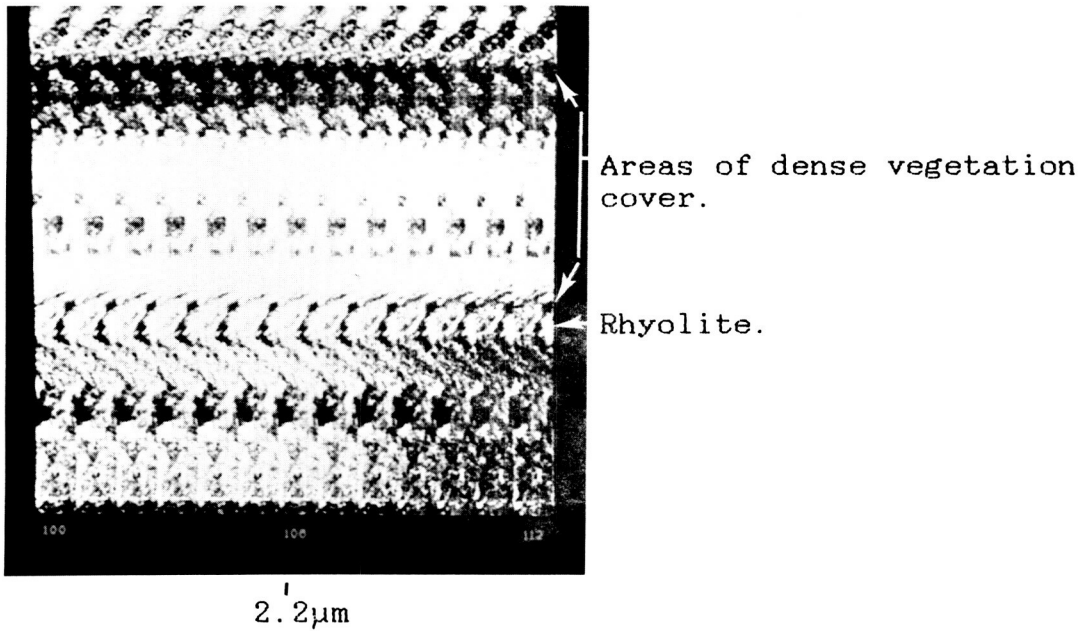
Areas of dense vegetation
cover.

Rhyolite.

2.2μm

Figure 3: Fanned set of log residual images covering bands 100 to 112 (2.14 – 2.26μm), computed from all 128 AIS channels.
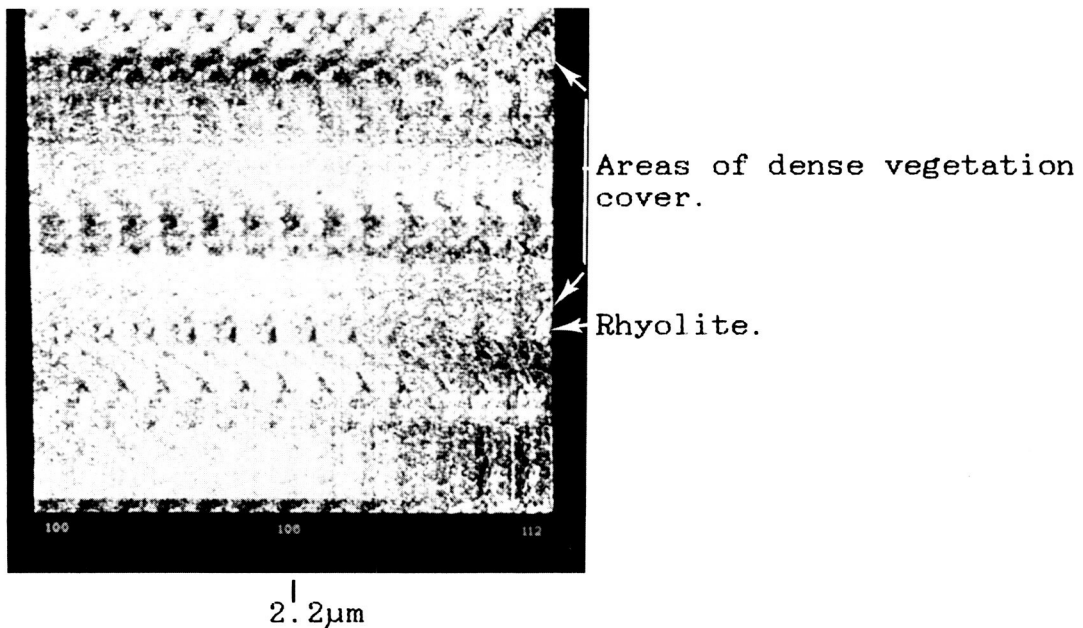

Areas of dense vegetation
cover.

Rhyolite.

2.2μm

Figure 4: Fanned set of Ratio Group Normalised images covering bands 100 to 112 (2.14 – 2.26μm), computed from all 128 AIS channels.
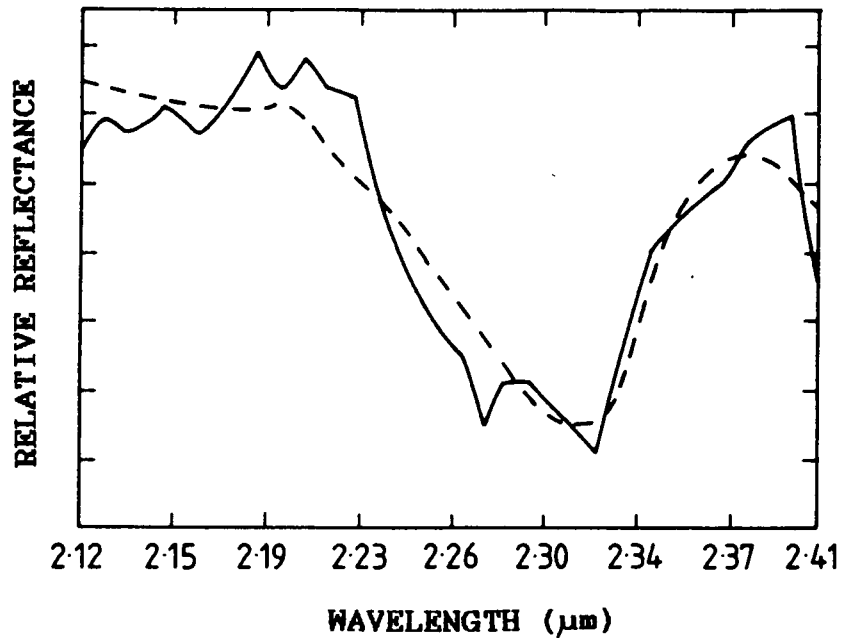
Figure 5: Plot of averaged AIS spectral curve from area
of epidote altered andesite (solid line),
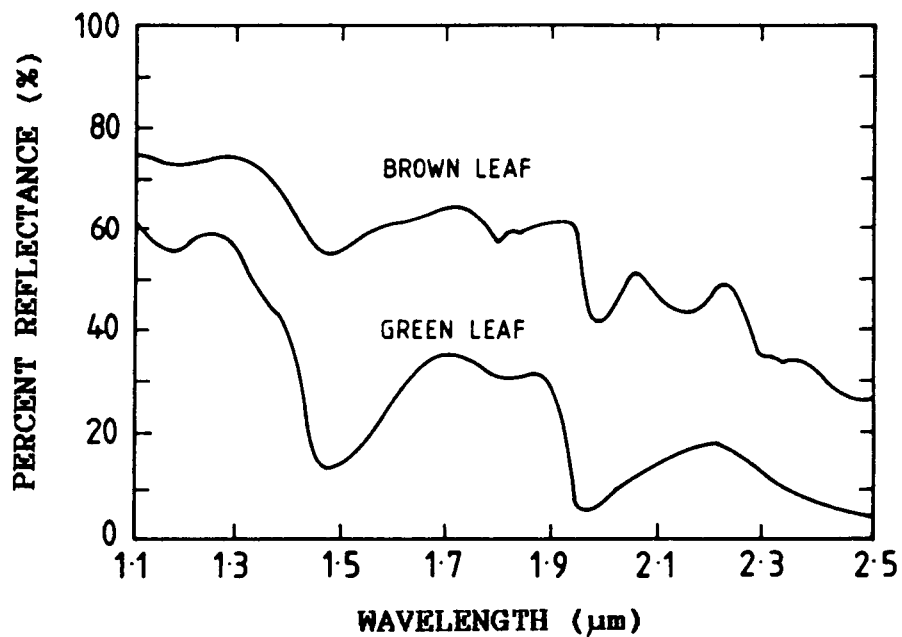matched with SPAM library curve for Calcite.C.2
(dashed line).

Figure 6: Representative spectral curves for green and
dry vegetation. Note the steep drop off in the
curve for dry vegetation around 2.25µm. This is
related to a cellulose absorption feature.