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HCMM AND LANDSAT IMAGERY FOR GEOLOGICAL MAPPING

IN NORTHWEST QUEENSLAND

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Repetitive HCMM imagery of western Queensland and northern South Australia is being analysed to assess its role alongside Landsat imagery for geological mapping and terrain evaluation. The study area straddles the Precambrian Shield, within which lies the Mount Isa-Cloncurry mineral belt contained in highly folded and faulted Proterozoic sedimentary rocks, the level plains of the Great Artesian Basin, floored by Mesozoic and later sediments, and the inland drainage basin focussing on Lake Eyre.

THE HCMM IMAGERY AVAILABLE

HCMM imagery in the form of Day Visible, Day IR and Night IR products, radiometrically and geometrically corrected and contrast stretched, for specified months within one year of launch, is available to Principal Investigators as Standing Order Data Products. The Night IR image is first acquired when surface diurnal temperature is its minimum, and then twelve hours later, when surface temperature reaches the daily maximum, the Day Visible and Day IR imagery is obtained. The Principal Investigator selects the best imagery for requested Registered Day-Night Temperature Difference and Apparent Thermal Inertia Images.

The temperatures sensed at the satellite, after transmission of radiation through the atmosphere, are consistently lower than temperatures at the surface owing to atmospheric absorption in the 10.5-12.5 µm window used for the IR imagery. Obviously, the effects of this absorption must propagate directly into the Day-Night Temperature difference product, resulting in smaller temperature differences than at surface. These are relatively constant across a 700 x 700 kilometre HCMM image frame. In order to assess the effects of absorption, NASA supply RADTRA, in IR radiative transfer program (Rangaswamy et al. 1978). RADTRA utilises as input data an atmospheric profile of temperature and vapour pressure for the appropriate date, derived from radiosonde ascent.

The Apparent Thermal Inertia (ATI) is defined by the algorithm $ATI = NC(1 - a/\Delta T)$, where a is the apparent albedo and (1 - a) corrects for variable energy reflections of different surfaces; and C is a factor compensating for seasonal variation at given latitudes. The ATI provides only an indicator of relative thermal inertia and should not be identified directly with an absolute definition.

THERMAL INERTIA MAPPING

Since Watson published his formulation for diurnal surface temperature variation (Watson 1971), many attempts at creating thermal inertia image have been made. Watson's program assumes one-dimensional periodic heating of a uniform half space, conduction of heat within the ground, and reradiation to the atmosphere where consideration is given to radiative transfer. The aim of Thermal Inertia Mapping is the discrimination of geological units and soils on the basis of their bulk thermal properties, through parameters that can be remotely sensed. The model of diurnal termperature variation, when inverted, relates the primary factors P and A to T, i.e. a unique value of P may be assigned to a pixel with knowledge of a and T, as measured by thermal IR scanning at the two extremes of the diurnal temperature curve.

It was hoped to generate a Thermal Inertia Image by optical registration of the Day and Night IR data sets, but unfortunately no suitable Night IR cover for the test site areas has been acquired. Therefore in the absence of Night IR cover, the utility of the diurnal temperature model and of the radiative transfer function, RADTRA, was tested to ascertain whether model predictions for selected cross sections of geological interest were in agreement with observed values for Day IR imagery. To do this, the HCMM negatives were scanned and digitized using a Joyce Loebl Scanning microdensitometer having a range 0-999. The white portion of the Grey Scale was scanned to assign an upper value corresponding to 255, the highest value on the CCTs. The black portion was scanned to assign a value corresponding to 0. The range thus arbitrarily defined corresponds to 0-255. A scaling factor brings the densitometer data to the range 0-255. The data was transformed and normalized to ensure linearity and meaningful comparison between HCMM frames.

The CCTs have a correspondence to temperature measured, vis $T(0) = 260.0^{o}K$ and $T(255) = 340.0^{o}K$. The CCT data can be converted to absolute temperatures sensed at the satellite from the equation $T(I) = K2/\ln((K1/I - K3) + 1$ where $K1 = 14421.587$, $K2 = 1251.1591$ and $K3 = 118.21378$. The calibration lookup table was adapted for use in this process. Thus a cross section of temperatures as recorded by the satellite was derived. Inputting this data to RADTRA with temperature and humidity measured at certain standard and significant pressure levels, the ground surface temperatures were calculated. Watson's thermal modelling program, adapted for use in the southern hemisphere, was then used to predict surface temperatures across the same geological cross sections (Figures

INTERPRETATION OF HCMM and LANDSAT IMAGERY OF NORTHWEST QUEENSLAND

The Landsat and HCMM imagery respectively offer differing and complementary information for geological mapping and terrain evaluation. In the first place, whereas the Landsat imagery provides a ground resolution of around 79 metres that of the HCMM cover is only 700 metres. Secondly, whereas the Landsat imagery comprises four MSS bands respectively the 0.5-0.6 µm, 0.6-0.7 µm, 0.7-0.8 µm and 0.8-1.1 µm within the visible and near infra-red range, the HCMM imagery comprises only two bands one spanning the 0.5-1.1 µm range in the Day Visible and the other spanning the 10.5-12.5 µm range in the Day IR and Night IR cover. Hence, whereas the Landsat cover offers opportunities for the discrimination of features from information in each of the blue/green, red and near infra bands and in colour composites generated from them, the HCMM cover provide only general information over the visible range: most interest in it centres on additional information, albeit as a small scale, in the IR band.

Excellent Landsat imagery of northwest Queensland is available for February 1973, March, July September and November 1975 and December 1972 (Figure 1). Good quality Day Visible and Day IR HCMM Imagery is available for June, July, September and October 1978 (Figure 2). Unfortunately, no good HCMM imagery is available for the summer rainy period (January to March) when the Landsat imagery contained most information and no Night IR cover of acceptable quality has been obtained at all. Hence the comparative studies outlined in this paper concentrate on dry season day coverage. Even at this season the quality of the HCMM imagery varies greatly over individual frames and consequently evaluation of the information for different areas is based on imagery acquired on different dates. Since neither magnetic tapes nor thermal inertia data have been available, assessment of the HCMM imagery has been carried out on photographic prints made from negatives of the Day Visible and Day IR cover of selected areas. For these areas, comparison is made with enhanced colour composites generated from Landsat computer compatible tapes and films. For the inland drainage basin focussing on Lake Eyre excellent HCMM imagery has been acquired at monthly intervals but there is no Landsat cover available. Assessment of the respective imagery for geological mapping is therefore confined to northwest Queensland.

Initial examination of good HCMM coverage revealed excellent discrimination of drainage systems, notably those directed towards Lake Eyre: it indicated good delineation of the major faults in the Mount Isa-Cloncurry region and of the bedrock geological units outlining the Mitakoodi anticlinorium south east of Mary Kathleen and comprising the Corella sequence near the Dugald River lead-zinc lode. Recognition of these features provided the basis for the overall identification of the areas covered by the HCMM frames. A grid based on degrees of latitude and of longitude was established over each frame and photographic prints of the imagery for selected grid sections were produced at the same scale as the 1:253,440 geological maps with which the interpretations were compared. Any loss of definition in the image at this enlargement is compensated by accurate positioning. On the Day IR coverage of the Mount Isa area this has permitted the identification of an area of high emission as a bush fire in the plains south of the Barkly Highway and eliminated any possible consideration of its being an interesting geological feature (Figure 3).

South and east of Duchess and Boulia, the HCMM Day Visible and Day IR imagery clearly outlines the drainage network, notably that of the Diamantina. Additionally, north of the Hamilton River the Day IR imagery reveals a deltaic pattern of distributaries not seen on the Day Visible cover. This pattern may depict the courses of ephemeral streams following rainfall, but since it is displayed on imagery for June, July, September and October taken at intervals through the dry season, it is a persistent feature which may represent an older drainage system. Its revelation of the IR imagery must be related to lower temperatures occasioned either by finer textured alluvial material or by moister conditions along the former or periodic drainage lines. When geochemical investigations were undertaken over the flat plains near Trekelano, southeast of Duchess in 1962 (Nicholls 1964) trenches over copper anomalies revealed former river channels. Since the reconstruction of the system to which such channels belonged is of vital importance for the interpretation of soil geochemistry in this type of terrain, the evidence provided by the HCMM IR imagery may be regarded as highly significant. Landsat imagery is not available for this area but for selected areas north of Cloncurry, studies of enhanced colour composites generated from contrast stretched MSS bands 4, 5 and 7 and displayed at scales of 1:30,000 or greater show that former drainage channels can be identified within the Cloncurry river drainage system. Clearly complementary imagery which includes the blue/green, red and near infra-red bands within the visible range and the thermal IR bands offers a considerable potential for the reconstruction of drainage history vital for correct interpretation of geochemical data. For accurate field applications, imagery of greater resolution and on a larger scale than that afforded by the HCMM cover is essential. The potential of Landsat imagery in the study of water areas is readily demonstrated from the results obtained from contrast stretching and density slicing the data in the individual MSS bands, especially MSS 4, for Lake Moondarra, the small reservoir supplying Mount Isa. The resulting output of MSS band 4 discriminates water of differing depths and sediment content and the colour composite generated from the stretched MSS 4, 5 and 7 additionally shows the disposition of sediment entering the lake at the southern end. (Figure

Southeast of Mary Kathleen distinctive and strongly contrasting spectral signatures on the colour composites generated from contrast stretched MSS bands 4, 5 and 7 of Landsat imagery characterize the individual lithological units belonging to the Argylla formation, Marraba volcanics and Mitakoodi anitclinorium. The whole feature which comprises the Bulonga and Duck Creek anticlines and the Wakeful syncline and extends over a meridional distance of some 100 kilometres is clearly outlined. This is largely because the Overhang jasperlite which overlies the Mitakoodi quartzite has a dominantly very dark blue spectral reflectance which contrasts sharply with the light green and red spectral reflectances of the latter geological unit. The outcrops of the individual lithological/stratigraphical units are also outlined and the major faults are clearly discerned. The size of the Mitakoodi anticlinorium as well as the contrasts of spectral reflectance between its constituent lithological units results in its clear delineation on the Day Visible HCMM imagery, notably that for 5 October 1978 (Figures and On the Day IR imagery for this date, the overall feature is discernible but the differences in thermal response appear to be more closely related to the nature of the terrain that to the geology. High thermal emissivity characterizes the plains areas whereas low thermal emissivity is a feature of the high ground. The areas of outcropping Mitakoodi quartzite, outlined by dark tones, have particularly low emissivity values whereas those of the jasperlite are variable. Similar relationships are evident on the Day Visible and Day IR imagery for 22 July and 24 September which, however, is of poorer quality.

Enhanced colour composites generated at a scale of 1:50,000 from the Landsat imagery acquired over the Cloncurry area in December 1972, and March and July 1975 permitted the preparation of more detailed geological maps than the one compiled by the Bureau of Mineral Resources at the 1:253,440 scale, at the time the only map of the area. Most information emanated from the colour composites generated from the computer compatible tapes of the March 1975 imagery. Distinctive spectral signatures discriminated different lithological units within the Proterozoic sedimentary sequence, outlined areas of intrusive granite and distinguished areas of outcropping and near surface bedrock from those with deep residual or alluvial cover. Certain hitherto unknown structural features as well as known faults were revealed by discordant linear relationship between spectral signatures (Cole and Owen-Jones 1977). Within the Lower Proterozoic Corella formation the Dugald River lead-zinc lode, its shale host rock and bedded argillaceous limestone footwall rock were clearly delineated, their dark dominantly blue spectral signatures contrasting sharply with both the reddish signatures over the calc-silicate rocks and the light green ones over the overlying Knapdale quartzite which forms a prominant range to the west of the level terrain in which the lead-zinc deposit occurs. To the southwest dominantly dark blue spectral signatures again delineated outcropping and suboutcropping well bedded argillaceous limestone, while to the east variable light red and yellow hues characterized granite areas. In contrast to these areas of outcropping and suboutcropping bedrock, sparsely covered by trees and shrubs and weakly reflecting narrow rolled leaved grasses, the alluvial plains, supporting at this season a continuous cover of strongly reflecting borad bladed grasses were outlined by strong dark red spectral signatures. Within the plains, areas of dominantly green or blue reflectances betrayed the presence of near surface bedrock while across them, discordant spectral patterns revealed the presence of deep seated structures.

On the Day Visible cover of the HCMM imagery for 5 October 1978, the outcrop of the Knapdale quartzite is clearly outlined between areas of darker tone which delineate the area of bedded argillaceous limestone to the south-west and the Dugald River lode and its associated host and footwall rocks to the east. Further east, as might be anticipated, light tones mark the areas of granite outcrop and to the south dark ones those of the Quamby conglomerate. On the Day IR cover, the Knapdale quartzite and the Quamby conglomerate are sharply delineated as areas of low emissivity, the Dugald River lode and its associated host and footwall rocks cannot be distinguished and the area of of bedded argillaceous limestone to the south east shows variable levels of emissivity.

Over the plains drained by the Cloncurry and Williams Rivers distinctive spectral signatures on the colour composites generated from the Landsat imagery distinguished discrete vegetation associations and plant communities whose distribution is directly related to the distribution of alluvium, colluvium and bedrock outcrop (Cole and Owen-Jones 1977). The HCMM Day Visible cover shows a mosaic of tonal levels which can only be interpreted by reference to the Landsat cover (Figures and). This is because on the HCMM imagery dark tones characterize both areas of tree cover (mainly of Acacia cambagei or Eucalyptus spp, whose weak reflectances produce purplish hues on Landsat colour composites) near the creeks and also areas of strongly reflecting grassland (producing strong red hues on the Landsat colour composites) on the plains. On the HCMM Day Visible imagery the differing plant communities which are characterised by contrasting spectral hues on the Landsat colour composites and which clearly distinguish between areas of alluvium and colluvium, cannot be discriminated. The Day IR cover shows generally high levels of emissivity indicating that under the clear skies and high midday temperatures of the dry season, the treeless plains absorb and emit more heat than the areas of outcropping and near surface bedrock which carry a low tree and shrub savanna.

The coarse resolution of the HCMM imagery renders it virtually impossible to tell whether or not areas of mineralization can be detected by thermal imagery. In the Mount Isa area, notably near Hilton mine, the Mount Isa shales have a higher emissivity than adjacent lithological units. Small areas of higher emissivity, persistent on sequential imagery, occur at Hampden/Kuridala and Mount Elliot/Selwyn where, however, they may be related to the extensive old mine dumps which are bare of vegetation and constitute very dry sites likely to absorb and emit heat very readily under high midday temperatures in the dry season. The Dugald River lead-zinc lode is not detectable on the Day IR imagery. This deposit and also the Lady Loretta lead-zinc deposit near Lady Annie, however, were detected on 1:15,000 scale thermal imagery acquired by air survey (Cole 1977).

Overall the studies carried out in the Mount Isa-Cloncurry area show that enhanced colour composites generated from Landsat imagery at scales of 1:50,000 or larger yield valuable geological information, notably deep seated structures and on lithological/stratigraphical units. Areas favourable for mineral deposits may be outlined but larger scale aerial photography is normally needed for the delineation of target areas including those characterized by anomalous vegetation. The only area know to the author where a mineral deposit is distinguished by a unique spectral signature on Landsat imagery is that of the Lady Annie phosphate deposit which is characterized by a large geobotanical anomaly dominated by Atalaya hemiglauca trees (Cole 1977, Cole and Owen-Jones 1977). For geological mapping purposes the HCMM imagery is of limited value. While large scale features like the Mitakoodi anticlinorium, contrasting lithological units and major fault structures may be distinguished on the Day Visible and Day IR cover, the spectral bands are too broad and the resolution too coarse even for regional mapping purposes. The imagery appears to be most useful for drainage studies. Where drainage is seasonal, sequential imagery permits the monitoring of broad scale water movement while the Day IR cover yields valuable information on former channels. In plains areas subject to periodic changes of stream courses comparable IR cover at a larger scale would offer a considerable potential for the reconstruction of former drainage patterns essential for the correct interpretation of geochemical data relative to mineral exploration.

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