Geological Mapping using SWIR and VNIR Bands of ASTER Image Data

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Abstract: This study aims to extract maximum geological information using the ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer) images of a part of south India. The area chosen for this study is characterized by rock types such as Migmatite, Magnetite Quartzite, Charnockite, Granite, dykes, Granitoid gneiss and Ultramafic rocks, and minerals such as Bauxite, Magnesite, Iron ores, Calcite etc. Advantage was taken of the characteristic reflectance and absorption phenomenon in the VNIR, SWIR and TIR bands for these rocks and minerals, and they were mapped in detail. Image processing methods such as contrast stretching, PC analysis, band ratios and fusion were used in this study. The results of the processing matched with the field details and showed additional details, thus demonstrating the usefulness of ASTER (especially the SWIR bands) data for better geological mapping.
Keywords: ASTER, Image Processing, Geologic Mapping.

1. Introduction

An important tool for geologists is a map depicting the distribution and identity of rock units exposed at the Earth's surface. Field based geological mapping involves sampling and observing litho-boundaries and structures along traverses in the ground. This approach, however, has certain limitations such as consuming much time, inaccessibility to certain terrains, and omission of certain outcrops when the sampling interval is large. Synoptivity and spectral data, offered by remotely sensed images can be beneficially used to obtain enhanced geological information and thus prepare better geological maps.

The spectral signatures of rock units suggest that better information about them can be obtained by using information from both SWIR and VNIR bands [1]. ASTER is a remote sensing sensor that provides VNIR, SWIR and TIR images at reasonably high resolution and can greatly improve geologists' abilities to produce more accurate geologic maps compared to the ground-based methods. Many researchers have demonstrated the capabilities of ASTER data for geologic mapping [2], [3].

The aim of the work reported here is to obtain more information from NVIR and SWIR bands by certain image processing methods and by integrating the complementary information (in VNIR and SWIR) than cannot be derived from a single sensor data alone. ASTER data, supported by existing maps and field studies, were used to map an area in the Tamilnadu stste of south India. Common lithologies here include Migmatite, Magnetite Quartzite, Charnockite, Granite, Basic dykes, Granitoid gneiss, Pyroxene Granulite, Ultramafics, Fissile Hornblende-Biotite gneiss and Basic rocks. Advantage was taken of the characteristic reflectance and absorption phenomenon in the VNIR and SWIR bands for these rock types, and they were mapped in detail. This is an unique attempt because this is probably the first such study in India that has attempted to use the image data obtained from the ASTER sensor.

2. Image data and study area

The digital image data used in the study has been obtained by the ASTER sensor. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument on board TERRA -1, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS). ASTER is used to obtain detailed maps of land surface temperature, emissivity, reflectance and elevation and is a suite of three high-performance optical radiometers with 14 spectral channels (Table.1) that contribute valuable scientific and operational data on the earth. The VNIR high-resolution radiometer observes the targets using solar radiation reflected from the earth surfaces in three visible and near infrared bands. Its main objectives are land survey, vegetation assessment, environmental protection and disaster prevention. The SWIR instrument is an advanced high-resolution multispectral radiometer, which detects reflected solar radiation from the earth surfaces in the wavelength region of 1.6 – 2.43 micrometer. SWIR is especially useful for resources discriminations such as rocks and minerals and for environmental survey such as vegetations and volcanoes [4].

Three study regions were chosen such that each was different from the other in terms of lithological composition. The first region is a part of the mining district of Salem, Tamilnadu state, south India. Common rocks and minerals here include Magnetite Quartzite, Ultramafics, Charnockite, Fissile hornblende biotite gneiss, Jalagandapuram syenite, Epidote Hornblende gneiss, Magnesite, and Bauxite. The second region is in and around Krishnagiri town, south India and is characterized by Samalpatti and Koratti syenite, Ultramafics, Charnockite, Epidote Hornblende gneiss, pink migmatite, dykes and the Pikkili syenite. The third is the Palar river region, south of Madras city. This area contains rock types such as Boulder beds, conglomerate, shale, sandstone, Basal conglomerate, shale with limestone, fluvial sediments, Laterite, Epidote Hornblende gneiss, Charnockite and Fissile hornblende biotite gneiss [5].

Table 1: Characters and applications of ASTER bands

Subsystem	Band Number	Spectral Range (microns)	Applications
VNIR (visible to near infrared)	1	0.52 to 0.60	Coral mapping, DEM, Geology, Polar and Glacier studies, Land classification, soil moisture, Urban growth, Vegetation and Volcanic studies.
	2	0.63 to 0.69	
	3	0.76 to 0.86	
SWIR (shortwave infrared)	4	1.60 to 1.70	Geology, Mineral exploration, Land classification and change detection, Surface energy balance, Volcano monitoring
	5	2.145 to 2.185	
	6	2.185 to 2.225	
	7	2.235 to 2.285	
	8	2.295 to 2.365	
	9	2.36 to 2.43	
TIR (thermal infrared)	10	8.125 to 8.475	Fire monitoring, Geology, Land classification, Polar Soil moisture, Surface emissivity, Urban growth, Vegetation stress, Volcano and Wetlands monitoring
	11	8.475 to 8.825	
	12	8.925 to 9.275	
	13	10.25 to 10.95	
	14	10.95 to 11.65	

3. Concept and Methodology

Within the image processing techniques available [1], the image enhancement techniques are found to be more suitable for geological applications since they improve the sharpness and contrast for interpretation. In this study many single- and multi-band operations of image enhancement were carried out. These include linear and contrast stretch, band ratios, PCA and fusion (multi-sensor). Fusion is more useful as it provides images with better resolution and takes into account the complementary information present in the VNIR and SWIR bands.

1) Image Fusion for rock and mineral mapping

In the **IHS method** of fusion the bands of lower resolution data are transformed to the Intensity (I), Hue (H) and Saturation (S) space. The stretched higher resolution image replaces the intensity component. The H and S components are over sampled to higher resolution and the images are re-transformed to the original space.

The **PCA (Principal Componant Analysis) method** is much similar to the IHS method and removes the redundancy of information content. The XS bands are used as input to the PCA procedure. All the bands of the image are simplified into the PC axes and fused.

The **Brovey Transformation method of fusion** is a special arithmetic combination including ratios. It normalizes the XS bands used for an RGB display and multiplies the result by any other higher resolution image to add the intensity components to the image [6].

2) Spectral Separability of Rocks and Minerals

An important aspect in this study was to determine the spectral separability of the different rock types and minerals present in the study sites (Figure 1A1, B1, C1). The relative worths of features in an image may be assessed in a quantitative way using the mathematical *separability* of classes. A few of these measures are the Euclidean distance, Divergence, Jeffries-Matusita (JM) distance and Transformed divergence (TD) [7]. *Euclidean distance* refers to the distance between means of the spectral classes. This measure gives us a broad idea of the separability between the classes. *Divergence* is a measure of the separability of a pair of probability distributions that has its basis in their degree of overlap. Divergence, however, is a pairwise distance measure and an *m*-wise ($m > 2$) generalisation has not been formulated [9]. Hence, divergence has not been considered in this study. The *Jeffries Matusita* (JM) distance, also known as Bhattacharya distance, between two spectral classes is seen to be a measure of the average distance between the two class density functions. There is a saturating behaviour of the JM distance with increasing class separation. This behaviour has been verified experimentally and a similar function called *Transformed Divergence* has been suggested. TD and JM are monotonically related to classification accuracies and both have been computed in this study. Only TD is used here due to its advantages [7]

4. Observations and Discussions

Enhancement of VNIR and SWIR images has brought out many geologic details. Spectral signatures of rocks result due to specific absorption features of its constituents. The VNIR region (0.4µm - 1.3 µm) is characterised by broad spectral absorption features (ferrous iron absorption feature near 1 µm). In the SWIR region, absorption at 1.4µm - 1.9µm is due to unordered arrangement of water molecules; absorption in the 1.8µm - 2.5µm region is due to the presence of OH and CO_3 molecules and absorption near 1.4µm -2.2µm is due to layer silicate structure and moisture [1]. Hence, fusion of SWIR and VNIR images has brought out complementary information (Figs 1A2, B2, C2) in both the wavelength regions.

It may be inferred from Figure 1 A1,B1,C1 that separability measure TD yields values between 1.21 and 2.00, where 1.21 indicates appreciable overlap between the rock types and 2.00 indicates a complete separation between them. The following rules are suggested for the ranges of the separability in terms of the TD values ‘ x’ .

$1.21 < x < 1.80$ (poor separability)
$1.80 < x < 1.95$ (moderate separability)
$1.95 < x < 2.00$ (good separability)

Poor average separability ($1.21 < x < 1.80$) values for the Krishnagiri region indicates that the rock types have signatures that are statistically close to each other. Moderate separability ($1.80 < x < 1.95$) indicates that the signatures are separable to some extent. In the Palar and Salem region, the average serability of rocks is higher than the Krishnagiri region. Only the syenites and carbonatites have higher separability, while the gneisses and migmatites have overlapping spectra.

5. Conclusions

ASTER images proved useful in identifying rock types in igneous, sedimentary and metamorphic terrains. Surface expressions of certain mineral deposits such as magnetite, magnesite and bauxite are clearly brought out by processing the SWIR and VNIR images. Geologic

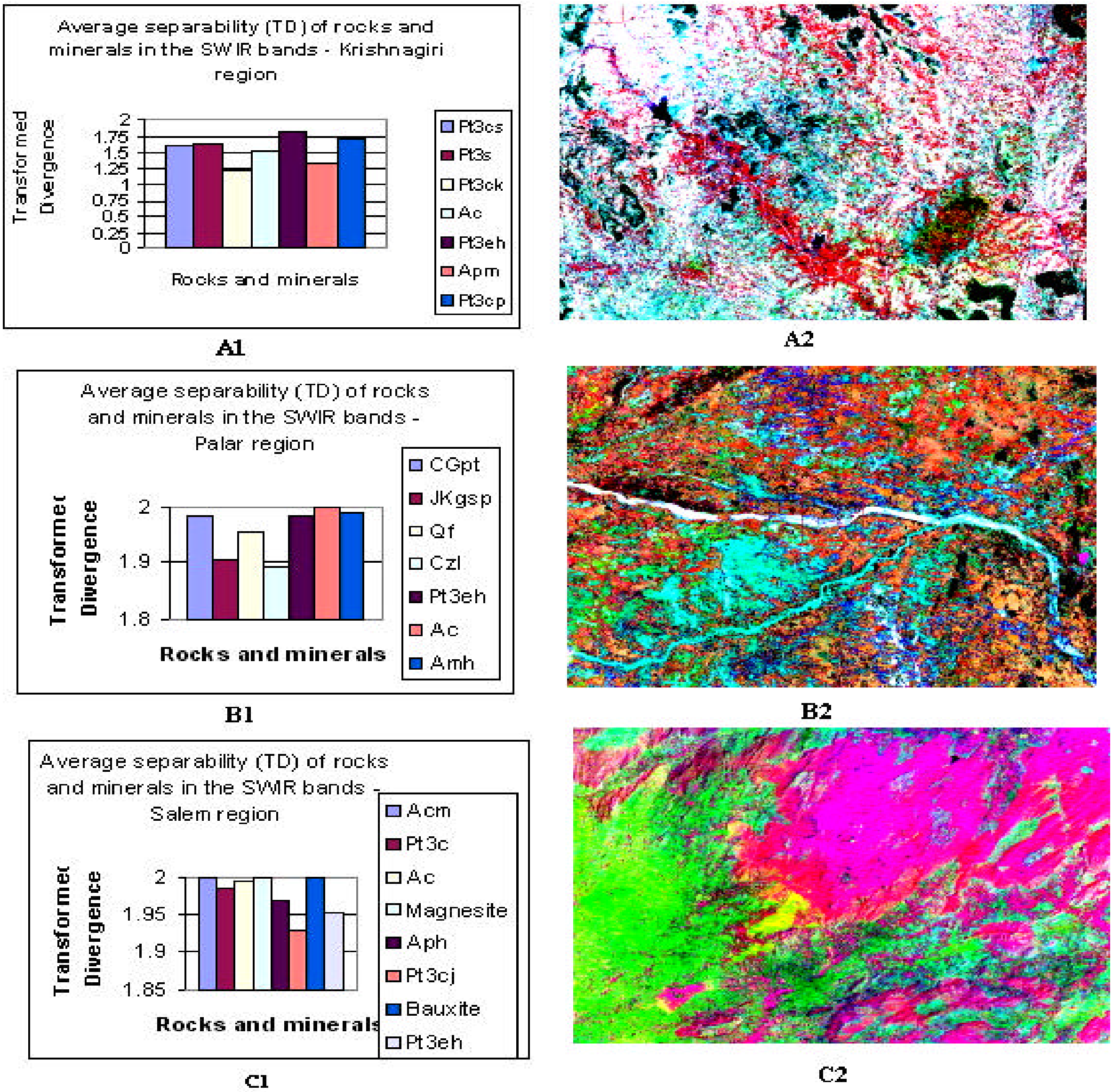

Fig 2. Spectral separability (A1, B1 and C1) of the rock types in SWIR bands and examples of enhanced images (A2= SWIR and VNIR bands fused using Brovey Transform; B2= IHS fusion of SWIR PC1 and VNIR images; and C2= RGB to HLS Colour transform SWIR bands 864). A=Krishnagiri Region, B=Palar Region, C=Salem Region. Please note the excellent portrayal the rock types. *Note* : The colour scheme for the bar chart and the images are not the same. Acm (Magnetite Quartzite), Pt3 (Ultramaics), Ac(Charnockite),Aph (Fissile Hornblende biotite gneiss), Pt3cj (Jalagandapuram syenite),pt3eh (Epidote Hornblende gneiss), Cpgt (Boulder beds, conglomerate, shale and sst), jkgsp (Basal conglomerate, shale with l.st),Qf (fluvial),Czl (Laterite), Apm (migmatite).

mapping with these bands is effective when used in conjunction with fieldwork and published maps. ASTER data may be used for mapping similar terrains, especially when interpretation is based on knowledge of the terrain's geology and morphology.

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