LANDSAT ETM+ 7

INFORMATION, PROCESSING & ENHANCMENTS

SATELLITE INSTRUMENTATION

IMAGE PROCESSING

IMAGE RESULTS

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SATELLITE INSTRUMENTATION

The LANDSAT Enhanced Thematic Mapper System

The “Enhanced Thematic Mapper” broad-band multispectral scanner on board the LANDSAT satellite (No. 7) was launched on April 15, 1999. This satellite system has the same seven spectral bands as its predecessor, TM5, but has an added panchromatic band with 15 metre resolution and a higher resolution thermal band of 60 metres. The ETM+ sensor also has a five percent absolute radiometric calibration. Six of the bands detect reflected radiation in the visible to shortwave-infrared wavelength regions, and the remaining band detects emitted radiation in the mid-infrared wavelength region.

TABLE 1: LANDSAT TM Wavelength Bands

Band 1:	0.45 to 0.52µm	(visible)
Band 2:	0.52 to 0.60 µm	(visible)
Band 3:	0.63 to 0.69 µm	(visible)
Band 4:	0.76 to 0.90 µm	(near infrared)
Band 5:	1.55 to 1.75 µm	(shortwave-infrared)
Band 6:	10.40 to 12.5µm	(thermal mid-infrared)
Band 7:	2.08 to 2.35 µm	(shortwave-infrared)
Band 8:	0.52 to 0.90 µm	(near infrared)

The spatial resolution of individual pixel is 30 by 30 metres for the 6 visible to shortwave-infrared bands and 60 by 60 metres for the mid-infrared band. The panchromatic band has a resolution of 15 by 15 metres.

The two shortwave-infrared bands were designed for geological applications. Band 5, centred at 1.65 microns (Figure 1) is located where most rocks have their highest reflectances. Band 7, centred at 2.22 microns, covers the absorption region of Mg-OH, Al-OH and CO^3 bearing minerals. These minerals include the chlorite, clay, mica, brittle mica, serpentine, amphibole and carbonate groups, which are important alteration mineral groups. In addition, the “visible” band 3 is useful for discriminating iron oxides and vegetation. At this wavelength, iron oxides have a reflectance peak while vegetation has a major absorption feature.

PROCESSING TECHNIQUES

The methods used to analyse the geological significance of the LANDSAT imagery included the implementation of the following techniques:

I. displaying and contrast stretching raw bands, e.g. bands 2, 5 & 7
II. generating ratios, including Abrams and Podwysocki ratio combinations for mineral alteration
III. using the ratioing process to remove vegetation effects.

Ratios

Raw LANDSAT data is affected by atmospheric absorption (multiplicative effect), atmospheric scattering (additive effect), topographic illumination and various surface spectral responses. The surface spectral responses include the spectra derived from the different types and proportions of minerals and vegetation, as well as the textural effects and variations in moisture content. Ratios are extensively used in image processing for largely removing the topographic illumination variations and albedo. What is generally left, apart from the atmospheric effects, is the variability between the bands which relates to the physical properties of the reflecting surface.

Multiplicative atmospheric attenuation can be partly removed using ratios but these depend on the wavelengths of the bands. Additive atmospheric scattering effects, such as Mie and Rayleigh scattering are difficult to remove using ratios. These effects have a profound affect on the shorter wavelength bands and cause more energy to be directed to the sensor. This added energy will affect the spectral interpretation of ratio images which use the shorter wavelength bands, e.g. the application of a 0.66/0.48 ratio to discriminate iron oxides.

Ratios are prepared by dividing the digital numbers of one band by the corresponding digital numbers of another band. The usefulness of applying ratios for mineralogical discrimination is well demonstrated by Yamaguchi (1987). Plotting the LANDSAT TM bands, 7 versus 5, a clear division in groupings occurs between the altered and unaltered rocks. Surfaces with large differences in albedo can also cause problems when using ratios. This was demonstrated by Miller and Elvidge (1985) who showed that a 0.66/0.48 ratio, used to detect limonite staining, varied as a result of the albedo of the surface.

Work by Abrams et al (1983), in the Helvetia-Rosemount area, Arizona, USA, using the airborne thematic mapper simulator, found that ratio combinations of bands centred at 0.66/0.56, 1.65/2.2 and 0.83/1.65 micrometres could discriminate iron oxides, clays and vegetation respectively (Table 2). The increased development of iron oxides and clay minerals were indicative of alteration-mineralisation assemblages.

TABLE 1: The display colours used on the Abrams ratios, and the surfaces discriminated.

Display Colour	TM Bands	Wavelength (micrometres)	Discriminates
Blue	5/7	1.65/2.20	Clays & vegetation
Green	2/3	0.56/0.66	Iron oxides
Red	4/5	0.83/1.65	Vegetation

Podwysocki et al (1983) worked in the Marysvale region, Utah, USA, with the NASA Bendix multispectral scanner. These workers used the following spectral band ratios: 1.6/2.2, 1.6/0.48 and 0.67/1.0 micrometres to emphasise clays, iron oxides and vegetation, respectively. The equivalent TM bands and colours used to display these ratios in this study are shown in Table 3:

TABLE 2: The display colours used on the Podwysocki ratios, and the surfaces discriminated.

Display Colour	TM Bands	Wavelength (micrometres)	Discriminates
Blue	5/7	1.65/2.20	Clays & vegetation
Green	3/4	0.66/0.83	Vegetation
Red	5/1	1.65/0.48	Iron oxides

TABLE 3: Ratio developed for Iron oxide discrimination

Display Colour	TM Bands	Wavelength (micrometres)	Discriminates
Blue	4/2	0.83/0.56	Iron & silica
Green	4/7	0.83/2.20	Fe-O & vegetation
Red	5/7	1.65/2.20	Clays, FeOH & silica

TABLE 4: Ratio developed for Iron oxide – carbonate discrimination

Display Colour	TM Bands	Wavelength (micrometres)	Discriminates
Blue	3/1	0.66/0.48	Fe clays
Green	5/4	1.65/0.83	Carbonate & silica
Red	5/7	1.65/2.20	Clays, FeOH & silica

TABLE 5: Minerals and geological materials identified from various ratio treatments.

LANDSAT TM/ETM Band Ratio	Discriminates
5/7 or 7/4	Bright Responses: Rocks that contain kaolinite, montmorillonite, chlorite and talc. Examples of surface types: mineralised zones; breakaways; foliated and chlorite/sericite-rich zones; clay development over the granitoids; and vegetation along drainage channels. Dark Responses: Mafic units without a pronounced foliation.
3/5 or 5/3	Bright Responses: Iron oxide rich surfaces, e.g. laterite; sedimentary horizons including pale coloured felsic volcanics, quartz veins, granitoids. Dark Responses: Mafic rocks generally.
4/1 or 5/2	Bright Responses: Massive mafic rocks. Dark Responses: Sediments and Felsic Volcanics.

IMAGE RESULTS

The types of lithologies and minerals that can be discriminated are shown below.

Colour	***Lithology or Surface Type***
Red/Red-Brown	Mineral alteration, FeOH & clay species. Mafic rocks, vegetation with clay rich soil. Granitoids with Felsic Volcanics. Fire scar with re-vegetation.
Brown	Mafic rock and soils.
Purple/Blue	Basalt/Dacite/Rhyodacite flows. Quartzite ridges and brecciated silica zones. Scree slopes.
Blue/Blue-Green	Metamorphic rock types with quartz ridges. Mylonite, shear zones.
Green	Recent alluvial clay/soils with vegetation.
Pale Green/Yellow	Breakaway clays & drainage, sedimentary horizons.
Yellow/Orange	Minor felsic volcanic formations.
Cyan & White	Granitoids & clay breakaway development