MAPPING OF HYDROTHERMALLY ALTERED AREAS IN VEGETATED TERRAIN, USING MULTISOURCE DATA INTEGRATION AND SEGMENTATION TECHNIQUES

Raimundo Almeida-Filho
Ícaro Vitorello
National Institute for Space Research - INPE
C.P. 515 - São José dos Campos/SP/Brazil
e-mail: rai@ltid.inpe.br

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ABSTRACT

Abstract *Field spectra data were used to guide the selection of the best Landsat-TM bands to map areas of hydrothermally altered materials in a savanna vegetated terrain. Landsat images were merged with a digitalized aerial photograph via IHS techniques. The resulting hybrid products kept the high spatial resolution of the aerial photograph and the spectral information derived from the Landsat images. A supervised region classifier algorithm was applied to a segmented image, obtained from the hybrid product. The produced region classified image permitted the accurate mapping of the target areas, even in areas where vegetation (mainly herbaceous plants) covered up to 60% of the terrain surface.*

1. INTRODUCTION

Several studies using airborne or orbital images have indicated the feasibility of mapping hydrothermally altered areas, which are potential sites for mineral deposits (Abrams et al., 1977; Prost, 1980; Rowan and Kahle, 1982; Podwysocki et al., 1983). These studies are based on the fact that diagnostic minerals associated with hydrothermal processes, such as iron-bearing minerals (limonite) and hydroxyl-bearing minerals (clays, K-micas etc), show diagnostic spectral features that allow their identification by remote sensing techniques. However, the use of these techniques has been constrained to arid and semi-arid environments with sparse vegetation cover that permit the spectral information to be collected directly from the rock-soil assemblage. Furthermore, in the tropics, the diagnostic minerals may also be ubiquitous products from weathering processes. On the other hand, strong leaching might cause the removal of the hydrothermal-derived products from alteration zones. Such environmental conditions drastically reduce the chance of successful use of these techniques in the tropics. So, the use of remote sensing techniques for mapping hydrothermally altered materials in the tropics requires judicious analysis of the role of the different environmental factors that contribute to the information registered by the sensor systems. In this study we evaluate the feasibility of spectral discrimination of hydrothermally altered materials in a vegetated terrain, using the Serra do Mendes granitoid as a case-study area.

2. STUDY AREA

The study area is located in central Brazil, a region of tropical savanna climate, with a well-defined rainy summer and a dry winter. Weathering processes have created poor soils, with high concentration of iron and aluminum oxides. The vegetation is a savanna-like vegetation cover constituted by sparse small trees and interspersed shrubs and herbaceous plants.

The Serra do Mendes massif is one of the more than twenty granitoid bodies of middle-to-low Proterozoic age (Araújo and Alves, 1979; Marini and Botelho, 1986) of the Tin Province of Goiás. The granitoid is a 22 km long by 10 km wide dome that rises up to 400 meters above the surrounding gneisses and migmatites of the Central Brazilian Shield of Archean age (Almeida et al., 1981). It is constituted mainly of dark-grey biotite-granitoids with medium-to-coarse hypiodiomorphic granular texture. Facies of hydrothermal alteration, composed of greisenized and albitized muscovite-granitoids with cassiterite, have been found in the central part of the Serra do Mendes massif (Padilha and

Laguna, 1981). This part of the massif constitutes the study area, which is approximately 2 km wide by 3 km long (Figure 1). In this area, leaching processes have concentrated insoluble elements (silica and iron oxides) in the surface and developed extensive lateritic crusts, that induce the predominance of herbaceous plants. The areas of alteration materials are recognized in the field by the presence of abundant quartz, microcline, albite, and muscovite, covered by thin grasses and sparse tiny shrubs.

3. FIELD DATA ACQUISITION

Eighty-five field spectra obtained from altered and non-altered rock/soils under variable grass cover, were acquired between May 5th to 12th, from 9:00 to 11:00 am local time, roughly in accordance with the date and day-time of the Landsat Thematic Mapper (TM) images (path 221, row 69), which were obtained on May 10, 1984, under a solar elevation angle of 42°. Determinations were made with a portable radiometer *(Barringer's Hand Held Ratioing Radiometer* - HHRR) fitted with Landsat-TM equivalent bandpasses. Measurements were obtained with nadir viewing at a distance of about 1.3 meters from the surface. Field photographs of the scene under the field of view of the sensor system were obtained, in order to estimate the percentage of the different surface constituents that contributed to compose each spectra.

The *in situ* spectra provided a unique insight on the spectral behavior of the different terrain features, since the measurements were obtained with the surface materials in their natural conditions. The major concerns were to define the best Landsat-TM bands to discriminate hydrothermally altered materials and to determine the effect of the vegetation cover (especially herbaceous plants), in the discrimination of different rock-soil types.

4. DATA PROCESSING AND ANALYSIS

Figure 2 shows field spectra obtained from different rock-soil-vegetation associations in the study area. Two main conclusions may be deduced from these data. The first one indicates that the equivalent bands TM-1, TM-2 and TM-7 show the best spectral separability between bare soils derived from hydrothermally altered granitoids, and bare lateritic soils developed over non-altered granitoids (biotite-granites). In the visible region (TM-1 and TM-2), the separability is due to the presence of broad absorption bands associated with iron-oxide minerals from the lateritic soils, which are absent in the hydrothermally altered areas. In the infrared band (TM-7), the spectral separability between both soils is related to prominent absorptions bands around 2200 nm due to hydroxide-bearing minerals associated with the hydrothermal activities. As a second conclusion, the spectra data showed that even under vegetation cover of up to 60%, hydrothermally altered areas could be discriminated from the surrounding non-altered areas, particularly, areas of lateritic covers. However, the presence of the green vegetation tends to lower the overall spectra as the percentage of vegetation cover is increased. On the other hand, the decrease on the overall spectra depends on the soil background. So, areas of lateritic soils derived from biotite-granites with 40% of vegetation cover, show lower overall spectra than areas of hydrothermally-derived soils with 60% of vegetation cover. This conclusion is in accordance with the results obtained by Siegal & Goetz (1977).

Based on the field spectra data, the first attempt to discriminate hydrothermally altered areas was to combine the TM-1, TM-2, and TM-7 bands to produce different color composites of the study area. However, the high radiometric signals from the bare soils in the TM-7 band masked the subtle spectral contrast among the different soil covers in the color composites. For this reason, TM-7 band was discarded. Best results were obtained with a natural color composite combining TM-1, TM-2, and TM-3 bands with blue, green, and red filters, respectively. According to Davis and Grolier (1984), the main advantage of this product is to reproduce the scene in natural colors, as observed by human eyes, a fact which facilitates geologic interpretation. In this color composite, areas of hydrothermally altered materials appear in light tones due to the high spectral response in the three TM bands. Lateritic soils derived from biotite-granites appear in yellow and red-brownish colors due to the response of ubiquitous ferric oxides in the yellow-red TM-3 band. Heavily vegetated areas appear in dark greenish tones because of the green vegetation peak in the TM-2 band.

To obtain a better definition of the study area, Landsat-TM bands were combined with a high-resolution panchromatic aerial photograph (pixel

3x3 meters). Forward and reverse intensity, hue, and saturation (IHS) transforms (Haydn et al., 1982) were applied to the TM color composite. In the reverse transform to the RGB (red, green, and blue) domain, the intensity and the saturation channels were replaced by the aerial photograph and by the TM-1 band, respectively. The objective of such procedure was to generate an image with high spatial resolution and spectral information retained from the TM bands. The replacement of the saturation channel by the TM-1 band was to enhance the areas of hydrothermal alteration, because this band presents the best contrast between altered and unaltered materials (Figure 2). The resulting hybrid product with the spatial resolution of the aerial photograph and the spectral information derived from the Landsat TM bands facilitated the identification of the areas of hydrothermally altered materials, and the mapping of the main faults that cut across the study area.

In order to produce a generalized map showing the main lithological/physiographical domains present in the study area, a segmentation technique that uses a region growing method was applied to the hybrid images. A segmented image was obtained which showed a number of homogeneous regions whose pixels can be assumed to belong to the same class. The segmented image was classified using a supervised region classifier method which identified four different classes of homogeneous regions. Field data were used to identify each classified region. Based on the classified image a map of the study area was produced (Figure 3) which showed a very accurate delineation of the areas of hydrothermally altered materials.

5. CONCLUSIONS

The results showed that a simulated natural color composite of Landsat-TM images was a very efficient tool to map hydrothermally altered materials in vegetated terrains. For the natural conditions of the study area, target areas were discriminated even when vegetation covered up to 60% of the terrain surface.

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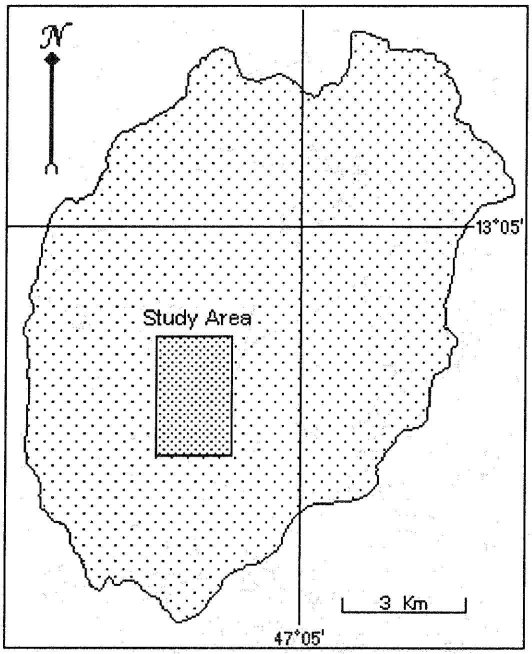

Figure 1 - Location of the study area within the Serra do Mendes granitoid.

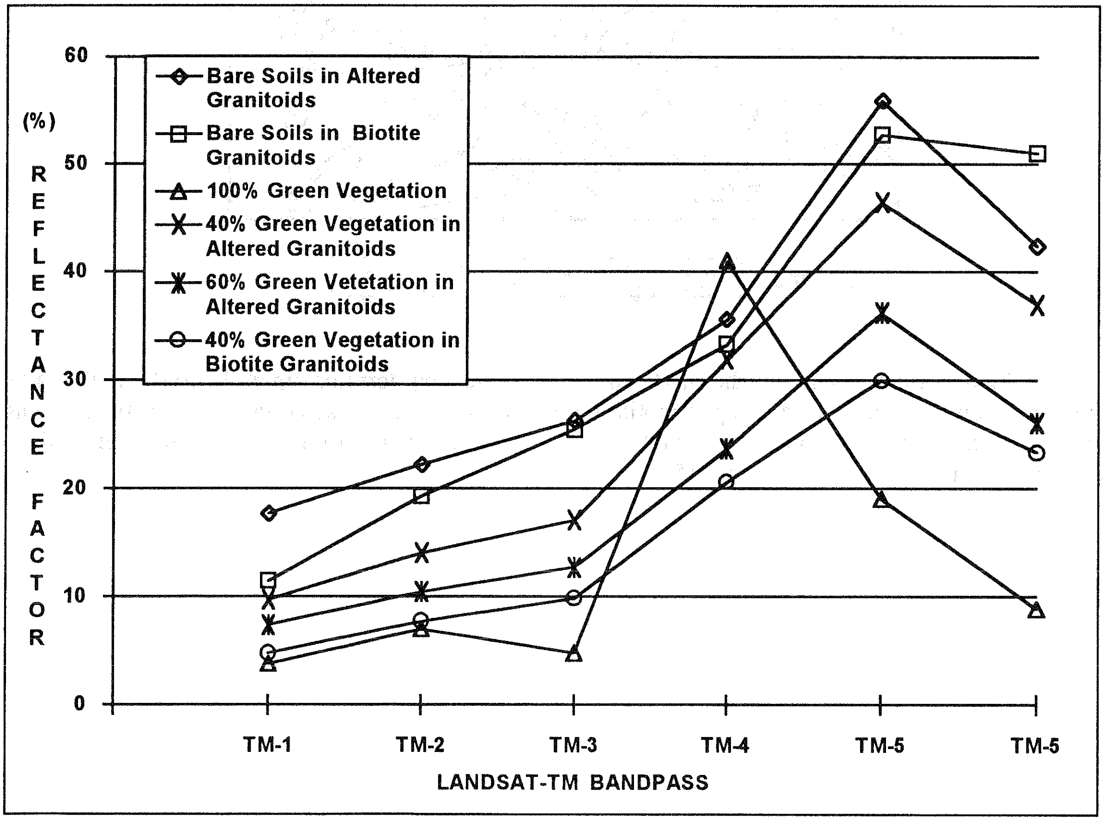

Figure 2 - Field spectra data for different assemblages of soil-vegetation (herbaceous plants) in the study area.

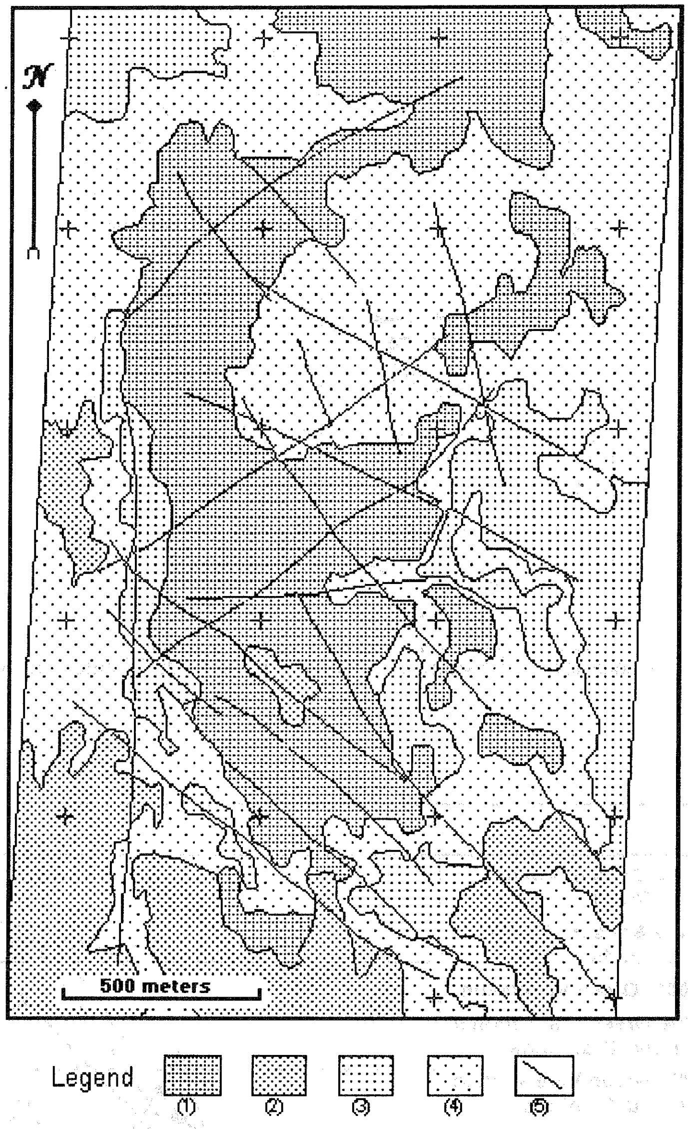

Figure 3 - Phytogeologic map of the study area: low-vegetated terrains upon hydrothermally altered materials (1); low-vegetated terrains upon biotite-granite-derived lateritic soils with duricrusts (2); densely vegetated terrains upon biotite granite-derived soils (3); low-vegetated terrains upon biotite granite-derived soils (4); and fault cutting across the area (5).