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Use of ASTER short-wave infrared bands for the spectral discrimination of hydrothermally altered-materials: evaluation in a tropical savannah environment

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Abstract. ASTER data were used to evaluate the spectral discrimination of hydrothermally altered materials. The study area (Serra do Mendes granitoid) is located in Central Brazil. The vegetation is characterized by the presence of tropical savannah (the Brazilian Cerrados). The Spectral Angle Mapper (SAM) technique was used to detect the presence of hydroxyl-bearing minerals (*e.g.* kaolinite and K-micas) in the alteration zone. Results showed that the mineral detection was restricted to a small number of pixels of exposed altered materials. The presence of a sparse grass cover in the alteration zone produced a slight increase in the SAM classification angles and the replacement of the 2200 nm hydroxyl absorption band by the lignin-cellulose spectral feature.

Key-words: ASTER-SWIR, Spectral discrimination, altered materials

1. Introduction

Some minerals associated with hydrothermal processes (*e.g.* kaolinite and K-micas) usually show spectral features that allow their remote identification (Clark, 1999). Remote sensing detection of these minerals has been conducted in arid and semi-arid terrains. In such terrains, large exposures of geologic materials allow the acquisition of spectral information directly from rock-soil assemblages. However, in tropical environments, the presence of vegetation usually alters the spectral expression of the underlying geologic substrate (e.g., Bierwith, 1990; Crippen and Blom, 2001). Thus, the remote measurement of the absorption bands on a per-pixel basis depends on the degree of exposure of the remotely sensed geologic materials and on the effects of the green and dry (non-photosynthetic) vegetation on their spectral responses.

The objective of this work was to evaluate the use of the short-wave infrared multispectral bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) to detect hydrothermally altered materials (albitized-greisenized facies) in the Serra do Mendes granitoid. The study area comprises a tropical savannah environment (the Brazilian Cerrados) in Central Brazil. The influence of vegetation cover in subduing the appearance of the hydroxyl absorption bands in pixel spectra is discussed.

2. Study area

The Serra do Mendes granitoid is located in the northern portion of the Goiás State, Central Brazil (**Figure 1**). The region has a tropical climate with an annual rainfall around 1500mm. The native vegetation cover is a savannah-like vegetation (the Brazilian cerrados).

The Serra do Mendes is one of the about twenty Late-Proterozoic granitoids of the Tin Province of Goiás, emplaced into Archean high-grade metamorphic rocks. It constitutes a dome rising up to 400m above the surrounding, composed of a dark-gray biotite-granite with a medium-to-coarse hypiodiomorphic granular texture. In the central part of the granitoid occurs an approximately 2km long by 1km wide north south oriented body of hydrothermally altered materials, which constitutes the study area.

Figure 1 shows the major phytogeological units present in the study area, according to a field classification criterion adopted by Almeida-Filho and Vitorello (1997), based on terrain characteristics. According to Almeida-Filho et al. (1996) and Almeida-Filho and Vitorello (1997), the hydrothermally altered body comprises a light-gray albitized-greisenized muscovite-granite.

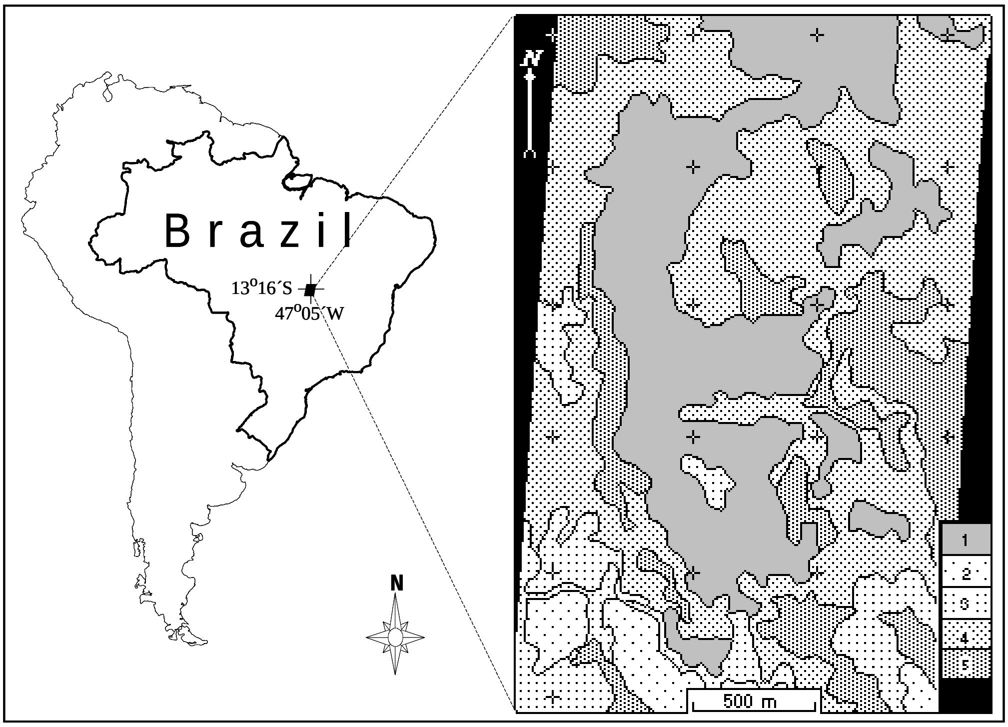

Figure 1. Phytogeological map of the study area (modified from Almeida-Filho et al., 1997). Grey indicates areas of hydrothermally altered materials. The legend is: (1) poorly-vegetated terrains upon hydrothermally altered materials; (2) low-vegetated terrains upon lateritic soils and duricrusts derived from biotite-granites; (3) vegetated terrains upon biotite granite-derived soils; (4) densely vegetated terrains upon biotite granite-derived soils; and (5) densely vegetated areas along streams.

3. Methodology

ASTER scene in the study area was collected on August 2, 2000, at the peak of the dry season. To preserve the spectral characteristics of the SWIR bands, the VNIR bands were spatially resized (nearest neighbor algorithm) to match the spatial resolution of the SWIR bands. The SWIR bands were corrected for the crosstalk effect (Rowan and Mars, 2003) by using the crosstalk correcting software provided by ERSDAC (2001).

The Atmospheric Correction Now (ACORN) software (Imspec, 2001) was used to minimize scattering and atmospheric absorption effects, that is, to convert ASTER data into surface reflectance images.

The Spectral Angle Mapper (SAM) technique (Kruse et al., 1993) was applied to test the spectral similarity between pixel spectra and mineral reference spectra for kaolinite (PS-1A) and muscovite (PS-16A). The reference spectra were extracted from the National Aeronautics and Space Administration/Jet Propulsion Laboratory/ (NASA/JPL) spectral library, and were re-sampled to the same ASTER bands widths, using filter functions. Similarities between image spectra and reference spectra were calculated. Small SAM angles indicate great similarity between pixel spectra and reference spectra. Bands 5 to 8, around the 2200 nm diagnostic hydroxyl absorption band, were used in the analysis.

To enhance variations in the depth of the 2200 nm absorption bands on a per-pixel basis, the continuum removal method (Clark and Roush, 1984; Clark, 1999) was applied on bands 5 to 8. The impact of the vegetation cover on the retrieval of 2200 nm absorption features of hydroxyl-bearing minerals was estimated, from a spectral mixture modeling (Adams et al., 1986). A simple three-endmember model (green vegetation, soil, and shade) was selected to characterize the land cover components. For endmember selection, a semi-automatic procedure, based on the sequential use of the minimum noise fraction (MNF) and pixel purity index (PPI) techniques, was applied to the surface reflectance values of the ASTER VNIR-SWIR bands (Green et al. 1988, Boardman and Kruse, 1994). Endmembers were selected from the inspection of extreme pixel spectra extracted from PPI and projected as points in *n*-dimensional scatter plots of the higher-order four MNF images.

4. Results and discussion

The spatial distribution of the major scene components can be visualized in **Figure 2.** In this figure, brighter pixels represent greater endmember abundance. In the green vegetation fraction image (**Figure 2a**), the brightest pixels correspond to the riparian forest and other areas of dense savannah vegetation cover. In the soil fraction image (**Figure 2b**), the area of hydrothermally altered materials indicated in the phytogelogical map of the **Figure 1** is well delineated. Shadowed vegetated terrains associated with biotite-granite are represented by bright pixels in the shading fraction images (**Figure 2c**).

Figure 3a shows results of the application of the SAM technique to map pixels with occurrence of hydroxyl-bearing minerals (kaolinite) in the altered zone. In **Figure 3a**, smaller angles indicating greater similarity between ASTER SWIR-derived spectra and reference spectra from NASA/JPL spectral library. **Figure 3b** shows variation in the depth of the 2200 nm absorption features associated with hydroxyl-bearing minerals in the altered zone. Variations in depth of the 2200 nm hydroxyl absorption band, obtained from the continuum removal method, indicated only small number of pixels with well-defined 2200 nm absorption bands. These pixels correspond to red colors in **Figure 3b**.

In general, the deepest 2200 nm absorption bands in ASTER pixel spectra were associated with high soil fraction and low SAM angle values (all the red colored pixels in **Figures 3a, 3b and 3c**). SAM angle values lower than 0.045 radians in **Figure 3a** correspond to pixel spectra with well-defined 2200 nm hydroxyl absorption bands in **Figure 3b**, whereas values higher than 0.045 comprise mainly pixel spectra with non-photosynthetic vegetation spectral features instead of hydroxyl-bearing mineral features.

The presence of a small number of pixels with well-defined 2200 nm absorption band in pixel spectra is due to the influence of the non-photosynthetic vegetation (dried-out grass) that subdues the expression of this spectral feature. This causes large SAM angles or dissimilarity between pixel spectra and reference spectra, mainly by replacing the 2200 nm hydroxyl absorption band by the 2100-2300 nm lignin-cellulose spectral features.

5. Conclusions

Results showed that the detection of hydroxyl-bearing minerals in the alteration zone of the Serra do Mendes granitoid with ASTER SWIR data was highly dependent on the spectral effects of vegetation (either green and non-photosynthetic vegetation) on the reflectance of the substrate. The presence of a grass cover over the substrate produced the replacement of the 2200 nm mineral absorption band by the lignin-cellulose spectral feature and restricted mineral detection to a small number of pixels with well-defined hydroxyl absorption band.

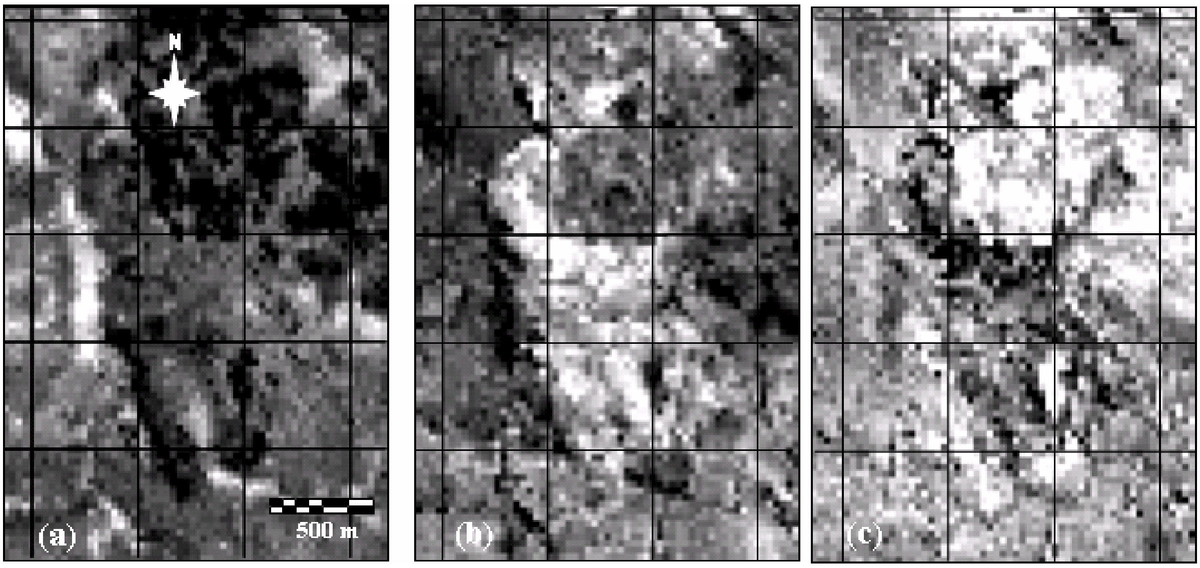

Figure 2. Fraction images derived from the spectral mixture modelling: (a) green vegetation (riparian forest); (b) soil (lithosols in the alteration zone); and (c) shade (shadowed vegetated terrain over biotite-granite).

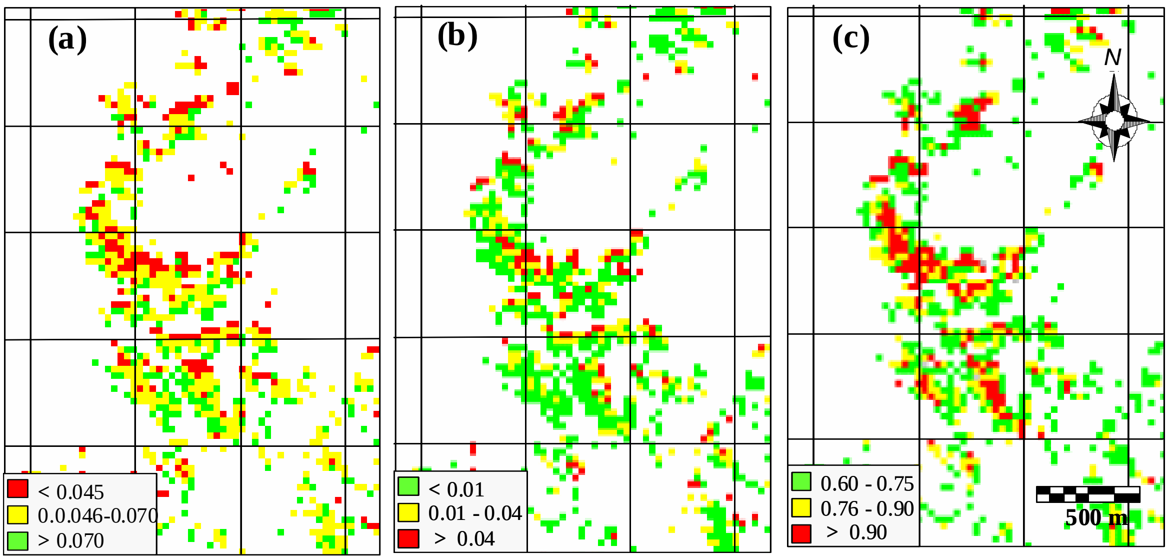

Figure 3. (a) SAM classification results for kaolinite; (b) variations in depth of the 2200 nm absorption band; and (c) soil fraction image enhancing pixels with abundance values higher than 0.6. Results are presented for the alteration zone.

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