Integral Spectral Analysis (ISA) Applied to AVIRIS Data for Manganese Mineralized Laterites in São João da Aliança /GO, Brazil

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1 INTRODUCTION

In Brazil, the lateritic mantle covers nearly 65% of its territory (Melphi *et al*., 1988). There lateritic process is responsible for metal accumulation in several areas. The products of the weathering of different rocks constituted important ore deposits.

The most important deposits are **iron-manganese**, from Archean to Neoproterozoic age (Carajás/PA, Quadrilátero Ferrífero/MG, Urucum/MT, Serra do Navio/AP); **aluminum**, from Cretaceous Alkaline massifs (Southeast), Tertiary continental sediments (Trombetas-Paragominas and Jari/PA), Precambrian metamorphic or volcanic rocks (Central East) and **nickel,** by the weathering of ultramafic rocks (Barro Alto and Niquelândia/GO) (Melphi *et al*., 1988).

The objective aim of this paper is to show the results about the application of the hyperspectral analysis over mineral-target composed by supergenic manganese mineralization in a tropical country, utilizing espectroradiometry analysis and X-Ray Diffraction. The study area, characterized by middle deposits with high concentration of manganese, is located in S.João D'Aliança District of Goiás State (Baeta *et al*, 1977 and Guimarães, 1978).

Hyperspectral remote sensing data were acquired in some areas in 1995 using NASA's Advanced Visible and Near-Infrared Imaging Spectrometer (AVIRIS). This survey was part of SCAR-B (Smoke, cloud and radiation-Brazil), a scientific mission among NASA, the Brazilian Space Agency (AEB) and the Brazilian National Space Research Institute (INPE).

2 GEOLOGICAL SETTING

São João D'Aliança's District is located in the outer portion of Brasília Folded Belt, a major tectonic unit formed lately during the Brasiliano/Pan African orogeny. Brasília Folded Belt is north-south oriented along the occidental margin of the São Francisco Craton, crossing over states of Goiás and Minas Gerais.

Manganese deposits in São João D'Aliança District occur associated with lateritic processes over sedimentary rocks of the Paranoá Group (1.200–900 m.y.). This unit is a passive margin sequence constituted by conglomerates, sandstones, silstones and mudrocks with intercalations of limestones and dolomites (Dardenne, 1978, 1979; Faria, 1995).

3 METHODOLOGY

The methodology sequence applied is:

1 Selection of AVIRIS images related to target areas;

2 Atmospheric correction of images by Green method;
3 Selection of Extrema Mine as target priority (Fig. 1);
4 Field sampling for superficial materials;
5 Spectral and X-ray diffraction analysis; and
6 Processing of digital images with application of Integral Spectral Analysis (ISA).

Figure 1– Shows part of the Extrema-target with manganese and clay minerals exposed on the soil surface.

4 SPECTRAL BEHAVIOUR OF MANGANESE MINERALS

Massive manganese ore is a mixture of several different minerals, usually with psilomelane and pyrolusite (fig.2 and 3). Its spectra are opaque and spectrally featureless, due to a conduction band of MnO_2 extending throughout this spectral range (Hunt, 1971). Conduction band has electrons possessing so much energy that they are not attached to any specific atom, but are free to wander throughout crystal structures (Hunt, 1980).

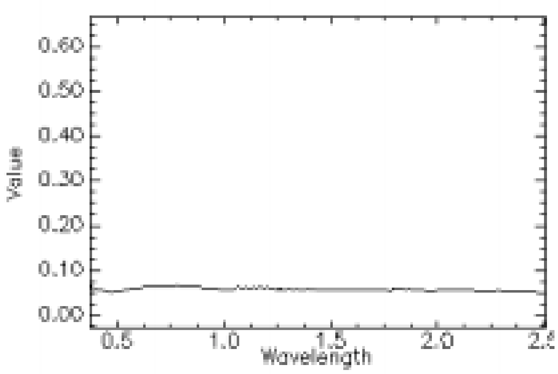

Figure 2 – spectrum of psilomelane

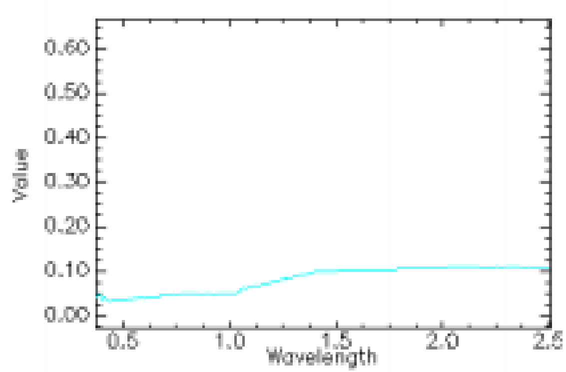

Figure 3 – spectrum of pyrolusite

In the Extrema-target, manganese minerals are commonly associated to clay minerals. The figure 4 shows a series of mixtures of ore manganese and clay minerals enhancing the effects of opaque absorption. Complementary study with X-ray diffraction was done for minerals assemblies identification (fig. 5). It demonstrates that a small amount of manganese minerals is very effective at reducing the reflectance and spectral contrast of the mixture. These results are consistent with previous studies of opaque and not opaque mineral assemblages (Pieters, 1973; Nash and Conel, 1974; Singer, 1981; Madeira Netto, 1991).

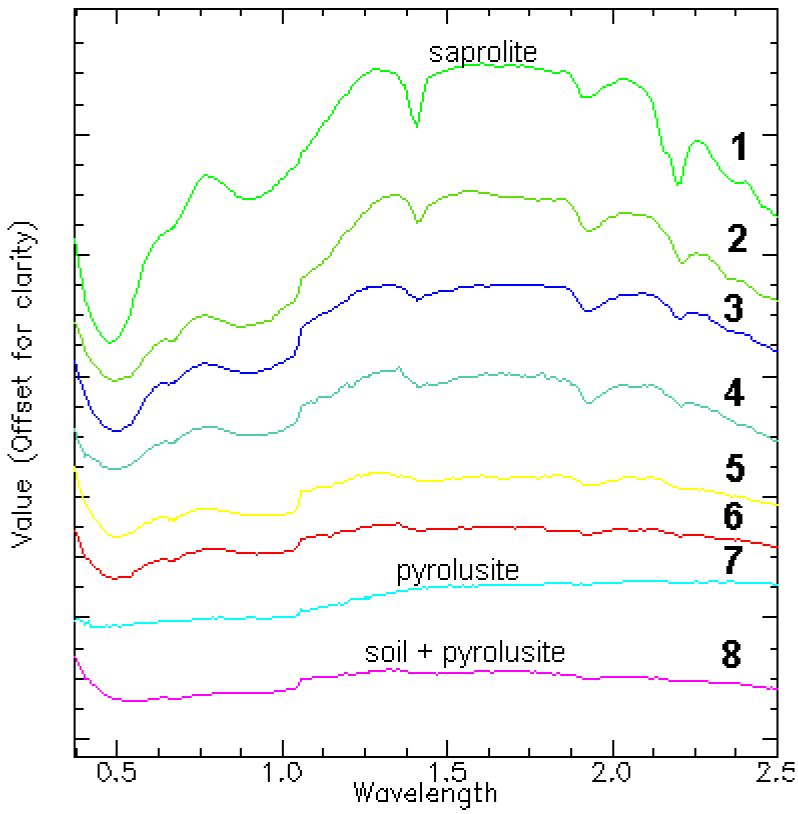

Figure 4 – Sequence of Spectral Curves for opaque and clay minerals.

5 INTEGRAL SPECTRA ANALYSIS (ISA)

Due to the lack of a specific absorption feature in the manganese ore spectral classification methods as Tricorder (Clark *et al*., 1990 and Clark & Swayze, 1995) and Spectral Feature Fitting (ENVI, 1997) are not effective. Diagnostic characteristics of manganese minerals is quite low reflectance throughout the spectral range.

So, a method was developed for identification of manganese minerals using spectrum integral. The integral of minerals manganese spectrum presents values lower than other materials. This fact is related to the material's reflectance. However, shade and other opaque minerals can provoke mistaken indications of manganese minerals. In this case, the association with other factors can be considered. As an example, slope relief might be utilized for indication of shaded areas.

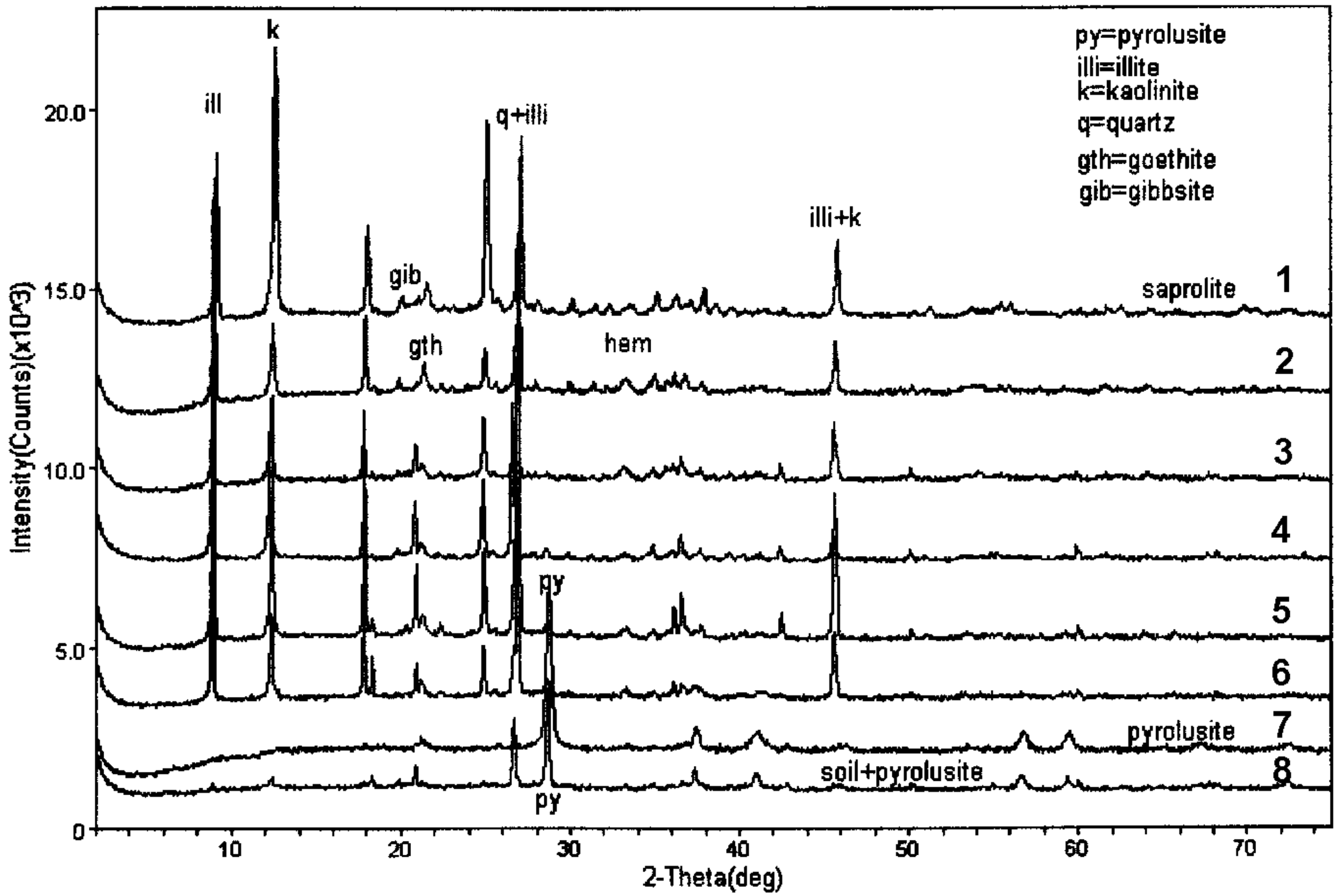

Figure 5 – Sequence of X-Ray Diffraction Analysis for opaque and clay minerals.

Spectral integral is the sum of reflectance intensity on bands multiplied by their respective FWHM:

$$\textbf{Spectral Integral} = \Sigma(R_b * FWHM_b)$$

Areas with opaque minerals present lower values of hyperspectral image. The direct integral sum for the spectrum with out atmospheric absorption bands presents great superposition on areas of shade. Shade interference at the target area is due to large areas covered with vegetation and irregular relief. To reduce that interference we had developed the following formula:

$$\textbf{Opaque Image Index} = \int_{0.82}^{1.28} \; * \; \textbf{abs} \; \left(\int_{1.47}^{1.77} - \int_{2.06}^{2.36}\right)$$

That formulation turns the shaded areas with vegetation into higher values than areas rich in opaque minerals. It is used in the context of study here presented. The density slice of image allows to identify opaque minerals.

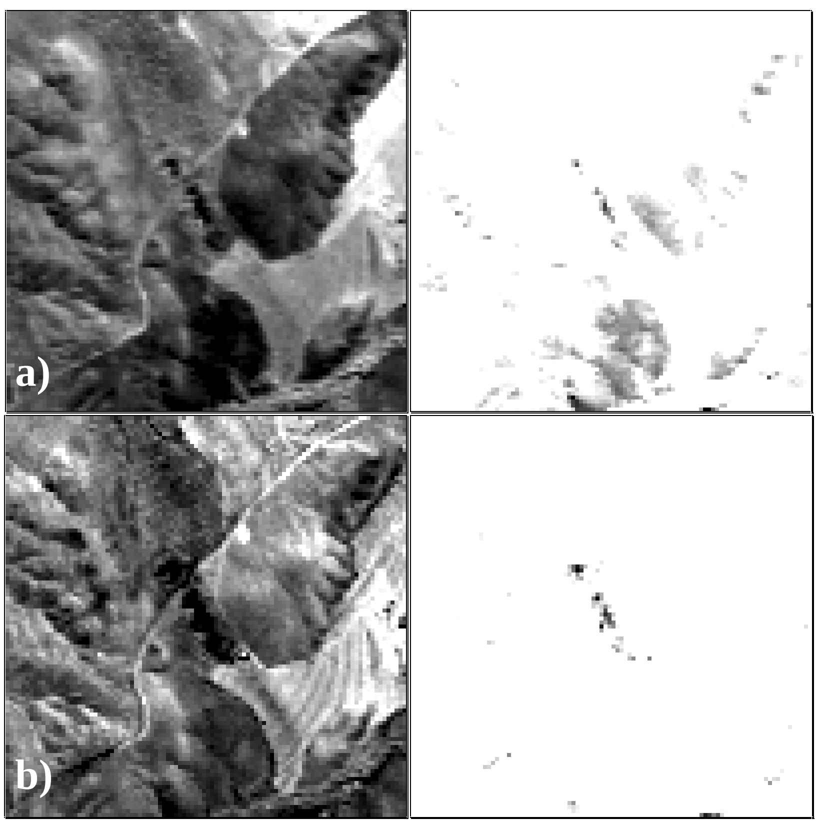

Figure 6 – a) spectral integral image b) opaque image index

The ISA method was implemented as an applicative for the ENVI program as an algorithm for the formulation of opaque images which improves softening of areas with vegetation and shading.

For areas with shading complexity and mineral mixtures we also use pre-defined points for the integral method. In these selected points it was made a mask and than applied in the MNF transform. This way pixels behave can be observed. At the present case one scatterplot of bands 1^{o} MNF and 2^{o} MNF enables to define different groups (fig.7).

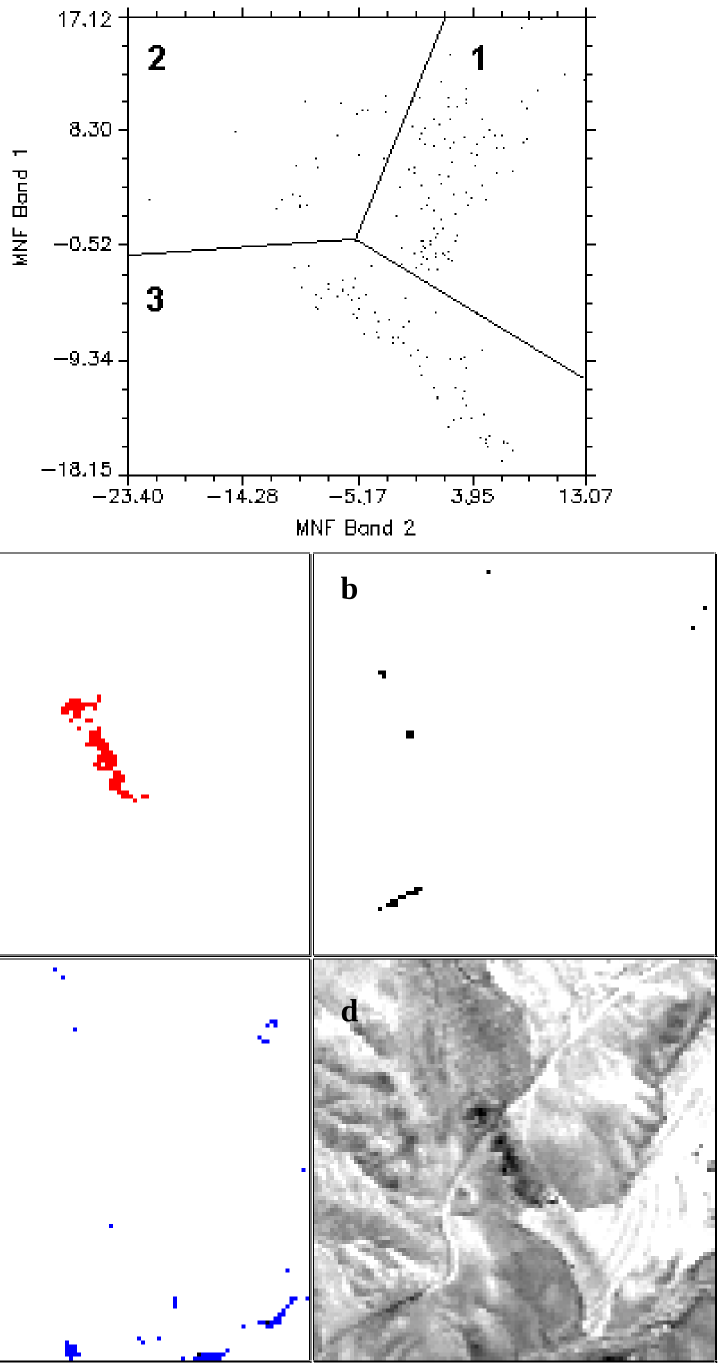

Figure 7 –MNF applying over pre-defined areas selected by ISA method allows to observe three distinct aspects: (a) area of manganese mine b) shaded area c) shade on vegetation area.

6 CONCLUSION

This combined X-ray diffraction / reflectance spectroscopy study opaque minerals showed that less percentual of manganese minerals (mainly pyrolusite) present on the soil surface of Extrema-target is sufficient to mask the digital values of clay minerals. This way, opaque minerals originated by lateritic process over sedimentary rocks can control the spectral curves pattern (conduction band) applied on imaging spectroscopy. Integral Spectral Analysis (ISA), here presented is an efficient method for mapping an opaque body (100m x 300m) in the Extrema-target.

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