USE OF DIGITAL IMAGES AS A MINERAL PROSPECTING TOOL IN THE TIN PROVINCE OF GOIÁS, BRAZIL

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ABSTRACT

This paper discusses the application of LANDSAT-TM images as an auxiliary tool for mineral prospecting in the Tin Province of Goiás, Central Brazil. Six granitoid massifs have been studied through multispectral/multiseasonal analysis of digitally enhanced images. The presence of locally specific geobotanical association has permitted the discrimination of albitized/greisenized facies in these granitoids. These metasomatically altered facies are important as lithological control of significant tin (cassiterite) mineralization in the region. Field check has indicated the occurrence of cassiterite in most of the target areas identified by the study. This fact has allowed to produce accurate maps which show potentially mineralized areas for each granitoid. Prospection for primary tin deposits in the region should be directed to specific target areas, which represent less than 5% of the total surface of the granitoids, resulting in substantial saving in time and cost.

1. INTRODUCTION

The synoptic view yielded by orbital remote sensing images has drive the use of these products basically to regional geological studies. In such studies, performed generally at a reconnaissance level, the main aim is to map the distribution of regional geological units and large faults. This picture is specially true under the Brazilian condition: a continental size country poorly geologically known. However, the continuous technological development of the orbital remote sensing devices (high spatial, spectral and radiometric resolutions), and the associated computer-aided digital images enhancement facilities, has allowed to change this sole approach. Thus orbital imagery have also been used as a strategic tool for mineral prospecting (Bernie and Francica, 1981; Darch and Barber, 1983; Almeida Filho, 1984; Conradsen and Hartpoth, 1984).

When orbital remote sensing images are used for mapping of potentially mineralized areas, the spectral response of the considered metallotects is the most important parameter to be taken into account. In most of the cases, such metallotects are stood for in the remote sensing data by complex rock-soil-vegeta

tion associations (sometimes with particular topographic features), which can subtlety be registered by multispectral data. Obviously such an approach is strongly dependent on the physiographic characteristics of the study area, which control the rock weathering and soil formation processes and the pattern of the native vegetation cover.

The Central and Northeast regions of Brazil, which is more than 3,000,000 Sq.Km wide in area, are greatly favorable to application of remote sensing techniques as described in the approach above. The regions present shallow soils, which in turn sometimes show closed association to the subjacent parent rock. The native vegetation cover is represented by "cerrados" (savannas) in the central area, and "caatingas" (dry savannas) to northeastern. The occurrence of specific rock-soil-vegetation associations in such a physiographic ecosystem, has enabled to use remote sensing techniques to obtain geological information through spectral data.

Within the context above the paper discusses the applicability of computer enhanced digital LANDSAT-TM images as mineral prospecting tool, based on the spectral discrimination of target areas favorable to the occurrence of cassiterite. These target areas correspond to the occurrence of albitized-greisenized facies in granitoid bodies of the Tin Province of Goiás, Central Brasil.

2. GENERAL CHARACTERISTIC OF THE STUDY AREA

The Tin Province of Goiás covers an area of 200 km by 100 km in the Central-East portion of Goiás State. The region has a tropical savanna climate with a summer rainy season (October to April), with an annual average precipitation around 1500 mm, and a dry winter (May to September). The mean annual temperature in the area is around 25^{0}C. The native vegetation cover is a savanna-like vegetation called "cerrado" in Brazil, which is characterized by sparsed small trees with twisted trunks and branches, shrubs, and a continuous grass mat covering the soil. The grass is very sensitive to the soil moisture, becoming vigorous soon after the first rains.

Geologically, the study area is part of the Central Brazilian Shield (Almeida et al., 1984), which is composed by high-grade metamorphosed rocks with ages greater than 2,600 m.a.. These rocks show a very complex geological evolution, with evidences of polymetamorphism effects and superimposed fracturing events. The Central Brazilian Shield is surrounded by the Uruaçuano and Brasiliano foldbelt , developed between 1,700 and 500 m.a. ago. The Uruçuano foldbelt is constituted mainly by pelitic and psammitic metasediments, including metabasites and tin-bearing granitoids . The Brasiliano event presents a so-called "miogeosynclinical" sedimentation type which was metamorphosed in greenschist facies.

Preliminary radiometric data discussed by Reis Neto (1983) show ages around 1,600 m.a. to the tin-bearing granitoid emplacement. Field relations show a complex evolution of these bodies,related

to the tectonic evolution of both Uruaçuano and Brasiliano fold-belts. The granitoids crop out in high-grade basement metamorphic rocks, and do not show thermal metamorphism effects. Cataclastic textures are frequently developed in the contact zones, and some granitoids show structural contacts with younger Upper Proterozoic metasedimentary rocks (Arai Group). The Granitoid bodies form coarsely circular dome-shaped landforms rising around 400 m relative to the surrounding metamorphic rocks. They are composed predominantly by pink to grey biotite-granite with an overall medium-to-coarse grained texture and local variations to aplitic and porphyritic ones. Some granitoids show metasomatically altered types, resulting in several facies which vary from typical greisens to slightly albitized/greisenized muscovite-granites. These types are enriched with cassiterite, and constitute important primary and colluvial/alluvial tin deposits in the region. Additionaly, columbite-tantalite and cassiterite deposits related to pegmatites and aplites are also known in the basement complex.

Around twenty granitoids have been mentioned to occur in the Tin Province of Goias (Araújo and Alves, 1979;Bettencourt et al., 1981). However, in this study only the granitoids of the eastern part of the Province are considered, which occur along with the Paranã river valley (Fig.1). Among these granitoids only the Pedra Branca and Passa-e-Fica have been geologically well studied (Padilha and Laguna, 1981). In the remainder granitoids occurrence of metasomatically altered facies were unknown (Almeida Filho, 1983).

3. METHODOLOGICAL APPROACH

Previous successful results on the spectral discrimination of potentially mineralized target areas in the Pedra Branca granitoid, using digitally enhanced LANDSAT-MSS images, have already been obtained (Almeida Filho, 1984). Thus, this granitoid was chosen as a model test-area to establish methodological procedures to be applied in the study of the remainder granitoids of the region.

The areas of occurrence of metasomatically altered facies in the Pedra Branca granitoid show particular superficial characteristics, which enable their discrimination through orbital remote sensing images. These areas are characterized by the occurrence of whitish lithosols with an upper cover of quartz fragments, which bear a specialized vegetation cover represented mainly by grass and shrubs. This rock-soil-vegetation association makes contrast to the "cerrado" vegetation occurring in the remainder of the granitoid. It was assumed that this geobotanical association in the Pedra Branca granitoid could occur for the others granitoids of the study area, since they have developed over similar geological and physiographic environments. The previous analysis in the Pedra Branca massif showed that the best discrimination of the target areas occured for images obtained in the end of the rainy season. Thus LANDSAT-TM images obtained on May, 10, 1984, under a solar elevation angle of 42°, were chosen.

The images were analysed in the IMAGE-100 Multispectral Image Analyser, with a grey scale of 256 levels distributed between zero (black) and 255 (white). The images were enlarged at a video scale varying between 1:75,000 and 1:50,000, depending on the size of each granitoid. As the target areas have specific rock-soil-vegetation associations, the TM4/TM3 band ratio was selected as the most suitable digital enhancement technique to be applied. Besides minimizing pixels shading effects related to the solar elevation angle and topography, ratio techniques between non-correlated channels are effective means to show percentage variation of soil vegetation cover. In the particular case of the granitoids bodies such variations should be related to geobotanical associations occurring in the potentially mineralized target areas. Using TM4/TM3 ratio images, target areas were enhanced by grey level slicer and superimposed on the contrast-stretched TM4-band. The use of this image as a background is necessary for geographic location of the target areas, since the ratio image subdues morphological features by minimizing shadowing effects. The ratio images were analysed in conjunction with RADAR imagery (photographically enlarged at scale of 1:75,000), aerial photographs (1:60,000), topographic charts (1:50,000); and light aircraft reconnaissance flights. This approach allowed a less expensive and more effective field checking phase.

4. RESULTS AND DISCUSSION

The Pedra Branca Granitoid.

The Pedra Branca granitoid is located just in the south-eastern corner of the study area (Fig.1). It is a dome 12 km long by 9 km wide, emplaced in the basement complex. Its east border makes structural contact with metasedimentary rocks of the Arai Group. The granitoid is predominantly composed by grey-to-pink biotite-granite with an overall medium-to-coarse grained texture. Several metasomatically altered rock-types varying from slightly albitized/greisenized muscovite-granite to typical greisens occur in the granitoid. They are controlled by a well-definded N20-30W faulting/fracturing system. The main area of albitites and greisens occurs in the "Bacia" area, a 4 km by 2 km basin-like depression in the western part of the granitoid. These metasomatites and their derived soils are rich in cassiterite, being the most important deposits known in the region.

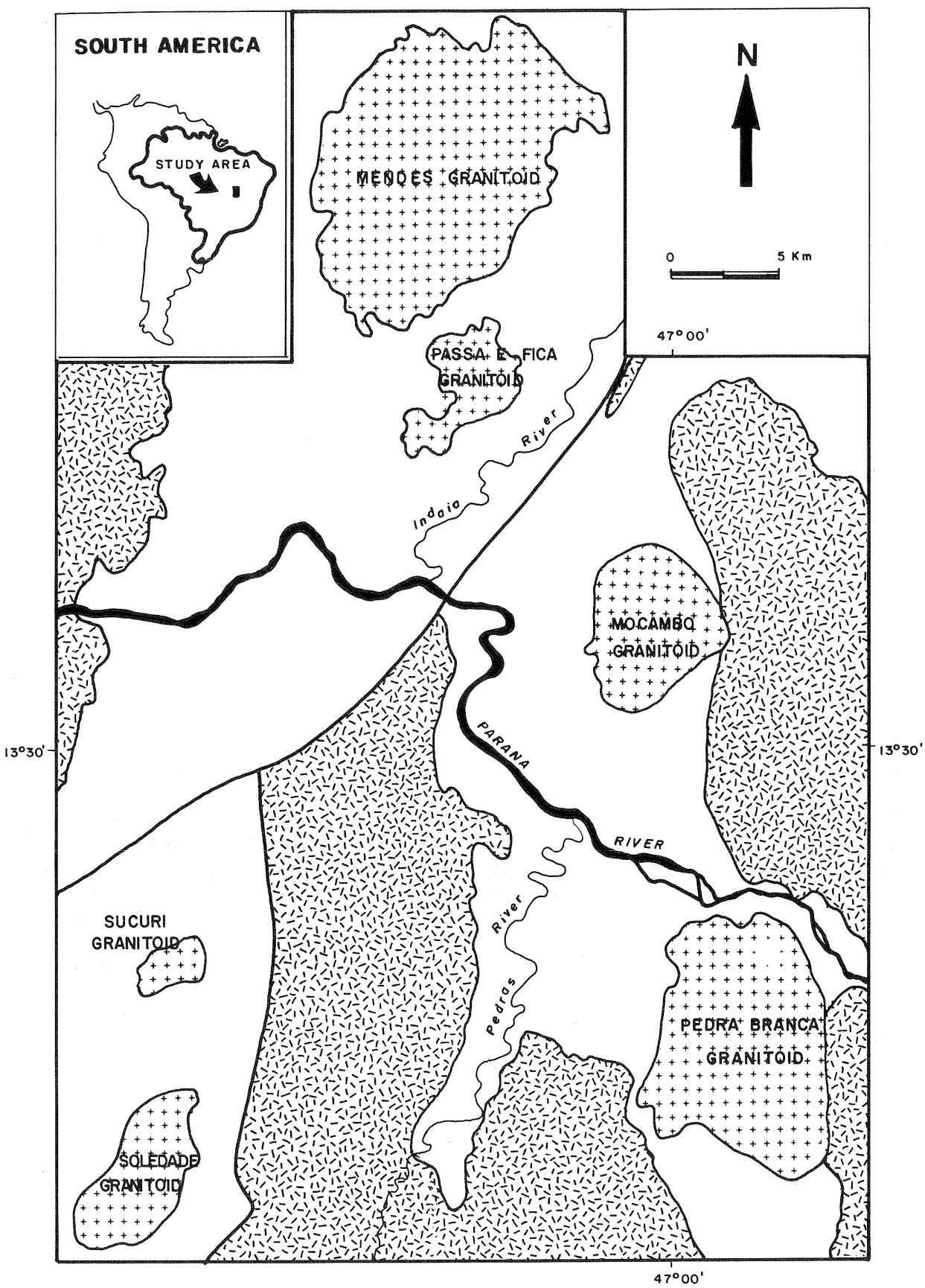

Fig 1 - GEOLOGICAL SKETCH MAP OF THE STUDY AREA :

- Stanniferous Granitoides
- Metasedimentary Covers
- Basement
- Regional Faults

Figure 2 is the contrast-stretched TM4-band indicating the potentially mineralized target areas (white spots) in the Pedra Branca granitoid. The extensive target area occurring in the western part of the granitoid correspond to the albitized/ greisenized muscovite-granites, in the "Bacia" area. The target areas in the south and south-eastern were previously unknown. Field works showed that they were also associated to the occurrence of metasomatically altered facies. A detailed discussion on the application of LANDSAT-MSS images in the Pedra Branca granitoid has already been presented previously (Almeida Filho, 1984).

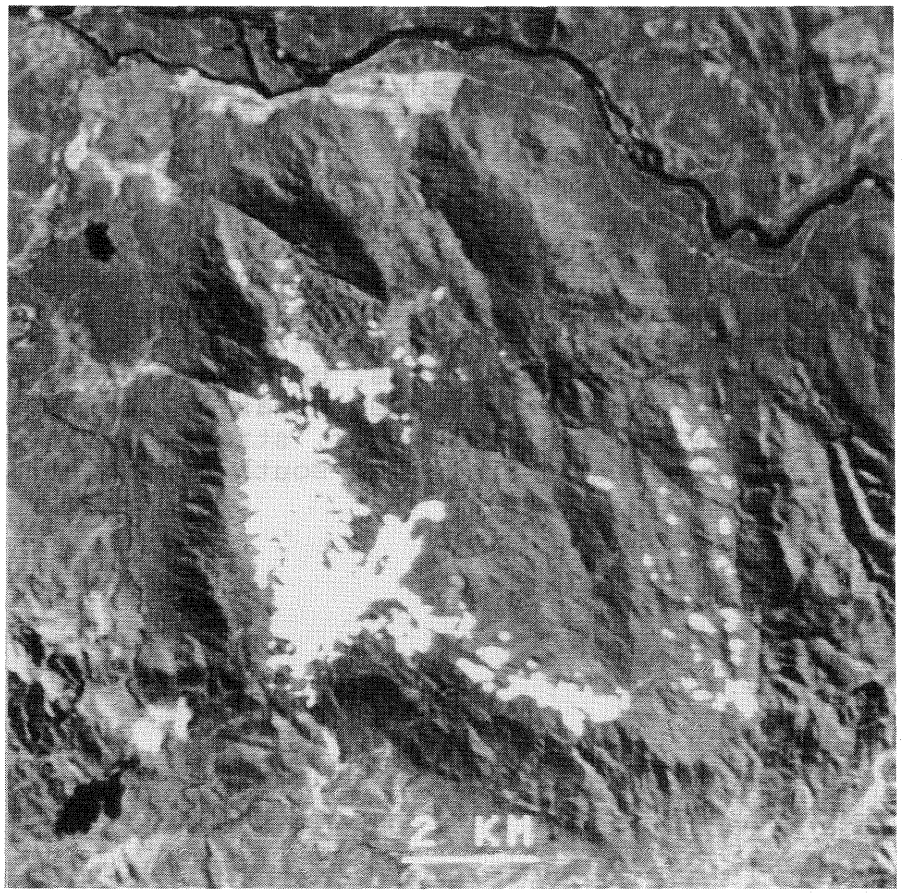

Fig. 2 - Potentially mineralized target areas (white spots) in the Pedra Branca granitoid.

The Mocambo Granitoid

The Mocambo granitoid is approximately 10 km north of the Pedra Branca massif (Fig. 1). It crop out in high-grade metamorphic rocks, being also in structural contact with metasedimentary rocks of the Arai Group. The granitoid has a coarse circular shape with diameter around 7 km. It is composed basically by pink biotite-granite with hypidiomorphic-granular texture, where euhedral to subhedral crystals of K-feldspar are predominant. The granitoid shows a well-defined faulting/fracturing system orientated around N50W. The Mocambo body is one of the less geolically known among the tin-bearing granitoids of the region. Metasomatic facies had no been noticed in this granitoid up to Almeida Filho (1983).

Figure 3 is a contrast-stretched TM4-band of the Mocambo granitoid, which shows target areas (white spots) indicated as potential to occurrences of tin mineralization. These spectrally anomalous areas are structurally controlled by extensive faulting/fracturing system cutting across the granitoid in the northwest direction. Field check at the target area in the central-north part of the massif, has shown rock-soil-vegetation associations like those previously described to the Pedra Branca granitoid. Preliminary petrographic analysis have confirmed albitized muscovite-granite and greisens (white mica quartz--greisen, topaz white mica-greisen, etc.) for this site. Additinally, chemical analysis have shown significant anomalous values to tin for those metasomatites. Up to now no field work has been carried out yet in the target areas of the eastern and western parts of the granitoid. However, stream-tin have been found along of streams which drain the southern target area.

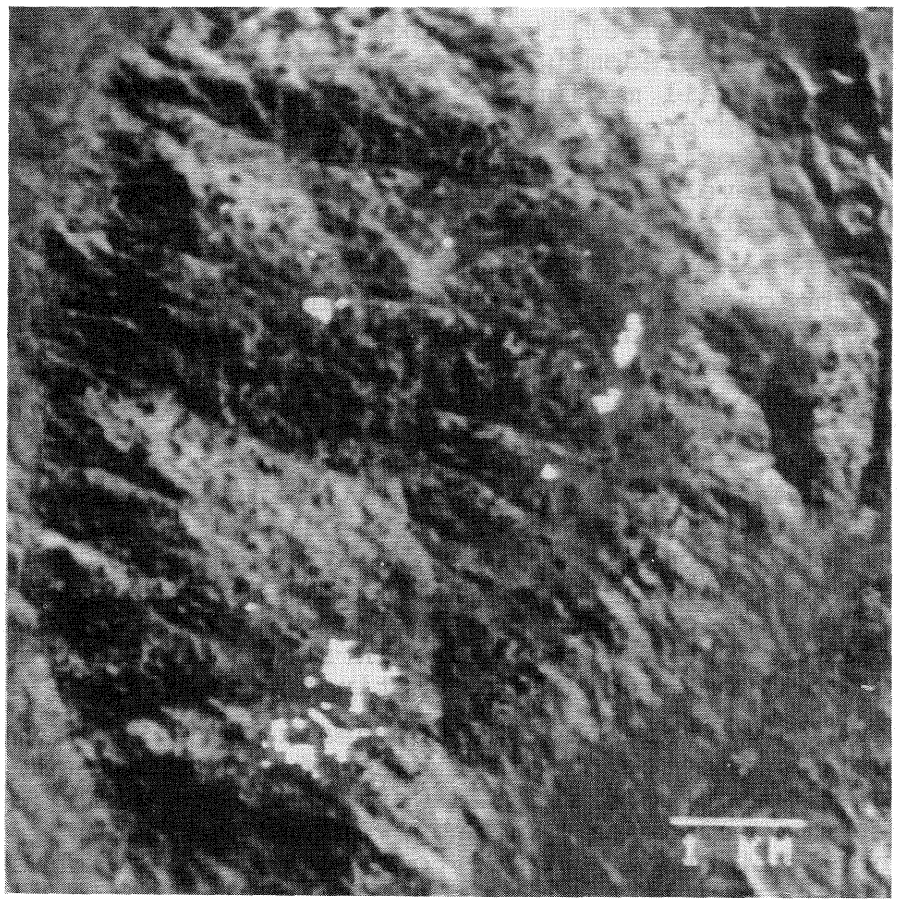

Fig. 3 - Potentially mineralized target areas (white spots) in the Mocambo granitoid.

The Mendes and Passa-e-Fica Granitoids

These granitoids occur in the north part of the study area (Fig. 1), emplaced in the basement complex. While the Mendes granitoid forms a dome 22 km long by 10 km wide, the Passa-e-Fica one seems to be a satellite stock of the Mendes granitoid. Both granitoids are predominantly composed by dark grey biotite-granite with a overall medium-to-coarse hypidiomorphic-granular texture. The Mendes granitoid shows a well-defined faulting/fracturing system orientated around N20W. This structural system displays strong development of cataclastic textures, and may include small occurrences of volcanic rocks, mainly rhyolites and rhyodacites.

Figure 4 is the contrast-stretched TM4-image of the Mendes and Passa-e-Fica bodies, and shows the target areas pointed out as suitable for tin prospecting. The anomalous areas in the Mendes granitoid form two main clusters in central and northeast parts of the massif. Field check at the central target area assured the occurrence of the same, already described, rock-soil-vegetation association. In this area a grey to whitish muscovite-granite predominates which shows the following visually estimated mean modal composition (% of volume): K-feldspar: 35%; albite: 30%; quartz: 25%; white mica: 8%; others: 2%. Some greisens facies (quartz mica-greisen, topaz mica-greisen) have also been found over there. Chemical analyses in rock samples from this area have shown anomalous values to tin and tungsten.

The extensive target area in the northeast part of the Mendes granitoid correspond to the occurrence of non-metasomatically altered rocks. Prior to the field work campaign, this area had already been discarded for tin prospecting. During the reconaissance flights it showed to have red-yellowish soils instead whitish ones like the target areas previously known. This red-yellowish stained area was classified by the TM4/TM3 band ratio because having also sparse vegetation cover developed on hardened ferruginous material.

The anomalous target area in the south part of the Passa-e-Fica granitoid (Fig. 4) has been exploited over the 70's by "garimpeiros" (manual prospectors). Field work carried out by DOCEGEO company (Padilha and Laguna, 1981) noticed the occurrence of muscovite-granite and greisens in this area, which hold tin mineralization and secondary occurrences of fluorite, topaz and sulfides.

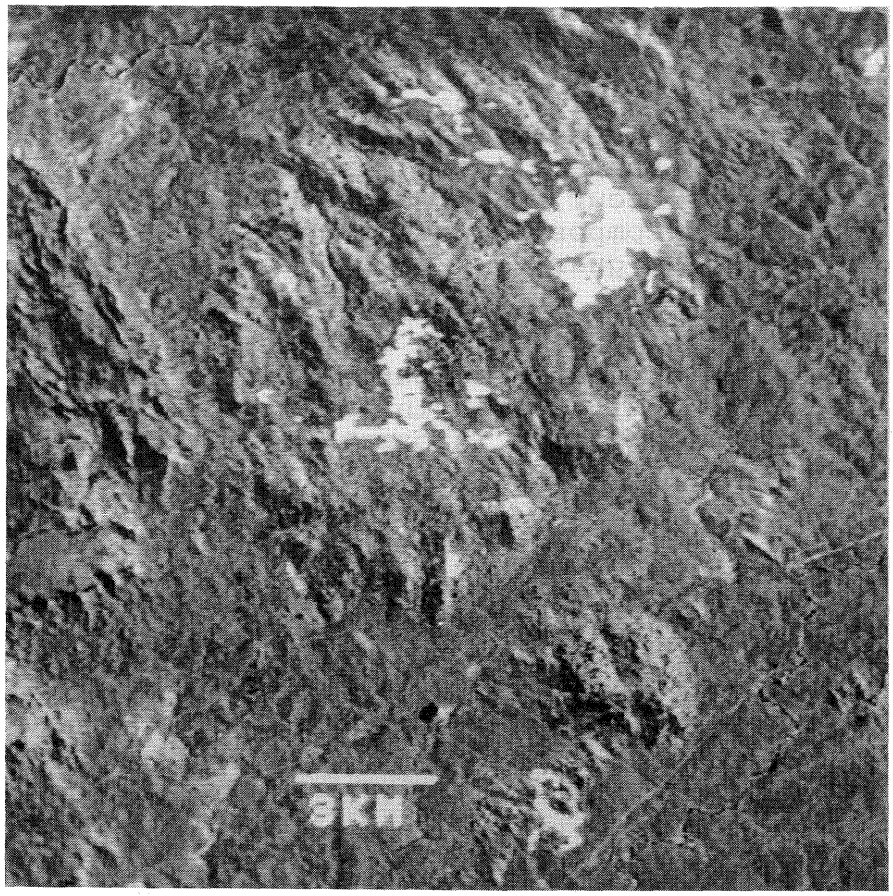

Fig. 4 - Potentially mineralized target areas (white spots) in the Mendes and Passa-e-Fica granitoids.

The Soledade and Sucuri Granitoids

Soledade granitoid occurs just in the southwestern corner of the study area, emplaced in high-grade metamorphic rocks of the basement complex (Fig. 1). Digital image analysis processing techniques has allowed to enhance spectrally anomalous areas in the central part of this body (Fig. 5). In spite of having vegetation cover with similar characteristics to the albitized/ greisenized areas, field works showed non-existence of metasomatites types there. In this area extrusive rocks with granophyric textures occur, which have the following visually estimated mean modal composition (% of volume): K-feldspar: 30%; Na-plagioclases: 30%; quartz: 23%; biotite: 12%; and epidote 5% .

The Sucuri granitoid is a small stock situated 5 km north away from the Soledade one (Fig. 1). It is a grey to pink biotite-granite with medium-to-coarse texture. Significant anomalous target areas have been indicated in north part of the stock (Fig. 5). Up to present field information has not been carried out from these areas.

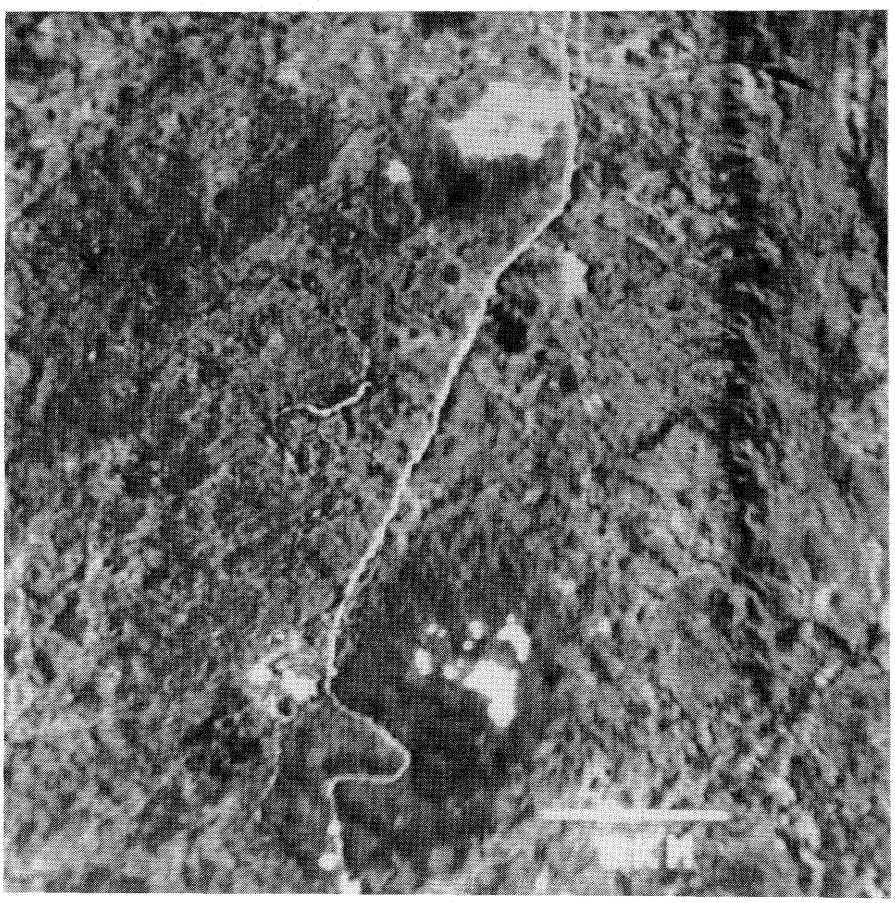

Fig. 5 - Anomalous target areas (white spots) in the Soledade and Sucuri granitoids.

5. CONCLUSIONS

Specific superficial characteristics of the studied areas (vegetation cover and soils controlled by the subjacent lithology) have permitted the spectral discrimination of the target areas related to the occurrence of albitized/greisenized rocks with cassiterite. It was possible to produce accurate thematic maps of these potentially mineralized areas to each analysed granitoid body. Thus, prospection for primary tin deposits in the region may be constrained to the delineated target areas, which are less than 5% of the total surface of the granitoids, resulting in substantial saving in time and cost.

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