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        These summaries present some of the recent researches done at
INPE in the area of geology focusing on the applications of LANDSAT
imagery for the survey of mineral resources.

17.Remarks

INDEX

STUDY OF RADIOACTIVE MINERAL DEPOSITS IN POÇOS DE CALDAS BY LANDSAT IMAGERY

Raimundo Almeida Filho
Waldir Renato Paradella

The Poços de Caldas alkaline massif concentrates the largest uranium deposits in Brazil and represents, from the geological point of view, a reazonably studied area.

Visual and automatic interpretation of multispectral LANDSAT images permitted the disclosure of new and important controls of the radioactive deposits (Uranium and Thorium) in the region.

It was verified that the known radioactive anomalies and mineral occurrences are located mainly around secondary circular structures associated with the development of caldera (Figs. 1 and 2). These internal circular structures and the associated faults provided favorable zones of weakness through which the mineral solutions were percolated. The interpretation results agree with available geological, altimetric and geophysical data.

The identification of several other circular structures, inside the main caldera, is highly suggestive as a guide for the prospection of new deposits in the area and in other similar complexes.

Fig. 1 - The Poços de Caldas Alkaline Massif and the internal circular structures enhanced by contrast stretch (Image-100).

Fig. 2 - The internal secondary structures of the Poços de Caldas Complex enhanced by the Image-100, using vegetation as training areas (yellow).

AUTOMATIC INTERPRETATION OF LANDSAT MULTISPECTRAL DATA
FOR THE PROSPECTION OF CLAY DEPOSITS

Raimundo Almeida Filho
Waldir Renato Paradella

This work was carried out with the objective to test the applicability of automatic interpretation of LANDSAT MSS data for location of new deposits suitable for use in the ceramic industry.

LANDSAT MSS computer compatible tapes were analyzed in the Image-100 multispectral analyzer. The Poços de Caldas area, where important clay deposits are known to occur, was selected as a training area. Spectral characteristics were obtained by single and multi-cell signature acquisition techniques. The results obtained for the Poços de Caldas area are displayed in figure 1, where the yellow color corresponds to the clay deposits of economic interest.

The spectral signatures obtained for the Poços de Caldas area were applied to the Rio Claro - Pindaíba - São Pedro area, where the geological setting is favourable for the occurrence of similar deposits. Figure 2 shows the results obtained where the yellow spots along the drainage lines corresponds to clay occurrences confirmed by later field checks.

The results obtained are very suggestive for the use of LANDSAT data for prospecting of industrial minerals and rocks.

Fig. 1 - Poços de Caldas Alkaline Complex. Yellow color indicates areas of clay occurrences. Approximate scale 1:250,000.

Fig. 2 - Rio Claro-Pindaiba-São Pedro region. The small yellow spots along the main drainage lines indicate potential areas for the prospection of clay occurrences. Approximate scale 1:100,000.

APPLICATION OF LANDSAT IMAGERY TO REGIONAL GEOLOGICAL MAPPING OF THE BRAZILIAN AMAZON REGION

Gilberto Amaral[*]

As an attempt to establish a scheme for the geological development of the shield areas within the Brazilian portion of the Amazon region, the author has carried out the interpretation of 80 LANDSAT scenes and 120 mosaics of radar imagery. Ground truth was provided by literature analysis and field work in test areas. As a result, a map at the 1:5,000,000 scale was produced, covering an area of about 4 million sq. km. This map, shown in figure 1, presents the main geologic units and their structures. With this map, and near 300 geochronological determinations, it was possible to determine the sequence of events that affected the region during the Precambrian. Iron and manganese bearing metasediment ary rocks were easily mapped. An important episode of acidic to indermediate volcanism was identified and mapped. It is considered the largest known volcanic event of this type that occurred during the Precambrian. It is associated with several occurrences of tin, wolframium, niobium, gold, copper, lead, zinc and molybdenum, being the economically most important unit of the region. Tin bearing granites and nickel and chromium bearing ultrabasic rocks were also identified. Flat laying Precambrian sedimentary sequences were easily mapped which are associated with high grade manganese deposits.

Three months of work were necessary for the analysis of the imagery and preparation of the final map. This map, with the respective report, has been used, since 1974, as a reference frame for other detailed geological work being done on the region.

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Fig. 1 - main geologic units and their structures.

AUTOMATIC INTERPRETATION OF LANDSAT IMAGERY FOR PROSPECTION
OF MINERAL DEPOSITS IN THE AMAZON REGION

Gilberto Amaral [*]

The purpose of this project is to evaluate the potential-
ities of LANDSAT imagery for the location of new mineral deposits in the
densely forested portion of the Amazon region. As a first approach, three
test sites were selected, all with known mineral deposits. The first one
was the Serra dos Carajás area with the largest brazilian iron deposits
(20 billion tons of high grade ore). A very clear association between
supergene ore and vegetation is known to occur, and is clearly discernible
in photographic images. However, newly deforested areas present the same
visual pattern. An attempt was made to use automatic interpretation
(Image-100) for discriminating only the ore bearing areas. The results
are shown in figure 1, which presents the iron bearing zones in green.
The only interferences were observed in parts of the main rivers of the
area and can be easily eliminated by visual analysis. The automatic
interpretation parameters obtained in this way will be used for
prospecting similar deposits in potentially favorable areas in other
parts of the region.

The second test site was the Xingu River valley, where tin-
bearing alkaline granites are known to occur. These granites are rich in
potassium,and soil cover is thinner than other types of granites. This
results in clear differences in vegetation cover. Shape of intrusions,
tonal differences and morphological aspects are strong aids for visual
interpretation. Similar results were obtained by automatic interpretation.

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Fig. 1 - iron bearing zones.

when ratioing of channels 5 and 7 was used, enhancing the contrasts among these granites and other ones.

The third selected area was the Oriximinã region at the Trombetas River valley, where 200 billion tons of bauxite deposits are known to occur. A subtle tonal difference was observed by visual analysis of images of band 7, associated with a characteristic morphology (table mountains). Automatic analysis did not present the same results because large areas of lowlands were interpreted as bauxite bearing areas. A preliminar interpretation of such results is the erosion of bauxite from the table mountains and deposition in the lower portions. This project is being continued with analysis of imagery obtained in different seasons, where the relations among vegetation and ore are better displayed.

The results obtained up to the moment are very encouraging and the project will be continued for manganese and nickel deposits.

GEOLOGY OF RIO DE JANEIRO STATE BY LANDSAT-1 IMAGERY

Liu Chan Chiang
Paulo Roberto Menezes

Rio de Janeiro State is situated in the south-east coastal region of Brazil. The extremely stressed Precambrian complex is distributed in the whole state and is composed of various kinds of gneisses, migmatites and igneous intrusives. In the last two decades, different aspects of geological research and field surveys have been carried out in several specific portions of the state, but because of the difficulty of differentiation of the lithological mapping units and delineation of the regional structural features, only a synoptic view as the one provided by the LANDSAT system allowed the construction of a geological map covering the whole state. The advent of the remote sensing technology, especifically the LANDSAT system, made it possible for the mapping of such a broad region in a short period of time, especially under the requirements of economy, be carried out.

The state is covered by eight MSS frames. Only visual interpretation using the bulk images (4 bands) in the scale of 1:500,000 were used. The following features were considered in the interpretation of the images: topography, drainage patterns, distribution and density of vegetal coverage, land use and gray levels (tones).

The Precambrian complex distributed in the state is divided into three large groups named the "Indetermined Precambrian Complex", the "Paraíba do Sul Group" and the "Serra dos Orgãos Group". This division is based mainly on the major topographic differences and is coincident to the existing geochronological studies (Cordani et alii, 1968-1973) and the history of the tectonic events. Except for the "Indeterm ined Precambrian Complex", the "Paraíba do Sul Group" and the "Serra dos Orgãos Group" are still subdivided into three units. These subdivisions were made by the analysis of the image feature such as topographic varieties, the drainage anomalies, and the contrast of gray levels. Other wise, marble has been recognized at some places in the state. It is

massive crystalline granular rock composed of calcite grains. The imagery
also shows very well the igneous intrusive bodies along the "Serra do Mar"
mountain range and the sedimentary accumulations of different depositional
environments on the coastal plain and along the coast. All the aerogeologic
mapping units were checked in the field and are in agreement with the
lithologic differences.

The LANDSAT imagery shows a clear picture of various struc
tural patterns of the numerous lineaments of diverse trends. Along the
broad Paraíba do Sul river valley, where the Paraíba do Sul Group is
distributed, two principal sets of structural lineaments can be examined.
One of them is longitudinal and shows the principal structural trend
extending from São Paulo state in a general direction of $N60^{o}-70^{o}E$ parallel
to the river valley. Another set of structural lineaments is transverse,
striking diagonally or perpendicularly the longitudinal lineaments. Along
the "Serra do Mar" mountain range, where the "Serra dos Orgãos Group" is
distributed, the structural lineaments can be grouped into three sets,
which trend in directions respectively around $N45^{o}W$, $N40^{o}E$ and $70^{o}-80^{o}W$.
Some of these lineaments extend into the Paraíba do Sul river valley,
intersect and displace those longitudinal lineaments as well as those
transverse lineaments. The broad coastal plain region is almost topographic
ally featureless because it is well denuded and covered by various deposits
having structures that are concealed and hard to be examined. However, a
general linear trend in a direction around $N60^{o}-70^{o}E$ can also be observed
by comparing the four bands. In the area of study, numerous fault lines
could be inferred by any of the following categories:

- straight or smoothly curved scarps;
- different mapping units contacting with rather straight
  or smoothly curved scarps;
- different mapping units contacting with straight or
  smoothly curved lines;
- truncation of mapping units along a line.

From the differentiation of the rock units and the

delineation of the structural lineaments, the occurrence of marble was clarified. The great deposits of marble occur in regions where the Unit $P\mathcal{E}_b$ and Unit $P\mathcal{E}_c$ of the Paraíba do Sul Group are distributed. These marble deposits form lentils interspaced or inbedded with gneisses, and are parallel to the main structural trends in the Paraíba do Sul river valley.

This work, which included the following phases: analysis and interpretation of the imagery, construction of the preliminary interpretative geological map, study of the existing geological works, field checking, construction of the final geological map and the writing of the report, took only six months, which proves that the LANDSAT imagery is an effective, economical and practical remote sensing tool for regional geological study.

Fig. 1 - Geological map of Rio de Janeiro State concentrated by INPE and DRM-RJ.

APPLICATION OF LANDSAT IMAGERY TO REGIONAL GEOLOGICAL
MAPPING - THE BELO HORIZONTE QUADRANGLE

Gilberto Amaral
Juércio T. de Mattos
Raimundo Almeida Filho
Roberto P. da Cunha
Waldir R. Paradella

The Belo Horizonte Quadrangle of the International Chart of the World on the Millionth Scale was selected to test the applicability of LANDSAT imagery for regional geological mapping in a geologically complex area and with abundant available geological information. The first objective was the development of a methodology for regional geological mapping, and the second one was the improvement of the geological knowledge of the area with a better framing of existing problems. The work consisted of interpretation of 12 LANDSAT frames, analysis of nearly 300 literature references and surveying along 12000 km of geological tranverses.

Figure 1 displays the resulting map which can be compared with the most recent map (1976) available for the greatest part of the area (Figure 2). It is obvious that the map obtained by the proposed methodology is much more complete from the lithological and structural point of view. Many of the existing problems, related to stratigraphical setting, correlation among units and geotectonic evolution of the region were clarified. As a by-product of this project, an updating of the cartographic base at the 1:1,000,000 scale was made.

From the geological point of view, the results permitted a review of previous stratigraphical classifications and detailing of some units. The main structural features were clearly identified together with new ones, previously unknown. The amount of information now available imposes several questions as to previously suggested schemes of geological evolution. The boundaries of the main geotectonic units were better

Fig. 1 - Geological map of the Belo Horizonte Quadrangle
constructed by INPE.

Fig. 2 - The most recent map for the greatest part of the Belo
Horizonte Quadrangle.

defined, in particular the Canastra Arch, which is associated with alkalic-ultrabasic magmatism enclosing phosphate, niobium and rare earth deposits and kimberlite pipes.

USE OF MSS LANDSAT-1 IMAGERY TO STUDY GEOTECTONIC UNITS IN THE BRAZILIAN MID-WEST.

Paulo Roberto Martini
Edison Crepani

1. INTRODUCTION

The purpose of this work is to outline the general units involved in the tectonic evolution of an extensive area in the mid-west of Brazil. An attempt was made to establish some criteria to discriminate geossinclinal and typical plataform structures. Also, a tectonic outline, including folding belt boundaries, platform covers, intrusive bodies and major structural geology was done.

2. METHODOLOGY

The main source of data was the MSS Landsat-1 system.

The following products were used:

1. Four channels black and white prints in the scale 1:1,000,000;

2. MSS Computer Compatible Tapes.

First, two mosaics of channels 5 and 7 respectively were produced. This provided a general view of the area. Subsequently, a systematic interpretation was carried out. For each image an overlay with drainage pattern, cities, main roads using mainly channels 5 and 7, and sometimes channels 4 and 6 was produced. With these overlays and geodetic information, the IBGE(Brazilian Institute of Geography and Statistics) prepared a basic map.

Visual interpretation was done on the 1:1,000,000 imagery to outline photogeologic units ans structures. Some specific areas were automatically analyzed in the Multispectral Image Analyzer System (Image-100).

The photo units were compared and identified according to the bibliographic references. The preliminar map was checked with field work and corrections were made. Finally, these overlays were plotted on the IBGE basic map.

3. RESULTS

It was possible to discriminate the broad holomorfic folding of geossinclinal origin from the idiomorfic types of platform and or foredeep areas. The folds were defined by tracing the structural lineaments originated from high dip metamorphic and parametamorphic beds. The areas deeply involved with tectonic movements are rather different from the horizontal beds of platform covers.

There are three major rock units related to three folding belts developed at least during the upper Precambrian orogenic cycles. The Uruaçu Folding Belt related to the Uruaçuano Orogenic Cycle of early upper Precambrian age. The Brasilia and Paraguai-Araguaia Folding Belts related to the Brasiliano Orogenic Cycle of late upper Precambrian age.

Denovian and Permocarboniferous sediments of Parana Basin were outlined as well as the block-faulted tectonic. A lot of magmatic bodies related to at least three phases of intrusion were delineated. Some of these intrusions have rich mineralizations with nickel, crome and thin being the more important.

Large lineaments and faulting trends have also been mapped.

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Fig. 1 - Geotectonic outline obtained from MSS LANDSAT imageries.

4. CONCLUSIONS

1. MSS Landsat-1 imagery provided the capability for regional mapping in a very cheap and fast way. Significant results can be obtained using this remote sensing system in a large and relatively unknown large country as Brazil.

2. A 294.000 Km^2 area was mapped in short time with details comparable to the others conventional, greater scale works.

3. MSS imagery provides good guidence for planning field work.

4. MSS imagery is excellent for checking out bibliography.

5. The MSS imagery interpretation brought a lot of new knowledge in the area of structural geology, and new approaches for economic geology have been obtained.

REMOTE SENSING AS AN AID TO SOLVE SOME GEOLOGICAL
UNCERTAINTIES ABOUT THE SÃO FRANCISCO

Paulo Roberto Menezes
Athos Ribeiro dos Santos
Ubiratan Porto dos Santos

Geological research work on the area covered by the São
Francisco sheet (area between $8°-12°S$ and $42°-48°W$) is being carried out
for at least one decade. The interpretation and description of the strati_
graphy of the area, in various publications, are quite different. With
the purpose of solving some of these uncertainties, a regional geological
research was carried out. The following remote sensing data was used in
the study: LANDSAT MSS imagery, SLAR mosaics, and the multispectral
photographs of SKYLAB.

The existing geological literature was also consulted.
First a initial photogeological interpretation was carried out, and the
preliminary geological maps were obtained and checked with some field
work. Three different institutions (Petrobrás, RADAM, DNPM) studied the
area independently. Their work is described as follows:

- PETROBRÃS: Detailed and semi-detailed mapping based mainly on
field work;
- RADAM: Photointerpretation of SLAR imagery with field work, but
without utilizing the previous geological knowledge of the
area;
- DNPM: Compilation of previous works.

All the above mentioned geological mapping were presented in their final
form in the scale of 1:1,000,000.

The greatest controversy about the area is the stratigraphic
divisions of the Paleozoic-Mesozoic sedimentary basin of Parnaiba because
the stratigraphic sequences, in all the existing geological maps, are not
in agreement. The lithologic divisions of the metamorphic complex of the
Precambrian basement, in several literatures, do not agree also but it

yields less controversy. The geological maps,constructed by RADAM and DNPM, show a stratigraphic sequence in the sedimentary area more simple than that of previous maps and quite different from that of PETROBRÃS' map.

With the interpretation of the various remote sensing data mentioned above, the stratigraphic division and sequence in the area of study were revised. This revised stratigraphic sequence is in agreement with the sequences shown on some of the previous geological maps, especially the map of PETROBRÃS. The revised map is not in agreement with the works of RADAM and DNPM. We believe that the use of various types of sensors that complement each other can yield much more information for geological interpretation than only one type. Additionally, some of the lithologic units could not be delineated with these various types of images and in this case, field work was necessary.

From the various types of imagery, numerous structure features, which were not shown on the previous geological maps, were found and augmented the knowledge of geology in the area of study. Examining the relationship between the locations of the known mineral deposits and the structural features, three areas of mineral potentiality (manganese, talc and diamond) were indicated.

Fig. 1 - Geological map of the São Francisco
Quadrangle constructed by INPE.

Fig. 2 - Previously known geological map of the São
Francisco Quadrangle.