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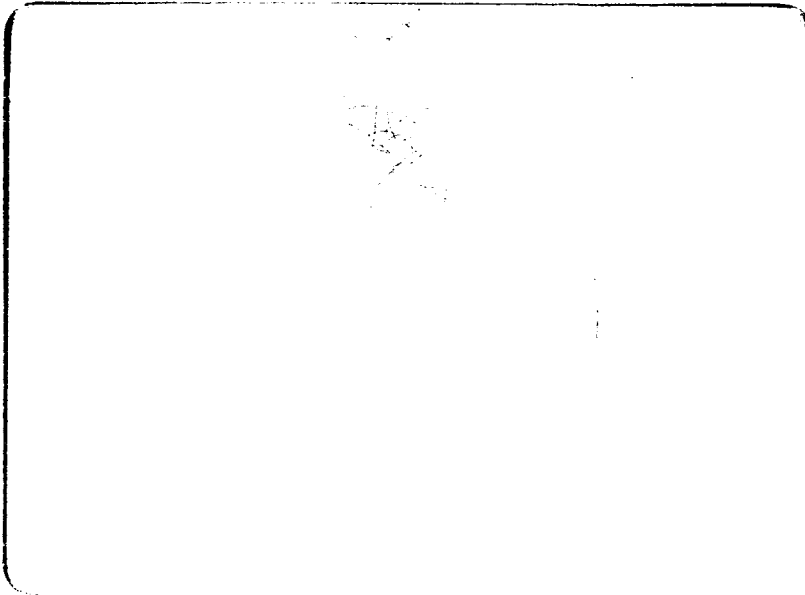
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In relation to the geological structure, the southern part of the study area lying west of 42°00'W, is characterized by wrench zone faults with ENE - WSW direction. This direction is imposed on different geological units and is associated to cataclastic rocks.

To the eastern side of 42°00' meridian, the great faults are bending to N up to 41°00'W. From Vitoria city towards NNW, there are faulting areas which occur without spatial continuity.

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The foliation is oriented parallel to regional structural direction, presenting only local discordances.

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### 4. METHODOLOGY FOR AUTOMATIC ANALYSIS

As an example of automatic analysis the Campos area, in northern Rio de Janeiro State was selected. The main reason for selecting this area was the presence of the Itaoca granitic massif. Quaternary and Tertiary sediments as well as charnockitic and gneissic rocks of precambrian age are also found in the study area (Figure 2). Topographic enhancement of Itaoca massif makes the visual interpretation easier.

To proceed the spectral discrimination of the granitic massif, the following algorithms were used: single cell signature, grey level slicer, MAXVER System, K-Means algorithm and Spatial Features Acquisition.

## LANDSAT AND RADAR MAPPING OF INTRUSIVE ROCKS IN SE-BRAZIL

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### ABSTRACT

The objectives of this study were: 1) to study the feasibility to intrusive rock mapping and to establish criteria for regional geological mapping at the scale of 1:500,000 in polycyclic and polymetamorphic areas using Logic Method of photointerpretation of LANDSAT imagery and RADAR from RADAMBRASIL project. 2) to evaluate the spectral behavior of intrusive rocks, using the Interactive Multispectral Image Analysis System (Image-100). The region of Campos (city) in northern Rio de Janeiro State was selected as the study area and digital imagery processing and pattern recognition techniques were applied. Various maps at the 1:250,000 scale were obtained to evaluate the results of automatic data processing.

### 1. INTRODUCTION

The main objective of this research was to study the viability of identifying intrusive rocks and to establish criteria for regional geological mapping in polycyclic and polymetamorphic areas by means of visual interpretation of small scale remotely sensed data. It will be also evaluated the spectral behavior of intrusive rocks using the IMAGE-100 System.

The Logical Method of Photointerpretation (Guy, 1966) developed for aerial photograph was adapted to data acquired from small images such as: MSS/LANDSAT (1:250,000 and 1:500,000) and RADAMBRASIL mosaics (1:250,000). Computer compatible tapes were used for automatic analysis.

### 2. METHODOLOGY FOR VISUAL INTERPRETATION

To adapt the Logical Method the following aspects had to be taken into account: 1 - the products used in this work (LANDSAT and RADAR data) present scales smaller than usual scales of aerial photography; 2 - These products also present poor spatial resolution and lack of stereoscopic viewing. However, in spite of those limiting factors, the adaptation is possible because MSS and RADAR images are subjected to the same factor which control photographic texture.

The Logical Method is based upon the following rules:

- 1) Photographic lecture - it means the recognition and identification of some features on photographic image with corresponding objects;
- 2) Photographic analysis - it means the analysis of textural photographic elements and shape properties of photographic image so as define homologous areas;
- 3) Photographic interpretation - it means the inductive and deductive processing of the data so as to identify their geological meaning.

Texture, structure and shape their main elements for photographic interpretation and they can be related to drainage network properties and relief texture properties.

\* Presented at the Sixteenth International Symposium on Remote Sensing of Environment, Buenos Aires, Argentina, June 2-9, 1982.

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Textural density, alignments, lineaments, assymetric shape, negative and positive ruptures (for relief), drainage direction and drainge uniformity are the main drainage and relief properties which can be evaluated using LANDSAT and RADAR products.

Shadow effects and tone are also of primary importance for data acquirement since the terrain morphology can be expressed by shadowing effect. This effect also enhances slope ruptures and relief breakings expressing also the textural density of relief and compensating the lack stereoscopic viewing.

By means of those textural properties, homologous zones can be defined. The limits of these zones can be sharp or difuse and not necessarily coincident with geological contacts. Those textural properties also permit to define the degree of relief and drainage organization and therefore give information about anisotropy of rock material. These properties can indicate the occurrence of faultings and foldings by means of density of alignments and relief and drainage lineaments per unit of area.

The degree of asymmetry (for relief and drainage network) can give information about the dip direction of plane feature and the degree of drainage uniformity so as to deduce the material homogeneity.

The development of this work followed two phases. In the first one, the specific objective was to explore the high density of linear features observed on remotely sensed data and to correlate them to geological structure.

To reach this objective, maps at the scale of 1:250,000 were obtained having the following information:

- 1) Traces of fault - linear features derived from alignment of drainage or relief texture elements. These features presented dimensions larger than 3.5 km of extension;
- 2) Traces of fracture - Lines representing zones of fracture concentration. Linear features derived from lineaments of drainage and relief textural elements, presented dimension less than 3,5 km of extension;
- 3) Traces of foliation - Linear features derived from lineaments of drainage and relief textural elements;
- 4) Circular structures - Linear features derived from drainage curvature (classic anelar pattern) radial drainage, and curvature of the relief lineaments.

This phase was complemented in thirty days of field work during which circular structures were checked.

In the second phase of this study the data from field work, bibliography and photointerpretation were combined to establish the relationship geology an intrusive rock occurrence.

This phase followed the following steps:

- 1) Drainage Network Analysis - this analysis gives information about the location and extension of surface material and its control factors; relative permeability, degree of material uniformity; local variations; slope extension; degree of dissection; nature of rock and dip of plane features.

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- 2) **Relief Analysis** - this analysis gives information about the shape of the geological units present on the surface (landform); the relative degree of resistance to erosion of different materials; degree of influence of structure over the relief. It allows also to infer about the rock nature and plane feature dip. Morphogenetic factors (climate, recent tectonic, etc.), lithological factors (resistance to erosion, permeability, plasticity, anisotropy) and deforming factors (faults and foldings) which control the image texture are directly related to the textural properties of the relief and drainage network.
- 3) **Grey Level Analysis** - this analysis allowed to identify great areas whose soil-vegetation-rock-water association could represent regional geological units. The analysis was made primarily using LANDSAT/MSS data.
- 4) **Photointerpretation** - photointerpretation models for drainage network and relief were obtained during the analytical phase. These data were interated into 1:250,000 sheet and processed to determine their geological meaning.

The main differences between the results and other published maps were checked during ground observation and new maps were obtained: Photogeological Map with the ground data and bibliography at the scale 1:500,000.

### 3. DISCUSSION OF VISUAL ANALYSIS RESULTS

The area covered by this study is formed by metamorphic rocks of several ages and complex structures with lithological aspects deeply changed due to various geological events. There are also magmatic bodies with variable ages and composition as well as cenozoic sedimentary cover.

Figure 1 is a simplified map obtained from the maps made by the study of the Intrusive Rocks Project (Santos et al., 1982). The present paper is a summary of that project.

Due to the complex evolution of the area and the poor definition of its lithostratigraphic relationships, the authors decided to adapt Almeida et al., (1977) approach, which divides the precambrian area into structural provinces. These provinces are related to the great tectono-orogenic cycles affecting the area (Jequié - 2,800 my; Trans-Amazonian - 1,800 - 2,200 my; Uruaçu - 900 - 1,400 my and Brazilian - 450 - 700 my). The area of occurrence of each cycle was tentatively defined for each geological province. Based upon those aspects lithological, dominance units were defined. It is important to emphasize that these units do not present stratigraphic connotation. The precambrian rocks were arranged as follows:

#### Mantiqueira Province

This unit can be divided into two great regions with particular evolution features.

- 1) **Remobilized Basement** - According several authors, this region includes rocks of Transamazonian age or older. These rocks were remobilized in the following tectonic events such as Brazilian Cycle which is the most important of them. The lithology is variable: heterogeneous and homogeneous migmatites (metatexites and diatexites) with different structures; gneiss; granitoid rocks; ecinitic rocks (metasediments); charnockitic rocks; enderbitic rocks; granulitic rocks; marbles, etc.
- 2) **Southeast Folding Region** (Almeida et al., 1976). This unit includes rocks of Brazilian age. The main lithologic types are ecinitic rocks (metasediments); heterogeneous and homogeneous migmatites with different structural styles and belonging to a single cycle. It presents also gneiss and granitoid.

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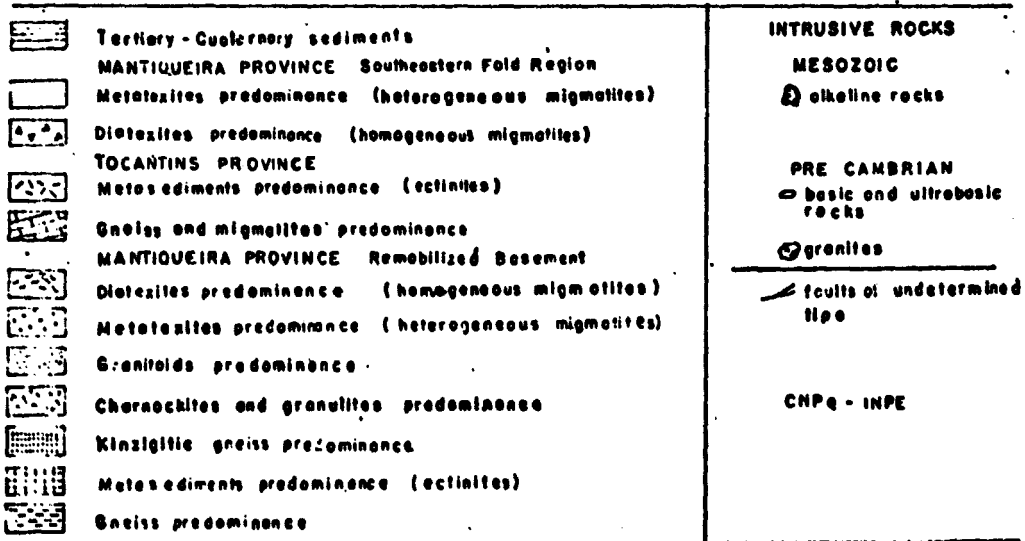
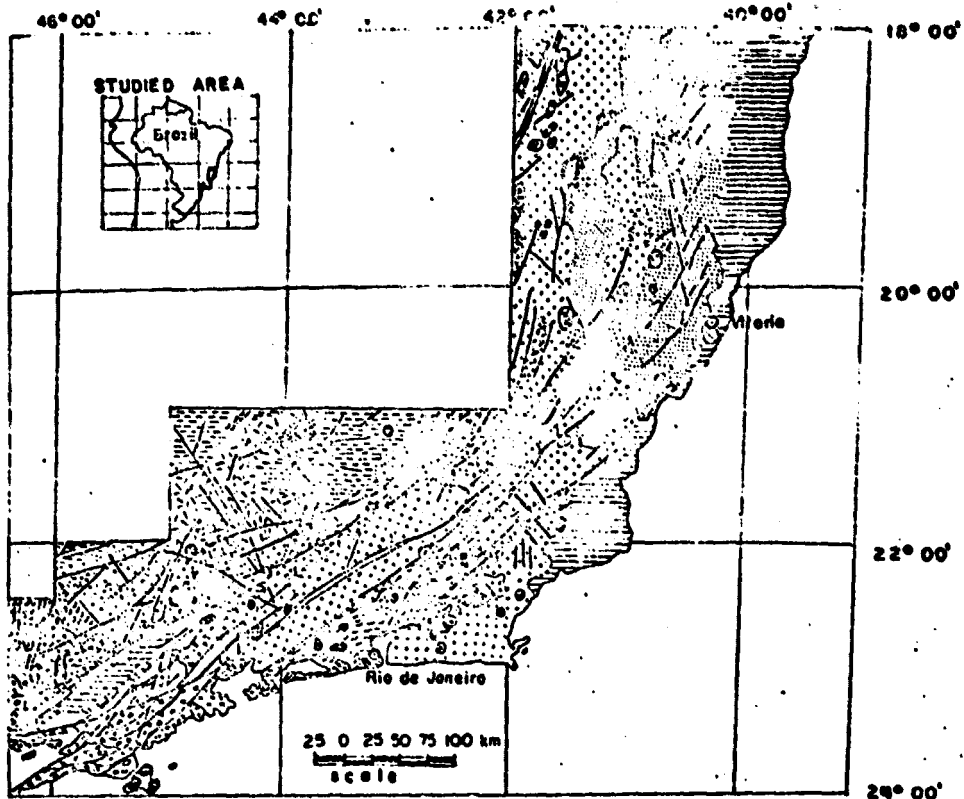


Figure 1. Simplified geologic map.

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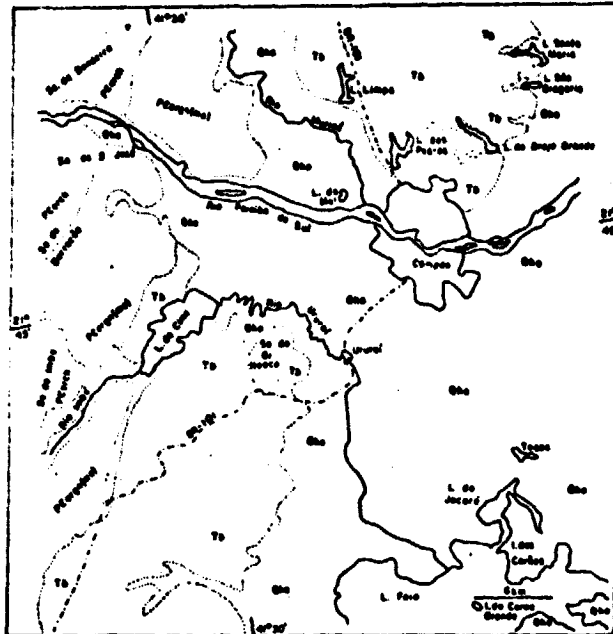


Figure 2. Distribution of the geologic units-Itaoca Massif.

Qha - Quaternary sediments; Tb - Tertiary sediments;  
Pgergn (me) - gneiss and heterogenous migmatites;  
Pgerch - Charnockitic rocks; Gr - granite

Single Cell option was applied to study the spectral behavior of Itaoca Massif in relation to the remaining of the test site. The following classes were analyzed: class g - granite, class Q - quaternary sediments, class T - tertiary sediments, class G - gneiss, class Ch - charnockites; class Ci - Campos town; class V - Flooding area; class A - lagoon.

For each class, training area were selected. These training areas were composed by 36 pixels and 180 pixels samples. The total test site was composed by 736 pixels.

Histograms were acquired for each class in order to verify the gaussian assumption.

The Slicer option is an auxiliary useful program to divide the total range of grey level within each channel into slices of similar density (GE, 1975). In the present work the normal-slice option was applied and 8 classes of equal interval were obtained. Channel 7 was used because it showed the best enhancement the granitic body.

The MAXVER System was applied for multispectral image classification. It is a supervised system where before starting the classification the number of classes as well as sample areas for each class must be provided by the user (Velasco et al., 1979). To implement MAXVER classification, it was used the same samples as for the Single Cell option. The sample areas presented 36 pixel and 180 pixel (5 x 36).

The K-Means algorithm is a non-supervised option for classification multispectral data. It clusters the data based on their natural relationships (Dutra et al., 1982). This algorithm can identify up to 32 classes, but in the present work only 8 classes were selected.

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The K-Means option helped to define classes based upon euclidian distance. The classification of each pixel for each test site was based on maximum likelihood criterium (Dutra et al., 1982).

Finally, the Spatial Features Acquisition algorithm was applied as well the MAXVER System and the K-Means System. The image features can be divided into: 1) Natural Features, which are derived from the grey level and texture. 2) Artificial Feature, which are obtained from grey level manipulation. These algorithms allow to generate new channels from the 4 original channels, and to select the best channels to be used for the thematic classification by means of K-Means and MAXVER Systems.

**5. AUTOMATIC ANALYSIS RESULTS**

The single-cell option showed that the class g, defined on the granitic body presents the shortest overlap with the other classes.

The results obtained using Slicer option were not good, allowing just to identify the following classes: A, Ci and V.

The MAXVER System allowed a good class discrimination when 36 pixels sample areas were used (Figure 3). Large sample areas determined an increase of the overlap between classes.

The results of K-Means algorithm using 4 and 2 channels were not satisfactory inclusive to the identification of the granitic body (Figure 4).

The use of Spatial Features Extraction and MAXVER (36 pixels) allowed to identify the granitic massif (Figure 5). The use of K-Means System over the modified data doesn't allow meaningful results.

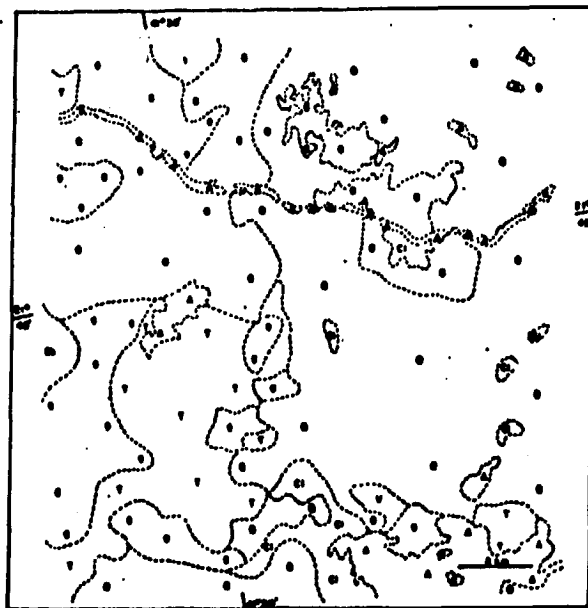


Figure 3. MAXVER Classification (36 pixels) - Itaoca Massif.  
(.....) - Limits of spectral classes.

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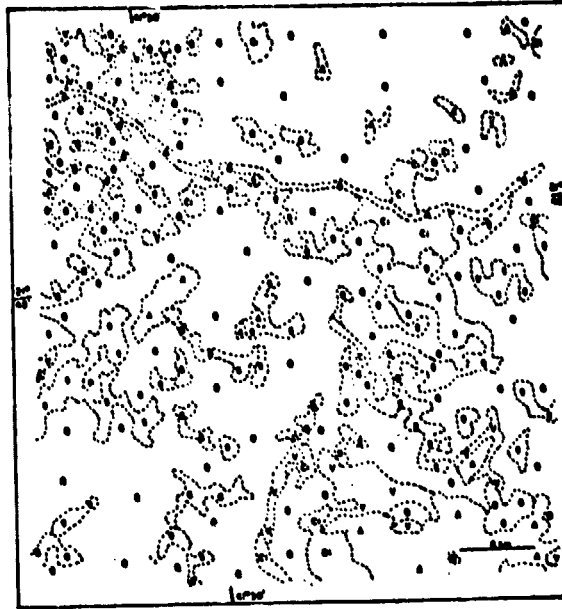


Figure 4. K-Means Classification - Two Channels - Itaoca Massif  
(.....) - Limits of spectral classes.

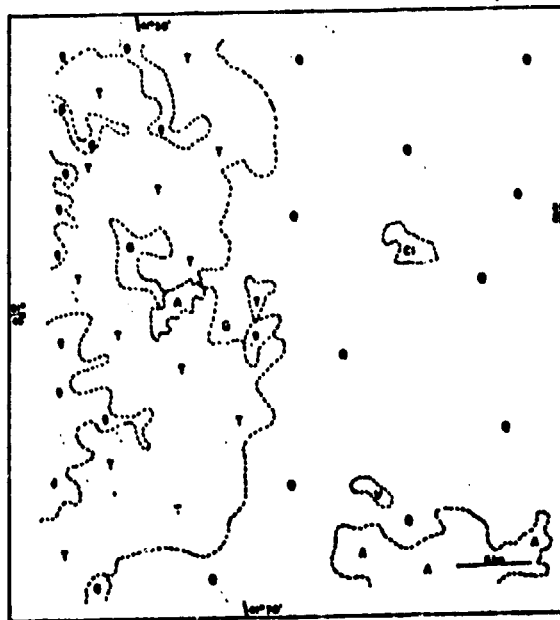


Figure 5. Spatial Features Acquisition. MAXVER Classification Itaoca Massif.  
(.....) - Limits of spectral classes.

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The combined processing (K-Means and MAXVER) allowed a very good discrimination of the granitic massif.

#### 5. CONCLUSIONS

1. The intrusive bodies could be individualized satisfactorily even though it was considered their dimensions in relation to the spatial resolution of the used products. In spite sometimes the similar nature of the adjacent rocks the bodies could be differentiated by relief contrast.
2. The adaptation of the Logical Method for Photointerpretation allowed the best use of the small scale products used in the present work.
3. The compartmentation into major tectonic units and the division of these units into zones of lithologic dominance was a good classification approach to polycyclic and polymetamorphic area.
4. About the detail found in the final maps of the Study of the Intrusive Rocks Project, it is important to emphasize the following aspects:
  - in the macroscopic point of view, most of, the geological and structural features were identified. It can be emphasized for instance the tectonic conditioning of granitic bodies by means of structural traces and their relationship to underlying rocks (concordant, partially concordant, discordant).
  - in the mesoscopic point of view it was possible to identify foliations related to phases of deformation responsible for foldings, but it was not possible to define the foldings themselves over the image. However in some places it was possible to identify the direction of the dip.
5. The use of several remote sensing products of small scale optimizes the cost/benefit relationship for regional geology.
6. Single-cell option was useful to show the gaussian distribution of the samples, showing in this was the viability to use more accurate techniques for thematic classification.
7. The Itaoca massif could be identified only by supervised classification methods.
8. The results showed that it was not possible to relate a single spectral response to a single geological target.
9. To obtain better separability than it was obtained between two classes it is necessary to find sharp differences of grey level between the target and surroundings.
10. The results of thematic information are only characteristics for the same area. It is not possible to extend target information from one area to another.

#### 6. REFERENCES

- ALMEIDA, F.F.M. de; AMARAL, G.; CORDANI, U.G.; KAWASHITA, K. The Precambrian Evolution of the South America Cratonic Margin South of the Amazon River. In: NAIRN, E.M.; STEHLI, F.G. *The Ocean basin and margins*. New York. Plenum, 1973. v. 1, p. 411-446.

- ALMEIDA, F.M. de; HASUI, Y.; BRITO NEVES, B.B. de; FUCK, R.A. Provincias Estruturais Brasileiras. In: SIMPÓSIO DE GEOLOGIA DO NORDESTE, 7, Campina Grande, 1977. Atas. p. 363-391.
- ALMEIDA, F.F.M de; HASUI, Y.; BRITO NEVES, B.B. de. The Upper Precambrian of South America. *Boletim do Instituto de Geociências da Universidade de São Paulo*, 7:45-80, 1976.
- DUTRA, L.V. Extração de Atributos Espaciais em Imagens Multiespectrais. São José dos Campos, INPE, 1982.
- DUTRA, L.V.; MOREIRA, J.C.; II, F.A.M. Manual do Usuário dos Sistemas de Tratamento de Imagens Digitais. São José dos Campos, INPE, 1982 (in press)
- GENERAL ELECTRIC COMPANY (GE). Image-100. *User Manual*. Daytona Beach, Florida USA, 1975.
- GUY, M. Quelques Principes et Quelques Expériences sur la Methodologie de la Photo-interpretation. In: SIMPOSIUM INTERNATIONAL DE PHOTOINTERPRETATION. 2, Paris, 1966. Acte. v. 1, p. 21-41.
- HASUI, Y. *Tectônica de Área das Folhas de São Roque e Pilar do Sul*. Tese de Livre Docência em Geologia. São Paulo, USP, 1973.
- HASUI, Y.; CARNEIRO, C.D.R.; BISTRICH, C.A. Os Granitos e Granitoides da Região de Dobramentos Sudeste nos Estados de São Paulo e Paraná. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 30, Recife, 1978. Anais. v. 6, p. 2594-2608.
- SANTOS, A.R.; ANJOS, C.E. dos; BARBOSA, V.P.; VENEZIANI, P. Projeto Estudo de Rochas Intrusivas. São José dos Campos, INPE, 1982. (in press).
- VELASCO, F.R.D.; PRADO, L.O.C.; SOUZA, R.C.M. Sistema MAXVER. *Manual do Usuário*. São José dos Campos, INPE, 1979.
- WERNICK, E.; PENALVA, F. Contribuição ao Conhecimento das Rochas Granitoides do Sul do Brasil. *Revista Brasileira de Geociências*, 8(2):113-133, 1978.