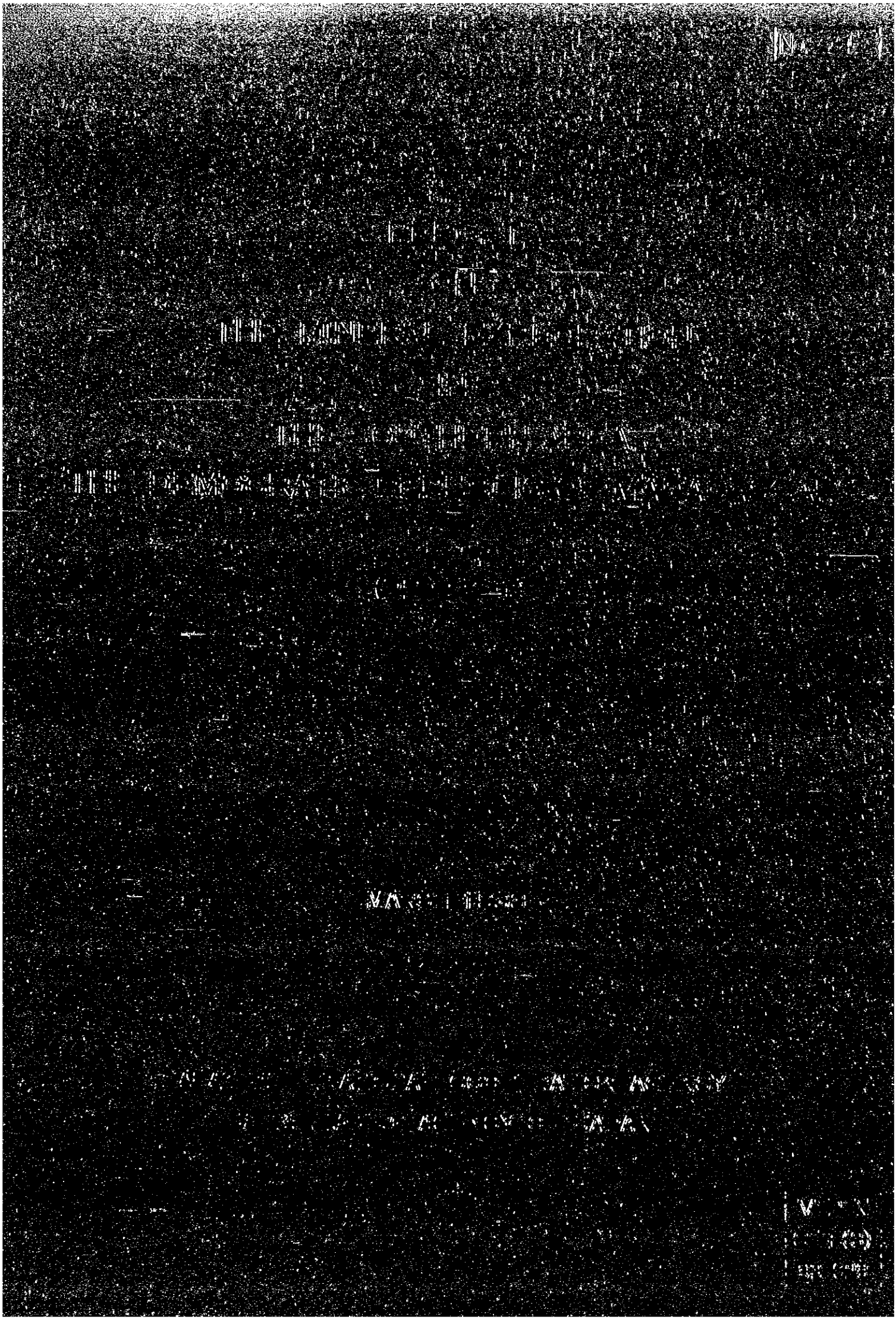


REPORT
ON
THE MINERAL EXPLORATION
IN
THE SOUTHERN AREA,
THE DEMOCRATIC REPUBLIC OF MADAGASCAR

(PHASE II)

MARCH 1993

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of the Democratic Republic of Madagascar, the Japanese Government decided to conduct a Mineral Exploration in the Southern Area Project and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

We have done satellite data analysis and image interpretation in Japan in the second year (1992) of the Project. This report which is based on these results should form a part of the final report.

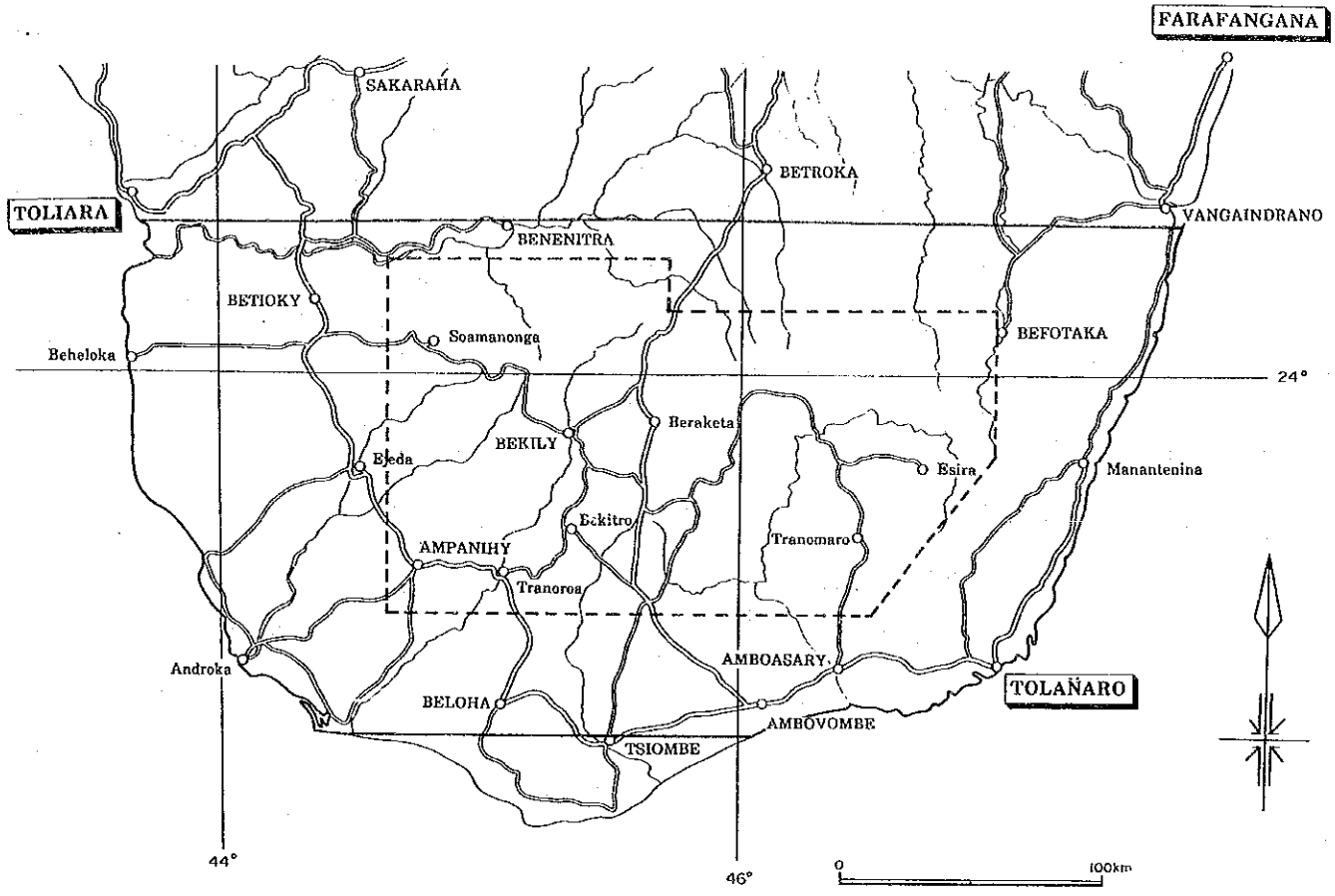
We hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

We wish to express our deep appreciation to the officials concerned of the Government of the Democratic Republic of Madagascar for their close cooperation extended to us.

March, 1993

Kensuke YANAGIYA
President,
Japan International Cooperation Agency

Takashi Ishikawa
President
Metal Mining Agency of Japan



LEGEND

- Survey Area of Phase I
- Road
- City, Town
- River
- Survey Area of Phase II

INDEX MAP

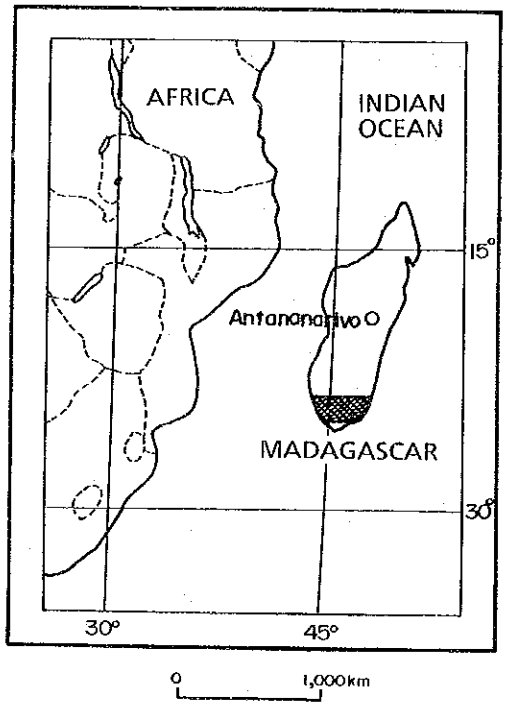


Fig.1-1 Location map of survey area

Résumé

L'étude effectuée l'année précédente avait porté sur une superficie de 66.300 km3 située entre 23°25" et 25°17" de latitude sud dans la région sud de la République Démocratique de Madagascar, et consisté à regrouper des informations et à analyser les données transmises par le satellite Landsat sur ladite superficie. Une analyse graphique à l'aide des données obtenues à partir du satellite Landsat a été effectuée cette année sur un périmètre de 30.000 km2 présentant un potentiel de gisements métallifères, délimité d'après les résultats de l'étude entreprise l'année précédente, en tant que travail préliminaire pour la mission en site qui aura lieu l'année prochaine. En outre, une analyse globale a été effectuée en ajoutant les données existantes aux résultats de l'analyse graphique.

(1) Analyse des données du satellite Landsat

L'année dernière, la recherche de la répartition des lithofaciès ainsi que la lecture des structures géologiques sur la totalité de la région sud de Madagascar ont été effectuées une vaste superficie. Durant ces opérations, plusieurs types d'images en fausse couleur grandeur nature ayant des associations de bandes

différentes ont été produites et l'image de l'association de la bande 234 a été utilisée pour la lecture, ayant été jugée la plus adéquate pour la recherche des conditions géologiques sur une vaste étendue.

Dans la région objet de l'étude effectuée cette année, en raison de l'importance des gisements ainsi que des signes miniers, à savoir des particularités géologiques, et de l'intention de lecture de petites unités et de structures géologiques, que l'on avait pu détecter l'année dernière d'après les documents existants, en prenant pour modèles la région de Soamanonga connue pour ses gisements de bornite disséminée contenant de l'or et de l'argent ainsi que la région de Tranomaro possédant des gisements d'uranium et de thorium, nous avons étudié quelles étaient l'association des bandes ainsi que la méthode de traitement d'image les plus appropriées à la lecture géologique et à la recherche des zones d'altération. En résultat, nous avons compris que les images en couleur fausse de la bande 457 étaient appropriées à la différenciation des lithofaciès ainsi qu'à la lecture des structures géologiques, que le rapport d'opération graphique 5/7 de la bande représentait de manière optimale les mineraux argileux et qu'il était approprié au repérage

des zones d'altération. Sur la base de ces résultats, nous avons élaboré une image en fausse couleur de bande 457 couvrant l'ensemble de la zone d'étude ainsi qu'un rapport d'opération graphique de 5/7 que avons imprimé en couleur aux échelles du 1/200.000ème et du 1/500.000ème. Les résultats de la lecture géologique effectuée sur la base des ces images ont montré qu'un grand nombre de minéraux argileux étaient présents (1): dans la région à l'extrême nord-ouest du permien inférieur et du triassique inférieur; (2) dans une partie du complexe de roches éruptives dispersé dans la zone de déformation par glissement circulaire de la région est ainsi qu'à l'intérieur de cette zone et (3) dans la zone de terrains plats de l'extrême-sud. Si des anomalies ont été décelées, reflétées par les différences de lithofaciès dans les régions (1) et (3), l'existence potentielle d'une zone d'altération a été révélée en (2) par action hydrothermique.

(2) Analyse globale

Parmi les différents gisements métallifères de la zone concernée, les gisements de bornite disséminée contenant de l'or et de l'argent de la région de Soamanonga ont été jugés prometteurs d'un point de vue économique. Ces

gisements sont disséminés à la proximité de la formation granitique proche de la délimitation entre pré-cambrie, et permien et triassique inférieurs. Ils sont dans la plupart des cas situés dans des failles ou des alignements structuraux. Dans la région sud de Soamanonga, si parmi le précambrien, plusieurs lithofaciès granitiques qui semblent présenter un horizon identique ont été décelés, les documents existants n'indiquent pas la présence de gisements. La présente étude, en recherchant les caractéristiques géologiques du lithofaciès granitique de la région sud de Soamanonga ainsi que la répartition des gisements connus, pourra juger des possibilités de découverte de nouveaux gisements dans cette région.

Par ailleurs, les anomalies de la bande 5/7 TM détectée dans la déformation circulaire par glissement situé à l'est de la région objet du projet de la mission de cette année ainsi que le complexe de roches éruptives situé à l'intérieur de cette déformation permettent de supposer la présence d'une ceinture d'altération hydrothermale et il serait nécessaire de procéder à une étude en site ayant pour objectif une vérification "vérité terrain".

(3) Recommandations pour l'étude de la troisième année

Sur la base des résultats de l'analyse globale, il

serait souhaitable qu'une étude de troisième année soit effectuée selon les modalités suivantes:

1) Prise de l'alignement structural par radar à ouvertures composées ou par données stérospot de la formation granitique de la région de Soamanonga et de la zone sud.
2) Collecte de documentation sur la géologie et sur les gisements métallifères de la zone de Soamanonga à Madagascar.
3) Etude géologique et exploration géochimique de la zone dans laquelle est située la formation granitique dans la région de Soamanonga et de sa partie sud.
4) Vérification "vérité terrain" ayant pour objet de déterminer la bande 5/7 TM anormale détectée dans la déformation circulaire par glissement située à l'est de la région de l'étude ainsi que le complexe de roches éruptives situé à l'intérieur de cette déformation.

CONTENTS

Preface

Location map of survey area

Resume

Chapter 1 Outline of survey
1-1 Background and purpose of the survey 1
1-2 Outline results of the first year 1
1-3 Term of the survey and organization of the survey team 3

Chapter 2 Geography of the survey area
2-1 Location and transportation 5
2-2 Topography and drainage system 5
2-3 Climate and vegetation 5

Chapter 3 Available geologic information about the survey area
3-1 Outline of existing data 7
3-2 Outline of geology and ore deposits in the southern Madagascar 7
3-3 Geology of the survey area 8
3-4 Ore deposits of the survey area and brief history of mining 9

Chapter 4 Satellite image analyses
4-1 Data and analytic method 11
4-2 Results of image analyses 12

Chapter 5 Conclusions and recommendation
5-1 Conclusion 17
5-2 Recommendation for phese III survey 18

References

List of Figures

Fig.1-1 Location map of survey area

Fig.3-1 Geologic map of the southern area of Democlatic Republic of Madagascar

Fig.4-1 Location of LANDSAT TM data

Fig.4-2 Location of Soamanonga area and Tranomaro area

Fig.4-3 Topographic map of Soamanonga area

Fig.4-4 Geologic map of Soamanonga area

Fig.4-5 False color image of band145=BGR of Soamanonga area

Fig.4-6 False color image of band157=BGR of Soamanonga area

Fig.4-7 False color image of band457=BGR of Soamanonga area

Fig.4-8 Pseudo color image of band3/band2 ratio of Soamanonga area

Fig.4-9 Pseudo color image of band4/band3 ratio of Soamanonga area

Fig.4-10 Pseudo color image of band5/band7 ratio of Soamanonga area

Fig.4-11 DPCA image of Soamanonga area

Fig.4-12 Interpretation map of images of Soamanonga area

Fig.4-13 Topographic map of Tranomaro area

Fig.4-14 Geologic map of Tranomaro area

Fig.4-15 False color image of band145=BGR of Tranomaro area

Fig.4-16 False color image of band157=BGR of Tranomaro area

Fig.4-17 False color image of band457=BGR of Tranomaro area

Fig.4-18 Pseudo color image of band3/band2 ratio of Tranomaro area

Fig.4-19 Pseudo color image of band4/band3 ratio of Tranomaro area

Fig.4-20 Pseudo color image of band5/band7 ratio of Tranomaro area

Fig.4-21 DPCA image of Tranomaro area

Fig.4-22 Interpretation map of images of Tranomaro area

Fig.4-23 Mosaic of false color images of band 457=BGR

Fig.4-24 Mosaic of pseudo color images of babd5/band7 ratio

Fig.4-25 Geologic interpretation map of LANDSAT TM false color images

Fig.5-1 Integrated map of image analyses

List of Table

Table 4-1 LANDSAT TM data list

List of Plates

PL. 1 Geological interpretation map of LANDSAT TM false color imagery (scale 1:500,000)

PL. 2 Integrated map of image analyses (scale 1:500,000)

CHAPTER 1 OUTLINE OF SURVEY

1-1 Background and purpose of the survey

The Democratic Republic of Madagascar is a country, having an area of about 590,000km^2. Geologically, two third of the land consist of the Precambrian igneous and metamorphic rocks, and one third is the post- Carboniferous sedimentary and igneous rocks, respectively. Although Madagascar is rich in mineral resources of various kinds, they have been poorly developed due to poorly maintained infrastructure and to lack of capital. The mineral resources which are worked now are chromite, phlogopite, graphite and precious stones (ruby, garnet, beryl etc.). In addition, ore showings of iron, coal, uranothorianite, nickel, bauxite, ilmenite, niobium, tantalum, gold, copper, lead, zinc etc. are known. During and after the period when the country was governed by France, geological survey and exploration have been done. The Andriamena chromite deposit, Soalala iron deposit, Manantenina bauxite deposit etc. have been discovered through the exploration done by the Direction of Mines and Geology (DMG).

The exploration for the mineral resources, being put into effect by the Japanese Government in response to the request of the Government of the Democratic Republic of Madagascar, has been practiced based on the Scope of Work concluded dated June 19, 1991.

The purpose of the survey is to clarify the ore-forming conditions through making clear the geological environment. Therefore, in last year, we had collected and analyzed the resources-related data obtainable in Japan. Using the results, we had analyzed the satellite images, resulting in the understanding of the regional geologic structure and mineralization throughout the survey area. This year, we have analyzed the LANDSAT TM data to extract and delineate the altered areas from the high potential areas of mineralization based on the last year's result.

1-2 Outline results of the first year study

The survey area, as shown in Fig. 1, is situated between 23 degree 27 minute Lat. and 25 degree 22 minute Lat., the southern area of the Madagascar Island, covering an area of about 66,300km^2.

1-2-1 Existing data compilation

Geology of the southern area of the Madagascar Island consists of the Precambrian basement and the Permian to Quaternary formations covering the former. These formations are distributed almost parallel to the elongation (N-S) of the island, and show an asymmetrical structure, with their wide distribution in the western part, while with their narrow distribution along the eastern coast. The Precambrian rocks forms the inland central highland, where most of various ore deposits occur.

In the survey area, distributed are the ore deposits and showings of black sand (monazite, ilmenite, rutile, zircon), graphite, phlogopite, precious stones (garnet, corundum, beryl etc.), uranothorianite, gold, silver, copper, zinc, iron, chromium, kaolin, bauxite and so on. Of these, uranothorianite, phlogopite, gold, silver, copper and zinc deposits were mined previously. However, most of the ore deposits and showings have been poorly explored, resulting in their poor development. Only phlogopite and precious stones are worked on a small scale.

The ore deposits and showings of each district are summarized as follows:

Tolanaro (Fort-Dauphin) district: A number of deposits of black sand which contain monazite, ilmenite, rutile and zircon are formed in the sand- dune sediments and in the present littoral sediments along the coast line, facing the Indian Ocean. Bauxite deposit occurs at Manantenina.

Tranomaro district: Ore deposits and showings of precious stones (corundum), phlogopite, uranothorianite, cassiterite etc. are known.

Bekitro district: Ore showings such as phlogopite, manganese, precious stones (beryl and garnet), ilmenite etc. are known. Phlogopite deposits occur as stratiform or lenticular bodies of pegmatite within pyroxenite of the Androyen System composed of gneiss and leptinite.

Ampanihy district: Although ore showings such as precious stones (ruby, garnet etc.), graphite, phlogopite, ilmenite, copper, manganese etc. have been known, only the precious stones are mined now.

Northern Beraketa district: Ore deposits and showings of phlogopite have been known. Phlogopite deposits were mined at the Marovala, Ampandramdava, Ambararata and other mines from the beginning of 1900's to about 1940. In addition to the phlogopite deposits, ore showings of graphite, uranothorianite and beryl occur in this district.

Soamanonga district (Vohibory district): Ore showings of gold, silver, copper, zinc and manganese were known. They were mined at the Besakoa mine etc. in the colonial times. The Sakoa Group of the Karroo System in the district contains coal seams.

1-2-2 LANDSAT TM image interpretation

Six false color images are made from CCT data, with a linear stretch and edge enhancement process, and the bands 2, 3 and 4 are displayed as blue, green and red, respectively. We divide the area into 29 geological units as a result of photogeological interpretation. There exists an elliptical igneous composite body, measuring about 70 km in N-S and about 45 km in E-W, in the east-central part of the survey area. Encircling the northern to northeastern margin of the igneous body, a distinct collapse structure is recognized. Such a large-scale magmatism has a possibility to form some kind of mineralization.

1-3 Term of the survey and organization of the survey team

1-3-1 Term of the survey

Scheming of the survey	Jan.28,1993 - Feb.1,1993
Image processing and interpretation	Feb.1,1993 - Feb.20,1993
Data analysis and preparation of report	Feb.21,1993 - Mar.1,1993

1-3-2 Survey team

The survey team members of the second year are as follows:

Itoshi KOHNO,	Chief engineer, summarization of survey, Satellite image analyses	MINDECO
Koji YASHIRO,	Satellite image analyses	MINDECO
Kazuhiro ADACHI,	Satellite image analyses	MINDECO
Hidehisa WATANABE,	Satellite image analyses	MINDECO

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Location and transportation

The Democratic Republic of Madagascar is an island country on the Indian Ocean, which is located 350km east of the eastern coast of Africa through the Mozambique Strait. It measures 1,580km in N-S length, 560km in maximum width and about 590,000km2 in area, corresponding to about 1.6 times that of Japan. The country is located between 12° S Lat. and 26° S Lat. and belongs to the tropical zone extending over the Tropic of Capricorn. Figure 1 shows the survey area of this year.

Except Fridays, they have seven flights per week from Toliara, which is located 90km northwest of the survey area, to the capital, Anatananarivo. They have four flights per week from Tolanaro, 50km east of the area, to the capital except Mondays, Wednesdays and Saturdays. They have one or two flights per week from Toliara to Tolanaro and among Toliara, Ampanihy and Bekily. In the eastern mountainous district, the road is badly developed, while in other areas, they have roads connecting the main cities. From Toliara to Sakaraha 70km northeast and from Tolanaro to Ambovombe 110km west, roads are paved, while in other paved roads are not available.

2-2 Topography and drainage system

In the Madagascar Island, an elevation decreases from the eastern coast area forming a mountainous district, through the central highland, toward the western lowland. The southern part of the island is also similar in topography with the mountain range of about 2,000m above sea level in the eastern coast. The mountainous district, about 100km wide, ranges in north to south along the eastern coast. Except the district, the survey area has generally a gentle topography with low relief.

Rivers run to the east in the eastern side of the mountainous district, while they flow to the west or south in the gentle hilly district of its western side.

2-3 Climate and vegetation

According to the geographical location, topography, effects of ocean and wind direction, climatic seasons of the island are divided into two. April to October correspond

to winter season. During the season, due to the southeast trade wind, wet and cold wind blows to the eastern coast, while it is dry in the western part beyond the central highland. November to March correspond to hot summer season and rainy one. Throughout the eastern coast, annual rainfall amounts to 2,000 to 3,600mm, because rain originated from the trade wind or monsoon is shut out by the mountainous district. In the central highland and the northern half of the western coast, and in the southwestern and the southernmost parts, it amounts to 1,000 to 2,000mm and less than 400mm, respectively, showing the variation from the tropical rainy climate to the tropical semi-arid climate. In the eastern mountainous district, annual precipitation is abundant, resulting in the wide tropical rain forest zone. However, it is small in amount in the hilly district covered by thickly growing thorny shrubs and grassland. Along rivers trees grow thick.

CHAPTER 3 AVAILABLE GEOLOGIC INFORMATION ABOUT THE SURVEY AREA

The first year's report describes geologic information about the survey area in detail. We refer to that report and rewrite the contents in relation to the study of this year.

3-1 Outline of existing data

3-1-1 Geological maps

Geological mapping in this area had been carried out by H. BESAIRIE, J. AUROUZE, J. BOULANGER, G. NOIZET and others from 1920's to 1960's at a scale of 1:100,000 and their explanations. Compiling these results, H. BESAIRIE published the geological maps at a scale of 1:1,000,000 in 1964 and the geological maps at a scale of 1:500,000 in 1970.

3-1-2 Ore deposits

As to the ore deposits throughout Madagascar, there have been the reports on each mineral by J. BEHIER (1960) and H. BESAIRIE (1966). The ore deposits and showings in the survey area are described in the geological maps at a scale of 1:100,000 and their explanations. In 1956, H. BESAIRIE compiled the Carte Miniere et des Indices (1:500,000) in which these ore deposits and showings are shown. The mines in this area were all closed in 1960's. Recently, graphite, phlogopite and garnet have been mined on a small scale by private owners. Therefore, summary report for the ore deposits is unavailable. The Overseas Technical Cooperation Agency of Japan sent a survey team in 1964 in order to carry out a survey of mineral resources throughout the Madagascar Island.

3-2 Outline of geology and ore deposits in the southern Madagascar

The southern part of the Madagascar Island consists of the Precambrian basement and the Permian to Quaternary formations. These formations are distributed almost parallel to the elongation (N-S) of the island, and show an asymmetrical structure, with their wide distribution in the western part, while with their narrow distribution along the eastern coast.

The Precambrian rocks crop out on the inland central highland, where most of various ore deposits occur. The Permian to Quaternary formations are distributed mainly in the western part of the island, becoming young from east to west.

In the survey area, distributed are the ore deposits and showings of black sand (monazite, ilmenite, rutile, zircon), graphite, phlogopite, precious stones (garnet, corundum, beryl etc.), uranothorianite, gold, silver, copper, zinc, iron, chromium, kaolin, bauxite and so on. Of these, uranothorianite, phlogopite, gold, silver, copper and zinc deposits were previously mined. However, most of the ore deposits and showings have been poorly explored, resulting in their poor development. Now only phlogopite and precious stones are worked on a small scale.

3-3 Geology of the survey area

3-3-1 Precambrian and Cambrian rocks

The Precambrian rocks exposed in the survey area consist of the three systems, Androyen system, Graphite system and Vohivory system, which are correlated with the Lower to Middle Proterozoic (2,650±200Ma to 1,100±200Ma), based on radiometric dating on galena, monazite, uraninite, thorianite and zircon.

Intruding the Precambrian rocks, granite, charnockite, syenite and pegmatite occur as sheets in the Precambrian schist and gneiss. The radiometric ages of these intrusives from different parts of the island range from 550 Ma to 485 Ma, indicating intrusions of Cambrian to Early Ordovician age. These ages are consistent with that of thorianite mineralization (485Ma: R.FURON, 1963). Quartz, beryl, garnet, columbite-tantalite etc. occur in these rocks.

3-3-2 Karroo System

The Permian to Jurassic sediments on the Madagascar Island are called the Karroo System (The Madagascar Karroo) based upon their similarities to those of the Karroo System in South Africa. This System is mainly made of continental beds and is divided into the three groups, Sakoa Group (Lower Permian), Sakamena Group (Upper Permian to Lower Triassic) and Isalo Group (Upper Triassic to Middle Jurassic Bajocian Stage), by unconformity and intercalation of marine beds and becomes young westward. In the northern part, the continental facies shows a gradual change to marine facies which corresponds to the stratigraphically upper part. The older two groups cover the study area of this year.

3-3-3 Cretaceous System

In western Tranomaro in the southeastern part of this area, the basalts and rhyolites form an elliptical composite igneous mass, measuring about 70 km in N-S and about 45 km in E-W. Basalt is black, compact, and contains augite phenocryst with rare olivine.

3-4 Ore deposits of the survey area and brief history of mining

Although ore deposits and showings of various kinds have been discovered in Madagascar, only a few of them have been exploited as a mine. This is because they are of a small-scale possibly due to poor exploration and also sufficient ore reserves are not confirmed.

Mineral resources mined at present are mainly chromite, phlogopite, graphite and precious stones. In addition, ore showings of iron, coal, uranium, nickel, bauxite, ilmenite, niobium, tantalium, copper, lead, zinc etc. are known.

Pegmatites (precious stones), gold, iron, phlogopite, copper, nickel etc. have been explored by the MIEM (Ministry of Industry Energy & Mines) and OMNIS (Office Militaire National pour les Industries Strategique) with the aids of France, Italy, old USSR, UK etc.

In the survey area, the occurrence of ore deposits and showings of black sand (monazite, ilmenite, rutile, zircon), graphite, phlogopite, precious stones (garnet, corundum, beryl etc.), uranothorianite, gold, silver, copper, zinc, iron, chromium, kaolin, bauxite and so on are known. The ore deposits and showings of each district are described below.

Tranomaro district: Ore deposits and showings of precious stones (corundum), phlogopite, uranothorianite, cassiterite etc. are known. At present, only phlogopite is mined on a small scale. Uranothorianite was mined actively at the Marosohy, Androtsabo and Amboanemba mines etc. by CEA (Commissariat a l'Energie Atomique) from 1954 to 1964. Uranothorianite is distributed within a district measuring about 60km in N-S and about 20km in E-W along the Manamboro river. The ore deposits occur as lenticular or pipe-like bodies within pyroxenite of the Androyen System consisting of pyroxenite, charnockite and marble. It is said that uranothorianite ores with U grade higher than 12% were mined and the main deposits were almost mined out.

Bekitro district: Ore showings such as phlogopite, manganese, precious stones (beryl and garnet), ilmenite etc. are known. Phlogopite deposits occur as stratiform or

lenticular bodies of pegmatite within pyroxenite of the Androyen System composed of gneiss and leptinite.

Ampanihy district: Although ore showings such as precious stones (ruby, garnet etc.), graphite, phlogopite, ilmenite, copper, manganese etc. have been known, only the precious stones are mined now. Graphite, in particular, is expected to be worked in this district. Garnet (spessartine) is mined where garnet-bearing leptinite of the Graphite System has been subjected to lateritization. Like garnet, graphite was worked as a graphite mine where graphite-bearing leptinite had been lateritized. About 4km southeast of Ampanihy, a kaolin deposit is exposed almost horizontally in the semidesert area. It occurs near the boundary between the hornblende schist of the Graphite System and the red sandstone of the Sakoa Group of the Upper Karroo System. Drillings have proved their thickness to be about 10m.

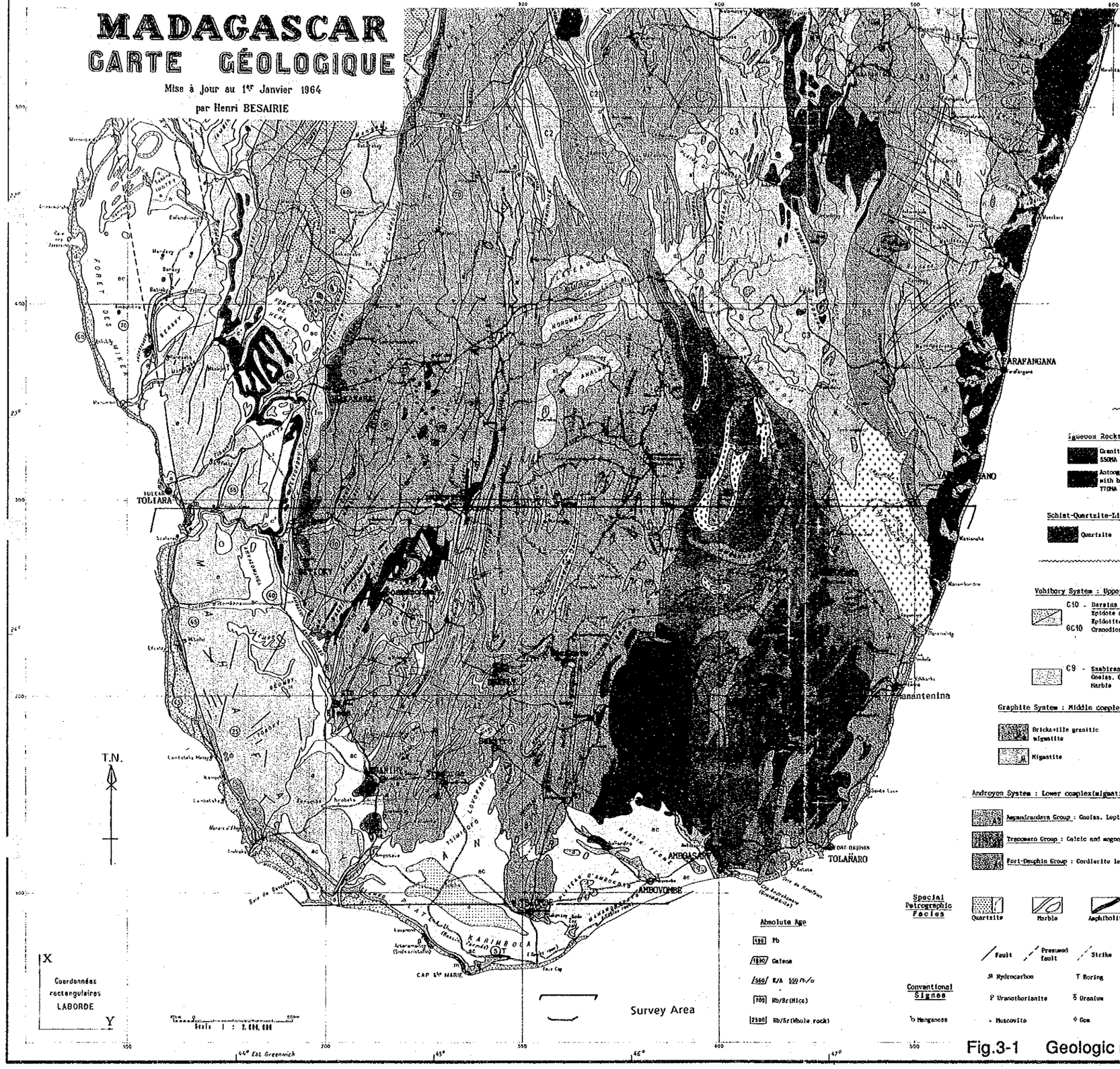
Northern Beraketa district: Ore deposits and showings of phlogopite were known. Phlogopite deposits were mined at the Marovala, Ampandramdava, Ambararata and other mines from the beginning of 1900's to about 1940. They occur as stratiform or lenticular bodies of pegmatite within pyroxenite of the Androyen System consisting mainly of gneiss and leptinite. Calcite, diopside, apatite, gypsum, pyrite, molybdenite etc. are associated with phlogopite. In addition to the phlogopite deposits, ore showings of graphite, uranothorianite and beryl are distributed in this district.

Soamanonga district (Vohibory district): Ore showings of gold, silver, copper, zinc and manganese have been known. They were mined at the Besakoa mine etc. in the colonial time. Copper mineralization in this district is recognized as disseminated bornite or as quartz vein in the Vohibory System with a small amount of gold and silver (Lanapera and Besakoa deposits). Zinc-rich copper-zinc mineralization occurs at the Besakoa deposit. In addition, disseminated or lenticular copper ore is recognized in the red sandstone bed of the Permian to Jurassic Karroo System (Bevalaha deposit). The Sakoa Group of the Karroo System in the district contains coal seams, which are now explored by the British BB-C Coal Co. in Ankinany along the Sakoa river. There occur iron-bearing sandstones with average thickness of 30cm in southern Betioky situated to the west of this district. According to BRGM (Bureau de Recherches Geologiques et Minieres, 1959-1960), probable reserves are estimated as follows: 6 mil.tons (10-14% Fe) or 1.5 mil.tons (24% Fe) or 0.6 mil.tons (29% Fe). According to H. BESAIRIE (1966), possible reserves are estimated to be: 130 mil.tons (10-14% Fe) or 30 mil.tons (24% Fe).

MADAGASCAR
CARTE GÉOLOGIQUE

Mise à jour au 1er Janvier 1964

par Henri BESAIRIE



LEGEND

Alluvia
Dune
Eluviated white sand
Mangrove mud
Elevator Quaternary
Carapace sand
Aepyornis old dune
Laterite clay
Plio-Pleistocene lacustrine sediment
Pliocene continental sediment

Volcanic Rocks Pleistocene and Neogene
Rhyolite, Trachyte
Basalt, Labrado.itite
Ankaramite

Marine Facies
Miocene
Oligocene
Eocene
Danian
Upper Cretaceous
Middle and lower Cretaceous
Upper Jurassic
Middle Jurassic
Upper Lias
Lower Triassic
Upper Permian

Continental Facies
Neogene
Upper Cretaceous
Middle and lower Cretaceous
Upper Jurassic(mixed facies)
Mixed facies Isalo III
Isalo III
Isalo II
Isalo I
Sakamena
Sakoa
Condensed facies

Cretaceous Effusive Rocks
Rhyolite, Dellenite, Trachyte
Basalt, Labradoritite, Sakalavite
Dolerite and basic dikes
Granite, Syenite
Nepheline syenite
Phonolite
Gabbro

Profondeur du socle sous le niveau de la mer, en hectomètres (Bétsiléo)

Unconformity

Igneous Rocks
Granite 550MA
Granite and migmatite 550MA
Syenite
Gabbro
Peridotite Pyroxenite
Antongil Granite with basic enclaves 770MA
Anosyennes Granite with charnockite 780-900MA
Varavato Granite 700-1100MA
Nepheline syenite
Ultrabasite

Schist-Quartzite-Limestone Series(Precambrian)
Quartzite
Schist, Mica schist
Marble

Major Orogenic Unconformity 2600MA

Vohibory System : Upper complex, mainly amphibole complex of old Precambrian
C10 - Daraina Group : Epidote amphibolite, Epidotite, Gneiss Cmonodiorite
GC10
C9 - Saabirano Group : Gneiss, Quartzite, Marble
C8. Antongil Group : Epidote migmatite
C7. Androdrianna Group : Feldspathic mica schist
C6. Maevatanana Group : Amphibolite, Green schist, Migmatite quartzite, Gneiss
C5. Beforona Group : Amphibole migmatite, Amphibolite
C4. Manajary Group : Mica schist, Gneiss, Green schist, Migmatite
C3. Amborompotsy Group : Gneiss, Amphibolite, Marble, MC3 Migmatite
C2. Malakialina Group : Mica schist, Marble, Quartzite
C1. Vohibory Group : Leptinite, Amphibole gneiss, Amphibolite, Marble

Graphite System : Middle complex(migmatitic-gneissic)
Brickaville granitic migmatite
Migmatite
B4. Andriba Group : Migmatite and Gneiss without graphite
B3. Ambatolampy Group : Mica schist and Gneiss with graphite
B2. Manampotsy Group : Gneiss and Migmatite with graphite
B1. Ampanihy Group : Leptinite with graphite

Androyen System : Lower complex(migmatitic-leptinitic)
Ampandrandava Group : Gneiss, Leptinite, Pyroxenite, Marble, Charnockite
Tranomaro Group : Calcic and magnesian paragneiss, Hemeritite, Pyroxenite, Marble, Leptinite
Fort-Dauphin Group : Cordierite leptinite

Special Petrographic Facies
Quartzite
Marble
Amphibolite
Phlogopite Pyroxenite
Graphite
Colitic migmatite
Charnockite
Anorthosite
Granite
Bauxite

Characteristic Minerals
Muscovite
Cyanite
Garnet
Sillimanite
Cordierite

Conventional Signs
Fault
Presumed fault
Strike
Hot spring
Spring water
Cave
Lignite
Coal
Fossil
Hydrocarbon
Boring
Gold
Copper
Lead
Nickel
Chromium
Platinum
Columbite
Gypsum
Uranothorianite
Uranium
Titanium
Beryl
Cassiterite
Corundum
Quartz
Phlogopite
Saline soil
Manganese
Muscovite
Gem
Iron
Mine
Barite
Monazite
Pyrochlore
Kaolinite
Bentonite

Fig.3-1 Geologic map of the southern area of Democlatic Republic of Madagascar

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CHAPTER 4 SATELLITE IMAGE ANALYSES

4-1 Data and analytic method

4-1-1 Data

LANDSAT TM data prepared for phase I survey are listed in Table 4-1. Coverage of each data is shown in Fig.4-1. We used 5 scenes of satellite image for this year's analyses except path 158 row 76.

4-1-2 Analytic method

We carried out image interpretation to delineate general distribution of geological units and structures in southern Madagascar area last year. We emploied TM bands 234 false color images which were chosen from several kinds of band combinations, because this combination is the most adequate one for that purpose.

Many ore deposits and showings are distributed in the survey area of this year so that this area is supposed to have some special geological situations and we expected to extract that by this year's work. We have to choose, therefore, the most adequate combination of TM bands for false color images to achieve interpretation accurately, and for ratioing to delineate alteration zones. To find the best combination of TM bands, we selected Soamanonga area where gold and silver bearing copper ore deposits are distributed and Tranomaro area where uranothorianite deposits are known as fields for case study. Location of Soamanonga area and Tranomaro area is shown in Fig.4-2. Three kinds of false color image (bands 145, 157, 457), three kinds of pseudo color image of ratioing (band3/band2, band4/band3, band5/band7) and a directed principal component analysis image (DPCA image), which is a result of principal component analysis from band4/band3 ratio and band5/band7 ratio, are prepared for Soamanonga area and Tranomaro area. We compared each subscene image of two areas with existing geologic data and chose bands 457 false color image in which geologic units and structures are represented well. Pseudo color image of band5/band7 ratio is supposed to show distribution of clay minerals. We also referred to correlation coefficient matrix of 6 bands and entropy of 3 bands to choose band combination for false color image.

According to these results, we prepared TM bands 457 false color images and band5/band7 ratio pseudo color images which cover this year's study area for photogeologic interpretation and delineation of alteration zones.