REPORT ON THE COOPERATIVE MINERAL EXPLORATION IN THE MACDOUGALL AREA THE REPUBLIC OF ZIMBABWE

PHASE 1

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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P R E F A C E

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

JICA and MMAJ sent to Zimbabwe a survey team headed by Mr. Fumio Wada from 18 September to 16 November, 1989.

The team exchanged views with the officials concerned of the Government of Zimbabwe and conducted a field survey in the Macdougall area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

We wish to express our deep appreciation to the officials concerned of the Government of Zimbabwe for their close cooperation extended to the team.

February 1990

Kensuke YANAGIYA
President
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President
Metal Mining Agency of Japan

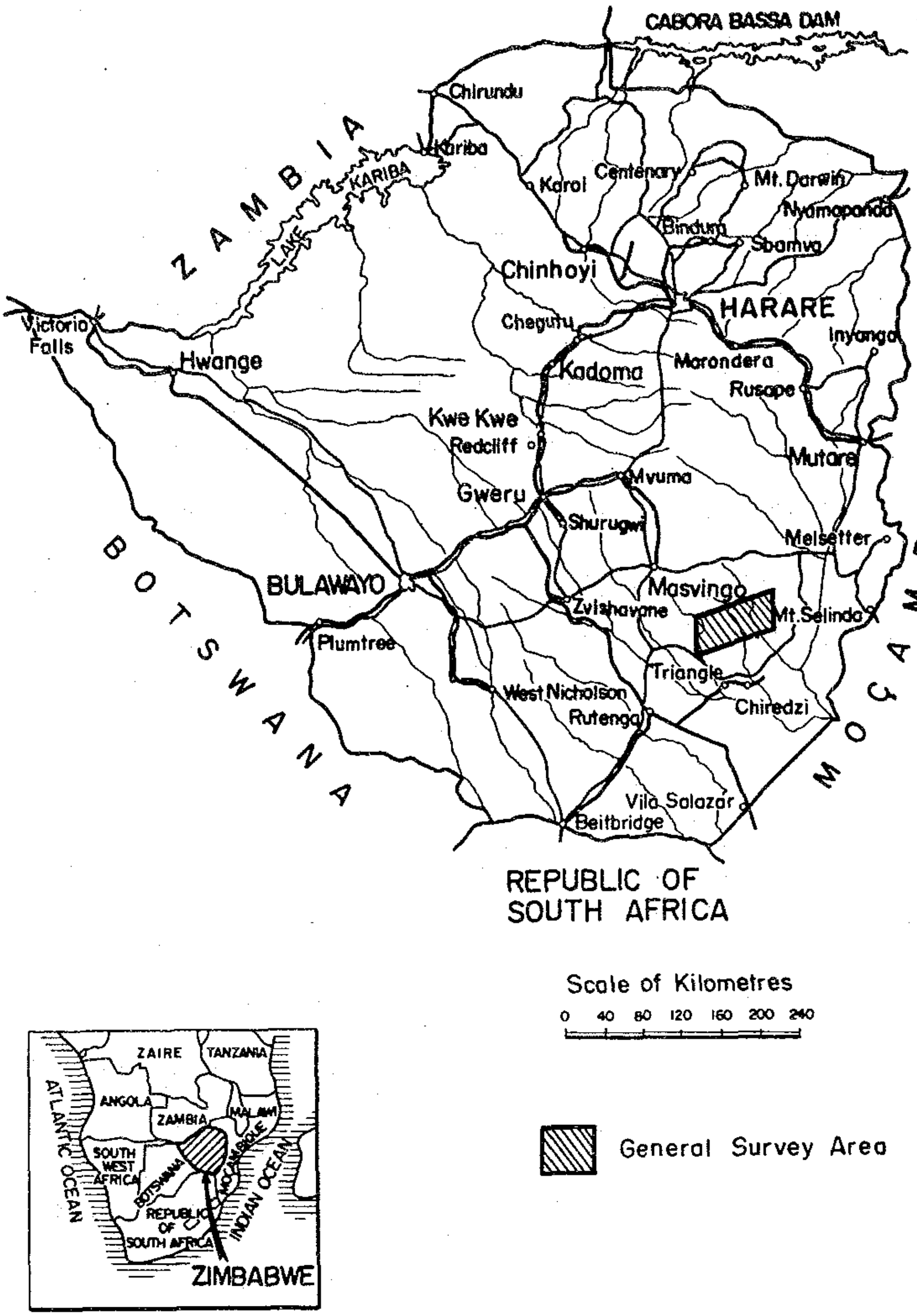


FIG. G-1 Location Map of the Macdougall Area, Zimbabwe

S U M M A R Y

A mineral exploration programme was conducted in the Macdougall area in Zimbabwe in fiscal 1989. The programme consists of Landsat image interpretation, a geological survey and geochemical exploration. A summary of each survey is described in the following:

Landsat Image Interpretation: CCT (Computer Compatible Tape) was used in the analysis. The following kinds of GEOPIC equivalent images were composed from CCT:

a) False-colour, full-scene, scale: 1/250,000
b) False-colour, sub-scene, scale: 1/100,000
c) Ratio image, sub-scene, scale: 1/100,000
d) Full-scene, black-and-white image, scale: 1/500,000
e) Ratio image (black-and-white), full-scene, scale: 1/200,000
f) Principal component image, scale: 1/100,000

These images were used for geological unit analysis based on which the survey area could be divided into six geological units. Regarding geological structure, the major lineaments of the survey area could be classified into three groups, as shown in chronological order of formation in the following:

a) ENE-WSW system and NW-SE system
b) N-S system and NE-SW system
c) NW-SE system

Spectroscopic measurement of representative rocks was carried out to detect alteration zones. Based on the results, two kinds of alteration zones could be identified, in which Fe-minerals and mainly montmorillonite and sericite were assumed to be main constituent minerals.

It can be concluded that Landsat image could be effectively used throughout the survey for a predictive examination of areas for which sufficient basic data have not been accumulated. This is because the Landsat image method is unique in that geographical and geological data of a vast survey area can be obtained readily and rapidly by examining wide angle Landsat images.

Geological Survey: The survey area is located in the Northern Marginal Zone (NMZ) of the Limpopo Mobile Belt, which stretches from ENE to WSW, dividing

Zimbabwe Craton from Kaapvaal Craton. The NMZ is 30 to 40 km wide at the section which is in contact with Zimbabwe Craton. The area consists of the following geological units:

a) Gneissose Granite: (granite in Zimbabwe Craton)
b) Gneissose Granulite: (high grade metamorphic rock)
c) Felsic Granulite: (high grade metamorphic rock)
d) Mafic Granulite: (high grade metamorphic rock)
e) Iron Formation: (sedimentary rock)
f) Dolerite: (intrusive rock)

The geological structure of the survey area is characterized by the ENE-WSW (N60-70E) system foliations. Although most of the foliations dip toward the south, there are also foliations descending toward the north in the southern part of the survey area. The whole survey area shows a heavy fold. The survey area is divided into four blocks by principal faults, and these blocks ascend or descend.

In the survey area, eleven mineralized zones were identified. Except for some zones, the detail occurrences of which are unknown, all the mineralized zones are classified as vein-type deposits. Consequently, this type of deposit is different from that of the Renco Deposit which is located to the southwest of the survey area.

Although the results of analysis of samples collected from each mineralized zone showed that the grade of all the analyzed elements (Au, Ag, As, Bi, Cu, F, Zn, Cr, Ni, Fe, etc.) was low, the following zones were assumed to be promising on the basis of the Au grade and the content of the elements which are generally found along with Au mineralization(e.g. As and Bi):

a) Jegede mineralized zone
b) Juwere mineralized zone
c) Muchacha mineralized zone

<u>Geochemical Exploration</u>: Some 2,305 stream sediments and 150 panned samples were collected from the survey area which was 2,300 km^2 wide. Analysis was carried out for Au, Ag, As, Bi, Cu, F, Zn, Cr, Ni and Fe, and the results were interpreted by single variate analysis and multivariate analysis. The results of these analyses were applied to understand the geochemical characteristics of each geological unit. Finally, the following seven Au anomalous zones were selected:

I_{Au} anomalous zone

IV_{Au} anomalous zone

V_{Au} anomalous zone

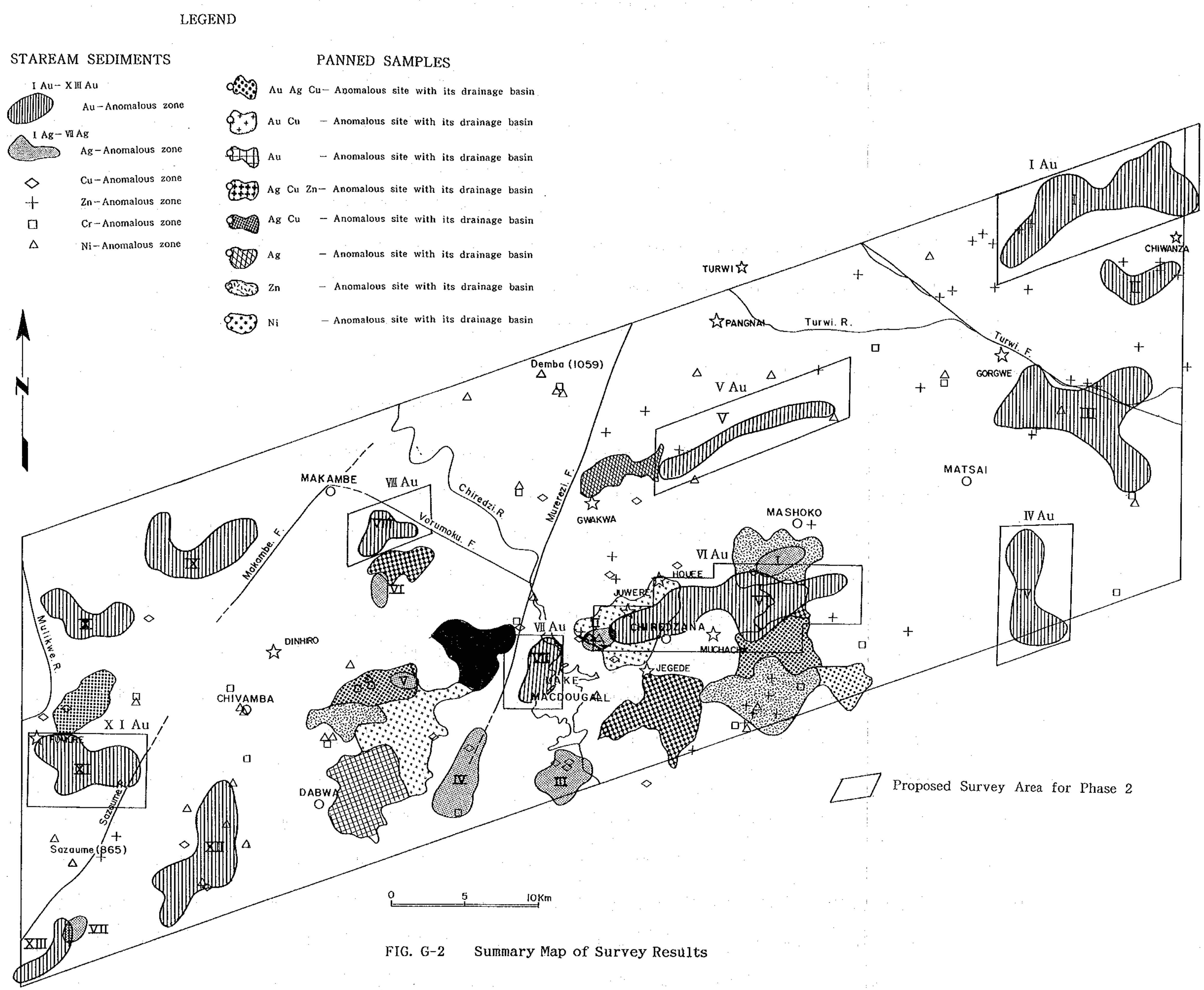
VI_{Au} anomalous zone

VII_{Au} anomalous zone

$VIII_{Au}$ anomalous zone

XI_{Au} anomalous zone

For Ag and other elements, the content of these was very low in the mineralized zones in the survey area, geochemical anomalous zones were found only sporadically in comparison with those for Au, consequently, no promising anomalous zones were identified.



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PART I GENERAL REMARKS

PART I GENERAL REMARKS

CHAPTER 1 INTRODUCTION

1-1 History and Purpose of the Survey

The survey was planned to be carried out over three years, starting at the beginning of this fiscal year, 1989. Since the geological features of the Macdougall area which is to be surveyed, are similar to those of the Renco Deposit, the possibility of finding a similar deposit in the area is thought to be high. This fiscal year, Landsat image analysis, geological survey, and stream sediments geochemical exploration were carried out to evaluate the feasibility of finding a deposit in the area.

1-2 The Survey Area and Outline of the Survey

The survey area is 2,300 km^2 wide, the base points being at longitude 31° 15' west and latitude 20° 30' south in the southwest edge, and at longitude 32° 00' west and latitude 20° 15' south in the northeast edge. Macdougall lake is nearly at the center of the survey area.

This fiscal year, Landsat image interpretation, geological survey, and geochemical exploration of stream sediment were carried out.

In the Landsat image analysis, the following kinds of images were composed from CCT (taken on September 3, 1984) to be used for geological analysis:

a) False-colour, full-scene, scale: 1/250,000

b) False-colour, sub-scene, scale: 1/100,000

c) Ratio image, sub-scene, scale: 1/100,000

d) Full scene, black-and-white image, scale: 1/500,000

e) Ratio image (black-and-white), full-scene, scale: 1/200,000

f) Principal component image, scale: 1/100,000

These images were used to try to divide the area into geological units, to determine the geological structure, and to find alteration zones. The lineaments found on the images are shown in a rose diagram. Among these images, the ratio image (band 3/5, 4/3, 3/1 BGR) could be seen to have clearly reflected the geology and the geological structure of the area, and the false color, subscene (band 2, 3, 4 BGR; 2, 3, 5 BGR) could be used effectively in analyzing the geological structure.

In the geological survey, efforts were made to clarify the geology and the extent of mineralization of the survey area to indicate promising deposits, making use of the results of the Landsat image analysis. For the field survey, a topographical map in scale of 1:50,000, was enlarged to a scale of 1:25,000 and used as a route map. The survey route was determined by examining the results of the Landsat image analysis and taking the geological structure of the survey area into consideration. Aerial photographs and magnetic susceptibility meters were used in the survey. Sampling was performed carefully to identify rocks and rock facies typical to each survey location, and the interrelation between them. Thin section samples were collected from each species of rock or each type of rock with different rock facies, in the case where a species showed various rock facies, so that a microscopic examination could be carried out. In addition, sampling for x-ray diffraction was performed as necessary. Samples of ores and mineralized rocks were collected for polishing, examination, and chemical analysis.

The overall length of the survey route was 1,200 km, covering the whole survey area.

In the geochemical exploration, stream sediment was collected after careful study of sampling conditions.

Although it was first determined to collect stream sediment samples for panning where heavy minerals were concentrated directly on the bedrock, it was difficult to find locations which satisfy these conditions because bedrock is rarely exposed; consequently, samples were collected at any locations where heavy minerals were concentrated. Panned samples were examined under a microscope to check for the presence of gold and platinum particles, and to identify the main constituent minerals. Powder samples of 50 g or more were kept for each stream sediment which had been chemically analyzed so that it could be used in re-analysis.

The contents of the survey are shown in Table 1-1-1.

TABLE 1-1-1(1) OUTLINE OF SURVEY

SURVEY METHOD	AREA	CONTENTS
INTERPRETATION OF LANDSAT IMAGE	2,300 Km^2	①FALSE-COLOUR IMAGE(1:250,000) ②FALSE-COLOUR IMAGE(1:100,000) ③RATIO IMAGE(1:100,000) ④B. & W. IMAGE(1:500,000) ⑤B. & W. RATIO IMAGE(1:200,000) ⑥P. C. IMAGE(1:100,000)
GEOLOGICAL SURVEY	2,300 Km^2	1,200 Km SURVEY ROUTE LINE
GEOCHEMICAL SURVEY	2,300 Km^2	2,305 STREAM SEDIMENTS 150 PANNED STREAM SEDIMENTS

P. C. : Principal Component

TABLE 1-1-1(2) OUTLINE OF SURVEY

KIND OF TESTS	NO. OF SAMPLES	REMARKS
①MICROSCOPIC OBSERVATION OF ROCK THIN SECTIONS	125	
②MICROSCOPIC OBSERVATION OF ORE POLISHED SECTIONS	11	
③MICROSCOPIC OBSERVATION OF POLISHED-THIN SECTIONS	21	
④CHEMICAL ANALYSIS		
ROCKS	25	SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Au, Ag, As, Bi, Cu, F, Zn, Cr, Ni
STREAM SEDIMENTS	2,455	Au, Ag, As, Bi, Cu, F, Zn, Cr, Ni, Fe
⑤X-RAY DIFFRACTION TEST	6	
⑥EPMA ANALYSIS	21	
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1-3 Members of Survey Team

The members involved in the planning, managing and field survey are as follows:

Planning and Managing

JAPANESE MEMBER		ZIMBABWEAN MEMBER	
HIDEO HIRANO	M M A J	N. BAGLOW	G S D
HIROSHI SHIMOTORI	M M A J		
MASATSUGU OGASAWARA	J G S		

Field Survey

JAPANESE MEMBER		ZIMBABWEAN MEMBER	
FUMIO WADA	D O W A	TAFIRENYIKA CHIYANIKE	G S D
TSUTOMU KODAMA	D O W A	FOBES MUGUMBATE	G S D
SHINICHI IWAYA	D O W A		
HEIZABURO YAMAMOTO	D O W A		
TOSIAKI KAZAMA	D O W A		
HIROSHI YOKOYAMA	D O W A		
SOUICHIRO TANAKA	D O W A		

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Location and Transportation

The survey area lies within the catchment area of the Savi river which is located in the south-eastern part of the Republic of Zimbabwe. The mileage and time required by vehicle from Harare to the survey area are as followed;

① Harare to Beatrice : 50 Km / 0.7 hour

② Beatrice to Chivhu : 80 Km / 1.0 hour

③ Chivhu to Gutu : 80 Km / 1.0 hour

④ Gutu to Zaka : 90 Km / 1.3 hour

⑤ Zaka to Chiredzi : 90 Km / 1.3 hour

The area is served by the main tar road from Harare, branching off the Masvingo through Zaka to Chiredzi. This road traverses the survey area and good quality gravel road and tracks of variable condition serve as survey routes. Major parts of the area are accessible to a 4-wheel drive vehicle during the dry season

2-2 Topography and Drainage

The topography in the area is characterized by the gentle undulation of peneplain due to the bedrock geology of Archaean rocks. The area, lying at about 600 m elevation, covers the junction between the lowvelt and highvelt country. The highest peak in the area is Demba Mountain (1,059 m) and other prominent peaks are Babaninga M.(1,037 m) and Muromahoto M.(1,001 m) both lying in the northern part of the area. The alignment of the mountains and hills are strongly influenced by the geological structure prevailing in the area. The main drainages in the area are the Mashavutwe River, Chiredzi R., and Turwi R., and these flow down to the Savi River. Although most drainages dry up in the dry season, these 3 rivers have discharged all year round.

2-3 Climate and Vegetation

The climate of the area is clearly divided into two seasons, a dry season from April to October and a wet season from November to March. The temperature in October rises to more than 40° c due to the low elevation of some 600 m and low latitude of 20° s. Annual rainfall average of 700 mm and 600 mm have been recorded at Zaka and Baffalo Range to the north and south of the survey area, respectively. Almost all rainfall concentrates in the wet season, especially December to February. Vegetation in the area consists mainly of mopane and mangwe with a few baobao, acacias, and palms. The well-managed ranches are generally well-grassed, but the area of over-grazing has caused depletion of vegetation. Although the large scale sugar cane cultivation prevails in the lowvelt country south of the survey area, agriculture within the survey area is limited to small scale.

CHAPTER 3 PREVIOUS STUDIES IN THE SURVEY AREA

3-1 Outline of Previous Studies

Although some explorations based on E. P. O. were carried out within the area, few geological studies have been performed.

Approximately 10 % of the area lies in the area mapped by Odell(1975). The earliest 1 : 1,000,000 geological maps of the country did not distinguish between the gneisses of the Limpopo Mobile Belt and those of the Zimbabwe Craton,but the author showed that a structural and metamorphic gradation existed between the two geological terrains.

E. P. O. No. 299 was granted to Johannesburg Consolidated Investment Company Limited on the 11th October, 1969. E. P. O. covers 540 km^2 situated between the Chiredzi and Mkwasine rivers. Field work started on 5 January and was completed on 25 February 1970. The soil samples were collected and analysed for copper and nickel. A number of copper soil anomalies were found during the regional traversing. They were attributed to the lithological control of the bedrocks.
Claims were not pegged prior to the revocation of the order.

E. P. O. No. 300 was granted at the same time as E. P. O. 299. This covers the northernmost part of the survey area. The reservation was covered by reconnaissance soil sampling and geological mapping at scale of 1:25,000 and 1 : 50,000. In all a total of 61,700 samples were analysed and numerous copper anomalies were found in a belt extending 3 km north of the Turgwe river and 9 km from Resurgwe river(Turgwe copper prospects).

E. P. O. No. 353 was granted in August 1970 for the purpose of detailed exploration of the Turgwe copper prospects. A total 11,424 soil samples were collected and analysed for copper, nickel and cobalt. Detailed soil sampling, geological mapping, a magnetometer survey, trenching and wagon drilling defined two mineralized zones over the pyroxinite and contact between the pyroxinite and the gabbro.

The extension of the Turgwe copper prospect was reserved under E. P. O. No. 355. The area was geologically mapped and geochemically soil sampled. All anomalous results were examined in the field.
No significant mineralization of any kind was found.

E. P. O. No. 462 was granted to Prospecting Venture Limited on 22 February 1974 in respect to copper, nickel, lead, and precious metals. This covers northwestern

most portion of the survey area. Later E. P. O. No. 548 was granted in December 1979 covering 9.6 % of the area originally covered by E. P. O. No. 462.
Reconnaissance drainage sampling of the E. P. O. No. 462 led to the soil sampling of 23 areas of anomalous geochemistry. Traces of mineralization worthy of further work were found in four of the 23 blocks.
Finally, no small deposits of an economic grade of mineralization of interest to smallworkers were detected during the tenure of the E. P. O.

3-2 General Geology

The Limpopo Mobile Belt is an extensive east-north-east trending of high grade metamorphic rocks that lies between the Zimbabwe and Kaapvaal cratons. It is approximately 600 km long by 300 km wide and continues across the southern portion of Zimbabwe into Botswana.
The belt may be subdivided into three zones, that is, northern and southern marginal zones and a central zone. The northern marginal zone is further subdivided into a granulite subzone, characterized by metamorphism of granulite facies and a a zone suffered intense shear deformation and retrograde metamorphism.

In regard to geological structure, the predominant feature throughout the Northern Marginal Zone is a persistent east-north-easterly foliation. Isoclinal folding is strongly suggested due to constant south dipping of the foliation.
But the rock units in the area are complexly folded and refolded on all scale.

Measurements of foliation have been made of the orientation of the mineral banding in the granulite. These data are presented in stereographic projections. No significant differences of foliation pattern are recognized in either the southwestern or northeastern area. The poles have been interpreted as the predominant fold axis.

In the central part of the area, the mafic granulite forms flow folding which is revealed by Landsat image and the mapping. This type of folding is recognizable throughout the area on a small scale in individual outcrops.

3-3 Geological Background of the survey area

The Northern Marginal Zone of the Limpopo Mobile Belt comprises high grade metamorphic rocks. No formal lithologic or stratigraphic subdivision of the rocks has been made. The emplacement ages of the rocks in the Northern Marginal Zone are uncertain but are probably more than about 2,870 Ma(Barton, 1983; Hickman, 1978). Metamorphic conditions in the Northern Marginal Zone are thought to have been greater than 750 ℃ and 5 kilobars at about 2,870 Ma ago(Robertson and Du Toit, 1981). It is thought that this metamorphic event was strong enough to eliminate any possible previous metamorphic evidents. A second metamorphism may have occurred about 2,700 Ma ago. This is roughly coeval with the last metamorphism in the Southern Marginal Zone.

Also this belt has been affected by deformations. On the this topic, agreement has not been reached among researchers. In the Northern Marginal Zone, at least two regional deformational events are recognized(Robertson and Du Toit, 1981)but the age of these deformations is uncertain.

Occurrences of mineralization in the Northern Marginal Zone are quite limited. Economic mineralization of chromite within a serpentinite complex and highly folded gold mineralization in enderbites at Renco deposit are the principal ones. Exploration for Cu-Ni mineralization has been largely unsuccessful although small deposits associated with mafic granulite are found.

3-4 Mining History of the Survey Area

Economic mineralization of significance in the area is restricted to folded gold mineralization in enderbites at the Renco Mine north of Bangala Dam.

Exploration for copper-nickel mineralization has been largely unsuccessful although small deposits associated with mafic granulite are known and several geophysical anomalies discovered during exploration exercises proved to be massive pyrite-pyrrhotite bodies not otherwise mineralized (Stagman,1978).

Mineral production in Zimbabwe in 1988 amounted to $Z 985.63 million (about $US 540 million), compared with $Z 815.40 million (about $US 480 million) in 1987. The overall pattern of the preceding years was maintained with a steady increase in the value of output in US dollar terms since 1984, when the value was just under $US 400 million(Mining Journal, 1989).

The actual value of mineral production exported rose to $Z 1.3 billion ($ US 714 million). The overall mineral output figures are the result of a number of gains and losses in the industry in 1988. The contribution to revenue from gold, whose declared output was 14,961 kg worth $Z 379.53 million ($US 209 million), represents an 8.7% rise in terms of Zimbabwe dollar revenue over the 1987 figures, but only a 1.7% increase in volume. The 1987 figures were, however, increased by selling of reserves held by the Zimbabwe Reserve Bank, and in fact a number of new gold projects came on-stream in 1988.

The most noteworthy of these was the Freda-Rebecca project of Cluff Mineral Exploration Ltd. The two-plant operation(heap leaching of the oxides) was formally started in April, 1989. The Freda-Rebecca operation will be the largest single gold producer in Zimbabwe; the oxide plant generating about 470kg/y (15,000 oz) from a 1,800t/d operation and the sulphide plant about 1,500kg/y (48,000oz) at a milling rate of 2,000t/d.

Other increases in gold production came from the Lonrho group mines, particularly Athens and Redwing, while major expanding programmes were announced for Shamba and Tiger Reef. Other projects announced included a major tailing treatment plant at Rio Tinto's Cam and Motor mine which would raise the output there from 150kg/y at present to 650kg/y and Anglo-American's first major gold project, Isabella heap leaching operation in Bulawayo area.

Nickel output increased by 10%, reflecting the Bindura Nickel Corp's bounce back into profitability after an extremely near shutdown the previous year.

Silver output dropped by 16%, in parallel with copper, due to a loss of production at the Mhanghura copper mines of the Zimbabwe Mining Development Corp. and problems with the smelter at Lomagundi Smelting and Mining near Chinyi.

In summary, 1988 was the best year for mining in Zimbabwe since independence, and with the implementation of announced changes in government policy, the industry should be able to maintain its momentum.

TABLE 1-3-1 Mineral Production of Zimbabwe, 1987-1988

Mineral Production in Zimbabwe, 1987-88

Commodity	Units	1987	Value** $US×10^6	1988	Value* $US×10^6
Asbestes	t	193,925	58・65	186,581	53・68
Chromite	t	570,298	26・47	561,177	24・89
Coal	t	4,638,759	61・97	4,517,630	58・13
Cobalt oxide	t	110	0・82	126	1・54
Copper	t	18,819	27・61	16,116	35・55
Emeralds (out)	ct	3,769	0・84	3,682	0・75
Emeralds (rough)	kg	1,207	1・91	563	1・29
Gold	kg	14,710	209・71	14,961	208・67
Graphite	t	13,530	2・53	11,441	2・66
Iron ore	t	1,328,393	17・28	1,020,901	13・49
Iron pyrites	t	46,606	1・20	39,659	1・29
Limestone	t	1,536,803	6・65	1,408,244	6・08
Lithium minerals	t	14,959	2・52	15,073	2・44
Magnesite	t	28,991	0・56	30,121	0・70
Nickel	t	10,394	43・84	11,490	108・88
PGMs and selenium	kg	2,660	0・46	2,680	0・66
Phosphate rock	t	154,827	6・87	121,156	5・39
Silver	kg	25,351	9・57	21,953	7・28
Tantalite	t	37	0・42	66	0・42
Tin metal	t	1,038	6・92	855	6・14
Total			486・79		539・91

** Average 1987 exchange rate, Zimbabwe dollar = US-¢ 59.93.

* Average 1988 exchange rate, Zimbabwe dollar = US-¢ 54.98.

CHAPTER 4 DISCUSSION ON THE SURVEY RESULTS

4-1 Relation between Geological Structure and Mineralization

Geological structure is roughly classified into two domains, the western and eastern parts of the area. The former is characterized by very constant continuous foliation suggesting tightly-folded structure and the latter is variable in direction representing different deformation history.

The relationship between mineralized zones in the area and geological structure has not been clarified. The zones, however, can be tentatively classified into 5 categories from the sulphide mineralization point of view.

It was observed that for the ore minerals (sulphide minerals and partially oxidized minerals) the following groups of mineralized zones could be identified, each having similar mineralization characteristics with slight differences in occurrence:

(1)Jegede, Juwere, Hovee, Muchacha

The ore minerals found in these zones consist of pyrrhotite, pyrite, marcasite, chalcopyrite and magnetite-ilmenite association. The ratio of these constituent minerals is also similar, and this suggests that the mineralization process of these mineralized zones might have been similar.

(2)Gorgwe

The ore minerals found in this zone consist of pyrrhotite and chalcopyrite. The ratio of these constituent minerals is also similar to (1), but different in its mineral combination. Mineralization process of this mineralized zone might have been different from that of (1). According to the analytical results by EPMA, millerite (NiS) was found.

(3)Dinhiro

The ore minerals found in this zone consist of only pyrrhotite. The country rock of the zone is iron formation.

(4)Turwi, Panganai

These zones can be characterized by very little amount of sulphide minerals in comparison with the zones of group (1), (2), and (3).

(5)Fumure, Chiwanza, Gwakwa

The mineralization characteristics are not known except that Fe-hydroxides are found. No details of the mineralization in the zones are known. Since a mineralized zone is frequently formed by ascending ore solution through fractures, the relationship between these mineralized zones and the geological structure was examined. However, no particular relationship to the main faults or lineaments was found, except that the area of low mylonitization (at the center of the southeast area) has fewer mineralized zones and anomalous geochemical zones.

The results of the chemical analysis of samples taken from each mineralized zone were examined for a better understanding of the mineralization characteristics of the survey area and the geochemistry of each mineralized zone could be considered to be as follows:

(1) Jegede, Muchacha

The elements and the combinations of these which characterize these zones are:

Au-As-Cu-Zn

In particular, the As content is higher than in the other zones. Although the combination of sulfides and the frequency of occurrence is nearly the same as in the other zones, the combination of elements and the content is different.

(2) Juwere

The elements and the combination of these which characterize these zones are:

Au-Bi-Cu

In particular, the samples collected in this survey are characterized by the content of Au and Bi which is higher than in the other zones.

(3) Hovee

The elements and the combination of these which characterize this zone are:

Au-Cu-Zn

Although the content of Zn is higher than in the other zones, Zn sulfide minerals are not found in this zone.

(4) Turwi, Panganai, Dinhiro, Fumure, Chiwanza

The element which characterizes these zones is Cr. There is not a significant high content for any other element.

(5) Gorgwe

The element which characterizes this zone is F. In some locations, the content of Cr is also high.

(6) Gwakwa

There is no element which characterizes this zone. When comparing these results with the results of analysis of ores in the Renco Deposit, it was found that, among the above mentioned mineralized zones, the following zones show similar concentration pattern of elements to those within the reef of the Renco Deposit:

Jegede mineralized zone

Juwere mineralized zone

Muchacha mineralized zone

The comparatively high content of F in the Gorgwe mineralized zone suggested that a pegamatite-related mineralization process, which is similar to that seen in the Renco Deposit, may be considered.

On the control of mineralization, there is little evidence throughout the survey area that the mineralization process has been restricted by particular geological occurrence. From the geological point of view, however, many of the mineralized zones have mafic granulite as country rock, in spite of the fact that the distribution area of mafic granulite is quite small considering the whole survey area. This coincides with the tendency that the background value of geochemical indicators in mafic granulite is high from the results of the geochemical exploration. Since the mineralized zones in the survey area are all formed by epigenetic mineralization, the relationship between the type of country rocks and the origin of mineralization cannot in general be discussed.

4-2 Mineral Potential on the Survey Area

In the survey for the Phase 1, the mineralized zones identified in the survey area were classified into five groups according to the occurrence of sulfides , and into six groups according to the elements, the content of which was shown to be high from chemical analysis. Among these mineralized zones, the following zones were determined to be promising in view of the Au grade and the elements generally found with Au mineralization (e.g. Ag, As and Bi):

Jegede mineralized zone

Juwere mineralized zone

Muchacha mineralized zone

These mineralized zones are all located near Chirezana Business Center. Although the concentration of elements are slightly different (Jegede and Muchacha zones: Au-As-Cu-Zn, Juwere zone: Au-Bi-Cu), the kinds of sulfide minerals and the occurrence of mineralizations are similar. This suggests that these zones were formed in the course of a series of mineralization processes. In particular, the Juwere mineralization zone is located in the VI_{Au} anomalous zone, which proved to be one of the most promising geochemical anomalous zones found in the survey in the Phase 1. It can be expected that more mineralized zones of the same kind may be found in the area covering the zones mentioned above.

TABLE 1-4-1 SUMMARY OF MINERALIZED ZONES

N A M E M. Z.	MINERALIZATION	ANOMALOUS INDICATORS	G E O L O G Y	G. C. ANOMALOUS Z O N E(Au)
JEGEDE	Au?	Au-As-Cu-Zn?-Cr??	Mafic Granulite	
JUWERE	Au	Au-Bi-Cu-Cr??	Gneissose granulite	VI_{Au}
TURWI	Au?, Cr??	Au?-Cr??	Mafic Granulite	
PANGANAI	Au?, Cr??	Au?-Cr??	Gneissose granulite	
GORWGE	Au??	Au?-F-Cr??	Gneissose granulite	
DINHIRO	Au?, Cu, Cr?	Au-Cu-Cr	Iron Formation	
HOVEE	Au, Cu, Zn	Au-Cu-Zn	Mafic Granulite	
MUCHACHA	Au, Cu, Zn	Au-As-Bi?-Cu-Zn-Ni?	Mafic Granulite?	
FUMURE	Au?, Cr?	Cr	Mafic Granulite?	XI_{Au}
CHIWANZA	Au?, Cr?	Cr	Gneissose granulite?	
GWAKWA	Au?, Cr?	?	Felsic Granulite?	

G. C. : geochemical M. Z. : mineralized zone

4-3 Relation between Geochemical Anomalies and Mineralization

The mineralization in the area is not so promising judging from the assay results of samples from the mineralized zones(TABLE 2-2-2). Detected promising mineralized zones are all related to Au mineralization. We tried a comparison between the concentration of elements(Au, Ag, As, Bi, etc.) within the zones and reef in Renco Deposit.

TABLE 1-4-2 MAXIMUM VALUES OF VARIOUS ELEMENTS FOUND WITHIN REEF(ppm)

ELEMENTS	VALUES	ELEMENTS	VALUES
Au	1,760	Pb	587
Ag	31.6	Zn	480
Cu	50,000	Co	229
Bi	1,900	As	882
Ni	469	S	38,000
Cr	167	Fe	400,000
Te	present	Wo	present

After Bohmke & Varndell(1986)

As a result of the interpretation, the following zones have similar geochemical characteristics to those of reef in Renco Deposit.

Jegede mineralized zone

Juwere mineralized zone

Muchacha mineralized zone

An investigation was carried out to delineate the relation between the mineralized zones and geochemical anomalies. Since only Juwere, and Fumure mineralized zones are included within the geochemical anomalous zones, the relationship between mineralization and geochemical anomalies is not so clear in general. It can be concluded that the following seven geochemical anomalous zones have rather similar geochemical characteristics to those of the above mentioned three mineralized zones on the basis of their analytical results, especially on the concentration of elements(such as Ag, As, Bi) which are accompanied with Au mineralization .

TABLE 1-4-3 PRINCIPAL GEOCHEMICAL ANOMALOUS ZONES(Au)

NAME A.Z.	ANOMALOUS INDICATORS BY STREAM SEDIMENTS	ANOMALOUS INDICATORS BY P. C. SCORE	ANOMALOUS INDICATORS BY PANNED SAMPLES	MINERALIZED ZONE
I Au	As, Zn	Au-As		
IV Au	Bi	Au-As	As-Bi, Au	
V Au	Ag, Bi, Cu, Zn	Zn-Fe		
VI Au	Ag, As, Bi, Cu	Au-Ag, As-Bi, Au-As	Au, Ag, Cu, Zn Ag-Cu-Zn	Juwere
VII Au	As, Bi, Zn	Au-As-Bi, Au		
VIII Au	Bi	Au-As-Bi		
XI Au	Ag, As, Bi,	Au, Au-Ag, Au-As Au-As-Bi	Bi	Fumure

A. Z.: anomalous zones P. C.: principal component

All the mineralized zones in the survey area may be classified as vein-type deposits. Consequently, type of deposits in the area is different from that of Renco deposit which is assumed to be a synsedimentary exhalative deposit.

More detailed studies on the mineralization in the survey area are warranted.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5-1 Conclusion

In the phase 1 programme, Landsat image interpretation, geological survey, and geochemical exploration in the Macdougall area were conducted to select favourable zones for the exploration of ore deposits.

Conclusions are as follows:

Landsat Image Interpretation : CCT(Computer Compatible Tape) used this interpretation is the data of Landsat TM(Thematic Mapper). Using the data, the following GEOPIC equivalent image was produced.

a) False-colour image full-scene, 1:250,000

b) False-colour image sub-scene, 1:100,000

c) Ratio image sub-scene, 1:100,000

d) Black & white image full-scene, 1:500,000

e) Black & white ratio image full-scene, 1:200,000

f) Principal component image sub-scene, 1:100,000

An effort was concentrated into the determination of geological units and structure, and also detection of hydrothermally altered zones.

An interpretation of geological units and structure through Landsat image was conducted chiefly based on the differences of susceptibility to weathering, tones, vegetation patterns, drainage pattern and its density. As a results of the interpretation, the following 6 rock units were detected:

Unit: Pg (Paragneisses)

Unit: Gf (Gneissose granulite and felsic granulite)

Unit: Mg (Mafic granulite)

Unit: If (Iron formation)

Unit: Do (Dolerite)

Unit: Gg (Gneissose granite)

The lineament shows N-S, NE-SW, NW-SE, and ENE-WSW direction, among which the N-S direction is the most conspicuous.

When the formation of the lineaments in the survey area is considered, they are thought to have developed in the following order:

1. ENE-WSW and NW-SE direction (formed the ENE-WSW fold axis)
2. N-S and NE-SW direction (with dolerite intrusion)
3. NW-SE direction

For the purpose of delineation of alteration zones in the area, spectrum measurement was conducted on rocks from the principal geological units.
Based on the results of the measurement, the following two main alteration zones are selected on the Landsat image.

1) Fe-hydroxides, chlorite, epidote etc. having Fe in their molecular formulas.
2) representative clay minerals such as montmorillonite, sericite, kaolinite etc..

Landsat image has the advantage of allowing reconnaissance survey to be performed in a limited period covering a large area where no data of geoscience are available, due to good consistency and uniformity in contrast to aerial photography.
Ratio image (band 3/5, 4/3, 3/1 BGR) is good for the interpretation of geological units and structure, and also false-colour image for geological structures.

Geological Survey : The survey area is situated in the Limpopo Mobile Belt which is an extensive east-north-east trending of high grade metamorphic rocks that lies between the Zimbabwe and Kaapvaal cratons. It is approximately 600 Km long by 300 Km wide and continues across the southern portion of Zimbabwe into Botswana.

The survey area comprises mainly high grade metamorphic rocks.
The main geological units are as follows:

Gneissose granite: This unit is distributed in the northwestern margin of the area. It retains granitic texture under the microscope. The rock forms a part of Zimbabwe Craton.

Gneissose granulite: This unit predominates in the area. The rock is characterized by clear banded structure presenting a trend N 50° -70° E in general.

Felsic granulite: This unit is included in gneissose granulite and typical luecocratic one. Main distribution area of the rock is in the eastern part of the area.

Mafic granulite: This unit is included in gneissose granulite and felsic granulite with a width of several hundreds to 1,000 metres. It distributes mainly in southwestern to central areas. One characteristic of the rock is the formation of red soil by weathering.

Iron formation: Only several hundreds of metre width of the rock is confirmed in the field. It comprises several centimetres wide Fe-hydroxide band in quartz matrix.

By weathering, it frequently exhibits a red surface appearance.

Dolerite: This is dyke rock intruding in predominantly N-S trend, however, some exhibits the same trend with WSW-ENE foliations.

The geological structure of the survey area is characterized by the ENE-WSW (N60-70E) system foliations. Although most of the foliatiations dip toward the south, there are also foliations dipping toward the north in the southern area. The whole area shows a heavy fold. It is highly possible that the survey area was divided into blocks by Sazaume-Makambe, Murerezi and Turwi faults, and that the third block between the Murerezi and Turwi faults, in which foliation was disturbed, rose comparatively high.

Eleven mineralized zones have been recognized in the area. Except for the zones poorly understood, others can be classified into the vein type deposits. Consequently, it is different from that of Renco Deposit which is a synsedimentary exhalative deposit.
Almost all assay results of samples from the mineralized zones are not so attractive from an economical point of view.

Since a mineralization zone is frequently formed by ascending ore solution through fractures, the relation between these mineralization zones and the geological structure was examined. However, no particular relationship to the main faults or lineaments was found, except that the area of low mylonitization (at the center of the southeast part in the survey area) has fewer mineralization zones and anomalous geochemical zones.

Among these mineralized zones, the following zones were determined to be promising in view of the Au grade and the elements generally found with Au mineralization (e.g. Ag,As and Bi):

Jegede mineralized zone

Juwere mineralized zone

Muchacha mineralized zone

Geochemical similarities in some elements(e.g. : Au, Ag, As, Bi) can be pointed out between these three mineralized zones and Renco Deposit.

Geochemical Exploration : Some 2,305 stream sediments and 150 panned samples were collected from the survey area which was 2,300 km^2 wide. Analysis was carried out for Au, Ag, As, Bi, Cu, F, Zn, Cr, Ni and Fe, and the results were used in single variate analysis and multivariate analysis. The results of these analyses were used to understand the geochemical characteristics of each geological unit.

Except for Au , the content of other elements was very low in the mineralized zones in the survey area. Geochemical anomalous zones for these were found only sporadically in comparison with those for Au, and the correlation coefficients among indicators was rather weak; consequently, no promising anomalous zones were identified.

On the other hand, 13 Au anomalous zones were detected as concentrations of anomalous geochemical values.

On the basis of the following criteria, finally seven promising Au anomalous zones have been selected.

Criteria:

(1)Number(B) of Au anomalous value which is included in an anomalous zone counts 2 points as a score.

(2)Number(C) of anomalous values of elements(Ag, As, Bi) which are included in an anomalous zone counts 1 point as a score.

(3)Number(C) of anomalous values of principal component score which are geochemically correlated to Au mineralization counts 1 point as a score.

(4)Calculation of "Index of geochemical anomaly"

"Index of geochemical anomaly"= [(B)+(C)] / (A)

Where, (A) stands for the dimension(km^2) of the anomalous zone.

The selected calculation results of "Index of geochemical anomaly" are listed below:

ANOMALOUS ZONE	DIMENSION OF A. Z. (A)	SCORE COUNTED BY Au ANOMALY (B)	SCORE COUNTED BY OTHER A. (C)	" INDEX OF GEOCHEMICAL ANOMALY" [(B)+(C)] ／ (A)
① I Au ANOMALY	65 km^2	38	8	0.71
② IV Au ANOMALY	32 km^2	12	10	0.69
③ V Au ANOMALY	14 km^2	12	4	1.14
④ VI Au ANOMALY	90 km^2	44	27	0.79
⑤ VII Au ANOMALY	15 km^2	10	6	1.07
⑥ VIII Au ANOMALY	12 km^2	14	5	1.58
⑦ X I Au ANOMALY	28 km^2	14	15	1.04

A. Z. : ANOMALOUS ZONE A. : ANOMALY

Seven Au anomalous zones were selected.

The results can be divided into 3 groups depending acquired scores:

ANOMALOUS ZONE	"INDEX OF GEOCHEMICAL ANOMALY" VALUE	PRIORITY
Ⅷ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 1.58	A
Ⅴ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 1.14	B
Ⅵ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 0.79	B
Ⅶ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 1.07	B
XI Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 1.04	B
Ⅰ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 0.71	C
Ⅳ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY" 0.69	C

Taking all related factors, especially mineralized zones included, into consideration, the seven anomalous zones were evaluated for priority.

The results are as follows:

ANOMALOUS ZONE	"INDEX OF GEOCHEMICAL ANOMALY" VALUE	
GROUP 1		
Ⅷ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	1.58
GROUP 2		
Ⅴ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	1.14
Ⅶ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	1.07
XI Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	1.04
GROUP 3		
Ⅵ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	0.79
Ⅰ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	0.71
Ⅳ Au ANOMALY	"INDEX OF GEOCHEMICAL ANOMALY"	0.69

Because of no definite discovery of mineralized zones, we calculated an "index of geochemical anomaly" as an expedient.

5-2 Recommendation

Based on the results and conclusions of the Phase 1 programme, the following surveys are recommended for the Phase 2 programme.

Exploration targets for Phase 2 are the selected 7 anomalous zones.

ANOMALOUS ZONE	PRIORITY
VIII Au ANOMALY	A
V Au ANOMALY	B
VI Au ANOMALY	B
VII Au ANOMALY	B
X I Au ANOMALY	B
I Au ANOMALY	C
IV Au ANOMALY	C

Detailed geological survey and geochemical survey by soil should also be conducted.

Geological survey : A detailed geological mapping within the geochemical anomalous zones and mineralized zones is recommended. After the interpretation of the survey results, target areas for geochemical survey by soil should be selected.

Geochemical survey : Geochemical survey consists of soil geochemistry.

Indicators applied are Au, Ag, As, Bi, Cu, F, Cr, Ni, Fe as well as the Phase 1 programme. Systematic line cutting and some trenches should be conducted.

PART II DETAILS OF THE SURVEY

PART II DETAILS OF THE SURVEY

CHAPTER 1 LANDSAT IMAGE INTERPRETATION

1-1 Survey Methods

In many geological applications, Landsat data are used with other types of geoscience data. Comparisons of analyzed image data with geological, geophysical, and geochemical data are an important component of the interpretive process.

CCT(Computer Compatible Tape) used in this interpretation is the data from Landsat TM(Thematic Mapper) which fully covers the study area(Fig.2-1-1). Using the data, a GEOPIC equivalent image was produced. Correction of radiometric, edge and contrast stretching which were essential for an application to geological interpretation were done in the process of developing the image. The following 6 kinds of image were prepared:

a) False-colour image full-scene, 1:250,000
b) False-colour image sub-scene, 1:100,000
c) Ratio image sub-scene, 1:100,000
d) Black & white image full-scene, 1:500,000
e) Black & white ratio image full-scene, 1:200,000
f) Principal component image sub-scene, 1:100,000

1-2 Survey Results

Effort was concentrated into the determination of geological units and structure, and also detection of hydrothermally altered zones.

An interpretation of geological units and structure through Landsat images was conducted chiefly based on the differences of susceptibility to weathering, tones, vegetation patterns, drainage pattern and density. As a results of the interpretation, the following 6 geological units were detected:

(1) Geological Unit

Unit Pg (Paragneisses) : The relatively low resistance reduces relief, causing an unclear fracture pattern. However, an N-S fracture pattern can be observed, though it is not distinct. No bedding pattern can be seen because it is covered with surface soil or located in a metamorphic rock area.

For the drainage pattern, one limited by an N-S fracture and another showing a lattice or dendritic shape are found.

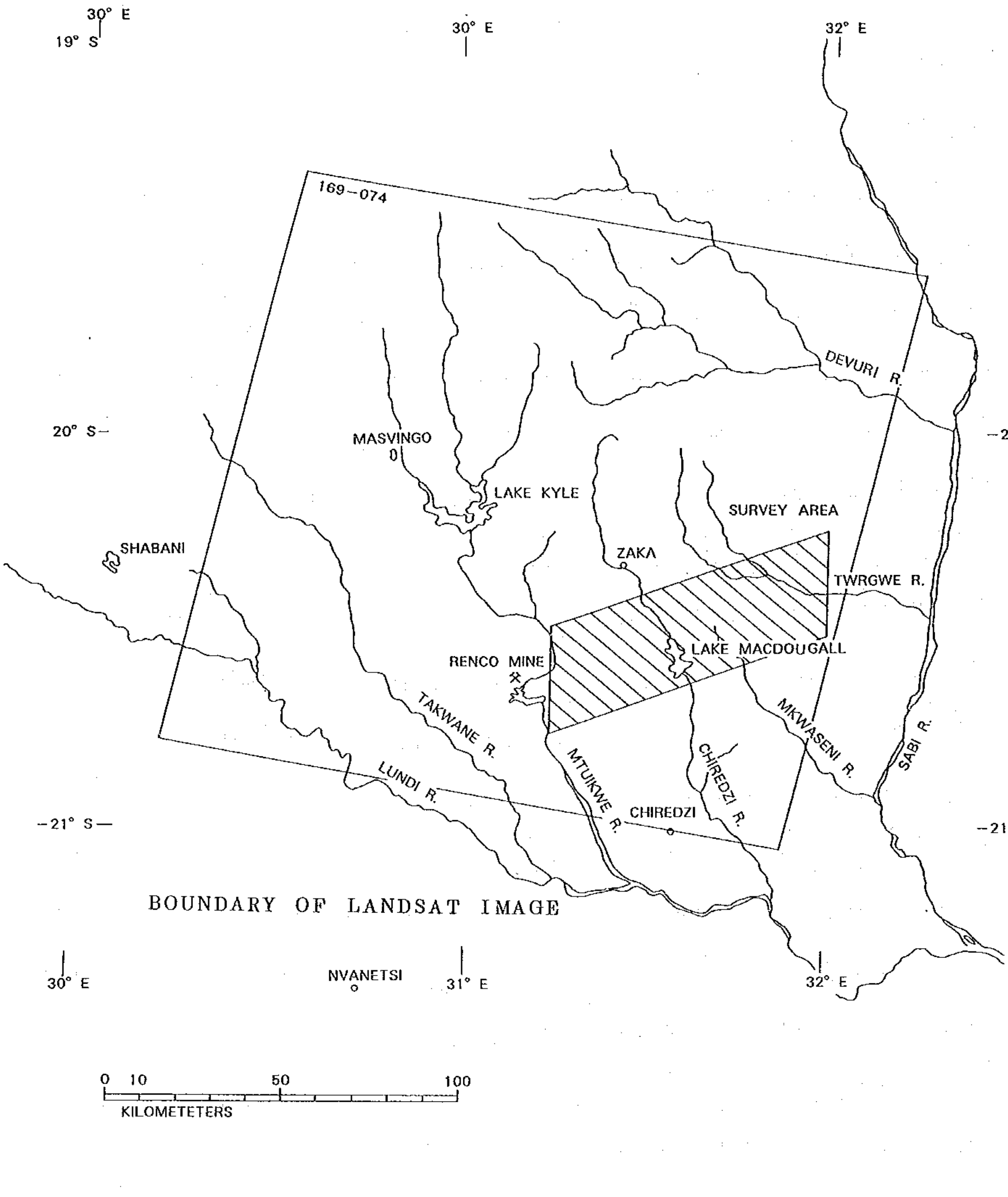


FIG.2-1-1 Locality Map of Landsat Image

The boundary between this unit and Unit Gf has not been established clearly and can be narrowly distinguished by tracing a weak linear pattern on the image with reference to the existing geological map. In some places, however, a small change in the drainage pattern is observed. In case that the detailed drainage is observed by using the 256 BGR image in the vicinity of the boundary, the Gf side often shows lattice or parallel (meeting at right angles to the direction of foliation) pattern. However, the Pg side shows a dendritic shape and even a slight change in drainage pattern.

Unit Gf (Gneissose granulite and felsic granulite) : The resistance is slightly high and the axis of synform forms a ridge. The fracture pattern has made the largest development in the N-S direction, but fracture in the NE-SW and NW-SE directions is also found. The pattern also seems to be found in the ENE-WSW direction, but it is difficult to determine the properties of the fracture pattern because of the overlap with foliation which dominates the survey area.
Foliation is observed based on topographical properties and slight differences in contrast (i.e. 256 BGR of the ratio image), but is weak.
The drainage pattern shows a lattice shape in the western survey area, where regular folding has developed, but shows a dendritic shape in the eastern area. Felsic granulite and gneissose granulite, which are included together in this unit, are difficult to differentiate from each other in the image.

Unit Mg (Mafic granulite) : The resistance is of about medium class in comparison with other geological units. The fracture pattern cannot be observed clearly because the distribution of this unit is shown in a thin layer shape or vein shape, but is considered to be the same as that of Unit Gf.
In regard to foliation, the detailed structure within this unit is unclear, but the pattern can be observed from the manner by which this unit is distributed in Unit Gf. That is, this unit generally extends in the ENE-WSW direction. In the western part of the survey area, rocks have been folded with relatively longer wave length than that in the eastern part and also show favorable continuity of foliation. In the eastern part, however, there are many folds which have short wave length, the details of which are unclear, and the continuity of foliation is also inferior to that in the western part.
The drainage pattern cannot be observed clearly because the distribution of this unit is shown as a thin layer shape or vein shape and also because it is distributed in a small area. However, the pattern is probably considered to be the

same as that of Unit Gf.

This unit is one of those which have the most distinguishable image contrasts among geological units distributed in the survey area. It is clearly observed in the image which includes band 3 of TM, and is particularly shown clearly in the comparative image at a ratio 3/1, which is often used for extracting Fe-hydroxide.

Unit If (Iron formation) : The resistance is at a normal level. The fracture pattern, foliation, and drainage pattern cannot be observed because of the small distribution area of this unit.

The unit closely resembles Unit Mg in terms of the contrast in images, but this unit is slightly superior in image texture.

Unit Do (Dolerite) : The resistance is relatively low.

The fracture pattern cannot be observed owing to the small distribution area of this unit, but fracture is thought to have developed less frequently.

The drainage pattern also cannot be observed adequately because this unit is distributed in a small area.

The image contrast is almost the same as that of Unit Mg, so that distinction between the two is difficult to make. However, we have made the distinction based on the fact that this unit has a slightly higher saturation of green in the 234 BGR image and has a characteristic distribution pattern (linear-band type distribution). The distribution pattern seems to show that this unit has intruded chiefly along a N-S (partially E-W to NE-SW) fracture.

In almost all cases, the direction of foliation of this unit crosses those of Unit Gf and Unit Mg.

Unit Gg (Gneissose granite) : The relatively low resistance reduces relief.

The fracture pattern is generally unclear but unlike Unit Gf and Unit Mg, the fracture in the ENE-WSW direction is observed comparatively clearly. However, the pattern if this direction may be a linear pattern from something other than a fracture (e.g. foliation). The drainage pattern shows a dendritic shape.

The boundary between this unit and Unit Gf is not clear, but we have expressed it in FIG. 2-1-2(1) by tracing a faint linear pattern on the image.

The interpretation of geological units and structure was mainly made by using Landsat false-colour image(FIG.2-1-2(2)) and ratio image(FIG.2-1-2(3)).

(2) Geological Structure

The lineament shows N-S, NE-SW, NW-SE, and ENE-WSW direction, among which the

N-S direction is the most conspicuous(FIG.2-1-3). The lineament of this type is shown as a clear straight line when an image of a small scale (1:500,000) is observed over a wide range. However, it appears as a group of more than one (relatively) short lineament when an image of greater scale (1:100,000) covering only the survey area is observed, and it is also cut by other-direction lineaments in many cases. As the N-S type lineament group in this survey area, one group (partially intruding dolerite) and two groups are distributed in an area near the western end of the area and in its eastern side, respectively. Among these lineaments, many of those in the eastern part have dolerite intrusions. The dolerite has also intruded slightly into the NE-SW lineament. Lineaments in the E-W direction are estimated to exist in a large quantity, but they are difficult to extract because their directions coincide with that of foliation.

A group of NE-SW lineaments, which traverse the northern end of Lake Macdougall located in the central part of the survey area, has developed for only units Gf and Mg. The western side to this lineament group is covered by a comparatively regular fold structure but the eastern side is covered by a more complicated structure which is difficult to identify. Considering that the fold axis adjacent to the lineament group runs not in the ENE-WSW direction but slightly in the NW-SE direction, this lineament group might have had a rightward angle. (A bookshelf-type fracture can also be considered by combining the fracture at the boundaries between Units Pg and Gf and Units Gf and Gg with this lineament groups.) The NW-SE lineament along the Turwi River at the eastern end of the area has good continuity without being crossed by other lineaments. Accordingly, this is the newest lineament.

When the formation of the lineaments in the survey area is considered from these facts, they are thought to have developed in the following order:

1. ENE-WSW and NW-SE direction (formed the ENE-WSW fold axis)
2. N-S and NE-SW direction (with dolerite intrusion)
3. NW-SE direction

The results of geological and structural interpretation are shown in Fig.2-1-2(1). Lineaments detected from image have a concentration into north - north-west direction which is roughly perpendicular to the foliations (ENE-WSW) predominant in the area. As geological units, however, are widely traceable to

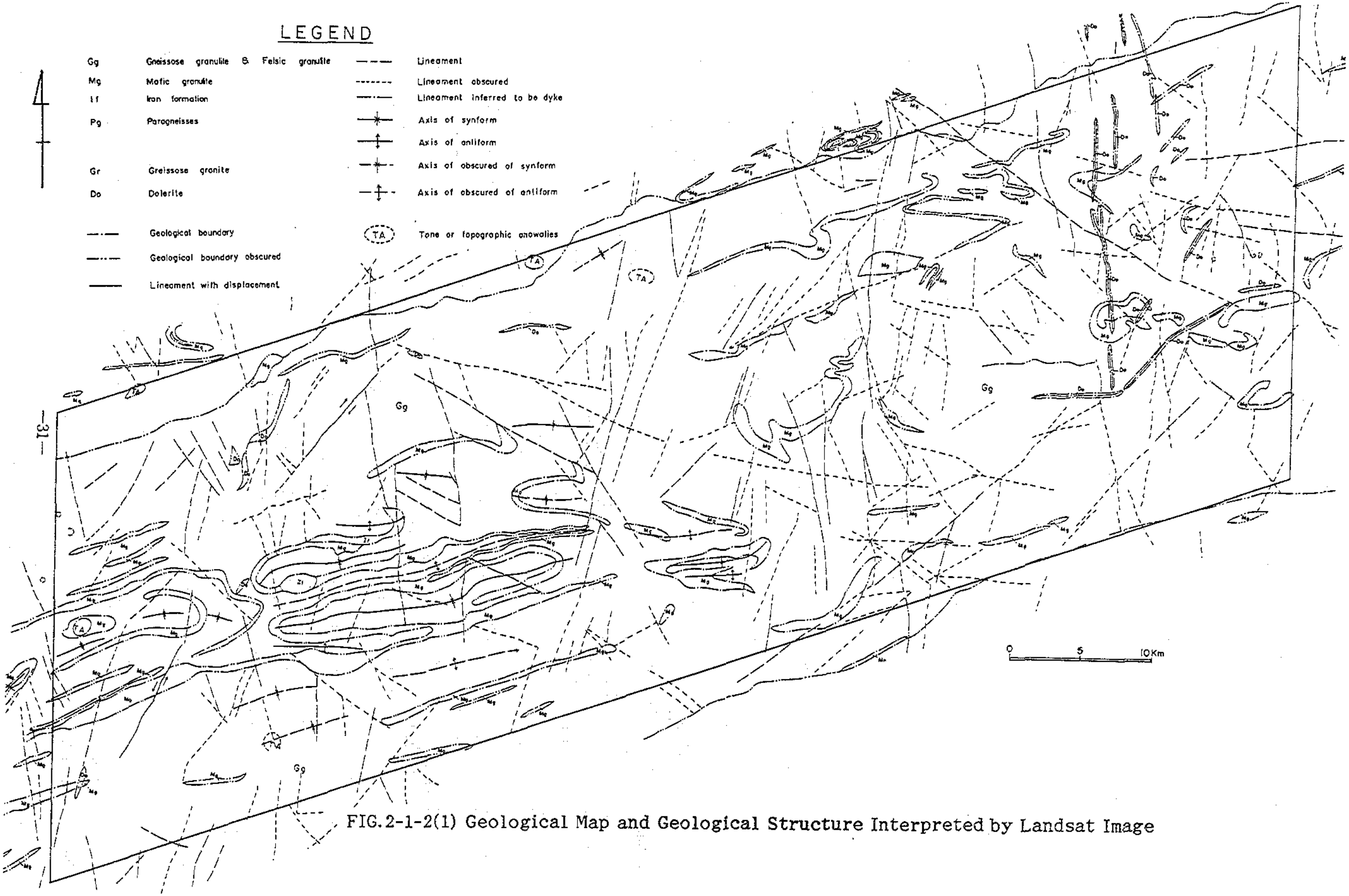
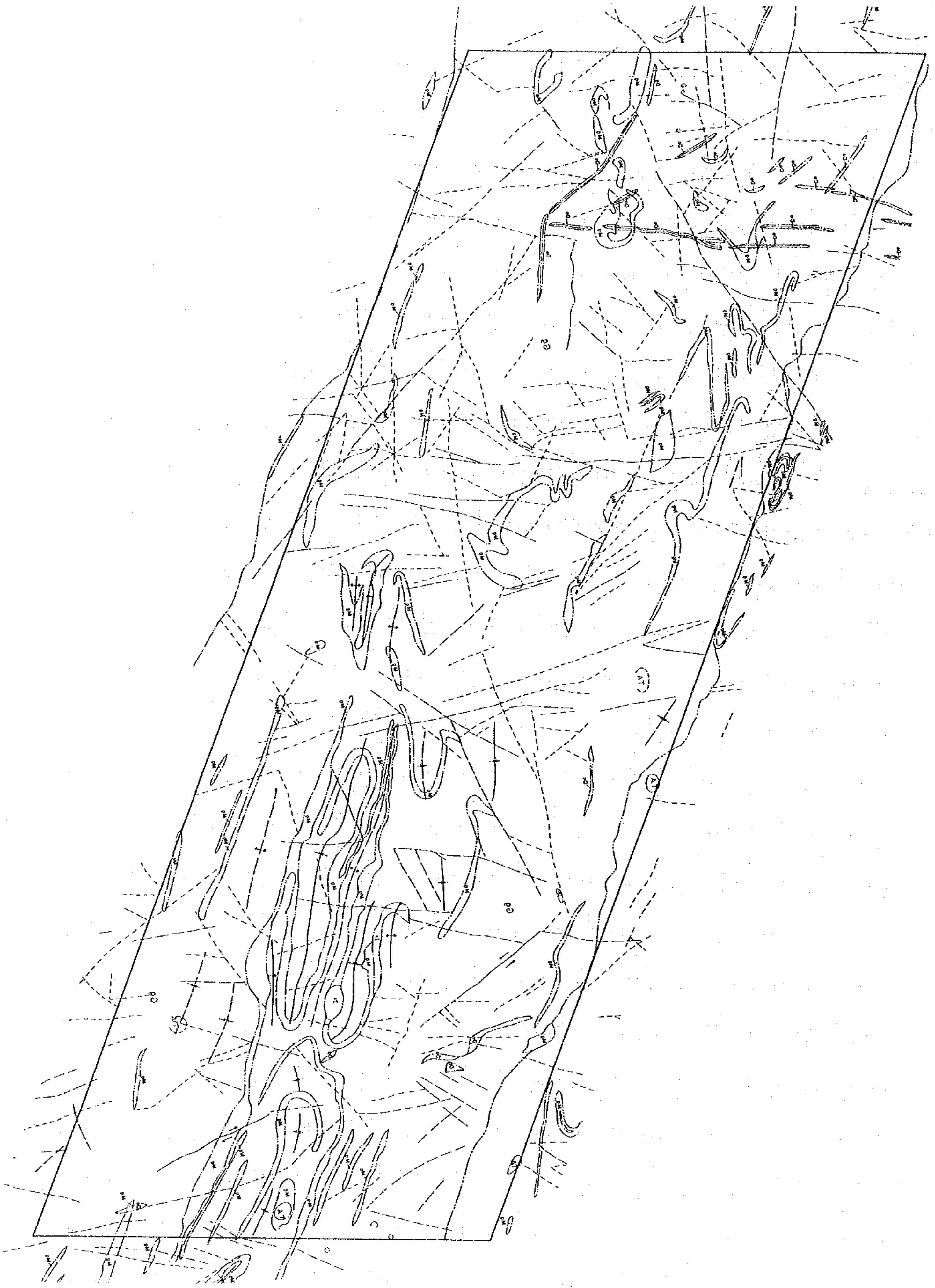


FIG.2-1-2(1) Geological Map and Geological Structure Interpreted by Landsat Image


AT

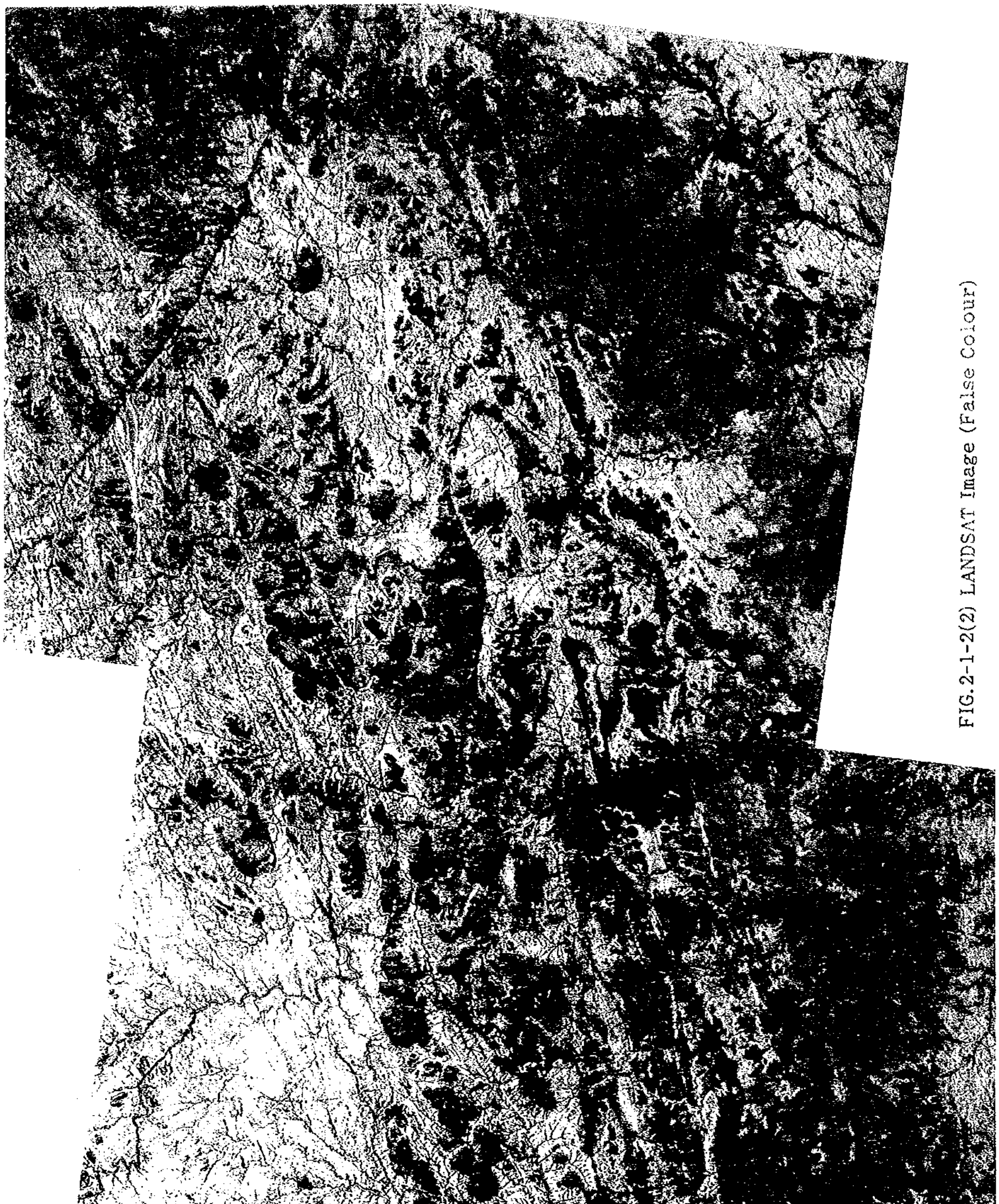


FIG.2-1-2(2) LANDSAT Image (False Colour)

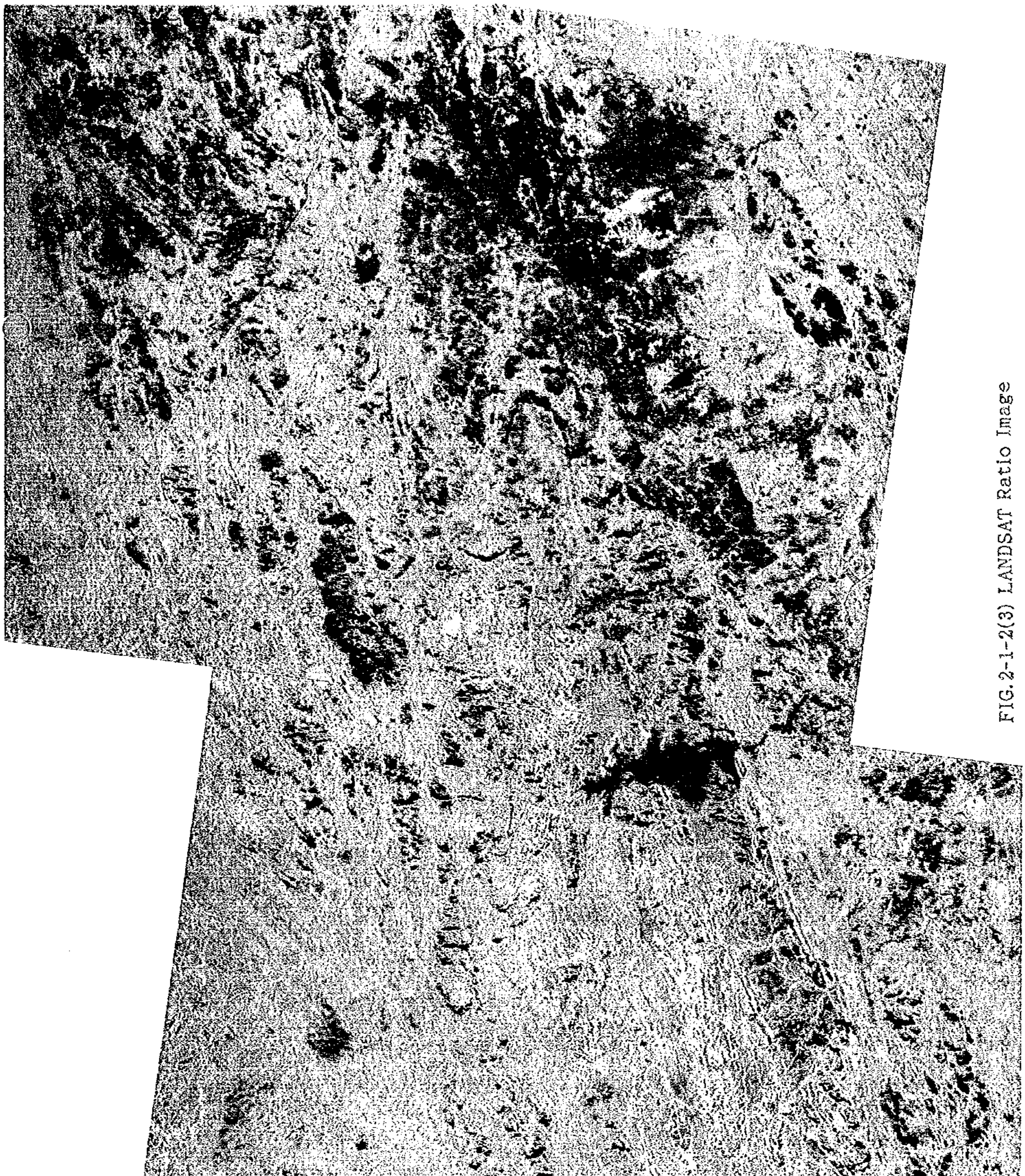
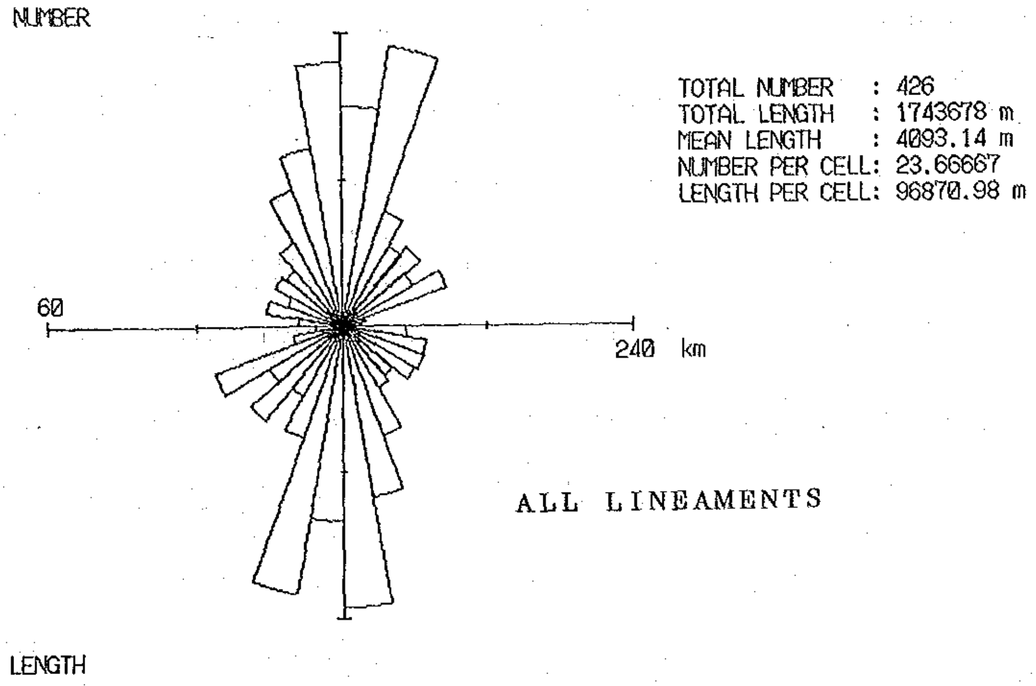


FIG.2-1-2(3) LANDSAT Ratio Image



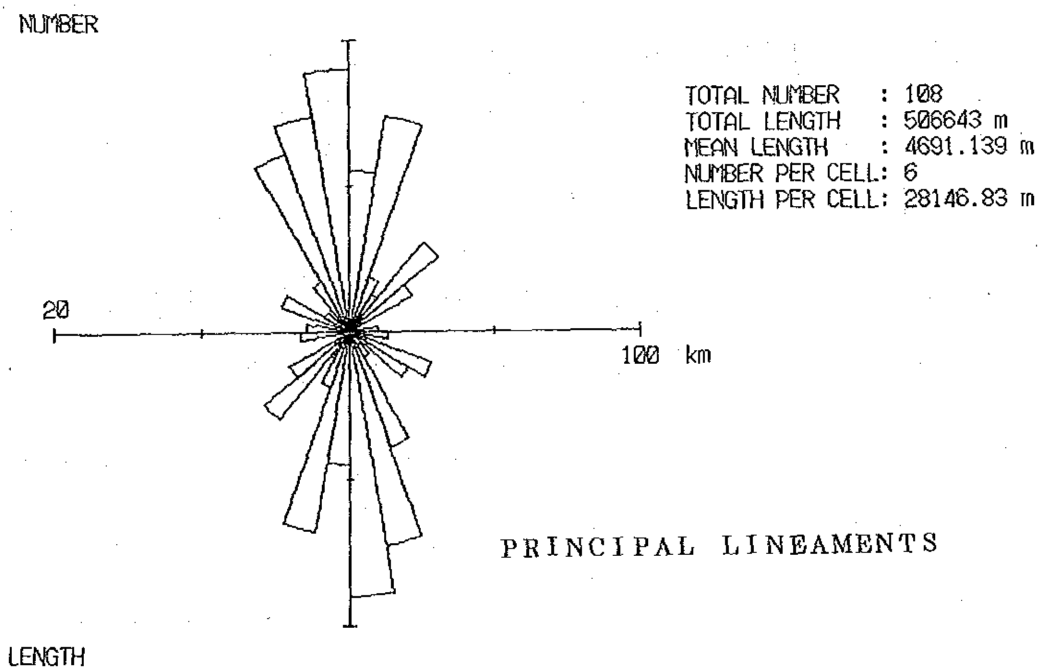


FIG. 2-1-3 Rose Diagram of Lineaments Interpreted by Landsat Image

ENE-WSW direction, the lineaments would not serve to distinguish the geological units.
It is highly possible that the survey area was divided into blocks by Sazaume-Makambe, Murerezi and Turwi faults, and that the third block between the Murerezi and Turwi faults, in which foliation was disturbed, rose comparatively high.

(3) Hydrothermal Alteration Detected by Landsat Image Interpretation

Alteration in the area extends in a very restricted area around the mineralized zone. At Renco mine, the wall rock alteration is an effect of pegmatite intrusion, but no relationship exists between degree of alteration and gold mineralization (Bohmke and Varndell, 1986).

Within a mineral province, areas with numerous fracture intersections are good exploration targets because fractures are conduits for hydrothermal(ore-forming) solution.

For the purpose of delineation of alteration zones in the area, spectrum measurement was conducted on rocks from the principal geological units(FIG.2-1-4).

On the interpretation map (Fig.2-1-5), major fractures are plotted together with location of mineralized zones. No areas are selected because they do not show good coincidence of the geochemical anomalies, mineralized zones and concentration of fractures, and no acting mines exist in the area.

Based on the results of the measurement, the following two main zones are selected on the Landsat image.

1) Fe-hydroxides, chlorite, epidote etc. having Fe in their molecular formulas.
2) Representative clay minerals such as montmorillonite, sericite, kaolinite etc..

Minerals included in 1) are characterized by strong absorption of spectrum on band 1 and result in exaggerated DN value of band 3/1. This is reflected as red colour on the ratio image of band 3/1.

Minerals included in 2) can be classified from other minerals due to high DN value of band 5/7. As a result of the interpretation of ratios on each band, band 3/5 shows similar tendency with band 5/7. This results in an exaggerated blue colour on the ratio image.
The results are shown in FIG. 2-1-5.

According to the interpretation results, minerals of 1) category roughly correspond in distribution to the geological unit of mafic granulite.
On the other hand, the minerals of 2) category mainly distribute within the ge-

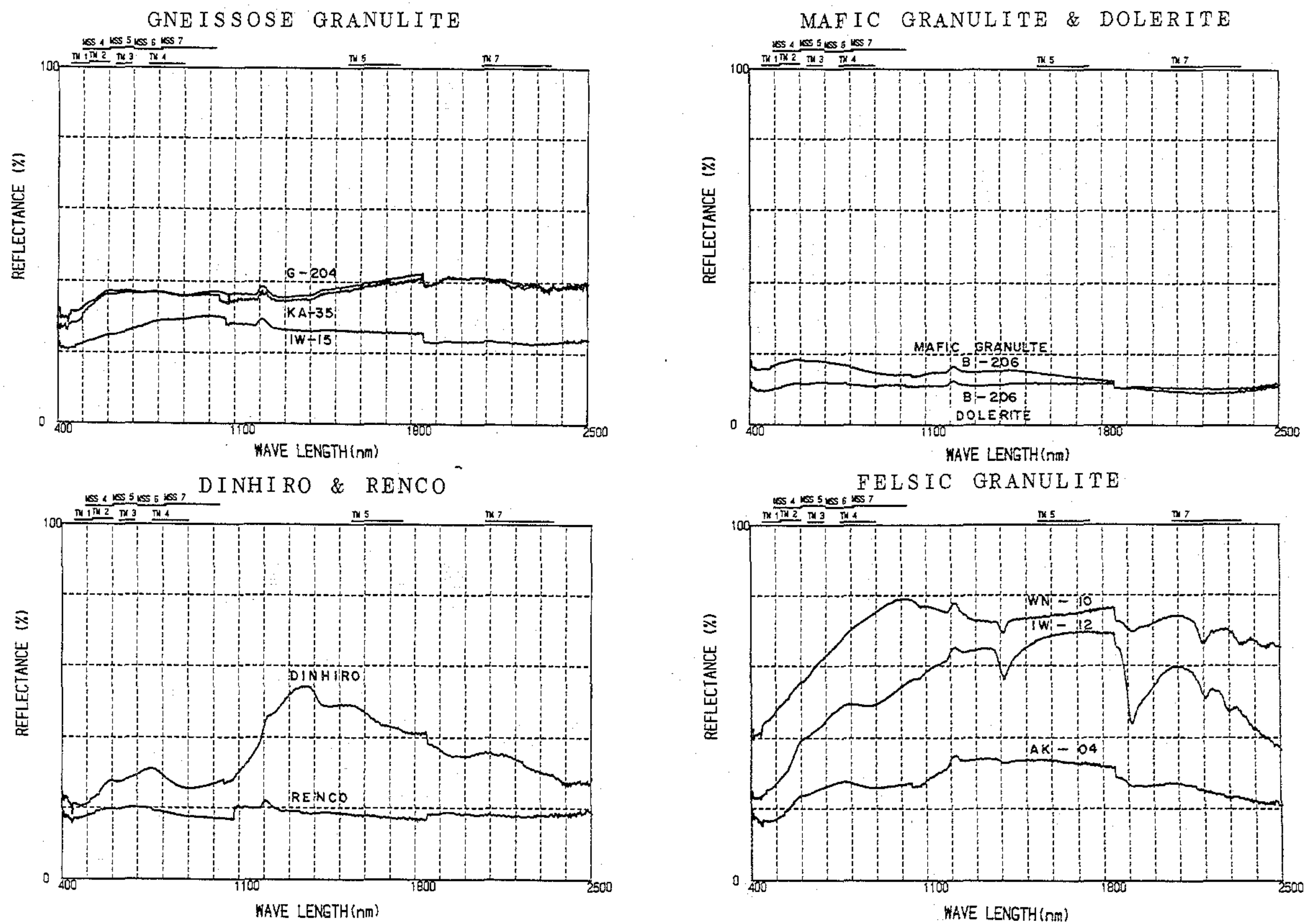


FIG.2-1-4 Spectrum-chart of Principal Rock Species

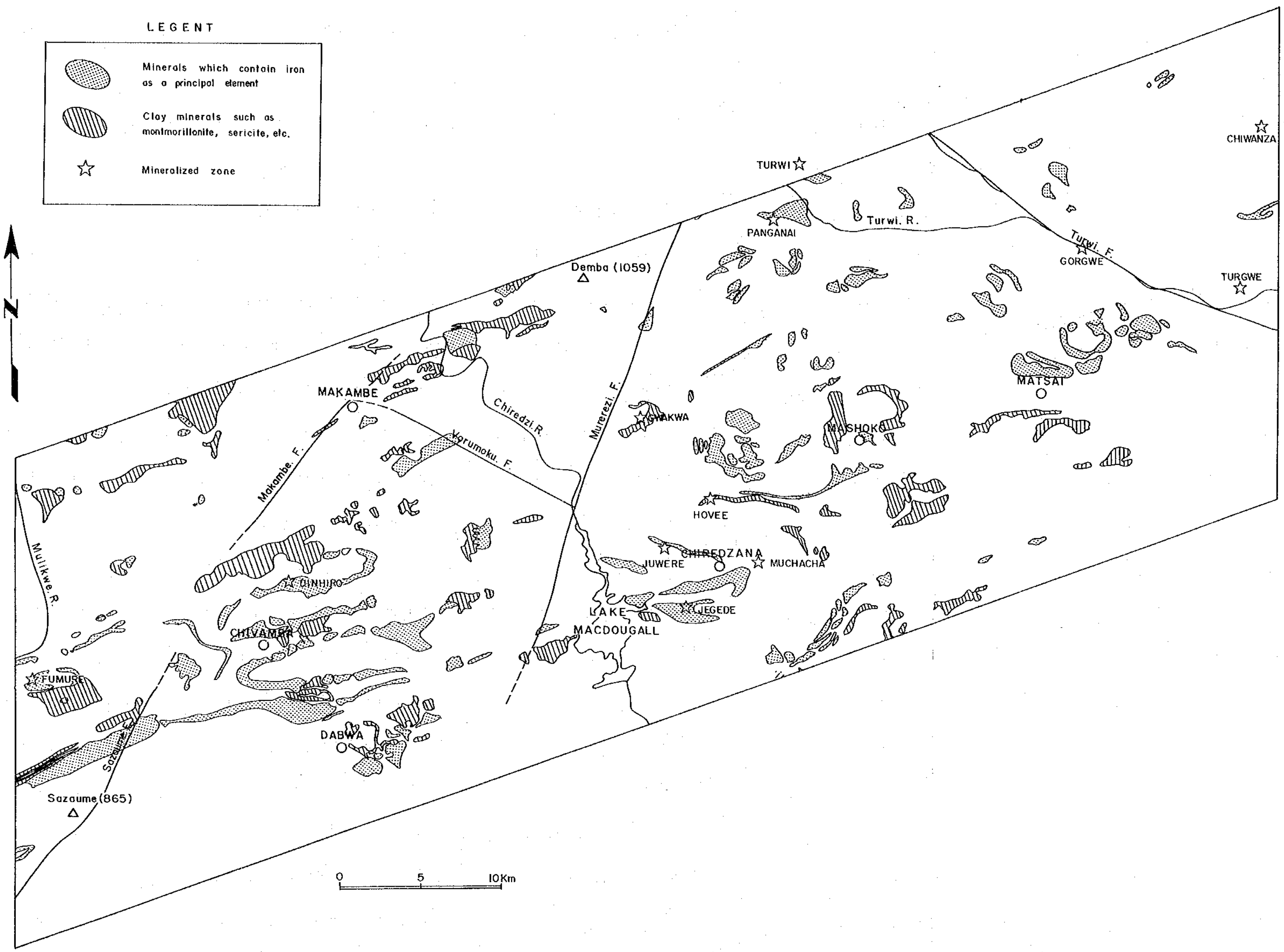


FIG. 2-1-5 Alteration Map Interpreted by Landsat Image

ological units of gneissose granulite and felsic granulite. The existence of the minerals are shown by clear absorption spectrum indicating the clay minerals on the measurement. This result indicates that the minerals such as montmorillonite etc. are under producing in the delineated zones, although no alteration zones were detected during geological survey.

The detailed investigation on the mode of occurrence of the alteration zones detected by the Landsat image needs a further study of X-ray diffractometry on the rock specimens from the area.

Together with ratio image interpretation, also principal component image was investigated to detect the alteration zones, but no positive results were obtained because of high correlation coefficient among bands in the principal component.

1-3 Consideration

It can be concluded that a Landsat interpretation provides a bird's-eye view that allows the geological interpreter to see landform in its entirety.

Landsat image has an advantage of permitting reconnaissance survey to be concluded in a limited period over a large area where no geoscience data are available, due to its good consistency and uniformity in contrast to aerial photography.

Ratio image (band 3/5, 4/3, 3/1 BGR) is good for the interpretation of geological units and structure, and also false-colour image for geological structures.

According to the exploration on ore deposits, many deposits are formed by hydrothermal solution, that invade the country rock. During formation of the ore minerals, these solutions also interact chemically with the country rock to alter the mineral composition beyond the site of ore deposition and form zones of hydrothermal alteration around the ore deposits. Not all alteration, however, is associated with ore bodies, and not all ore bodies are marked by alteration zones. These zones are valuable indicators of possible deposits.

In Renco deposit, situated to the southwest of the area, the wall rock alteration is possibly an effect of pegmatite intrusion, but no relationship exists between the degree of alteration and Au mineralization other than very erratic distribution. Indeed, several instances of high Au values have been recorded in country rock outside the limits of alteration, suggesting some minor redistribution of Au(Bohmke & Varndell, 1986). The mineralization in the area may be poorly accompanied hydrothermal alteration.