REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE VITI LEVU AREA,
THE REPUBLIC OF FIJI

CONSOLIDATED REPORT

MARCH 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request extended by the Government of the Republic of Fiji, agreed to conduct a metallic mineral exploration survey in the Viti Levu Area, and commissioned its implementation to the Japan International Cooperation Agency.

The agency, taking into consideration the importance of the technical nature of the survey work, sought the cooperation of the Metal Mining Agency of Japan to accomplish the task.

The Government of the Republic of Fiji appointed the Mineral Resources Department (MRD) to execute the survey as a counterpart to the Japanese team. The survey has been carried out jointly by experts of both Governments.

The collaboration survey for metallic mineral, which lasted three years, consists of geological, geochemical, and geophysical surveys, supported by drilling and laboratory work. This consolidated report hereby submitted summarizes results of the said survey.

We wish to take this opportunity to express our gratitude to all sides concerned in the execution of the survey.

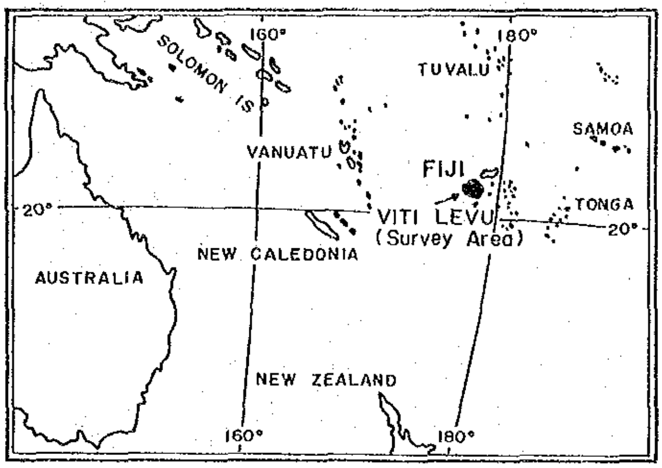
March 1993

Kensuke Yanagiya

Kensuke YANAGIYA
President,
Japan International Cooperation Agency

Takashi Ishikawa

Takashi Ishikawa
President
Metal Mining Agency of Japan



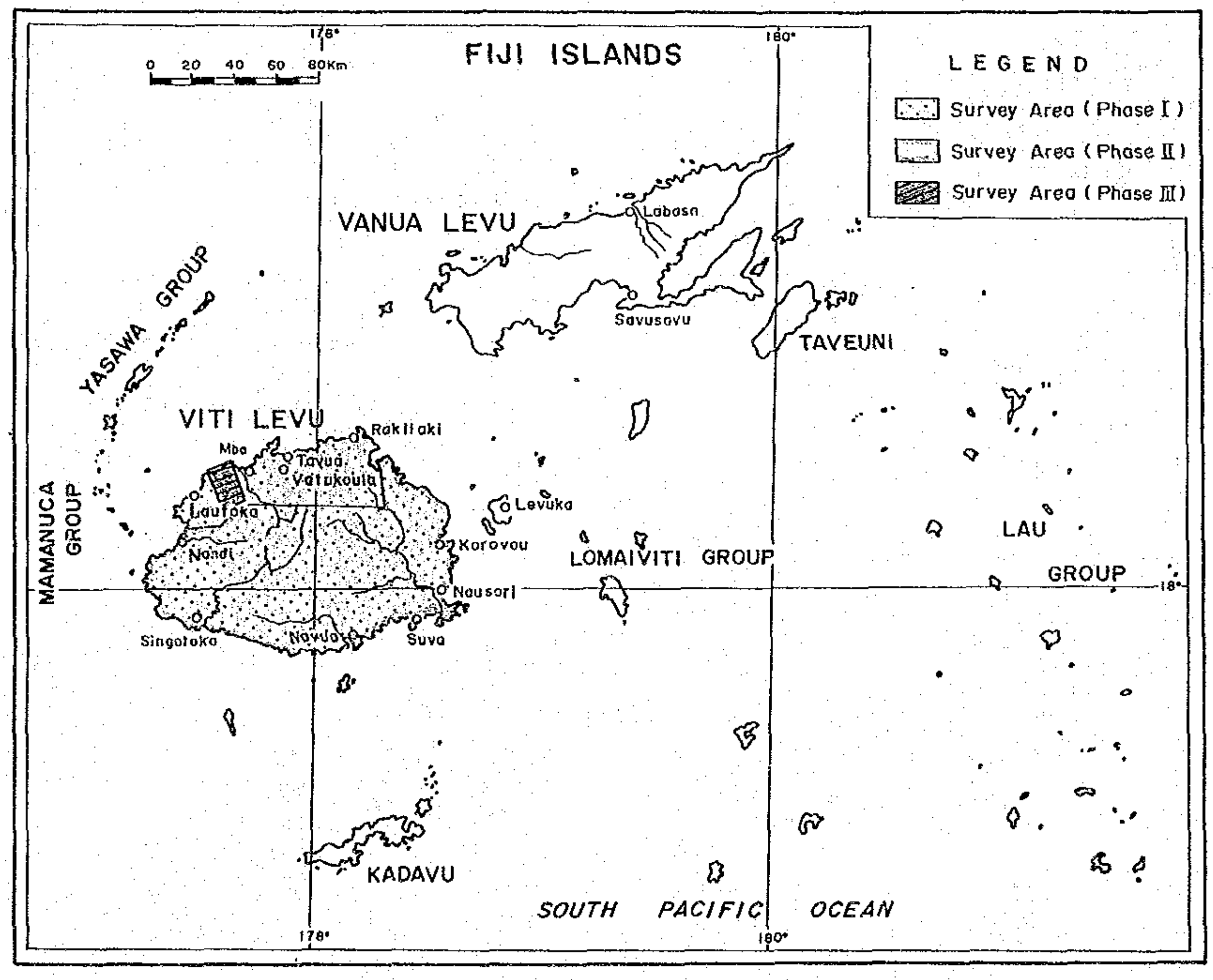


Fig. 1-1 Index Map of the Project Area

SUMMARY

Cooperative Mineral Exploration was carried out in the Viti Levu Island of the Republic of Fiji during the period of three years from 1990 to 1992. The objective of the project was to assess the mineral potential of the area by geological survey, geochemical survey, geophysical survey, and drilling.

During the first year of the project, the following activities were carried out. Compilation of all existing data and information regarding the geology and mineral resources of the area; analysis of SLAR images and SPOT images and geological survey; gravity survey of the Tavua area in the north; and geochemical orientation survey of the area east of the Emperor Mine.

During the second year of the project, the following works were carried out for the areas delineated as promising from the results of the first year survey. Photogeological analysis, geological survey, geochemical prospecting, and drilling in the Mba-west area; and geological survey and geochemical survey in the Sigatoka area. Also gravity survey of the southern part of the island was carried out in order to understand the geologic structure of the area.

The work of the third year comprised geological survey and drilling in three localities in Mba-west. These are areas delineated as mineral prospects by the results of the work of the previous year.

Analysis and interpretation of the remote-sensing images were extremely effective in extracting areas for geoscientific survey. Also, as volcanism and gravity anomaly are very closely related, it was demonstrated that gravity survey is one of the most effective tools for exploration of epithermal gold mineralization.

The areas concluded to have high mineral potential from the results of photogeological analysis, geological survey, gravity survey, and the study of past exploration results are Mba-west and Sigatoka.

The Sigatoka area was proven to have rather weak surface manifestation by geological and geochemical survey. The area is thus concluded to have low mineral potential.

In the Mba-west area, promising mineralized and altered zones were extracted by geological and geochemical surveys and drilling was carried out in four of these zones. The conclusions obtained from the results of the drilling are; (a) the high-grade part was probably eroded out in the Namosau Creek,(b) the mineral potential is low in the Nayanggali Creek because mineral showings could not be found, (c) the gold potential of the Narotawa area is high because relatively large low-grade gold veins were confirmed, (d) gold potential exists in the Yaloku area because low-grade gold veins were confirmed. It is also considered that gold potential exists in the Raviravi Altered Zone of Mba-west where drilling was not carried out this year.

[Viti Levu Island]

The geology consists mainly of Late Eocene-Early Oligocene volcanic and plutonic rocks, Late Oligocene-Middle Miocene volcanic and sedimentary rocks, Middle to Late Miocene plutonic rocks, Late Miocene-Early Pleistocene volcanic, plutonic and sedimentary rocks, and Pleistocene-Holocene sediments.

Vein, network dissemination, porphyry copper, replacement, skarn, and sedimentary type mineralization occur in this island.

Of the above, the largest deposits are the veins of the Emperor Mine and the Namosi porphyry copper deposit. The former occurs in the fissures of the periphery of a Pliocene caldera while the latter is associated with porphyry intruding latest Miocene andesite and with andesite plugs.

The geologic environment necessary for the formation of epi-mesothermal deposits is the existence of magmatic heat, subsurface fractures and circulating water. The magmatic heat and the subsurface fractures are likely to exist in volcanic collapsed and volcanic dome structures. The circulating water formed the mineralized and altered zones. Structures which are likely to be volcanic collapse and volcanic domes were extracted through photogeologic studies of annular, caldera and dome structures; gravity anomalies; and field survey. Of these zones; vicinity of Rakiraki, Tavua Caldera zone, area west of Mba and southward, Sabeto Range, south of Lautoka and Namosi area are considered to contain high potential for locating mineralized and altered zones.

[Mba-west Area]

The geology consists mostly of; Miocene-Pliocene volcanic products;

Pliocene volcanic products and sedimentary rocks; Holocene alluvium; and intrusive rocks (plutonic and volcanic rocks) penetrating the Pliocene formations. The Miocene and Pliocene formations largely dip northward at low angles and are superposed. Thus the strata become younger northward.

The gold mineralization was brought about by hydrothermal activities related to Pliocene volcanism. And it is considered that high sulfidation type epithermal gold mineralization occurred above the shallow small magma chamber (short-wavelength high gravity zone) while low sulfidation type occurred near the volcanic center in the central part of the deep and large chamber (medium-wavelength high gravity zone).

Drilling was carried out at four sites in the Mba-west area, and although of low grade, the existence of groups of epithermal auriferous veins was confirmed in the lower parts of Nalotawa and Yaloku Alteration Zones. It is anticipated that bonanzas exist in the vicinity of these mineral showings, and it is hoped that drilling be carried out in the near future in order to locate them.

[Sigatoka Area]

The geology consists of; Miocene volcanic products, and sedimentary rocks; Pleistocene (?) fluviatile sediments; and intrusive bodies (plutonic and volcanic rocks) penetrating Miocene Series. The Miocene units largely dip southwestward and are superposed.

The mineralization is closely related to the activities of the Colo Plutonic Suite and they are emplaced in fractured zones in the vicinity of the plutonic and porphyry bodies, thus, it is considered that the mineralization took the form of veins, replacement, porphyry, and other types of meso- to hypothermal activity.

The intensity of the mineralization/alteration is weak with some exceptions. The intensity of the geochemical anomalies is also generally low. Many of the altered zones and anomalies have been drilled without significant success. There are two undrilled localities where multi-component anomalies are noted. If large deposits are to be anticipated, the weak surface manifestation indicates deep occurrences.

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PART I OVERVIEW

PART I OVERVIEW

Chapter 1 Outline of Project

1-1 Areas and Objectives

In response to the request by the Government of the Republic of Fiji to conduct mineral exploration in Viti Levu Island, the Japanese Government dispatched a mission to discuss the details of the project. And as a result of the consultations between the Mineral Resources Department (MRD) of the Ministry of Lands and Mineral Resources, and the Metal Mining Agency of Japan, an agreement was reached for cooperative exploration of the Viti Levu Island. The "Scope of Work"(SW) was signed by the representatives of both governments in August 1990. The objective of this project is to assess the mineral potential of the area through geological survey, geochemical exploration, geophysical exploration and drilling during the three year period of Fiscal 1990 to 1992.

The objective of the first year survey was to clarify the geology and mineralization of Viti Levu and thereby extract high potential areas for mineral exploration. This was done by compilation of all existing geoscientific and resource data and information, analysis of SLAR and SPOT satellite data, and geological survey of the whole island (10,000km^2); and gravity survey of the Tavua area (2,000km^2) in the north. Also geochemical orientation survey was carried out in the area east of the Emperor Mine in order to obtain data for planning geochemical prospecting.

The objective of the second year survey was the detailed survey of the high potential areas delineated by the first year survey as follows.

(1) Extract prospective zones by photogeological analysis, geological survey, and soil geochemical prospecting in Mba-west (206km^2) and Sigatoka (160km^2) areas.

(2) Drill in a part of the prospective zones of Mba-west in order to clarify the subsurface mineralization.

(3) Elucidate the gravity structure of southern Viti Levu (8,400km^2) in order to understand the relation between the geologic structure and mineralization.

The objective of the third year survey was to discover new deposits by detailed geological survey and drilling of three localities of Mba-west where the potential for locating mineral deposits were high. And also the transfer technology to the Fijian counterpart personnel.

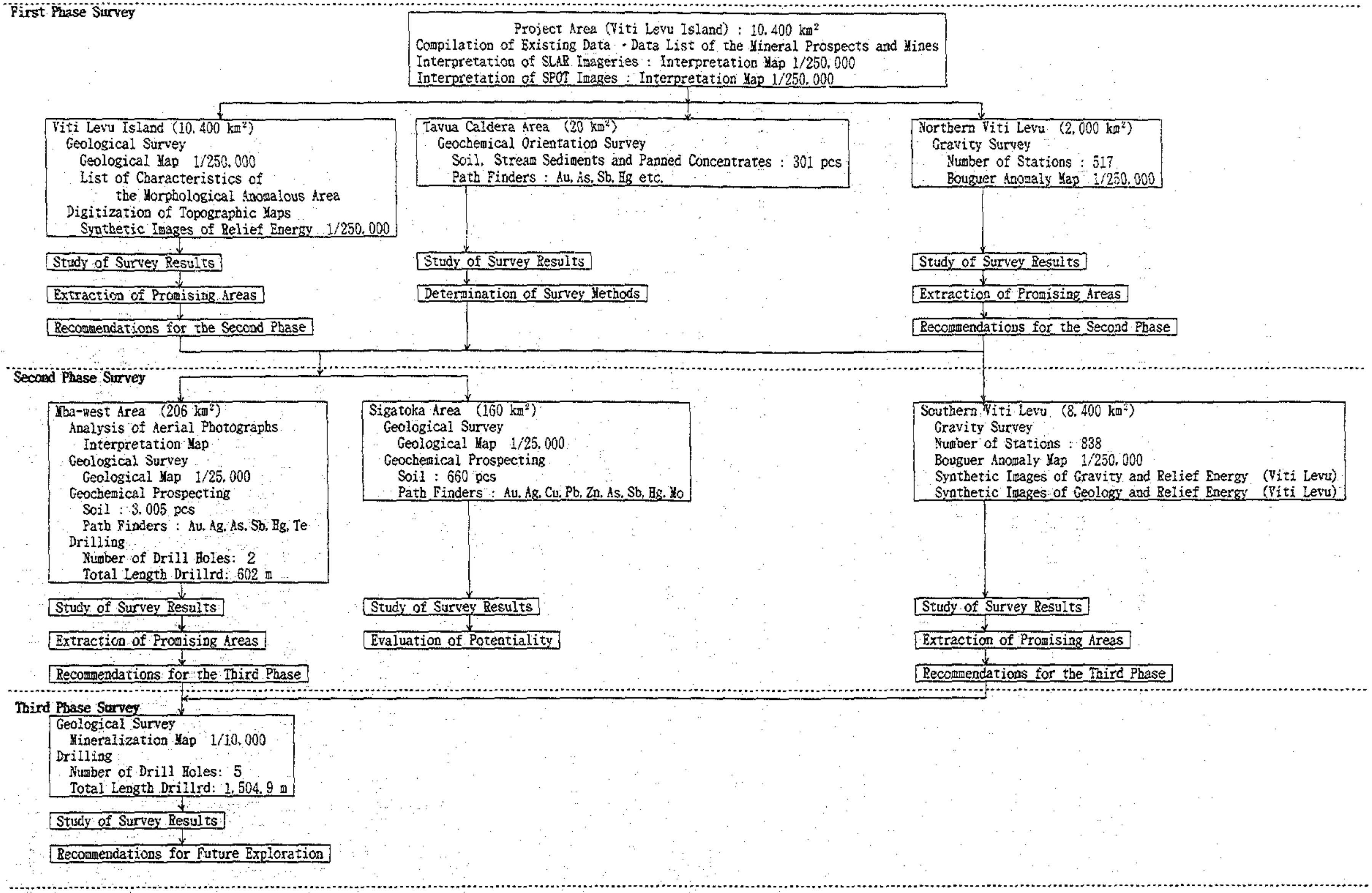


Fig.1-2 Flowsheet of Survey

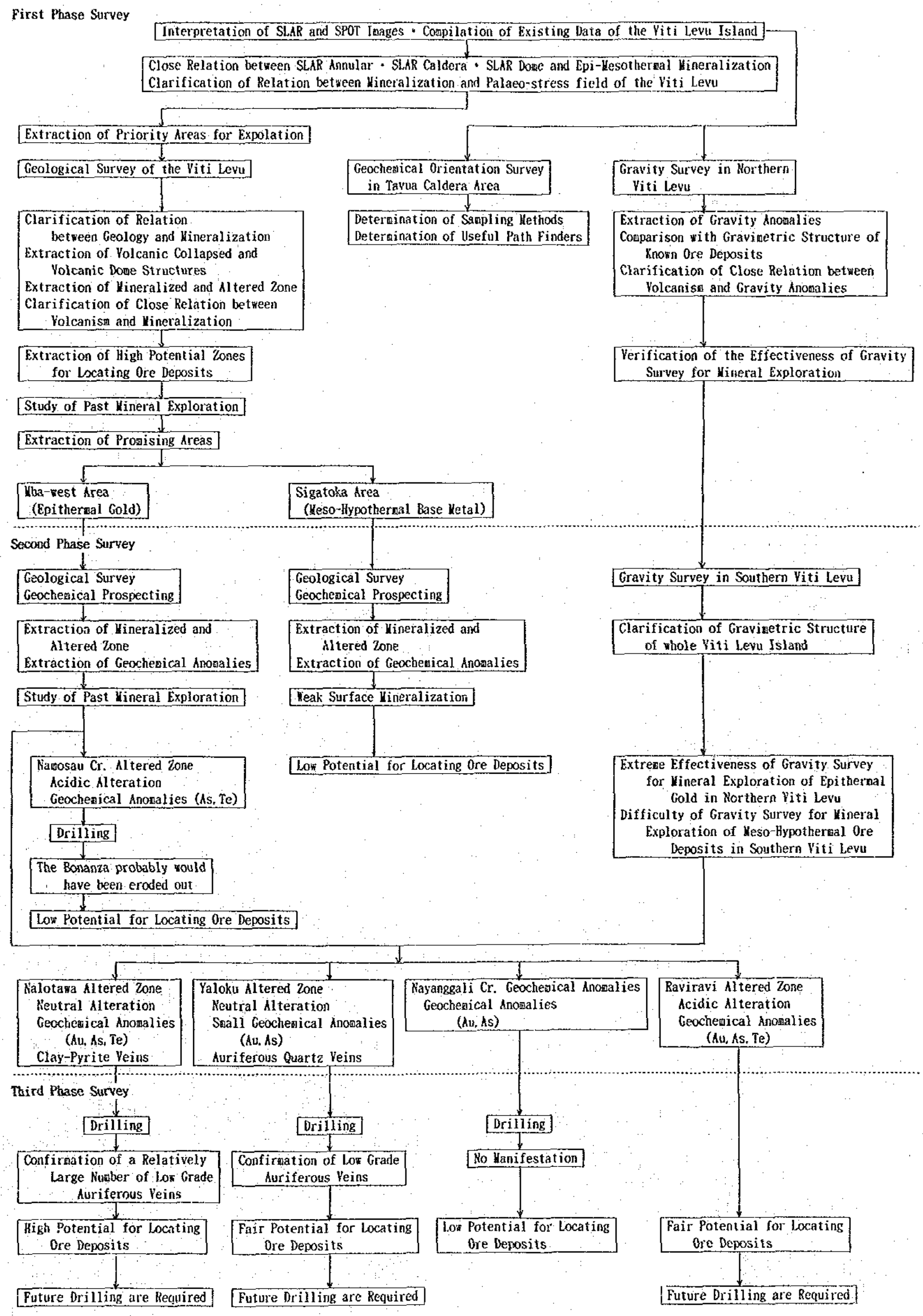


Fig.1-3 Exploration Flowsheet-Viti Levu-

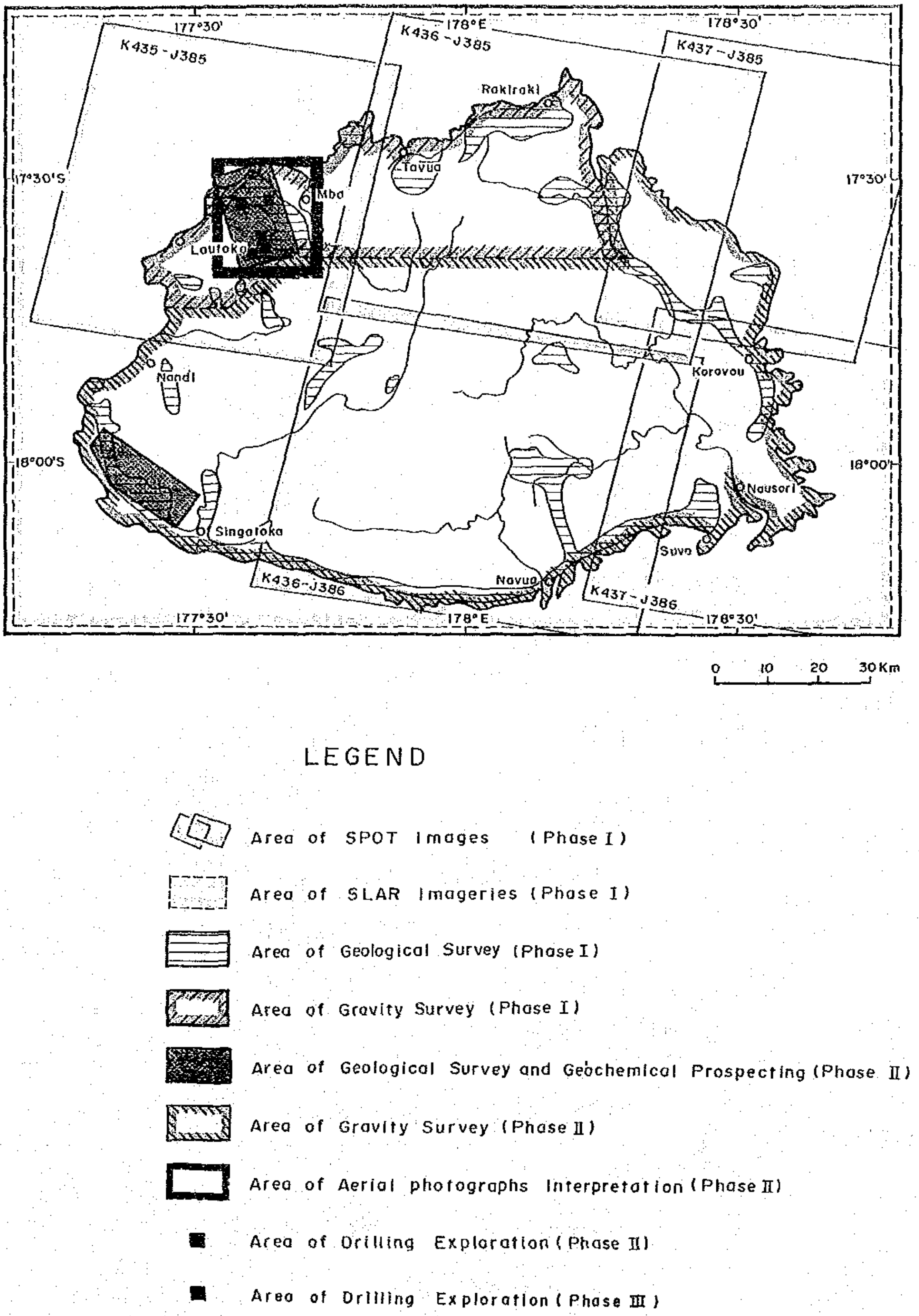


Fig. 1-4 Location Map of the Project Area (Viti Levu Island)

Table 1-1 Amount of Work

Phase	Survey Method	Area	Amounts
First	Compilation of Existing Data	Whole Viti Levu Island	Areal extent 10,400 km²
	Interpretation of SLAR & SPOT Images	Whole Viti Levu Island	Areal extent 10,400 km²
	Geological Survey	Whole Viti Levu Island	Areal extent 10,400 km² Length of traverse 550 km Laboratory work Thin section microscopy 23 sections X-ray diffraction analysis 27 samples Radiometric age determination 5 samples Polished section microscopy 5 sections whole rock chemical analysis 10 samples
	Geophysical Survey (Gravity)	Tavua Area (Northern Viti Levu)	Areal extent 2,000 km² Number of stations 517 Density measurements 38 samples
		Whole Viti Levu Island	Digitization of topographic maps Synthetic images of relief energy 10,400 km²
	Geochemical Orientation Survey	Near Emperor Mine	Areal extent about 20 km² Soil 130 samples Stream sediments 119 samples Panned concentrates 52 samples
Second	Analysis of Aerial Photographs	Mba-west Area	Areal extent 500 km² Number of sheets 51
	Geological Survey and Geochemical Survey	Mba-west Area	Areal extent 206 km² Length of traverse 400 km Laboratory work Thin section microscopy 14 sections X-ray diffraction analysis 152 samples Ore assey 26 samples Geochemical analysis 3,005 samples
		Sigatoka Area	Areal extent 160 km² Length of traverse 200 km Laboratory work Thin section microscopy 11 sections X-ray diffraction analysis 35 samples Ore assey 10 samples Geochemical analysis 660 samples
	Drilling	Mba-west Area	Number of drill holes 2 Total length drilled 602 m Laboratory work Thin section microscopy 10 sections Polished section microscopy 5 sections X-ray diffraction analysis 22 samples Ore assey 61 samples
	Geophysical Survey (Gravity)	Southern Part of Viti Levu Island	Areal extent 8,400 km² Number of stations 838 Density measurements 108 samples
		Whole Viti Levu Island	Synthetic images of gravity and relief energy 10,400 km² Synthetic images of geology and relief energy 10,400 km²
Third	Geological Survey	Mba-west Area	Areal extent 10 km² Length of traverse 10.5 km Laboratory work X-ray diffraction analysis 3 samples Ore assey 44 samples
	Drilling	Mba-west Area	Number of drill holes 5 Total length drilled 1504.9 m Laboratory work Thin section microscopy 21 sections Poished section microscopy 15 sections X-ray diffraction analysis 55 samples Ore assey 159 samples

Table 1-2 Duration of Survey and Participants

Phase	Contents	Duration	Japanese Members	Fijian Members
First	Project Finding and Scope of Work Consultation	23 Jul. 1990- 4 Aug. 1990	Katsumi YOKOKAWA [4] * Yoshiyuki ISODA [1] Junichi TOMINAGA [2] Yoshihisa OKUDA [2] Hiromichi MURAKAMI [3] Hiroyasu KAINUMA [4] Takashi OOKA [4] Keiichi GOTO [4]	Abdul RAHIMAN [5] Alf SIMPSON [5] Neville EBSWORTH [5] Don J. FLINT [5] Suli NIUROU [5] Radi KUMAR [6]
	Field Supervisor		Katsumi YOKOKAWA [4]	
	Geological Survey	24 Oct. 1990- 29 Dec. 1990	Masaaki SUGAWARA [7] * Ken OBARA [7]	Abdul RAHIMAN [5] Alf SIMPSON [5]
	Geophysical Survey	12 Nov. 1990- 29 Dec. 1990	Masasamu OYANAGI [7] Toshihisa ISHIBASHI [7] Tadanori IWASAKI [7]	Peter RODDA [5] Don J. FLINT [5] Suli NIUROU [5] Isireli NAGATA [5] Vijendra PRASAD [5]
	Geochemical Orientation Survey	9 Dec. 1990- 22 Dec. 1990	Katsumi YOKOKAWA [4] * Tetsuo SUZUKI [4] Kouji SEGAWA [4] Satoshi YAMAGUCHI [4]	Abdul RAHIMAN [5] Vijendra PRASAD [5] Suli NIUROU [5]
Second	Field Supervisor		Kenzo MASUTA [4] Koji KOIWA [4]	
	Geological and Geochemical Survey	15 Jun. 1991- 25 Oct. 1991	Masaaki SUGAWARA [7] * Keiichi KUMITA [7] Ken OBARA [7] Yasushi AOKI [7]	Abdul RAHIMAN [5] Alf SIMPSON [5] Vijendra PRASAD [5] Don J. FLINT [5] Suli NIUROU [5]
	Geophysical Survey	15 Jun. 1991- 10 Sep. 1991	Shigeo MORIBAYASHI [7] Masasamu OYANAGI [7] Norikiyo SUGIURA [7]	
	Drilling	31 Oct. 1991- 25 Dec. 1991	Hatsuo KUMANO [7] Hidemitsu ITODA [7] Fumio ENDO [7]	
Third	Field Supervisor		Katsuo YOKOYAMA [4] Takechiyo TAKATA [4] Osamu TSUKAMOTO [4]	
	Geological Survey	15 Aug. 1992- 4 Sep. 1992	Masaaki SUGAWARA [7] *	Alf SIMPSON [5] Don J. FLINT [5]
	Drilling	15 Aug. 1992- 19 Dec. 1992	Masaaki SUGAWARA [7] Yukio KAWAMURA [7] Mitsuo SASAKI [7] Yoshiki IMURA [7]	Suli NIUROU [5] Subashni DEO [5]

[1] : Ministry of Foreign Affairs, [2] : Ministry of International Trade and Industry,
[3] : Japan International Cooperation Agency, [4] : Metal Mining Agency of Japan,
[5] : Mineral Resources Department (MRD), [6] : Ministry of Finance, Fiji,
[7] : Nikko Exploration and Development Co., Ltd., * : Team Leader

1-2 Methods and Contents

The methods employed during the course of this project are; compilation of existing data, SLAR and SPOT image analysis, geological survey, gravity survey, photogeological analysis, soil geochemical prospecting, drilling and various laboratory work. The methods used each year and the amount of work carried out are laid out in Table 1-1.

1-3 Duration and Participants

The duration and the members of the survey team are listed in Table 1-2.

Chapter 2 Previous Survey

The outline of the geology of Fiji was reviewed and summarized by Rodda (1989), Okuda (1989) and others.

Geological maps of Viti Levu at 1:50,000 have been published covering the whole island by the Geological Survey of Fiji (GSF: now MRD) and the Mineral Resources Department(MRD). Compilation of the geology based on 1:50,000 sheets on east-northeast, south, and north-central Viti Levu was published by Hirst (1965), Band (1968), and Rodda (1976) respectively.

A 1:25,000 scale geological map was prepared by GSF for the Tavua Caldera area and petrography of the area was published by Ibbotson (1966).

Sheets of 1:250,000 scale geological maps compiled from 1:50,000 maps have been published by the GSF and cover the entire island (Rodda and Band, 1966).

The results of the whole rock chemical analysis of the rocks of Fiji have been compiled by Rodda (1969) of GSF.

Regarding the studies of the igneous activities of the island arc, there are, petrochemical work including rare earths by Gill and Stork (1979), Gill (1987), and Gill and Whelan (1989a,b). Also Gill(1984) carried out studies based on Sr-Pb-Nd isotope analysis.

Radiometric age determination of the rocks of Viti Levu was conducted by Rodda et al., (1967) and that of the rocks of Fiji by Whelan et al., (1985).

The gold mineralization of the western Pacific region including Fiji has been summarized by Ishihara and Urabe (1989).

The metallic mineral deposits of Fiji was reviewed by Colley (1976, 1980) of MRD and a 1:250,000 scale metallogenic map of the country was published. Regarding those of Viti Levu; Ahmad et al.,(1987), Anderson and Eaton (1990), Kwak (1990) and others reported on the Emperor Gold deposit in the north, Lawrence et al., (1976) studied the Wainivesi Cu-Pb-Zn deposit area in the east and Rugless (1983) published a report on the Wainaleka Cu-Zn deposit area in the south.

Colley (1986) reported on the epithermal gold mineralization associated with Miocene-Pliocene volcanism of Fiji.

In the survey of first phase, a list of relevant data from the above material was compiled and is attached as appendix as well as a list of mines and mineral prospects compiled from various documents including exploration reports of the private sector.

Chapter 3 General Geology of the Project Area

In the vicinity of Viti Levu Island, there are the Vanua Levu and Taveuni Islands in the northeast, Lau Islands in the east across the Koro Sea, Mamanutha Islands and Yasawa Islands in the northwest and Kadavu Island in the south. The above islands constitute the Fiji Islands. The geology of the Fiji Islands consists totally of Cenozoic units. The oldest unit is the Eocene (limestone and volcanics) and the youngest is the volcanic ejecta of historic times in Taveuni Island (Fig. 1-5).

In Vanua Levu, the geologic units are Late Miocene to Late Pliocene strata and the lithology consists mainly of volcanic rocks (basalts, andesites, dacites) accompanied by sandstone, mudstone and marl. At the Udu Peninsula in the northeast, Kuroko type deposit occurs in the felsic volcanics, and in the southeast, acid sulfate type epithermal gold deposits occur in andesite plug. Post Pliocene basalts are the major constituent of the Taveuni Island and volcanic activities continue to the Recent. The islands of Koro Sea are volcanic islands consisting of Pliocene and Pleistocene basalts.

Middle Miocene to Quaternary strata are distributed in the Lau Islands and they are mainly volcanics (andesites, basalts, dacites and rhyo-

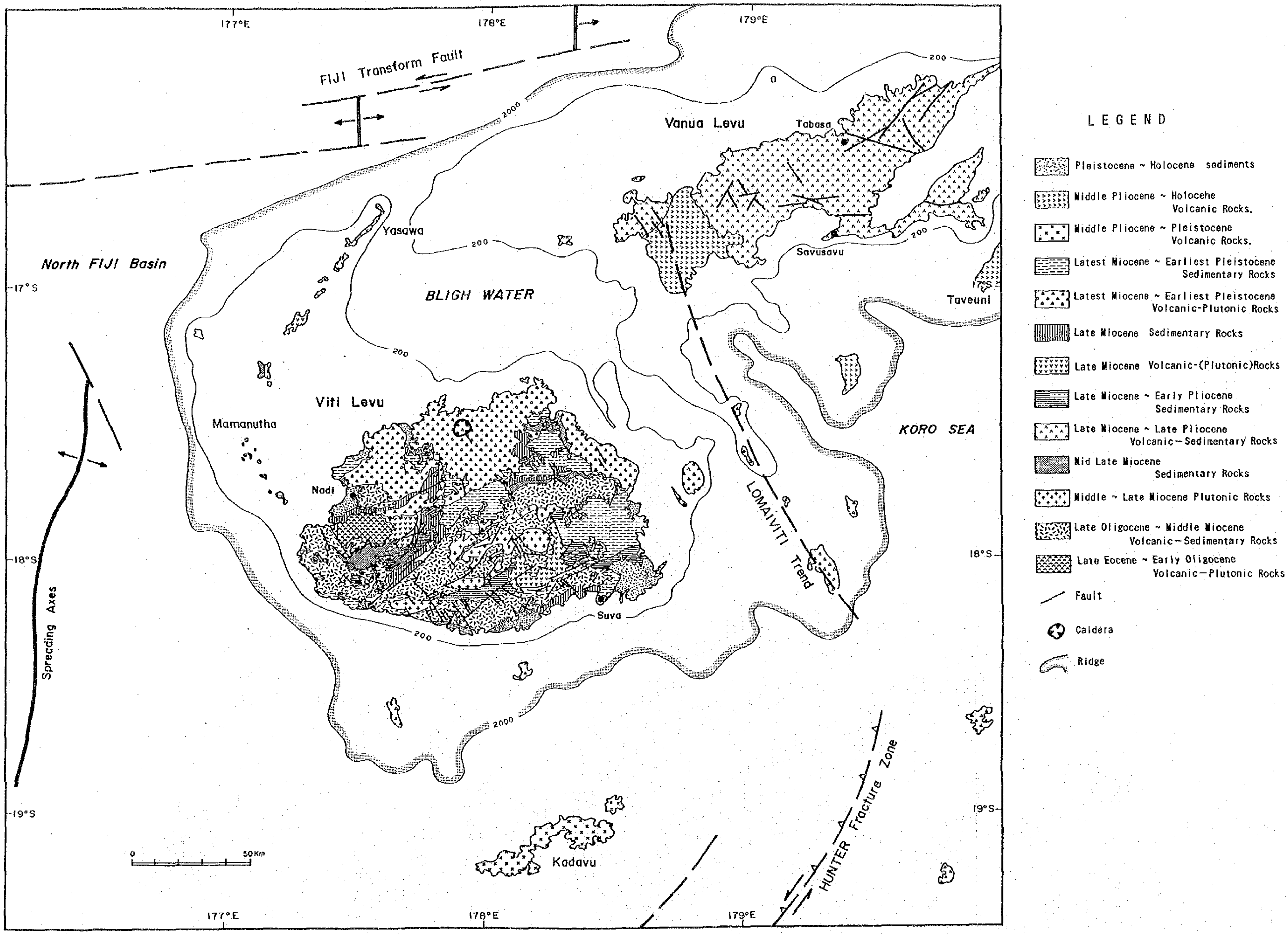


Fig. 1-5 Simplified Geological Map of the Survey Area

lites) accompanied by limestone. Middle Pliocene to Pleistocene volcanics (basalts, andesites and dacites) constitute the Kadavu Island. Late Oligocene to Late Miocene strata are distributed over the Mamanutha and the Yasawa Islands. The lithology is mostly volcanics (basalts, andesites and dacites). Pelagic limestone occurs to the south of the Yasawa Islands accompanying these volcanics.

Stratigraphically, the geological units of Viti Levu are largely grouped into; Late Eocene to Middle Miocene volcanics (basalts, andesites, and dacites) and sedimentary rocks (limestone, sandstone, conglomerate, mudstone), and Late Miocene to Late Pliocene volcanics (basalts and andesites) and sedimentary rocks (sandstone, mudstone and limestone). In between these two groups, sedimentary units are lacking and orogenic movement accompanied by intrusion of plutonic rocks occurred during that time.

Tectonically, Fiji Islands are located at the eastern margin of the Indo-Australian Plate and form an island arc on an ocean ridge (Lau Ridge) at a point where it bends from ENE-WSW to N-S direction. At the Tonga Trench on the eastern side of the Tonga Arc which is located to the east of the Lau Ridge, the Pacific Plate is being subducted westward and the Indo-Australian Plate is being subducted eastward at the Vanuatu Trench on the western side of the Vanuatu Arc located to the west of Viti Levu. The Lau Basin is located between the Tonga Arc and the Lau Ridge, and the North Fiji Basin between Vanuatu and Viti Levu. Both these basins have spreading axis. The northern side of Viti Levu is bounded by the left lateral Fiji Transform Fault and the southern side by the Hunter Fracture Zone (a left lateral transform fault). The northern part of the Fiji Islands are considered to be rotating anticlockwise due to the eastward movement of the Indo-Australian Plate south of the Hunter Fracture Zone and the spreading of the North Fiji Basin. This rotation is believed to have begun during Late Miocene to Early Pliocene time. Before the advent of the spreading of the North Fiji Basin (Eocene-Miocene), a chain of island arcs (Vanuatu Arc - Fiji Islands - Tonga·Lau Arc) continuous in the NW-SE to N-S direction is believed to have existed due to the subduction of the Pacific Plate at the Tonga Trench and its northward extension.

Chapter 4 Geography of the Project Area

4-1 Location and Access

The island of Viti Levu is located at lat. 17°18'-18°16'S., long. 177°15'-178°41'E., and is approximately 2,700km east of the eastern coast of Australia, approximately 1,900km north of New Zealand and approximately 2,000km south of the equator.

The island is approximately 150km east-west, 90km north-south and 400km in circumference.

The international airport is at Nadi on the west coast of Viti Levu. The capital city of Suva is located in the southeastern part of the island and is 115 km from Nadi as the crow flies. Nadi to Suva is traveled by air in 50 minutes via Nausori and is about four hours by car along the southern coast of the island.

Population centers are developed along the coast, namely Sigatoka in the southwest, Lautoka and Mba in the northwest, Tavua in the north, Rakiraki in the northeast and Korovou in the east as well as Nadi and Suva.

Roads are developed circling and also crossing the island joining the southeastern and southwestern parts with Tavua Area in the north. The road connecting Korovou-Suva-Sigatoka-Nadi-Lautoka-Mba-Tavua-Rakiraki along the coast is paved, but those along the eastern coast and across the island are unpaved. The vicinity of drilling targets of the third phase survey is accessible by car through rough roads from Mba. In some cases, however, roads were continued for transportation of equipment to the site itself.

4-2 Topography, Drainage, Climate and Vegetation

4-2-1 Topography

(1) Topography of Viti Levu

There is a highland with an altitude of around 1,000m in the island. There are three major systems of mountain ranges in the island. They are; in the central part, the Rairaimatuku Plateau, Korombasanga Range and other mountains extending in the N-S to ENE-WSW direction; in the northwestern part, the Mount Evans Range, Naroto Range and others extending in the NE-SW to E-W direction; and in the northeastern part, the Nakauvandra Range and Nakorotumbu Range extending in the E-W to NW-SE direction. The topography is very rugged and the highest peak is the Tomanivi (Mt. Victoria) located to the north of the central part with the elevation of 1,323m.

Hilly zone of 150-600m in elevation with relatively distinct relief is developed surrounding the above highland.

Alluvial plains are developed from the northern to the southwestern part of the island, also in the southeastern part, as well as along the coast and along the large river valleys.

Deltas are developed in many parts around the island where mangroves grow and coral reefs are developed on the outer side of these deltas.

(2) Topography of Mba-west

The southwestern margin of this area belongs to a part of the Mt. Evans Range and has a very rugged topography with elevation of 800 - 900m. The Yaloku Altered Zone is located on the northern steep slope (elevation, 400-750m) of the ridge which extends in the ESE direction from the eastern edge of the Mount Evans Range. The vicinity of Nalotawa, Nanuku, and Yaloku Villages in the southern part of this area is in the periphery of the Mount Evans Range and has a topography with abundant relief between 300 to 500m.

The relative topographic high of this area extends northward from Nalotawa and forms the drainage divide between the Ba area to the east and Lautoka area to the west. The Nalotawa Altered Zone is developed on the steep slope on the eastern side of this divide.

In the northern part of this area, a topographic high of around 450m elevation including Mt. Koronggele is distributed in a semi-circle opening eastward. Also in the northwesternmost part of the area, a high of 150-200m elevation continuing to Mt. Koroivunatoto further west is distributed in a semi-circle opening northward. The geochemical anomaly zone of Nayanggali Cr. is located in the gentle hills (elevation, about 100m) between the above two highlands.

Low hills and lowland occupy the 2km wide area between the northern coast and the inner part of the area and deltas occur along the coastal zone.

(3) Topography of Sigatoka

Highlands with relatively high relief from 150 to 300m is observed in the northwest, southeast and along the northeastern border of the survey area. Most of this area surrounded by the above highland comprises gentle hilly zone with elevation of several tens of meters.

4-2-2 Drainage

(1) Drainage of the Viti Levu Island

The drainage of the Viti Levu Island consists of the following river systems. Sigatoka River system which flows southwestward from the north-central part of the island; Rowa River system which flows southeastward from the northeastern and central part of the island; Mba River system in the northwest; Nadi River system in the west; and Navua River system in the south.

The former two river systems are the larger drainage of the island. Rewa River system is widely distributed in the eastern half of the island and comprises Wainibuka River, Wainimala River, Waindina River; each with many tributaries.

(2) Drainage of Mba-west

Mba River meanders from the southeast to northwest in the eastern part of this area. The drainage system of this area all belong to this river system with the exception of the northwestern part and the northern coastal zone. Relatively large rivers flow in this area with fairly large discharge throughout the year, they are; Nggalinambulu Creek, and Nandrou Creek in the south, Varathiva Creek in the central part, and Namosau Creek in the north. The tributaries of these rivers usually have low discharge and many are underflows.

The Yaloku Altered Zone is situated in the uppermost reaches of Nggalinambulu and Nandrou Creeks and the Nalotawa Alteration Zone in the uppermost reaches of Wainasa Creek which is a tributary of the Varathiva Creek. On the other hand, the Nayanggali Geochemical Anomalies occur in the upper reaches of the Teidamu Creek which belongs to the drainage system of the Lautoka area.

(3) Drainage of Sigatoka

The major rivers in this area meanders from the northeast to southwest. They are; Tuva River in the central part, Kumbuna River in the northwest, and Voua Creek and Nggerengere Creek in the southeast. These all have considerable flow and the Tuva is the largest river in the area. Many of the tributaries of these rivers are dry.

4-2-3 Climate and Vegetation

(1) Climate

As Fiji belongs to the tropical rain forest climatic zone, it has two seasons, dry (May-October) and rainy (November-April). Also the country is located in the monsoon zone, and there is a southeasterly trade wind throughout the year. Since there is a highland with an altitude of around 1,000m extending in the north-south to ENE-WSW direction in the central part of Viti Levu, precipitation is high in the southeastern side of the island - over 200 days of rain every year - and annual precipitation reaches 5,000 mm in the Namosi district, while the northwestern side is relatively dry with the temperature often approaching 40°C.

The Mba-west area and the Sigatoka area in the western part of Viti Levu belong to the drier areas, but during the wet season strong rainfall is not uncommon and heavy rain due to cyclones is observed. The annual precipitation in the southern part of Mba-west reaches 3,000mm. The monthly mean temperature and precipitation observed at Nadi in western Viti Levu over 30 years (1951-1980) is shown below.

1990

	Jan	Feb	Mar	Apl	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Average(°C) Temperature	26.6	26.6	26.3	25.7	24.6	23.8	23.0	23.2	24.0	24.8	25.6	26.2	25.0
Average(mm) Precipitation	313.8	292.5	367.4	172.3	83.7	77.9	51.9	58.1	92.9	96.9	168.9	168.9	1912.6

The average annual precipitation over 47 years (1942-1989) is 3,036mm in Suva and 1,849mm in Nadi.

(2) Vegetation

Viti Levu belongs to the tropical rain forest zone and the southeastern part is largely covered by dense jungle.

On the other hand, in the west to northeastern part of the island the lowlands and gentle hills are mostly cultivated for sugar canes. There are jungles along the creeks and in the mountainous regions. The relatively low mountains and high hills are often covered by 2m-high reeds or reforested pines.

In the coastal deltaic region, mangrove forests are developed as well as coconut palms near the villages.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

5-1-1 Viti Levu Island

(1) The major geology of Viti Levu are mainly of Late Eocene-Early Oligocene volcanic and plutonic rocks, Late Oligocene-Middle Miocene volcanic and sedimentary rocks, Middle to Late Miocene plutonic rocks, Late Miocene-Early Pleistocene volcanic, plutonic and sedimentary rocks, and Pleistocene-Holocene sediments.

(2) Vein, network, dissemination, porphyry copper, replacement, skarn, and sedimentary type mineralization occur in this island.

The vein and dissemination types are grouped into epithermal gold and meso-hypothermal base metal mineralization. The epithermal group is further classified into adularia-sericite type and acidic sulfate type. The epithermal gold mineralized zones in the Mba and Koroimavua Volcanic Groups occur near the volcanic centers which were the source of the volcanic rocks or near the zones where these centers are inferred to have existed.

The epithermal gold mineralized zones are distributed in the ENE-WSW direction from the northern to western Viti Levu.

(3) A total of 1,060 lineaments were extracted from SLAR imageries. Many of these lineaments are considered to have been formed associated with the lateral faults caused by maximum horizontal compressional stress in three main directions. Most of the mines and mineral prospects of Viti Levu, with the exception of bedded manganese, residual, placer deposits and those of the western part, occur within the zone of lineaments formed by ENE to ESE trending horizontal stress or in the vicinity.

(4) It is seen from SLAR studies, that annular structures and caldera structures occur in the vicinity of the epithermal gold deposits of the Emperor Mine, and that annular, caldera and dome structures exist near the Namosi porphyry copper deposit. These photogeologic structures were interpreted to reflect the intrusion of magma in the area. Working on this hypothesis, 15 areas which contain at least one of the SLAR structures, namely annular, SLAR caldera or dome structures were selected. From these 15 areas, Rakiraki, east of Vatukoula, upper reaches of the Mba River, northeast of Nadi, and South of Mba area were selected as having strong geoscientific resemblance to the area near the Emperor Mine. Also north-

east of Nadi and south of Mba area were selected as areas with geologic environment very similar to the Namosi Deposit area.

(5) The locations of the centers of the volcanism of the latest Miocene-earliest Late Pliocene Mba Volcanic Group were inferred from the distribution of the volcanic rocks and the photogeologic annular, caldera and dome structures. It is considered from the above that volcanic chains existed extending in the ENE direction in northern Viti Levu and in the NW direction in the eastern part of the island. These volcanoes are believed to have formed over the deep fissure zones.

(6) Many of the lineaments formed under latest Miocene-Early Pliocene NNW to NNE compressional field are distributed in the west and northwest to southeast Viti Levu. On the other hand, NW trending deep fissures are believed to have existed from northwest to southeast Viti Levu at that time. This is inferred from the distribution of the then active volcanic rocks, locations of the volcanic centers at the time and the distribution of the above lineaments.

(7) Medium-wavelength gravity features indicate that to the north of the NE-SW trending line joining Verevere in the northeast and Sigatoka in the southwest, large scale gravity highs with circular to oval shape occur isolated in a generally low gravity area, while to the southeast of the line, high and low anomalies elongated in the NE-SW direction in belt-form are distributed alternating each other. Thus the gravity features of the two areas are clearly different. The westernmost high anomaly southeast of Nadi in the northwestern part coincides well with the distribution of the Yavuna Group, but the other three highs cannot be correlated with surface geology. The zonal distribution of the high and low anomalies in the southeast more or less coincides with the distribution of the "Wainimala Group - Colo Plutonic Suite" and "Medrausucu Group - Verata Sedimentary Group".

(8) There are large medium-wavelength gravity highs at three localities, southwest of Mba, east of Vatukoula, and west of Rakiraki. Annular, caldera, dome structures identified photogeologically and collapsed structures, intrusive bodies, altered zones, and marked short-wavelength gravity anomalies are concentrated in the centers of these medium-wavelength gravity highs. The gravity gradient of the peripheral parts of these medium-wavelength highs is steep and the shape of these anomalies is circular to oval. These are considered to indicate the existence of subsurface high density igneous bodies and it is inferred that there was a large magma chamber in the deeper parts.

(9) The Emperor Mine is situated at the periphery of the collapsed structure in the center of the medium-wavelength gravity high to the east of Vatukoula, the Kingston Mine in the center of the medium-wavelength gravity high to the southwest of Mba. Together with the high west of Rakiraki, the centers of these three medium-wavelength gravity highs are considered to be the localities where active volcanism occurred repeatedly. Therefore, these are listed as promising for epithermal gold exploration. The anomalies in the northern Mba-west are on the northern extension of the medium-wavelength gravity high to the southwest of Mba, and with the coincidence of SLAR annular and caldera structures and the short-wavelength gravity highs, it is believed that the northern Mba-west was the place of activity of small magma chamber branched out from large magma chamber. The area is listed as promising for epithermal gold deposit occurrence.

(10) The zones where volcanic centers are inferred to have existed in northern Viti Levu correspond to the zones of short-wavelength high gravity anomalies related to basaltic activities. It is believed that since the contents of the magmatic chambers of that time has changed from basalt to olivine-gabbro of higher density, there are positive gravity anomalies near the altered volcanic centers. However, even in cases of Kilauea type caldera, the interior of the caldera is filled with thick compact lava which is more dense than the whole volcano and thus the center of eruption would show somewhat higher density.

(11) The Tavua Caldera whose upper parts are filled by low density formations such as andesitic pyroclastics and lacustrine sediments show short-wavelength low gravity anomaly surrounded by gravity lineaments. The SLAR annular structure zone near Rakiraki in northeast Viti Levu and the vicinity of the volcanic centers west of Mba are the zones which have Tavua Caldera type gravity structure among the possible collapse caldera zones extracted photogeologically.

(12) The geologic environment necessary for the formation of epi-mesothermal deposits is the existence of magmatic heat, subsurface fractures and circulating water. The magmatic heat and the subsurface fractures are mostly likely to exist in volcanic collapsed and volcanic dome structures. The circulating water formed the mineralized and altered zones. Structures which are likely to be volcanic collapse and volcanic domes were extracted through photogeologic studies of annular, caldera and dome structures; short-wavelength gravity anomalies; and field survey. Of these zones; vicinity of Rakiraki, Tavua Caldera zone, area west of Mba to the southern part, Sabeto Range, south of Lautoka and Namosi area are considered to contain high potential for locating mineralized and altered zones.

Regarding the selection of the survey areas for the second phase and further work, the area from west of Mba to southern Mba was chosen because it was relatively unexplored; the Sigatoka area because it was considered to have relatively high mineral potential from the occurrences of alteration and mineralized zones (porphyry cooper, skarn and other types) around plutonic bodies.

(13) It was shown by the geochemical orientation survey that gold tends to be concentrated in the A soil horizon. Also it was clarified that zones of gold concentration are continuous vertically in the A and B soil horizons. It was shown by this survey that Au has high positive correlation with As, Te, Sb, Hg, F, Tl in the A horizon, while As, Hg, Pb have positive correlation with Au in the B horizon.

5-1-2 Mba-west Area

(1) The main geologic unit of Mba-west are Miocene-Pliocene andesitic/basaltic volcanic products and limestone; Pliocene basaltic/andesitic volcanic products, sandstone, and conglomerates; Holocene alluvium; and intrusive rocks (monzonite, dacite, andesite, basalt) penetrating the Pliocene formations. The Miocene and Pliocene formations largely dip northward at low angles and are superposed. Thus the strata become younger northward.

(2) A total of 95 lineaments was extracted photogeologically in the Mba-west. Many of these are concentrated in the southern and northern parts of the area. The directions of the maximum horizontal compressional stress axes were inferred to be NNW to NNE and ENE to ESE from the en echelon arrangement of the lineaments.

(3) Many lineaments of Mba-west are developed near the inferred volcanic centers in north and south, also lineaments with various trends are developed within the photogeologic annular structures. Also in short-wavelength low gravity zones and in parts of the short-wavelength high gravity zones, lineaments parallel to the elongation of the zones are developed in and near the zones. This is interpreted as reflecting fractures which were developed as the result of the vertical block movement accompanying the rise of magma.

(4) The circular depression extracted in southern Mba-west as photogeological annular structure is believed to have been the center of volcanic activity from the distribution of the volcanic products and intrusive bodies. A large scale medium-wavelength gravity high is distributed

throughout this area. This gravity high is believed to reflect high density rock bodies (deep-seated bedded basic intrusive bodies) formed by the solidification of the magma chamber which supplied the volcanic products of this area. The above annular structure is located near the center of this high gravity anomaly.

(5) Propylitized zones and sericitized zones are developed near the southern photogeological annular structures, and geochemical anomalies related to Au mineralization and auriferous quartz veins occur overlapping some of these altered zones. These features regarding geologic structure and mineralization/alteration are very similar to those of the Emperor Mine area. It is anticipated that low sulfidation epithermal gold mineralization akin to that of the Emperor Mine would exist in this area.

(6) Photogeological caldera structures were extracted at three localities in northern Mba-west and volcanic products are distributed in the vicinity. These calderas all occur in short-wavelength high gravity zones. This reflects the fact that these calderas are crater and/or volcanic collapsed structures and that the short-wavelength highs are caused by shallow high density rocks. These shallow bodies are considered to be small magma chambers formed as offshoots of the large, deeper chamber whose existence is inferred from medium-wavelength gravity high.

(7) Acidic alteration zones accompanied by silicification are developed in some of the photogeological calderas in northern Mba-west. Geochemical anomalies related to Au mineralization occur overlapping these altered zones. This is of the high sulfidation epithermal gold mineralization. This type is considered to form under shallower environment than the low sulfidation type. The results of drilling at Namosau Alteration Zone of this year, showed that the deposits could have been eroded out. The conditions of the lower parts of the Raviravi Alteration Zone is not clear, and the possibility of the occurrence of gold deposits has not died.

(8) Marked Au, As, Te geochemical anomaly zones which coincide with the altered/mineralized zones on the surface were extracted at four localities (Raviravi, Nalotawa, Nanuku-Yaloku and Tavanasa Creek) in Mba-west area. Aside from the above, small geochemical anomalies not associated with alteration/mineralization were confirmed at several localities (Namosau Creek, Lololo Creek, Nayanggali Creek, Tauarau Creek, Koroniviria and Karawa) and blind buried altered/mineralized zones were anticipated to occur in shallow subsurface parts.

(9) The mineralization of Mba-west was brought about by hydrothermal activ-

ities related to Pliocene volcanism. And it is considered that high sulfidation type epithermal gold mineralization occurred above the shallow small magma chamber while low sulfidation type occurred near the volcanic center in the central part of the deep and large scale chamber

(10) Drilling was conducted at four localities of Mba-west Area. The following conclusions were obtained.

Namosau Creek Alteration Zone: Two holes drilled in this zone penetrated through basalt lava and basaltic pyroclastics of the Pliocene Namosau Volcanics belonging to the Ba Volcanic Group and confirmed wide argillized zone accompanied by pyrite dissemination, but promising Au mineralization could not be confirmed.

Nayanggali Creek Geochemical Anomalous Zone: The subsurface geology confirmed by drilling (MJF-3) comprises basalt lava, basaltic pyroclastics, and sedimentary rocks of the Ba Volcanic Group, basalt lava and basaltic pyroclastics of the Namosau Volcanics, and basalt dykes.

Mineral showings and alteration of significance are not found in this zone. The central part of volcanic activities probably occurred in this zone and NE-SW trending fractures of NE-SW trend are inferred to exist in the deeper parts. The Au, As, Hg geochemical anomalies are inferred to be the products of ascending post volcanic hydrothermal fluids along the NE-SW trending fissures. Subsurface gold mineralization of this zone, if any, is concluded to be small.

Nalotawa Alteration Zone: The subsurface geology comprises basalt lava, basaltic pyroclastics of the Koroyanitu Volcanic Products and intrusive bodies (basalt, hornblende andesite, altered andesite).

There are many clay-pyrite veins, but evidences of gold mineralization do not exist on the surface.

On the other hand, in the subsurface parts, occurrence of gold in quartz-calcite veins, calcite veins, and clay-pyrite-(calcite) network is confirmed by drilling. The best part contains Au 0.176g/t in 18.10m of the drill core (include 1m of Au 0.52g/t).

In this zone, the assemblage of major gangue minerals (quartz, calcite, adularia, smectite, sericite) and that of the major alteration minerals in the host rock near the veins (quartz, calcite, pyrite, smectite) is very close to that of the low sulfidation epithermal veins.

The potential for gold occurrence in the deeper parts of this zone is concluded to be high.

Yaloku Alteration Zone: The subsurface geology comprises andesite lava, andesitic pyroclastics, basalt lava of the Sabeto Volcanics, and basalt dykes.

Quartz veins, clay-pyrite veins, and calcite veins occur on the surface of this zone. These veins are divided into the western and eastern groups. Auriferous quartz veins occur in both groups and the highest grades are 12.10g/t (15cm wide) in the western group and 4.52g/t (3cm wide) in the east.

In the east, calcite-quartz network with Au 0.114g/t (sampling width 40cm) was confirmed by drilling, but generally the development of the veins is poor. The auriferous quartz veins exposed on the surface deteriorates downward. The potential for gold vein occurrence is concluded to be poor in the eastern side.

In the west, although of low grade, a large number of auriferous veins were confirmed by drilling. Regarding N-S trending veins, a group of relatively wide auriferous veins (Au 0.055g/t, sampling width 400cm, clay-calcite-dolomite vein; Au 0.20g/t, sampling width 15cm, pyrite-calcite-dolomite vein; others) was confirmed almost at the lower extension of the exposed gold-bearing quartz vein (Au 12.10g/t). With ENE-WSW to E-W veins, the grade of the downward extension of the exposed vein (Au 2.19g/t) deteriorates, but a different group of auriferous veins (Au 0.375r/t, Ag 880g/t, Cu 6.76%, sampling width 3cm, chalcopyrite vein; others) were found by drilling.

The common ore minerals of this zone are chalcopyrite and pyrite, with rare association of molybdenite, bornite, galena, and stromeyerite in the west. This mineral assemblage corresponds to those of the high temperature epithermal deposits formed at relatively deeper parts.

The assemblage of the main gangue minerals is quartz-smectite-chlorite-calcite in the east while it is quartz-potash feldspar in the west. Adularia is associated in both groups at times.

The alteration mineral assemblage of the host rock near the veins also differ between the western and the eastern groups. The assemblage common for both groups is quartz-chlorite-calcite-smectite with sericite in the east and potash feldspar in the west.

The above assemblages of gangue and alteration minerals are very similar to those of the low sulfidation epithermal mineralization. It is concluded that the veins in the west were formed under higher temperature.

The mode of occurrence of the veins confirmed by drilling in this zone corresponds to the quartz + adularia + illite + Ag sulfides + base metal sulfide zone of the low sulfidation (quartz-adularia type) epithermal model (Berger and Eimon, 1983). Therefore, it is believed that the three bore-holes were drilled below the bonanza.

Regarding the drill holes in the west, it is inferred from the above model that the bonanza lies higher than the gold showings confirmed by drilling. This gold occurrence is only about 70m below the surface. Therefore, the potential of these veins are controlled by the topography and the direction of the ore shoots. There is not sufficient data for determining the direction of the shoot.

5-1-3 Sigatoka Area

(1) The geology of Sigatoka consists of; Miocene basaltic and/or andesitic volcanic products, and detrital sediments; Pleistocene (?) fluviatile sediments; and intrusive bodies (granodiorite porphyry-diorite porphyry bodies, granodiorite, diorite, diorite porphyry, quartz porphyry, aplite, basalt, andesite, dacite, and rhyolite) penetrating Miocene Series. The Miocene units largely dip southwestward are superposed.

(2) Most of the mineralized/altered zones occur in either near the above faults, near the Colo Plutonic Suite bodies, near the SLAR lineaments, and near the en echelon dykes. Also some of them occur within the Colo Plutonic Suite bodies.

(3) Four large geochemical anomalous zones were extracted in the Sigatoka area. These four zones coincide with the surface mineralized/altered zones, and many other small anomalies were also extracted. These are believed to be anomalies related to the activities of the Colo Plutonic Suite which occur extensively in the deeper parts.

(4) The mineralization of the Sigatoka area is closely related to the activities of the Colo Plutonic Suite and they are emplaced in fractured zones in the vicinity of the plutonic and porphyry bodies. And the mineralization took the form of veins, replacement, porphyry, and other types of meso- to hypothermal activity.

(5) The intensity of the mineralization/alteration is weak with some exceptions. The intensity of the geochemical anomalies is also generally low. Many of the altered zones and anomalies have been drilled without significant success. There are two undrilled localities where multi-component anomalies are noted. If large deposits are to be anticipated, the weak surface manifestation indicates deep occurrences.

5-2 Recommendations for Future Exploration

(1) Nalotawa Alteration Zone

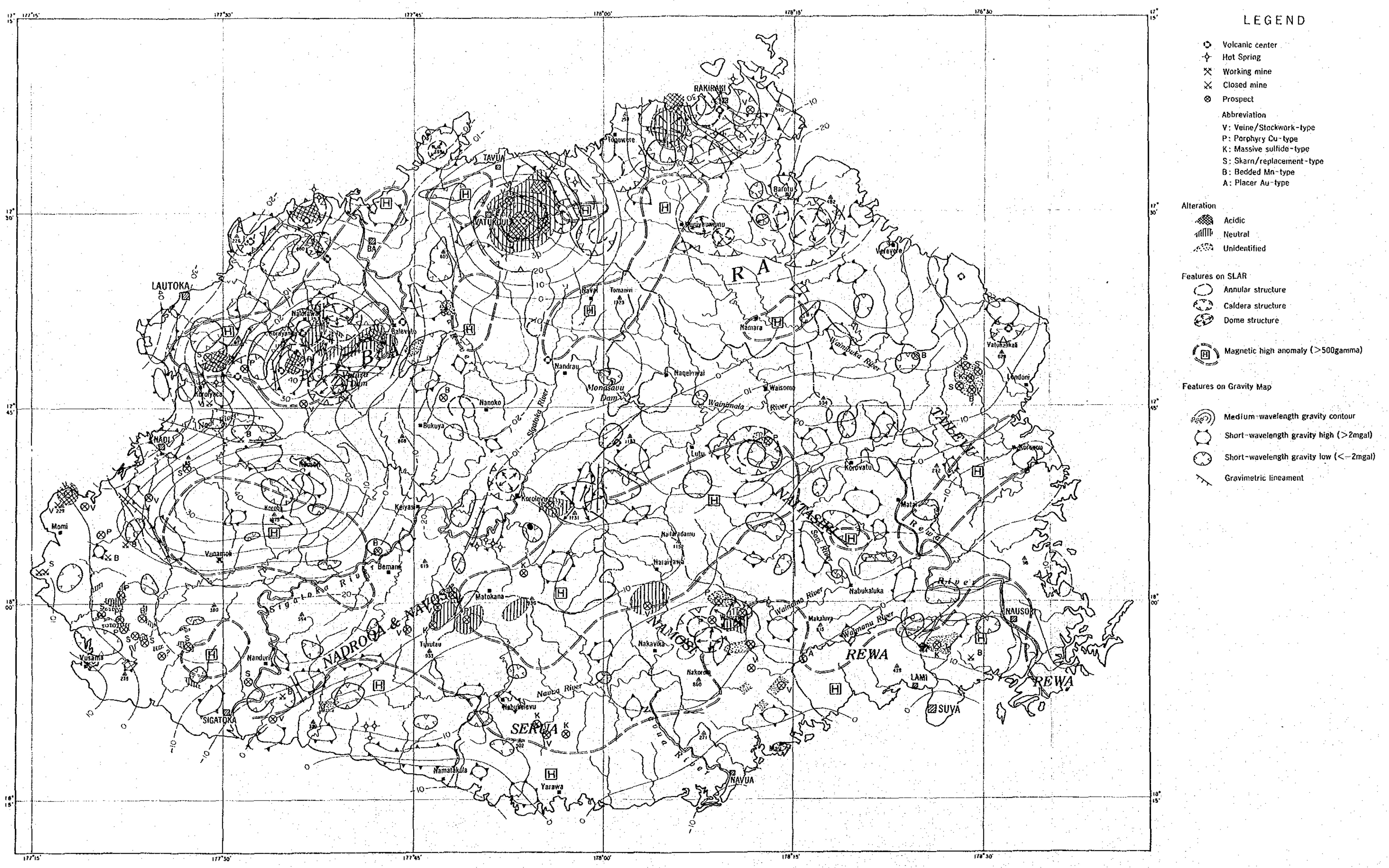
A total of three holes is recommended to be drilled in order to confirm the state of gold mineralization of the veins located by MJF-4. These veins are inferred to extend in the NNE-SSW direction and two holes should be drilled westward from the eastern side of MJF-4. Also one drilling should be made south-westward from MJF-4 in order to explore the lower parts of the NE-SW veins which exist in this zone.

(2) Yaloku Alteration Zone

A total of three holes is recommended to be drilled as follows in order to confirm the state of gold mineralization of the auriferous veins located by MJF-6 and -7 in western part of this zone. One hole should be drilled westward for exploring the N-S trending veins to the south of MJF-6. Also one northward hole should be drilled each from the east and west of MJF-7 in order to explore the ENE-WSW to E-W veins.

(3) It is recommended that one hole be drilled westward from the eastern side of the geochemical anomalies of eastern Yaloku in order to confirm the subsurface mineralization of the anomalies to the north of MJF-5.

(4) It is recommended that one vertical hole be drilled at the gold anomalies of Raviravi Alteration Zone for confirming the high sulfidation epithermal gold mineralization.



1 : 500,000
0 10 20 30 40km

Fig. 1-6 Integrated Interpretation Map (Viti Levu Island)

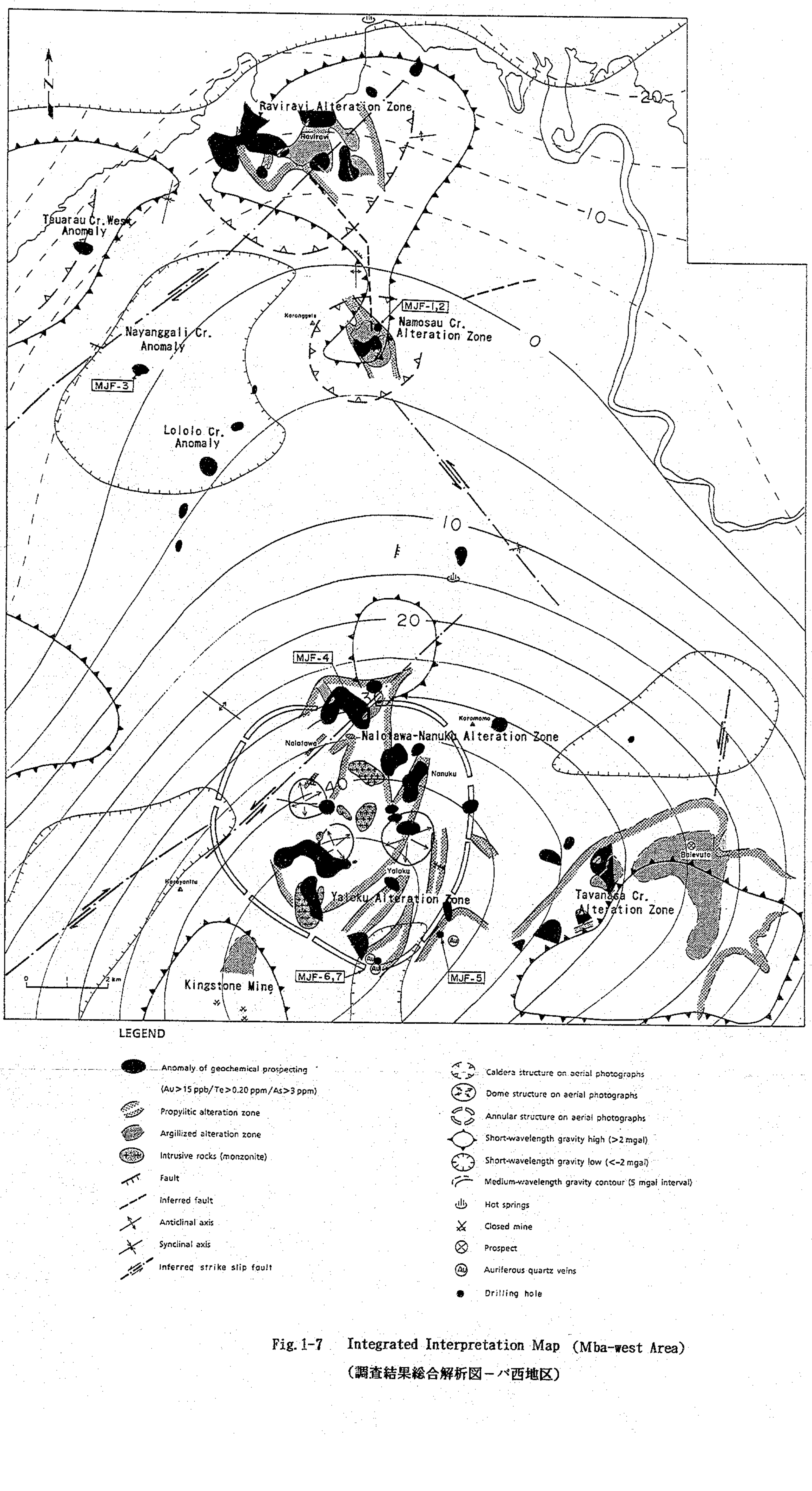
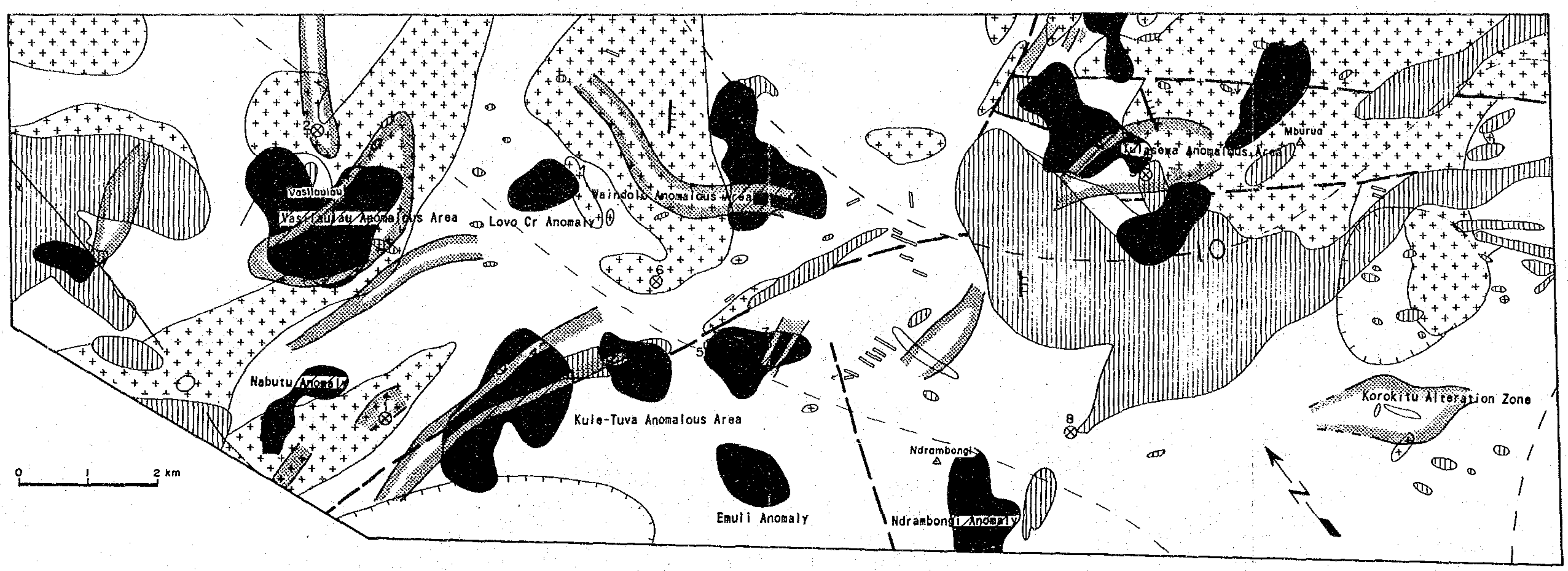


Fig. 1-7 Integrated Interpretation Map (Mba-west Area)

(調査結果総合解析図ーバ西地区)



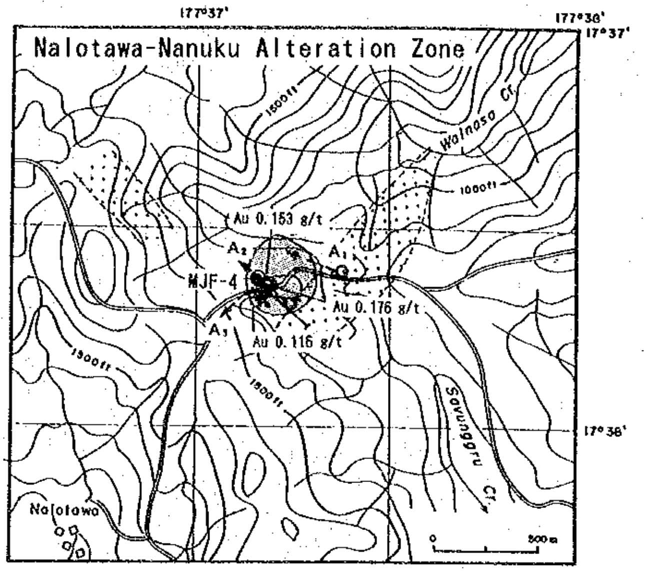
LEGEND

- Anomaly of geochemical prospecting (Cu>74 ppm, Pb>5 ppm, Zn>155 ppm)
- Alteration zone
- Intrusive rocks (granodiorite porphyry-diorite porphyry)
- Intrusive rocks (granodiorite, diorite and another Colo plutonic suite)
- Intrusive rocks (dacite)
- Fault
- Inferred fault
- Synclinal axis
- Short-wavelength gravity low (< -2 mgal)
- Medium-wavelength gravity contour (5 mgal interval)

1-9 Prospect

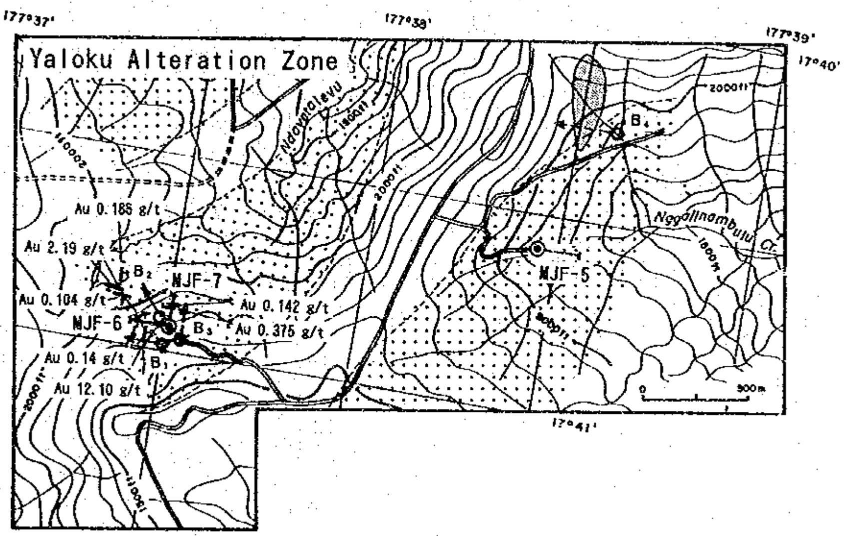
1 Kumbuna river (Zn-Pb-Cu)
2 Nathilenga (Cu-Mo)
3 Kule (Cu)
4 Kule creek (Zn(Cu-Ag) vein)
5 Natualevu (Cu-Zn)
6 Naitaki creek (Cu-Pb-Zn)
7 Tuva river (Cu vein)
8 Voua creek (Cu-Pb-Zn)
9 Tulasewa (Zn-Cu)

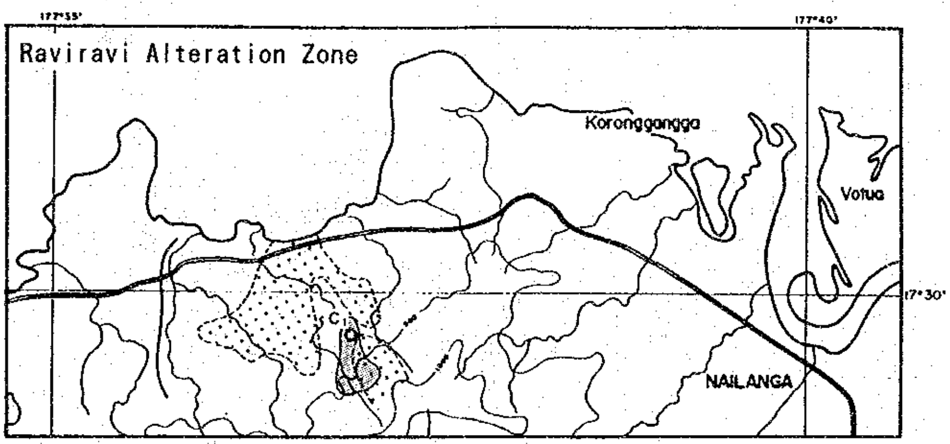
Fig. 1-8 Integrated Interpretation Map (Sigatoka Area)



Drilling holes recommended for future exploration

Drill No.	Direction (for true north)	Inclination	Drilling length m
A_1	N65W	-40	400
A_2	N55W	-50	300
A_3	N45W	-50	400
B_1	W	-55	250
B_2	N35W	-40	250
B_3	N10W	-35	300
B_4	W	-45	300
C_1	-	-90	200





LEGEND

Anomaly of geochemical prospecting(Au>15ppb)

Alteration Zone

Fig. 1-9 Location Map of Drilling Holes Recommended

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Viti Levu Island

1-1 Interpretation of SLAR and SPOT Images

1-1-1 Geological Interpretation of SLAR Imageries

(1) Objectives

This work was carried out in order to understand the distribution of the geologic units and the regional geologic structure of the project area by photogeological interpretation of SLAR (Side Looking Airborne Radar) imageries. SLAR is an all-weather active sensor and data can be obtained over areas with constant cloud cover.

(2) Area for interpretation

The area interpreted is the Viti Levu Island, the largest of the Fiji Islands (Fig. 1-4).

(3) Imageries used

SLAR is a sensor loaded on an aircraft, which transmits microwave pulses obliquely downward, receives pulses reflected from the earth's surface and forms two-dimensional imageries as the aircraft flies straight along a prescribed course. The variation of the scattering of the reflected waves are recorded on the radar imageries as variation in tone. Those used during the present work were two kinds of black and white imageries provided by the MRD as shown in Fig. 2-1-1. Their characteristics are as follows.

a. System

Wavelength: approximately 1 cm (K band)

b. Imageries

Looking directions: 2 (northward, southward)
Northward looking : 12 strips
Southward looking : 11 strips
Scale of imageries: 1:250,000
Mosaic prepared : October 1984

(4) Methods of interpretation

Regional photogeological interpretation was carried out. The geologic units were delineated and the geologic structure was interpreted. The photogeologic characteristics of the known mines and prospects were clarified and areas showing similar features were extracted.

(5) Standards for interpretation

a. Delineation of geologic units

The standards used for delineating geologic units are as follows.

Photographic characteristics:

Texture; very fine, fine, medium, coarse.

Tone; indicating the brightness by light, medium, dark.

Morphological characteristics:

Drainage patterns; dendritic, parallel, trellis, radial, meandering.

Drainage density; high, medium, low, very low.

Rock resistance; very high, high, medium, low, very low.

Development of bedding; high, low.

Development of lineaments; high, medium, low.

Other factors; relief energy, shape of mountains and ridges.

b. Geologic structure

The standards used for interpreting the geologic structure are as follows.

Folds: Folds are identified by considering the distribution of geologic units, bends in drainage patterns, trace of cuesta topography, extraction of strike ridges and other factors.

Lineaments: Lineaments indicate the existence of fractures on the surface or at shallow subsurface regions. Only those morphological features considered to be geologically significant were extracted as lineaments. These were grouped by their clarity and represented in the map as solid and broken lines.

The major morphological features used for identifying lineaments are as follows.

① The existence of fault scarps.
② The existence of linear fault valleys.
③ Notably linear flow of rivers.
④ The existence of kerncols and kernbuts.
⑤ The linear continuation of break points of slopes.

The above features vary in accordance with the geology, geologic structure and other factors of the area in question. However, empirically it can be safely considered that most of the lineaments on the imageries represent the features ① to ⑤.

<u>Annular and dome structures</u>: The morphological features for identifying annular structures are as follows.

① The curved, circular or semi-circular patterns of the drainage system.
② The circular or arc shaped enclosed depressions with similarly shaped marginal ridges.
③ Features indicating dome structures are, zones raised relative to the adjoining areas with circular or oval periphery.

In the structural features mentioned in ②, there are sharp fault scarps along the inner sides of the marginal ridges and it strongly suggests the existence of calderas. Thus these are called caldera structures (Fig. 2-1-1). Therefore, during the present survey, only the features described in ① were designated as annular structures. The three types of structures extracted from SLAR imagery analysis were verified and evaluated by geological survey carried out subsequently. The results will be reported in section 1-2. Since those reported in this chapter are structures identified in the imageries only, they will be labeled SLAR annular structures and so on.

(6) Results of Interpretation

a. Delineation of geologic units

The geology of the survey area was photogeologically divided into 12 geologic units as shown in Fig. 2-1-1 from the combination of the factors mentioned in the previous section. The Geological Map of Viti Levu (scale 1:250,000, 1966) was used as reference for this work.

The results of this work is correlated with those of the geological map prepared by the present survey (1:250,000, 1991) and of the geological interpretation of the SPOT images to be reported later is shown in Table 2-1-1.

b. Structural characteristics

<u>Folds:</u> Anticlines and synclines are observed the central to the southern part of the survey area.

<u>Anticlines:</u> There are seven anticlines in the areas of Units A, B, D and F. Two almost parallel anticlines are observed in Unit A area to the south of Nadi. The axes of these structures trend NW-SE and WNW-ESE and they extend for 7 km and 20 km.

Table 2-1-1 Stratigraphic Correlation of the Geologic Units Interpreted from SLAR and SPOT Images with those of the Geological Map

SLAR units	Geological map (1:250,000, 1991)	SPOT units
L	Alluvial sediments, flood plain sediments	L
K	Verata Sedimentary Group	K
J	Ba Volcanic Group and Ra Sedimentary Group	J_4 J_3 J_2 J_1
I	Cuvu Sedimentary Group	-
H	Koroimavua Volcanic Group	H
G	Navosa Sedimentary Group	G
F	Nadi Sedimentary Group	F
E	Medrausucu Group	E
D	Tuva Group	D
C	Colo Plutonic Suite	C
B	Wainimala Group and Savura Volcanic Group	B
A	Yavuna Group and Wainimala Group	-

Within the Unit B area, an anticline occurs to the northwest of Vunindawa and to the northwest of Naitonitoni. The axial trend of both anticlines is ENE-WSW and their extension is 20 km and 12 km respectively.

There is an anticline in the Unit D area along the middle reaches of the Sigatoka River and its axial trend is ENE-WSW and the length 12 km.

There are two anticlinal structures in the Unit F area along the Nadi River. They extend in the NNE-SSW and ENE-WSW directions and are considered to form the culmination of a single structure. Their length is 30 km including the depressed parts of the anticline.

Synclines: Four synclines are recognized in the Units B, D and E areas. In Unit B, synclines are observed at two localities, northeast of Sigatoka and north of Vunindawa. The axis of the former structure trend in approximately E-W direction and extends for 15 km while that of the latter syncline extends for 5 km in the ENE-WSW direction. Also the trend of the Vunindawa syncline axis is similar to that of an anticline to the south and thus is considered to have formed simultaneously. The wavelength of these structures is inferred to be 10 km and a lineament parallel to the axes is extracted between the anticline and syncline.

There is one syncline in Unit D along the middle reaches of the Sigatoka River. The axis trends WNW-ESE and is 6 km long. This syncline lies between two parallel anticlines in Unit A and the wavelength of this fold structure is 5 to 10 km.

In Unit E along the Navua River, a syncline with axis trending approximately ENE-WSW and extending for 30 km is observed. This is parallel to the anticline to the south and thus the two structures are considered to have formed simultaneously. The fold wavelength is inferred to be 16 km.

Lineaments: A total of 1,060 lineaments were extracted from the survey area as shown in Fig. 2-1-1. The following characteristics regarding the distribution and the trends of the lineaments are found from the above.

Lineaments occur densely in areas of the southern half of the survey area in the Units A, B and C. In the northern half, lineaments are densely distributed near Vatukoula and in very small scale in other parts.
They are all in Unit J.

The predominant trends of the lineaments are NW (28 %), NE (21 %), NNW (17 %) and less than 5 % in the N and E directions.

Regarding the length, 2 to 4 km are the most abundant, 490 lineaments, followed by less than 2 km, 390, these two constitute 83 % of the total number of lineaments.

Lineaments in NE and ENE direction tend to be continuous.

The possibility of the continuous lineaments being faults is high.

Where the lineaments are developed, the direction of lineaments coincide with the approximate direction of the intrusion of igneous bodies.

SLAR annular structure, SLAR caldera structure and SLAR dome structure: The SLAR annular, caldera and dome structures were identified in 30 localities of the survey area including the vicinity of Vatukoula and Rakiraki. Of these, 20 are within the Unit J which is distributed widely in the northern half of the survey area. Although there are cases when one of these structures occur singly, but often two or more of these occur forming compound structures.

When the SLAR caldera structures occur together with other structures, caldera structures always without exception occur on the outer side of the compound structure. SLAR dome structures mostly have closed circular or oval form, but the other two often have arcuate open form rather than circular. These are called SLAR semi-annular and semi-caldera structures. These are believed to have been closed originally and broken by volcanic activities and/or erosion, thus it is considered that the closed and semi-closed forms reflect the age of the formation of these structures.

The distribution of these structures are laid out below, here the semi-annular and semi-caldera structures are grouped together with the closed structures.

Structures	Geologic units				
	B	G	H	J	Total
Annular structures single	-	1	-	2	3
Caldera structures single	-	-	1	4	5
Dome structures single	2	-	-	4	6
Caldera·annular compound	2	-	1	7	10
Caldera·dome compound	1	-	2	3	6
Grand Total	5	1	4	20	30

1-1-2 Geological Interpretation of SPOT Images

(1) Objectives

This work was carried out in order to understand the distribution of the geologic units and the regional geologic structure of the survey area by photogeological interpretation of the SPOT (System Probatoire d'Observation de la Terre) images. The ground resolution of the SPOT images is higher than that of the images obtained from the optical sensors of LANDSAT and more detailed geological interpretation is possible.

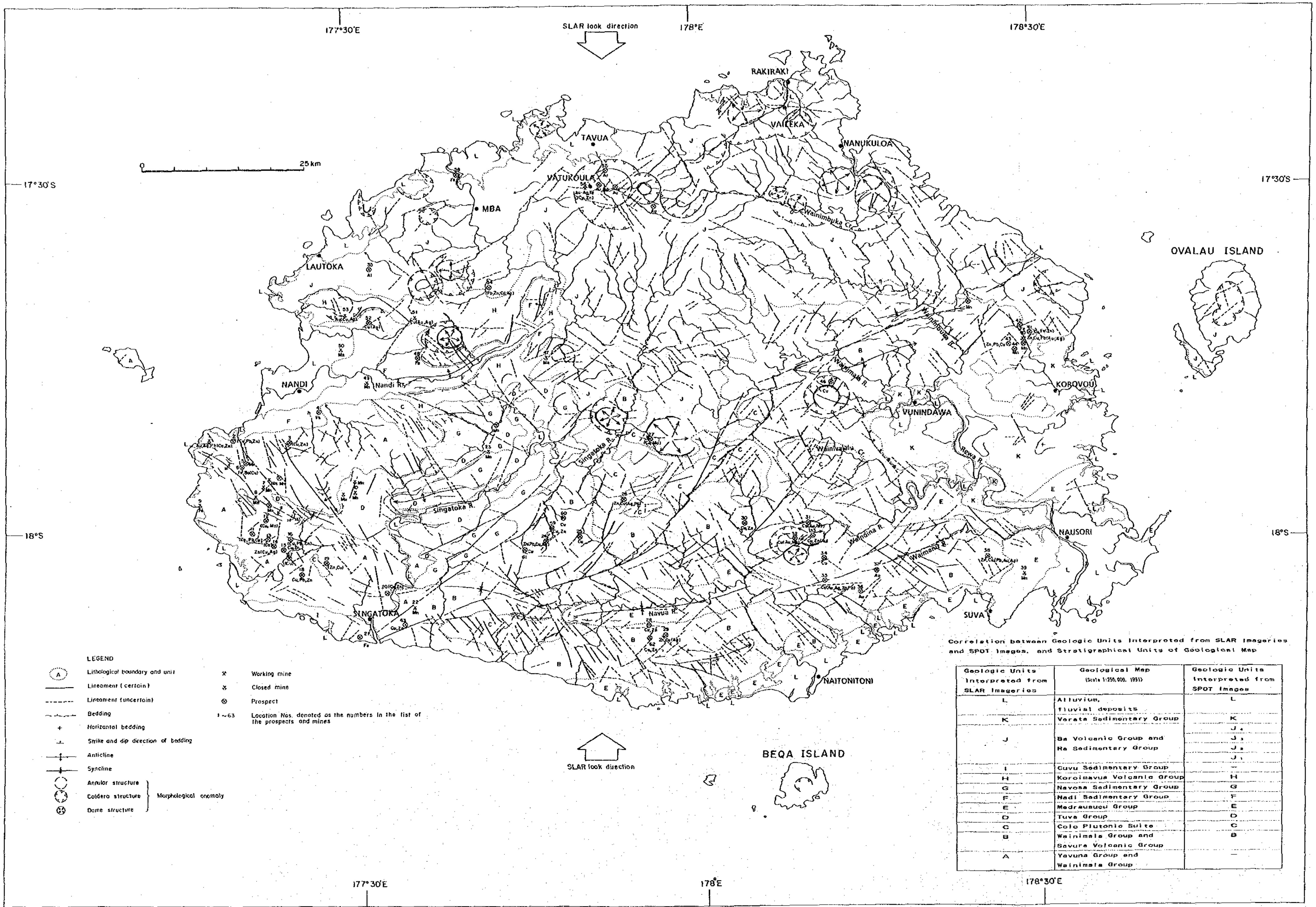
(2) Interpreted area

The area interpreted is the Viti Levu Island, the largest of the Fiji Islands. One scene in the southwestern part of the island, however, was not available as of October, 1990 and thus this part was not studied (Fig.1-4).

(3) Images used

SPOT is an earth observation satellite launched by CNES (Centre National d'Etudes Spatiales) in 1986. This carries a sensor called HRV (High Resolution Visible Imaging System) which observes visible and near infrared range and which can also observe sideways enabling three-dimensional imaging. The ground resolution is high at 20 m for multispectral mode (3 bands) and 10 m for panchromatic mode (1 band). The details of the five scenes used are as follows.

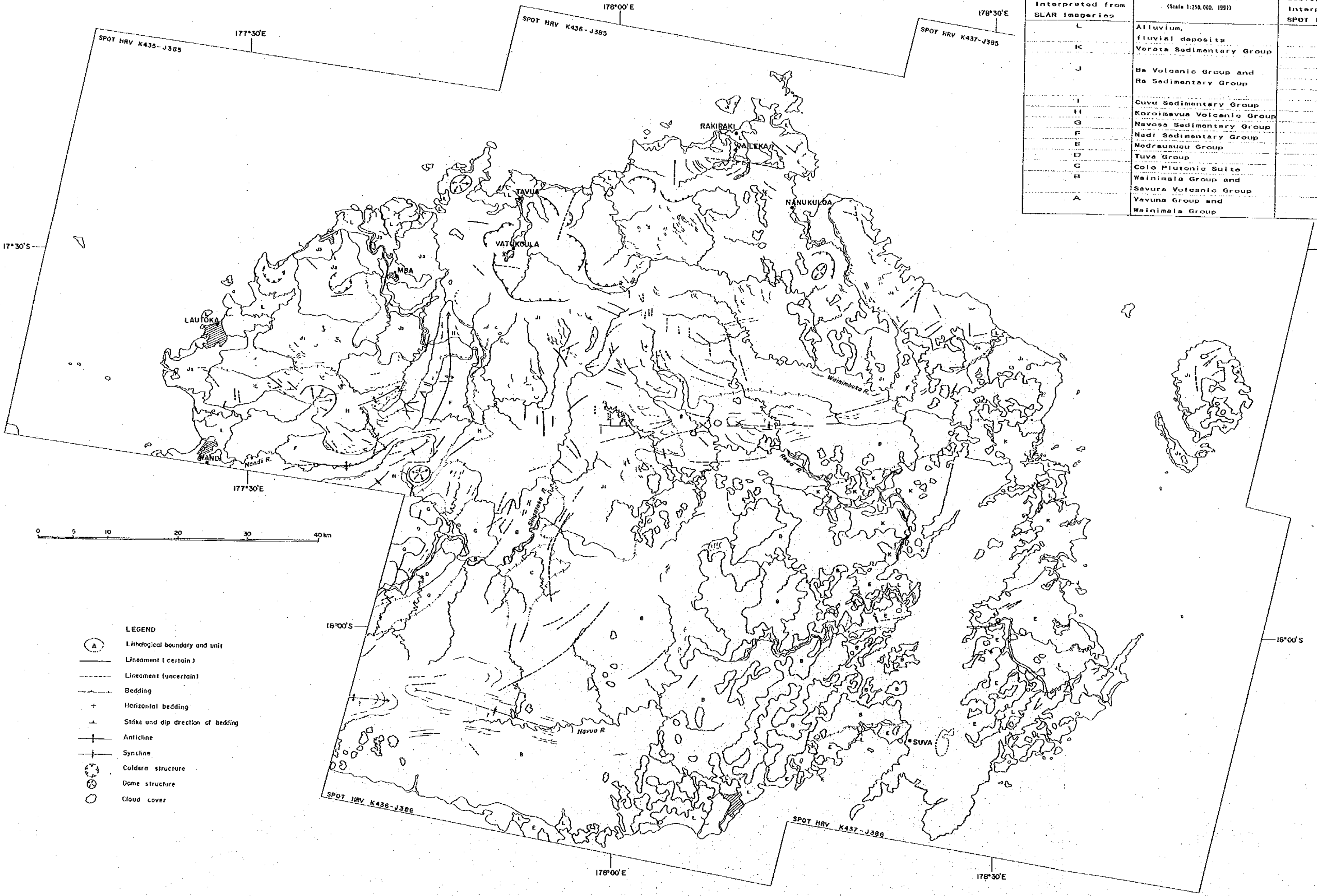
The column 436/line 386 scene is a black and white image (scale 1:200,000) due to the panchromatic mode, but the other four scenes are false colour composite images (1:200,000) from three band spectra. These are all single images and stereoscopic interpretation was not carried out.



Correlation between Geologic Units Interpreted from SLAR Imageries and SPOT Images, and Stratigraphical Units of Geological Map

Geologic Units Interpreted from SLAR Imageries	Geological Map (Scale 1:250,000, 1991)	Geologic Units Interpreted from SPOT Images
L	Alluvium, fluvial deposits	L
K	Verata Sedimentary Group	K
J	Ba Volcanic Group and Ra Sedimentary Group	J_4
		J_3
		J_2
		J_1
I	Cuvu Sedimentary Group	—
H	Koroimavua Volcanic Group	H
G	Navosa Sedimentary Group	G
F	Nadi Sedimentary Group	F
E	Medrausucu Group	E
D	Tuva Group	D
C	Colo Plutonic Suite	C
B	Wainimala Group and Savura Volcanic Group	B
A	Yavuna Group and Wainimala Group	—

Fig. 2-1-1 Photogeological Interpretation Map Using SLAR Imageries of Viti Levu Island



Correlation between Geologic Units Interpreted from SLAR Imageries and SPOT Images, and Stratigraphical Units of Geological Map

Geologic Units Interpreted from SLAR Imageries	Geological Map (Scale 1:250,000, 1991)	Geologic Units Interpreted from SPOT Images
L	Alluvium, fluvial deposits	L
K	Vorata Sedimentary Group	K
J	Ba Volcanic Group and Ra Sedimentary Group	J_4 J_3 J_2 J_1
I	Cuvu Sedimentary Group	—
H	Koroimavua Volcanic Group	H
G	Navosa Sedimentary Group	G
F	Nadi Sedimentary Group	F
E	Medrausucu Group	E
D	Tuva Group	D
C	Colo Plutonic Suite	C
B	Wainimala Group and Savura Volcanic Group	B
A	Yavuna Group and Wainimala Group	—

Fig. 2-1-2 Photogeological Interpretation Map Using SPOT Images of Viti Levu Island

K	J		Cloud	ID	Center of	Sun	
Column	Line	Date	cover	Number	Image	Azimuth	Elevation
435	385	1988.04.24	0 %	0389603S	S17°31'/E177°30'	39°00'	51°42'
436	385	1990.05.01	10 %	0789338D	S17°31'/E178°09'	42°24'	47°17'
437	385	1988.01.17	15 %	0355409K	S17°31'/E178°37'	101°11'	62°24'
436	386	1989.01.31	15 %	0522780Y	S18°01'/E178°02'	94°02'	59°08'
437	386	1987.07.24	20 %	0288497P	S18°01'/E178°34'	36°13'	43°20'

(4) Methods of interpretation

Regional photogeological interpretation was carried out. The geologic units were delineated and the geologic structure was interpreted. The photogeologic characteristics of the known mines and prospects were clarified and areas showing similar features were extracted.

(5) Standards for interpretation

Methods used for SLAR imagery interpretation (1-1-1-(5)) were used.

(6) Results of Interpretation

a. Delineation of geologic units

The geology of the survey area was divided into 13 geologic units as shown in Fig. 2-1-2 from the combination of the factors mentioned earlier. The correlation of the geologic units with those of the Geological Map of Viti Levu (1:250,000, 1991) and the results of SLAR imagery interpretation was shown earlier in Table 2-1-1.

The distribution of the geologic units and the morphological nature are very similar to the SLAR imagery analysis.

b. Geologic structure

Folds: The following facts regarding the fold structure of the survey area were clarified by the SPOT analysis.

Anticlinal structure with ENE-WSW trend and 6 km in length was observed northeast of Nadi in Unit H. The fold identified to be an anticline by SLAR analysis at the upper reaches of Rewa River is probably a synclinal structure.

Lineaments: The number of lineaments extracted is less than that of SLAR analysis. The characteristics of the lineaments extracted by SPOT analysis are as follows.

The density of lineaments is high in Units H and J1. The lineaments in the E-W or WNW-ESE direction intersecting fold axes are predominant in Unit H. Lineament with E-W and N-S trends are observed fairly abundantly in Unit J1 and other units. These were not extracted from SLAR imageries. Short lineaments (less than 1 km) in Unit J1 are believed to be joints.

Caldera and dome structures: Circular drainage patterns indicating annular structure were not extracted from the SPOT images. The caldera and dome structures extracted are compared with those from SLAR imageries as follows.

The two caldera structures identified west of Mba by the SPOT analysis have more typically circular or semi-circular topography than in the SLAR imageries. The caldera structure at Vatukoula is not as circular as in the SLAR imageries and is irregularly shaped. Most of the SLAR annular, caldera and dome structures extracted at Rakiraki are not very clear in the SPOT images. Semi-dome and dome structures were extracted from the SPOT images at 18 km northeast and at 30 km east of Nadi. The former is in Unit H and the latter in F. These could not be observed in SLAR imageries.

1-1-3 Discussions

(1) The Effectiveness of SLAR and SPOT Images for Geological Reconnaissance

SLAR is equipped with an active sensor and it functions under all weather regardless of the cloud coverage. Therefore, it is a very effective method for obtaining morphological and geological information on areas with long rainy seasons such as the southern part of the present survey area. However, as the signal is received at an oblique angle from above, the recorded terrain features are generally exaggerated, particularly the slopes of the direction at 30° to the looking direction are emphasized. HRV of SPOT, on the other hand, is a passive sensor and the signals are received at very high altitude, resulting in undistorted morphological information. But it being an optical sensor, information below cloud cover is totally unavailable.

The comparative study of the SLAR imageries and SPOT images for the survey area resulted in identifying the following advantages for using SLAR imageries over SPOT images.

a. SLAR imageries cover the entire survey area.
b. It is not affected by cloud cover.
c. The morphological characteristics of the area can be better interpreted.

d. Photogeologic features of the vicinity of the known mines and mineral prospects are better shown.

(2) Structural Features of the Survey Area Interpreted from SLAR Imageries

Generally the lineaments in a geologic unit are considered to have formed after the formation of the geologic unit. Therefore, a larger number of lineaments are observed in the older Units A and B compared to the relatively younger units such as Unit K.

The NE and ENE trending lineaments tend to be continuous and those extracted could be large faults.

Abrupt change in geologic structure is inferred at an E-W line joining Nadi and a point 10 km north of Vunindawa because of the difference in the development of the lineaments and the geology. Younger volcanics are predominant and annular structures more abundant to the north of this line.

In the Tectonic Interpretation Map on SLAR Lineament by Systems (Fig. 2-1-3), groups extending in certain directions are in echelon arrangement and the existence of lateral faults is inferred. In this figure the inferred lateral faults and the sense of their displacement are shown. If wrench faults existed in the vicinity of Viti Levu, these lateral faults were formed by the movement of these wrench faults. Under this hypothesis, the directions of the maximum horizontal compressional stress axes responsible for each lateral fault movement are shown in the Fig. 2-1-3.

The directions of the above maximum horizontal compressional stress axes are largely grouped into three directions, namely ENE to ESE, NW and NNW to NNE.

The maximum horizontal compressional stress in the ENE to ESE direction formed many of the lineaments with NE, ENE and WNW trends. These lineaments are distributed in the Wainimala Group and the Colo Plutonic Suite in the southern Viti Levu and in the Koroimavua Volcanic Group and the Ba Volcanic Group in the north.

The maximum horizontal compressional stress in the NW direction formed many of the lineaments with NNW and NW trends. These lineaments are mostly distributed in the Yavuna Group and the Wainimala Group in the southern Viti Levu and partly in the Ba Volcanic Group in the north.

The maximum horizontal compressional stress in the NNW to NNE direction formed many of the lineaments with NNE trend and some of those with

NNW, NW, WNW and NE trends. These lineaments are well developed in the Yavuna and the Wainimala Groups in the southwestern Viti Levu, the Navosa Sedimentary and the Koroimavua Volcanic Groups in the west and the Wainimala Group, the Colo Plutonic Suite and the Medrausucu Group in the eastern side of the central Viti Levu; also a part of them are developed in the Ba Volcanic Group in the northeast.

Lineaments are believed to have developed in the stress field which was predominant after the formation of the geologic unit. Therefore, the stress field characteristic to a lower geologic formation can be inferred by filtering out the lineaments similar to the most developed lineaments of the upper geologic formation. This method is useful in determining the dominant stress fields for various geologic times.

After around the Middle Pliocene (after the formation of the Ba Volcanic Group), the maximum horizontal compressional stress in the ENE to ESE direction is considered to have been predominant. During the Late Miocene to the Early Pliocene (after the formation of the Navosa Sedimentary Group, the Koroimavua Volcanic Group and the Medrausucu Group to the early stages of the formation of the Ba Volcanic Group) maximum horizontal compressional stress in the NNW to NNE direction was predominant.

The intrusion of the Colo Plutonic Suite in the Late Miocene occurred elongated in ENE to ESE direction and thus the maximum horizontal compressional stress at that time is inferred to be in the ENE to ESE direction. This is harmonious with the fact that the lineaments formed under the ENE to ESE maximum horizontal compressional stress are developed in the Wainimala Group and are predominant in the Colo Plutonic Suite area.

The distribution of the lineaments formed by the maximum horizontal compressional stress of the NW direction partly overlaps with that of the lineaments formed by NNW to NNE maximum horizontal compressional stress and that of the Ba Volcanic Group. Thus the maximum horizontal compressional stress in the NW direction probably show the direction of the stress field during the period of rotation of the field from NNW through NNE to ENE through ESE.

The distribution of the lineaments formed by the maximum horizontal compressional stress in the above three directions and the distribution of the mines and mineral prospects are shown in Fig. 2-1-4. It is seen that the distribution of the lineaments of the ENE to ESE maximum horizontal compressional stress and that of the mines and prospects show the best correlation, but in the western Viti Levu, the mines and prospects occur in the area of lineaments formed by all three maximum horizontal compressional stress directions.

(3) Extraction of Priority Areas for Exploration

The photogeologic features of the vicinity of the known mines and prospects were studied on SLAR imageries based on the results of photogeologic analysis and existing geologic material (Geology of Viti Levu 1:250,000, 1966 and Metallogenic Map of Viti Levu 1:250,000,1978).

As a result, 15 areas (A to O; Fig. 2-1-5) were extracted where morphological anomalies such as SLAR annular, SLAR caldera and SLAR dome structures occur. Regarding Area A, it was clarified that the gold vein deposits of the Emperor Mine and the Waikatakata Prospect occur inside and at the periphery of the SLAR annular structure, and that lineaments occur very densely in the area. Also in Area G, it was observed, that in the Namosi district where the porphyry copper deposits and prospects occur, SLAR annular and SLAR caldera structures occur near the SLAR dome structure (Fig. 2-1-1).

The largest known deposits and prospects occur in the above two areas, and it is inferred that the large-scale epi-mesothermal mineralization is closely related to the SLAR annular, SLAR caldera and SLAR dome structures. Therefore, the 15 areas where these structures occur were accorded high priorities for field survey (Table 2-1-2). Also, by using the above two areas as models, it should be possible to select areas of higher priorities by comparing the relevant characteristics of the 15 areas.

The photogeologic and geologic characteristics of Area A are the following eight points.

a. Existence of SLAR annular structure.
b. Existence of SLAR caldera structure.
c. Existence of high lineament-density zones.
d. Predominance of NE-SW trending lineaments.
e. Existence of Au mineralization near the SLAR annular and SLAR caldera structures and also within the SLAR annular structures.
f. Existence of Au mineralization at the intersection of and on the lineaments.
g. Existence of the Ba Volcanic Group.
h. Existence of granitic rocks intruding the Ba Volcanic Group.