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

PHASE I

FEBRUARY 1991

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

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

The JICA and MMAJ sent to the Republic of Fiji a survey team headed by Mr. Masaaki Sugawara from 24 October to 29 December 1990.

The team exchanged views with the officials concerned of the Government of the Republic of Fiji and conducted a field survey in the Viti Levu 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 relations between our two countries.

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

February, 1991

Kensuke Yanagiya

Kensuke YANAGIYA
President,
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President,
Metal Mining Agency of Japan

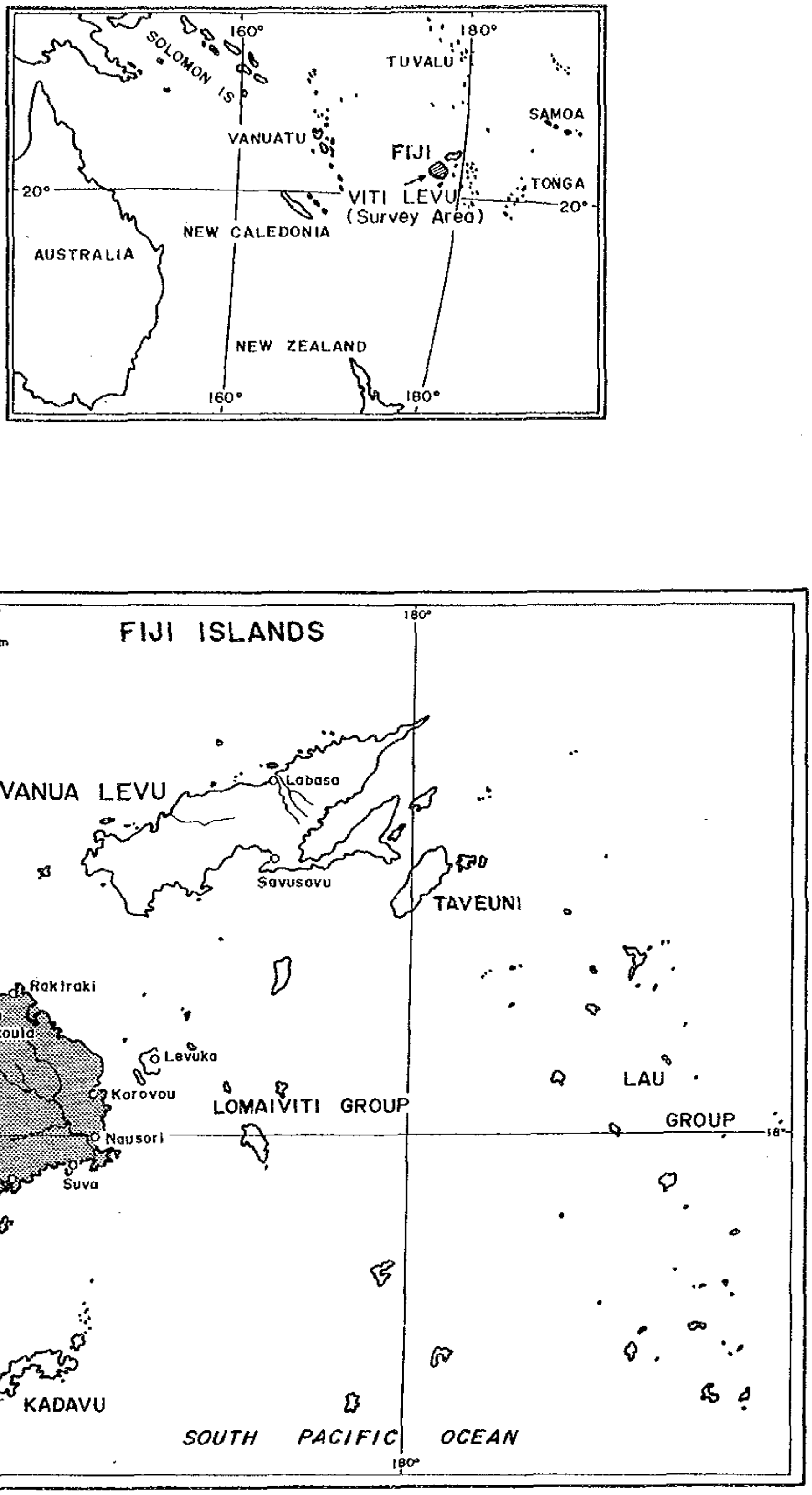

Fig. 1-1 Index Map of the Survey Area

Summary

(1) The objective of the first year survey of the Viti Levu Island, Republic of Fiji was to clarify the geologic environment relevant to mineral resources of the island and to delineate promising areas for further detailed exploratory work through geoscientific studies. This objective was achieved by; compilation of all existing geoscientific data and information of Viti Levu (area of 10,400 km^2), analysis and interpretation of SLAR imageries and SPOT images, field geological survey, and gravity survey (517 stations) of Tavua area (2,000 km^2) in the northern part of the island. Brief outline of the above work are summarized in the following sections.

(2) Twelve geologic units were delineated by SLAR imagery interpretation and 13 units by SPOT interpretation.

(3) Anticlinal and synclinal structures extracted from SLAR imageries and SPOT images are distributed from the central to the southern part of the island.

(4) 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.

(5) It was 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 annular, SLAR caldera and SLAR dome structures were selected. From these 15 areas, Rakiraki, east of Vatukoula, upper reaches of the Mba River, northeast of Nandi and South of Mba area were selected as having strong geoscientific semblance to the area near the Emperor Mine. Also northeast of Nandi and South of Mba area were selected as areas with geologic environment very similar to the Namosi Deposit area.

(6) The geology of Viti Levu 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.

(7) Large number of faults occur to the south of the Colo Plutonic Suite in the central part and near the Yavuna Group in the southwest. ENE and NW trending faults are predominant to the south of the Colo Plutonic Suite while those with ENE to NNE and NNW trend are developed in the Colo Plutonic Suite zone. Faults with various trends occur in the vicinity of the Yavuna Group.

(8) A large number of folds occur in zones of many faults. Anticlines and synclines occur parallel to the elongation of the plutonic rocks (ENE to ESE, NNE) near the Colo Plutonic Suite zone and anticlines and synclines of many trends occur in the Yavuna Group zone in the southwest.

(9) The direction of the maximum horizontal compressional stress inferred from the lineament analysis and the distribution of the Colo Plutonic Suite is ENE to ESE during Late Miocene and after Middle Pliocene, NNW to NNE during latest Miocene-Early Pliocene, NW during Early-Middle Pliocene. It is inferred, thus, that compressional stress in the ENE to ESE direction affected the area for the longest period in geologic history resulting in the largest number of basins elongated in this direction and of deep fissures also with this trend.

(10) The locations of the centres of the volcanism of the latest Miocene - earliest Late Pliocene Ba 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.

(11) 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 centres at the time and the distribution of the above lineaments.

(12) Large scale high gravity anomalies were discovered in four localities at west of Mba, Tavua caldera, Rakiraki and east of Nandi. It is inferred that these anomalies reflect the fact that high density rocks (amphibolite, granulite and others) occur at shallower depths at the four localities than in the surrounding areas.

(13) The zones where volcanic centres 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 olivin-gabbro of higher density, there are positive gravity anomalies near the altered volcanic centres. 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 centre of eruption would show somewhat higher density.

(14) 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 centres west of Mba are the zones which have Tavua Caldera type gravity structure among the possible collapse caldera zones extracted photogeologically.

(15) There are distinct differences in the magnetic anomalies of the north and south Viti Levu. The anomalies in the north have very large amplitude with small size and consequently it is believed to have been caused by strongly magnetic bodies at shallow depth. The surface is widely covered by Ba Volcanic Group and the individual magnetic anomalies could be reflecting the lithological variation in this Group.

Whereas in the south, large scale magnetic anomalies occur. The Colo Plutonic Suite and the Yavuna Group zones correspond to the magnetic high zone (over 500 γ) while the distribution of Wainimala and Medrausucu Groups correspond to the low magnetic anomalous zones with fair degree of agreement.

It is possible that Colo Plutonic Suite exist in deeper zones at the large high magnetic anomalous zone in the eastern part. Also the Yavuna Group or intrusive bodies may exist in the large magnetic high in the northwest.

(16) Vein, network dissemination, porphyry copper, replacement, skarn and sedimentary type mineralization occur in this survey area.

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 Ba and Koroimavua Volcanic Groups occur near the volcanic centres which were the source of the volcanic rocks or near the zones where these centres are inferred to have existed.

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

The porphyry copper type mineralization is classified into the plutonic and volcanic types.

The volcanic type porphyry copper mineralized zones occur within and the vicinity of the latest Miocene to Early Pliocene volcano-plutonic complex (Namosi Andesite of Medrausucu Group, Sabeto Volcanics・Navilawa Stock・Nawainiu Intrusive Complex of Koroimavua Volcanic Group).

The plutonic type porphyry copper and the meso to hypothermal base-metal mineralized zones occur within and the vicinity of the Middle to Late Miocene Colo Plutonic Suite.

The skarn type mineralization occurs in the contact zone of the Colo Plutonic Suite and Wainimala Group limestone. The replacement type mineralization occurs in the Wainimala Group in the vicinity of the Colo Plutonic Suite.

Sedimentary mineralization is divided into massive sulfide, bedded manganese, residual and placer type concentration.

The massive sulfide mineralization is stratabound type which occurs in pyroclastics of the Wainimala Group formed by submarine volcanic activity.

The major bedded manganese deposits are stratabound type which occur in the bedded volcano-sedimentary formations of the Wainimala Group. These also tend to occur near the replacement and skarn type mineralized zones.

The residual deposit found in Viti Levu is a small bauxite deposit formed by lateritic weathering of basaltic pyroclastics of the Ba Volcanic Group.

The placer deposits in the survey area are gold concentration in alluvium and iron oxides in deltas and sand dunes.

(17) 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 southern part, Sabeto Range south of Lautoka and Namosi area are considered to contain high potential for locating mineralized and altered zones.

(18) Of the areas extracted with anticipation of epithermal gold mineralization, that extending southward from west of Mba is relatively unexplored. This lies within a 20 km x 10 km area, extend in the NNW direction, alteration zones occur scattered inside, Balevuto Gold Prospect exists to the south, volcanic collapsed zones and volcanic domes probably exist to the southwest and north, and gravity structure similar to the Tavua Caldera exists in the northwest portion. From these features, the possibility of finding mineralization is considered to be high in this area. Promising mineral showings, however, have not been found yet. From the above reasons, geochemical prospecting and detailed geological survey for delineating promising zones in this area are recommended.

(19) Close relationship between the distribution of mineralized zones and lineaments is inferred from the results of the SLAR imagery analysis. It is recommended that lineament analysis of aerial photographs be carried out and promising areas be delineated from the areas extracted as possessing high potential during the first year survey, namely vicinity of Rakiraki, Tavua

Caldera, southward from west of Mba , Sabeto Range south of Lautoka, and the Namosi area.

(20) In the western part of Viti Levu, the Yavuna Group which forms the basement of the island is distributed and the Colo Plutonic Suite intrudes into the Wainimala Group. Alteration zones occur widely in the NW to WNW direction around the Colo Plutonic Suite and porphyry and skarn type mineralized zones are distributed within these altered zones. Epithermal gold deposit (Faddy's) of acidic sulfate type occur in the Wainimala Group in the western edge of the island, but the factors controlling the mineralization are not clear.

It is considered from the above that western Viti Levu has a relatively high mineral potential. It is, thus, recommended that gravity survey be carried out in western Viti Levu and that the basement structure, subsurface distribution of Colo Plutonic Suite, the existence of volcanic centres be clarified by geological analysis. This will also clarify the high gravity anomaly zones and high magnetic anomaly zones and the relationship between the geologic structure of the island and mineralization.

(21) Epi-mesothermal mineralization occurs in the vicinity of the known and inferred volcanic centres. Also areas of these centres show gravimetric characteristics such as short-wavelength high gravity anomalies or short-wavelength low anomalies according to the difference of the nature of the volcanic activity. Thus, gravity survey is an extremely effective method for mineral exploration in this geologic environment and gravity survey of the entire Viti Levu with the exception of the area covered during the first year is recommended.

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PART I OVERVIEW

Chapter 1. Introduction

1-1 Background and Objectives

In response to the request by the Government of the Republic of Fiji to conduct mineral exploration in Viti Levu area, 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 1990 to 1992.

1-2 Objectives and Outline of Operations of the First Phase Survey

During the first phase of the project to be carried out in fiscal 1990, compilation of existing data, analysis and interpretation of SLAR imageries and satellite images, geological and geophysical surveys were to be conducted over the whole Viti Levu Island (10,400 km^2) (Fig. 1-1) with the purpose of clarifying the geology and the geological environment relevant to mineral resources of the area and of extracting promising zones for future prospecting. Also geochemical orientation survey was carried out in order to prepare plans for systematic geochemical exploration of the promising areas.

The scope of the work during this phase is as follows.

Survey	Particulars
1.Geological Survey	Whole Viti Levu Island
Areal extent	10,400 km^2
Length of traverse	550 km
Laboratory work	
Thin section microscopy	23 sections
X-ray diffraction	27 samples
Radiometric age determination	5 samples
Polished section microscopy	5 sections
Whole rock chemical analysis	10 samples

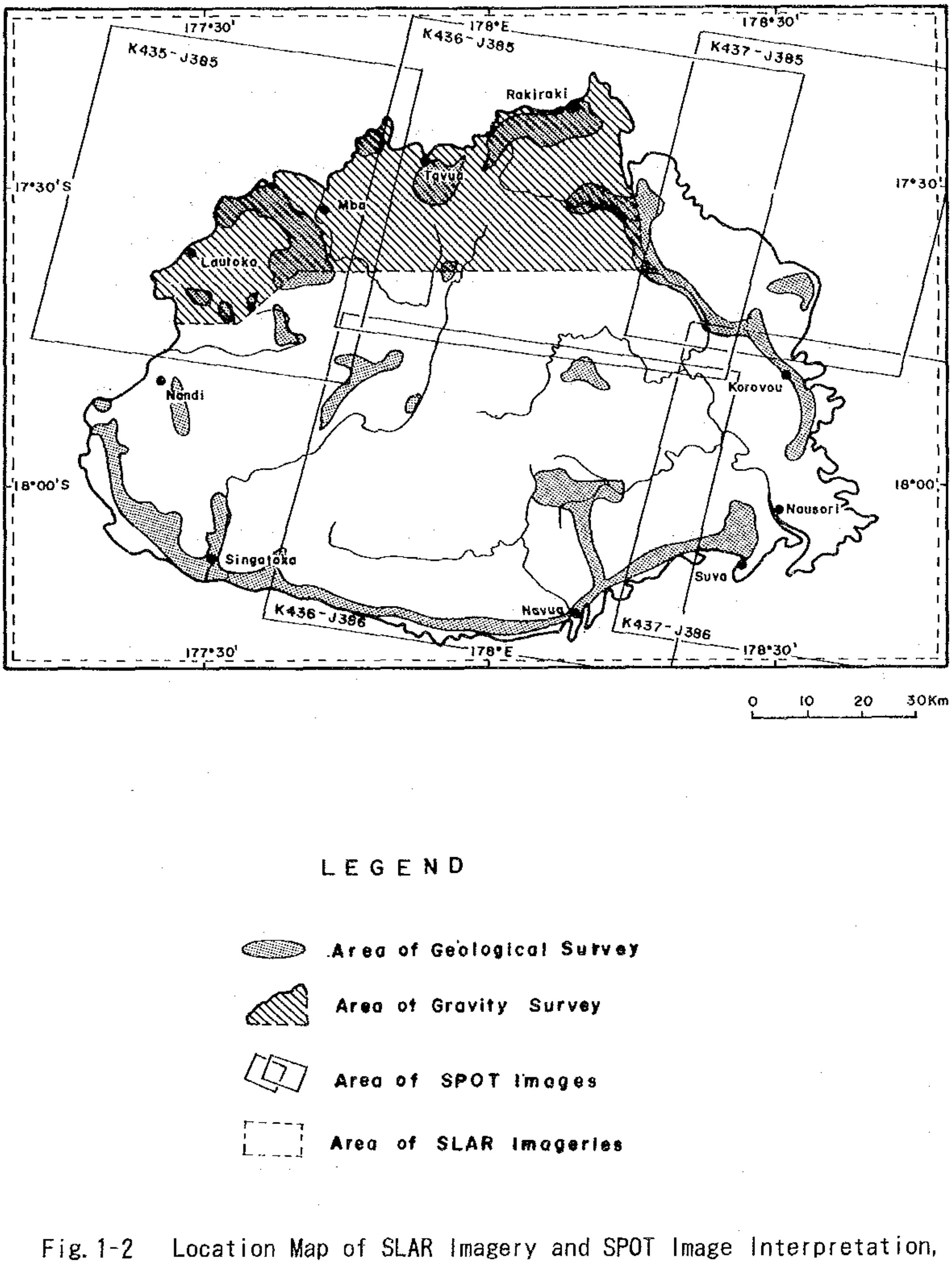


Fig. 1-2 Location Map of SLAR Imagery and SPOT Image Interpretation, Geological Survey and Gravity Survey Areas

Survey	Particulars
2.Geophysical Survey (Gravity) Areal extent Number of stations Laboratory work Density measurements	Tavua area 2,000 km² 517 38 samples
3.Digitization of topographic maps Areal extent	Whole Viti Levu Island 10,400 km²
4.Geochemical Orientation Survey Areal extent Number of Samples Soil Stream Sediments Panned Concentrates	Near Emperor Mine about 20 km² 301 samples 130 samples 119 samples 52 samples

1-3 Participants of the First Phase Survey

(1) Mission for project finding and scope of work consultation
(23 July 1990 - 4 August 1990)

Fijian members

Abdul RAHIMAN	Director, MRD
Alf SIMPSON	Assistant Director, MRD
Neville EBSWORTH	Principal Engineer, MRD
Don J. FLINT	Senior Economic Geologist, MRD
Suli NIUROU	Economic Geologist, MRD
Radi KUMAR	Aid Unit, Ministry of Finance

Japanese members

Katsumi YOKOKAWA	Metal Mining Agency of Japan
Yoshiyuki ISODA	Ministry of Foreign Affairs
Junichi TOMINAGA	Ministry of International Trade and Industry
Yoshihisa OKUDA	Ministry of International Trade and Industry
Hiromichi MURAKAMI	Japan International Cooperation Agency
Hiroyasu KAINUMA	Metal Mining Agency of Japan
Takashi OOKA	Metal Mining Agency of Japan
Keiichi GOTO	Metal Mining Agency of Japan (Canberra)

(2) Survey team

The survey of the first phase was carried out during the period from 15 October 1990 to 29 December 1990. Duration of the field survey and the organization of the survey team were as follows.

Duration of the study of existing material and photogeological interpretation in Japan
15 October 1990 - 25 October 1990.

Duration of the geological survey
24 October 1990 - 29 December 1990.

Duration of the geophysical survey
12 November 1990 - 29 December 1990.

Duration of the geochemical orientation survey
9 December 1990 - 22 December 1990.

Geological and Geophysical Survey

Fijian members

Abdul RAHIMAN	Director, MRD
Alf SIMPSON	Assistant Director, MRD
Peter RODDA	Principal Geologist, MRD
Don J. FLINT	Senior Economic Geologist, MRD
Suli NIUROU	Economic Geologist, MRD
Isireli NAGATA	Geologist, MRD
Vijendra PRASAD	Senior Geophysicist, MRD

Japanese members

Masaaki SUGAWARA	Team leader, Chief Geologist, NED
Ken OBARA	Geologist, NED
Masasamu OYANAGI	Geophysicist, NED
Toshihisa ISHIBASHI	Geophysicist, NED
Tadanori IWASAKI	Geophysicist, NED

Geochemical Orientation Survey

Fijian members

Abdul RAHIMAN	Director, MRD
Vijendra PRASAD	Senior Geophysicist, MRD
Suli NIUROU	Economic Geologist, MRD

Japanese members

Katsumi YOKOKAWA	Metal Mining Agency of Japan
Tetsuo SUZUKI	Metal Mining Agency of Japan
Kouji SEGAWA	Metal Mining Agency of Japan
Satoshi YAMAGUCHI	Metal Mining Agency of Japan

Note MRD : Mineral Resources Department
NED : Nikko Exploration and Development Co., Ltd.

Chapter 2 Geography of the Survey Area

2-1 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 2,700 km east of the eastern coast of Australia, approximately 1,900 km north of New Zealand and approximately 2,000 km south of the equator.

The international airport is at Nandi 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 Nandi as the crow flies. Nandi to Suva is travelled by air in 50 minutes via Nausori and is about four hours by car along the southern coast of the island.

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

Population centers are developed along the coast, namely Singatoka 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 the island and also crossing the island joining the southeastern and southwestern parts with Tavua Area in the north. The road connecting Suva-Singatoka-Nandi-Lautoka-Mba-Tavua-Rakiraki is paved, but those along the eastern coast and across the island are unpaved.

2-2 Topography and Drainage

(1) Topography

There is a highland with an altitude of around 1,000 m 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 1,323 m.

Hilly zone of 150-600 m 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 rivers 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) Drainage

The major drainage of the Viti Levu Island consists of; the Singatoka River System which flows southwestward from the north-central part of the island, the Rewa River System flowing southeastward from the northeastern to the central part, the Mba River System in the northwestern part, the Nadi River System in the west and the Navua River System in the south. The first two systems are the largest. The Rewa System covers a wide area, close to the eastern half of the island and comprises Wainimbuka, Wainimala and Waindina Rivers. Many tributaries are associated with all these rivers.

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 the central part is occupied by highland in Viti Levu, precipitation is high in the southeastern side of the island - over 200 days of rain every year -, while the northwestern side is relatively dry with the temperature often approaching 40°C. The monthly mean temperature and precipitation observed at Nadi in western Viti Levu over 30 years (1951-1980) is listed below.

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Average Temperature (°C)	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 Precipitation (mm)	313.8	292.5	367.4	172.3	83.7	77.9	51.9	58.1	92.9	96.9	136.4	168.9	1912.6

(Observed at: 17°45'S, 177°27'E, Elevation 18 m)

(2) Vegetation

The southeastern Viti Levu is in the tropical rain forest zone and the greater part is covered by dense virgin forest, while the northwestern part is covered by sparsely growing shrubs with planted pine trees. There are many coconut palms along the coast.

Chapter 3 Available Geological Information

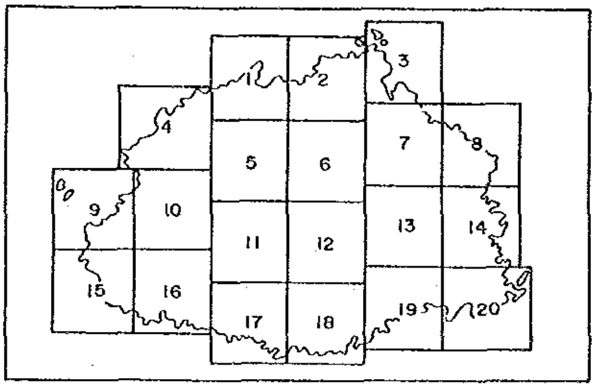
3-1 Outline of Past Geological Surveys

The outline of the geology of Fiji is 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). The sheet number, area and the index map are shown below.

①Tavua (Ibbotson, 1967), ②Vaileka (Rodda, 1964), ③Nanukuloa (Hirst, 1966), ④Lautoka (Rao, 1983), ⑤Mbalevuto (Rickard, 1962?), ⑥Nandarivatu (Rodda, 1964), ⑦Wainimbuka River (Hirst, 1967), ⑧Londoni (Hirst, 1967), ⑨⑮Lomawai-Momi (Houtz, 1960?), ⑩Nandi (?), ⑪Keiyasi (Houtz, 1963), ⑫Namosi (Rodda, 1970), ⑬Vunindawa (Hirst,1966), ⑭Nanduruloulou (Hirst, 1967), ⑯Singatoka (?), ⑰Korolevu Bay (Band, 1967), ⑱Navua River (Band,1967), ⑲Mau (Band, 1967), ⑳Suva (Ibbotson, 1960)

Index Map



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.

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.

3-2 General Geology of the Survey 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

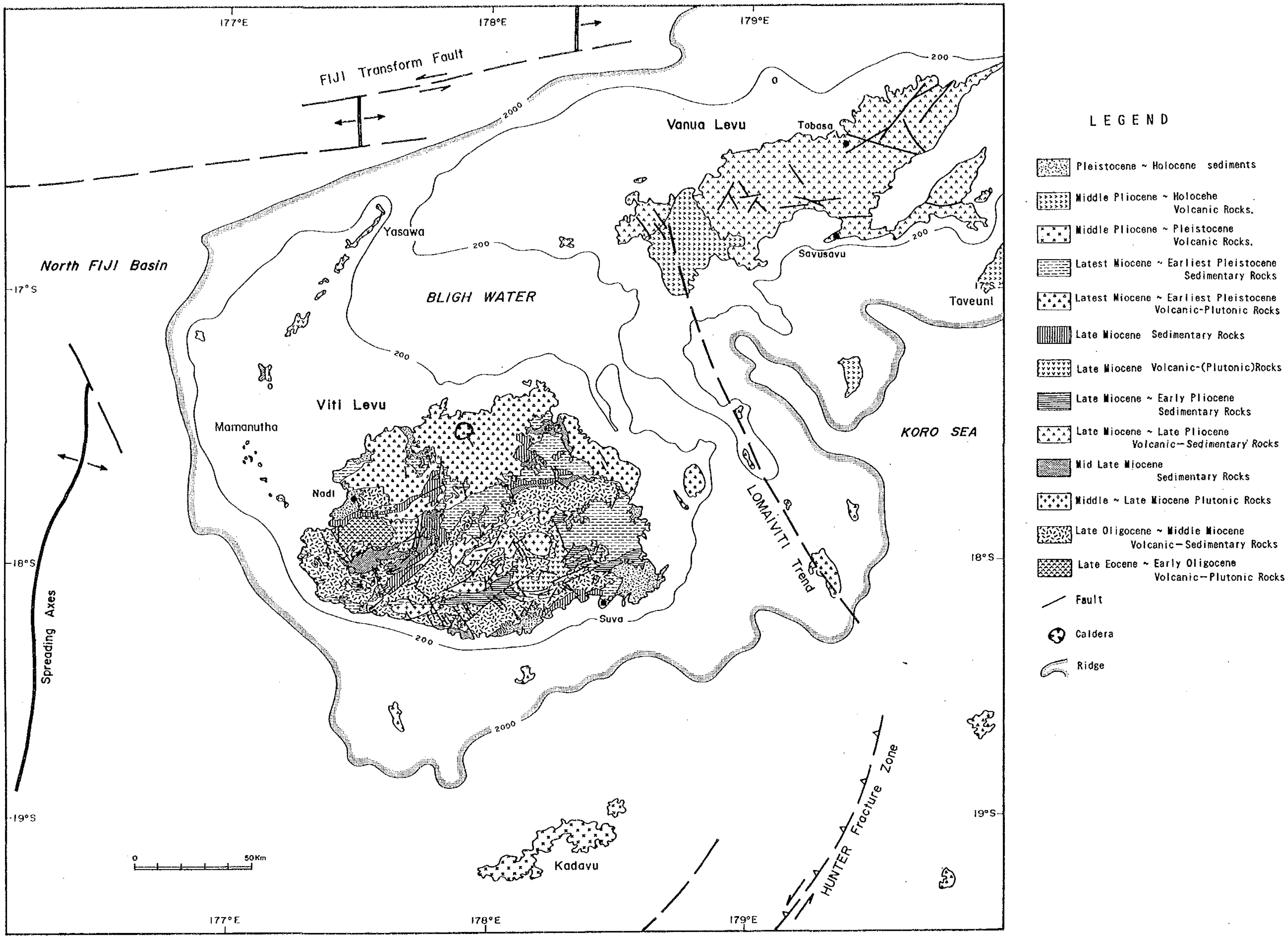


Fig. 1-3 Simplified Geological Map of the Survey Area

volcanic ejecta of historic times in Taveuni Island.

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 rhyolites) 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.

3-3 Geologic Setting of the Survey Area

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.

3-4 Brief History of Mining in the Survey Area

Various types of mineralization are known in Viti Levu and there are many prospects and mines in the island. The major exploration activities and the production in the past are as follows.

(1) Placer concentration

i . Waimaru River

1909-1935 Explored by prospectors.

1960-1961 Explored by Geological Survey of Fiji (GSF) and Mines Department (MD)(36 pits, total length 79.3 m), ore reserves: 150,000 m^3, Au 100 to 200 mg/m^3.

(2) Vein mineralization

i . Emperor Mine

1932 Discovered by prospectors.

1935 Production started by three companies.

1964-1966 GSF and Emperor Gold Mining Co., Ltd., (EGM) conducted geochemical prospecting and drilling in the periphery of calderas such as Waikatakata, Homeward Bound East and Nasivi No.3. Ores containing 13.5 ppm Au were discovered by drilling at Waikatakata. The thickness of the veins there was 22.5 cm.

1989 The production of the joint venture EGM-Western Mining Corp. (Fiji) Ltd., for this year was Au 4.2 t (crude ore 606,000 t), the cumulative production for 1933-89 is 132 t Au (14.18 million tons crude ore).

ii . Mistry Mine

1937 Deposit discovered.

1947-1958 Produced Au 23 kg, Ag 6 kg, Pb concentrate 20 t (crude ore 1,720 t).

1958-1960 Prospected by GSF.

1974-1975 Prospected by EGM. Remaining reserves 2,300 t (Au 4.4 ppm).

iii . Tulasewa

1976-1977 Prospected by Amoko Minerals Fiji Ltd., (AMFL) (drilled 5 holes - 591 m), confirmed Zn-Cu mineralization.

iv . Kavika-Lo

1980 Prospected by Anglo-American (Fiji) Pty. Ltd., (drilled 7 holes - 327 m), confirmed Zn-Cu-Pb-Au-Ag mineralization.

(3) Network-dissemination type mineralization

i . Kingston Mine

1906 Underground prospecting, later flooded.

1923, 1952 Underground prospecting, later flooded.

1952 Sample collected from a shaft contained 20.3 % Cu, 97 ppm Au, 434 ppm Ag.

1963-1964 Prospected by GSF.

1970-1971 Prospected by Barringer Fiji Ltd., (BFL) (drilled 14 holes - 1,124.5 m).

ii . Vuda

1937 Reserves of 2,500 to 3,000 t (Au 8.4 ppm) confirmed.

1938-1954 Produced 22.6 kg Au and 5.5 kg Ag.

1969-1974 Prospected by Manganex Ltd., and MRD (drilled 4 holes - 267.3 m).

1975-recent Prospected by many Western enterprises, many drilling operations.

iii . Balevuto

1963 Rickard (GSF) reported the existence of altered zones.

? Prospected by BFL (drilled 2 holes - 399 m).

? Surveyed by MRD, confirmed Cu 0.3 to 0.42 %, Pb 0.96 to 2.02 %, Zn 0.76 to 3.84 %, Au 0.26 to 0.54 ppm, Ag 7 to 16 ppm (grab sample).

1989 Prospected by Picon Exploration (drilled 5 holes - 810.5 m).

iv . Namosi District

Early 1900's Discovered.

1936-1937 Prospected by a local company, detected minor amount of Au in Cu-Zn bearing quartz vein.

1966 Rodda (GSF) and Band (GSF, 1968) pointed out the possibility of dissemination deposits in Waisoi and Waivaka prospects.

1968-1979 Prospected by a consortium consisting of Anglo-American (Fiji) Pty. Ltd., RST (Fiji) Inc., (a subsidiary of Amax Exploration (Australia) Inc.,) and others. Prospects of porphyry copper were confirmed at Waisoi, Waivaka and Wainambama. Reserves of 230 million t (Au 0.16 g/t, Cu 0.47 %, Mo 143 ppm) at Waisoi confirmed by drilling 197 holes - 48,526 m, and 360 million t (Au 0.14 g/t, Cu 0.47 %) at Wainambama by 14 holes.

v . Koroisa

1950's Barite mass discovered.

1959 Houtz (GSF) confirmed the massive barite and mineralized zone including gossan and quartz veins.

1972-1974 Prospected by AMFL, confirmed Au by panning, drilled seven holes - 1,570 m in total, confirmed weak Cu mineralization.

vi . Wainivau

1966 Rodda (GSF) reported the occurrence of strong pyritization and weak copper mineralization.

1971-1972 Prospected by BFL.

1974-1975 Prospected by AMFL (5 holes drilled - 1,168 m, confirmed weak Cu mineralization).

vii . Rama Creek

1971 BFL discovered the area through stream sediment sampling.

1975-1976 Prospected by Anglo-American Ventures Ltd., (drilled 4 holes - 802.4 m; in one hole, Cu 0.22 % - 244 m).

viii . Nacilega

1976 Prospected by AMFL (drilled 5 holes - 766.5 m), Cu-Mo mineralization confirmed.

ix . Kule

1978 Prospected by AMFL (drilled 4 holes - 609.4 m), Cu mineralization confirmed.

x . Natualevu

1978 Prospected by AMFL (drilled 3 holes - 500 m), Zn-Cu-Ag mineralization confirmed.

xi . Kula

1984 Drilled 200 m, confirmed Cu-Zn-Au-Ag mineralization.

xii . Faddy's

1980-1981 Drilled, 920,000 t (Au 4.9 g/t) reserve confirmed.

(4) Massive sulfide mineralization

i . Tholo-i-Suva/Colo-i-Suva

1935-1937 Underground prospecting for precious metals by private firm.

1957-1961 Prospected by GSF for base metals, concluded as grade insufficient for development.

1968-1974 Prospected by EGM (drilled 14 holes), 26 million t (Cu 0.12 %) reserves confirmed.

1971-1972 Prospected by BFL.

ii . Wainivesi Mine

1935-1943 Discovered in 1935. Underground prospecting by a small company (maximum grade Cu 7.18 %, Pb 3.64 %, Zn 36.97 %, Au 27.5 ppm, Ag 796 ppm).

1955-1961 Produced 1,500 t.

1962? Prospected by EGM and GSF (drilled 7 holes - 199.6 m). Concluded not economic (Rodda, 1963).

1971? Prospected by Colonial Sugar Refining Co. Ltd., (CSR) (drilled one hole - 111.6 m), confirmed low grade ore.

(5) Contact metasomatic mineralization

i . Wailotu

1957 Discovered by GSF (Houtz, 1958).

1958-1960 Prospected by EGM.

1968-1971 Prospected by CSR (drilled 11 holes - 1,202 m), confirmed low grade ore.

1973-1974 Prospected by Utah International Inc. for porphyry copper, not successful.

ii . Wainiviti

1957 Discovered by GSF (Houtz, 1958).

1957-1960 Prospected by EGM and GSF (drilled 5 holes - 158.9 m), confirmed low grade Cu-Pb-Zn ore.

(6) Manganese mineralization

Nambu, Vunamoli, Nasauthoko and other areas

Early 1900's Discovered.

1950-1971 Produced approximately 197,700 t (Mn about 55 %).

(7) Massive iron deposit

Tuveriki

1933 Discovered magnetite and jasper mass, 400 t.

1957-1971 Banno Oceania Ltd., produced 58,000 t (Fe 55 to 65 %) of ore.

Chapter 4 Results of the Survey

4-1 Geologic Structure, Characterisitics of Mineralization and Mineralization Control

4-1-1 Geologic Structure

Many of the post-Eocene formations of the survey area are largely elongated in the E-W direction. The direction of the maximum horizontal compressional stress of this area is inferred from the lineament analysis and the distribution of Colo Plutonic Suite for various periods of geologic history. They are; ENE to ESE for Late Miocene and after Middle Pliocene, NNW to NNE for latest Miocene to Early Pliocene, NW for Early to Middle Pliocene. It is seen that this area was under ENE to ESE compressional field for the longest period of time in its history and consequently largest number of sedimentary basins and deep fissures are elongated in this direction.

The locations of the latest Miocene to early Late Pliocene volcanic centres, which are the sources of the Ba Volcanic Group, are inferred from the distribution of volcanics and the photogeologic annular, caldera and dome structures. From this study, it is believed that volcanic chains existed, at that time, extending in the ENE direction in northern Viti Levu and in the NW direction in the east. These volcanic chains are most probably a manifestation of deep fracture zones with these directions which existed at that time. On the other hand, as the area was under NNW to NNE compressional stress during latest Miocene to Early Pliocene as mentioned above, it is inferred that the ENE trending volcanic chain represents the deep fractured zones formed before Late Miocene.

Many of the lineaments formed under NNW to NNE compressional field during latest Miocene to Early Pliocene are distributed in the western and northwest to southeastern Viti Levu. The volcanic centres, which were active during latest Miocene to Early Pliocene, are distributed in the zone of the above lineaments or in the vicinity. It is thus considered that there are deep-seated fractured zones with NW trend extending from northwestern Viti Levu to southeastern part of the island.

Large scale high gravity anomalies were found in four localities at; west of Mba, Tavua, Rakiraki and east of Nadni. In these four zones, the high density rocks (amphibolite, granulite and others), which are inferred to exist in the deeper parts, most probably occur in shallower zones than in the surrounding areas and thus caused the high gravity.

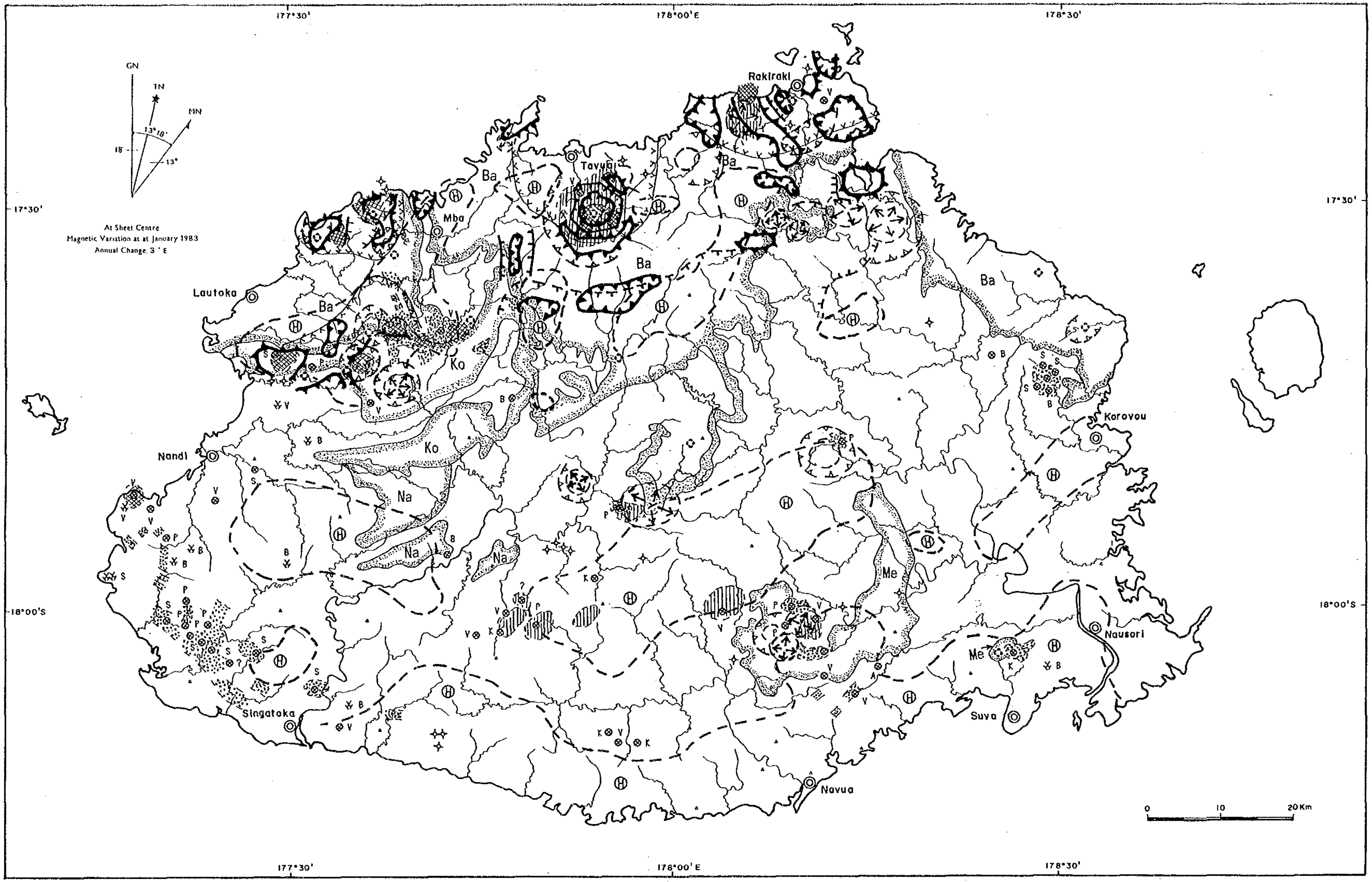
Many of the zones where volcanic centres are inferred from photogeologic studies, correspond to short-wavelength high gravity anomaly zones caused by basaltic activities. The basalt which filled the magma chambers under the volcanic centres at the time of volcanic activity probably changed subsequently to solidified olivin-gabbros which have higher density and this is considered to be the cause of the positive gravity anomalies near the old volcanic centres. However, even with the Kilauea-type model, caldera will be filled by thick and dense lava with higher density than the whole volcano resulting in positive gravity anomaly around the caldera (Yokoyama, 1963).

The Tavua Caldera which is filled with less dense materials such as andesitic pyroclastics and lacustrine formations are geophysically expressed as a short-wavelength low gravity anomaly surrounded by gravity faults. This type of gravity structure is observed around the SLAR annular structure near Rakiraki in northeast Viti Levu among the photogeologic structures interpreted to represent collapsed calderas. Also Tavua Caldera-type gravity structure occurs near the volcanic centre west of Mba.

There are clear differences between the dimensions of the magnetic anomalies in the north Viti Levu and the southern part. In the north, magnetic anomalies with very large amplitudes and small scale are predominant and it is interpreted to reflect the strong magnetic bodies in shallow subsurface zones. Ba Volcanic Group is distributed on the surface and it is also possible that the individual anomalies reflect the difference in lithology of the members of this group. For example basalt and andesite have strong magnetism while that of sedimentary rocks such as sandstone and siltstone is weak.

On the other hand, in the south, large scale magnetic anomalies are prevalent. The high anomalies (over 500 γ) correspond to the zones of Colo Plutonic Suite and Yavuna Group distribution. The low magnetic anomalies correspond to the zones of Wainimala Group and Medrausucu Group. The former plutonic and old units have strong magnetism while the latter groups have weaker magnetism.

In the large scale high magnetic anomaly zone in the east central part, there is a possibility of Colo Plutonic Suite existing in the deeper zones. Also regarding the gravity highs in the northwest, the possibility of Yavuna Group and intrusive bodies existing in the deeper zones cannot be ignored.



LEGEND

- Volcanic center
- Hot Spring
- Working mine
- Closed mine
- Prospect

Alteration
- Acidic
- Neutral
- Unidentified

Abbreviation
- V: Veine/Stockwork-type
- P: Porphyry Cu-type
- K: Massive sulfide-type
- S: Skarn/replacement-type
- B: Bedded Mn -type
- A: Placer Au-type

- Ba: Ba Volcanic Group
- Ko: Koroimavua Volcanic Group
- Me: Medrausucu Group
- Na: Navosa Sedimentary Group

Features on SLAR
- Annular structure
- Caldera structure
- Dome structure

Features on Gravity Survey
- Gravity high zone (>50mgal)
- Gravity low zone (<0mgal)
- Short-wavelength gravity high (>2mgal)
- Short-wevelength gravity low (<-2mgal)
- Gravimetric lineament

- Magnetic high anomaly (>500gamma)

Fig. 1-4 Integrated Interpretation Map of the Survey Area

4-1-2 Characteristics of Mineralization

Veins, network-dissemination, porphyry copper, replacement, contact metasomatic, and sedimentary mineralization are the known in Viti Levu. The major mines and mineral prospects are listed in Appendix 1.

(1) Vein, network dissemination type mineralization

This type of mineralization in Viti Levu can be grouped into the epithermal gold system and the meso-hypothermal base-metal system. The epithermal gold zones occur extending from northeast Viti Levu to the western part of the island. The host rocks are Ba Volcanic Group, Koroimavua Volcanic Group and Wainimala Group, while the meso-hypothermal base-metal zones occur in the Wainimala Group, the Medrausucu Group and the Colo Plutonic Suite in a zone extending from the south Viti Levu to the western part of the island.

The epithermal gold mineralization is further divided into the adularia-sericite type and the acidic sulfate type.

A representaive deposit of the adularia-sericite type is that of the Emperor Mine. This deposit is characterized by continuation of the veins into the deeper parts; bonanza type with many ore shoots at the intersection of the fractures; major minerals consisting of petzite, native gold, pyrite, quartz, calcite and adularia; association of narrow alteration zone consisting of sercite, silica minerals, carbonates, adularia, pyrite, smectite and others; and the lack of wide alterration zones.

There are mineralized zones of the acidic sulfate type, such as the prospects in; central Tavua Caldera, Balevuto, north of the Kingston Mine, Vuda and Faddy's. These zones are characterized by acidic alteration zones consisting of alunite, kaolin, quartz with limonite network dissemination and silicified veins.

The meso-hypothermal base-metal veins are Cu or Cu-Zn mineralization and occur in plutonic bodies or in their vicinity.

(2) Porphyry copper type mineralization

The porphyry type mineralization in Viti Levu is classified into two groups, namely the "plutonic type" which occur in the Colo Plutonic Suite and in the Wainimala Group near the plutonic suite in the central east to southwest Viti Levu, and the "volcanic type" which is found in the Medrausucu Group in the south and in the Koroimavua Volcanic Group in the northwest. Both types are copper sulfide network dissemination without oxidized or secondary enrichment zones and are accompanied by sercitized, propylitized and pyritized zones. Large deposits discovered to data are the volcanic type in the Namosi area. The volcanic type is associated with gold mineralization and it has been reported that high grade Cu-Au-Ag veins occur near the micromonzonite-latite plug at the Kingston Mine.

(3) Replacement and skarn type mineralization

These mineralized zones occur in the Wainimala Group near the Colo Plutonic Suite as dissemination, veins and lenses of base-metal sulfides. The replacement type is accompanied by limestone lenses and at times forms massive iron deposit. The skarn type mineralization occurs in the skarn formed in the contact zone of the limestone of the Wainimala Group and the Colo Plutonic Suite.

The alteration zone is composed of quartz, sericite, propylite and pyrite.

(4) Sedimentary mineralization

In this group, there are massive sulfide, bedded manganese, residual and placer type concentration.

The massive sulfide mineralization in Viti Levu occurs as stratabound Cu-Zn concentration in Wainimala Group horizon. This has many similarities to Kuroko-type deposits, but it occurs mainly in andesitic to mafic pyroclastics and does not accompany sulfate bodies.

The bedded manganese ores occur in Wainimala Group, Nadi Sedimentary Group and Medrausucu Group. The major deposits occur in Wainimala Group. This occurs as bedded or irregular massive manganese oxide deposits in stratified volcano-sedimentary formations. It often is accompanied by iron oxide-bearing siliceous rocks. The host rocks in the vicinity are chloritized.

The residual type prospect in Viti Leve is a small bauxite body formed by the lateritic weathering of basaltic pyroclastics of the Ba Volcanic Group.

Placer deposits in the survey area are gold placers in alluvium and iron sands in deltas and sand dunes.

4-1-3 Mineralization Control

The epithermal gold mineralized zones of the Ba Volcanic Group and Koroimavua Volcanic Group are distributed at the volcanic centres or the vicinity of the centres which are the sources of the host rock volcanics.

The epithermal gold mineralized zones extend in the ENE-WSW direction from the northern to the western part of Viti Levu.

The volcanic type porphyry copper mineralized zones occur within the latest Miocene to Early Pliocene volcanic complex (Namosi Andesite of the Medrausucu Group, Sabeto Volcanics, Navilawa Stock and Nawainiu Intrusive Complex of the Koroimavua Volcanic Group) and its vicinity.

The plutonic type porphyry copper mineralized zones occur in Middle to Late Miocene Colo Plutonic Suite or its vicinity.

The skarn mineralized zones are formed at the contact of Colo Plutonic Suite and limestone of the Wainimala Group. The replacement mineralized zones occur within the Wainimala Group near the Colo Plutonic Suite.

The massive sulfide deposits are stratabound type occurring in pyroclastics of the submarine volcanic activity of the Wainimala Group.

The major bedded manganese deposits are stratabound type occurring in bedded volcano-sedimentary formations of the Wainimala Group. These tend to be developed near the replacement and skarn mineralized zones.

Lineament analysis shows that the lineaments of the survey area were formed by the movements of the lateral faults which, in turn, were formed by the major three maximum horizontal compressional stress. Most of the deposits and mineral prospects of Viti Levu, with the exception of those in the western part and bedded manganese, residual and placer concentration, are distributed in the zone of lineaments formed by the maximum horizontal compressional stress of the ENE to ESE direction.

4-2 Mineral Potential of Viti Levu

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 collapse 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-wave gravity anomalies; and field survey. Of these zones; vicinity of Rakiraki, Tavua caldera zone, area west of Mba to southern part, Sabeto Range south of Lautoka and Namosi Area are considered to contain high potential for locating mineralized and altered zones. Within these high potential zones; the epithermal deposits of the Emperor Mine is presently being exploited in the Tavua Caldera zone, porphyry copper deposits have been discovered in the Namosi area, and drilling is now conducted at Tavua Caldera, Sabeto Range and Balevuto area in the south of Mba .

In these zones, acidic sulfate type epithermal gold veins are anticipated below acidic alteration zones, volcanic porphyry copper in the vicinity of volcano-plutonic complexes, and adularia-sericite type epithermal gold veins in other localities.

Plutonic porphyry copper, replacement and skarn mineralization are anticipated near the Colo Plutonic Suite, but the mineral potential is expected to be relatively low near those in the central part of the island where the erosion is deep. Whereas the southwestern Viti Levu has higher potential where large scale plutonic bodies are expected from the wide white alteration zone on the surface.

The massive sulfide mineralization is known in the southern, eastern and southeastern Viti Levu. In the Wainivesi area in the east, many bedded manganese zones occur near the massive sulfide zone which probably indicate the relatively small size of the reducing environment which is important for the formation of the massive sulfides. Thus the potential here for large massive sulfide mineralization may be small.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

During the course of the first phase of the Viti Levu Island survey, compilation of all existing geoscientific data and information of Viti Levu (area of 10,400 km^2), analysis and interpretation of SLAR imageries and SPOT images, field geological survey, and gravity survey (517 stations) of Tavua area (2,000 km^2) in the northern part of the island were carried out with the following conclusions.

(1) Twelve geologic units were delineated by SLAR imagery interpretation and 13 units by SPOT interpretation.

(2) Anticlinal and synclinal structures extracted from SLAR imageries and SPOT images are distributed from the central to the southern part of the island.

(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 was 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 annular, SLAR caldera and SLAR dome structures were selected. From these 15 areas, Rakiraki, east of Vatukoula, upper reaches of the Mba River, northeast of Nandi and South of Mba area were selected as having strong geoscientific semblance to the area near the Emperor Mine. Also northeast of Nandi and South of Mba area were selected as areas with geologic environment very similar to the Namosi Deposit area.

(5) The geology of Viti Levu 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.

(6) Large number of faults occur to the south of the Colo Plutonic Suite in the central part and near the Yavuna Group in the southwest. ENE and NW trending faults are predominant to the south of the Colo Plutonic Suite while those with ENE to NNE and NNW trend are developed in the Colo Plutonic Suite zone. Faults with various trends occur in the vicinity of the Yavuna Group.

(7) A large number of folds occur in zones of many faults. Anticlines and synclines occur parallel to the elongation of the plutonic rocks (ENE to ESE, NNE) near the Colo Plutonic Suite zone and anticlines and synclines of many trends occur in the Yavuna Group zone in the southwest.

(8) The direction of the maximum horizontal compressional stress inferred from the lineament analysis and the distribution of the Colo Plutonic Suite is ENE to ESE during Late Miocene and after Middle Pliocene, NNW to NNE during latest Miocene-Early Pliocene, NW during Early-Middle Pliocene. It is inferred, thus, that compressional stress in the ENE to ESE direction affected the area for the longest period in geologic history resulting in the largest number of basins elongated in this direction and of deep fissures also with this trend.

(9) The locations of the centres of the volcanism of the latest Miocene - earliest Late Pliocene Ba 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.

(10) 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 centres at the time and the distribution of the above lineaments.

(11) Large scale high gravity anomalies were discovered in four localities at west of Mba, Tavua caldera, Rakiraki and east of Nandi. It is inferred that these anomalies reflect the fact that high density rocks (amphibolite, granulite and others) occur at shallower depths at the four localities than in the surrounding areas.

(12) The zones where volcanic centres 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 olivin-gabbro of higher density, there are positive gravity anomalies near the altered volcanic centres. 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 centre of eruption would show somewhat higher density.

(13) 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 centres west of Mba are the zones which have Tavua Caldera type gravity structure among the possible collapse caldera zones extracted photogeologically.

(14) There are distinct differences in the magnetic anomalies of the north and south Viti Levu. The anomalies in the north have very large amplitude with small size and consequently it is believed to have been caused by strongly magnetic bodies at shallow depth. The surface is widely covered by Ba Volcanic Group and the individual magnetic anomalies could be reflecting the lithological variation in this Group.

Whereas in the south, large scale magnetic anomalies occur. The Colo Plutonic Suite and the Yavuna Group zones correspond to the magnetic high zone (over 500 γ) while the distribution of Wainimala and Medrausucu Groups correspond to the low magnetic anomalous zones with fair degree of agreement.

It is possible that Colo Plutonic Suite exist in deeper zones at the large high magnetic anomalous zone in the eastern part. Also the Yavuna Group or intrusive bodies may exist in the large magnetic high in the northwest.

(15) Vein, network dissemination, porphyry copper, replacement, skarn and sedimentary type mineralization occur in this survey area.

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 Ba and Koroimavua Volcanic Groups occur near the volcanic centres which were the source of the volcanic rocks or near the zones where these centres are inferred to have existed.

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

The porphyry copper type mineralization is classified into the plutonic and volcanic types.

The volcanic type porphyry copper mineralized zones occur within and the vicinity of the latest Miocene to Early Pliocene volcano-plutonic complex (Namosi Andesite of Medrausucu Group, Sabeto Volcanics · Navilawa Stock · Nawainiu Intrusive Complex of Koroimavua Volcanic Group).

The plutonic type porphyry copper and the meso to hypothermal base-metal mineralized zones occur within and the vicinity of the Middle to Late Miocene Colo Plutonic Suite.

The skarn type mineralization occurs in the contact zone of the Colo Plutonic Suite and Wainimala Group limestone. The replacement type mineralization occurs in the Wainimala Group in the vicinity of the Colo Plutonic Suite.

Sedimentary mineralization is divided into massive sulfide, bedded manganese, residual and placer type concentration.

The massive sulfide mineralization is stratabound type which occurs in pyroclastics of the Wainimala Group formed by submarine volcanic activity.

The major bedded manganese deposits are stratabound type which occur in the bedded volcano-sedimentary formations of the Wainimala Group. These also tend to occur near the replacement and skarn type mineralized zones.

The residual deposit found in Viti Levu is a small bauxite deposit formed by lateritic weathering of basaltic pyroclastics of the Ba Volcanic Group.

The placer deposits in the survey area are gold concentration in alluvium and iron oxides in deltas and sand dunes.

(16) 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 southern part, Sabeto Range south of Lautoka and Namosi area are considered to contain high potential for locating mineralized and altered zones.

5-2 Recommendations for the Second Phase

(1) Geochemical prospecting and detailed geological survey

Of the areas extracted with anticipation of epithermal gold mineralization, that extending southward from west of Mba is relatively unexplored. This lies within a 20 km x 10 km area, extend in the NNW direction, alteration zones occur scattered inside, Balevuto Gold Prospect exists to the south, volcanic collapsed zones and volcanic domes probably exist to the southwest and north, and gravity structure similar to the Tavua Caldera exists in the northwest portion. From these features, the possibility of finding mineralization is considered to be high in this area. Promising mineral showings, however, have not been found yet. From the above reasons, geochemical prospecting and detailed geological survey for delineating promising zones in this area are recommended.

(2) Lineament analysis of aerial photographs

Close relationship between the distribution of mineralized zones and lineaments is inferred from the results of the SLAR imagery analysis. It is recommended that lineament analysis of aerial photographs be carried out and promising areas be delineated from the areas extracted as possessing high potential during the first year survey, namely vicinity of Rakiraki, Tavua

Caldera, southward from west of Mba, Sabeto Range south of Lautoka, and the Namosi area.

(3) Gravity survey

In the western part of Viti Levu, the Yavuna Group which forms the basement of the island is distributed and the Colo Plutonic Suite intrudes into the Wainimala Group. Alteration zones occur widely in the NW to WNW direction around the Colo Plutonic Suite and porphyry and skarn type mineralized zones are distributed within these altered zones. Epithermal gold deposit (Faddy's) of acidic sulfate type occur in the Wainimala Group in the western edge of the island, but the factors controlling the mineralization are not clear.

It is considered from the above that western Viti Levu has a relatively high mineral potential. It is, thus, recommended that gravity survey be carried out in western Viti Levu and that the basement structure, subsurface distribution of Colo Plutonic Suite, the existence of volcanic centres be clarified by geological analysis. This will also clarify the high gravity anomaly zones and high magnetic anomaly zones and the relationship between the geologic structure of the island and mineralization.

Epi-mesothermal mineralization occurs in the vicinity of the known and inferred volcanic centres. Also areas of these centres show gravimetric characteristics such as short-wavelength high gravity anomalies or short-wavelength low anomalies according to the difference of the nature of the volcanic activity. Thus, gravity survey is an extremely effective method for mineral exploration in this geologic environment and gravity survey of the entire Viti Levu with the exception of the area covered during the first year is recommended.

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Geological Interpretation of SLAR Imageries and SPOT Images

1-1 SLAR Imagery Interpretation

1-1-1 Outline

(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 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. 1-2).

(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 Figure 2-1-1. Their characteristics are as follows.

i . System

Wavelength	approximately 1 cm (K band)

ii . 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

i . Delineation of geologic units

The standards used for delineating geologic units are as follows.

a. Photographic characteristics

Texture; very fine, fine, medium, coarse.

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

b. 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.

ii . Geologic structure

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

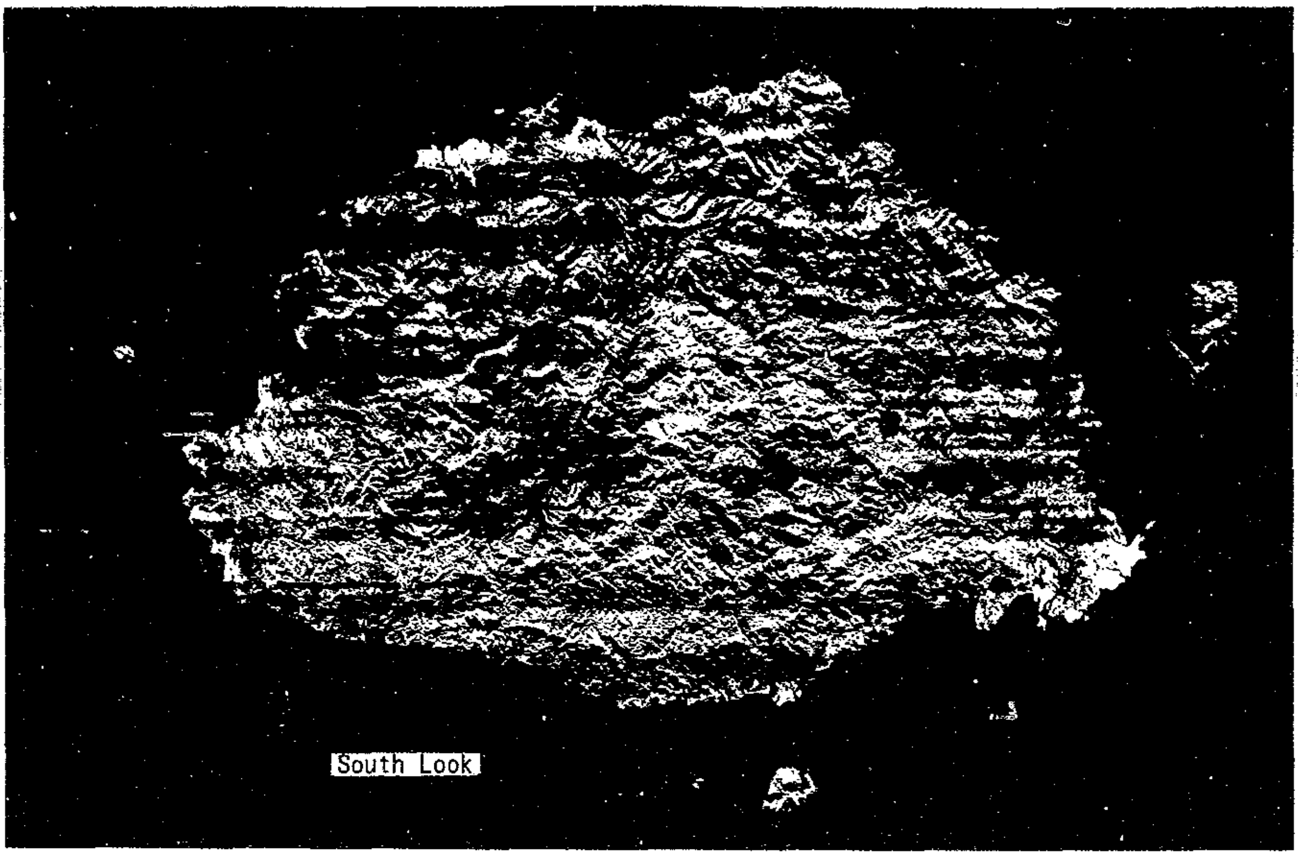
a. Folds

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.

b. Lineaments

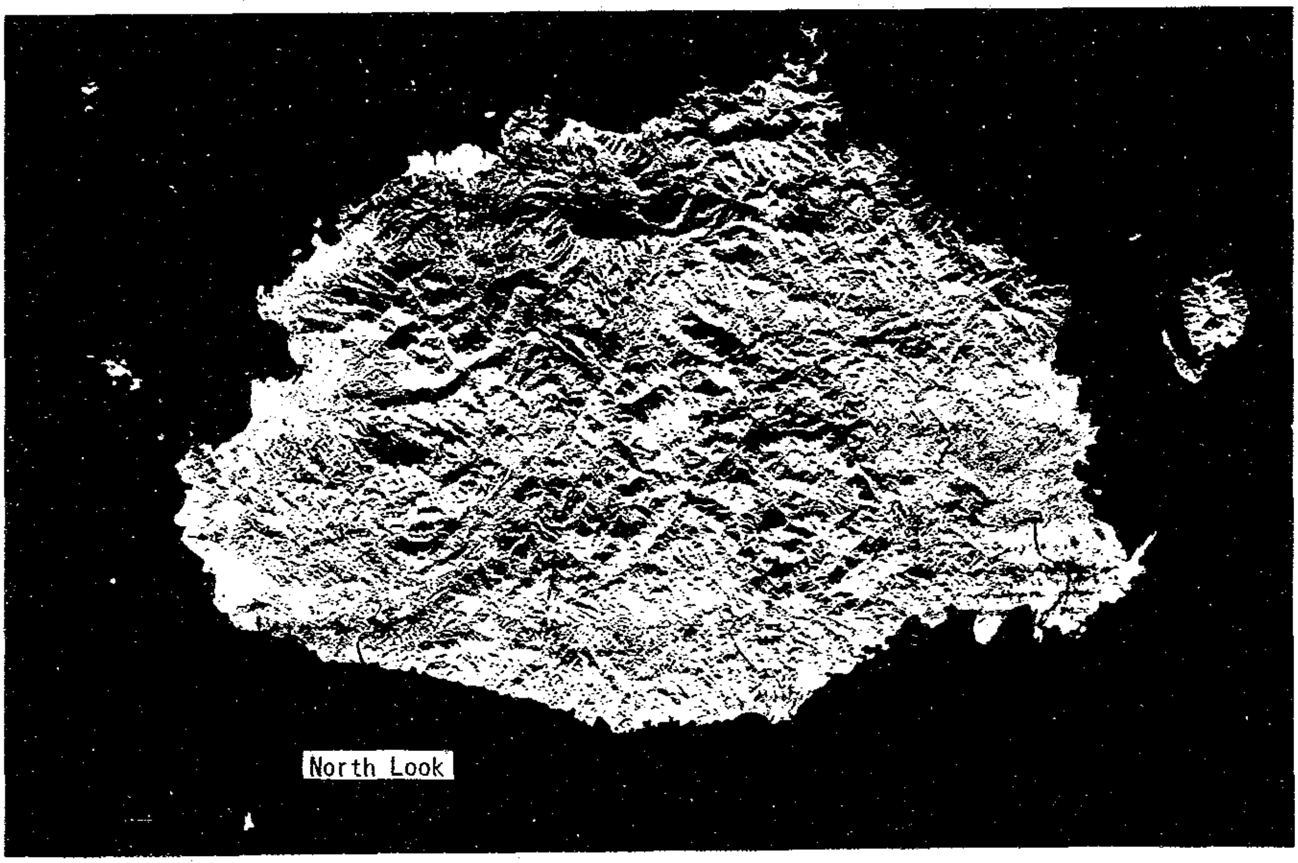
Lineaments indicate the existence of fractures on the surface or at shallow subsurface regions. Only those morphological features considered to be geologically significant were extracted as lineaments. These were grouped by their clarity and represented in the map as solid and broken lines.

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



B

VITI LEVU, FIJI
SLAR MOSAIC
SOUTH LOOK
OCTOBER 1984



B

VITI LEVU, FIJI
SLAR MOSAIC

Fig. 2-1-1 SLAR Imagery Mosaic of Viti Levu Island

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.

c. Annular and dome structures

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. 2-1-2). 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 the field geological survey carried out subsequently. The results will be reported in chapter 2. Since those reported in this chapter are structures identified in the imageries only, they will be labeled SLAR annular structures and so on.

1-1-2 Results of Interpretation

(1) Delineation of geologic units

The geology of the survey area was photogeologically divided into 12 geologic units as shown in Figure 2-1-2 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.

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

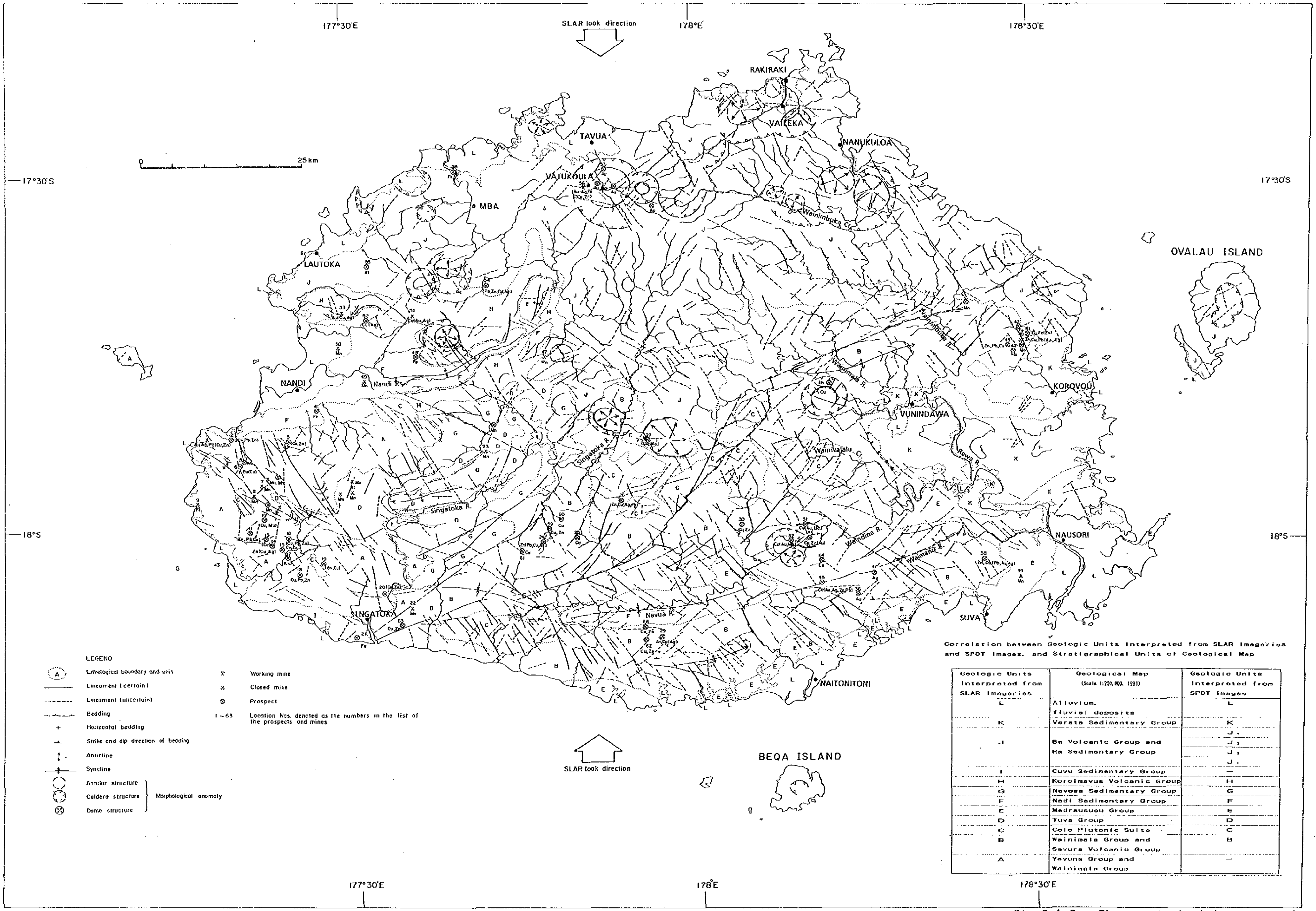
SLAR units	Geological map (1:250,000, 1991)	SPOT units
L	Alluvial sediments, flood plain sediments	L
K	Verata Sedimentary Group	K
J	Ba Volcanic Group and Ra Sedimentary Group	J_4 J_3 J_2 J_1
I	Cuvu Sedimentary Group	-
H	Koroimavua Volcanic Group	H
G	Navosa Sedimentary Group	G
F	Nadi Sedimentary Group	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	-

The distribution and the photogeological characteristics of the geologic units are described below. These units are labeled alphabetically from the oldest to the younger ones.

i . Unit A

This unit is distributed in the southwestern part of the survey area.

The texture is medium and the tone is dark-medium. Resistance is low and the relief energy small. The unit is massive in the northeast, but bedding with NW-SE strike is observed from the northwest to the central part. The development of lineaments is high next to Unit B.



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	J4 J3 J2 J1
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 SLAR Imageries of Viti Levu Island

ii . Unit B

This unit is widely distributed from the central to southern part of the survey area. The distribution is very wide next to Unit J.

The texture is coarse and the tone light. The resistance is generally high with large relief energy. The bedding is developed along the Wainimala River and at the mountains to the west of Naitonitoni. The development of lineaments is the highest among all the units.

The distribution of this unit corresponds to that of the Wainimala Group and the Early to Middle Miocene Savura Volcanic Group.

iii . Unit C

Most of this unit occurs within the area of Units A and B distribution. Its largest occurrence is from the Wainivalalu westward to the Singatoka River.

The resistance of this unit varies from high to low and the relief energy from large to small, but within a single mass, the unit is homogeneous.

The area of distribution of this unit corresponds to that of the Middle-Late Miocene Colo Plutonic Suite consisting of tonalite, diorite and gabbro.

iv . Unit D

This unit is distributed along the middle reaches of the Singatoka River. Bedding is developed and folding is observed in this unit.

The area of distribution of this unit corresponds to that of the middle Late Miocene Tuva Group consisting of sedimentary rocks and volcanic rocks.

v . Unit E

This unit is distributed along the coast from Suva to Naitonitoni.

The resistance of this unit is low and the relief energy small.

The area of distribution of this unit corresponds to that of the Late Miocene– Early Pliocene Medrausucu Group consisting of sedimentary rocks, volcanic rocks and pyroclastic rocks.

vi . Unit F

This unit is distributed along the Nadi River.

The resistance is high and bedding developed. It is inferred from the strike and dip of the bedding that an anticlinal structure is formed along the Nadi River.

The area of distribution of this unit corresponds to that of the Late Miocene Nadi Sedimentary Group consisting of sandstone and pyroclastic rocks.

vii. Unit G

This unit is distributed surrounding the Unit D along the Singatoka River.

The relief energy is large and bedding is observed in parts of this unit.

The area of distribution of this unit corresponds to that of the Late Miocene Navosa Sedimentary Group consisting of sedimentary rocks.

viii. Unit H

This unit is distributed surrounding Unit F along the Nadi River.

This is characterized by high resistance and large relief energy. It overlies the lower Unit F in apparent conformity.

The area of distribution of this unit corresponds to that of the latest Miocene–Early Pliocene Koroimavua Volcanic Group consisting of pyroclastic and volcanic rocks.

ix. Unit I

This unit is distributed in small belts along the coast west of Singatoka.

The resistance is low and the relief energy is very small.

The area of distribution of this unit corresponds to that of the latest Miocene–Early Pliocene Cuvu Sedimentary Group consisting of sedimentary rocks.

x. Unit J

This unit is distributed in the northern half of the survey area and has the widest distribution of all the units identified.

The texture is coarse and the tone is light and dark. The resistance is generally very high with some low parts. The relief energy is the largest among all units. At Vatukoula and Rakiraki, radial drainage pattern and annular to semi-annular structure are observed.

The area of distribution of this unit corresponds to that of the latest Miocene–Early Pliocene Ba Volcanic Group consisting of volcanic and pyroclastic rocks and of the Late Miocene Ra Sedimentary Group.

xi . Unit K

This unit is distributed in the eastern part of the survey area in the vicinity of Korovou.

The texture is fine and homogeneous. The tone is medium. The resistance is very low and the relief energy is also very small.

The area of the distribution of this unit corresponds to that of the Early Pliocene–Early Pleistocene Verata Sedimentary Group.

xii . Unit L

This unit is distributed relatively widely in the low areas along the coast such as near Nadi and Nausori. Also it forms narrow valley plains along the major rivers such as the Singatoka River and the Rewa River.

The texture is very fine and homogeneous. The tone varies from light to dark. The resistance is very low.

The distribution of this unit corresponds to that of the Pleistocene flood plain sediments and Late Pleistocene? to Holocene alluvium.

(2) Structural characteristics

i . Folds

Anticlines and synclines are observed the central to the southern part of the survey area.

a. Anticlines

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.

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 Singatoka 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.

b. Synclines

Four synclines are recognized in the Units B, D and E areas.

In Unit B, synclines are observed at two localities, northeast of Singatoka 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 Singatoka 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.

ii . Lineaments

A total of 1,060 lineaments were extracted from the survey area as shown in Figure 2-1-3. Lineament density, the length of lineaments per unit area, is shown in Figure 2-1-4 in order to obtain the general trend of the distribution of the lineaments. The window size is 5 km x 5 km and the moving average-interval is 2.5 km for this operation. The rose diagram of the lineaments and the histogram of the length are laid out in Figure 2-1-5. In Figure 2-1-6, the directions of all the lineaments of the survey area are divided into eight groups of 22.5° each.

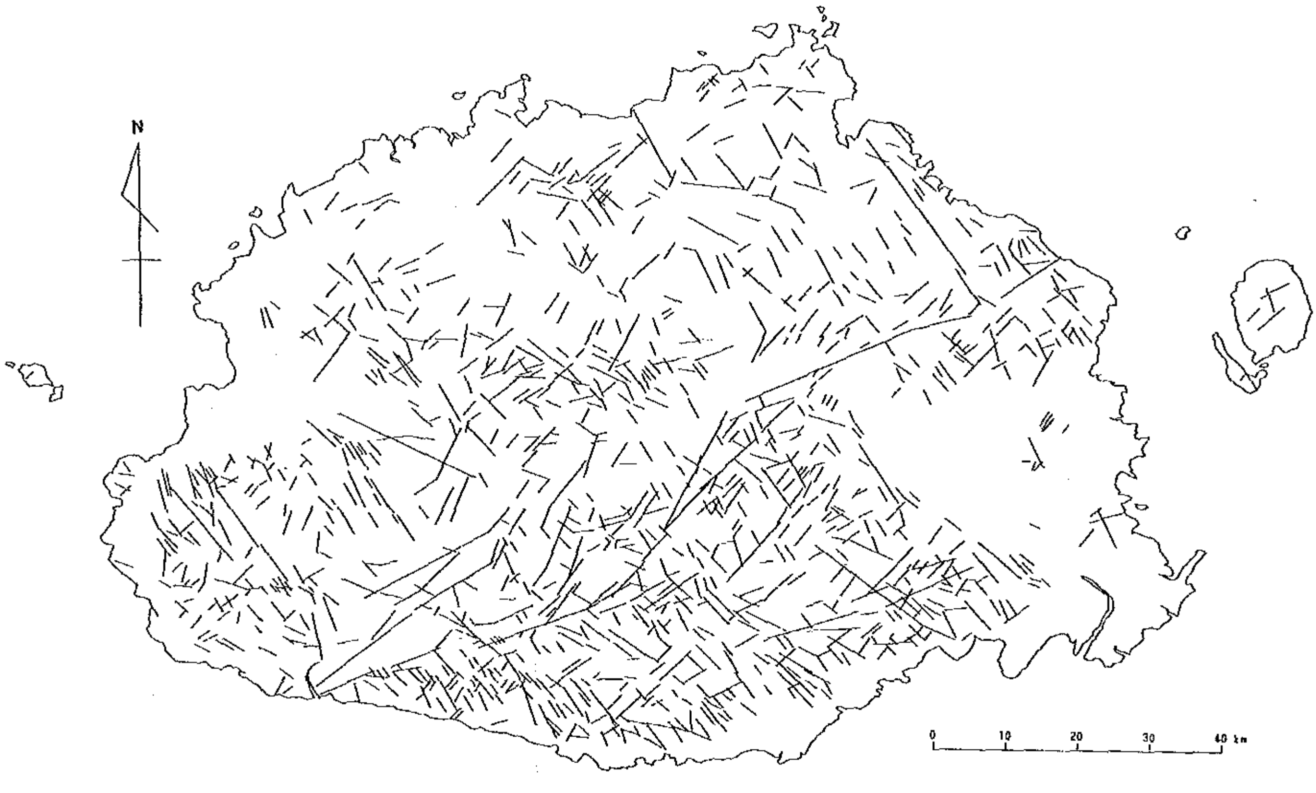


Fig. 2-1-3 Lineament Map Interpreted from SLAR Imageries of Viti Levu Island

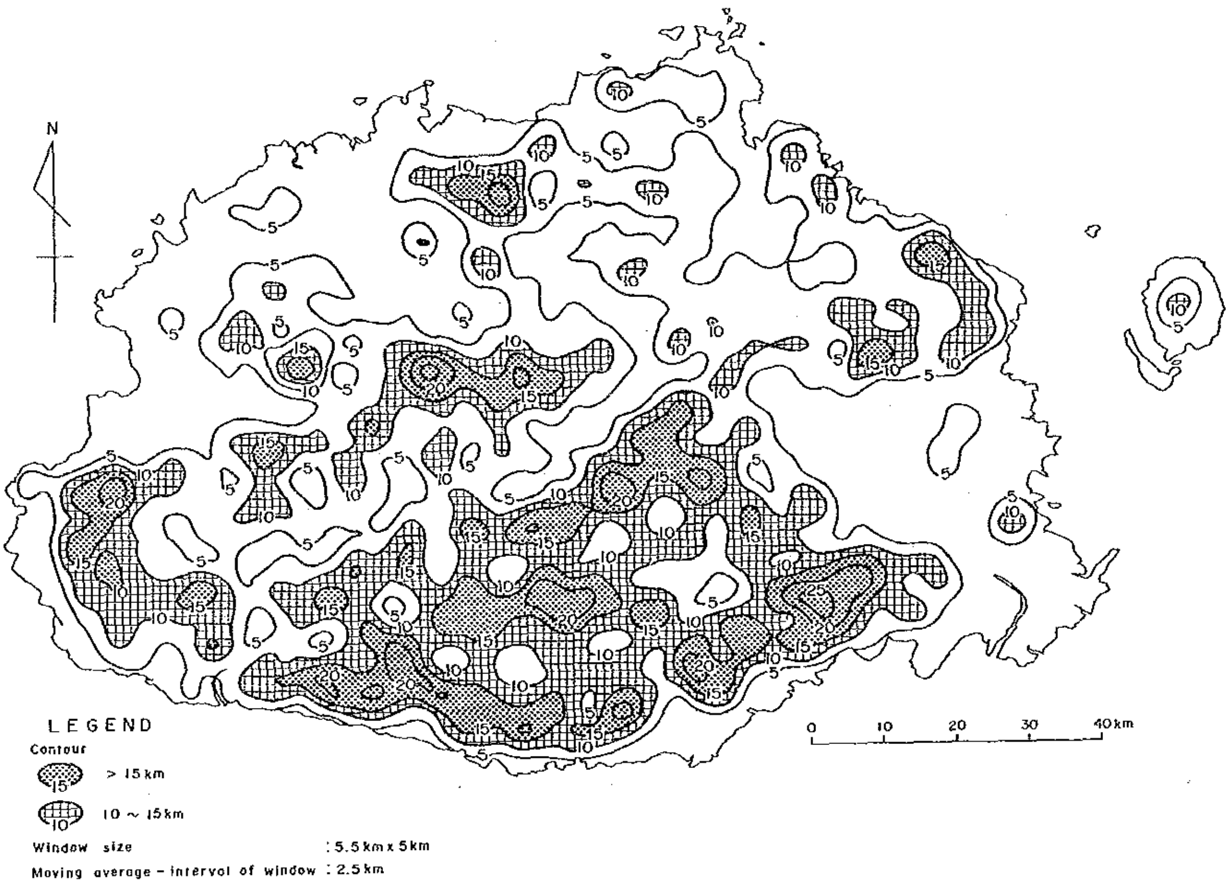
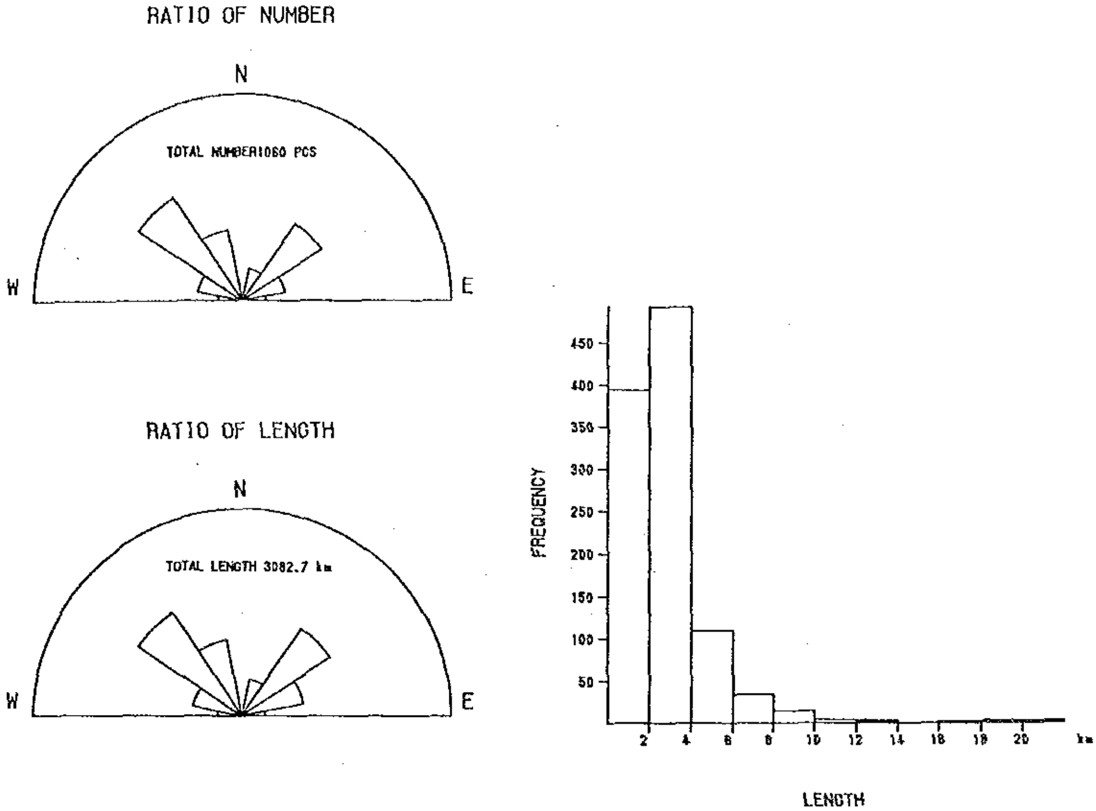


Fig. 2-1-4 Lineament-Density Map Interpreted from SLAR Imageries of Viti Levu Island



DIRECTIONS		NUMBER PCS	%	LENGTH km	%
E	S78.75°E-N78.75°E	57	5	152.8	5
ENE	N78.75°E-N56.25°E	104	10	397.2	13
NE	N56.25°E-N33.75°E	227	21	670.0	22
NNE	N33.75°E-N11.25°E	79	7	235.6	8
N	N11.25°E-N11.25°W	9	1	24.7	1
NNW	N11.25°W-N33.75°W	176	17	495.2	16
NW	N33.75°W-N56.25°W	299	28	792.3	26
WNW	N56.25°W-N78.75°W	109	10	314.9	10
	TOTAL	1060		3082.7	

Fig. 2-1-5 Rose Diagrams of Number and Length, and Histogram of Length of Lineaments Interpreted from SLAR Imageries of Viti Levu Island

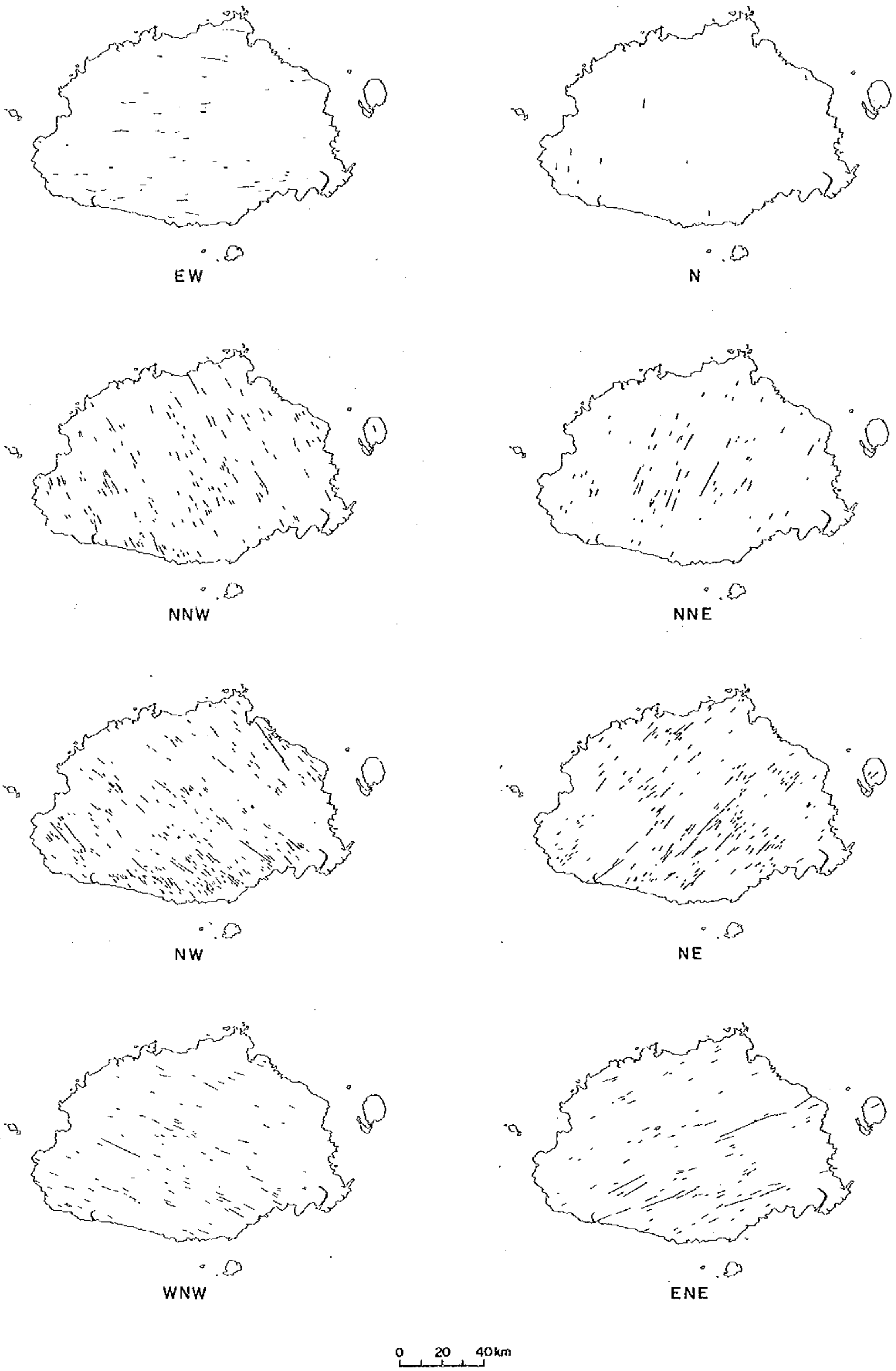


Fig. 2-1-6　Lineament-System Map Interpreted from SLAR Imageries of Viti Levu Island

The following characteristics regarding the distribution and the trends of the lineaments are found from the above.

① 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.

② The predominant trends of the lineaments are NW (28 %), NE (21 %), NNW (17 %) and less than 5 % in the N and E directions.

③ 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.

④ Lineaments in NE and ENE direction tend to be continuous.

⑤ The possibility of the continuous lineaments being faults is high.

⑥ Where the lineaments are developed, the direction of lineaments coincide with the approximate direction of the intrusion of igneous bodies.

iii. 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

1-2 SPOT Image Interpretation

1-2-1 Outline

(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.

(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.

K Column	J Line	Date	Cloud cover	ID Number	Center of Image	Sun Azimuth	Sun 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′

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.

(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.

1-2-2 Results of Interpretation

(1) Delineation of geologic units

The geology of the survey area was divided into 13 geologic units as shown in Figure 2-1-8 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. The results which differ from the SLAR analysis are reported below.

i . Unit B

This unit is distributed in the southern part of the survey area and occupy a major part of the images. The tone reflects dense forests and is mostly dark. Also the sun elevation was high at the time of the observation and the relief is not sufficiently expressed. Thus the detailed geology is difficult to decipher.

ii . Unit C

This unit occurs elongated in the N-S direction at only one locality on the left bank of the middle reaches of the Singatoka River, but the boundary is not clear. It is inferred that the resistance is low.

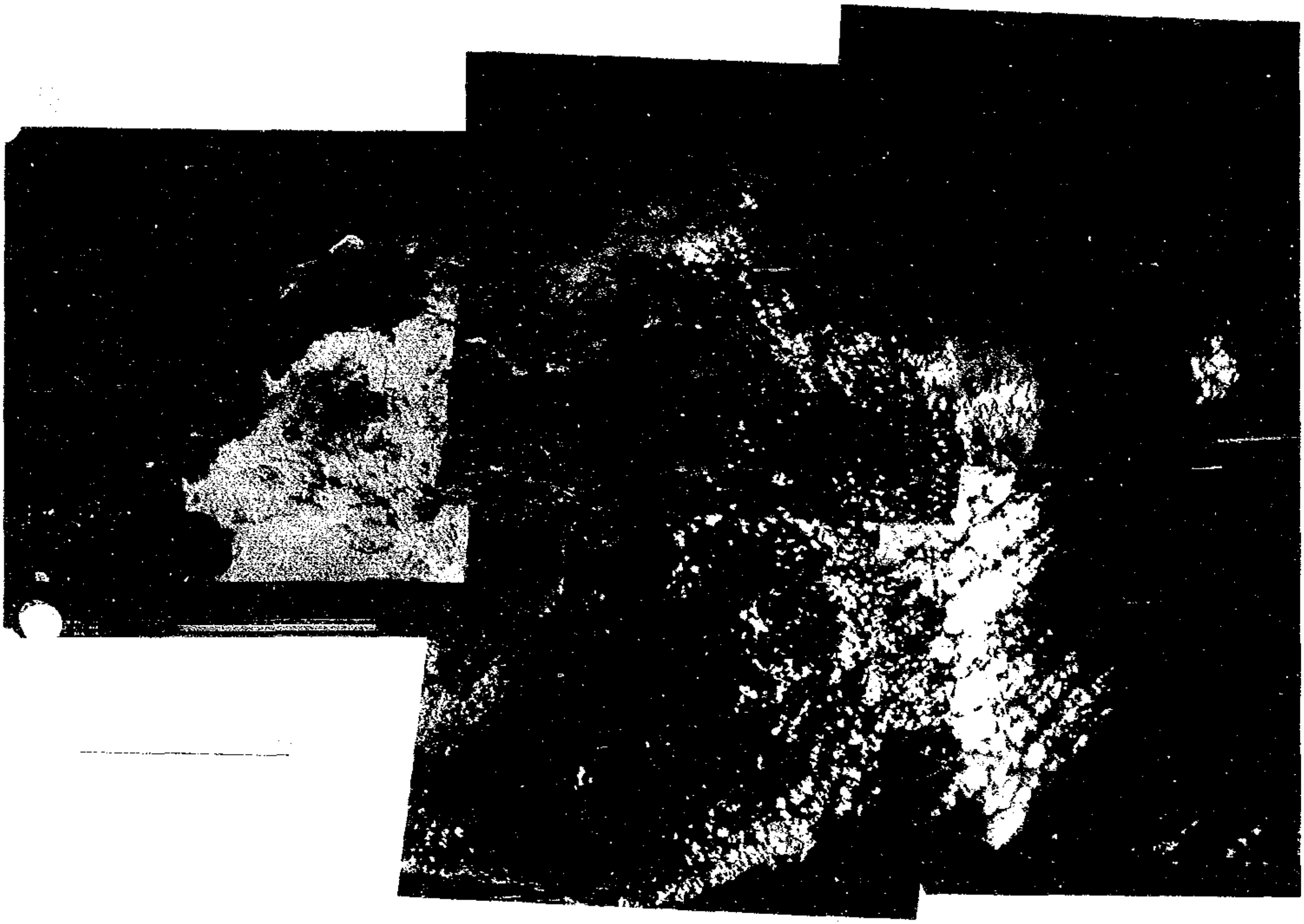


Fig. 2-1-7 SPOT Image Mosaic of the Viti Levu Island

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	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 Sevura Volcanic Group	B
A	Yavuna Group and Wainimala Group	—

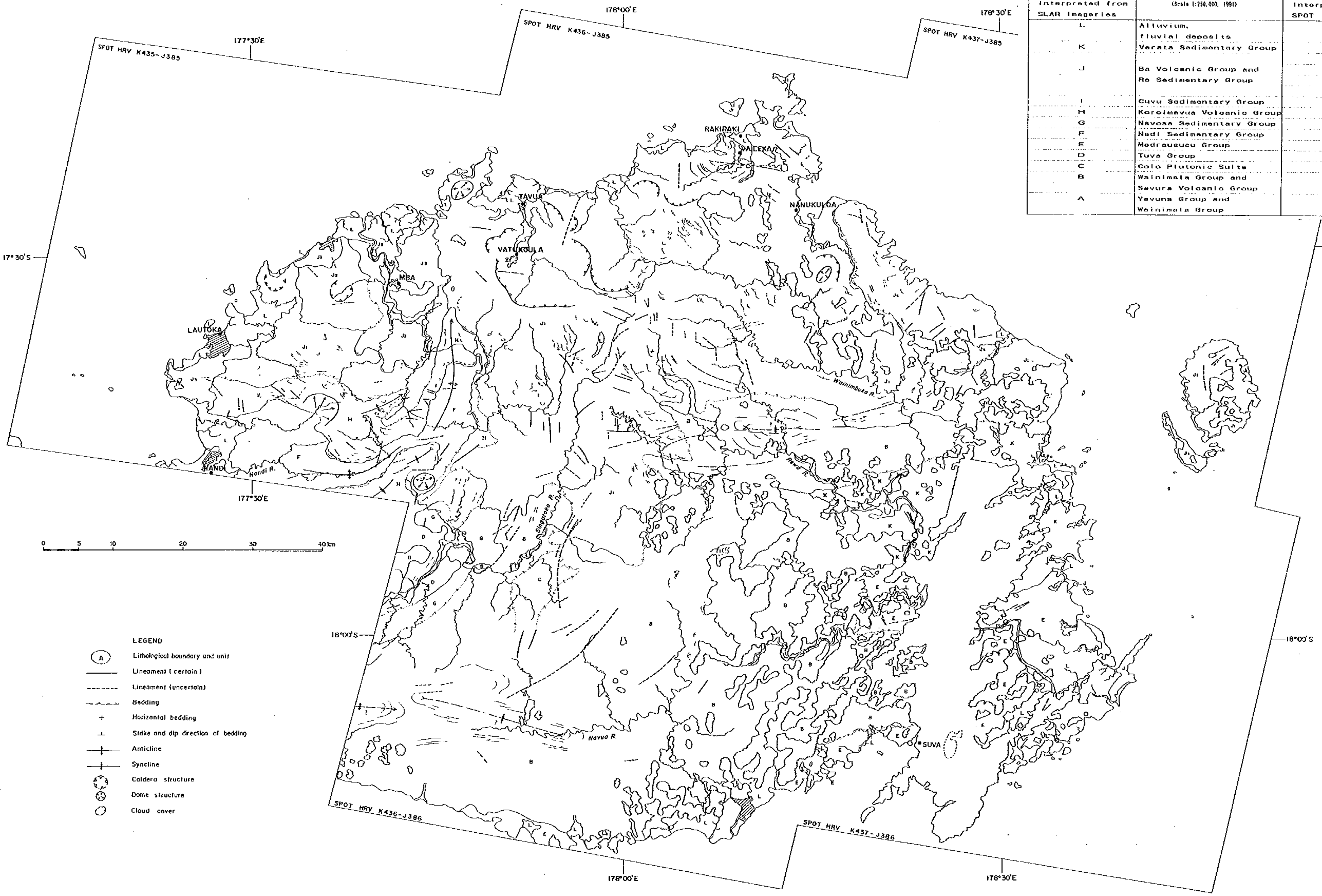


Fig. 2-1-8 Photogeological Interpretation Map Using SPOT Images of Viti Levu Island

iii . Unit D

This unit is distributed along the middle reaches of the Singatoka River. Bedding is well developed. The fold structure observed in the SLAR imageries is located in the southwest extension of this unit where the SPOT image is lacking and could not be verified.

iv . Unit E

This unit occurs near Suva. The boundary with Unit B is not clear because of the cloud cover.

v . Unit F

This unit is distributed along the Nadi River. Culmination of anticlines and depressions are observed in the SLAR imageries and the anticline was previously considered to be not continuous, but the SPOT images indicate otherwise.

vi . Unit G

This unit is distributed surrounding the Unit D along the Singatoka River. Bedding is not observed within the images used.

vii . Unit H

This unit is stratigraphically above the Unit F distributed along the Nadi River and occurs surrounding it.

viii . Unit J_1

This unit occupies the major part of the Unit J and is distributed widely in the northern half of the survey area. The resistance is generally very high. Also the bedding which could not be identified by SLAR is seen to be a dominant feature of this unit.

ix . Unit J_2

This unit is distributed to the west of Mba and is a part of the SLAR Unit J. The resistance is very high with radial drainage pattern typical for young volcanic areas and the central part of the mountain has annular structure which is inferred to be caldera.

x . Unit J_3

This unit is distributed in the vicinity of Mba and Lautoka and belongs to the SLAR Unit J. Resistance is low and the lithology is inferred to be clastic rocks.

xi . Unit J_4

This unit is distributed to the southeast of Nanukuloa and is a part of the SLAR Unit J. The resistance is high and a steep scarp is formed along its boundary with Unit J_1. It is stratigraphically situated above the J_1 and bedding which is considered to indicate the cumulative layering of the lava is developed.

xii . Unit K

This unit is distributed in the eastern part of the survey area. The resistance is low. There is a large area covered by cloud and the boundaries between B, E and J_1 are not clear. The stratigraphic relation with these units cannot be determined from the images.

xiii . Unit L

This unit forms the low zone along the coast near Nadi and other areas which are cultivated.

(2) Geologic structure

i . Folds

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

① Anticlinal structure with ENE-WSW trend and 6 km in length was observed northeast of Nadi in Unit H.

② The fold identified to be an anticline by SLAR analysis at the upper reaches of Rewa River is probably a synclinal structure.

ii . 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.

① The density of lineaments is high in Units H and J_1.

② The lineaments in the E-W or WNW-ESE direction intersecting fold axes are predominant in Unit H.

③ Lineament with E-W and N-S trends are observed fairly abundantly in Unit J_1 and other units. These were not extracted from SLAR imageries.

④ Short lineaments (less than 1 km) in Unit J_1 are believed to be joints.

iii. 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.

① 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.

② The caldera structure at Vatukoula is not as circular as in the SLAR imageries and is irregularly shaped.

③ Most of the SLAR annular, caldera and dome structures extracted at Rakiraki are not very clear in the SPOT images.

④ 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.

1-3 Discussions

(1) The Effectiveness of SLAR Imageries 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.

i. SLAR imageries cover the entire survey area.

ii. It is not affected by cloud cover.

iii. The morphological characteristics of the area can be better interpreted.

iv . 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

i . 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.

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

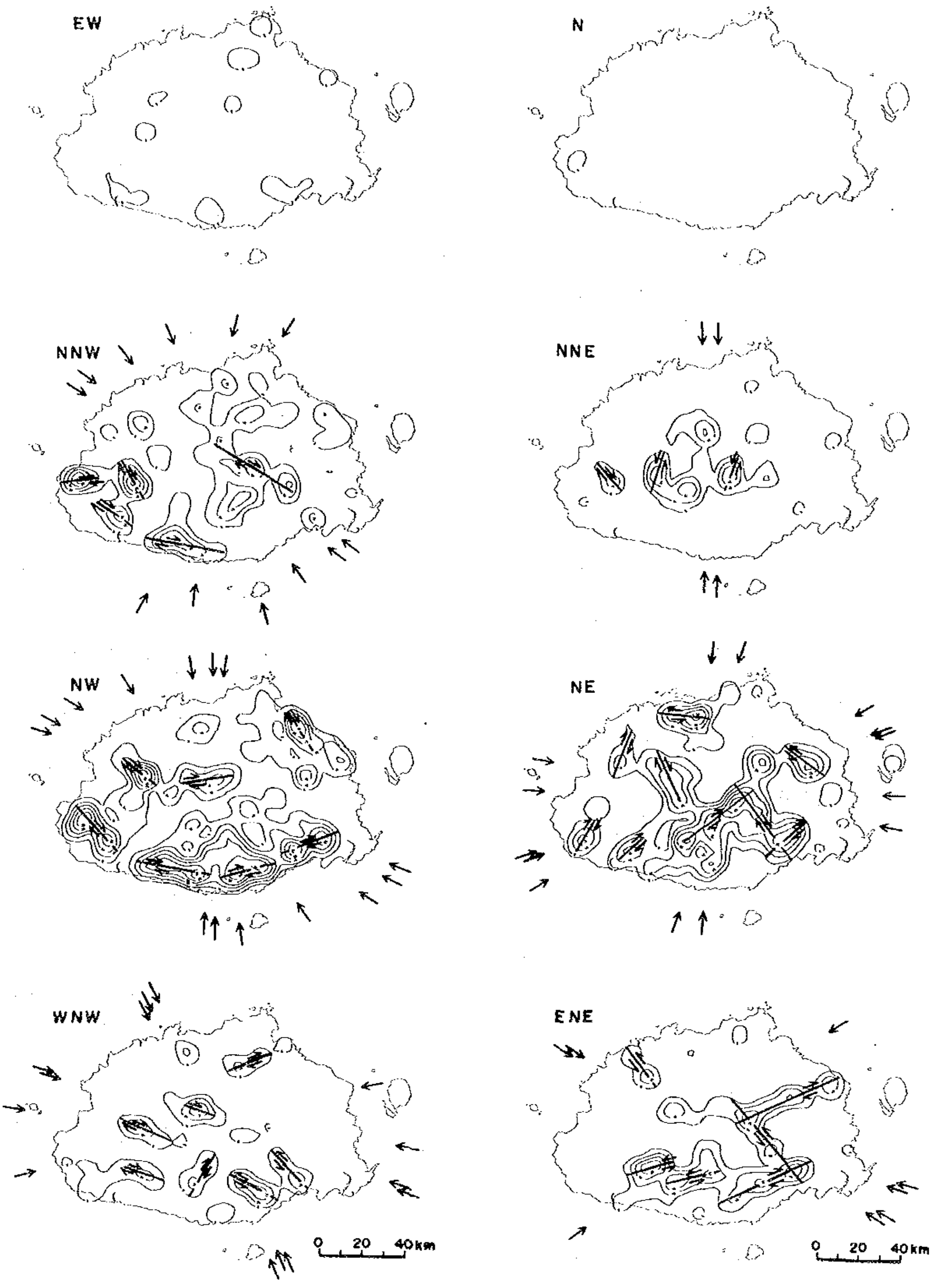
iii . Abrupt change in geologic structure is inferred at an E-W line joining Nadi and a point 10 km north of Vunindawa because of the difference in the development of the lineaments and the geology. Younger volcanics are predominant and annular structures more abundant to the north of this line.

iv . In the Tectonic Interpretation Map on SLAR Lineament by Systems (Fig. 2-1-9), 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 Figure 2-1-9.

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



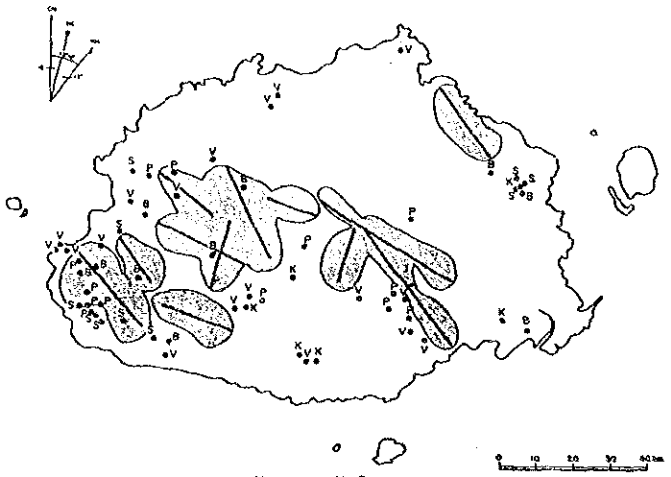
LEGEND

: Contour of total length of the lineaments covered by a filter of 100 Km^2(10Km×10Km) stepping each 5 km

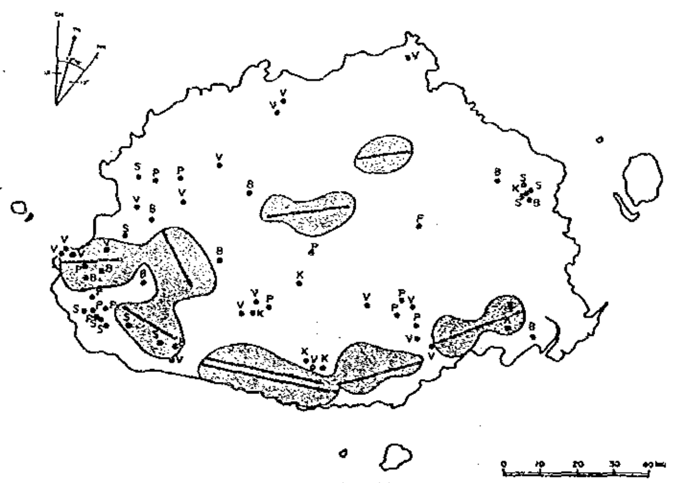
: Synthetic or Antithetic strike slip fault

: Vector of compression derived from wrenching

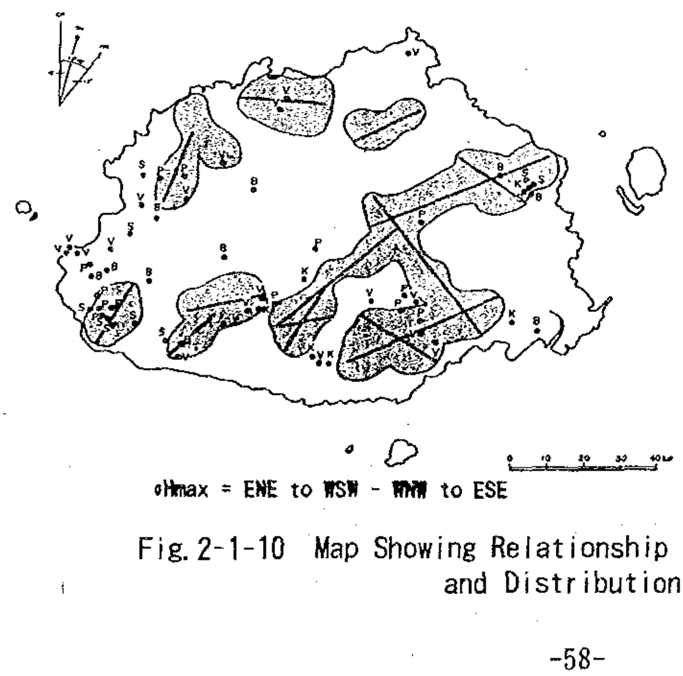
Fig. 2-1-9 Tectonic Interpretation Map on SLAR Lineament by Systems



σHmax = N-S



σHmax = NW-SE



σHmax = ENE to WSW - WNW to ESE

LEGEND

— Inferred Synthetic or Antithetic strike-slip fault

Zone of lineament

• Mines and Prospects

V: Vein-type

P: Porphyry-type

K: Kuroko-type

S: Skarn/replacement-type

B: Bedded Mn deposit

σHmax : Direction of the maximum horizontal compression at the desplacement of the principal strike-slip faults.

Fig. 2-1-10 Map Showing Relationship between Mines-Prospects and Distribution Area of SLAR Lineament 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.

v . 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 Figure 2-1-10. 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.

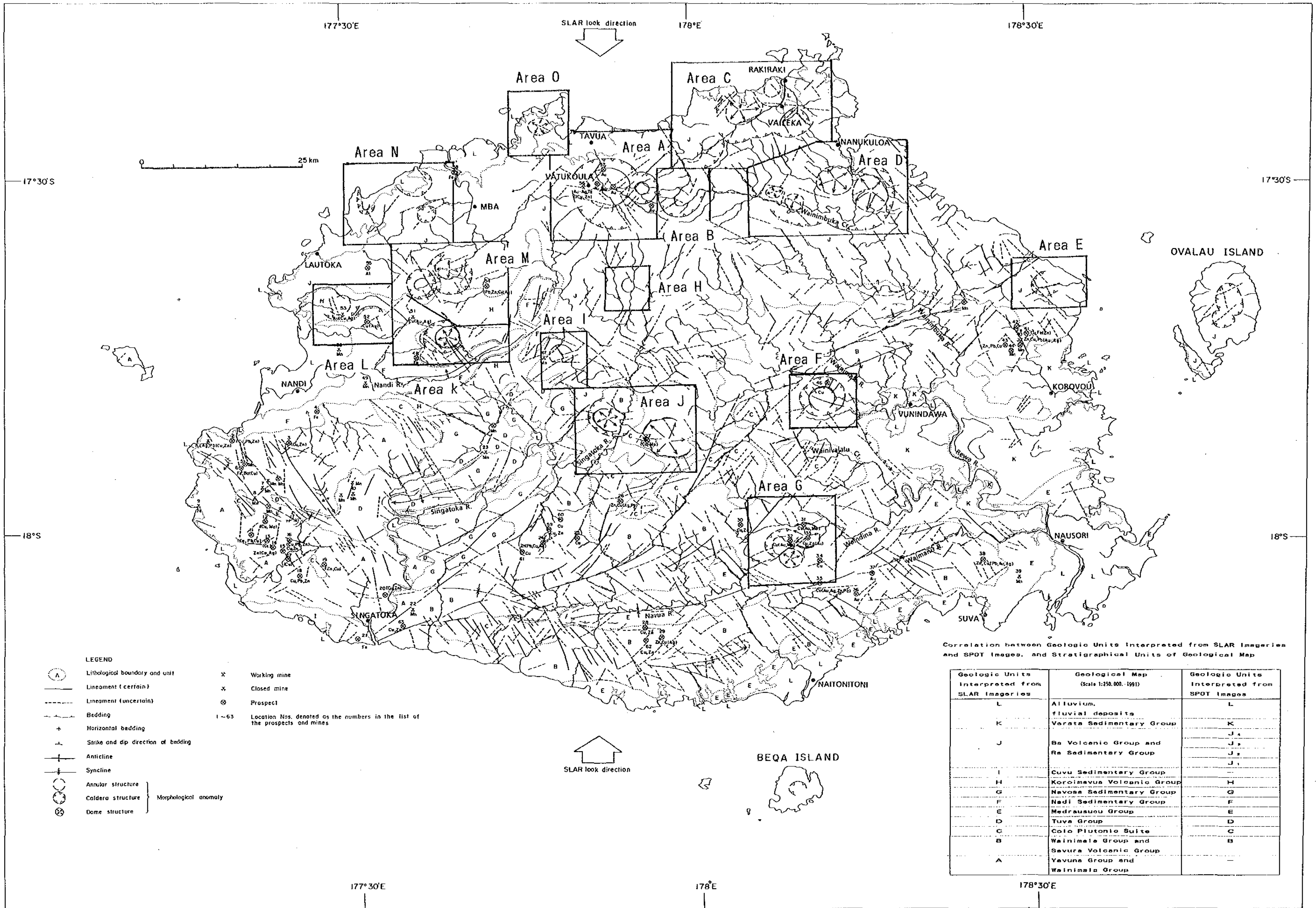
1-3-3 Extraction of Priority Areas for Exploration

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. 2-1-11) 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. 2-1-2).

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.



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	Varata 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	Medrausuou 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. 2-1-11 Location Map of the Morphological Anomalous Areas Extracted by Photogeological Interpretation of SLAR Imageries

Table 2-1-2 Characteristics of Promising Areas Extracted from Photogeological Interpretation of SLAR Imageries

	Interpretation / Factor / Area	Photogeological Characteristics: Morphological Anomalies on SLAR Imageries SA	SC	SD	High-Density Zone of Lineament	Lineament of NE-SW Direction	Gold Mineralization found within or in the vicinity of SA or SC	Gold Mineralization located on Lineament or Intersection of Plural Lineaments	Geological Characteristics: Ba Volcanic Group	Granitc Rocks intruded into Ba Volcanics	Mineralization of Cu-Pb-Zn -Mo etc.	Complex of Late Miocene to Early Pliocene	Comparison with Model Areas A and G (Number of Coincident Factor): Area A ○	Area A △	Area A Total	Area G ○	Area G △	Area G Total
A	Emperor Mine	○	○	–	○	○	○	○	○	○	–	–	8	–	⑧	2	–	2
B	E-Vatukoula	●	○	–	△	–	○	–	○	–	–	–	4	1	⑤	2	–	2
C	Rakiraki	●	○	●	△	△	–	–	○	○	–	–	4	2	⑥	3	–	3
D	S-Nanukuloa	–	●	●	△	–	–	–	○	○	–	–	3	1	4	2	–	2
E	N-Korovou	–	○	–	○	–	–	–	○	–	△	–	3	–	3	1	1	2
F	W-Vunindawa	●	●	–	△	△	–	–	–	–	○	–	2	2	4	3	–	3
G	U-Waindina River	●	○	●	–	–	–	–	–	–	○	○	2	1	3	5	–	⑤
H	S-Vatukoula	●	–	–	–	–	–	–	○	△	–	–	2	1	3	1	–	1
I	U-Mba River	●	–	–	○	○	–	–	○	△	–	–	4	1	⑤	1	–	1
J	U-Singatoka River	–	●	●	–	–	–	–	○	○	○	–	3	–	3	3	–	3
K	E-Nandi	–	●	●	○	–	–	–	○	△	△	–	3	1	4	2	1	3
L	NE-Nandi	●	○	–	–	–	○	–	○	△	△	○	4	1	⑤	3	1	④
M	S-Mba	○	○	●	△	–	–	–	○	○	△	–	4	2	⑥	3	1	④
N	W-Mba	●	○	–	–	–	–	–	○	–	–	–	3	–	3	2	–	2
O	W-Tavua	–	–	○	–	–	–	–	○	–	–	–	1	–	1	1	–	1
Symbols	●	present(newly extracted)			–	–	–	–	–	–	–	–			–			–
Symbols	○	present (known)			large	dense	present	present	present	present(in the vicinity)	present(in the vicinity)	presnt(in the vicinity)			high			high
Symbols	△	–			small	scarce	–	–	–	present (periphery)	present (periphery)	present (periphery)			–			–
Symbols	–	non			non	non	non	non	non	non	non	non			–			–

Abbreviations

N: to the north of W : to the west of SA: SLAR Annular structure ▭ Model Areas
S: to the south of NE: to the northeast of SC: SLAR Caldera structure
E: to the east of U : upstream part of SD: SLAR Dome structure

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 aiso 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.

The characteristics of the Area G are the following five points.

a. Existence of SLAR annular structure.
b. Existence of SLAR caldera structure.
c. Existence of SLAR dome structures.
d. Existence of Cu, Pb, Zn, Mo mineralization.
e. Existence of the volcanic-plutonic complex of Late Miocene to Early Pliocene.

Of the selected 15 areas, the following five have geologic characteristics similar to those of the vicinity of the deposits of the Emperor Mine.

Area B : East of Vatukoula.
Area C : Rakiraki (Vaileka)
Area I : Upper reaches of the Mba River.
Area L : Northeast of Nandi.
Area M : South of Mba.

The following two areas have geologic similarity to the vicinity of the porphyry copper deposits.

Area L : Northeast of Nandi.
Area M : South of Mba.