No. 34

REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE TORAJA AREA, SULAWESI
THE REPUBLIC OF INDONESIA

PHASE I

FEBRUARY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

NPN
CR (3)
92-076

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PREFACE

The Japanese Government, in response to a request extended by the Government of Indonesia, decided to conduct a mineral exploration in the Toraja area, Sulawesi, 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 Indonesia a survey team headed by Mr. Kohei Iida from November 1991 to January 1992.

The Japanese team exchanged views with the officials of the Government of the Republic of Indonesia and carried out a field survey in the Toraja area with Indonesian experts sent from the Directorate of Mineral Resources. After the team returned to Japan, further studies consisting of laboratory and analytical works were made and the report has been prepared.

We hope that this report will serve for the developement of the project and contribute to the promotion of freindly relationship between the two contries.

We wish to express our sincere appreciation to the officials concerned of the Government of the Republic of Indonesia for thier close cooperation extended to the team.

February 1992

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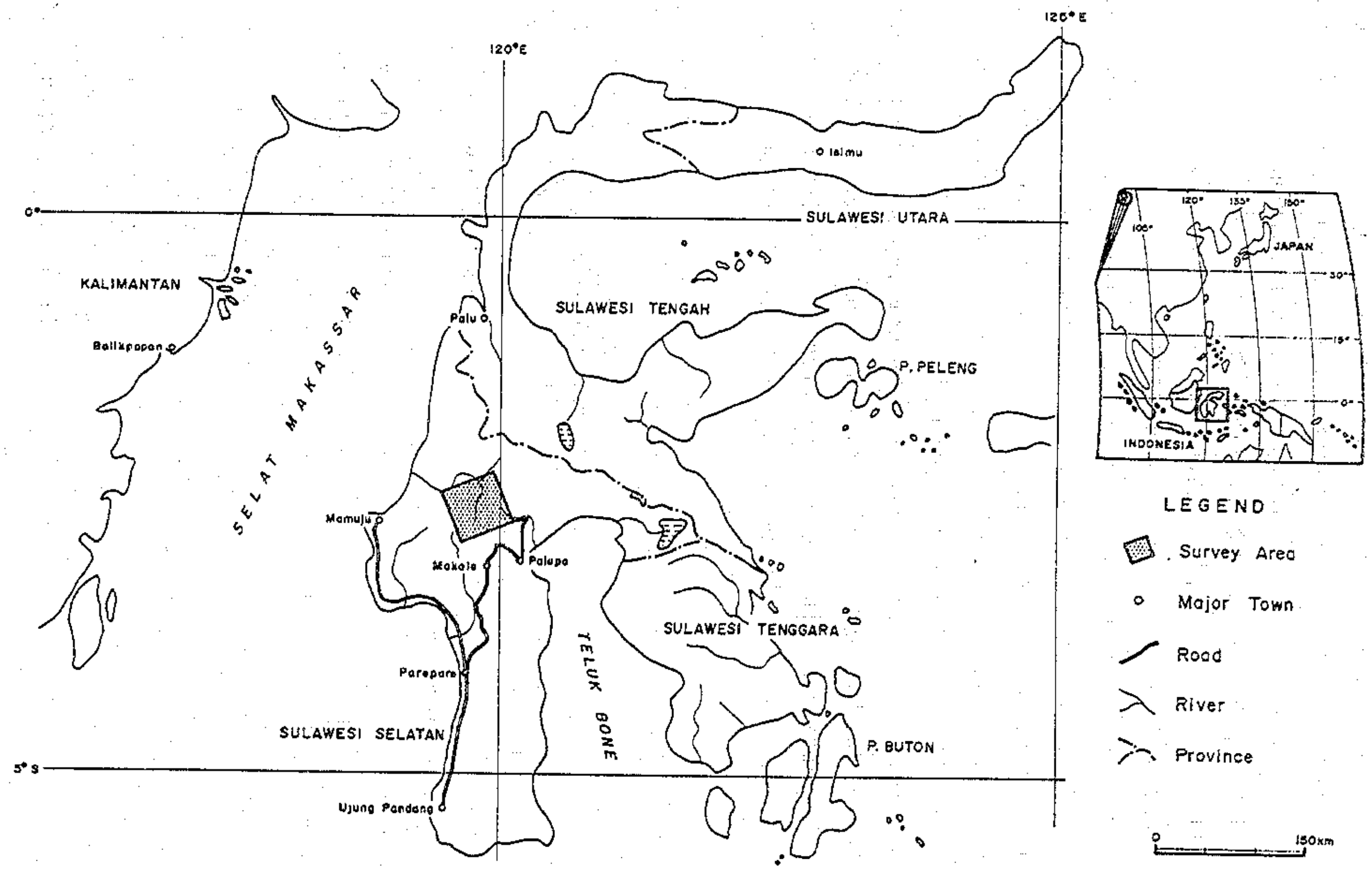

Fig.1-1 Location Map of the Survey Area

SUMMARY

Exploration in this year corresponds to the first phase of three year exploation programme in the Toraja area, Sulawesi, and aims at extracting zones with high probability of mineral occurrence by elucidating the geological setting, the relationship between mineralization and geologic structure, and the mode of occurrence of mineral deposits through geological survey and geochemical exploration in the area. The works conducted this year were the study of existing geological materials, satellite imagery photogeological interpretation, regional geological and geochemical survey, semi-detailed geological and geochemical survey, and preliminary works for plant leaf biogeochemistry and mercury gas geochemistry. Total traverse length of 477 km was achieved during the regional and semi-detailed survey in this year.

As the results of regional and semi-detailed survey, primary gold mineralization was focused as a target for exploration, and northwestern area of approximately 150 km^2 including both Bau and Batuisi prospects was extracted.

The geology of the survey area consists of metamorphic rocks and metasediments of Mesozoic formation, Paleogene continental shelf strata, thick Miocene volcanic-sedimentary sequences accompanying with granitic rocks, and Pleistocene pyroclastic rocks and terrestorial sediments. Biotite gneiss and mica schist of Mesozoic metamorphic rocks were found locally in the western area and also in the southwestern area. Metasediments and associated volcanic rocks of probably Cretaceous period are widely distributed in the northwestern area. Paleogene shelf sediments have limited distribution in the southeastern area. Major part of the survey area is covered by thick Miocene volcanic-sedimentary sequences. Two granite batholiths of Miocene age occur both at the eastern and western borders of the area. At the high altitudes in the eastern area, dacitic pyroclastic rocks of Pleistocene age are developed.

Photogeological study using satellite imagery revealed the prominent direction of NNE to N-S in the distribution of leneaments and fracture traces in the western area. Geological survey confirmed the distinctive anticlinal structure of N-S axis in the northwestern to central area within metasediments. Both structures are spatially related to the distribution of the Mamasa granite body, and were interpreted as the products of granitic intrusion.

Indications of primary gold mineralization were caught at several places in the northwestern area. The indications are; ① occurrence of gold in pan concentrates, ② distribution of quartz floats, and ③ outcrops of quartz veins.

Based on the field evidences, it was assumed that the gold in pan concentrates might come from quartz veins／networks intensively developed at the upper reaches of creeks in the prospects. 31 samples of quartz veins and quartz floats were collected from all over the survey area and provided for assaying. The results were disappointing. Almost all samples showed very low gold values.

Characteristic features of gold mineralization recognized in the prospects are ; ① metasediments hosted, ② intensive development of massive quartz veins, ③ associated with sulphide minerals, ④ lack of silver mineral, and ⑤ hydrothermal alteration mainly composed of silicification and chloritization.

Fissure patterns of quartz veins show the dominant NNW trend in both Bau and Batuisi prospects. It was interpreted as an aggregate of veins arranged en echelon of NNW trend, though overall arrangement of zones tended to be NW direction in the Batuisi prospect. The patterns of quartz veins are not consistent with the structures of NNE to N-S trend obtained through the photogeological study and regional geological survey in the northwestern area. It is necessary for the further exploration to study the structural relationship between the formation of veins and the emplacement of granite through much detailed survey.

The source of gold in pan concentrates has not been identified this time. It is supposed that gold could be contained either in the quartz veins or in the alteration zones adjacent to veins. For the purpose of identifying the source of gold, much detailed and minute sampling must be carried out in the next phase survey. The next exploration has to be aimed at finding out primary gold mineralization and delineating the distribution of ore within the areas of extensive quartz veining.

Two detailed survey prospects and one semi-detailed survey prospect are picked up. Detailed survey mainly comprising gridding, geological survey with utilizing trenching, and soil sampling is recommended in the Batuisi prospect. In the Bau prospect, detailed survey of similar works with wider survey intervals is recommended because of its rugged topography. Along S. Lebutang and its tributaries, semi-detailed survey consisting of geological survey, pan concentrate sampling, and soil sampling is recommended.

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PART I OVERVIEW

Chapter 1 Introduction

1-1 Background and Objective

The Indonesia-Japan Cooperative Mineral Exploration has been carried out in six areas of the Republic of Indonesia; Sulawesi (1970-1972), Kalimantan (1974-1977), West Kalimantan (1979-1981), North Sumatra (1982-1984), South Sumatra (1985-1987), and Pegunungan Tigapuluh (1989-1990). As a result of those works, a large amount of information regarding metallic mineral resources was obtained. The exploration also contributed to the technical progress of the Geological Survey of Indonesia and the Directorate of Mineral Resources, as well as to the acquisition and accumulation of knowledge regarding geology and mineral deposits of the country.

The Ministry of Mines and Energy of Indonesia planned to conduct mineral exploration in the Toraja area, Sulawesi, and requested the cooperation of the Japanese Government. In August 1991, the Japanese Government, complying with the request, sent a mission for project-finding, discussing the Scope of Work and to make a preliminary survey trip to the area. As a result of consultations with the Ministry of Mines and Energy of Indonesia, counterpart of the Metal Mining Agency of Japan, an agreement was reached for cooperative exploration of the Toraja area in September 5, 1991.

The principal objectives of this project were to explore and assess the mineral potential of the survey area, and to pursue technology transfer to the Indonesian counterpart personnel in the course of the project.

1-2 Outline of the Work

(1) Survey Area

The survey area, approximately 3,000 km^2, is located in the central part of western Sulawesi, and is surrounded by the coordinates listed below. Administration of the area is under the jurisdiction of South Sulawesi Province.

The location map of the survey area is shown in Fig.1-1.

1	2° 12′ 40″S	119° 53′ 40″E
2	2° 37′ 40″S	120° 05′ 20″E
3	2° 50′ 40″S	119° 37′ 20″E
4	2° 25′ 40″S	119° 25′ 40″E

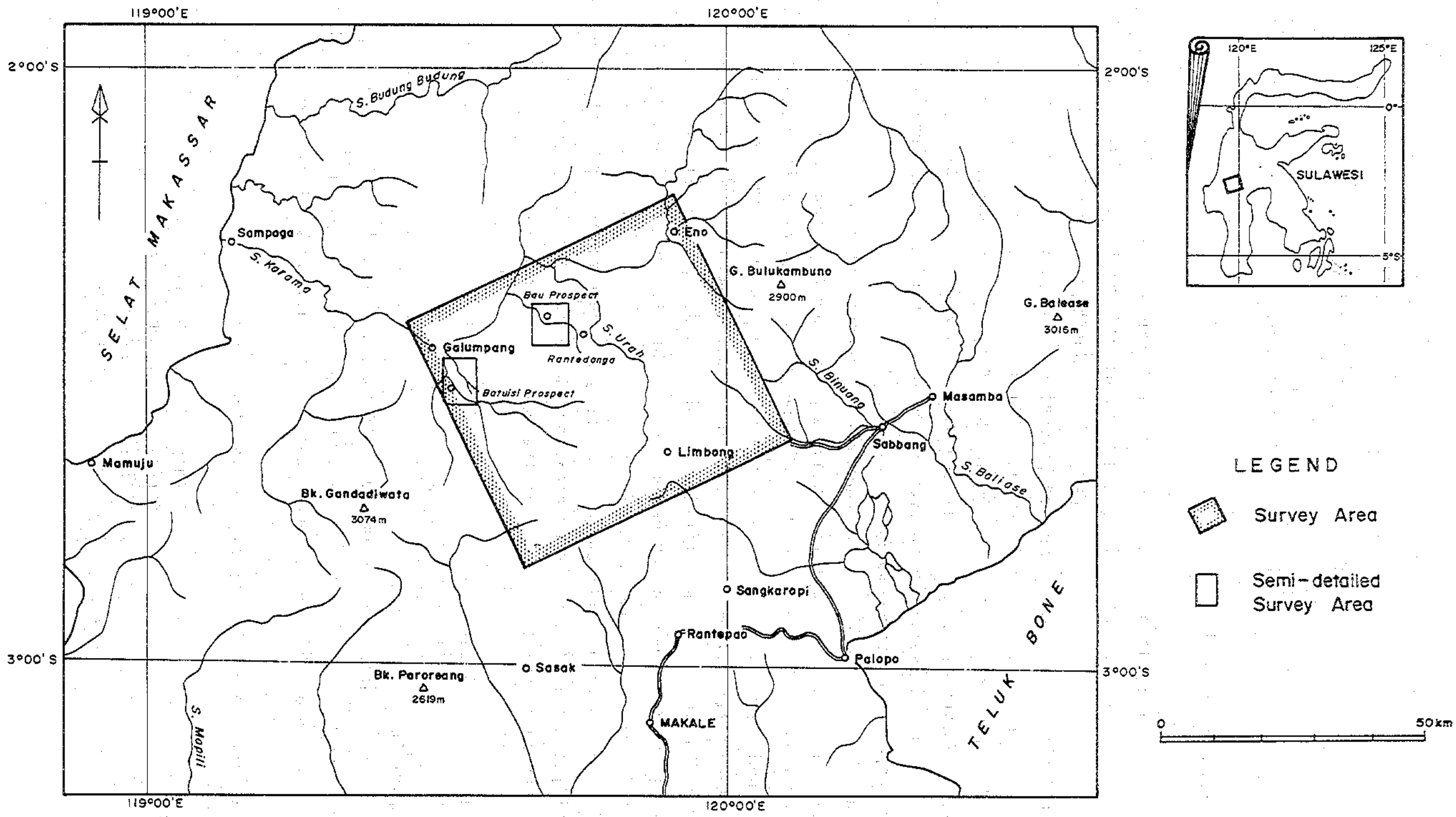


Fig.1-2 Map Showing the Areas of Photogeological Interpretation, Geological Survey and Geochemical Survey

(2) Exploration Work

Exploration in this year corresponds to the first phase of nominal three year exploration programme, and aims at extracting zones with high probability of mineral occurrence by elucidating the geological setting, the relationship between mineralization and geologic structure, and the mode of occurrence of mineral deposits through geological survey and geochemical exploration in the Toraja area.

The works conducted this year were the study of existing materials, satellite imagery photogeological analysis, regional geological and geochemical survey, semi-detailed geological and geochemical survey, and application tests of plant leaf biogeochemistry and mercury gas geochemistry to the tropical rainforest land.

Satellite imagery analysis

No topographic map of required scale of the area was available at the start of this project. It had been, first of all, for obtaining topographic information that the satellite imageries were analyzed. TM and SPOT digital data were processed and 1:100,000 scale false colour imageries were produced. Drainage systems and other topographic information were analyzed on the imageries, and 1:50,000 scale drainage system maps were produced. For geological interpretation, (i) pattern and density of drainage, resistance to weathering and erosion, valley profile, ridge shape and other topographic features, and (ii) image characteristics such as tone and texture were examined. On the basis of these details, the geologic units and structural demarcations were defined and expressed on the drainage system map.

Regional geological and geochemical survey

The entire 3,000 km^2 area was divided into three blocks, and a couple of base camps was set up at each block ; Limbong, Rantedonga, Bau, Galumpang, and Batuisi. In addition to base camps, a series of flying camps was utilized for durations of one to two weeks survey at a time. A series of 1:50,000 scale drainage system maps compiled from the satellite imageries was used in the field. For determining the exact location, every important topographic points were surveyed by GPS (Global Positioning System) instruments.

Geochemical fine sand samples sieved from stream sediments were collected concurrently during the regional geological survey. An average of one stream sediment sample per 300 m length was taken along the survey route. More than 300 km of survey length were archieved and more than 1,000 stream sediment samples were collected altogether in this year. The results of the regional geological survey were compiled in a 1:100,000 scale geological map.

Semi-detailed geological and geochemical survey

A couple of mineralized areas was found during the regional geological and geochemical survey, and some detailed geochemical works were carried out.

The areas where the semi-detailed geological survey and geochemical samplings were carried out are ; ① Bau prospect, and ② Batuisi prospect. It consisted of approximately 100 km^2 in total.

The works were composed of geological survey, pan concentrate sampling, and soil sampling. The 1:10,000 scale route maps were produced by pacing or with fifty meters tape and a Brunton-type compass, together with GPS instruments, in the semi-detailed survey areas. Total length of traverses was more than 150 km. The results of the semi-detailed survey were compiled on a series of 1:25,000 maps.

Pan concentrate samples were obtained from stream sediments. One bucketful of sand and gravel -- roughly 2 liters -- was gathered and panned out, yielding approximately 5 grams of concentrate. Number of gold grains was counted and mineral composition of concentrate was examined by roupe in the field and under the microscope in the laboratory.

Soil samples were collected from B-layer of residual soil at the depth of 20 to 60 cm from the surface. Samples were taken every 300 m interval along the traverses which were almost set cross-cutting the presumed strike direction of mineralization.

Numbers of pan concentrate samples and soil samples were amounted to more than 200 and 500 respectively in this year.

Preliminary works of biogeochemistry and mercury gas geochemistry

In the Batuisi prospect, test sampling of plant leaves and measurements of mercury gas were made.

6 kinds of grass leaves were collected from 10 locations. Each locations were within 20 m radius from the soil sampled points. Leaves were washed by creek water, then dried under the sun. 100 grams of dried leaf samples was obtained finally, and sent for chemical analysis.

Mercury contents of gas from soil were measured using portable mercury detector. Gas of 1.2 liters in soil from soil sampled hole was gathered and analyzed at every point. Detection limit of the detector was 0.01 nanograms. Readouts of the detector were converted to nanograms per one cubic meter of soil gas. 50 mesurements were made in this year.

(3) Amount of works in the first phase

Amount of works done this year is summarized as follows:

Survey	Area and Amount of Samples	
Geology & geochemistry	Regional survey	Semi-detailed survey
Area	3,000 km^2	100 km^2
Surveyed length	324 km	153 km
Geochemical samples	1,010 (Stream sediments)	510 (Soils) 50 (Plant leaves) 50 (Hg Gas) 366 (Pan concentrates)

① Thin Sections - 70 pcs
② Polished Sections of Ore - 10 pcs
③ X-Ray Diffraction Analyses - 51 pcs
④ Absolute Age Determination (K-Ar Method) - 5 pcs
⑤ Chemical Analyses
  a) Whole Rocks - 50 pcs
  b) Stream Sediments - 1,010 pcs
  c) Soils - 510 pcs
  d) Ores - 31 pcs
  e) Plant Leaves - 50 pcs

1-3 Member of the Survey Team

(1) Mission for the project finding and Scope of Work

The Japanese mission for project finding visited to Indonesia from August 26 to September 7, 1991. The Scope of Work was concluded at September 5, 1991 among Japan International Cooperation Agency, Metal Mining Agency of Japan, and Ministry of Mines and Energy of Indonesia, Directorate General of Geology and Mineral Resources.

The menbers participated in the discussion were as follows.

[Indonesian members]

Dr.Adjat Sudrajat	Director General, Directorate General of Geology and Mineral Resources, Ministry of Mines and Energy (DGGMR)
Kingking A.Margaeidjaja	Director, Directorate of Mineral Resources (DMR)
Yaya Sunarya	Head, Metallic Mineral Exploration Division
Subandi Widasaputra	Chief, Precious Metals Section
Poedjosudjarwo	Staff, Precious Metals Section
Yayat Ruchiyat	Chief, Foreign Technical Cooperation Sub Section
Nenen Adriyani	Staff, Foreign Technical Cooperation Sub Section

[Japanese members]

Makoto ISHIDA	Metal Mining Agency of Japan
Mitsuaki INOUE	Ministry of International Trade and Industry
Masato YONEDA	Ministry of Foreign Affairs
Nobuyuki OKAMOTO	Japan International Cooperation Agency
Kenzo MASUTA	Metal Mining Agency of Japan

(2) Survey team

The survey of the first phase was carried out during the period from November 4, 1991 to January 22, 1992. Laboratory work and reporting were followed to the field work. The organization of the survey team was as follows.

[Indonesian members]

Subandi Widasaputra	(DMR)	Coordinator and geologist
Pudjosudjarwo	(DMR)	Team leader and geologist
Banbang Pardiarto	(DMR)	Geologist
Wahyu Widodo	(DMR)	Geologist
Eko Palmadi	(DMR)	Geologist
Atok S Prapto	(DMR)	Geologist

[Metal Mining Agency of Japan]

Kenzo MASUTA	Coordinator and geologist
Kenichi TAKAHASHI	Coordinator

[Japanese members]

Kohei IIDA	(NED)	Team leader and chief geologist
Hideya KIKUCHI	(NED)	Geologist
Yoshihiro KIKUCHI	(NED)	Geologist
Tetsuo SATO	(NED)	Geologist and photogeologist
Masami IWAYA	(NED)	Geologist
Saburo TACHIKAWA	(NED)	Geologist

*Note: NED means Nikko Exploration and Development Co., Ltd.

Chapter 2 Geography of the Survey Area

2-1 Location and Access

Sulawesi is the fourth biggest island in Indonesia. The area is 179,400 km^2 and the population is more than ten millions. It forms K-shaped land.

The survey area is located in the central part of western Sulawesi.
Access to the area is; from Jakarta to Ujung Pandang by air, from Ujung Pandang to Rantepao by car on sealed road or by charter airplane. Rantepao, which is located some 30 km due south of the survey area, is the major town of the Toraja area.

The survey area, shaped as a rectangular of approximately 56 km x 51 km, is in a mountaneous land. A mountain range runs north and south through the area, dividing the area into two; the eastern part and the western part. Access inland is slow and mainly on foot, generally following drainages. The eastern area is accessible by unsealed road from Saban which is at the end of sealed road from Rantepao. Limbong is the second biggest village in the eastern area, located at the end of the road, and is one of the coffee producing place. There is no other vehicle road in the area. Only horse tracks and footpaths are available.

The western area is only accessible by boat through up the river S.(sungai) Karama. Mamuju is the terminal town on the sealed road, and is located about 90 km west of the survey area. From Mamuju to Talleilu, there is an unsealed road running along the coast. It takes some six hours from Talleilu to Galumpang, the biggest village in the area, by engine canoe. There are several little villages in the area. Rivers and footpaths are the only ways connecting the villages.

2-2 Topography and Drainage System

The survey area is situated in a steep mountainous land. The topography is rugged. The greater part of the area is more than 500 m in elevation. There are several high mountains of more than 2,000 m in the survey area. Altitude of the highest peak, name unknown, is 2,914 m . B.(bukit) Malimongan is the fifth highest peak (2,224 m) in the area.

A series of mountains running in the area forms the dividing range. It is called Pengunungan Takolekaju. In the east of the range, rivers flow down to east into Teluk Bone. S. Rapakang is the major drainage system in the eastern area. Whereas in the central and western area, rivers flow down to west into Selat Makassar. S. Karama is the major drainage system in the western area.

2-3 Climate and Vegetation

Even though it is situated in a tropical rain forest zone, the climate of the area is rather mild due to its peculiar land structure -- mountaneous bony frame and surrounded by the sea on all sides. It has two seasons, rainy and dry. From June to October is usually the dry season, and the rainy season generally continues from November till May.

Mean temperature and monthly precipitation in the rainy season is 26 °C and 400 mm. Mean temperature and monthly precipitation in the dry season is 27 °C and 70 mm (climatological data for Makassar).

Lower part of mountains in the area is covered by tropical rain forest. The major part of the mountaineous area, however, belongs to the tropical highland forest -- broad leaved evergreen vegetation and coniferous vegetation. Alluvial patches and even flanks of hills among the mountains are reclaimed, and paddy rice is cultivated in such place. On the steep hills among the mountains, dry field rice and coffee plant is rather extensively cultivated by the slash-and-burn farming.

Chapter 3 Geology of the Survey Area

3-1 General Geology of the Central Part of Western Sulawesi

Sulawesi is formed of three major tectonic units, and is composed of four geographic arms. The western section, comprizing the North and South Arms, is made up of a series of overlapping volcano-plutonic arcs of Mesozoic to Recent age. The eastern section of Sulawesi (the East and Southeast Arms) is composed of a Paleogene-Neogene subduction melange, glaucophane schists and ophiolites. The easternmost islands of Banggai-Sula and Buton are continental fragments drifted westwards from New Guinea along major strike-slip faults (Carlile et al.,1990).

The geology of the central part of the Western Arc is composed of three major units:

① Cretaceous subduction complexes which are overlain by sediments perhaps deposited in an outer-arc basin.

② Upper Paleogene continental shelf strata deposited on the Cretaceous sediments.

③ Neogene sedimentary and volcanic rocks. They are intruded by Neogene granitic rocks.

The oldest rocks of the area are inferred to be Mesozoic gneiss and schist from the broad view of the Western Arc. Cretaceous metasediments are widely distributed in the area. It is composed of mostly clastic rocks - slate, black shale, turbiditic siltstone, greywacke, and minor limestone. Some of the rocks are partly sheared and weakly metamorphosed.

Overlying the Cretaceous turbiditic facies are upper Paleogene shelf sections, deformed only moderately. It is composed of marine and marly shale, quartz sandstone, and limestone.

At the Miocene time, the stable platform conditions changed drastically into active magmatism and extensive volcaniclastic sedimentation.
Batholiths and stocks are widely developed in the area. Biotite granite and quartz monzonite are the dominant granitic rocks. According to the age datings on the granitic rocks, the magmatism occurred at least mostly within middle and late Miocene time (Hamilton,1979). Extensive submarine volcanism, a major orogenic event started at the beginning of early Miocene and continued to Pliocene time, took place elsewhere in Western Sulawesi. It consists of dacitic

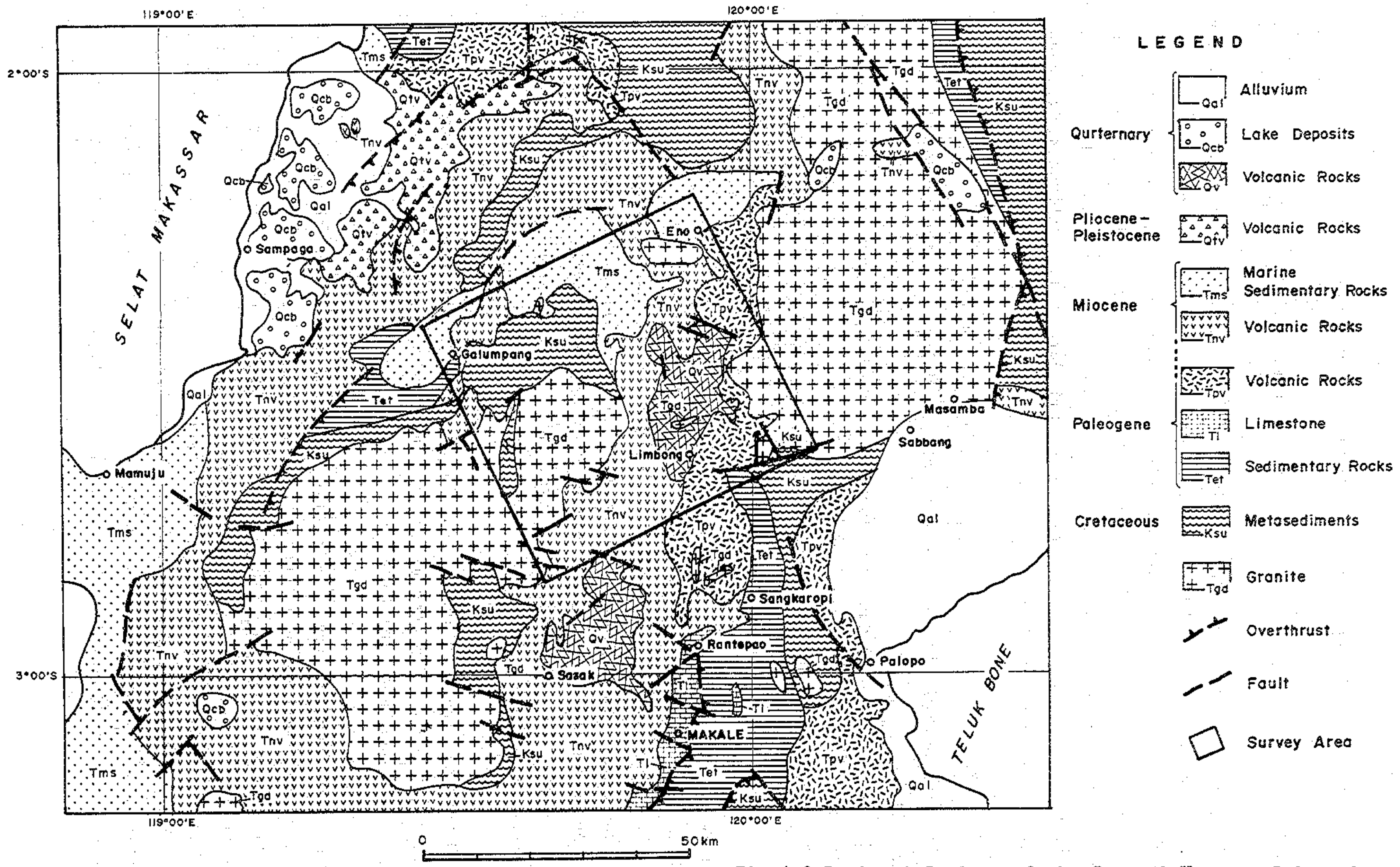


Fig.1-3 Regional Geology of the Central Western Sulawesi

to andesitic volcanism. Renewed volcanic activity in the Plio-Pleistocene produced dacitic to andesitic pyroclastic rocks.

3-2 Geological Setting of the Survey Area

The following summary of geology of the survey area and formation names are mainly based on the Geological Map of Indonesia, Ujung Pandang Sheet (Sukamto,1975), and the Geological Map of the Mamuju Quadrangle, South Sulawesi (Geological Research and Development Centre,1988).

The oldest rock in the survey area is biotite gneiss and mica schist of the Batuan Malihan Metamorphic Rocks. It occurs partly in the western area and also in the south-easten area.

Metasediments are widely distributed in the western area and in some part of the eastern area. It is composed of slate, phyllitic shale/siltstone. It is supposed of Cretaceous age according to the existing geological informations. It is called the Latimojong Formation. Andesite lava and basic tuff are intercalated mainly in the upper part of metasediments.

Overlying unconformably on the Cretaceous metasediments are Paleogene shelf sediments. It is composed of shale, sandstone, and limestone. It is called the Toraja Formation.

The major part of the survey area, especially in the eastern area, is covered by the Miocene series called the Lamasi Volcanic rocks. Acid to intermediate volcanic and pyroclastic rocks such as fine tuff, lapilli tuff and dacite lava are the major constituents of the rocks. Shale and basalt lava occur in the lower part of the pyroclastic sequences in some places.

Alternation of calcareous sediments and basic tuffs occur overlying the acid to intermediate pyroclastic rocks. The upper part gradually changes to basic lava. Those rocks are subdivided into three sequences - the Beropa Tuffs, the Sekala Formation, and the Talaya Volcanic Rocks in accending order.

Two granite batholiths are developed at the eastern and western borders of the area. Each batholith accompanies with several small stocks. The eastern batholith is called the Kambuno granite, and the western one the Mamasa granite.

Dacitic tuff of probably Pleistocene age occurs at high altitudes in the eastern part of the survey area. It is called the Barupu Tuffs.

3-3 Mineralization

There are at least three kinds of mineralization known in and around the area.

The first one which is widespread in the area is represented by silicification, kaolinitization and quartz veinning. The quartz veins sometimes contain sulphide minerals such as pyrite and basemetal minerals. This kind of mineralization was reported in several localities in Galumpang area. Cinnabar and gold are found as alluvial placer in Galumpang area too. Alluvial gold was reported in several tributaries of S. Karama. The spatial proximity of the occurrences of alluvial gold with quartz veinning implies the source of gold.

Alluvial gold occurrences are distributed within Cretaceous metasediments, Paleogene shelf sediments, and Miocene pyroclastic rocks. The developments of primary gold mineralization are highly promising in the area.

The second type is characterized as an extensive hydrothermal alteration within the Miocene pyroclastic rocks in the south-eastern part of the area. There are several places where sericitization and chloritization are recognized accompaning with pyrite dissemination and some silicification. This is believed to be something related to the Sangkaropi type massive sulphide mineralization. The Sangkaropi deposits are located 20 kilometers south of the survey area, and in the Pt. Aneka Tambang concession.

The Sangkaropi sulphide deposits are found within the Miocene acid to intermediate pyroclastic rocks. It is composed of stratiform massive and fragmental ores and underlying stockwork ore. Sphalerite, galena, pyrite, and barite are the major constituent minerals of massive and fragmental ores. Top of the ores is generally covered by a thin layer of barite. The stockwork ore consists of veins of quartz and sulphide minerals (Yoshida et al.,1982).

The other one which is expected to occur in the area is the porphyry copper mineralization similar to the Sasak deposit. Sasak is located 25 kilometers from the southern border of the survey area, and also belongs to the Pt. Aneka Tambang concession.

The Sasak porphyry copper-gold mineralization is found within monzonite and syenite stocks of Miocene age. The hypogene mineralization occurs both in disseminated form and as veinlets. The disseminated mineralization consists of magnetite, pyrite, chalcopyrite, and electrum. Sulphides in veinlets are usually associated with quartz, and consist of pyrite and chalcopyrite with minor amount of galena and sphalerite. The most prominent alteration is a quartz-clay-sericite assemblage (Taylor and van Leeuwen,1980).

Chapter 4 Results of Survey

4-1 Geology and Geologic Structure

The oldest unit in the survey area is composed of Mesozoic metamorphic rocks. The occurrence of biotite gneiss and mica schist was confirmed in the western part and in the southeastern part of the area.

Metasediments are widely distributed in the northwestern area and in some part of the southeastern area. It is mainly composed of slate and phyllitic shale/siltstone. It is called the Latimojong Formation. It had been explained as of the Createceous system according to the existing geological maps. The result of K-Ar age dating this time, however, indicated some possibility of much older age. Andesite, basalt, and dolerite occur within the metasediments. Gold mineralization in the northwestern area was found mainly within the metasediments.

Overlying unconformably on the metasediments are Paleogene sedimentary rocks of the Toraja Formation. It is composed of shale, sandstone, and limestone. It has only limited distribution in the survey area.

The major part of the survey area, especially in the eastern area, is covered by thick Miocene volcanic-sedimentary sequences. The lower part of the sequences is composed mainly of acid to intermediate volcanic and pyroclastic rocks, and is called the Lamasi Volcanic Rocks. Dacite lava, fine tuff, and lapilli tuff are the major constituents of the rock member. Shale and basalt lava occur in the lower part of the pyroclastic sequence in some places.

Middle to upper Miocene volcanic-sedimentary rocks are subdivided into three sequences ; Beropa Tuffs, Sekala Formation, and Talaya Volcanic Rocks.

The Beropa Tuffs consists of alternation of andesite, basalt, andesitic to basaltic tuff, siltstone, and sandstone.

The Sekala Formation consists of black shale, siltstone, and limestone. Thin layers of basalt lava and basaltic tuff are interbeded with sedimentary rocks.

Volcanic rocks of intermediate to basic composition occur at the uppermost part of the Neogene Tertiary system. The Talaya Volcanic Rocks is mainly composed of andesite lava and volcanic breccia. Basalt lava and basaltic tuff are interbeded with this members. Major part of the high mountain area in the southwestern to northeastern part is covered by this volcanic rocks.

Dacite lava and dacitic tuff of Pleistocene age are widely developed at the high altitudes in the eastern part of the survey area. It is called the Barupu Tuffs. It forms very steep hills and mountains in the area.

Two granite batholiths are developed at the eastern and western borders of the area. The eastern batholith -- Kambuno granite -- is mainly composed of quartz monzonite. Granodiorite, quartz diorite, and aplite are associated. The western batholith -- Mamasa granite -- is also composed mainly of quartz monzonite. Granodiorite, diorite, and porphyritic quartz diorite are associated with quartz monzonite in the Mamasa granite batholith.

Age determination through K-Ar analyses was tested on the both granitic rocks, yielding late Miocene in age.

Prominent direction of NNE to N-S system was embossed in the northwestern part of the survey area through the satellite imagery photogeological interpretation. Nearly half of lineaments and fracture traces recognized in the area showed the trend of NNE to N-S.

Regional anticlinal structure and several local folds were observed during the regional survey in the northwestern area. They have axes of N-S direction.

Minor faults trending NW to WNW, E-W, and NE were recognized in the survey area. But any fault of N-S to NNE has not been found during the survey.

4-2 Mineralization

Among initial three target mineralizations, two of them -- massive sulphide mineralization and porphyry copper-gold mineralization -- were not found during the regional survey. Regarding the remaining one target, some indications of primary gold mineralization were caught at several places in the western part of the survey area. Occurrences of gold in pan concentrates were counted in many places. Floats of vein quartz are distributed in some part of S. Karama and its tributaries. Outcrops of gold bearing quartz veins were located in Bau, Batuisi, and in some other places. In Bau and Batuisi prospects, semi-detailed geological and geochemical survey was carried out. During the regional and semi-detailed survey, 31 ore samples -- mainly composed of vein quartz -- were collected and provided for assaying. The results were dissapointing. Only trace of gold was detected in those samples.

(1) Bau prospect

The Bau prospect is located along S. Salore and its tributaries. One continuous zone of gold-bearing quartz veins/networks was delineated in the prospect. Although width of each veins is not so thick (up to 30 cm), the zone extends more than 2.5 km to north-northwest. Quartz veins are hosted by slate, black shale/siltstone, andesite, and basalt/dolerite of the Latimojong Formation. Quartz veins sometimes contain a small amount of sulphide minerals such as pyrite and chalcopyrite. Silicification, pyritization, chloritization, and weak sericitization and carbonatization were observed in the vicinity of veins.

A few other mineralized zones was found within the prospect.

(2) Batuisi prospect

The Batuisi prospect lies between S. Karataun and the upper reaches of S. Pongo. The following three zones of quartz veins/networks containing gold and sulphide minerals were identified within the prospect:

① Middle reaches of S. Tarawa
② Upper reaches of S. Tarawa
③ S. Malela

Development of quartz veinning is quite extensive. The zone ①, trending northwestwards in overall, extends roughly more than 5 km. Quartz veins sometimes show massive features. Width of one of quartz veins in the zone ③ is more than 5 m. A small amount of pyrite, chalcopyrite, and galena is contained in quartz. Host rocks of veins are slate and shale/siltstone of metasediment member in most cases, and propylitic andesite and dolerite in some cases. Intensive silicification and pyrite dissemination were observed in the country rock near quartz vein. Chloritization and weak pyrophyllite alteration were also recognized in some places.

Test sampling of plant leaves for biogeochemistry was carried out in the Batuisi prospect. 6 kinds of grass leaves were collected from ten locations in the zone ①, where were positioned close to the soil sampled points.

Mercury contents in gas from soil sampled holes were measured using portable type mercury analyser in the zone ①. 50 measurements were made along a line which was arranged crosscutting the major quartz vein.

Results of both test works will be discussed on the next phase report together with the soil geochemistry.

(3) Other prospects

During the regional survey, gold and heavy mineral concentrations were detected by panning in many places. Distribution of quartz float zones was also found. Indications of gold mineralization were mainly obtained in the area between Bau and Batuisi along the tributaries of S. Karama. Geology of the area is composed of black shale, andesite, and dolerite of the Latimojong Formation. Major places where significant indications were caught are S. Lebutang and its tributaries including S. Taloto.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

The first phase exploration in the Toraja area consisted of satellite imergery photogeological interpretation, regional geological and geochemical survey, semi-detailed geological and geochemical survey, and preliminary works for plant leaf biogeochemistry and mercury gas geochemistry. Because of the limited time of the first phase, interpretations and discussions have been made only for photogeology, geology, and mineralization of the survey area. Results of geochemistry will be discussed in the report of the next phase.

Prior to the survey, three potential mineralizations in the survey area were picked up. Those were ; primary gold mineraization, massive sulphide mineralization, and porphyry copper-gold mineralization.

In the course of the regional survey, no positive indication of the latter two mineralizations has been found. Consequently they were eliminated from the target for exploration.

Indications of primary gold mineralization were caught at several places in the northwestern part of the survey area, and semi-detailed geological survey and geochemical sampling were carried out in two prospects -- Bau and Batuisi. The indications which show primary gold mineralization are ; ① occurrence of gold in pan concentrates, ② distribution of floats of vein quartz, and ③ outcrops of quartz veins.

In those prospects, distributions of gold, cinnabar, and some sulphide minerals in pan concentrates are closely related to each other forming "panning anomalies". Distribution of quartz veins and quartz floats overlaps on those anomalies in a broad scale.

Quartz veins generally contain a small amount of sulphide minerals. Pyrite, arsenopyrite, chalcopyrite, sphalerite, and galena were observed as primary minerals under the microscope. Gold and silver minerals have not been found in quartz so far.

Based on those evidences, it was assumed that the source of gold in pan concentrates might be quartz veins/networks intensively developed at the upper reaches of creeks in the prospects.

31 samples of quartz veins and quartz floats were collected from all over the survey area and provided for assaying this time. The results were

disappointing. Almost all samples showed very low gold values. Assay has not proven the origin of gold yet.

Petrography, ore microscopy and X-ray diffraction analysis showed several characteristic features of mineralization in this area ; ① metasediments hosted, ② intensive development of massive quartz veins, ③ associated with sulphide minerals, ④ lack of silver mineral, and ⑤ hydrothermal alteration mainly composed of silicification and chloritization. These features suggest that the gold mineralization in this area may be different from the typical epithermal gold mineralization.

Fissure patterns of quartz veins show the dominant NNW trend in both Bau and Batuisi prospects. It was interpreted as an aggregate of veins arranged en echelon of NNW trend, though overall arrangement of the zones tended to be NW direction in the Batuisi prospect.

Photogeological analysis using satellite imergery showed that the principal direction produced by the emplacement of the Mamasa granite might be NNE to N-S in the northwestern area. Anticlinorium recognized through the geological survey has an axis of N-S direction, and was interpreted to be the product of the granite intrusion. Whereas the patterns of quartz veins are different from the above structure. Any evidence genetically connecting the vein formation with the emplacement of granite bodies has not been found so far. Mechanism of vein formation is one of the important theme to be investigated in the next stage work.

Anyhow at this stage, the source of gold in pan concentrates has not been identified. It is supposed that gold could be contained either in the quartz veins／networks or in the alteration zones adjacent to veins. Samples collected in the prospects this time were limited. Only small part was tested. It is not sufficient for finding and delineating ore zone, compared to the extensive development of quartz veins／networks in the prospects. Much detailed and minute sampling is required for identifing primary gold mineralization. The next phase exploration must be aimed at finding primary gold mineralization and delineating the distribution of ore within the areas of extensive quartz veinning.

As the results of the regional and semi-detailed survey in the first phase exploration, northwestern area of approximately 150 km^2 including both Bau and Batuisi prospects is selected for further investigation in the next stage exploration.

5-2 Recommendations for the Second Phase

As the results of this year's survey, three areas have been picked up for the next phase exploration prospects. Those are ; ① Batuisi prospect, ② Bau prospect, and ③ S. Lebutang and its tributaries including S. Taroto.

① In the Batuisi prospect, central part of the intensive quartz veinning zone will be checked at first. Detailed survey mainly comprizing gridding, geological survey, and soil sampling is recommended in the prospect. Trenching will be effective for prospecting the nature of primary gold mineraization.

② In the Bau prospect, detailed survey mainly comprizing geological survey and soil sampling is also recommended. Topographic condition must be considered in the survey programme.

③ Along S. Lebutang and its tributaries, semi-detailed level of survey consisting of geological survey, pan concentrate sampling, and soil sampling is recommended. Amount and density of samples for assaying must be significant enough for identifing gold mineralization.

PART Ⅱ DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Satellite Imagery Photogeological Interpretation

1-1 Methods Used

The purpose of photogeological interpretation is ; ① to produce the drainage system maps for field survey, and ② to obtain guidelines for geological survey and geochemical exploration by elucidating the geologic units and the regional geologic structure of the survey area. As was already explained in the previous chapter, topographic information of the survey area was not available, thus the first puropose of satellite imageries had been very important, as well as the second one.

The imageries used in the examination were the Landsat TM and SPOT HRV false colour prints of 1:100,000 scale. Bands-1, 2, and 3 of the multispectral mode were selected and assigned to blue, green, and red respectively in case of SPOT imergery. Configuration of TM bands was made for the purpose of coherency. Bands-2, 3, and 4, which are suitable for geological interpretation in the plant cover area were selected. The imageries cover the area shown in Fig.2-1. Details of the imageries are listed below.

Generally speaking, the SPOT multispectral imagery has to be high resolution in itself. The specific scene, however, showed a misty view, something like covered by a thin film which was caused by evapotranspiration in the tropical rainforest land. The southeastern part of the survey area is not covered by the SPOT scene. These faults were compensated by the TM imagery, which had slightly bigger cloud covers. Results of geological interpretation using both TM and SPOT imageries were compared each other. No significant difference has been obtained in the analyses.

LANDSAT TM DATA (LANDSAT-4)	PATH 114	ROW 62	DATA ACQUISITION DATE 16 Dec, 1990	CLOUD COVER 10 %	ID NO Y4307501350XO
BAND SELECTION	2 3 4 = B G R				

SPOT HRV (SPOT-1)	K 309	J 355	DATA ACQUISITION DATE 18 Sep, 1987	CLOUD COVER 0～25 %	QUALITY E
MODE SELECTION	MULTISPECTRAL (XS)				

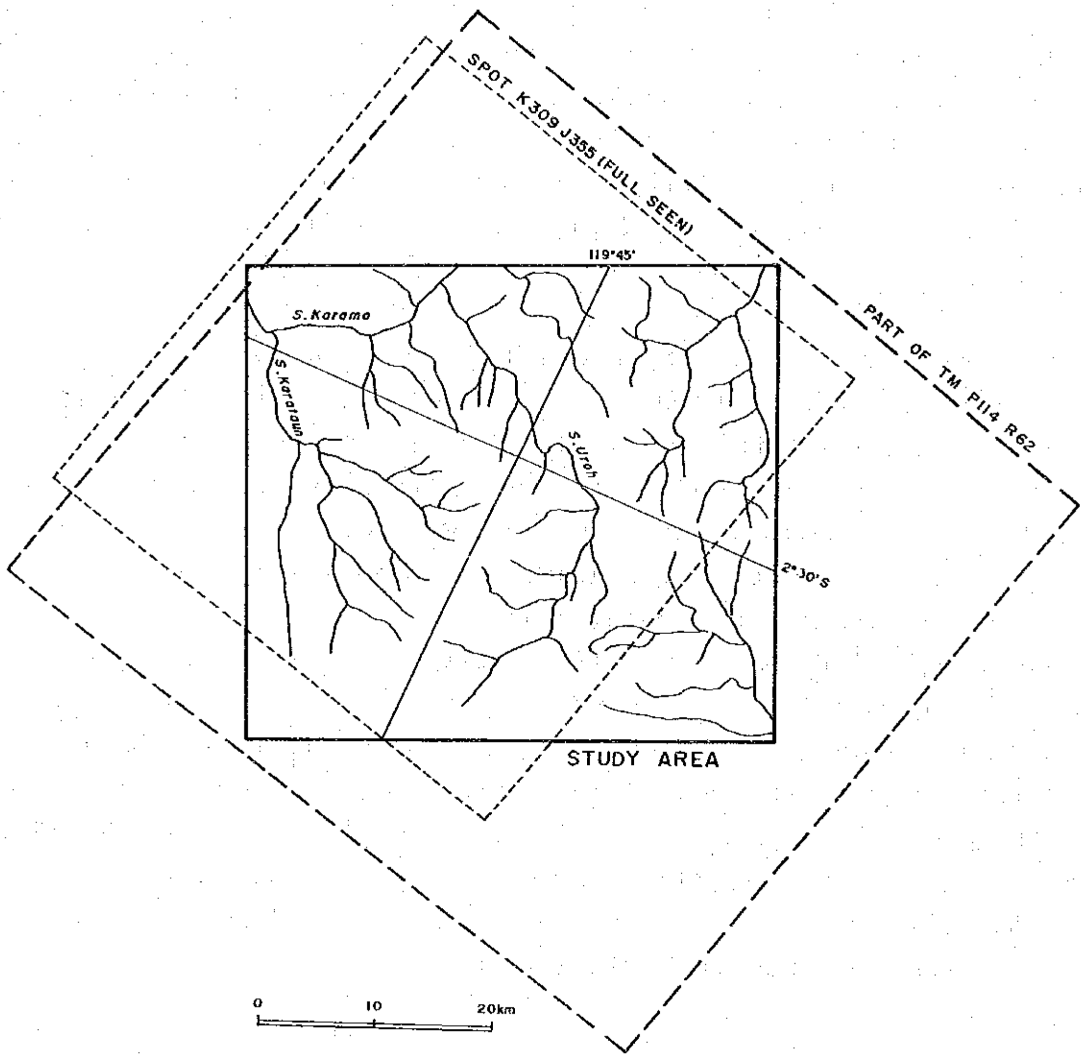


Fig.2-1 Map of the Coverage Areas of Satellite Imageries

As the survey area is situated in the tropical rainforest zone, it was presumed that vegetation cover would prevent the interpretation in some of the area. In addition to that, sedimentary structures, which could be ordinarily utilized to follow the succession of geologic units, were rather obscure in this area. A special attention was thus paid into the topographic features and texture, the drainage pattern and density, and the linear structures. The boundary of granite bodies was the other important point that deserved an attention.

1-2 Results of Interpretation

(1) Geologic units

Based upon the photogeological characteristics, four major geologic units were classified and identified in the survey area. It is composed of a high resistance igneous rock unit (G), a high to moderate resistance sedimentary rock unit (K), a moderate to low resistance clastic rock unit (T), and a very low resistance unconsolidated sediment unit (Q). The K and T units were further studied in details, and were subdivided into K_1 and K_2, and T_1 to T_5 respectively. Results of the photogeological classification are summarized in Table 2-1. The interpretation map is shown in Fig.2-2.

① Units K_1 and K_2

Unit K_1 is a high to moderate resistance rock unit. It occurs in the western area, within the distribution of igneous body (unit G). It shows some sedimentary feature, and has minor fracturing/bedding textures within itself. It corresponds to metamorphic rocks of the Mesozoic formation.

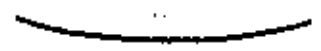
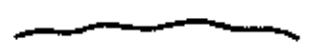
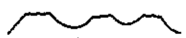
Unit K_2 is developed in the north-western area, mainly on the southern side of the upper reaches of S. Karama. It roughly corresponds to the distribution of metasediments of the Latimojong Formation. It is characterized by a moderate resistance rock unit. From the morphological features of the image, this unit appears to have a brittle nature. It means that the rock unit probably consists of argillaceous sedimentary rock, such as massive shale and siltstone.

② Unit G

Unit G is a hard, massive, and high resistance rock, impling igneous body. There were several occurrences observed in the survey area. The largest one is in the western area. Another bodies were found in the eastern area too. They almost correspond to the distribution of granite intrusions.

Within the western unit, minor lineaments of mainly NNE to N-S trend are

Table 2-1 Summary of Photogeological Interpretation

Geologic units \ Characteristics	Image-Characteristics			Morphological Expression					Correlation
	Tone	Texture	Vegetation	Drainage: Pattern	Drainage: Density	Landform: Cross Section	Landform: Resistance	Landform: Surface	
Q	Blueish to pale blue	Very fine	Low glass land	Meandering	Low		Very low	Smooth	Alluvial or fluvial and talus deposits
T_5	Dark blue to Dark brown	Fine	Moderate~high	Subdendritic	High		Low	Horizontal Smooth	Clastics and Pyroclastics
T_4	Reddish brown	Medium to coarse	High	Subdendritic to subparallel	High		Moderate	Massive	Volcanics (mainly lavas)
T_3	Dark brown	Coarse	Moderate~high	Subdendritic	High		Low to moderate	Rough	Tuff breccias or lavas
T_2	Dark brown	Coarse	High	Subdendritic to subparallel	Moderate		Moderate to high	Massive	Tuffs, lavas and some sediments
T_1	Brown	Medium to coarse	Moderate	Subdendritic	Moderate		Low	Moderate	Tuffs
K_2	Blueish brown	Fine	Low	Subdendritic	High to moderate		Moderate	Rough and smooth	Sediments and pyoclastics
K_1	Reddish pale brown	Coarse to medium	Moderate	Subdendritic Partly subparallel	High		Moderate to high	Moderate	Sediments
G	Reddish brown	Medium	Moderate	Subdendritic to subrectangular	High		High	Massive	Granites

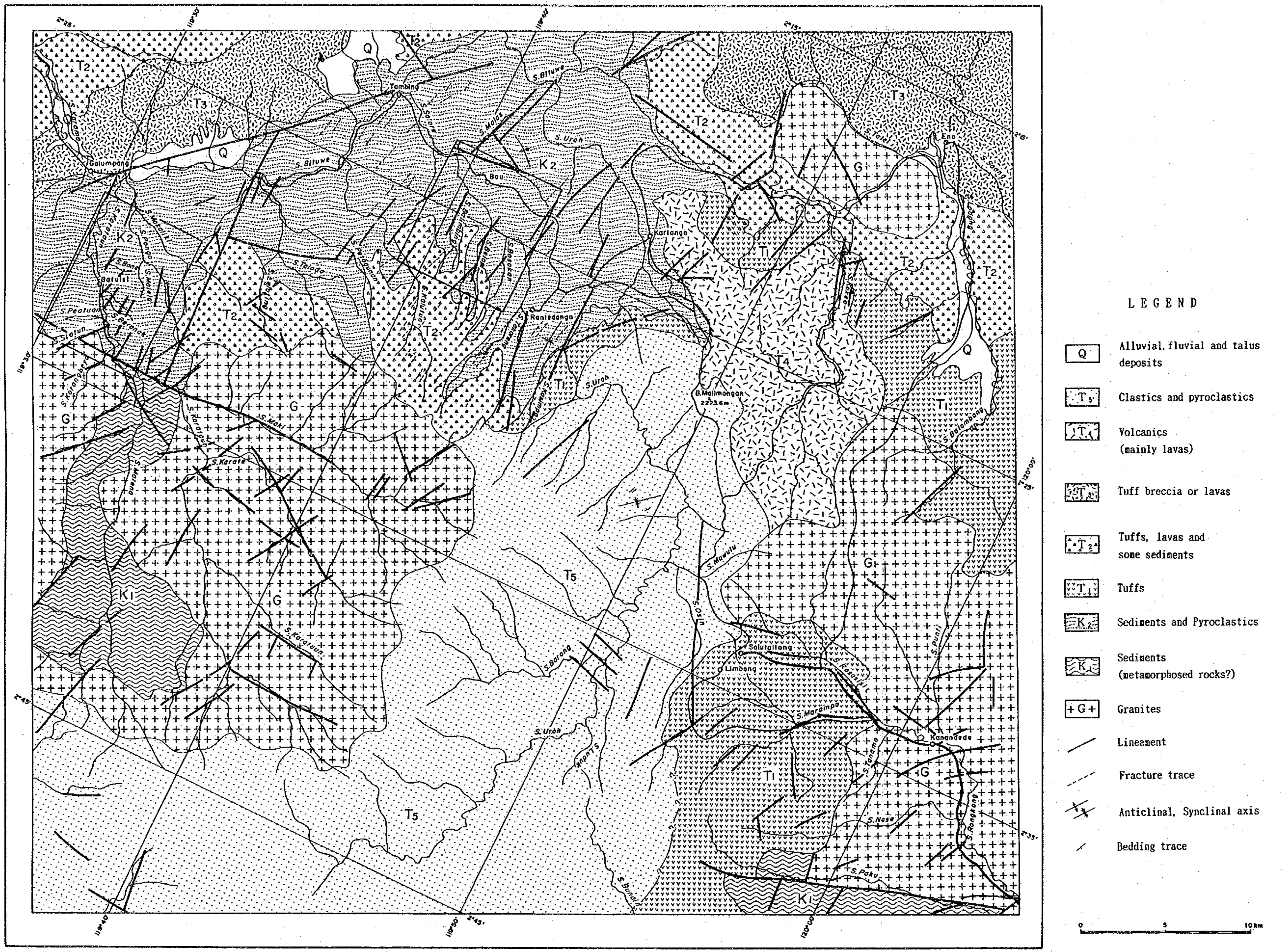
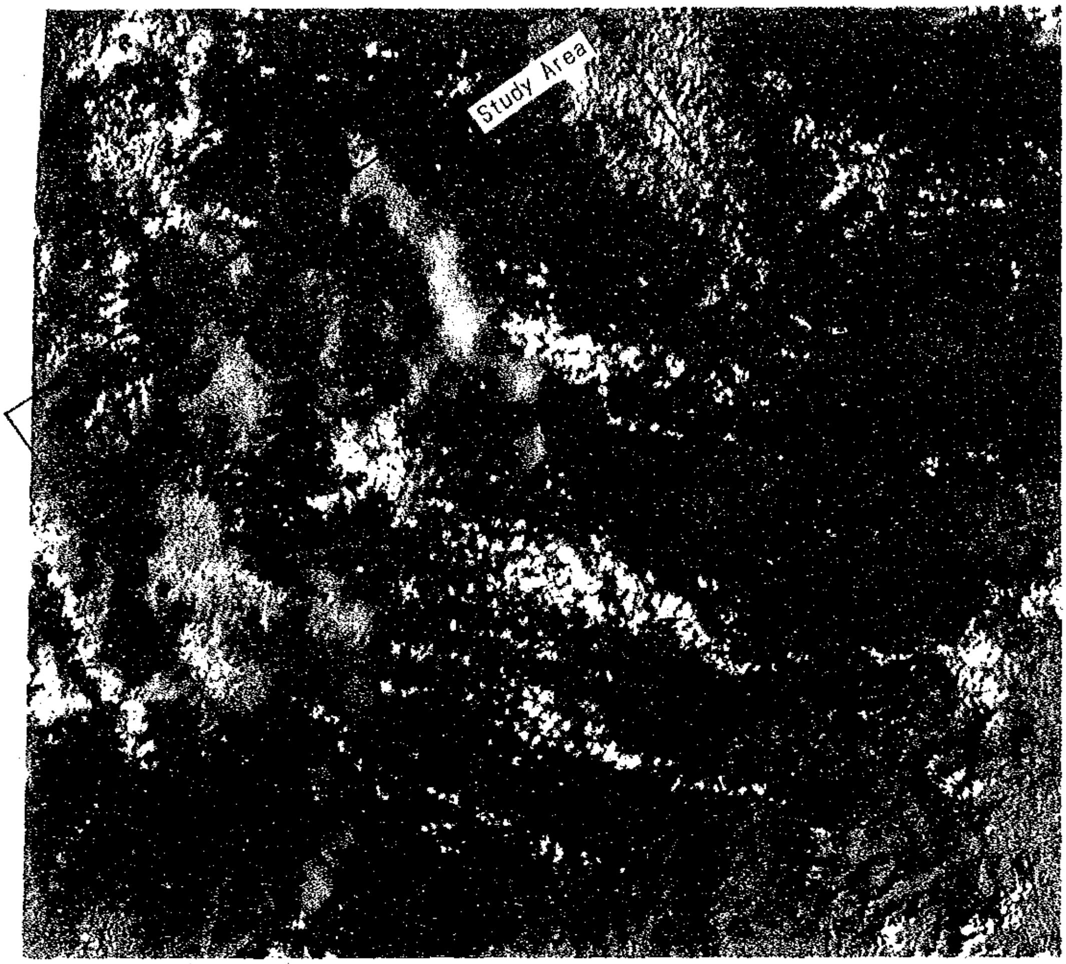


Fig.2-2 Results of Satellite Imagery Photogeological Interpretation

LANDSAT 4 TM
PATH 114 ROW 62 234



DATA ACQUISITION 16 DEC. 1990

0 10 20 30km

Fig. 2-3 False Colour Composite Image of Landsat TM

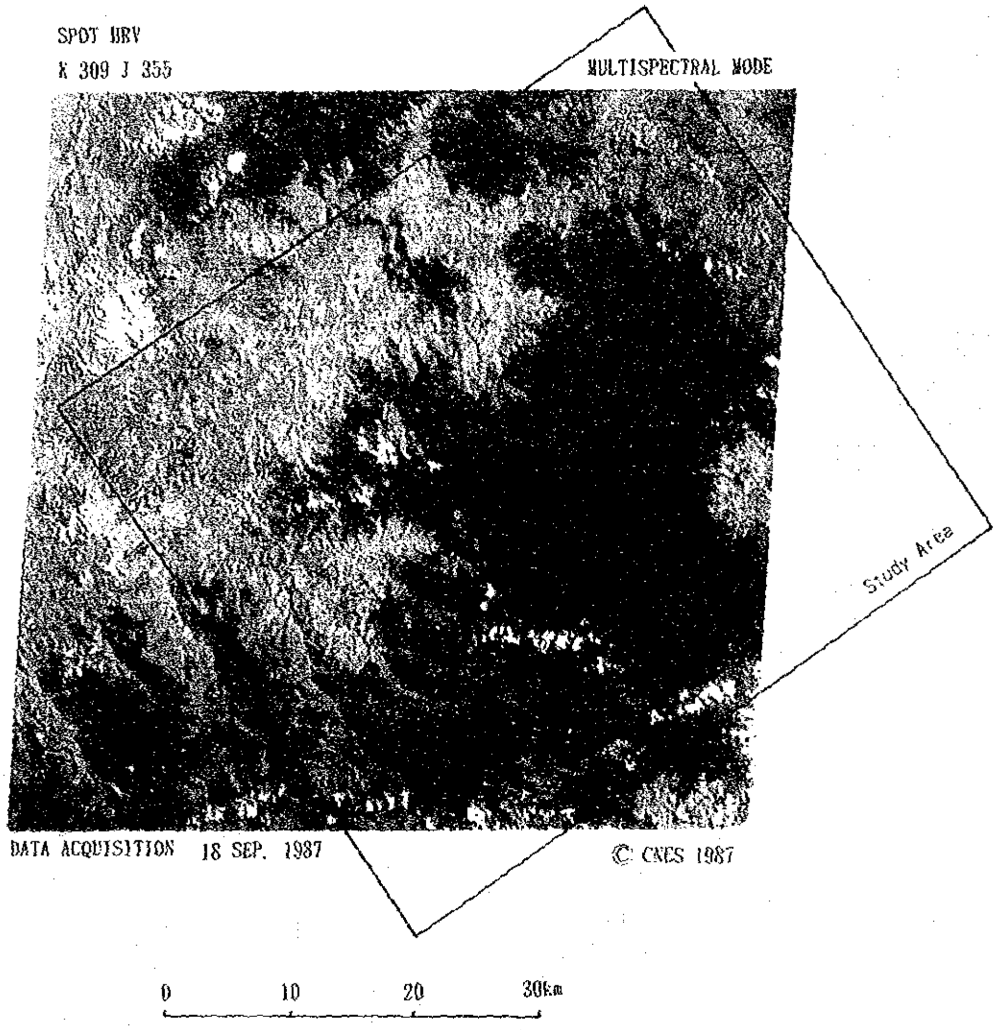


Fig. 2-4 False Colour Composite Image of SPOT HRV

extensively developed. They were supposed to be fractures or igneous joints. Major drainage pattern within and surrounding the body, composed mainly of secondary order, shows the similar trend (NNE to N-S).

③ Units T ($T_1 \sim T_5$)

A group of units (T) generally has moderate to low resistances. These units cover most of the area, apart from the distributions of metasediments and igneous bodies. Most of them show massive rough texture, lacking of sedimentary structure in general. These features, combined with the existing informations, indicate that the units correspond to the volcaniclastic rocks of Paleogene to Neogene Tertiary and Pleistocene age.

The members were subdivided into five ($T_1 \sim T_5$) on the bases of minor differences within the units. The difference of textures distinguished were ; massive vs. bedded, and rough vs. smooth. Photographic tone and pattern of drainage system were also considered in the subdivisions.

④ Unit Q

This unit occurs at two locations. One is in the north-western area on the northern side of S. Karama. Another location of the unit is in the north-eastern area near Eno along the upper-most reaches of S. Bituwe.

It is characterized by the very low resistance. The unit shows the development of meandering drainge system with low density. It also shows flat and smooth topography and very fine-grained texture. This unit was inferred to be composed of unconsolidated sediments of Quaternary. It also indicates the area of cultivated field and plantation land.

(2) Geologic structure

Bedding and other sedimentary structures were generally very obscure in the survey area. Successions and mutual relationship were hardly distinguishable among the units. Photolineaments representing faults and fracture zones, and fracture traces indicative of igneous joints or minor fissures or weak bedding were observed in the area. Small scale synclinal structures were recognized.

① Lineaments

A total of 176 lineaments was counted throughout the area.
Prominent direction of the lineaments is NNE. N-S and NE are the next dominant directions. These lineaments were characteristically found in the western area, especially within and around the G unit. The other dominant direction of lineaments is E-W. Distribution of lineaments is shown in Fig.2-5. Frequencies and total lengths of lineaments in each directions are counted as follows:

	DIRECTION	FREQUENCY	%	TOTAL LENGTH km	%
E-W	S78.75°E - N78.75°E	14	8	61.5	11
ENE	N78.75°E - N56.25°E	10	6	43.0	8
NE	N56.25°E - N33.75°E	24	14	85.5	16
NNE	N33.75°E - N11.25°E	59	34	161.5	29
N-S	N11.25°E - N11.25°W	38	21	90.0	16
NNW	N11.25°W - N33.75°W	8	4	33.5	6
NW	N33.75°W - N56.25°W	11	6	37.0	7
WNW	N56.25°W - N78.75°W	12	7	38.0	7
	TOTAL	176	100	550.0	100

② Fracture traces

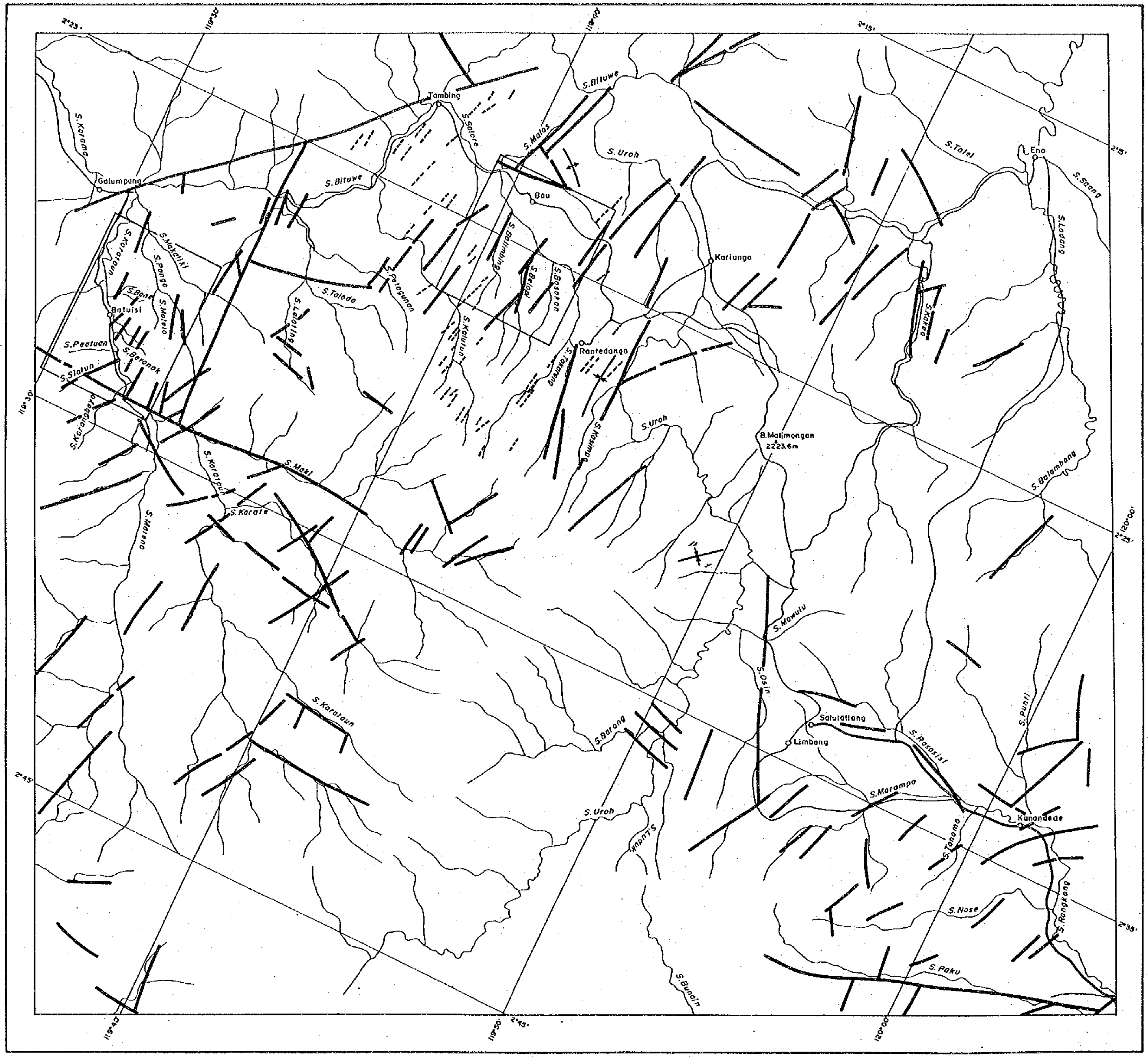
Numerous fracture traces were recognized in the western area. Most of them were found within K_1, K_2, and T_2 units. The major direction of fracture traces is NNE to N-S, same as the direction of lineaments.

③ Synclinal structure

Small scale synclinal structures were observed in Unit K_2 and Unit T_5. Axis of the synclines is N-S and NE respectively.

④ Drainage pattern

Tertiary and higher order drainage systems run meanderingly. Lower order drainage system has dendritic to subparallel pattern in general. Some of them, however, show parallel or subrectangular pattern having particular directions. Those in the western area, especially within and around the distribution of Unit G, show the distinctive NNE to N-S trend.



LEGEND

Lineament

Fracture trace

Anticlinal, Synclinal axis

Bedding trace

Fig.2-5 Distribution Map of Lineaments

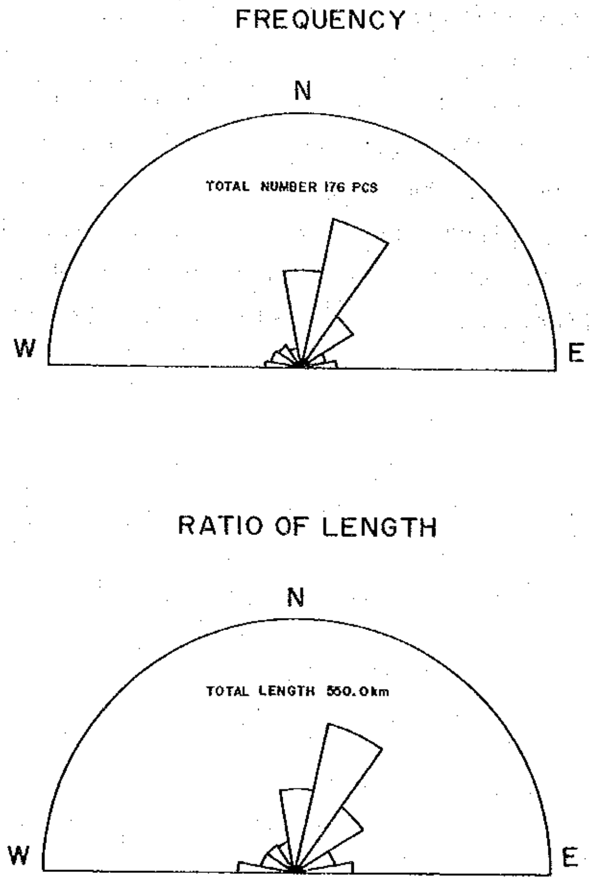


Fig.2-6 Rose Diagram of Lineament Statistics

1-3 Discussions

According to the existing geologic maps, systems of NW to NNW and E-W directions are two major structural trends in and around the survey area. Whereas, photogeological information has embossed the prominant direction of NNE to N-S system in the western area. The system comprizes a bundle of smaller lineaments, less than several kilometers long, and swarms of fracture traces. This characteristic feature indicates that the structure does not represent a single fracture zone, but expresses a regional stress field possibly of tensional nature. The area from in the vicinity of the Mamasa granite to up north is the zone where the fractures of NNE to N-S system is pervasively developed. Near the Bau and Batuisi prospects, the development of linearments is especially dense. Since the distribution of the NNE to N-S fractures spatially corresponds to the direction of elongation of the Mamasa granite, the formation of the fractures may be related to the emplacement of granite batholith.

Chapter 2 Geological Survey

2-1 Survey Methods

This is the first phase survey of the Toraja area, Sulawesi. The first phase operations consisted of geological survey and geochemical exploration, based on the analysis of existing geological information and satellite imagery photogeological interpretation, through which the geological setting of the survey area was defined.

Prior to the field work, the drainage system maps of 1:100,000 scale were prepared from the satellite imageries (TM and SPOT) which were used in the photogeological interpretation. A series of 1:50,000 drainage system maps enlarged from the satellite imageries was utilized in the regional survey. The GPS instruments were employed for locating major surveying points in the field.

In the course of the regional geological survey and stream sediment sampling, a couple of mineralized areas was found. Combined these field results with the existing information of alteration and mineralization on the area, semi-detailed geological survey and geochemical sampling comprizing panning and soil sampling were carried out in two areas ; ① Bau prospect, and ② Batuisi prospect. The route maps of 1:10,000 scale were produced during the semi-detailed survey, using foot pacing or 50 meters tape with a Brunton-type compass. The important mineral showings were studied in much detail, and samples were taken for laboratory analysis.

A total length of 324 kilometers was explored during the regional survey, and the geological information was compiled into a 1:100,000 map. A total of another 153 kilometers was exlored in the course of the semi-detailed survey, with the compilation of 1:25,000 geological maps.

The number of samples collected in the survey is; 1,010 stream sediment samples, 366 pan concentrate samples, 510 soil samples, more than 50 rock samples for thin sections and for whole rock analysis, more than 50 altered rock and clay samples for X-ray diffraction analysis, 5 igneous rock samples for age-dating, and more than 30 ore samples for assaying and for polished sections. Results of the laboratory works are briefly summarized in Tables 2-2 to 2-5.

2-2 Outline of Geology

As is already explained in the previous chapter, the geology of the survey area is composed of seven units.

① Mesozoic gneiss and schist (Batuan Malihan Metamorphic Rocks - basement of the area).

② Metasediments of supposed Cretaceous age, comprizing slate and shale/siltstone, andesite lava, and dolerite (Latimojong Formation).

③ Paleogene shelf sediments, such as shale, sandstone, and limestone (Toraja Formation).

④ Lower Miocene volcanic and pyroclastic rocks and sediments, mainly composed of acidic to intermediate pyroclastic rocks such as pumice tuff, tuff, dacite lava, and shale (Lamasi Volcanic Rocks).

⑤ Middle to upper Miocene volcanic and pyroclastic rocks and sediments, mainly composed of calcareous sediments, and basic tuff and lava (Beropa Tuffs, Sekala Formation, and Talaya Volcanic Rocks).

⑥ Neogene granitic batholiths and stocks (Mamasa and Kambuno granites).

⑦ Pleistocene acid volcanic and pyroclastic rocks, predominantly dacitic crystal tuff (Barupu Tuffs).

Regarding the geologic structure of the survey area, NW and E-W trending fault systems which cut Mesozoic to Neogene volcanic-sedimentary sequences occur. This area is situated at the south of the NW to NNW trending Fossa Sarasina fracture zone. And the regional north-northwest trending structure runs parellel to the Fossa Sarasina. The emplacement of granite batholiths makes another significant feature of the area. The major part of the survey area is sandwiched by two granite bodies from east and west.

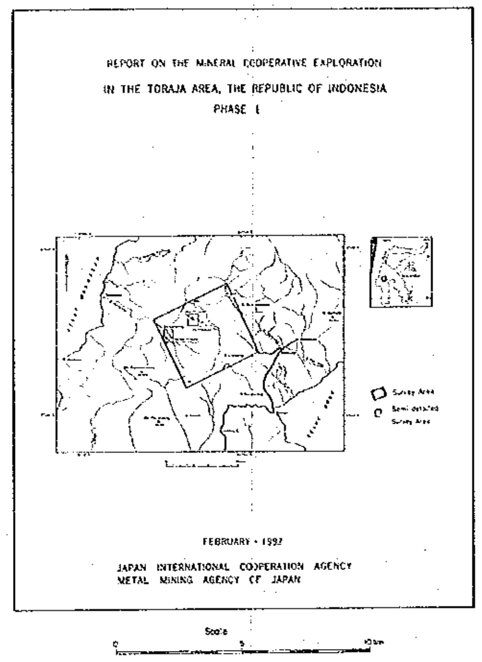
Figs.2-7, 2-8 shows the geology and geologic profile of the survey area. Fig.2-9 shows the stratigraphy and outline of igneous activity in the area.

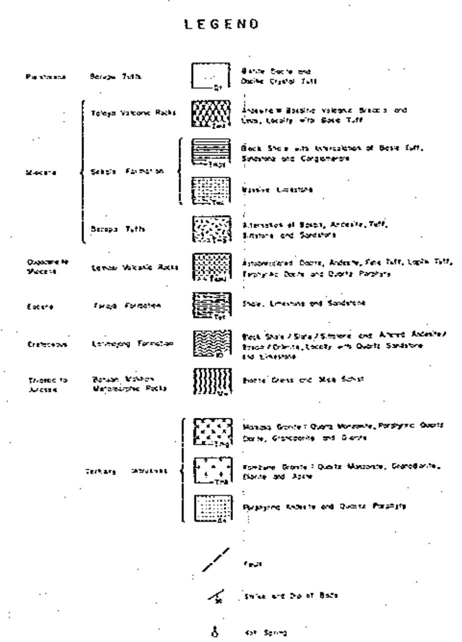
2-3 Stratigraphy

(1) Batuan Malihan Metamorphic Rocks

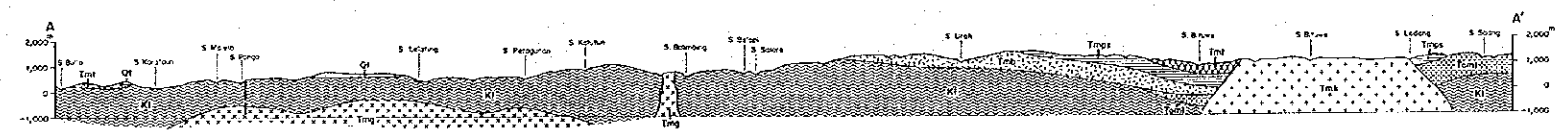
It is the oldest rock in the survey area. Biotite gneiss is the representative facies of the rock member in the western area. It crops out spatially associated with the Mamasa granite.

It shows light grey colour, gneissose to schistose texture. It is composed





Geologic Profile along Line A - A'



Geologic Profile along Line B - B'

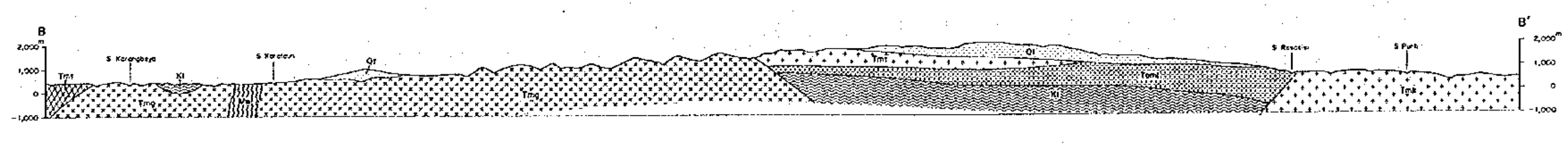
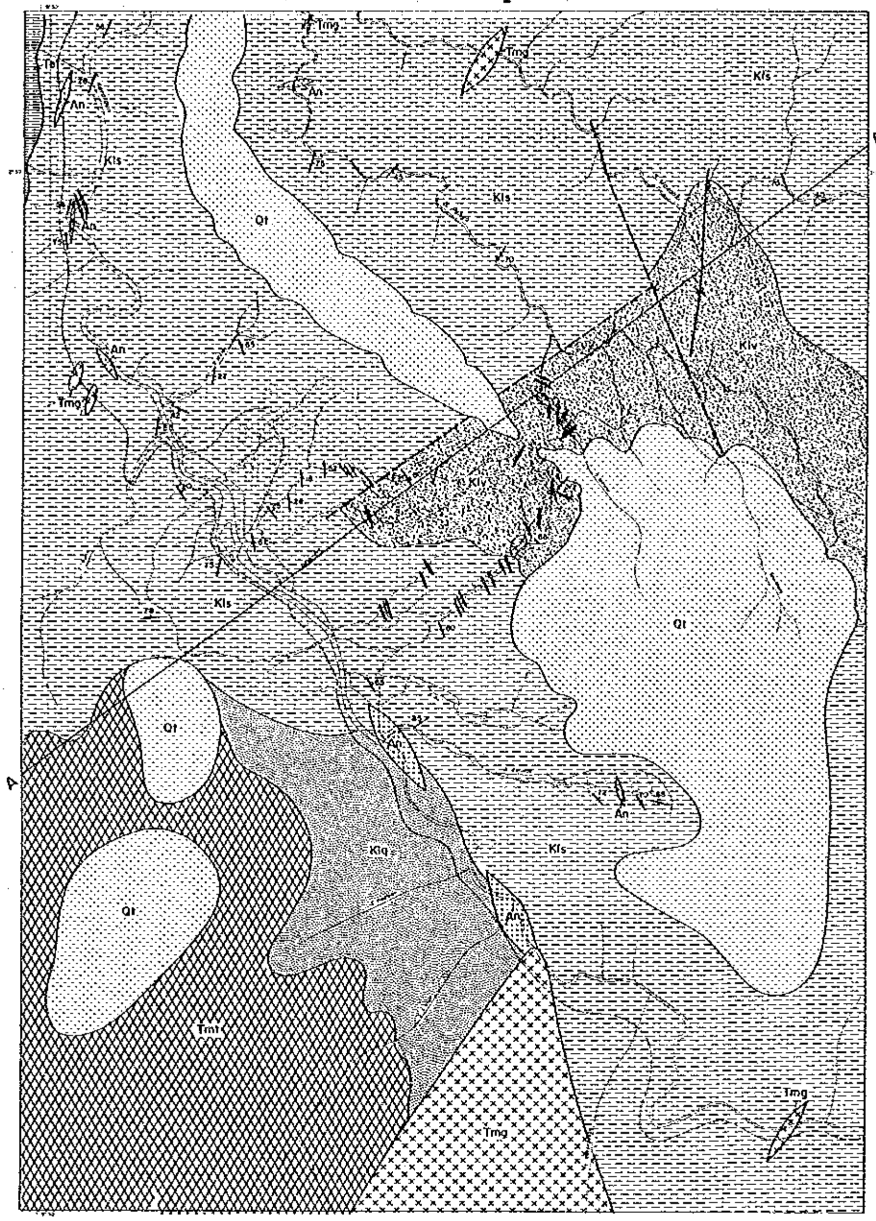
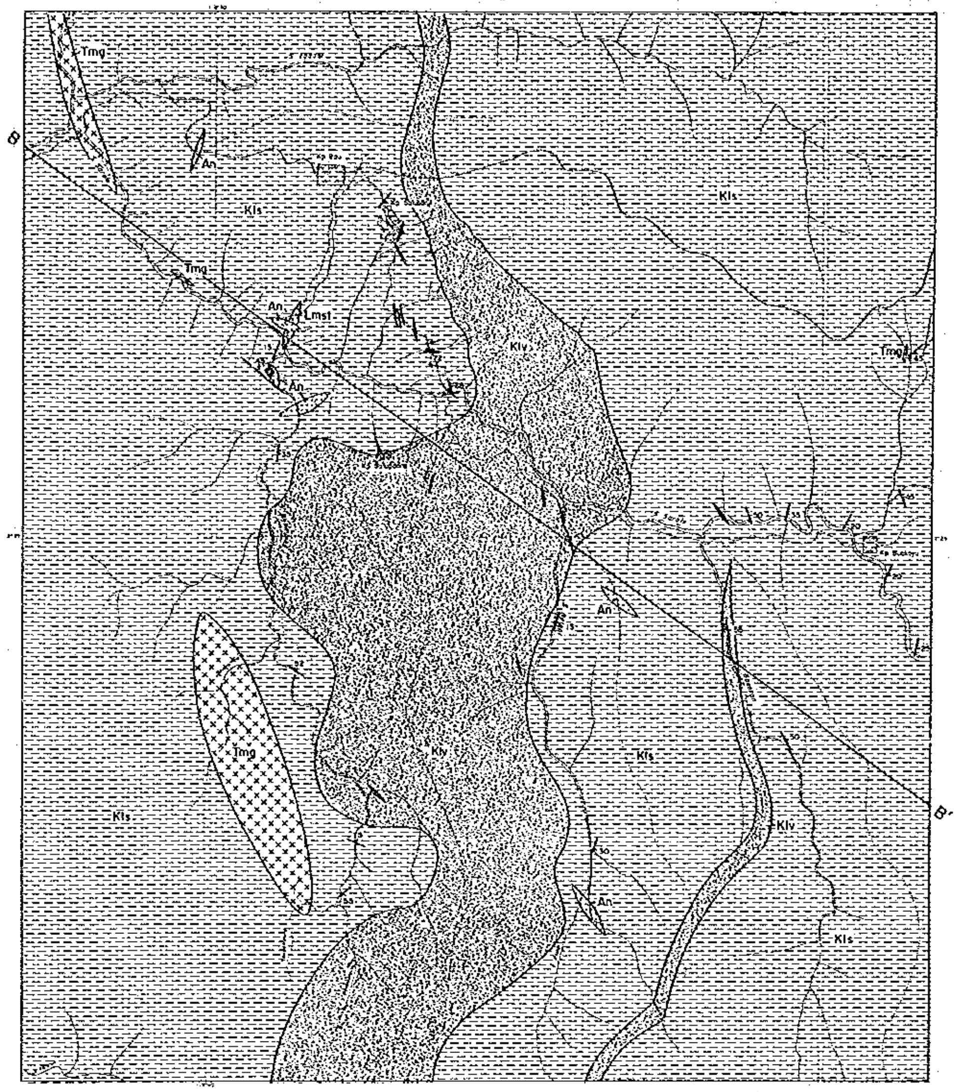


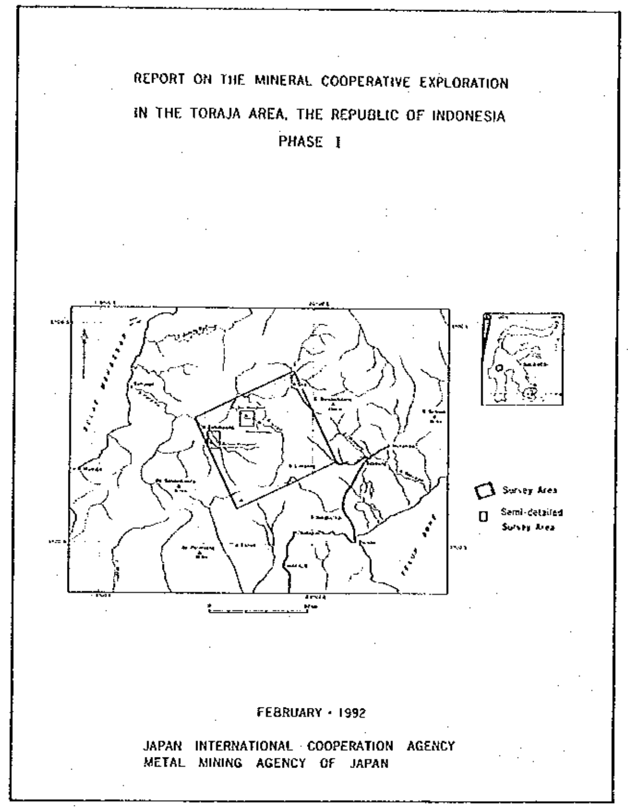
Fig.2-7 Geology and Geologic Profile of the Survey Area

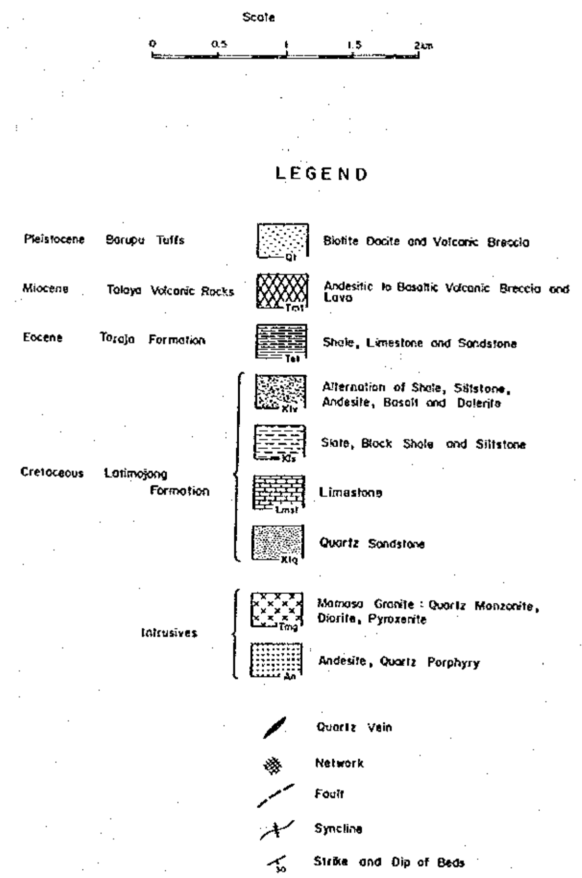
Batuisi Prospect Area



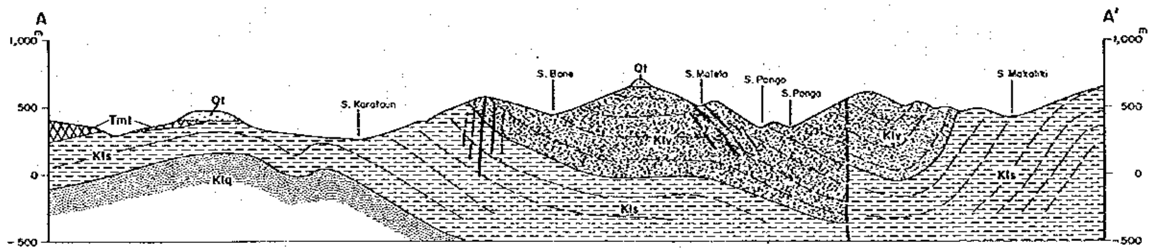
Bau Prospect Area







Geologic Profile along Line A – A'



Geologic Profile along Line B – B'

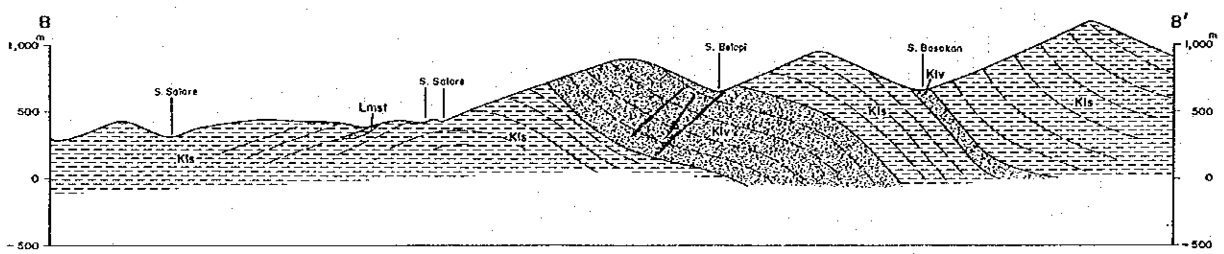


Fig.2-8 Geology and Geologic Profile of the Semi-Detailed Survey Areas

of medium-grained quartz, plagioclase, biotite, hornblende, and some opaque minerals. It shows a lepidoblastic texture under the microscope.

Biotite gneiss and mica schist of the Batuan Malihan metamorphic member also occur locally along S. Paku in the southeastern part of the survey area.

(2) Latimojong Formation

The Latimojong Formation is composed of slate, phyllitic shale/siltstone, altered andesite, and altered basalt/dolerite. It is widely distributed in the northwestern area. It also occurs partly in the southeastern area.

The lower part of the formation is generally composed of slate and phyllitic black shale. The upper part, on the other hand, is composed of rather massive siltstone. Quartz sandstone and lenticular limestone are locally interbeded within the lower part.

Andesite, basalt, and dolerite occur within the metasediments. In S. Salore and S. Karataun, andesite which shows dark green propylitic feature occurs. In S. Salore and S. Taroto, doleritic/diabasic facies occurs within the metasediments. Under the microscope, the rock shows ophitic texture. It consists of fine- to medium-grained plagioclase, pyroxene/hornblende, epidote, and some augite. Chloritization and weak sericitization were observed in the rock.

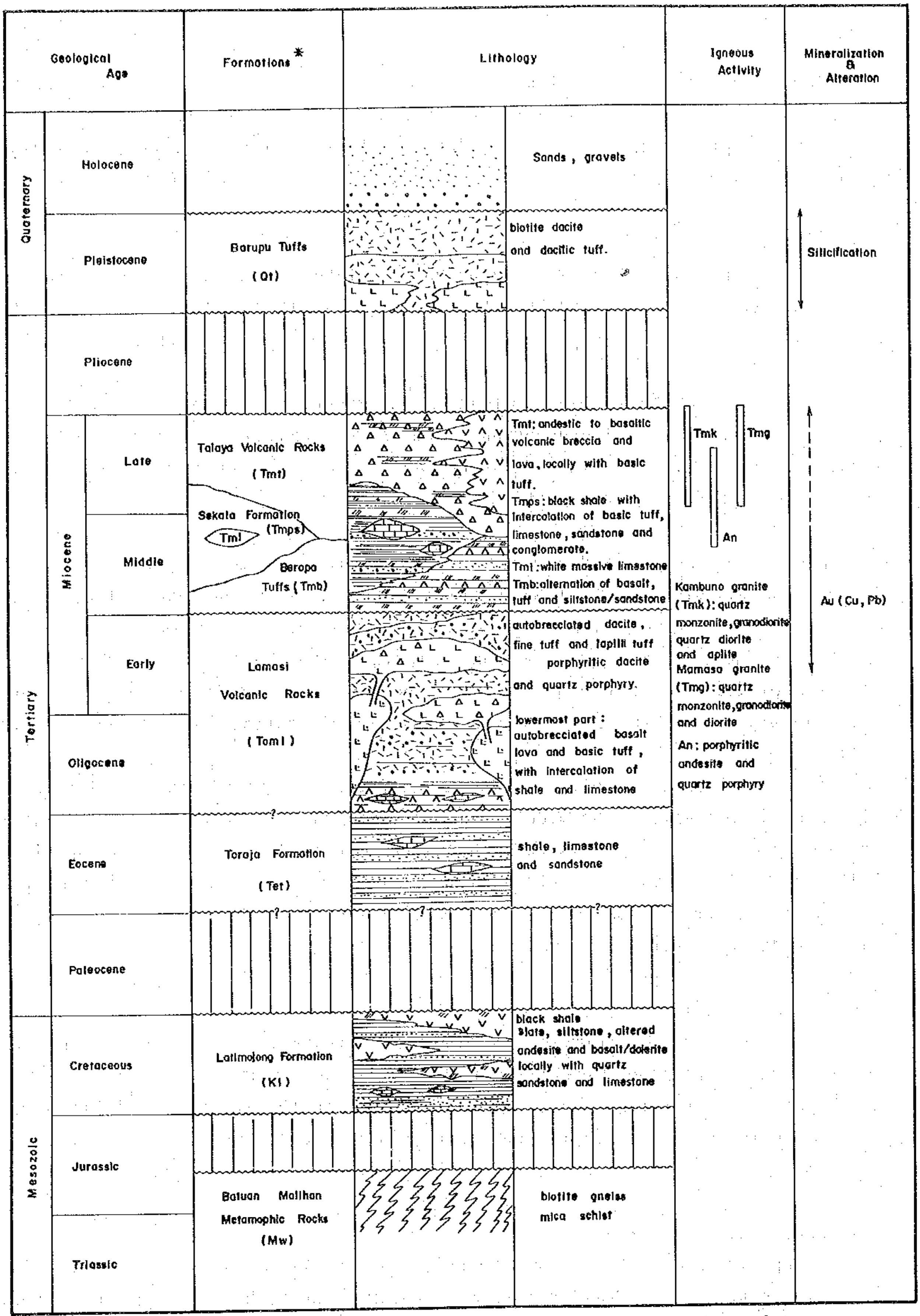
A intrusive body of olivine gabbro was found in metasediments at S. Tarawa. The rock occurs amidst the middle reaches of S. Tarawa mineralized zone, and is moderately chloritized. This rock (D38R) was provided to K-Ar age dating (Table 2-2). The result showed 205±10 Ma (Jurassic). It is indicated that some part of the Latimojong Formation is probably older than the existing geological information explained.

(3) Toraja Formation

Overlying unconformably on the Mesozoic strata are shale, sandstone, and limestone of Paleogene Toraja Formation. The distribution is limited in the northwest and southeast, and is mainly located at the southern outside of the area. The formation in the northwestern area is made up of calcareous shale and siltstone.

(4) Lamasi Volcanic Rocks

Lower Miocene volcanic and pyroclastic rocks of acid to intermediate composition are widely developed from S. Marampa and S. Rasasisi up to the north in the eastern area. Dacite and hornblende andesite lava, quartz porphyry dome,



* Formation Names : after Geological Research and Development Centre (1988), Geologic map of the Mamuju Quadrangle, South Sulawesi 1 : 250,000.

Fig.2-9 Stratigraphy of the Survey Area

and fine tuff and lapilli tuff are main constituents of the rocks. Lava generally has massive porphyritic features, whereas some part shows hyalocrastic texture. Sericitization and chloritization were weakly recognized. Strong alteration of chlorite-kaolinite-pyrite assemblage was observed in dacite lava along S. Marampa.

Thin layers of basalt lava and basaltic tuff occur within the Lamasi volcanics along S. Rasasisi. Shale and limestone are associated with basaltic layers. This facies is interpreted as the lower member of the Lamasi Volcanic Rocks, and probably of late Paleogene in age.

(5) Beropa Tuffs

Middle to upper Miocene volcanic-sedimentary rocks are subdivided into three sequences ; Beropa Tuffs, Sekala Formation, and Talaya Volcanic Rocks.

The Beropa Tuffs consists of alternation of andesite and basalt lavas, andesitic to basaltic tuffs, and siltstone/sandstone. It occurs mainly along the middle reaches of S. Uroh. Chlorite-carbonate alteration was observed in the Beropa Tuffs.

(6) Sekala Formation

The Sekala Formation consists mainly of black shale and siltstone. Thin layers of basalt lava and basaltic tuff are interbeded. Sedimentary facies is slightly metamorphosed in some places, showing phyllitic features. Limestone lenses occur within the Sekala Formation. The Sekala Formation is widely distributed in the northern part of the survey area.

(7) Talaya Volcanic Rocks

Volcanic rocks of intermediate to basic composition occur at the uppermost part of the Neogene Tertiary system. It is mainly composed of andesite lava and volcanic breccia. Basalt lava and basaltic tuff are interbeded with the volcanic rocks. Major part of the high mountain area in the southwestern to northeastern part is covered by the Talaya Volcanic Rocks. Near Galumpang in the northwestern area, the top of hills and mountains is also covered by this volcanics.

(8) Barupu Tuffs

The Barupu Tuffs mainly consists of dacite lava and dacitic tuff. It is widely developed at the high altitudes in the eastern part of the survey area. Dacitic crystal tuff is the representative facies of the rocks. Under the microscope, it is composed of biotite, plagioclase, quartz, and pyroxene fragments set in a spherulitic and microcrystalline feldspar. Lithic fragments were sometimes contained.

2-4 Intrusive Rocks

(1) Kambuno granite

The Kambuno granite batholith in the southeastern part of the survey area consists of quartz monzonite and diorite. Aplite dykes occur within the body in some places. Under the microscope, quartz monzonite is composed mainly of plagioclase, orthoclase, quartz, and biotite. Muscovite, hornblende, apatite, sphene, and zircon were also observed as accessary minerals. It generally shows fine- to medium-grained, holocrystalline, hypidiomorphic-granular texture.

Several small stocks and dykes of the Kambuno granite are distributed in the eastern area. The largest stock, approximately 2 km x 5 km in size, occurs at the upper reaches of S. Betuwe. It represents granodiorite facies, consisting of plagioclase, biotite, and some pyroxene phenocrysts. It shows fine- to medium-grained subhedral to euhedral porphyritic texture.

K-Ar age dating yielded 11.4-10.4 Ma (late Miocene). The results of age dating are shown in Table 2-2.

(2) Mamasa granite

The Mamasa granite batholith consists mainly of quartz monzonite and porphyritic quartz diorite. It is developed widely in the southwestern part of the survey area. Under the microscope, quartz monzonite shows medium- grained, holocrystalline, hypidiomorphic granular texture. Plagioclase, orthoclase, biotite, quartz, and hornblende represent phenocryst minerals. Apatite, sphene, and zircon occur as accessary minerals.

Porphyritic quartz diorite boulders, which contain feldspar phenocrysts as big as one's fist, were sometimes observed along the upper reaches of S. Karataun and S. Matena. This facies is one of the representative members of the Mamasa granite.

Small stocks and dykes of granodiorite and diorite occur mainly within metasediments of the Latimojong Formation in the northwestern part of the survey area.

K-Ar age dating yielded 7.5-7.1 Ma (late Miocene).

Table 2-2 Results of Potassium-Argon Analysis

Sample No.	Locality	Rock Name	Sample Type	K wt%	Rad ^{40}Ar 10^{-5}cc/gr	K-Ar age Ma	$\%^{40}Ar$
C12R	S.Marampa (1)	Quartz Monzonite	Whole Rock	3.46	0.140		62.0
				3.47	0.140	10.4±0.5	56.8
C23R	S.Betuwe (2)	Granodiorite	Whole Rock	3.50	0.156		72.0
				3.50	0.155	11.4±0.6	71.0
C33R	S.Karataun (3)	Quartz Monzonite	Whole Rock	3.26	0.089		56.2
				3.24	0.090	7.1±0.4	66.4
D30R	S.Matena (3)	Quartz Monzonite	Whole Rock	4.43	0.128		59.3
				4.39	0.128	7.5±0.4	61.8
D38R	S.Tarawa (4)	Gabbro	Whole Rock	0.27	0.231		73.8
				0.27	0.225	205±10	73.7

※ Samples are;

(1) Kambuno granite, (2) Stock of Kambuno granite, (3) Mamasa granite

(4) Dyke rock intruded in metasediments of the Latimojong Formation.

※ Analysis conducted by Teledyne Isotopes, USA.

(3) Porphyritic andesite

Porphyritic andesite which made up domes and dykes is the most popular intrusive rock in the survey area. It intrudes into from metasediments of the Latimojong Formation up to volcanic breccias of the Talaya Volcanic Rocks. It shows medium-grained porphyritic texture. According to the microscopic observation, most of them are hornblende andesite, and some are biotite andesite.

Several small stocks and dykes of quartz porphyry are distributed in the survey area. It occurs within from metasediments of the Latimojong Formation up to volcanic breccias of the Talaya Volcanic Rocks.

(4) Whole rock analysis

50 rock samples mainly consisting of igneous rocks were provided for whole rock analysis. 13 elements including BaO and LOI were analyzed at Chemex Labs Ltd. Results of chemical analysis and CIPW norm calculation are shown in Table 2-3. Rock names of igneous and volcanic rocks identified from field observations and thin sections were checked through the analysis.

Several compositional comparisons among the granitic rocks were made based on the chemical analysis (Fig.2-10). In the normative quartz–plagioclase–orthclase diagram, the Kambuno granite mainly occupies quartz-monzonite region. Few of the samples from the Kambuno granite were plotted in the granodiorite region. Whereas the Mamasa granite showed wider variation in its composition. Data of the Mamasa granite spread over the regions of quartz-monzonite, granodiorite, and diorite. In the K_2O-Na_2O-CaO compositional diagram, the Kambuno granite showed rather rich in K_2O. The Mamasa granite, on the contrary, showed comparatively rich in Na_2O.

On the $Fe^{3+}/Fe^{2+}-SiO_2$ diagram, which is applied for distinguishing between magnetite series and ilmenite series divisions of granite, most of the samples were plotted in the region of magnetite series granite (refer to Sato and Ishihara,1983). No specific difference between the Kambuno and Mamasa granites were recognized on the diagram. Some other comparisons -- DI (Differentiation Indices), and A/CNK Values (Al_2O_3/[CaO+Na_2O_3+K_2O] values) -- showed little difference between two granitic rocks.

These results show that there is no difference in their magmatic series between the Kambuno and Mamasa granite bodies, though they have their own compositional characters.

Table 2-3 Results of Whole Rock Analysis and Norm Calculation(1/3)

/S.No	A01R	A03R	A05R	A06R	A28R	A29R	A30R	B02R	B09R	B10R	B25R	B30R	B31R	B35R	C04R	C07R	C08R	C13R
SiO_2	67.590	72.850	58.900	68.110	47.050	61.120	57.550	64.850	60.460	57.290	49.120	50.480	49.000	45.350	67.580	51.450	71.570	52.640
TiO_2	0.440	0.440	1.000	0.450	0.540	0.470	0.690	0.630	0.710	0.640	1.340	1.530	1.450	1.880	0.510	0.680	0.380	1.180
Al_2O_3	15.960	13.450	13.630	13.060	8.910	17.160	17.850	15.490	15.820	13.460	16.410	13.600	14.080	15.730	15.250	18.390	14.530	17.180
Fe_2O_3	3.210	1.840	3.563	1.629	2.718	1.615	2.034	1.997	1.456	2.837	2.236	2.349	3.056	3.015	1.543	3.598	1.539	3.530
FeO	0.330	0.270	1.770	0.910	3.700	3.550	3.380	1.910	3.810	3.620	7.130	8.180	7.400	8.310	0.960	3.700	0.640	3.860
MnO	0.160	0.005	0.040	0.050	0.150	0.100	0.100	0.060	0.110	0.190	0.160	0.220	0.190	0.170	0.040	0.120	0.030	0.130
MgO	0.870	0.560	4.180	0.980	7.460	2.830	4.290	2.230	3.200	6.200	5.420	7.480	8.120	9.100	1.310	3.430	0.850	2.400
CaO	2.210	0.000	3.750	3.860	12.550	2.540	7.120	3.810	4.070	5.950	5.530	9.410	9.250	6.390	2.950	7.240	1.530	5.520
Na_2O	3.010	2.160	0.690	2.360	1.640	4.990	4.350	2.660	3.660	3.070	4.890	3.280	3.240	3.680	2.340	4.390	3.110	3.030
K_2O	4.260	4.750	4.920	3.340	0.130	1.160	0.900	4.210	3.850	3.030	0.150	0.130	0.120	0.060	3.030	0.780	4.270	5.420
P_2O_5	0.150	0.360	0.760	0.200	0.090	0.140	0.120	0.290	0.320	0.240	0.190	0.110	0.100	0.200	0.220	0.260	0.190	0.750
BaO	0.110	0.030	0.200	0.070	0.010	0.010	0.010	0.090	0.120	0.100	0.005	0.005	0.005	0.005	0.140	0.020	0.090	0.290
LOI	2.500	3.420	6.010	5.670	15.160	4.240	2.040	2.390	1.760	2.210	5.560	0.800	1.230	3.660	4.710	5.730	1.600	2.520
Total	100.830	100.185	99.413	100.689	100.108	99.925	100.434	100.617	99.346	98.887	98.141	97.574	97.241	97.550	100.583	99.788	100.329	98.450
Formation	Qt	Toml	Toml	Toml	Kl	Dyke	Dyke	Qt	Dyke	Dyke	Kl	Kl	Kl	Kl	Toml	Toml	Qt	Tmk
Locality	Uroh	Marampa	Marampa	Marampa	Karataun	Karataun	Karataun	Uroh	Urob	Uroh	Petagunan	Taroto	Taroto	Lebutang	Rasasisi	Rasasisi	Rasasisi	Kakea

/S.No	C14R	C15R	C16R	C17R	C24R	C30R	C31R	C32R	C34R	C36R	C37R	D07R	D08R	D11R	D12R	D18R	D24R	D25R
SiO_2	44.110	45.790	47.170	49.430	58.450	47.000	65.510	65.590	60.510	65.500	40.860	51.290	61.460	46.220	62.050	61.300	46.520	59.270
TiO_2	1.050	1.060	1.070	0.970	0.740	1.500	0.690	0.630	0.910	0.710	0.300	1.160	0.960	0.920	0.760	0.460	0.290	0.980
Al_2O_3	16.750	16.520	12.140	15.790	13.400	15.730	14.980	15.490	16.800	15.090	17.560	16.380	14.980	16.950	16.140	18.980	17.530	16.900
Fe_2O_3	5.806	4.912	7.650	3.968	2.443	1.741	1.964	1.441	2.180	1.741	3.597	5.696	3.225	6.316	3.024	4.411	2.914	3.146
FeO	3.540	4.740	3.320	4.330	3.120	5.820	2.210	2.060	3.140	2.420	2.540	3.360	1.300	3.720	3.020	0.440	4.010	2.370
MnO	0.180	0.170	0.160	0.160	0.130	0.140	0.070	0.080	0.090	0.070	0.310	0.140	0.060	0.160	0.070	0.110	0.120	0.070
MgO	5.870	6.060	6.510	6.410	5.880	6.620	2.820	1.410	3.860	2.840	8.250	4.370	2.700	5.140	2.920	1.900	10.970	4.020
CaO	8.420	10.760	9.970	8.480	5.250	6.150	3.800	3.740	5.330	3.740	24.430	6.760	3.480	9.950	1.020	1.670	10.260	5.300
Na_2O	3.030	2.690	2.390	2.470	2.980	5.380	3.210	3.050	3.480	3.180	0.360	4.620	3.400	1.870	3.480	5.070	2.240	3.180
K_2O	2.230	1.600	2.970	2.840	3.850	0.070	3.610	3.260	3.090	3.600	0.050	2.270	6.280	3.420	3.430	2.390	0.050	4.000
P_2O_5	0.570	0.600	0.570	0.530	0.450	0.180	0.240	0.280	0.350	0.270	0.005	0.820	0.760	0.640	0.340	0.370	0.010	0.460
BaO	0.100	0.110	0.130	0.190	0.130	0.005	0.070	0.070	0.080	0.070	0.005	0.330	0.260	0.180	0.100	0.150	0.005	0.160
LOI	7.050	3.370	4.160	3.640	2.100	6.520	0.870	3.550	0.970	0.970	1.640	1.990	1.180	3.630	3.140	3.570	4.130	0.005
Total	98.756	98.382	98.210	99.208	98.917	97.856	100.044	100.651	100.790	100.201	99.907	99.186	100.045	99.116	99.494	100.821	99.049	99.861
Formation	Tmt	Tmt	Tmt	Tmt	Tmk	Kl	Tmg	Qt	Tmg	Tmg	Dyke	Tmt	Tmb	Tmb	Dyke	Dyke	Dyke	Mw
Locality	Kakea	Kakea	Kakea	Kakea	Bituwe	Salore	Maki	Maki	Karate	Karataun	Karataun	Uroh	Uroh	Kasimpo	Kasimpo	Bau	Karataun	Matena

Abbreviations: Qt;Barupu Tuffs, Tmt;Talaya Volcanic Rocks, Tmk;Kambuno granite, Tmg;Mamasa granite, Tmb;Beropa Tuffs, Toml;Lamasi Volcanic Rocks, Kl;Latimojong Formation
Mw;Batuan Malihan Metamorphic Rocks

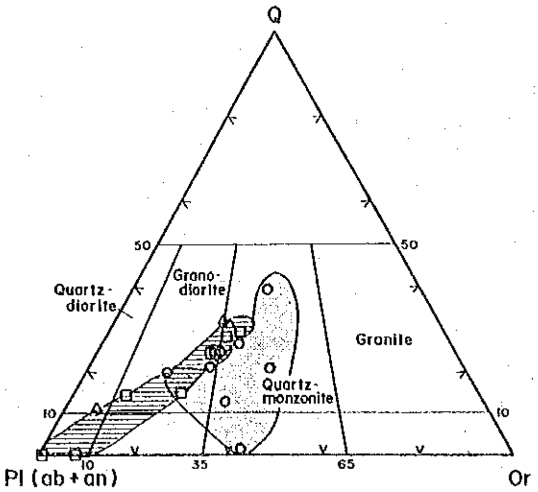
Table 2-3 Results of Whole Rock Analysis and Norm Calculation(2/3)

/S.No	D27R	D29R	D31R	D40R	E01R	E03R	E05R	E07R	E09R	E13R	E23R	E44R	E47R	G01R
SiO_2	68.130	67.800	67.930	44.690	66.750	63.630	61.970	58.470	64.950	76.560	55.220	62.090	51.640	67.730
TiO_2	0.620	0.620	0.630	4.350	0.590	0.700	0.780	1.000	0.540	0.080	0.570	0.430	1.560	0.420
Al_2O_3	15.240	15.160	15.650	12.080	15.760	15.520	16.420	16.710	15.630	13.290	18.010	17.680	16.500	15.060
Fe_2O_3	0.000	1.669	2.413	2.695	1.053	1.017	1.024	2.242	2.578	0.273	3.855	1.647	1.441	2.239
FeO	3.820	1.360	0.330	11.450	1.860	2.990	2.930	3.840	1.190	0.330	2.110	3.350	6.460	0.550
MnO	0.050	0.050	0.030	0.240	0.050	0.070	0.060	0.110	0.060	0.010	0.140	0.100	0.130	0.040
MgO	1.700	1.670	1.390	3.210	1.510	3.980	2.540	4.460	2.630	0.210	3.250	2.530	4.900	1.120
CaO	3.390	3.350	2.460	6.520	3.010	4.430	2.210	6.490	3.630	0.710	6.390	3.410	3.960	2.420
Na_2O	2.980	2.920	3.400	4.470	2.980	2.910	2.810	2.390	3.220	3.260	3.630	5.110	7.070	2.050
K_2O	3.790	3.830	4.300	0.070	4.400	3.530	5.200	2.190	3.720	4.730	1.520	1.080	0.840	4.380
P_2O_5	0.310	0.290	0.400	0.450	0.140	0.250	0.300	0.240	0.240	0.080	0.410	0.120	0.290	0.260
BaO	0.080	0.080	0.130	0.010	0.060	0.070	0.120	0.060	0.080	0.010	0.090	0.030	0.060	0.080
LOI	1.160	1.750	1.180	6.290	2.140	1.360	3.810	1.410	2.450	0.570	4.770	2.680	5.230	3.380
Total	100.245	100.549	100.243	96.525	100.303	100.457	100.174	99.612	100.918	100.113	99.965	100.257	100.081	99.729
Formation	Tmg	Dyke	Tmg	Tmg	Tmk	Tmk	Tmk	Tmk	Tmk	Tmk	Tmg	Dyke	Tmg	Qt
Locality	Matena	Matena	Matena	Tarawa	Rongkong	Rongkong	Rongkong	Rongkong	Punti	Rongkong	Malas	Fongo	Makalik	Uroh

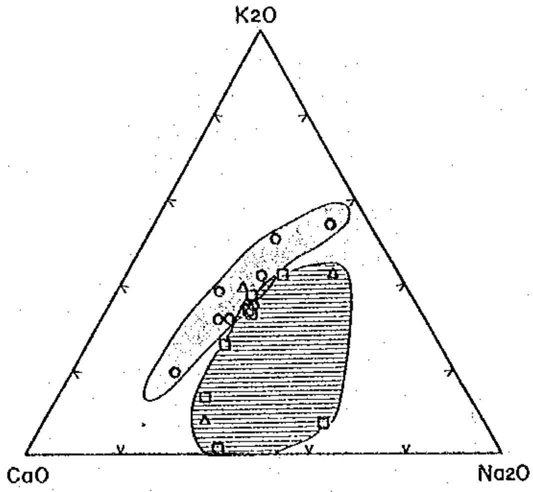
Abbreviations: Qt;Barupu Tuffs, Tmt;Talaya Volcanic Rocks, Tmk;Kambuno granite, Tmg;Mamasa granite, Tmb;Beropa Tuffs, Toml;Lamasi Volcanic Rocks, Kl;Latimojong Formation, Mw;Batuan Malihan Metamorphic Rocks

Table 2-3 Results of Whole Rock Analysis and Norm Calculation(3/3)

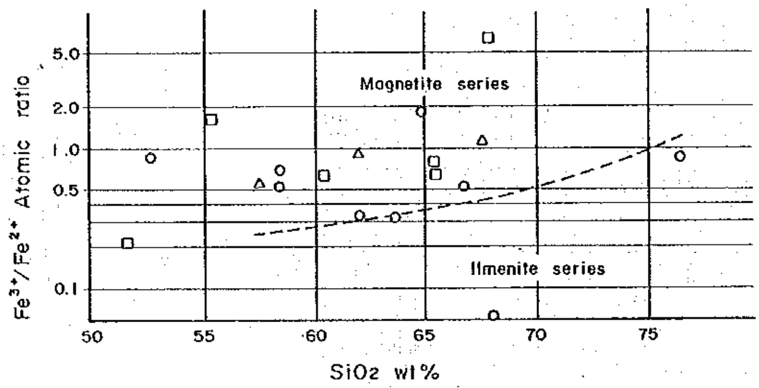
╱S.No	A30R	C13R	C24R	C31R	C34R	C36R	D12R	D27R	D29R	D31R	D40R	E01R	E03R	E05R	E07R	E09R	E13R	E23R	E47R
Q	7.618	0.993	8.783	21.038	11.734	20.972	22.235	24.221	27.231	25.660	0.000	23.527	17.159	16.528	15.097	20.975	37.777	11.062	0.000
C	0.000	0.000	0.000	0.000	0.000	0.000	5.656	0.810	0.811	2.173	0.000	0.958	0.000	2.864	0.000	0.279	1.708	0.000	0.000
or	5.319	32.032	22.754	21.335	18.262	21.276	20.271	22.399	22.635	25.413	0.414	26.004	20.862	30.732	12.943	21.985	27.954	8.983	4.964
ab	36.787	25.624	25.201	27.146	29.430	26.893	29.400	25.201	24.694	28.753	37.802	25.201	24.609	23.764	20.212	27.231	27.569	30.698	48.573
an	26.530	17.273	11.821	15.809	21.100	16.273	2.861	14.809	14.740	8.816	12.700	14.023	18.865	9.021	28.403	16.451	3.004	28.366	10.821
ne	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
wo	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
di-wo	3.342	2.195	4.721	0.620	1.283	0.221	0.000	0.000	0.000	0.000	6.984	0.000	0.622	0.000	0.932	0.000	0.000	0.282	2.899
di-en	2.302	1.443	3.551	0.464	0.917	0.158	0.000	0.000	0.000	0.000	2.810	0.000	0.420	0.000	0.641	0.000	0.000	0.243	1.648
di-fs	0.770	0.596	0.696	0.094	0.251	0.044	0.000	0.000	0.000	0.000	4.240	0.000	0.154	0.000	0.217	0.000	0.000	0.000	1.127
hy-en	8.377	4.531	11.087	6.556	8.692	6.912	7.269	4.232	4.157	3.460	3.735	3.759	9.487	6.323	10.462	6.547	0.523	7.847	0.000
hy-fs	2.803	1.870	2.173	1.332	2.378	1.920	1.923	6.929	0.188	0.000	5.637	1.664	3.470	3.358	3.536	0.000	0.267	0.010	0.000
ol-fo	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.394
ol-fa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.686	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.569
mt	2.947	5.116	3.460	2.846	3.160	2.523	4.382	0.000	2.418	0.000	3.906	1.526	1.474	1.484	3.250	2.466	0.396	5.587	2.088
hm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.412	0.000	0.000	0.000	0.000	0.000	0.876	0.000	0.000	0.000
il	1.311	2.242	1.406	1.311	1.729	1.349	1.444	1.178	1.178	0.761	8.264	1.121	1.330	1.482	1.900	1.026	0.152	1.083	2.964
tn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.563	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ap	0.284	1.776	1.065	0.568	0.829	0.639	0.805	0.734	0.687	0.947	1.065	0.331	0.592	0.710	0.568	0.568	0.189	0.971	0.687
Total	98.390	95.660	96.700	99.110	99.760	99.170	96.260	99.020	98.740	98.950	90.230	98.100	99.030	96.250	98.150	98.380	99.540	95.120	94.810
A/CNK	1.443	1.230	1.109	1.411	1.412	1.434	2.035	1.500		1.540	1.092	1.517	1.428	1.607	1.510	1.479	1.528	1.561	1.390
D.I.	49.724	58.649	56.738	69.519	59.426	69.141	71.936	71.821		79.826	38.216	74.732	62.630	71.024	48.252	70.191	93.300	50.743	53.537
Fe^3/Fe^2	0.542	0.823	0.693	0.800	0.625	0.647	0.901		1.104	6.579	0.212	0.509	0.306	0.315	0.525	1.949	0.744	1.644	0.201



Normative Quartz - Plagioclase - Orthoclase Diagram



$K_2O - Na_2O - CaO$ Diagram



Fe^{3+}/Fe^{2+} Ratio - SiO_2 Diagram

LEGEND

- ○ Kambuno Granite (Tmk)
- □ Mamasa Granite (Tmg)
- △ Stocks and Dykes

Fig.2-10 Normative and Chemical Composition Diagrams of Granitic Rocks

2-5 Geologic Structure

(1) Fold structure

Several fold systems, from regional anticline to local minor foldings, were observed in the survey area.

Regional anticlinal structure is distinctive in the northwestern to central area within metasediments of the Latimojong Formation, tuffaceous siltstone of the Beropa Tuffs, and black shale of the Sekala Formation. Slate and phyllitic shale along S. Karataun generally dip to the west. Whereas, black shale/siltstone along S. Betuwe commonly shows east dipping. Tuffaceous siltstone along the middle reaches of S. Uroh has a trend of gentle east dipping. This anticlinorium has an axis of north-south direction.

Local anticlines and synclines of similar trend are observable in the area between S. Pongo and Kp. Rantedonga. A couple of local anticline and syncline of north-south axis was recognized within black shale in the Bau prospect.

Mesozoic to Neogene structures in the eastern part of the survey area were not clear in most cases because of the indistinct bedding of formations.

(2) Fault

Faults of NW to WNW system were found within middle to upper Miocene volcanic-sedimentary rocks in the northeastern part of the survey area.

Faults of E-W trend occur within the Mamasa granite and the Barupu Tuffs in the southwestern area.

A couple of faults of NE trend was found within metasediments near the mineralized zones in the Batuisi prospect.

Any fault of NNE to N-S system, which was identified through the satellite imergery photogeological interpretation, has not been encountered during the geological survey. This type of fractures probably exists as igneous joints and/or minor faults of small displacement. Some of intrusive rocks showed the similar trend in the survey area.

2-6 Mineralization and Associated Alteration

Prior to the survey, examination of existing geological informations has been conducted. Together with discussions with geologists of DMR and other organization, target mineralizations in the survey area were set up as follows:

① Primary gold mineralization mainly in the western area.

② Massive sulphide mineralization within the Miocene pyroclasic rocks in the eastern area.

③ Porphyry copper-gold mineralization in the southwestern area.

In the course of regional survey, no positive indication of massive sulphide mineralization has been come out, even though the extensive development of Miocene dacitic to andesitic pyroclastic rocks in the eastern area. An alteration zone, which is composed of silicification and pyritization accompanying with weak sericite and/or kaoline minerals, was found within dacite lava along S. Marampa near Limbong. Any indication of basemetal mineralization, however, has not been detected in the zone. The possibility of porphyry copper-gold mineralization similar to the Sasak deposit was negative too in the vicinity of the Mamasa granite body in the southwestern part of the survey area.

Whereas in the northwestern area, indications of primary gold mineralization were caught at several places. Occurrences of gold in pan concentrates were counted in many places. Floats of vein quartz are relatively common in some places along S. Karama and its major tributaries. Outcrops of quartz veins were located in Bau, Batuisi, and a few other places. In Bau and Batuisi prospects, semi-detailed geological survey and geochemical sampling were carried out.

The following descriptions are based upon the results of field observations (geology and panning prospecting) and some laboratory works such as ore assaying, ore microscopy, and X-ray diffraction analysis. Assay results of ore samples in each area are shown in Tables 2-6 to 2-9.

(1) Bau prospect

The Bau prospect is located along S. Salore and its tributeries in the central northern part of the survey area (Fig.1-2). It covers an area of about 50 km^2. The area, situated in one of the most inland part of the central western Sulawesi, is sorrounded by steep hills and mountains of more than 1,000 m above sea level. Altitudes of the prospect are in the proximity between 460 m (at the bridge of S. Salore) and 660 m (at Kp. Bau). Access from the outer world is very difficult.

In this prospect, one continuous zone of quartz veins/networks was delineated from the junction of S. Salore and S. Belopi up to the vicinity of Kp. Bosokan. Although width of each quartz veins is not big, no wider than 30 cm, and continuation of each veins has yet been confirmed, the zone extends more than 2.5 km to north-northwest. Quartz veins are hosted by slate, phyllitic black shale, siltstone, andesite, and basalt/dolerite of the Latimojong Formation.

Table 2-4 Results of Microscopic Observation of Thin Section(1/2)

Sample No.	Locality	Rock Name	Formation	Texture	Phenocryst/Crystal Fragment									Groundmas/Matrix						Alteration
					Qz	Kf	Pl	Bi	Hb	Px	Ol	Ep	Op	Qz	Kf	Pl	Hb	Px	Gl	
A1R	S. Uroh	Crystal Tuff	Qt	Pycl	•		△	△		•						●			○	Bi·Px→Ch
A2R	S. Uroh	Crys-lith Tf	Qt	Pycl	○		○	△	•										○	Sandstone fragment
A3R	S. Marampa	Dacite	Toml	Porp	○		△	△					•	•		△			△	Pl·Bi→Ch
A5R	S. Marampa	Dacite	Toml	Prop			●	○					•	•		○			•	Pl·Bi→Ch·Ca
A6R	S. Marampa	Andesite	Toml	Porp		•	○		△				•			○	△			Pl→Ch·Se, Hb→Ch
A10R	Kariango	Andesitic Tf	Tmt	Lepb						○				○					△	Gl→Ch
A11R	S. Bituwe	Andesite	Dyke	Porp			●		○				•			○	△			
A12R	S. Bituwe	Andesite	Tmps	Porp	•		○		○				•			△	△			Pl·Hb→Se·Ch·Ca
A13R	S. Patoko	Andesite	Tmb	Glom-ph			△		○	○						△		•		Hb·Pl→Ch
A29R	S. Karataun	Andesite	Dyke	Porp			●		△				•			△				Pl→Ch·Se·Ca, Hb→Ch·Ca
A30R	S. Karataun	Qz Porphyry	Dyke	Hypd-gr	△		●			○			•							
B1R	Salutallang	Crystal Tuff	Qt	Pycl	△		△	△											○	
B9R	S. Uroh	Andesite	Dyke	Porp			●			△			•			△				Pl→Ch·Se·Ca, Px→Ch
B10R	S. Uroh	Andesite	Dyke	Porp			●	△		△			•	△		•				
B16R	S. Balimbing	Andesite	Kl	Porp			△						•			△				Pl→Se·Ch
B21R	S. Balimbing	Dolerite	Kl	Ophi			●			○		•	•							Pl→Ch
B25R	S. Petagunan	Andesite	Kl	Porp			●									○				Pl→Ca·Ch·Ep
B27R	S. Petagunan	Andesite	Kl	Porp			△			•			•			○				Pl→Se, Lithic fragment
B30R	S. Taroto	Dolerite	Kl	Ophi			●		●			△	•							Qz vein
B31R	S. Taroto	Dolerite	Kl	Ophi			●		●				•							
B35R	S. Lebutang	Basalt	Kl	Int-gr			●			○			•			△				
C4R	S. Rasasisi	Andesite	Toml	Porp			●		△							△				
C7R	S. Rasasisi	Andesite	Toml	Porp			●						•			△				Pl→Ch
C8R	S. Rasasisi	Dacite	Qt	Porp	△	△	△	△					•			△				
C9R	S. Marampa	Dacite	Toml	Porp	△		△									○				Pl→Se
C10R	S. Marampa	Andesite	Toml	Porp			●			△			•			△			△	Pl→Ch
C11R	S. Marampa	Qz Porphyry	Toml	Porp	△	△	•	○					•	○						
C12R	S. Marampa	Qz Monzonite	Tmk	Hypd-gr	△	○	○	△	△				•							
C13R	S. Kakea	Diorite	Tmk	Hypd-gr			●		•	△			•							
C14R	S. Kakea	Andesitic Tf	Tmt	Pycl			△			△			•			△				Pl→Ch
C15R	S. Kakea	Andesite	Tmt	Porp			●			△			•			•			△	Px→Ch·Ca
C17R	S. Kakea	Andesite	Tmt	Glom-ph			●			△						○			△	
C23R	S. Bituwe	Granodiorite	Tmk	Porp			○	△					•	△		△				Pl→Ca
C24R	S. Bituwe	Granodiorite	Tmk	Hypd-gr			●	△		○			•	•		•				
C30R	S. Salore	Basalt	Kl	Int-gr			△			•						•				Pl·Px→Ch
C31R	S. Maki	Qz Monzonite	Tmg	Hypd-gr	○	●	○	△	△											
C32R	S. Maki	Dacite	Qt	Porp			●	△		△				•		△				
C34R	S. Karate	Qz Monzonite	Tmg	Hypd-gr	•	○	●	△	△											
C36R	S. Karataun	Qz Monzonite	Tmg	Hypd-gr	△	●	○	△	△											
C37R	S. Karataun	Pyroxenite	Dyke	Hol-gr	•					○			•							Px→Ch

Abundance of Minerals: ●;Abundant, ○;Common, △;Rare, •;Trace

Abbreviations

Formation Names: Mw;Batuan Malihan Metamorphic Rocks, Kl;Latimojong Formation, Tet;Toraja Formation, Toml;Lamasi Volcanic Rocks, Tmb;Beropa Tuffs, Tmps;Sekala Formation, Tmt;Talaya Volcanic Rocks, Qt;Barupu Tuffs, Tmk;Kambuno granite, Tmg;Mamasa granite

Texture : Pycl;Pyroclastic, Porp;Porphyritic, Lepb;Lepidoblastic, Glom-ph;Glomerophyric Hypd-gr;Hypidiomorphic-granular, Ophi;Ophitic, Int-gr;Inter-granular, Hol-gr;Holocrystalline-granular, Altm-gr;Allotriomorphic-granular

Minerals : Qz;Quartz, Kf;Potash feldspar, Pl;Plagioclase, Bi;Biotite, Hb;Hornblende, Px;Pyroxene, Ol;Olivine Ep;Epidote, Op;Opaque Minerals, Gl;Glass, Ch;Chlorite, Se;Sericite, Ca;Carbonates

Table 2-4 Results of Microscopic Observation of Thin Section(2/2)

Sample No.	Locality	Rock Name	Formation	Texture	Phenocryst/Crystal Fragment									Groundmas/Matrix						Alteration
					Qz	Kf	Pl	Bi	Hb	Px	Ol	Ep	Op	Qz	Kf	Pl	Hb	Px	Gl	
D7R	S. Uroh	Andesite	Tmt	Porp			●			○			•			○		•	△	
D8R	S. Uroh	Andesite	Tmb	Porp			●	△		○			•			○		•	△	
D11R	S. Kasimpo	Basalt	Tmb	Int-gr			●			●	△		•			△		△		
D12R	S. Kasimpo	Granodi Porp	Dyke	Porp			●		△				•			△				Pl・Hb→Ch
D13R	S. Kasimpo	Andesitic Tf	Tmb	Pycl			○						•			△				Lithic fragment
D18R	Kp. Bau	Andesite	Dyke	Porp			●		△				•			△	•			Pl・Hb→Ch
D24R	S. Karataun	Pyroxenite	Dyke	Hol-gr						△										Px→Ch, Qz vein
D25R	S. Matena	Bi Gneiss	Mw	Lepb	●		○	○	○				•							
D26R	S. Matena	Aplite	Tmg	Altm-gr	○	●	○	△												
D27R	S. Matena	Qz Monzonite	Tmg	Hypd-gr	△	●	●	△	△											
D29R	S. Matena	Granodi Porp	Dyke	Hypd-gr			●	△		△						•				
D31R	S. Matena	Qz Diorite	Tmg	Porp	△		△	△								•				
D38R	S. Tarawa	Gabbro	Dyke	Porp			●			○	△		•			•				
D40R	S. Tarawa	Diorite	Tmg	Hypd-gr			●			○			•							Qz vein
D44R	S. Tarawa	Dolerite	Kl	Ophi		●	●			•			•							Kf・Pl→Ch
E1R	S. Rongkong	Qz Monzonite	Tmk	Hypd-gr	△	●	○	△												
E2R	S. Rongkong	Qz Monzonite	Tmk	Hypd-gr	△	○	●	△												
E3R	S. Rongkong	Qz Monzonite	Tmk	Hypd-gr	△	○	●	△	•											
E5R	S. Rongkong	Qz Monzonite	Tmk	Hypd-gr	○	○	●	•	•											Pl→Ch
E7R	S. Rongkong	Qz Monzonite	Tmk	Hypd-gr	△	•	●	△		△										
E9R	S. Punti	Qz Monzonite	Tmk	Hypd-gr	○	●	●	△												
E13R	S. Rongkong	Aplite	Tmk	Altm-gr	○	●	△	•							△					
E23R	S. Malas	Diorite	Tmg	Hypd-gr			●	•	•	○										Pl・Px→Ch
E24R	S. Salore	Granodiorite	Tmg	Porp			●	△		△		△				△				Pl→Ch
E43R	S. Pongo	Diorite	Tmg	Hypd-gr			●			•										
E44R	S. Pongo	Andesite	Dyke	Porp			●	△	△							△				Pl→Ch
E54R	S. Pongo	Shale	Kl	-	○								△							
E55R	S. Pongo	Shale	Kl	-			△													Andesite fragment
E69R	S. Malela	Dolerite	Kl	Ophi			●			●										Pl・Px→Ch
F37R	S. Kalutun	Diorite	Tmg	Hypd-gr			●			△			•							Pl→Se・Ch

Abundance of Minerals: ●;Abundant, ○;Common, △;Rare, ・;Trace

Abbreviations

Formation Names: Mw;Batuan Maliban Metamorphic Rocks, Kl;Latimojong Formation, Tet;Toraja Formation, Toml;Lamasi Volcanic Rocks, Tmb;Beropa Tuffs, Tmps;Sekala Formation, Tmt;Talaya Volcanic Rocks, Qt;Barupu Tuffs, Tmk;Kambuno granite, Tmg;Mamasa granite

Texture : Pycl;Pyroclastic, Porp;Porphyritic, Lepb;Lepidoblastic, Glom-ph;Glomerophyric, Hypd-gr;Hypidiomorphic-granular, Ophi;Ophitic, Int-gr;Inter-granular, Hol-gr;Holocrystalline-granular, Altm-gr;Allotriomorphic-granular

Minerals : Qz;Quartz, Kf;Potash feldspar, Pl;Plagioclase, Bi;Biotite, Hb;Hornblende, Px;Pyroxene, Ol;Olivine Ep;Epidote, Op;Opaque Minerals, Gl;Glass, Ch;Chlorite, Se;Sericite, Ca;Carbonates

Table 2-5 Results of X-ray Diffraction Analysis (1/2)

Sample No.	Remarks	Rock unit	Location	Clay Mineral							Sulfate m.			Carbonate			Silicate			Feld.		Miscellaneous m.					
				Mo	Ch	Se	Mu	Ka	Pr	Ha	Al	Gy	Ja	Ca	Do	Si	Cr	Tr	Qz	Pl	Kf	Py	Ma	He	Bi	Ho	
A4R	Altered andesite		S. Marampa			○													◎			o					
A6R	ditto		S. Marampa			o		●							●				◎	○	o						
A16R	Argillaceous shale		S. Salore			o		o											◎	○	●	o					
A17R	ditto		S. Salore																◎	○					○		
A27R	White argillaceous rock		Kp. Bau			o						●							◎	o	o	o?					
A39R	Wall rock of quartz vein		S. Tarawa		○									●	o				○	◎							
B7R	Quartz vein		S. Uroh																◎		o	o					
B13R	Altered andesite		S. Balimbing		●														◎								
B17R	Quartz vein		S. Balimbing			●?									o				◎	●		●					
B18R	Gray altered andesite		S. Balimbing		o	●								●					◎	○		o					
B19R	ditto		S. Balimbing		o									o					◎	◎		●					
B20R	ditto		S. Balimbing		○										●				○	○		●					
B28R	Quartz vein		S. Lebutang											●					◎	●		○					
B28AR	Green altered andesite		S. Lebutang		○									●					◎	○	●	○					o
B33R	Quartz vein		S. Taroto		o														●	○							○
B34R	Wall rock of Py vein		S. Lebutang									●							○			○	○				o
B36R	Quartz vein		S. Lelating		○														o	○							
B37R	ditto		S. Lelating		o									o					○								
B38R	Country rock of bedded Py		S. Bone			●		o						○					◎	○		○					
B46R	Wall rock of quartz vein		Ridg of Bone		○				●?										○								
C1R	Altered porphyritic dacite		S. Rasasisi		○	o								o					◎	○	○	o					
C2R	ditto		S. Rasasisi		o	●													◎	○	○						
C3R	ditto		S. Rasasisi		○	●													◎	◎	○						
C6R	silicified rock with Py		S. Rasasisi			●													○								
C10R	Wall rock of Py veinlets		S. Marampa			o		○											◎	●	●						

Abbreviations: ◎:Abundant ○:Common o:Few ●:Rare, Mo:Montmorillonite, Ch:Chlorite, Se:Sericite, Mu:Muscovite, Ka:Kaoline, Pr:Pyrophyllite, Ha:Halloysite, Al:Alunite, Gy:Gypsum, Ja:Jarosite, Ca:Calcite, Do:Dolomite, Si:Siderite, Cr:α-Cristobalite, Tr:Toridymite, Qz:Quartz, Pl:Plagioclase, Kf:Potassium feldspar, Py:Pyrite, Ma:Magnetite, He:Hematite, Bi;Biotite, Ho:Hornblende,

Table 2-5 Results of X-ray Diffraction Analysis(2/2)

Sample No.	Altered Rock	Rock unit	Location	Clay Mineral							Sulfate m.			Carbonate			Silicate			Feld.		Miscellaneous m.				
				Mo	Ch	Se	Mu	Ka	Pr	Ha	Al	Gy	Ja	Ca	Do	Si	Cr	Tr	Qz	Pl	Kf	Py	Mo	He	Bi	Ho
C19R	Quartz vein		S. Kakea																◎		●					
C20R	Silicified rock		S. Kakea																◎		o					
C21R	Quart veinlets		S. Kakea																◎							
C26R	Wall rock of Py vein		S. Belopi		○									o					◎							
C27R	ditto		S. Belopi		○														◎							
C29R	Quartz vein		S. Salore		o	●?								●	○				◎	●	●	○				
E20R	ditto		S. Bituwe											○	○				o					o		
E21R	Gray argillaceous rock		S. Bituwe			●?								◎					o	●						
E22R	Green argillaceous rock		S. Bituwe	○															○	◎		o				
E36R	Quartz vein		S. Bosokan																◎							
E38R	ditto		Kp. Bau		●														◎	○						
E45R	ditto		S. pongo					o						◎	o				○							
E50R	Altered tuff		S. Malela		○									●?					o	◎	o					
E51R	Quartz vein		S. Malela		o				●?					o					◎	o						
E52R	ditto		S. Malela		●									●?					◎							
E64R	Silicified rock with Py		S. Malera		o				●?										◎			●				
F13R	White argillaceous granite		S. Paku		○	o								o					◎	◎	◎					
F14R	ditto		S. Paku		○	o								○					◎	◎	◎					
F15R	ditto		S. Paku		○	●								o					◎	○	o					
F16R	ditto		S. Paku		○	●													◎	◎	○					
F20R	Altered porphyritic rock		S. Paku			o		○											◎		○					
F31R	Limestone with Py		S. Salore											◎					o	●		●				
F33R	Green altered rock		S. Salore		○	o								○					○	◎						
F35R	Quartz vein		S. Salore											◎					◎							
F37R	Green altered diorite		S. Kalutun		○				●?						●?					◎						
G5R	Gray silicified rock		Kp Buakayu																◎		●					

Abbreviations: ◎:Abundant ○:Common o:Few ●:Rare, Mo:Montmorillonite, Ch:Chlorite, Mu:Muscovite, Se:Sericite, Ka:Kaoline, Pr:Pyrophyllite, Ha:Halloysite, Al:Alunite, Gy:Gypsum, Ja:Jarosite, Ca:Calcite, Do:Dolomite, Si:Siderite, Cr:α-Cristobalite, Tr:Toridymite, Qz:Quartz, Pl:Plagioclase, Kf:Potassium feldspar, Py:Pyrite, Ma:Magnetite, He:Hematite, Bi:Biotite, Ho:Hornblende.