# REPORT ON GEOLOGICAL SURVEY OF CENTRAL SULAWESI, INDONESIA

Vol. I

GENERAL



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OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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## Preface

The Government of Japan, complying with the request of the Government of the Republic of Indonesia, committed to investigate the potentiality of mineral resources at block Number Four in Central Sulawesi, Indonesia and entrusted the Overseas Technical Cooperation Agency with the implementation of the survey.

The purpose of this survey was to select the most promising area with high potentialities of mineral resources in the above block Number Four (30 % of the block at the most) and prepare topographical maps of the scale, 1: 50,000. For this purpose, the Overseas Technical Cooperation Agency sent a survey team to Indonesia which carried out a field survey with the cooperation of the Metallic Minerals Exploration Agency of Japan, Kokusai Aerial Surveys Co., Ltd., Nikko Exploration & Development Co., Ltd., Indonesian Government and Geological Survey of Indonesia. The outline of the survey is as follows:

### Outline of the Survey

| | | | |
|---|---|---|---|
| 1. | Location | Central Sulawesi Province, Republic of Indonesia | |
| | | Latitude: | South Latitude from $1^{o}$ to $2^{o}$ |
| | | Longitude: | East Longitude from $120^{o}$ 28" 27.99" to the western coast line. |
| 2. | Area | 14,160 square kilometers | |
| 3. | Period of the field survey | From 21st September 1970 | |
| | | To 1st December 1970 | |

4. Items of the survey — Geological Ground Survey

Photogeological Survey

Aeromagnetic Survey

Aerial Photography

Control Point Survey

5. Number of persons

Japanese survey team: 17 persons

Indonesian survey team: 6 persons

Following the field survey, a series of related study and analysis was carried out in Japan and the results were summarized in a report comprising the following three volumes.

| | | |
|---|---|---|
| Volume 1 | | General |
| Volume 2 | Part 1 | Aerial photography |
| | Part 2 | Photogeology |
| | Part 3 | Control point surveys |
| Volume 3 | | Aeromagnetic survey |

The report concludes that a promising mineral resources exist in the area between south latitude $1^{\circ}$ to $1^{\circ}30'$ and east longitude from $119^{\circ}30'$ to $120^{\circ}15'$, on the basis of the results of the survey and available data.

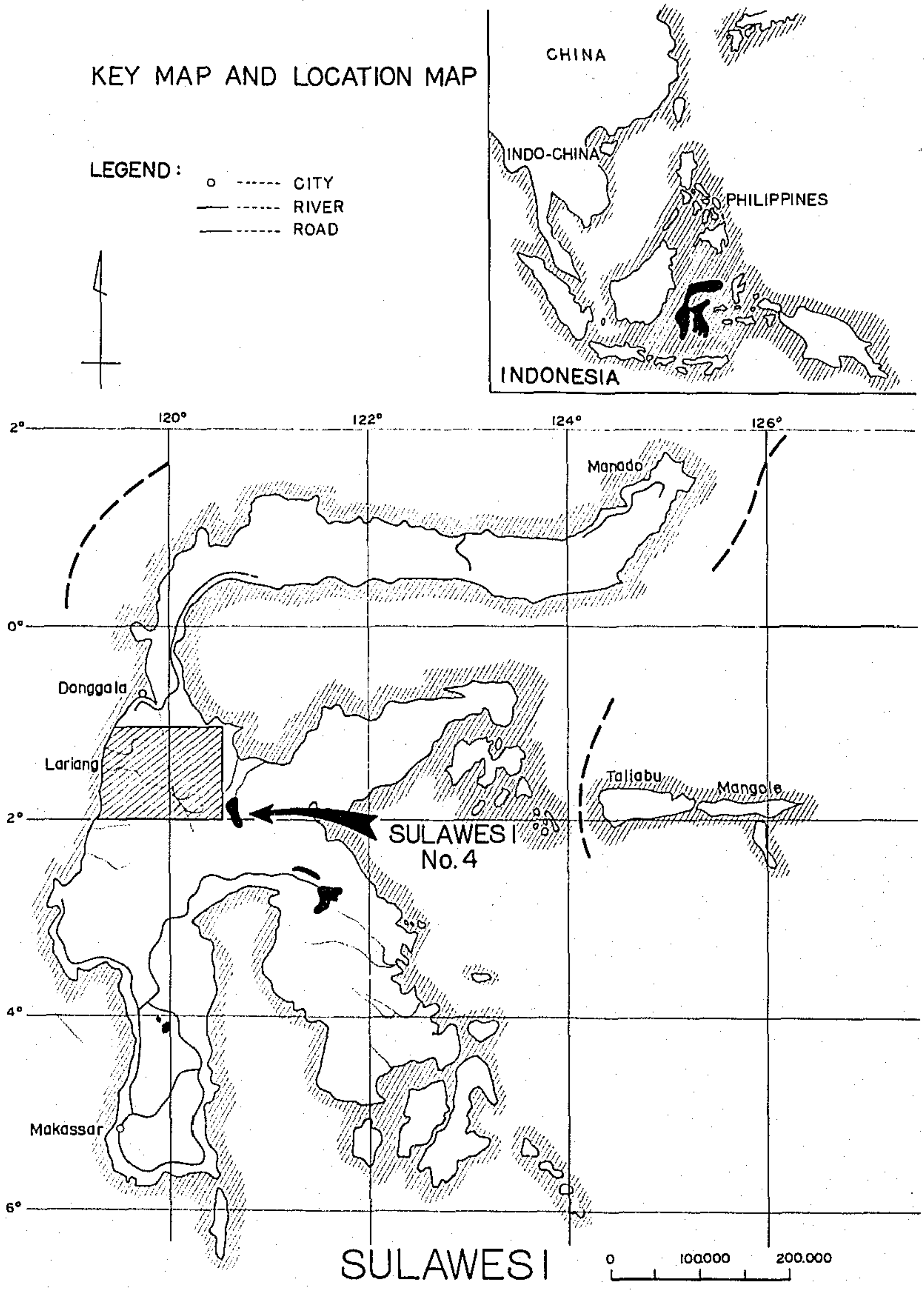
I would like to take this opportunity to express my gratitude to the members of the survey team for the job well-done and to officials of the Government of Indonesia and Geological Survey of Indonesia for their cooperator and kindness *shown to the survey team for the support in the implenmentation of the survey.*

June, 1971

KEIICHI TATSUKE

Director General

Overseas Technical Cooperation Agency.


KEY MAP AND LOCATION MAP
LEGEND :
CITY
RIVER
ROAD
CHINA
INDO-CHINA
PHILIPPINES
INDONESIA
120°
122°
124°
126°
2°
0°
2°
4°
6°
Manado
Donggala
Lariang
Taliabu
Mangole
SULAWESI
No. 4
Makassar
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100.000
200.000
SULAWESI

CONTENTS

## Abstract

This survey was conducted for the purpose of selecting an area of potential mineral resources in Central Sulawesi. For this purpose, a ground geological survey, aeromagnetic survey and photogeological survey were conducted accompanied by an aerial photography and control point survey.

Rocks in the survey area consist of sedimentary rocks, igneous rocks and metamorphic rocks. Sedimentary rocks consist of Quaternary deposit, Tertiary sedimentary rocks and slate which is presumed to have been formed in the Mesozoic era. Igneous rocks consist of granites, kentallenite, gabbro, dolerite, andesite, decite, v.s. which intruded in the latest Tertiary period. Metamorphic rocks consist of crystalline schists and gneiss of unknown age. The granite group is seen in nearly half of this area and the Quaternary deposit distributes extensively in the west coast district and along the Palu river.

The structural line which controls this survey area is in the direction of Tawaelia graben (N-S) recognized at the east part of this area, and of Fossa Sarasina (NNW-SSE) at the center of this area. The directions of each geological formation run parallel to the above one, and many of the intrusive and extrusive bodies of igneous rocks have intimate relation with above two grabens, especially with the latter.

The formation of these two grabens is considered to have taken a long time, but its completion is presumed to have been in the last period of Tertiary.

In this area, metallic mineral deposit of large scale worked or working, is not recognized, but along the upper stream of the river of Sopu, disseminated

zone mainly consisting of pyrite is recognized. Near the mouth of the river of Lariang, a sign of petroleum deposit is observed.

As the accuracy of ground geological survey in the recent survey was limited, the result of photogeological survey was frequently used for the interpretation of geology of this area. Especially in the interpretation of the Tertiary and Quaternary areas, photogeological survey is very useful.

As a result of aeromagnetic survey in this area, magnetic anomaly was recognized mainly in the igneous rocks and the result was used for the geological interpretation.

The advantageous geological condition for the existence of mineral deposits in this area is the existance of granites and the contamination zone of granite is particularly significant. The distribution of the mineral deposits may be controlled by the main structural direction of this area. Moreover the existance of altered zone, hornfelsized zone, and mineralized zone which is already known are favorable conditions for mineral exploration.

In this area, a rectangular district from $1^{o}$ to $1^{o}$ 30' South Latitude, from $119^{o}$ 30' to $120^{o}$ 15' East Longitude has been chosen as the most promising area for mineral resources.

In general it requires a long time and a tremendous amount of money whether mineral resources exist in a particular area. For the area like this survey area where there is very few data available, judgement on the existence of mineral resources will inevitably lack correctness. In the future, therefore, various methods of exploration including geological survey, geochemical survey and geophysical survey should be used to determine the existence of mineral resources and for the exploitation of the deposit.

At the same time, it is essential to endeavor for the economical and industrial developments in the area and for the expansion of demand for mineral resources.

# 1 Introduction

## 1-1 Purpose of Survey

The purpose of the survey in Central Sulawesi province for this year is to determine the area of high potentiality for mineral resources in the survey are. The area to be selected is less than 30 per cent of the survey area.

## 1-2 Process of Survey

As the details of field work are described in each report, this Chapter will only deal with the geological ground survey in detail.

### 1-2-1 Period of survey

Duration of the stay at the field.

From 21st, September to 1st, December, 1970. 72 days

Duration of the actual field survey.

From 14th, October to 16th, November, 1970. 33 days.

### 1-2-2 Type of survey

Geological survey of main route

Point survey using helicopter

Rough interpretation of photogeology

The geological survey was carried out on foot but automobiles and helicopters were used for transportation between the survey area and Palu city where base camp was established.

1-2-3 Length of the main survey route

| | | | |
|---|---|---|---|
| 1 | Palu river route | (Sidondo - Kulawi) | 45 KM |
| 2. | Mid-stream of Lariang river route | (Gimpu - Banggaiba) | 80 KM |
| 3 | Upper stream of Lariang river route | (Kulawi-Gintu-Marei river) | 90 KM |
| 4 | Karangana river route | (Turning point from the Lariang - Kalamanta) | 50 KM |
| 5 | Rompo river route | (Torire - Kulawi) | 50 KM |
| 6 | Sopu river route | (Bora-Palulu-Upper stream of Sopu river) | 40 KM |
| 7 | Rio route | (Baluase-Rio) | 50 KM |
| 8 | Lindu lake route | (Lindu lake - Wuasa) | 50 KM |
| Total | | | 455 KM |

1-3 Previous surveys

The main geological reports on the Central Sulawesi province published so far are by Brouwer, Hetzel, Straeter (1934 with the cooperation of Stolley, Broili, de Beaufort, van der Vlerk, Dozy), Willems (1937), Brouwer (1941, 1947), Egeler (1946, 1948) de Roever (1947). "The geology of Indonesia" (1949 by Bemmelen), a summary of these report, has been published.

Since the geological ground survey which was carried out by Brouwer in 1929, the study on the geology of this area has made rapid progress.

As the data previous to the Brouwer's the followings are available.

Comprehensive reports of the topography, climatology and geology were written by Abendanon. m.i. (1915-1918) as "Geologische en Geographische Doorkruisingen van Midden Celebes"

Also the three reports by Waterschoot van der Gracht (1915), Hovig & Ruffen (1918), Reyzer (1920) describe the geology of western Central Sulawesi. These reports refer to the Tertiary formations distributed from the western coast to the mountain district and also touch on the period of granite intrusion.

Abendanon, Hövig & Ruffen, and Reyzer definitely tell the age of volcanic pyloclastic formation which spreads widely in the southern part of this area.

Geological survey was carried out by Brouwer, Hetzel and Straeter under the leadership of Brouwer in 1929, centering on the Central Sulawesi province. The result was published by Brouwer, thus contributing greatly to the elucidation of the structural geology of this area. Brouwer divided this area into three zones, namely, Kolonodale, Poso, Palu zone and two sub zones, namely, Tawaelia, Peleru sub-zone and he also made a study on the structural line called "Median line".

In 1937, Willems concluded, as the result of his study about the crystalline schist in Poso zone, that regional metamorphism was epi to meso metamorphism decreased gradually from western part to eastern.

Egeler (1946, 1948) and de Roever (1947), after examining the rocks collected by Brouwer, came to the same conclusion.

As for the age of the crystalline schist formation, one of the previous studies is that by Kundig (1932), but Brouwer (1941) presented several objections against the former conclusion. In 1946 Egeler advanced petrological arguments and in effect attributed the main phase of regional metamorphism to the Hercynian orogenesis. in the latter part of the Mesozoic radiolarites and chart,

In 1934, Brouwer concluded that the age of the granite intrusions in Palu zone was not older than the late Mesozoic or Tertiary. Waterschoot van der Gracht (1915), Hovig & Ruffen (1918) and Reyzer (1920) maintained that some granites and diorites in the southern part of the Palu zone are post-Eocene age.

Both conclusions agree on the point that it was in young age, perhaps in the Tertiary.

The sediments in the Tawaelia sub-zone are young Miocene or younger according to van der Vlerk & Dozy (1934). In the drainage basin of the Karama river on the southwestern side of the Palu river, coal-bearing Eocene occurs, described by Reyzer (1920). Witkamp (1940) observed along the lower course of the Lariang river a formation of sandy shales and occasional limestones consisting some part of Mamudju-Doda embayment of Tertiary marine sediment. Further east, from the large hairpin bent in the Lariang to the boundary of the Pre-Tertiary, he observed a synclinal basin of Celebes Molasse.

The above is an outline of the previous investigations on the geology of this area. For the economic geology, "Verslagen en Mededeelingen etc" No. 12, Batavia (1920) described about the gold ore deposit at the southwestern part of the Central Sulawesi, but it assessed the above deposit as no value.

Near the mouth of the Lariang, Doda Oil Co., Ltd. explored and mined petroleum and natural gas. In the neibouring district, Batavia Oil Co., Ltd. took the same action. However, the data on these districts are not available in Japan and therefore details of the exploration are not known.

## 1-4 Bibliography & Map

### 1-4-1 Bibliography


| | | |
|---|---|---|
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| 2 | Metallic Minerals Exploration Agency of Japan: | Report by the Preliminary Survey Team of Sulawesi, Republic of Indonesia. |
| 3 | Ministry of Mines (1969): | Minerals and Mining in Indonesia. |
| 4 | P. Marks (1957): | Stratigraphic Lexicon of Indonesia. |
| 5 | Soetarjo Sigit (1962): | A Brief outline of the Geology of the Indonesian Archipelago. |
| 6 | Soetarjo Sigit (1964): | A Brief Explanatory Note to the Distribution Map of Coal Deposit, Industrial Minerals and Rocks of Indonesia. (Scale 1 : 5,000,000) |
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### 1-4-2 Map


| | | |
|---|---|---|
| 1 | Direktorat Topografi A.D. (1963): | SA 51-1, SA 50-8, SA 51-9 (Scale 1 : 250,000) |

2 Djumhani (1968): Metallic mineral map of Indonesia (Scale 1:: 5,000,000)

3 Geological Survey of Indonesia: List and Index of Published and Unpublished Geologic Maps of Indonesia

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## 2 Topography & Climatology

### 2-1 Topography

Controlled by the geological structure, the topography of this area may be divided into the following units from the west to the east.

1 Western Coast Plain District

2 Central Mountain District

3 Fossa Sarasina District

4 Eastern Mountain District

5 Tawaelia Graben District

6 Mountain District of Poso Zone

These units cross the survey area in the direction from N - NNW to S - SSE, showing a zonal distribution. The characteristics of these topographical units will be described hereinafter.

The west coast plain district is made up mainly of alluvial plain with scattering the damp low land and its elevation is below 200 M. In some part, gently-sloped hills with an elevation of 200 - 300 M are observed. Rivers in this district flow from east to west and meander frequently with some rescent lakes formed by the change of water-course. Along the coast line, marine terrace, elevated coal reaf are observed in part.

In the central mountain district, high peaks of about 2,500 M are seen continuously, and steep slopes are observed especially at the eastern slant. Main mountain range is seen near the Palu river and sub-ranges run in parallel to the main range near the west coast, controlling the direction of the rivers. Rivers in this district may be classified into three categories, namely, the Lariang river crossing the above mentined mountain ranges, large rivers, e.g. the Rio, flowing in N-S direction and in parallel to the mountain range and small rivers flowing in several directions.

Fossa Sarasina district is a product of graben occupying the central portion of the survey area and its stretches from NNW to SSE. In the northern part of this area, the graben is low in elevation and forms alluvial deposits, but from the center to the south, it forms a V-shaped valley. The rivers which run along this graben are large rivers, namely, the Palu and the Lariang.

The eastern district is composed of high mountain ranges about 2,500 M in height, running in N-S direction. The ridges which link main peaks are very complicated. Therefore, drainage patterns are also complicated and the rivers may be classified into three types, namely, the Lariang crossing the mountain range, large rivers (Sopu river etc.) which run through mountain ranges showing complicated courses and small branches flowing into the rivers of the above two types. At the center of this district, situates the Lindu lake.

Tawaëlia graben district is a plateau with the altitude of 600-800 M, extending from north to south. Different from Fossa Sarasina, this graben does not show abrupt changes in the topography. Along this graben, the upper stream of the Lariang runs southward.

Mountain district of Poso zone is barely seen at the eastern end of this area and consist of comparatively gently sloped mountains ranges running in N-S direction.

In the survey area, rivers show a complicated drainage pattern as described previously but may be largely classified as follows:

1 Palu river which flows northward along Fossa Sarasina.

2 Lariang river which flows westward along the two graben, crossing the mountain district.

3 Rivers (Pasangkaju river etc.) which originate in the central mountain district reach the Makassar straits.

4 Rivers which flow northward along Tawaelia graben, Flowing into the Golontalo bay.

Of these rivers, the Lariang water system covers the largest area. Reflecting the topography and climate, along the course, these rivers have a large discharge and a greater sediment load.

The above topographical features of this area tell that this area is in the state of young age topographically. As a matter of fact, this area is one of the districts which show the most rugged natural features on Sulawesi island.

## 2-2 Climatology

The climatological type of this area belongs to the tropical pluval forest characterized by high temperatures and humidity. The climate of this area may be classified into two seasons, namely, the eastern monsoon season which lasts from May to October, and the western one which lasts from November to April. Rainfall is more frequent in the middle of western monsoon season. The climatological data for this area was not available. However, according to the material of Makassar and Manado, the annual mean temperature is 25°C, the maximum 30°C and the minimum 22°C, and the annual mean humidity is 80%, the maximum 89%, and the minimum 66%. Rainfall is more frequent in the period from November to April with 75% of the annual mean precipitation of 3,000 mm, conectrating in this period, particularly from December to February. The rainfall in this area is tropical squally, with intensified rainfall in a short time and causes flooding of the river. The wind direction is from east in the period from May to October and from west in the November-June period. It is windy throughout the year in this area, with mean wind velocity being 5m/sec without major fluctuation throughout the year.

The above mentioned is the outline of the climate of the coast district. In the survey areas, however, where high mountaneous district is dominant, the temperature is fairly low compared with the coast district and the temperature decreases below 15°C at night. Also, the climate varies locally and thunderstorm is very frequent.

## 2-3 Vegetation

Favored by tropical sunshine and abundant rainfall, growth of vegetation is very rapid. Because of the natural conditions and few population, the vegetation form thick trackless forests which extend to the ridge of the mountain. Many kinds of broad-leaved trees and ferns are recognized but their density is not so high as to prevent the passage of human being.

In the coast district, thick forests of mangrove and marshes covered mainly with miscanthus develop extensively. The wet land is also seen in the southwestern part of the Lindu lake.

Most part of this area belongs to unartificial forest but some part have turned to grassland after felling for primitive agriculture. In the east district and alluvial plain along the Palu, rice field, and, cocoanut, banana, and coffee plantations are observed. The cocoanut plantation near Palu city is particularly large in scale.

# 3 General Geology

## 3-1 Sedimentary Rock

### 3-1-1 Slate group

This group is observed at two locations in this area. One is distributed from western part of this area, Rio river to the Karangana river by way of mid-stream of the Lariang, and the other along the Marei river. The former has a strike from north to south at the northern district and from northwest to southeast at the southern district, as a whole. The dip of the former is $40^{o}$ to southwestward, but it is variable locally. At Mamu along the Karangana, a strike is recognized NW $20^{o}$ and dip $40^{o}$E and at Kalamanta the strike is not changed, while the dip is seen from $30^{o}$W to $45^{o}$W showing small syncline. Such changes of the strike, and/or dip is observed at Kantewu and Kanuna along the Lariang.

The latter along the Marei shows a strike from N-S to NW-SE direction and a dip of $20^{o}$-$60^{o}$ to the west. Both of them are distributed generally in parallel to the direction of the main structural line, that is, from north to south or from northwest to southeast. The apparent width of the layer at the Lariang is about 5 - 15 KM and that of the Marei shows about 5 KM. Also along the Lariang, small layers of slate are observed in granites as xenolith.

The rock faces are noted as follows;

(1) Slate

The extent of the rock is wide, stretching from the Watupo Sampu, branch of the Rio: to the upper stream of the Karangana.

This rock has a black colour macroscopically, possessing hard and compact quality.

Microscopically, it is formed principally by breccia of quartz, generally accompanied by plagioclase, carbonaceous material, and in some case by pyroxene. Sericite and chlorite are commonly recognized as secondary products. Sulfide minerals which is made up of pyrite chiefly, is contained in a very small quantity. Grain size of this rock is fine in general but sometimes coarse and fine part shows a mutually banded texture when observed with a microscope.

(2) Sandstone

At Kalamanta, the upper stream of the Karangana, this rock is seen locally as a thin layer in slate. Macroscopically, it has a brown colour, fragile character and coaree grain-size as a rule. Microscopically, it consists of 0.1 mm not well sorted, long plagioclase quartz, chlorite, a small amount of biotite and magnetite. Plagioclase is relatively abundant.

This rock has concordant relation to the slate and the size grading is observed.

(3) Limestone

At Onu in the mid-stream of the Lariang, Banas along the Karangana and along the Marey limestone is seen in the form of boulder. The probability that this rock is laid between slate layer is greater than the other case, but from the mode of occurrence it is presumed that this rock does not have a wide distribution.

Macroscopically, it is grayish white or yellowish white in colour and siliceous part is observed in part.

Under microscope calcite shows a very fine grain of 0.01 mm size and quartz below 0.05 mm size.

(4) Basic Tuff

Distribution of this rock is seen near Momi in the mid-stream of the Lariang with a reddish brown colour macroscopically. It contains crystals of chlorite and plagioclase. Matrix is consists of sericite, chlorite and glassy part. Also fine veinlets of calcite are observed abundantly. Judging from the texture, it is considered to be tuff. Because of the alteration, it is difficult to presume the original rock, but analogizing of the quantity and quality of the secondary minerals and from the lack of quartz, the original rock is presumed to have basic nature.

(5) Sericite-Chlorite Schist

The Slate group suffer from local metamorphism, and in extreme case it shows the form of phyllitic or schistose. This metamorphosed parts are put between unmetamorphic layer or gradually change to unmetamorphosed slate. The injection by fault is not observed. The grade of metamorphism is very weak. The above phenomena shows that this metamorphis rock was locally produced. In this report, for the convenience of explanation, this rock is included in the sedimentary rock, not in the metamorphic rocks. Occasionally this rock cannot be distinguished from crystalline schist which is seen in other parts of this area.

The distribution of this rock is the same as the basic tuff, and shows green-colored, phyllitically-foliated, fragile macroscopically.

Under microscope biotite, sericite, chlorite and quartz are observed.

(6) Chert

This rock is reocgnized in the western part of Gintu along the Lariang as xenolith in granites. Macroscopically, it has a white colour and consists of very fine grains of quartz accompanied by carbonaceous materials disseminated and recirculated between quartz grain.

(7) Conglomerate

Distribution of this rock is seen as a layer in the slate along the Marei. It occupies lower portion in the Marei river's slate formation, but it not basal conglomerate but interbedded conglomerate. Gravel consists of quartzite, sandstone and limestone in that order. The gravel size attains 10 cm at the largest. Matrix shows sandy facies.

Rocks of this group are hornfelsized centering around granites, but the hornfels will be described at a later stage.

In this group fossils are not recognized even in limestone and therefore, it is impossible to determine its age accurately. But judging from the mode of occurrence, rock facies and materials already known in the surrounding area, the age of this sediments is presumed to be late Mesozoic era, perhaps the Cretaceous period.

3-1-2 Tertiary system

Tertiary system in this area may be divided into three blocks for distribution, namely, Fossa Sarasina district, Tawaëlia graben district and western foot of the central mountain district. In most parts of Fossa Sarasina, this system comes from valconic pyroclactic rock. The pyroclastics will be described at a later stage when dealing with the igneous rock. Distribution of this system in Tawaëlia graben is based on photogeological interpretation and details of the rock facies etc. are not clear.

At the western foot of the central mountain district, this system shows a near flat structure with the strike running from north to south, and the dip being below 20° and is situated in the elevation of 200 to 400 m topographically. Near Pakuli along the Palu at Fossa Sarasina district this system is distributed in the band-shape of less than 100 m in width. Also at the upper stream of the Karangana, local distribution is observed.

Different from the above two districts, this system at the northern part of Tawaëlia graben is seen in the mountains of 500 - 1,000 m above sea level and points out anticlinal structure by photogeology. From this, structural movement after sedimentation is presumed but details are unknown.

The rocks constituting this system are mentioned below.

(1) Sandstone

This was observed during the field survey at the Rio river, and upper stream of the Karangana river with yellowish brown colored and fragile nature. Coarse-grain part and fine one are seen in a mixture and the fine-grained part may be said to be siltstone. Under microscope, quartz grain composes the main part of the rock, followed partially by clay minerals, namely, sericite, chlorite, etc.

(2) Conglomerate

Conglomerate which is observed at the Rio, has the same character as the above mentioned sandstone and has a yellowish brown colore and fragile nature macroscopically. Pebbles are wholly rounded. The size of pebbles is about 10 cm at the greatest, and the sort of pebbles are granites, slate, sandstone, etc. Matrix is the same as the above mentioned sandstone

Against this, the conglomerate at the Palu is yellowish brown coloured and compact. Matrix is scarce, and pebbles account for the greater part. Pebbles are rounded, brecciated and subbrecciated with the maximum size being more than 30 cm. The pebbles are mostly granite, granitic gneiss. Matrix is sandy being composed of quartz, limonite and a small quantity of clay minerals..

Different type of conglomerate which is observed at the Rio and the Palu shows the circumstance of the sedimentation and difference of the hinterland. That is to say, the former conglomerate lies near the big river where its hinterland is comparatively gentle-sloped mountains, while the latter suggests the sedimentation of sand and gravel flew by violent stream because it lies at the branch of the Palu river forming V-shaped valley. Accordingly, the round pebble of the former means it was carried from distant location, while the latter has an eluvial character. The type of pebbles indicate the geology of hinterland.

(3) Siltstone

Being found in the sandstone layer at the Rio, it shows the same occurrence, mineral composition and distribution as the sandstone.

The above mentioned Tertiary system has developed by filling the topographical depression and covers granites and slate disconformably and no alteration is observed. Consequently, this system except alluvium is the newest sediment in this area and its age is considered to be after the formation of graben, namely, Fossa Sarasina etc.

The age of this system is presumed to be the last stage of the Tertiary, Pliocene period, or pleistocene of Quaternary in part, judging from the molusca recognized at the Rio. Although foraminifera at the same place cannot fix the age, some data shows the state of a shallow inland sea, while the other data indicates a continental shelf of open sea. Both of this foraminefera bearing rock can be seen within 1 KM at the distance, the circumstance of sedimentation is dissimilar from the state which we see nowadays, suggesting the local change after sedimentation.

3-1-3 Quaternary system

Deposits of Quaternary accounts for about 30% of this area and situates at Tawaelia graben district, around Lindu lake in eastern mountain district, at the basin of the river Sopu, along Fossa Sarasina district and at western coast district.

According to the mode of sedimentation, they may be divided into lake deposit, terrace deposit, alluvial deposit, talus deposit and elevated coral reef. The age of these deposits are both Pleistocene and Recent. Materials forming these deposits are composed of sand, silt and gravel of pre-Quaternary age.

For the interpretation of these deposits, photogeology is so efficient that its result were often quoted. Especially, as the ground survey did not cover the west coast district except the heliport at the mouth of the river of Lariang, interpretation of this district was made mainly by photogeology.

(1) Lake deposit

It distributes mainly in the basins dotted from north to south at the west side along Tawaëlia graben, at Palulu along the basin of the river of Sopu and around the southeastern shore of the lake Lindu. At Tawaëlia graben, there are three basins, namely, the basin about 200 $KM^2$ wide centering around the lake Rono, the basin about 50 $KM^2$ around Bariri and about 90 $KM^2$ around Pada. As the topographical dissection is progressed and altitude of these basins are comparatively higher than that of other districts, the age of these basins considered to be older than that of other districts, which is presumed to be Pleistocene. Fossil plant which is recognized near the lake Rono is considered to be tropical wide-leaved trees.

At Palulu, along the basin of the river of Sopu, distribution of this deposit is observed in an area of 150 $KM^2$. But it is doubtful whether all parts of the basin consist of lake deposit. There is a possibility that some part are of fan deposit. There are moors with a total area of about 50 $KM^2$ around the southwestern shore of the lake Lindu. Both basins may be the deposits of the Recent age brought about by the lake Lindu.

The lake deposit covers Pre-Quaternary rocks and layers disconformably but their boundary often shows a rectilinear figure. In such a case, it is presumed that this area, depressed by the dislocational movement, became a lake bringing about the deposit of this type.

(2) Fan deposit & River Terrace deposit

These deposits are observed at the branches at Pakuli and northward along the Palu, some part of the basin of the Sopu and some part from Gintu to Gimpu along the Lariang. Their scales are from several to ten-odd square kilometers. Among them, the Palu's and Sopu's deposits are fan deposits, others are terrace deposits. By photogeology, both types are presumed to have been formed in two ages, that is, Pleistocene and Recent, judging from the grade of weathering and of the galley's formation.

(3) Talus deposit

This deposit is recognized at Palulu along the Sopu and at the upper stream of the Karangana in small scale. The former is composed of granitic debris and its weathering materials and the latter of andesitic debris. Generally, talus deposit did not develop on a large scale, owing to the steep slope and heavy rainfall.

(4) Marine Terrace deposit

At the west coast district, particularly at Pasangkaju and northward and near Doda, marine terrace deposit is recognized, forming low terraces from 10 to 20 m in height.

(5) Alluvial deposit

It distributes widely along the downstream of the Palu and along the large rivers in the west coast district. This deposit occupies the lowest part of this area and is covered with deep soil layer and used artificially in part.

(6) Elevated Coral Reef

Coral reef develops in the sea of this area except the mouth of large rivers, forming fringing form. Some these reefs are observed as recently elevated reef at the beach.

## 3-2 Igneous Rock

### 3-2-1 Ultrabasic rock

This rock is recognized at the west part of Tomado, west bank of Lindu lake intruded dykelet of several meters width in granite. The strike of the dykelet is recognized to be EW-NW, dip 30-50$^{o}$. The name of this rock is pyroxenite with a little argillaceous alteration. Under microscope, it consists of orthopyroxene which measures from 2 to 5 mm, and contains a small quantity of olivine. The former is nearly bronzite, accounting for a greater part of this rock. Other minerals are chromite and serpentine which makes itself fibrous crystal and grows reticulately.

The above is the only location where ultrabasic rock was recognized and there was not any big mass of ultrabasic rock like Kolonodale zone.

### 3-2-2 Gabbro

This rock is observed in the granite of the eastern mountain district as dykelet of 2 - 3 m in thickness, at the east part of Lindu lake, near Namo, at the western of Gintu and eastern of Torro.

Macroscopically, it shows holocrystalline, melanocratic, intermediate grained and compact character and consists mainly of amphibole, plagioclase and titanite.

Microscopically plagioclase presents carlsbad and ablite twinning, amphibole is judged as green coloured, common hornblende. As these minerals exhibit micrographic texture, they are considered to be the products of crystallization at the same time.

Accessory minerals are apatite, sulfide mineral and clinopyroxene in part.

3-2-3 Dolerite

Near Bomba at the mid-stream of the Lariang, this rock is observed intruding into slate, forming a small dyke 1-2.KM in diameter.

Macroscopically, it has a grayish-black colour and compact nature and microscopically, it consists of oligoclase and common hornblende chiefly, making intergranular texture. A large amount of magnetite is also observed.

About the period of intrusion of this rock and kentallenite, the only thing which is certain is that it was after the sedimentation of slate group. But as this rock is not altered at all, though it is located near granite, it is presumed that intrusion of this rock is later than that of granite and perhaps at the same time as the ultrabasic rock and gabbro.

3-2-4 Kentallenite

This rock is recognized as two intrusive bodies near Kantewu at the mid-stream of the Lariang. Microscopically it seems to be intermidiate-grained, melanocratic, holocrystalline, alkali rock.

Microscopically it is composed of orthoclase, plagioclase, (oligoclase to andesine) biotite and augite (diallage), accompanied with magnetite and apatite. This rock intrudes into slate and is plutonic facies of dolerite and presumed to be intrusion of the same time with dolerite.

3-2-5 Andesite group

This group is found as dyke and lava of 20 KM in extension at the east bank of the Karangana, as a dykelet at the upper-stream of the Rompo, as several small dykes along Fossa Sarasina partially accompanying volcanic pyroclastics. Under micoscope they are divided as follows;

1 Augite biotite andesite

2 Hornblende biotite andesite

3 Hornblende andesite

4 Andesitic tuff breccia

Augite biotite andesite forms dyke near Gimpu, hornblende biotite andesite along the Karangana makes lava and dyke hornblende andesite at the upper-stream of the Rompo makes dyke in crystalline schist and andesitic tuff is observed at the western part of Torro. Although the existance of andesitic rock at the southwestern part of this area is pointed out according to the photogeological interpretation, details are not known as the field survey was not carried out in this part.

The rock facies of this group are mentioned next.

(1) Augite biotite andesite

Macroscopically this rock has a dark green color and glassy nature. Under microscope phenocryst is composed of plagioclase (andesine), augite and tremolite accompanied by biotite and olivine in part. Groundmass consists of plagioclase, pyroxene and magnetite showing felty texture. Both of phenocryst and groundmass suffer from chloritization.

(2) Hornblende biotite andesite

Macroscipically this rock shows a grayish white color and compact, fine-grained character. Microscopically plagioclase (andesine) is the most abundant mineral as phenocryst, showing carlsbad, albite twinning and zonal structure. Common hornblende and biotite are observed in general, one of which lack sin some case. Groundmass consists mainly of plagioclase, common hornblende and biotite having pilotaxitic texture. All of them suffer from chloritization and carbonitization. Accessory minerals are magnetite, apatite, calcite, zircon and sulfides.

(3) Hornblende andesite

Macroscopically it has a grayish white colour, and porphyritic texture with phenocryst of white colored feldspar. Phenocryst under microscope is plagioclase, and long-prismatic amphibole and magnetite. Most part of plagioclase and amphibole are altered to chlorite and carbonates. Groundmass is mainly fine spherulite.

(4) Andesitic tuff breccia

This rock has a grayish black or reddish gray color in breccia, yellowish gray color in cementing materials. Microscopically it has brecciated texture. Breccia is hornblende biotite andesite chiefly as essential component, but accidental granite, pyroxenite. are observed. Cementing materials are volcanic ash consisting of plagioclase and hornblende.

In part, brecciated andesite is observed but this rock is caused by the brecciation of andesite as it has the same rock facies as andesite.

3-2-6 Dacite group

This group is recognized as a dykelet along the Rio and macroscopically is black or gray colored and is glassy, compact and hard rock. Microscopically, quartz, plagioclase, biotite and hornblende mainly form phenocrysts with calcite, chlorite and sulfides. Groundmass is chiefly quartz showing hyalopilitic texture and chlorite is partially observed.

At the upper stream of the Karangana, dacitic tuff breccia is recognized on a small scale in its distribution. It has a grayish white color and microscopically breccia consists of fragments of amphibole, biotite, plagioclase, quartz and glassy materials, while groundmass dacitic ash.

3-2-7 Rhyolite group

Rhyolitic tuff is seen near Pangana and Gimpu along Fossa Sarasina in small distribution. It has a pale green color and compact nature. Microscopically it has crystals of quartz, orthoclase, plagioclase, biotite and amphibole and in part glassy materials.

Near Bangga of the Palu, rhyolite of grayish black color with flow-texture has a width of about 10 m. Microscopically it ha s flow-texture also. Phenodryst has a small quantity of plagioclase, and groundmass is quartz and plagielase with micrographic or ophitic texture. But considering the quantity of the component and the existence of glassy materials, it is presumed to be rhyolite.

### 3-2-8 Granite group

The batholithic body of granites is in existence covering about half of this area. The location is roughly divided into four, namely, massif occupying the principal part of the eastern mountain district, massif observed at left bank of the Palu in the central mountain district, massif observed around the Rio in the central mountain district and the massif at the south-western part of the Lariang. The last mass was judged from photogeology though field survey was not carried out.

As the granitic body shows north or northwest direction, that is to say, the main structural direction of this area, distributing in a belt-like form, it is assumed that granites have intruded conformably with the above structural line.

Of the rock facies, granites is largely divided into four, namely, biotite granite, hornblende-biotite granite, hornblende granite and gneissose biotite granite, partially including biotite granodiorite, hornblende diorite and hornblende biotite quartz diorite. The relationship between the rock facies and the mass is mentioned below.

1 At the massif of eastern mountains, granite are composed chiefly of fine granied, biotite granite. Coarse grained, hornblende biotite granite is observed in common. Gneissose biotite granite is observed only in this massif.

2 Compared to the above massif, granite of the left bank of the Palu are coarse granied generally showing the rock facies of hornblende biotite granite, followed by biotite granite.

3 The massif of the Rio is hornblende granite showing flow-like characteristic texture microscopically..

4 Quartz diorite and diorite are recognized at the margin of the massif ordinarily.

5 Details about the massif of the Lariang's southwestern part are not known at all.

Each rock facies is mentioned next.

(1) Biotite granite

This rock is the main component of the eastern mountain rock body and observed commonly at Palu body. Microscopically it shows leucocratic holocrystalline and compact nature. In some part, mafic minerals is so abundant that it looks like basic rock. This mafic zone was observed at the east ridge of Namo, showing N30$^{o}$E direction.

Under microscope orthoclase shows carlhsbad twinning and perthitic texture and plagioclase is from oligoclase to albite showing albite twinning. As plagioclase is comparatively abundant, some part of this rock may well be called adamellite. Biotite showing a reddish brown colour and pleochloic, is observed commonly and accessory minerals are zircon, titanite, apatite and magnetite. Quartz is poor in general, usually fine-granied and intersertal between feldspar, but sometimes shows big euhedral crystal.

(2) *Hornblende biotite granite*

This rock is predominant in the Palu's rock body, also observed in the eastern mountains body in common. Macroscopically it is coarse grained holocrystalline rock, especially characterized by pegmatitic feldspar.

Microscopically there are abundant euhedral crystals which have a size of 0.5 - 1 cm and show carlsbad twinning. Next to this, oligoclase and andesine of plogioclase group is superior. Quartz is observed partially. Biotite and amphilole (common hornblende) are observed usually. The above minerals are altered partially to chlorite, kaoline, epidote, titanite, v.s. As accessory minerals, calcite, magnetite, apatite and sulfide menerals are observed.

(3) Hornblende granite

This rock distributes around the Rio, showing a flow-like texture of mafic mineral (amphobole) microscopically. Under microscope orthoclase and plagioclase (oligoclase) are main component and as the latter is comparatively rich, it may be called adamellite. Common hornblende of green coloured, pleochloic presents as huge drystal of 0.5 - 1 cm in size. Accessory minerals are magnetite and chlorite.

(4) Gneissose biotite granite

This rock is frequently seen in the eastern mountain's massif, usually measuring several meters. This rock changes gradually to the biotite granite and no fault is observed between them. Therefore it is estimated to be the xenolith of old granitic rock, but by the contamination of new one, details of the old one are not known.

Microscopically, plagioclase and orthoclase are superior, presenting lemellatwinning. Also quartz and biotite are common rock-forming minerals. *The above minerals are seen in the definite direction. Other minerals* are titanite and kaoline.

Near the boundary betwen this rock and the crystalline schist in eastern part of Bora of the Sopu, sillimanite and garnet were observed in this rock. The same phenomina was observed near the turning point between the river of Sopu and Tongoa. A large quantity of sericite and chlorite is also observed partially. These facts may be explained as resulting from the contamination to the country rock.

(5) Biotite granodiorite

This rock distributes among the eastern mountain's and Palu river's massif and is considered to be the facies change of the above granites. Macroscopically it has holocrystalline, fine grained compact character and changes gradually into granite. Microscopically, quartz, orthoclase, plagioclase and biotite are the main rock-forming minerals and plagioclase is most predominant. Accessory minerals are apatite, garnet and a small quantity of pyroxene. Sulfide and carbonaceous minerals are also observed.

This rock is general recognized in the marginal zone of granite but there are exceptions.

(6) Diorite and quartz diorite

The distribution of these rocks is almost the same as the granodiorite and particularly remarkable in the marginal zone of granite and along Fossa-Sarasine. Among them the rock facies change sharply and there is variation in the quantity of mafic minerals. Macroscopically they show melanocratic, medium or fine grained and holocrystalline feature.

Under microscope, andesine showing lamella twinning, albite twinning and zonal structure, fine grained quartz which fills the interstice of other minerals, biotite and augite are rock forming minerals. Orthoclase is commonly observed. Accessory minerals are titanite, epidote, chlorite as secondary minerals. By microscopical observation, these rocks are identified as hornblende diorite and hornblende biotite quartz diorite.

Near Tomado, on the west bank of Lindu lake, this rock is observed as dykelet in granite.

(7) Aplite

To determine the difference in the alteration of these several granite, an investigation using X-ray was carried out, but no difference was observed. For rock magnetism, refer to Chapter 7.

For part of these granites, the dating by potash-argon method was used. Because of the limited samples available and other limitations, it is impossible to determine the age of granites accurately. But from the result of dating, the formation of these rocks is presumed to be 4,800,000 years ago (Pliocene) and in certain cases, the age further goes back to Miocene period.

From the data abovementioned the age near Fossa-Sarasina is the youngest. Therefore the intrusive body near Fossa Sarasina may be explained in two different ways: one is; as it was situated in the center of the batholith, with the period of cooling being the longest and the other is that it was the newest intrusive body.

Anyway, from the fact that the distribution of granite goes along the main structural line of this area, rock facies changes bordered on Fossa Sarasina and granite near Fossa Sarasina has the youngest age by dating, it is concluded that Fossa Sarasina has close relation with granite intrusion.

## 3-3 Metamorphic rock

### 3-3-1 Gneiss group

The gneiss group in this area is mostly granitic part. This part has already been mentioned in the previous paragraph, and is considered to be gneissose granite, judging from the mode of occurrence, texture and rock-forming minerals.

At the upper stream of the Sopu, biotite hornblende gneiss is observed as roof-pendant in granite. The rock is dark green or grayish colored and is compact macroscopically. Under microscope, it is composed of quartz, biotite, sillimanite, and amphibole, and is considered to belong to hornblende facies which has a sign of low pressure and temperature. As the survey route was on the line bordering the granite, contact metamorphic minerals such as biotite, sillimanite etc. were observed. Therefore, it is not called the typical gneiss. But this rock is presumed to have wide distribution judging from the boulders in the river.

### 3-3-2 Mascovite quartz schist

This rock is situated in the mountain district of Poso zone from north to south along the Tawaelia graben. The strike of this rock is from N15$^{o}$ E to N60$^{o}$E, with the dip inclines generally to the east but the lineation of this rock has not developed.

Macroscopically it has schistose texture with microfolding, milky green color and luster because of the abundance of muscovite.

Microscopically it is made up of quartz and muscovite with a small quantity of titanite and sulfide mineral.

### 3-3-3 Biotite schist

Centering around Towulu at the mid-stream of the Lariang, this rock distributes with an apparent width of 10-20 km and extends about 30 km.

It shows a reddish brown or grayish green color and banded structure and companct nature. Macroscopically alternation of leucocratic banding of quartz and plagioclase (andesine) and melanocratic banding chiefly consisting of biotite is observed. Other minor minerals are magnetite, chlorite, titanite and apatite with orthoclase in part.

There are some opinions that this rock is gneiss, especially when observed macroscopically. At any rate, the grade of metamorphism is high and different from the crystalline schists which will be mentioned in the next paragraph.

### 3-3-4 Quartz schist and phyllite group

This group is observed mainly on both sides of the Palu, namely along Roki-roki route, Sidondo, at the upper stream of the Rompo and at the junction of Karangana. Generally this group forms a layer along the main structural direction of this area, showing the strike of N20°E or N20°W and the dip 30°E. The mode of occurrence of this group is thought to be roof-pendant in granite.

The rock of this group has various types and phyllite is included in this paragraph.

Metamorphic facies is mainly chlorite facies but as biotite is formed by high temperature in some part, it may be closer to epidote amphibole facies. At the contact margin with granite, contact metamorphic minerals are formed and hornfels is observed. Generally speaking, the grade of motamorphism is higher in the west than in the east. But in general the grade of metamorphism is so low that lineation is scarcely observed. . This schist at the east part of Torro and along Fossa Sarasina consists chiefly of epidote chlorite quartz schist, layer at right bank of the Palu biotite quartz schist and layer at Roki-roki route sericite phyllite.

#### (1) Chlorite quartz schist

This rock is the main component of crystalline schist at the upper stream of the Rompo, along Fossa Sarasina district and is observed in parts of other crystalline schist layer. It is classified broadly into two facies, namely, sericite chlorite quartz schist and epidote chlorite quartz schist.

The former shows a grayish black or grayish white color and has a banded structure, while the latter exhibits a grayish green color, and has a schistose texture and partially brecciated structure perceived by anaided eye. Microscopically the former consists of medium and fine grained guartz, fibrous sericite, accompanied by chlorite which altered from both of them. Accessory minerals are carbonate and sulfide minerals and quartz veinlet is observed. The latter is made up of quartz, fibrous sericite, granular epidote and these minerals indicate the arrangement of fixed orientation. Accessory minerals are carbonate and sulfide minerals. The formation of biotite, existence of plagioclase are recognized in part.

(2) Biotite quartz schist

This is recognized in large quantity at Sidondo of the Palu showing a black color conceivable by unaided eye. Microscopically fine grained quartz, biotite and plagioclase shows a definite orientation. Accessory minerals are clinopyroxene and sulfide and at the border with granite ipidote and common hornblende also.

(3) Sericite phyllite

This rock forms the main part of the layer along Roki-roki route and macroscopically shows a color ranging from black to dark green, and has a phyllitic foliation and fragile nature. Microscopically it consists of quartz having a coarse and fine grained banded texture, sericite and chlorite. In the banded texture of quartz, microfolding is recognized.

### 3-3-5 Hornfels

At the contact part with granite, country rock suffers from thermo-metamorphism and becomes hornfels. During the field survey it was observed that slate, gneiss and schist are hornfelsized.

The rock facies of hornfels varies depending on the type of the country rock. In the case of the slate, hornfelsized rock shows a grayish brown or grayish black color and has compact nature. Microscopically it consists chiefly of quartz and biotite. Other minor minerals are chlorite, plagioclase, muscovite and sulfide minerals. In part sillimanite and garnet are observed. In the case of the granite, the formation of sillimanite, garnet, biotite are recognized.

The area where the hornfelsitization is observed is diverse and uncertain.

## 3-4 Stratigraphical relation

In the survey area, as the igneous rocks, including the granite and the Quaternary deposit have a wide distribution, sedimentary rocks are poor in general. Furthermore, in this survey the only limited information was available. So it is very difficult to interpretate the stratigraphical relation.

Again, as fossils are not recognized in this area except the young Tertiary formation, the age cannot be determined accurately. Based on the results of the recent survey, the presumed stratigraphical relation is described below. Each formation is named according to the distribution area, but as the naming is only tentative, it must be corrected with the progress of future investigation.

3-4-1 Poso crystalline schist group

The muscovite quartz schist observed at the eastern end of this area in the Marei belongs to this formation which is one of the components of Poso zone. According to Brouwer, this formation consists of muscovite rich crystalline schist and the grade of metamorphism is decreasing from west to east. As for the age of this formation, "the geology of Indonesia" written by Bemmelen touches on it but did not give a clear explanation. As this formation is cut by Tawaelia graben at the eastern end and it is located in a narrow portion of the survey area, the relations to the other rocks and formations are obscure.

3-4-2 Sopu river gneiss group

The gneiss group at the upper stream of the Sopu is included in this group. It is surrounded by granite and shows roof-pendant form. As the granitic part is observed and xenolith in granite is recognized frequently, the influence by granitic intrusion is anticipated. The gneiss which have epidote-amphibolite facies and granulite facies by Egeler corresponds to the group. According to Egeler and others the age of this group is presumed to be older than Mesozoic sediments, (not younder than the lower Mesozoic or young Paleozoic) and is attributed to the Hercynian orogenesis. From the results of this year's survey, it is presumed to be older than the slate which is presumed as Mesozoic.

3-4-3 Lariang river crystalline schist group

The biotite schist, developing around Towulu of the mid-stream of the Lariang, belongs to this group, some of which is observed in granite as xenolith.

This group has faulty boundary with slate in the south and suffers from granite intrusion in the north. Judging from the fact that this group is seen in a small area and borders with the fault or intrusion to the other rocks, the relation with other sedimentary rocks is not certain but it is highly probable that this group was formed in old age because of its advanced grade of metamorphism. Egeler considered this group the same as the Sopu river gneiss group. During the recent survey there was no objectional point about this rock for being treated the same as the above gneiss group.

3-4-4 Rompo river crystalline schist group

This group is observed in the central part of the eastern district, as well along Fossa Sarasina. It consists of chlorite quartz schist and the metamorphic facies are partially epidote-amplibole facies, but mainly chlorite facies. As this group is surrounded by granite, showing roof-pendant, the relation with other rocks and its formations are uncertain. It is difficult to determine whether the age of this group should be treated the way as the above Liaring river's group or the Palu river's group which will be mentioned later. However, from the standpoint of grade of metamorphism, it is advisable to treat it in the same way as the latter.

3-4-5 Palu river crystalline schist & phyllite group

This group develops on both sides of the Palu and is composed of sericite phyllite, biotite quartz schist etc., with low grade metamorphism. It is observed as roof-pendant in granite and the relation to others is obscure. Some parts of this rock exhibit the similar rock facies as that of Tinombo formation mentioned by Bemmelen and Egeler. Bemmelen attributed this group along the Karo to Tinombo formation. Egeler and de Roever divide the age of the metamorphic rock of Poso and Palu zone into two. The new one, as the Mesozoic sediments have metamorphosed, is presumed to have been formed later than Mesozoic, at least partly Eocene. They assumed this metamorphism also related to granite.

In this survey however, this group can not be treated equally to the above Sopu river gneiss and Lariang river schist, so it will be reasonable to presume that the formation of this group is after late-Mesozoic.

### 3-4-6 Karangana river formation

This formation distributes from the Karangana to the Rio via mid-stream of the Lariang and along the west bank of the Marei chiefly, consisting of slate including sandstone, tuff, chert etc. The former is intruded by granite and andesite in the south and in the east, bordered by the fault to Lariang river crystalline schist at the north and covered disconformably with Tertiary formation at the down-stream of the Lariang. The latter is cut off by Tawaelia graben at the east, intruded by granite at the west and in this formation dolerite is intruded. The age of this formation is thought to be before the granite intrusion because this rock suffers from alteration by granite. This formation has the rock facies similar to Tinombo formation described by Bemmelen in part but can not be compare correctly. It is reasonable to judge its age the Mesozoic due to the fact that in this formation the influence of tectonic movement of late Mesozoic or early Tertiary is observed.

### 3-4-7 Doda formation

This formation consists of Tertiary sedimentary rocks, namely, sandstone, silstone, shale and conglomerate. The distribution is in the west coast district, along the Rio and the Palu etc. This formation is correlated to the Tertiary marine sediments called Mamudju-Doda embayment mentioned by Bemmelen. As trodden route was very scarce in this formation during the recent survey, division of formation and correct correlation were not possible. This formation covers discomformably granite etc. It is thought to be the sediments of the latest Tertiary (Pliocene) and in part Pleistocene. Fossils from this formation supports the above judgement. The Tertiary formation at the northern part of Tawaelia graben may be similar to this formation but particulars are obscure.

Witkamp recognized conglomerate, sandstone etc. of 5,000 m in thickness near Touviora of the down-stream of the Lariang. He called it Celebes Molasse but because of the lack of field survey, details are unknown. For convenience sake, this Molasse is included in Doda formation.

### 3-4-8 Quaternary deposit

This deposit distributes in the west coast district, along the Palu and western part of Tawaelia graben and consists of Deluvium and Alluvium. The deposits which forms a plateau near Tawaelia graben may be of Deluvium, while the others which locates in depression may be of Alluvium.

3-4-9 Gabbro and Ultrabasic rock group

The rocks of this group intrude into granite and the direction of intrusive body is concordant to the gneissosity plane in the case of intrusion into gneissose granite. These facts suggest that these rocks were formed by the igneous activity after granitic intrusion and the age is presumed to be late Pliocene.

The direction of gabbro's distribution from the Palu to the Karangana is NNW-SSE, parallel to Fossa Sarasina. Consequently, the intrusion of this group is related with structural movement which was made known by Fossa Sarasina.

About the group of this rock, kentallenite and delerite, Bemmelen did not mention anything.

3-4-10 Kentallenite and Dolerite group

This group is seen as intrusive body into Karangana river formation but the realtion with others is not clear. But from the grade of alteration, the age of the intrusion is presumed to be post granitic intrusion similarly to the above gabbro and ultrabasic rock group.

3-4-11 Andesite, Dacite & Rhyolite group

This group is similar to the gabbro's group on the point of genesis judging from its distibution. It is mostly seen along Fossa Sarasina, which suggests close relations between them. The age of extrusion is presumed to be the latest Pliocene (partially Pleistocene?) Judging from the intrusion into granite and mode of occurrence. This group may be correlated to Barupü tuff which is acidic and of Pleistocene described by Bemmelen. However, it is very difficult to determine whether the period of extrusion is Pliocene or Pleistocene in this survey. Furthermore, the correlation with Barupu tuff is not always correct because Quarles Mountains where Barupu tuff was observed is far from this area.

### 3-4-12 Granite group

This group is divided by its distribution into, four, namely, central mountain's massif (Waukara massif), eastern mountain's massif (Nokila-laki massif), Rio's massif, Lariang's southwestern massif (Karosa-east massif). For the last item, details are not known because of lack of field survey. For the other three massifs, the period of intrusion is presumed to be about the same time and characteristic features of each mass is considered to have been resulted from change of the source. Also in this group, gneiss and gneissose part is observed and this fact suggests the capture of granitic rock in older geological age.

On the age of the granitic intrusions, Reyzer and others proved that some granites and diorites in the southern part of the Palu zone are of post-Eocene age. Also, Brouwer maintained that the Tinombo formation, which is at least partly Eocene, is contact-metamorphically altered by younger granites.

In this survey, as the granite intrudes into Sopu river gneiss, Lariang river schist, Rompo river schist, Palu river schist and Karangana river formation and covered with Doda formation and from the result of dating, the age of granitic intrusion is presumed to be from Miocene to Pliocene.

# 4 Structural Geology and Historical Geology

## 4-1 Structural geology

### 4-1-1 General structure

The geological structure of this area is regulated by the undermentioned two big fault through zone, namely, *Fossa Sarasina*, and Tawaelia. The former has N20$^{\circ}$W - S20$^{\circ}$E direction, while the latter N-S direction. The direction of the distribution of sedimentary and metamorphic rocks follows parallel to them and igneous intrusive bodies have close relation with the latter. Doda formation and Quaternary deposit sedumented after the completion of the graben and these have no direct relation. But some part of these two sediments are piled filling up the depression formed by graben or made up from the sediments of rivers running along the graben, so it may be said that these have indirect relation.

Slate, crystalline schist and gneiss have the strike of N20$^{\circ}$W-N20$^{\circ}$E, with the dip of 45$^{\circ}$W in general and mostly situate in granite as roof-pendant. Variations of bedding and local synclinal or anticlinal structure are observed, which suggests the disturbance by the granitic intrusion. In crystalline schist strong folding or large-scaled one is not observed and the development of lineation is scarce owing to the low grade metamorphism.

Of the igneous intrusion and extrusion, as mentioned in the Chapter 3, granite, andesite, dacite and rhyolite have close relationship with Fossa Sarasina, suggesting the intrusion and extrusion along this structural zone. Of the basic and ultrabasic rocks, the same relation may be pointed out though somewhat obscure.

Doda formation and Quaternary deposit have almost flat inclination. By the time of their sedimentation, the tectonic movement of this area has completed and these two are observed in the depression caused by the above movement. From the time of these sedimentation, even if oscillatory movement is observed, large-scaled or strong movement is absent.

4-1-2 Fault

In this area, there are two large faults which form Fossa Sarasina and Tawaëlia graben. Besides, fault groups running parallel to, diagonal to and directly crossing these big fault are recognized.

The fault called Median line which forms Tawaelia graben is not confirmed directly at the field survey, but presuming from the distribution of the rock, it observed at the east end of this district, from the river of Tawaelia to the Marei taking N-S direction. This fault is not linear but links of curved several fault by photogeology.

The fault called Palu fault which forms Fossa Sarasina shows $N20^{o}W$-$S20^{o}E$ direction. This fault crosses Tawaelia graben but as the crossing point is apart from this area, the relation between them is not clear. This fault consists of several parallel faults and the graben surrounded by these parallel faults, is recognized. The quantity of dislocation is not known because of the lack of key bed in this area. Judging from the fact that distribution of granite has different mode bordered on this fault, extension of volcanic rock is noticeable along this fault and Doda formation covers this fault, these two grabens are presumed to have been completed after the granitic intrusion and through the period of extrusion of several volcanic rocks. As many kinds of igneous activity are tied closely to these grabens, the period of graben formation is considered to have taken a long time.

These two fault troogh have several hundreds kilometers in length. Besides these, fault groups are recognized with scores of length on the contrary. Some of them were confirmed by field survey, for example, fault of NNE-SSW direction passing through Banggaiba at the mid-stream of the Lariang, but many of them are estimated by photogeological interpretation.

The directions of these faults are irregular, but never cross the above graben and they are recognized also in granite. Therefore they are presumed to have been formed at the same time as the above graben conjugately.

In this area, except Doda formation, big folding is hardly observed and only small scale syn-and anticline in Karangana river formation are recognized. The reason is assumed to be the lack of many of non igneous rocks and that survey is not carried out in detail.

## 4-2 Historical geology

As the geology of this area is composed mainly of rock younger than Pliocene granite, interpretation of the process of development of geological structure is extremely difficult. The interpretation assumed from the already known fact is as follows but reexamination is necessary.

The basement of the area is formed by crystalline schists and gneiss group which is presumed to have been earlier than Mesozoic era but the exact period is not known.

The Karangana river formation had sedimented disconformably direct to the basement. The age of this sediment is obscure but judging from the already known data and surrounding conditions, it is presumed to be Cretaceous period.

In Neogene, perhaps from late Miocene, great tectonic movement began in the whole area which is called Celebes Orogenesis. As a result, structural zones are formed in the direction from north to south. Related with this movement, igneous activities grew prosperous to intrude granite batholith from the late Miocene to Pliocene. The center of this intrusion is presumed to be Fossa Sarasina. By this intrusion, some part of basement rocks and slate formed roof-pendant on granite.

These structural zones were formed during a long period and completed at the end of Tertiary, to become Fossa Sarasina graben and Tawaëlia graben as observed nowadays. At the latest stage of graben's formation, kentallenite, ultrabasic rock, gabbro and dolerite were intruded and andesite, dacite and rhyolite formed effusive bodies and dykes.

The depression formed by the graben was buried with sediments and formed some of today's rivers and Lindu lake.

At Quaternary, oscillation is observed in this area but volcanic activity is not confirmed.

## 5. Economic Geology

Ore deposit in Salawesi island is well known for nickel, chrome and iron ore deposits accompanied by ultrabasic rock in Kolonodale zone.

In Palu and Poso zone, copper, lead, zinc, gold, iron sulfide ore deposits are known. The number of deposit is large but ore deposit on a large scale is not confirmed yet. Although in the Tertiary formation, petroleum and natural gas deposit are known but they were worked only on a small-scale in the past.

In the survey area, the known ore deposit is not existent but copper, lead, zinc, gold and iron sulfide ore deposits are expected to exist being accompanied by Palu and Poso zone.

But it is regrettable that during this survey large ore deposits were not recognized, although some indications of ore deposit were observed. In the survey area, informations about mineral resources is scarce because of the mantle of new age as Quaternary deposit, limited outcrop of the rock and few population. Therefore, it is extremely difficult to determine the existence of mineral resources by the survey in a short period of time and investigations using several methods and over a long period of time is necessary.

### 5-1 Alteration

The alteration in this area is very weak in general. There are of course, some alterations caused by weathering or cataclastic deformation caused by fault. But it has no important bearing on this survey. From the observation in the field, under microscope and by X-ray investigation, several alterations are recognized as follows.

5-1-1 Chloritization

This alteration has a wide range in the Tertiary sedimentary rock, slate, granite and volcanic rocks, usually replacing mafic minerals. It has no relation with the specific rock type and the distance from the structural line. But the grade of this alteration is low and the quantity of the alteration product is little.

5-1-2 Sericitization

This alteration shows a wide range similar to the chloritization. From the microscopical observation, the distribution is observed in Tertiary sedimentary rocks, slate near Banggaiba at the mid-stream of the Lariang, siltstone near the Rio, granite in central mountain district, granite and hornfels in the upper stream of the Sopu. But in almost all cases, sericite as secondary mineral is seen partially in primary mineral with low grade of alteration and little quantity.

5-1-3 Kaolinization

This is observed in wide distribution in chlorite schist of the Rompo, in granite near Baluase of the down stream of the Palu, in granite at the eastern part of Bora of the Sopu, in gneiss in the upper stream of the Sopu, in muscovite sericite schist at the eastern part of the Marei, etc. Usually it exists locally and in small quantity.

5-1-4 Carbonitization

This is seen in wide distribution like the above alterations. For example, it is seen in slate near Banggaiba of the mid-stream of the Lariang, in granite at the both sides of the Palu, in chlorite schist and phyllite. Usually it may be observed only under microscope as veinlet, it is found in small quantity, and the grade of this alteration is extremely weak.

5-1-5 Limonitization

Reflecting the natural features in the area, limonite is recognized on the surface of the earth. Also it is observed in large quantity, specially in fragile rock (conglomerate etc.) of Tertiary.

Pyrophyllitization, halloysitization, montmorillonitization and zeolitization are not recognized. The alterations related to the mineralization are undermentioned.

5-1-6 Hornfelsitization

This alteration, one of the contact metamorphic alteration forms sillimanite and garnet indicating high temperature such as observed at the upper stream of the Sopu. Distribution of this alteration is not confirmed in the field survey.

5-1-7 Skarnization

The limestone sampled near Towulu at the mid-stream of the Lariang is hardly suffering from this alteration even though it is seen far from granite and this alteration is not recognized clearly.

5-2 Metallic mineral deposit and mineralized zone

Mineralized zones confirmed in this survey are undermentioned.

5-2-1 Dissemination of pyrite

In each sample rock in this area, the existence of sulfide mineral is observed under miscroscope. Its greater part are pyrite scattered in rock in the size smaller than 1 mm, euhedral or anhedral. Pyrite does not have vein-like and massive form and seldom causes alteration to country minerals. Also its distribution is extensive, not concentrating in specific place or rock and is seen in small quantity. It is not recommended to treat it as profitable deposit judging from its quality and quantity. All these facts suggest that is the primary mineral.

### 5-2-2 Disseminated zone at the basin of the Sopu

Near the confluence of the upper stream of the Sopu and the Tongoa, disseimnation of sulfide mineral was recognized in granite as well as in gneiss, especially in hornfels of its margin. The result of chemical assay is shown in appendix but the grade is low.

Microscopically pyrite and chalcopyrite, molybdenite, zincblende and azurite are observed in very small quantity. The distribution of this zone is seen from east to west over 1 km (uncertain). A boulder similar to this type is recognized in the eastern part of Lindu lake. It consists of sulfide minerals disseminated in gneissose granite which includes basic xenolith. Therefore distribution of this zone from north to south is estimated to extend over 15 km. From the standpoint of quality, it can hardly be worked economically but this type of ore deposit, that is to say, disseminated ore in granite, has potentiality for large scale deposit in general.

### 5-2-3 Disseminated zone near Masewo of the Karangana

The disseminated vein with clay in slate of Karanagana river formation was recognized. It consists chiefly of pyrite, accompanied with chalcopyrite and zincblende. Gangue minerals are chlorite, sericite etc. The width of this vein is about 1 m, with trends for N5°E, 50°W. The result of assay shows that the quality is better than that of the Sopu. But it cannot be called as economical value at present judging from the small scale of vein and poor quality. This vein is estimated to be fissue-filling hydrothermal ore deposit formed by post-igneous action of granite and the ore deposit of this type is expected to be found in the whole survey area.

5-2-4 Laterite near Banas of the Karangana

This is reddish brown colored soil mainly due to the weathering of biotite andesite. The soil like this exists everywhere, according to the inhabitants. But the recognized scale is small, the deposit of laterite is expected to be scarce in this district for the reason that there is few distribution of basic igneous rocks and topographical condition.

5-2-5 Muscovite vein near Towulu of the Lariang

In biotite schist, intrusion of quartz vein including muscovite is observed in parallel to the schistosity. The width of quartz vein measures 5 to 10 cm in width and that of muscovite in platy or massive form measures 1 to 2 cm. In country rock, muscovite bearing biotite (partially altered to chlorite), quartz schist are observed. Also plagioclase is accompanied by in this vein. The vein has been explored and mined already according to the inhabitants, but the quality and quantity are of no economic value. This is presumed to be pegmatitic vein accompanied by intrusion of granite.

In this survey area, only the above mineral resources are recognized but in the southern district away from the survey area, there are many gold, silver and copper mines, including Sangkaropi mine. In the northern part away from this area, around Palu city, there are also some mines. The following are mines near Palu which were recognized during this survey.

5-2-6 Lead, Zinc vein along Uwewla river

This is situated 10 km from Palu to the northwest on the right bank of the Uwewla river 290 m above sea level forms a sheared zone of granite 30-80 cm in width. The trend of the vein is N40 -50 W strike, 15 -30 SW dip and traced 7 m along the strike. Ore minerals are chiefly galena concentrated in a patch-like form. Gangue minerals are quartz and clay minerals. This vein is formed by the hydrothermal mineralization which takes the form of intrusion into brecciated zone created after the granitic intrusion.

5-2-7 Disseminated copper deposit at Wani

The porphry copper-like samples from this deposit are exhibited in the showcase of the provincial office of Central Sulawesi. This deposit is situated 350 m above sea level on the left bank of the brook of Wani about 10 km east from Tawaëli, the eastern shore of the Palu bay. This deposit may be reached from Tawaëli to Wani by car via national road, by jeep via unimproved road 2 km from Wani, by foot via mountain path and by crossing brooks. The structural line which seems to be Tawaëlia zone or fault group running in parallel to it, is presumed to lie in the vicinity.

From the hills east of Wani village to 40m this side of deposit, the fragile mudstone looking like Pliocene, is observed continuously. It covers fine grained diorite, the wall rock of this deposit. Diorite suffers from argillaceous alteration for 30 - 40 m along the brook. In this argillaceous zone, silicified block including pyrite is observed. At the outcrop which lies at the southern end of the above altered zone, this zone borders with the altered sedimentary rock, with the plane showing N40 E strike and 35 NW dip. In this altered zone, no chalcopyrite is observed by unaided eye. As mineralization is not observed except the pyritization, and the scale of this altered zone is small, that is, 5 m in width and 40-50 m in length, this is no value.

5-2-8 Copper veinlet at Saum Parigi

This is situated at Saum Parigi, about 7.5 km south from Palu. The location is about 4 km north from the northern end of survey area. Geologically it is situated west side of Fossa Sarasina. Slate is observed mainly, phyllite partially, only a boulder including chalcopyrite and malachite veinlet of 5 mm in width is recognized. As outcrop and many of the boulders were not observed, it is difficult to estimate its economic value. This is the only metallic indication in the west side of Fossa Sarasina.

5-3 Petroleum and natural gas deposit

Near the mouth of the Lariang, a sign of petroleum is recognized. On this deposit, field survey has not been carried out, but from the already known data, drilling exploration was carried out in this location and natural gas and petroleum in certain quantity were produced in early 1900's.

From this area to Kalimantan island beyond the Makassar straits, the oil-bearing Tertiary formation is expected. In fact, exploration has been carried out on the Kalimantan side up to the day. According to the findings, the exploration of petroleum in this area and continental shelf of Makassar straits which lies western part of the area will be in the limelight.

But during this survey, Tertiary formation recognized only in the west coast district as Pliocene sediments and there was no indication of the above deposit.

5-4 Hot spring

It is recognized in several places of the survey area, more are expected according to the inhabitants. The confirmed places are as follows.

Torro along the river of Pebatua

South of Pada along the river of Lariang

Upper stream of the river of Sopu

Masewo along the river of Karangana

The temperature of the water is over 40 °C and deposition of sulfides was observed in part.

These hot springs are distributed in granitic zone and presumed to originate the fissure in granite. As most of them are observed near the fault zone and no volcano is in this area, they are hot springs of fault origin.

## 6. Recommendations on the photogeological survey

In this survey, photogeological survey was carried out together with geological ground survey to interprete the systematic geological feature.

The method of photogeological survey was: first preliminary survey prior to field survey, next constant comparison of field occurrence between the geological ground survey, and lastly, detailed analysis in Japan. For detailed analysis, ground survey team and photogeologists held discussions frequently and made necessary amendments to the findings. In this paragraph, the interpretation of questions pointed out by photogeology will be discussed mainly.

### 6-1 Topographic interpretation

The topography of this area reflects the geology of Tertiary sedimentary rock, Quaternary deposit and main grabens. Also the difference of topography (caused by the difference of rock, namely slate, crystalline schist and granite) can be read from the photos. But topographic character is formed not only by geological factor but also by climatology, especially at the area of tropical pluval forest type like this area.

### 6-2 On the geological interpretation

The strata and rocks in this area are difficult to judge from the photogeology alone except Quaternary deposit, Tertiary sediment and large extrusive body of volcanic rock, namely, andesite, etc. Because of poor outcrop of rock which is covered with thick forest influenced of climate, difficulties of division of rock facies, for example, between granite and gneiss is usual. So in the photogeological report, the naming of rock is followed by ground survey.

6-2-1 Muscovite schists of Poso zone ($S_1$)

The main reason for gentle slope of the topography in this rock area is that the rock itself is fragile. But on the rock which forms this zone details are not known because there were very few survey routes.

Tawaëlia graben has indefinite form on the photogeology. One of the reason the concealment with thick deposits of Quaternary and Tertiary sediment after the completion of the graben. Conversely speaking, it is obvious that there were topographically low land along this zone as this young strata are observed there.

6-2-2 Biotite schists of Palu zone ($S_2$)

On the photogeology, division of this rock from others is difficult in this district except Rompo group. This is because this rock interbedded with granite, scale of the distribution is rather small and gneissose part in granite is in existence.

6-2-3 Gneiss or gneissose granite (Gn)

Some part of this rock, that is to say, along the mid-stream of the Lariang, are not gneiss or gneissose granite but biotite schist as mentioned in Chapter 3. But the division of gneiss and schist is difficult microscopically. As mentioned in the photogeological report any outstanding features of photogeology are not observed and therefore, definite division is very difficult. In fact, the granite in eastern mountain district shows gneissose texture in part and cannot be separated from this gneiss. And as a greater part of biotite schists of Palu zone has no characteristic features, separation of this rock from biotite schist and slate of some part (especially schistose part observed at the mid-stream of the Lariang) will be extremely difficult or impossible.

From the photogeological report, the rock in the southern part along Fossa Sarasina is presumed to be similar to the rhyolite. If this is true, rock may have character similar to the rhyolite photogeologically.

6-2-4 Slate (Sl)

The division of this rock which distributes along the upper stream of the Pasangkaju (Rio river) is difficult photogeologically. It is due to the complexity of geology, alteration of slate and the character similar to the phyllite seen in the western part of the Rio along Roki-roki route.

The hornfels is not recognized photogeologically because of thick forest.

Concerning fault and disconformity, discussion will be made at a later stage.

6-2-5 Granitic rock I & II ($G_1$, $G_2$)

The difference between $G_1$ and $G_2$, as described on the photogeological report, was recognized prior to the preliminary interpretation of photogeology at the field, but it was confirmed that these two were completely identical. As mentioned in the above report, unevenness is observed on the distribution of $G_1$ and $G_2$ topographical, which causes the different process of erosion.

Division of granite and gneissose granite was so difficult in the field that the help of photogeology was needed. It is natural that the division between granite, granodiorite, diorite etc. is difficult since these rocks were formed from the same source and their occurrence are almost the same.

6-2-6 Granitic rock III ($G_3$)

As field survey was not carried out, details of this rock are not known. Judging from the boulder along the Karo, however, it is assumed to be granite.

6-2-7 Dykes and Dolerite (Dy, Do)

The reason that the dolerite, which is seen in distribution of a certain scale, cannot be divided, is as follows. This dolerite is subject to the weathering in the same way as the country rock because of its nature as basic rock (poor in silica).

6-2-8 Volcanic rock I, and II ($V_1$, $V_2$)

These rocks are effusives at the last stage of Fossa Sarasina period. Except Quaternary deposit and Tertiary sedimentary rock it was formed during the youngest geological age. Because of the fact that the place of effusion is near the graben, that it has fragile nature and is small in scale, these rocks are subject to erosion. Therefore the interpretation of photogeology in some part of the area is very difficult.

In addition to volcanic pyroclastic rocks, there are many dykes and lavas, of andesite, dacite and rhyolite along Fossa Sarasina.

6-2-9 Volcanic rock III and IV ($V_3$, $V_4$)

On this rock fine interpretation is impossible because of the lack of field survey. But assuming from the photogeological and aeromagnetic data, distribution of andesitic to rhyolitic effusive rock with its pyroclastics is presumed to exist. Also, distribution of sedimentary rock may be found in part.

6-2-10 Volcanic rock V ($V_5$)

The mode of occurrence of this rock is seen not only as lava but also as dyke without pyroclastics. The volcanic rock like this one is often recognized as dyke in the lower part and as lava in the upper part. For the clearness and unclearness of the boundary line of the volcanic rock, there are several factors and the cause cannot be determined simply.

6-2-11 Tertiary formation ($T_1$)

This was determined to be slate presumed to have been formed in Mesozoic. The question concerning this formation dealt in the photogeological report is about the geological structure, which will be discussed at a later stage. On the sedimentary rocks, namely, conglomerate, sandstone, clayshale which lies disconformably on the crystalline schist of Poso zone at the eastern end of Tawaëlia graben by Bouwer, their existence are not clear because of the low density of field survey.

6-2-12 Tertiary formation II and III ($T_2$, $T_3$)

On the question mentioned in the photogeological report, the western end of $T_2$ is presumed to cover granite disconformably, and there is no relation to the faulty or intrusive form. Concerning this feature, refer to the subsequent paragraph.

6-2-13 Tertiary formation IV, V, VI and VII ($T_4$, $T_5$, $T_6$, $T_7$)

The relationship between this formation and granite is considered to be that of disconformable.

6-2-14 Lake deposit I and II ($L_1$, $L_2$), Fan and Terrace deposit I and II ($F_1$, $F_2$) Talus deposit (Ta) and Alluvium (Al)

On these deposits, interpretation is impossible because of lack of field survey.

6-3 Interpretation of geological structure

6-3-1 Faulty contact and disconformity

In the photogeological report, there is an expression of "faulty contact". On the faulty contact, two cases are conceivable; one is the case in which the faulty contact is right, and the other is the case in which the apparent rectilinear boundary is seen. The relationship between the slate and the biotite schist (gneiss on photogeological report) at the mid-stream of the Lariang is the former, while the relationship between the granite and the Tertiary sedimentary rocks is the latter. The apparent rectiliner boundary is caused by the irregularity of the form of granitic batholith and sedimentation of Tertiary formation in depression formed at the same time or later by the tectonic movement with the granitic intrusion.

6-3-2 Median line and Tawaëlia graben

In the photogeological report, the location of the Median line is said to be along the Marei river. This is evident from the fact that the crystalline schist of Poso zone and slate of Palu zone was observed during the field survey. However, the photogeology only points out the fact that the Median line is in dislocation of the fault and therefore, it is doubtful whether it presents a serious problem or not. Besides $T_1$ formation is slate. Bemmelen and Brouwer described about the

Median line and Tawaëlia graben, the existence of Neogene sediments, mylonite and volcanic activity. But it is not confirmed owing to lack of field survey.

6-3-3 Of Fossa Sarasina

As described in the photogeological report, details of tectonic movement by Fossa Sarasina cannot be presumed from available data.

6-4 Mineral deposit, mineralized zone and altered zone

There is no detailed description about the above items in the photogeological report because of thick forests. Actually, it is very difficult to comprehend mineral deposit, mineralized zone and altered zone photogeologically. At any rate, a big ore deposit which is easily pointed out by photogeology, like mickel bearing laterite in South Sulawesi, will be hard to expect.

## 7. Recommendations on the aeromagnetic survey

### 7-1 Magnetic susceptibility of the rock

There is no direct relation between the result of magnetic measurement about the samples collected by ground survey, and high anomaly in aeromagnetic survey. High anomaly is controlled not only by the quantity of magnetic minerals in the rock but also by the mass of rock body itself, condition of distribution etc. Also, it is doubtful whether the collected rock samples are the typical ones of the rock type. But as it is clear that the above magnetic susceptibility is the important reference for the interpretation of high anomaly, measurement was carried out in the field and in the laboratory. As a result, the rocks showing high magnetic susceptibility are as follows:

1. basic igneous rocks, namely, andesites, dolerite, kentallenite, gabbro, etc.
2. hornblende granite (Rio massif)
3. a part of hornblende biotite granite & biotite granite
4. tuff and chert interbedded in slate layer
5. a part of hornfelsized gneiss and crystalline schist
6. sandstone of Doda formation

Among them, andesites show 2,000 x $10^{-6}$ e.m.u., dolerite 1,000 x $10^{-6}$ e.m.u., kentallenite & gabbro 700 x $10^{-6}$ e.m.u., a part of granite 600 - 800 x $10^{-6}$ e.m.u., a part of crystalline schist 1,700 x $10^{-6}$ e.m.u., and hornfels 100 - 200 x $10^{-6}$ e.m.u. of magnetic susceptibility.

The other rocks are below 50 x $10^{-6}$ e.m.u. It is noticeable that granite shows strong magnetism in part. Considering of the degree and distribution of the magnetic rock, basic igneous rock and granite are the most important rock magnetically in this area. But a part of almost all rocks and formation has magnetic character and estimated values of magnetic susceptibility of each rock is mostly equal. This will be one of the most difficult problem for the interpretation of aeromagnetic anomaly.

7-2 Interpretation of high anomaly

Anomalys summerized in the aeromagnetic survey report and the geological results are shown below.

7-2-1 Ultrabasic rock

The rocks presumed to be ultrabasic rock in aeromagnetic survey report are considered geologically as follows.

| No. | Location | Geological interpretation |
|---|---|---|
| UB1 (mu 2) | Rio | granite |
| UB2 (mu 5, 6) | North of Banggaiba | granite has high probability |
| UB3 (mu 18a) | Kulawi | andesite? |
| UB4 (mu 31) | Siwogi | uncertain |
| UB5 (mu 15) | Torro | granite or crystalline schist |
| UB 6 (mu 24) | Kantewu | kentallenite |
| (mu 24a) | Kodja | kentallenite |
| (mu 26) | Southwest of Kantewu | uncertain |

| No. | Location | Geological interpretation |
|---|---|---|
| UB 7 (mu 34) | Mora | uncertain |
| UB 8 (mu 28a) | Kalamanta | andesite |
| UB 9 (mu 22) | Au | andesite |
| UB 10 (mu 19) | Pada | dolerite |
| UB 11 | Torire | uncertain |

It is almost impossible to determine which of the interpretation, aero-magnetic or geological is correct, but the possibility of ultrabasic existence agreeing with aeromagnetic anomaly is little. The direct reason is: the distribution of ultrabasic rock is very limited and will not develop to the great extension. Also in Palu zone out of this survey area, wide distribution of ultrabasic rock is not recognized. Furthermore, ultrabasic rock does not occur on a large scale after the granitic activity of Pliocene, at least near the survey area. Consequently it is reasonable to presume that these anomalys are caused by granite or other igneous rocks.

7-2-2 Gneiss or amphibolite zone

This anomaly is situated mainly in the granitic zone, partially at the gneiss, biotite quartz schists zone etc., according to the field survey. As gneiss occupies only a small part of this anomaly and other basic igneous rock is seen on a large scale, this anomaly is probably caused by granite also.

7-2-3 Tawaëlia graben

In Tawaëlia graben, volcanic rock with N-S direction is pointed out.

Even when the field survey was carried out in part of this area, distribution of such big volcanic rock cannot be expected and sediments of this graben is not apt to consider to have strong magnetism. In this case, blind basic igneous rock or blind granite which is covered with thick Quaternary sediment will be expressed as this high magnetic anomaly.

7-3 Interpretation of geological structure

The tectonic zones which is clearly pointed out by the result of aeromagnetic survey are as follows:

1. Fossa Sarasina
2. Tawaëlia graben
3. Fault group at the east margin of Doda formation
4. Small fault groups which cross or run parallel to the above three tectonic line.

Concerning the last fault groups, they are in accord with the result of ground geological survey and photogeological survey in some cases. One of the chief reasons is the difference of definition of "Fault" in each method of survey. That is to say, in geological survey clear dislocation of strata is necessary. On the contrary, in photogeological survey, judgment of fault is based on photo-lineament.

In aeromagnetic survey, fault is judged on the basis of line of discontinuity of distribution of magnetic anomaly. Consequently dislocation of two rock bodies which have the same magnetic potential cannot be recognized by aeromagnetic method. On the contrary, sharp inclination of magnetic contour has probability to be judged to fault even if it is not the dislocation of rock body. Anyway in this area as small fault groups are observed throughout the area and they never cut the main structural line, these faults are considered to be conjugate with main structural line. But about the small fault crossing Tawaëlia graben, it is difficult to determine whether the formation of Tawaëlia graben is earlier than other structural line or such small fault is newly formed after the completion of main structural line.

The fault group which is situated at the eastern end of Doda formation is different from Fossa Sarasina and Tawaëlia graben because it is discontineous. It will express the irregular distribution of granitic batholith or local dislocation of granitic massif. About Fossa Sarasina and Tawaëlia graben, they agree mostly with the result anticipated by Bemmelen and also with the result of this field survey.

Especially, it is noticeable that Tawaëlia graben which is difficult to be recognized by photogeology, is clearly confirmed.

7-4 Recommendation on the exploration of mineral resources

The aeromagnetic survey report describes promising condition for the exploration of metallic mineral deposit as following; intrusion of ultrabasic rock, existence of metamorphic zone accompanied by serpentinization, and fault or sheared zone which is expressed as Tawaëlia graben. It is certain that the existence of nickel deposit has high potentiality if well serpentinized ultrabasic rock is observed at the surface.

But in this area, aeromagnetic anomaly never combines with ultrabasic rock directly and even if it combines, ultrabasic rock itself is not mineral deposit. Otherwise, mineral deposit which has relation with rock body and rock type of non magnetic character, is observed generally. This fact is one of the difficulties in the exploration of minerals. But in this survey, aeromagnetic anomaly zones are confirmed clearly in this area. Their result will be judged to be useful for the basic materials of the future exploration.

About the future geophysical survey method, it will be mentioned in detail in Chapter 9 and heliborne E.M. method has high adaptability for the exploration of this area.

## 8. Recommendations on mineral resources

For the selection of an area with potential mineral resources in this district, judgement was made mainly on the results of this survey. It is natural, therefore, that different judgment should be made when other survey methods are used or closer investigations are made. It should be noted specially that the estimated value of prospecting area will vary considerably depending on the future investigation in the area like this one where the already known data is very little or worked mines are very few.

Also, the estimated values are comparable only within this survey area and not with other area.

With the above as pre-conditions, the prospective area will be discussed below.

### 8-1 Ore deposit as related to the rocks, igneous activities in this area

The granites which distributes in the area accounting for the half of this district is the country rock of pegmatitic ore deposit, porphyry copper type ore deposit, and the igneous activity of their intrusion is related to the ore deposits of various vein types. Consequently, any mineral deposit existing in this area must first be related granite.

Pegmatitic ore deposit in this area was already recognized as muscovite vein, and other deposits are also expected. On the contrary, there are some negative factors concerning the existence of ore deposit of this type. That is to say, pegmatitic crystals are often recognized on the left bank of the Palu, but the barren of the metallic minerals and vein-like or druse-like pegmatite is not recognized. If these granites are of the age of Miocene, they are similar to those seen in north of the Philippines concerning distribution and rock facies. If so, porphyry copper type ore deposit like the ones found in the Philippines is anticipated. But on the age of the granite intrusion in this area, it is presumed to be somewhat younger than that of the Philippines and there is a possibility that it is of the Pleistocene in part. Therefore, there are some doubt about the similarity of the condition of porphyry copper mineralization. The disseminated ore deposit in the Sopu suggests the possibility of this type but it is uncertain.

Pneumatolytic deposit, and contact metasomatic deposit by the igneous activity after granitic intrusion was anticipated but there was no indications in this area. Of the deposit of former type, several kinds of alterations accompanied by it, namely, greisenization, tourmalinization, are not recognized. Concerning the latter, there are few calcareous rocks, namely, limestone, etc. and skarnization is not recognized. Therefore, there are many negative factors for the existence of these ore deposits.

Hydrothermal ore deposit is generally recognized in any part near granite and in Poso and Palu zone and many deposits are already known. Precious metal deposit, namely gold, silver, and base metal deposits including copper, lead, zinc are assumed to exist and their existence is confirmed near the granite in general. In this survey, favorable indication of this type ore deposit is not recognized.

As Sulawesi island is well known for nickel ore deposits originating in ultrabasic rocks, the existence of ore deposit of this type was expected. However,because of lack of ultrabasic rock, this placer deposit is not hopeful.

Volcanic deposit and subvolcanic one accompanied by andesite, dacite, etc., have wide distribution all over the world. Their existence cannot be denied in this area. But, the distribution of these rocks is narrow, limited and only on a small scale, so the ore deposit of this type is not considered to exist on a large scale.

The existence of manganese, iron, aluminium ore deposit in sedimentary rocks (slate) is possible. But there was no sign of them. The negative factors are that those ore beds develop in Paleozoic sediments and that the quantity of chert, which is usually seen with manganese bed is poor in this area. but lack if this type ore deposit has never been confirmed.

In the Tertiary sedimentary rock and Quaternary deposit at the west coast district, placer deposit is presumed. But the judgement is difficult because of lack of information and limited survey.

In metamorphic rock, especially in crystalline schist, bedded pyrite deposit and schistose iron ore deposit show world wide distribution. From the geological factor, the former is expected in chlorite schist. But it is difficult to confirm its existence, since there is no indication of ore deposit of this type, and the chlorite schist in this area cannot be determined to be the products of the subvolcanic activity in geosynclinal period.

The radioactive mineral deposit is presumed to revolve around granites. but as far as the radioactivity of the collected samples is concerned, there is no anomaly in all samples and it is hard to expect this mineral deposit in this area.

The petroleum and natural gas deposits is expected from the west coast district to Kalimentan, since there is a sign of this deposit near the north of the Lariang, were explored and worked in the past and exploration is continuing now at Kalimantan.

However, through the method used this year, the information on the distribution of the oil bearing strata to the inner land is difficult to obtain. From the fact that there is a sign of deposit at the Rio at the west foot of the central mountains alone, it is difficult to make a judgment.

There is no promising deposit of non-metallic minerals in this district except the above petroleum and natural gas. About the coal, there is no sign or information about it. On the carbonates, the distribution and production are observed along the Palu bay out of the survey area, but in this area, any large distribution is not recognized. Gypsum and salt which is the raw materials of chemicals, quartzite and quartz vein which are the raw materials of glass and kaoline of the ceramic ware are not in existence or very few if any.

But the granite as building and construction materials, rocks of several types for artcraft and appreciation are abundant. As the use of this type will diffuse with the progress of some industries, further study on this use will be necessary. in future.

To summarize the above, the rocks having close relations with economic geology are granite, crystalline schist, slate in that order.

The relation to the ore deposit of Tertiary sedimentary rocks and

Quaternary deposit cannot be judged except petroleum and natural gas. The types of ore deposit expected in this area are prophyry copper type, vein type, layer of petroleum and natural gas as the first grade, kieslager, manganese bed as the second.

8-2 Ore deposit as related to the geological structure

Generally speaking, the ore deposit has no direct relations with the large structural zone. So it may be said the same in this area except hot spring. As controlled by the granitic intrusion, large folding and basin structure is not recognized; which have relations with ore deposit sometimes in other areas. It is that the mineralization accompanied by granite is observed at the margin of the intrusive body (batholith) or near the stock and boss derived from the batholith. In this area, this relation is thought of the dissemination zone at the Sopu. That is to say, mineralized zone distributes at the margin of granite controlled by the structure of granitic batholith. Also it suffers from the influence indirectly exerted by the main structural line of this district, since granitic batholith itself is affected by this line.

8-3 Ore deposit as related to the alteration

As several types of alteration in this area are weak and scattered, it is of no use as the indication of ore deposit, although alteration is one of the most important factors for exploration. Among them, hornfelsitization is important as it is related with mineralization. This alteration is observed at the margin of granites and the mineralization will have high potentiality in its place.

8-4 Ore deposit and mineralized zone recognized

In this survey, workable ore deposit of large quantity and high quality was not observed and confirmation about the mine already worked was impossible. Generally speaking, the existence of mine or mineralized zone already known provides useful information about the mineral resources, but the lack of the above confirmation makes the judgment very difficult. The most interesting signs observed during this survey were the disseminated zone along the Sopu and that of Masewo along the Karangana.

8-5 Ore deposit as related to the photogeological interpretation and aeromagnetic interpretation

The former interpretation provides no detailed description about the ore deposit. The recommendations of aeromagnetic survey report, namely, ultrabasic rock, altered zone, Tawaëlia graben have some doubt about the accuracy of fact. Even if they are true, they are not direct signs of existence of mineral resources. Therefore it is difficult to obtain guidance from them.

Summarized the above discussions, the geological factors for the abstraction of the promising area of the mineral resources will be discussed below.

1. Existence of granite, especially at the margin of intrusive mass, stock and boss.
2. Structure of the margin of the granitic batholith, the main structural line in this area.
3. Existence of the alteration zone, (hornfelsized zone)
4. Ore deposit, mineralized zone and mineral indication recognized, including out of this area.

8-6. Method of abstraction of the promising area

*The prospective area is selected through summarization of the estimated* values on the basis of the above geological factors. Consequently, the selected areas will show irregularly and will be separately located along the boundary of the layer or rock, around the mineral sign, etc.

It will be most accurate if the promising area is expressed by the above style but even if the method of abstraction is correct and appropriate, the data which may be used for estimation is rough and few and the balance of their accuracy will be destroyed. For this reason and for the convenience of the survey to be continued in the future, especially topographical map making, the area of abstraction make accord with division of Indonesian topographical map.

That is to say, about the longitude, based on the east longitude line of $120^o$, the area is divided every 15 , about the latitude, based on the south latitude of $1^o$, the area is divided every 15 , As a result, the divided area shows near squares and each square is tentatively named as follows:

| | | East longitude 120 | | south latitude 1 |
|---|---|---|---|---|
| Pasangkaju | Rio north | Bora | Palulu | Wuasa north |
| Lariang | Rio south | Namo | Lindu | Wuasa |
| Bulu Pondju | Banggaiba | Towulu | Gimpu | Torire |
| Kakali | Karosa east | Kalamanta | Banas | Pada |

The above square is further divided into a square of 5' longitude and latitude. For this smallest square, the potential of mineral resources is estimated by the geological factor. Of course this estimated value is not absolutely and objectively correct but varies with the quality and quantity of the data used.

For the estimation, each of the geological factor is valued. For the existence of granite, for example, some marks are given for the distance from the boundary line from granite and some marks are provided for the hornfelsized zone etc. Consideration was given to the square which has geological conditions similar to the place of mineralized zone in the neighbourhood of this area and which belongs to the extension of ore deposit outside of this area. Of the square where its geological condition is quite obscure, it is treated as no value as evaluation is impractical.

8-7 Promising area for mineral resources

By the above method, each square is classified as follows.

| | |
|---|---|
| Classified as A grade | Palulu |
| Classified as B grade | Lindu, Bora |
| Classified as C grade | Rio north, Banas |
| Classified as D grade | Rio south, Namo, Gimpu, Kalamanta, Towulu |

There is little difference between the estimated value of C and D class.

As the standard area of abstraction is 30% of the whole survey area, 5 to 6 squares mentioned above should be selected. Therefore, all the squares classified as A, B, C and some of D will be abstracted. But considering the little difference between C and D classes and the future survey, it is desirable to select Palu, Lindu, Bora, Rio north, Rio south and Namo.

If necessary, Banas chart must be added instead of Rio south and/or Namo.

Thus the abstracted area is located from 119°30' to 120°15' of east longitude, from 1° to 1°30' of south latitude.

# 9. Conclusions and Future Problems

## 9-1 Conclusions

The prospective area having potential mineral resources is located from 119°30' to 120°15' of east longitude, from 1°to 1°30' of south latitude.

For the above selection, some conditions were attached. The main condition attached was the limited method and the limited accuracy in judgment. Also there are some difficulties in the estimation because of limited data. But when the amount of data necessary for accurate judgment is taken into consideration, the amount of data required for absolutely complete judgment will be infinite. The accuracy to reasonable extent and the use of several different methods will be effective for appropriate selection of the promising area for the mineral resources, but the calculation of necessary data quantitatively is extremely difficult.

The other condition is that the area is designated in accordance with the boundary of the topographic map of Indonesia. This is done because of the consideration of the future survey, especially, the topographic map making.

One of the most difficult things in the development of mineral resources is the judgment on the existénce of mineral resources. To determine the absence of the mineral resources is particularly difficult. There are many reasons for this. First, the data collected by the use of several methods, including the geological, geophysical, etc., which should be the base of the judgment is not necessarily correct; second, the exploration of mineral resources requires comprehensive technics to analyze the above data, and they have not been completed technically yet; third, the standards used for the determination of the existence or absence of mineral resources are not concrete in general; fourth, the value of the mineral resources varies with the economic and technical factors.

For example, when the condition like the following is attached; the object is the exploration of metallic mineral deposit in the blind massive form with its size more than 100 m in diameter, the depth from the surface is less than 500 m, and the quality is optional in a practical manner. The geological survey with geophysical and geochemical survey will tell the existence of the object to some degree. Finally the existence is confirmed by drilling or drift of 100 m grid.

But usually condition is not concrete and even if concrete it is not economical and of no use to start drilling or drift in the whole area. Even when the accuracy is not high, other methods, such as geological survey, geochemical survey etc. which are inexpensive and speedy, should be used.

As for this area, the survey this time was rough and the judgment about the mineral resources is limited in accuracy. Therefore, detailed survey must be made to collect sufficient data on mineral resources.

9-2 Future problems

9-2-1 Method of exploration

The probability of the discovery of prospective area for mineral resources is the product of the probability of the existence of mineral resources in the area and the probability of the discovery of the deposit. In this report the former has been discussed mainly so far. The latter will be discussed mainly in this paragraph. The probability of discovery is influenced by the method of exploration.

Besides geological survey, photogeological survey and aeromagnetic survey already conducted in this area. There are many methods of exploration. There are several types of geochemical survey, geophysical survey including gravimetric survey, seismic survey, electric survey, magnetic survey and radioactive survey, trenching and pitting, drilling and drifting.

The following is a brief description of the characteristic of the above methods and their adaptability to this area.

| No. | Name of method | Results expected | Cost by unit area | Adaptability to this area | Remarks' |
|---|---|---|---|---|---|
| A | Geological survey | Understanding of geological conditions. Recognization of indications of mineral deposits, mineralized and altered zone. | Different depending on the degree of accuracy required. (rough survey, detailed survey) Inexpensive in general | Effective As the accuracy of this survey is low, detailed survey is necessary. | This method is the basis of other methods. It is required in any case. But in the case of Quaternary deposit area, other methods must be used together with this method. |
| B | Photogeological survey | Same as A | Inexpensive (except photography) | Adaptability is high in such places as this area where geological ground survey is difficult. | Usually the effectiveness increases if used together with geological survey. The accuracy varies greatly with the area. |
| C | Geochemical survey | Recognization of indications of mineral resources | Inexpensive | Adaptability is high in this area | Several methods are used depending on the object. The selection of index element is important. |
| D | Gravimetric survey | Recognization of geological structure | Various with location and accuracy. Expensive compared to A, B, C. Generally used in wide area, in which the cost by unit area decreases. | Adaptability is not high because of the simplicity of structure and rock unit. But effective in exploration of petroleum and natural gas under Alluvial deposit. | Effective for the interpretation of under surface geological structure which cannot be presumed by geological survey. Also effective for the interpretation of the under Quaternary deposit. |
| E | | Same as D | Generally used in detailed survey. Cost by unit area is the highest among geophysical method. | Almost same as D. | Same as D. |

| No. | Name of method | Results expected | Cost by unit area | Adaptability to this area | Remarks |
|---|---|---|---|---|---|
| F | Electric survey I<br>Spontaneous polarization method (S.P. method)<br>Resistivity method | Exploration of electrical unusual materials and factors, namely, ore deposit, subterranean water, boundary of strata | Generally inexpensive | As these methods have not good accuracy for exploration of mineral resources, economical effect is low. | Effectiveness is limited near the surface.<br>In the depth, accuracy is very low because of noise.<br>Resistivity method is in wide application to subterranean water investigation etc. |
| G | Electric survey II<br>Electro-magnetic method (E.M. method)<br>Induced Polarization method (I.P. Method) | Same as F.<br>specially good for sulfide minerals exploration | Comparatively expensive among the geophysical method.<br>Varies with methods (by air or on the ground) and topographical condition. | Considering the topographical condition in area, rough survey by air borne method with high adaptability is desirable. Ground survey of the whole area is not effective by economic reason. But the fine survey at the limited place abstracted by the other methods, is effective. | One good way to use these methods is to use E.M. method first (which is less expensive but with low accuracy compared with I.P. method) for the survey of wide area, then use I.P. method when anomaly is recognized.<br>I.P. method is one of the best for direct exploration of metallic mineral deposit. |
| H | Magnetic survey | For the recognization of rocks and geological structure.<br>Investigation of ore deposit constituted mainly of magnetic minerals. | Varies with methods (by air or on the ground)<br>Comparatively inexpensive for use on ground. | Considering the topographic condition and the purpose of the survey, air borne magnetic survey is adaptable for the first stage. If the magnetic anomaly recognized is presumed to be connected with mineral re- | This is widely used for both surveys (by air, on the ground) in geophysical exploration. But its disadvantage is only connected with magnetic minerals as the direct mineral exploration.<br>Air borne magnetic<br><br>(to be cont'd.) |

| No. | Name of method | Results expected | Cost by unit area | Adaptability to this area | Remarks |
|---|---|---|---|---|---|
| H | | | | sources, the magnetic ground survey will be necessary. | method is used as a supplemental method to the geological survey. |
| I | Radioactive survey | Similar to H when the word "magnetic" is changed to "radio-active". | Similar to H | Similar to H when the word "magnetic" is changed to "radioactive". | Similar to H, if the word "magnetic" is changed to "radioactive". Several methods are used depending on the type of radioactivity. |
| J | Trenching and pitting | Used as the supplemental method of geological survey (if the outcrop is not abundant) and for the recognization of the scale of mineralized zone, and quality of ore deposit. | Varies with each case. | In this area, the outcrop is not so favorable in general. Adaptable as a supplemental method of geological survey. Also adaptable if the mineralized zone is observed near the surface. | The difficulty of the method is that it is limited to near the surface in its use. |
| K | Drilling | Effective for all purposes. | Generally expensive but varies with methods, objects and other conditions. | Adaptable in general but by the economical reason. It is ineffective as the first step of exploration. | This method has high accuracy even in the deep part. As it is expensive the use should be determined carefully. It should be used in the case in which the other methods cannot resolve the questions or absolute accuracy is required. |

| No. | Name of method | Results expected | Cost by unit area | Adaptability to this area | Remarks |
|---|---|---|---|---|---|
| L | Drifting | Effective for all purposes. | Almost same as K. | Almost same as K. | The accuracy is highest of all the methods but it requires a tremendous amount of money and time. The use should be determined carefully. Usually used as the final step of exploration. |

9-2-2 Future exploration in this area

For the prospective area for mineral resources selected this time, part or the whole methods mentioned below should be used for further investigation in the future.

1 Detailed geological survey must be carried out first in the whole abstracted area to determine geological phenomena, as the basis of mineral exploration.

2 To recognize the indication of mineral deposit, geochemical survey is necessary in the whole abstracted area. As the first step, rough survey will be sufficient for this object.

3 For the same purpose, the airborne electric survey in the whole abstracted area is effective.

4 For the prospective area for mineral resources which will be determined and limited by the above three methods, part or the whole of detailed geochemical survey, electric survey on the ground and drilling should be conducted as the second step to recognize the mineral deposit.

5 If the existence of an economically justified mineral deposit is recognized, trenching, pitting, drilling and drifting should be provided as necessary. This is the third step of mineral exploration.

Prior to the start of the above survey, topographic maps with accuracy consisting with the object in this area must be prepared.

To complete the above geological survey in three years, geochemical rough survey and airborne electric survey will be necessary in the second year.

For the survey in the third year, it is advisable to determine after reviewing the results of surveys in the second year.

As mentioned previously, selection of prospective area always requires accuracy. Therefore, when the accuracy of judgment is improved in the future, or when new data of geology which overrule the past judgement is obtained, or when the technique of the exploration is so improved as to make an accurate estimate the value of this area, it is natural that re-investigation and restudy should be made for the whole survey area.

9-2-3 Regional development

Originally, the definition "mineral deposit", means and points to economical factors to considerable extent. Some of the mineral deposit which lie undeveloped by the economical reason will be workable in the future by the change in market condition, the progress of technique, and the expansion of applications. Though it is out of the scope of this report to touch on this subject, the regional development, especially that of infrastructure is very important in relation to the survey area.

If such basic requirement as the means of transportation, communication network, power supply is secured, together with the growth of industry, substantial education and medical care further growth of agriculture and fishery, the development of mineral resources will be much easier. In fact, the development of mineral resources and regional development are an integral part of the development of the country.

Blessed by favorable natural conditions, the natural resources of various types lie undeveloped in the whole area. The development and effective use of these resources are the most important thing for this area and will be the key to the development of this area.

# APPENDIX

Appendix

TABLE 1 Fossil

(Molluscs)

| | | |
|---|---|---|
| Sample No | : | II-24 |
| Location | : | the river of Rio. |
| Formation | : | Doda formation |
| Rock name | : | siltstone |
| Species | : | Gastropoda : Strombus (Labiostrombus) canarium (LINNE)<br>Scaphopoda : Dentalium (Paradentalium) hexagonum GOULD |
| Explanation | : | These fossils are kinds of Molluscs and abiogenesis. There are fine shells in this rock but determination is impossible. The age suggested from these fossils is Pliocene (or Pleistocene). |

| | | |
|---|---|---|
| Sample No | : | II-27 |
| Location | : | the river of Rio |
| Formation | : | Doda formation |
| Rock name | : | siltstone |
| Species | : | Gastropoda : Strombus (Labiostrombus) canarium (LINNE)<br>Glabrinassa sp. |
| Explanation | : | Same as above II-24 |

(Flora)

| | | |
|---|---|---|
| Sample No | : | III-19 |
| Location | : | near Torire |
| Formation | : | Lake deposit |
| Rock name | : | Unconsolidated mud. |
| Species | : | Pasania n.s.p. |
| Explanation | : | This fossil flora is of recent. It grows thick in tropical oah laurel forest. |

(Foraminifera)

| | | |
|---|---|---|
| Sample No | : | II-24 |
| Location | : | the river of Rio |
| Formation | : | Doda formation |
| Rock name | : | siltstone |

(Foraminifera)

Species & quantity :

| | | | |
|---|---|---|---|
| Fissuvina sp. | 1 | Pararotalia sp. | 1 |
| Lenticulina spp. | 2 | Elphidium crispum (Linne) | 7 |
| Bolivina cf. striatella Cushman | 2 | Elphidium cf. decipiens (Costa) | 5 |
| Loxostomoides carinatum (Millet) | 16 | Elphidium reticulosum (Cushman) | 1 |
| Rectobolivina sp. | 1 | Elphidium spp. | 4 |
| Siphouvigerina cf. ampullacea (Brady) | 7 | Nonion cf. grateloupi (d' Orbigny) | 18 |
| Angulogerina angulosa (Williamson) | 1 | Nonion japonicum Asano | 3 |
| Rosalina bradyi (Cushman) | 1 | Astrononion sp. | 1 |
| Buccella sp. | 1 | Cibicides pseudoungerianus (Cushman) | 3 |
| Epistominella sp. | 1 | Cymbaloporetta bradyi (Cushman) | 1 |
| Ammonia spp. | 8 | Benthonic total | 85 |
| | | Globigerina spp. | 7 |

Explanation : Same as II-27 undermentioned

Sample No : II-27
Location : the river of Rio
Formation : Doda formation
Rock name : siltstone
Species & quantity :

| | | | |
|---|---|---|---|
| Triloculina sp. | 77 | Rosalina sp. | 1 |
| Miliolids gen. sp. indet. | 146 | Ammonia cf. beccarii (Linne) var. A | 75 |
| Fissurina spp. | 17 | Ammonia cf. beccarii (Linne) var. B | 5 |
| Dentalina sp. | 1 | Elphidium spp. | 10 |
| Bolivina spp. | 5 | Nonion cf. grateloupi (d' Orbigny) | 3 |
| Bulimina sp. | 2 | Cymbaloporetta bradyi (Cushman) | 1 |
| Cassidulina sp. | 6 | Benthonic total | 349 |
| | | Globigerina spp. | 6 |

Explanation : Forminifera of the above two samples are poor in planktonic one and rich in benthonic, which shows shallow sea. But these samples suggest different circumstance each other.
In II-27 sample, Miliolids (a kind of Quinqueloculina) and Ammonia beccarii are predominant which shows very shallow sea and somewhat embayment degree. On the contrary in II-24, Loxostomoides in Nonion, and Elphidium are abundant and Siphouvigerina which indicates somewhat deep sea is observed although small quantity.
As a whole, this sample shows open sea character and inner or middle shelf.
About the age of this rock, decision is uncertain, but it will be presumed to be late Miocene or Pliocene.

TABLE 2 Dating by Potash-Argon method

Table of measurement

| Sample No | Location | Rock name | Index mineral | Potash contents per cent | Air contamination per cent | Absolute age year |
|---|---|---|---|---|---|---|
| I - 5 | Mapahi | Biotite granite | Biotite | 7.19 | 82.77 | $1.62 \times 10^6$ |
| II - 5 | Bakubakuru | Biotite sheared granite | Biotite | 4.87 | 91.26 | $1.68 \times 10^6$ |
| II - 6 | Berdikari | Garnet sillimanite biotite hornfels | Biotite | 3.74 | 87.70 | $4.80 \times 10^6$ |
| II - A - 2 | Saluwa | Biotite schist | Biotite | 7.51 | 78.46 | $2.97 \times 10^6$ |
| III - 11B | Rundo | Biotite granite | Biotite | 7.22 | 77.68 | $3.35 \times 10^6$ |

Explanation : All of these samples were able to be measured corretly. Considering the result, II-6 sample shows the oldest age. This age is the nearest value of granitic intrusion. After the crystallization of igneous magma, the temperature of rock is gradually decreasing. It is reported that when it reaches about 300°C, $^{40}Ar$ (Argon) by the disintegration of $^{40}K$ (Potash) is held in crystal, but if more than 300°C, $^{40}Ar$ cannot remain in potash bearing crystal and in part it is scattered from the crystal.
*Therefore it must be noticed, that the value of above absolute age does not show correct age of intrusion and* biotite near the margin of grainte is concluded to show the closest age of intrusion.

Reference : About the period of cooling, some reports were described.
By the book written by Daly, the necessary time for cooling from 1100°C to 750°C of acidic magma which contacts with open air is as follows :

| | | | | | |
|---|---|---|---|---|---|
| Depth | 1 m | 10 m | 100 m | 1,000 m | 10,000 m |
| Time required | 12 days | 3 years | 300 years | 30,000 years | 3,000,000 years |

By Larsen, H.H. (1945) the time required for the crystallization of the great batholith of southern and lower California is as follows :

| | | | | |
|---|---|---|---|---|
| Width of dyke | 1 m | 1 km | 10 km | 100 km |
| Time required for complete crystallization | 2.5 days | 7,000 years | 700,000 years | 70,000,000 years |

TABLE 3 Microscopic Observation

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks. |
|---|---|---|---|---|---|---|
| I - 2 | South of Gimpu | Rhyolite group | Rhyolitic tuff | Pale greenish compact rock | A fine-grained mixture of quartz and glassy materials. Contains many crystal fragment of quartz, orthoclase, plagioclase, biotite and hornblende. | |
| I - 3 | South of Gimpu | Granite group (Nokila laki) massif) | Hornblende biotite granite | Coarse grained holocrystalline rock | Principal minerals are orthoclase, plagioclase, hornblende, biotite & quartz. Orthoclase has euhedral shape (0.5-1.0 cm long) and shows carlsbad twinning. Plagioclase, showing albite twinning, is almost andesine. Hornblende and biotite are altered to chlorite, calcite, and magnetite. There is a little sphene. | |
| I - 5 | Mapahi | Granite group (Waukara massif) | Biotite granite | Fine grained holocrystalline rock | Orthoclase, quartz, oligoclase (some of which shows carlsbad or albtite twinning and zonal structure) and biotite are the principal constituents. Small granular crystals of quartz, oligoclase, and biotite are irregularly scattered in a large orthoclase crystal showing poikilitic texture. Apatite, magnetite and zircon in biotite are accesory minerals. | |
| I - 6 | Banas | Andesite group | Hornblende biotite andesite | Gray, fine grained compact rock containing many euhedral hornblende and a little biotite. | Phenocrysts of plagioclase (andesine), hornblende and biotite in the matrix of plagioclase laths with chlorite patches, magnetite and carbonate. Hornblende and biotite are altered to aggregate of magnetite and chlorite. | |
| I - 7 | Masewo | Karangana river formation | Biotite hornfels | Brownish dark gray compact rock | Flakes of biotite is associated with quartz, chlorite, muscovite and plagioclase. It shows traces of foliation but biotite has a decussate texture. Opaque mineral may be pyrite. | |
| I - 9 | Mamu | Karangana river formation | Slate | Black, hard, pelitic rock | A little quartz, feldspar, chlorite and patches of mica. This rock has not been thermally metamorphosed. | See PL 1 |
| I - 10 | Kalamanta | Dacite group | Dacitic tuff breccia | Brownish gray rock having green and yellow patches. Many biotite crystals are observed. | Fragment of plagioclase (andesine), quartz, hornblende, biotite occur in a mixture of fine plagioclase laths, quartz and glassy matrix. | |
| I - 12 | Kalamanta | Karangana river formation | Sandstone | Yellowish gray loose rock Graded bedding is distinguishable. | Angular grains (about 0.1 mm long) of plagioclase, quartz, hornblende (almost altered to chlorite) and magnetite. More than 30% of grains is plagioclase, so it may called to be arkose sandstone. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| I - 13 | Kalamanta | Andesite group | Hornblende biotite andesite | Grey, fine-grained rock having fine crystals of hornblende and biotite (1 mm long). | Phenocryst of zoned plagioclase, green hornblende and biotite in a matrix of glass with many tiny plagioclase (oligoclase) microlites. Plagioclase, showing carlsbad and albite twinning is almost andesine. Hornblende has euhedral shape and some part of it are chloritized. Magnetite and apatite are accessories. | |
| I - 14 | Kalamanta | Andesite group | Honblende biotite andesite | Dark green glassy rock having biotite and plagioclase phenocryst. | Very similar to I-13, but plagioclase lath in a matrix of this section is richer than I-13. There is small amount of zircon in biotite. | See PL 5 |
| I - 18 | Banas | Andesite group | Crushed biotite andesite | Fine grained, gray rock with biotite and elongated plagio-clase phenocryst. | Crystals of zoned plagioclase showing carlsbad and albite twinning, biotite and hornblende are enclosed in a matrix of plagioclase laths and fibrous chlorite. It shows traces of strain. | |
| I - 21 | Banas | Andesite group | Hornblende biotite andesite | Dark gray fine grained compact rock with tiny biotite. | Modal ratio of phenocrysts is plagioclase≫ biotite> hornblende. Plagioclase, 1-2 mm long, is almost andesine and chlorite and many magnetite take the place of biotite and hornblende. Intersertal texture is partly observed. | |
| I - 22 | Mapahi | Grante group (Waukara massif) | Hornblende biotite quartz diorite. | Melanocratic, medium grained compact rock. | More than 80% of crystals are twinned plagioclase (andesine) which has euhedral form and about 5 mm length. Hornblende is the major constituent of mafic mineral. Also biotite is present. Both minerals are mostly altered to chlorite, calcite and magnetite. A few apatite grains are recognized in and near mafic minerals. Quartz grains fill the space of other crystals but its amount in few. | |
| I - 23 | Banas | Karangana river formation | Limestone | Prismatic calcites in the yellowish siliceous matrix. It shows vermicular-like pattern. | Crystallized calcite prisms are cemented by small quartz grains, carbonate and cherty material. | |
| I - 24 | Banas | Karangana river formation | Hornblende biotite hornfels | Dark brownish gray sandy compact rock | Chlorite flakes (altered from hornblende) are scattered in fine grained matrix of quartz and plagioclase. Bronw biotite newly recrystallized, is as vague more or less irregular patches. | |
| I - 25 | Banas | Granite group (Waukara massif) | Hornblende biotite quartz diorite | Fine grained melanocratic rock | The major constituents are twinned plagioclase (andesine) in euhedral to subhedral form, hornblende, biotite, and quartz. Hornblende is partially altered to chlorite but biotite is fresh. Modal ratio is plagioclase≫ hornblende> biotite> quartz. Magnetite and sphene are also present. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| I - 26 | Tompi | Andesite group | Augite biotite andesite | Purplish gray glassy rock | Phenocryst of euhedral plagioclase (andesine), subhedral augite and biotite are in a matrix of plagioclase laths, magnetite and glass. The size of phenocryst is less than 0.5 mm. | |
| I - 27 | Tompi | Karangana river formation | Limestone | Grayish white rock | Pellets of small size (less than 0.01 mm) of calcite and very small amount of quartz. (nearly 0.05 mm size) Opaque mineral may be pyrite. | |
| I - 28 | Tompi | Karangana river formation | Sheared quartzite | White hard rock with ferruginous streaks | Strained quartz shows traces of flowage. It contains angular feldspar chips, (oligoclase and orthoclase) pyrite, and interstitial chlorite. | |
| I - 29 | Kodja | Lariang river schist | Biotite schist | Greenish foliated rock | Biotite bands (almost altered to calcite aggregate and chlorite) and leucocratic band which is composed of plagioclase and quartz. | |
| I - 31 | Kodja | Rhyolite group | Rhyolitic tuff | White soft rock having 2-3 mm long quartz grain | Clips of quartz and feldspar (alkali-feldspar), flakes and patches of chlorite and brownish mica are visible in a less clearly defined glassy fragments | |
| I - 32 | Lonebasa | Grante groups (Waukara massif) | Hornblende biotite granite | Mesocratic medium grained rock | Modal ratio of constituent minerals is feldspar > quartz > biotite > hornblende.<br>Feldspar, including orthoclase, albite and plagioclase (oligoclase) is altered to kaoline and calcite. Biotite and hornblende are also decomposed to chlorite, epidote, calcite and magnetite throughly. There is a little cubic pyrite and prismatic apatite. | |
| I - 33 | Lonebasa | Karangana river formation | Biotite phyllite | Brownish yellow hard compact schistose rock | Flakes of biotite and chlorite and irregular grains of quartz with a distinct fissility. | |
| I - 34 | Kantewu | Andesite group | Andesitic intrusive breccia | Fine grained green rock with white spots | Fragment of plagioclase (oligoclase to andesine), alkali feldspar, hornblende and a litte chlorite in a matrix of pilotaxitic texture. Sphene and magnetite are accessory minerals. Calcite is seen as secondary mineral. | |
| I - 35 | Kantewu | Kentallenite | Kentallenite | Melanocratic medium grained rock. Colour index is about 70. | Grains of euhedral augite showing diallage parting (2 to 3 mm), biotite, olivine and prismatic twinned plagioclase (oligoclase to andesine) in orthoclase (poikilitic texture). Accessories are magnetite and apatite. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| I - 36 | Kantewu | Kentallenite | Kentallenite | Melanocratic medium grained rock. Colour index is 80-85. | The constituent minerals and texture are the same as I-35. The amount of plagioclase and magnetite (chiefly in mafic minerals) are larger than I-35. | |
| I - 37 | Onu | Karangana river formation | Chlorite sericite schist | Green compact rock. | Flakes of chlorite and sericite with a distinct schistosity. | |
| I - 40 | Kanuna | Karangana river formation | Basic tuff | Reddish brown colored rock. | A litte plagioclase, chlorite, sericite and patches of opaque minerals (some of them are magnetite) are distinguishable. There are many calcite veinlets. | |
| I - 42 | Towulu | Lariarg river formation | Muscovite bearing (in pegmatite vein) schist | Platy muscovite (1 to 2 cm long in quartz vein. Country rock is dark greenish schistose rock. | Large platy muscovite and feldspar crystals (alkali feldspar) are surrounded by a mozaic of quartz grains. Country rock is made up principally of flaky biotite 1 partially altered to chlorite), muscovite and quartz with a distinct schistosity. | |
| I - 43 | Mapahi | Karangana river formation | Epidote chlorite quartzite | Siliceous hard rock. | Epidote grains are scattered in aggregation of irregular quartz grains. Very litte amount of plagioclase is recognized. | |
| II - 1 | Bora | Grainte group (Nokila laki massif) | Biotite granite | Fine grained compact rock | Somewhat coarse grained feldspar (andesine, orthoclase) showing perthitic texture in part. Also biotite is main component mineral. | |
| II - 2 | Bora | Palu river schist | Hornblende chlorite schist | Dark gray - greenish colored compact rock. Alteration is observed. | Elongated hornbledne (common hornblende), quartz and plagioclase make low grade schist. Chlorite and epidote are observed in common. Mafic mineral will be made by the contact metamorphism with granite. | |
| II - 3 | Bora | Palu river schist | Epidote bearing phyllite | Dark gray colored fragile rock at the contact margin with granite | By the contamination, epidote makes veinlet and granularly scattered. Common hornblende is seen and dusty quartz is also main constituent. | |
| II - 4 | Bora | Granite group (Nokila laki massif) | Biotite granite | Leucocratic fine grained rock | Biotite, orthoclase and plagioclase (andesine) are main constituent minerals. Chlorite, sericite and magnetite are scarcely observed. Biotite has some orientation which will be explained as marginal facies of granite. | |
| II - 5 | Bakubakuru | Granite group (Nokila laki massif) | Biotite sheared granite | Medium grained leucocratic rock | Medium grained orthoclase and plagioclase are main comporents. Biotite, chlorite and sericite as secondary mineral are abundant. Garnet and sillimanite are seen a little. Other accessories are magnetite, apatite and titanite. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remakrs |
|---|---|---|---|---|---|---|
| II - 6 | Berdikari | Palu river schist | Garnet sillimanite biotite hornfels | Somewhat melanocratic compact rock. | Medium - grained orthoclase and plagioclase are abundant, showing perthitic texture and albite twinning. Biotite and chlorite are abundant. Therefore original rock is considered to be granitic rock. Quartz is seen as secondary products. Garnet, sillimanite, sericite are observed a little. Also sulfide minerals are seen in common. | |
| II - 7 | Berdikari | Granite group (Nokila laki massif) | Gneissose biotite granite | Medium - fine grained leucocratic rock | Grain size is rather small and granular in this rock. Orthoclase, plagioclase, biotite are main constituents. Gneissosity is obscure. Sulfide minerals are seen granularly but they give no effect to the country minerals. | |
| II - 8 | Berdikari | Granite group (Nokila laki massif) | Biotite granite | Fine grained compact leucocratic rock | Except very few crystal of biotite, this rock consist of only orthoclase and plagioclase, showing perthitic texture in part. So, it may be well to say, a kind of anorthosite. | |
| II - 9 | Berdikari | Sopu river gneiss | Garnet sillimanite biotite gneiss | Medium - fine grained, dark green compact rock | The main components of this rock are plagioclase, garnet, biotite, sillimanite, epidote and quartz. Plagioclase shows fine grained granular crystal.. Garnet is common showing granular occurrence and sillimanite fibrous interstitial texture. By the reason of such mineral's existence, this rock will be affected by the granitic contamination. | |
| II - 10 | Berdikari | Granite group (Nokila laki massif) | Biotite granodiorite | Fine grained compact rock | Plagioclase (oligoclase-andesine) and orthoclase showing zonal structure are main constituent minerals except biotite. Apatite, chlorite are sometimes observed, and only two pieces of common hornblende are observed. | |
| II - 11 | Berdikari | Granite group (Nokila laki massif) | Biotite garnet granodiorite. | Fine grained compact rock | Plagioclase (oligoclase - andesine), orthoclase and garnet are recognized commonly. Crystal size is small and form is granular. Accessory minerals are similar to II-10. | |
| II - 12 | Berdikari | Grainte group (Nokila laki massif) | Biotite hornblende gneissose granite | Dark green, melanocratic compact rock | Plagioclase (andesine), orthoclase and quartz are main components. Biotite flakes and hornblende prismatic crystals are observed in common. Sulfide minerals are somtimes recognized which are thought to be pyrite. Other accessories are chlorite, sericite and titanite. | |
| II - 13 | Berdikari | Granite group (Nokila laki massif) | Biotite granite | This rock is characterized by fine grained feldspar and biotite crystals. Leucocratic, compact rock | The mafic mineral is only biotite. Plagioclase and orthoclase are main constituent. The grain size is rather small and granular. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| II - 14 | Berdikari | Granite group (Nokila laki massif) | Biotite gneissose granite | Somewhat melanocratic, compact fine grained hard rock | This rock is chiefly composed of quartz, plagioclase, orthoclase, and biotite. Garnet, common hornblende are considerably observed. | |
| II - 16 | Baluase | Grainte group (Waukara massif) | Hornblende biotite granite | Coarse grained leucocratic rock. Pegmatitic crystal of feldspar is distinguishable. | Plagioclase (andesine), orthoclase and biotite are rich in this rock. Perthitic texture is common in feldspar. Hornblende is recognized generally but the amount is less than biotite. Apatite and titanite are observed scarcely. | |
| II - 18 | Baluase | Granite group (Waukara missif) | Biotite granodiorite | Fine grained compact rock | It consists mainly feldspar. (oligoclase, andesine and orthoclase) Biotite is observed a little amount. Other accessories are scarce. | |
| II - 19 | Waukara | Palu river schist | Sericite phyllite | Bedded fragile rock of dark greenish gray color. | It consists of sericite, carbonate and quartz which shows similar texture as II-20. grain size of quartz is usually very fine but in some part, coarse crystal is observed. | See PL 3 |
| II - 20 | Waukara | Palu river schist | Sericite phyllite | Bedded fragile rock with black to dark gray color. | Main constituents are quartz and sericite. Both minerals show microfolded texture. It divided into sericite rich band and fine grained quartzose band which changes gradually from fine to coarse grained part. No recrystallization is observed and above texture shows the condition of sedimentation. | |
| II - 21 | Waukara | Palu river schist | Felsic aggregates in phyllite. | White colored, porous hard rock. which is shown as aggeregate in phyllite. | Main constituents are plagioclase and quartz of medium grain. In some part fibrous aggregate of chlorite is observed. | |
| II - 23 | Rio | Granite group (Rio massif) | Hornblende granite | Mafic mineral (horn-blende) shows the flow texture. Compact rock. | Very large crystal (0.5 - 1 mm) of common hornblende and feldspar are main constituents. In feldspar plagioclase (andesine) to oligoclase) is richer than othoclase, so it may be said to be adamellite. Chlorite, magnetite are observed. | See PL 6 |
| II - 25 | Rio manta | Granite group (Rio massif) | Hornblende granite | Almost same as II-23 | Almost same as II-23. | |
| II - 26 | Rio manta | Karangara river formation | Biotite hornfels | Dark gray colored, silicified, very hard rock | Main constituents are biotite and quartz. Quartz is medium grain size and thought to be secondary mineral judged from the equigranular shape and size. | |
| II - 29 | Rio manta | Karangana river formation | Siliceous slate | Gray to brown colored very hard rock. | Main constituents are medium grained quartz and biotite. Chlorite and sericite are observed. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| II - 30 | Rio manta | Dacite group | Hornblende dacite | Pale gray to brown colored, very hard compact rock | Phenocryst consists of albite twinned plagioclase, hornblende and biotite. Quartz is scarcely observed. Groundmass is of quartz and plagioclase. Accessories are magnetite and chlorite. | |
| II-A-1 | Saluwa | Granite group (Nokila laki massif) | Biotite granite | Holocrystalline fine grained rock | It consists chiefly quartz and biotite. Apatite is included in quartz and biotite. Few crystal of augite is recognized. | |
| II-A-2 | Saluwa | Palu river schist | Biotite schist | Schistose rock showing biotite-rich band and leucocratic mineral band. | Modal ratio of this rock is plagioclase > quartz > biotite. Plagioclase shows subhedral, lamella twinning, quartz of subhedral form. Biotite is altered to chlorite. A little amount of titanite is observed in biotite. Other accessory mineral is apatite. | |
| II-B-1 | Saluwa | Granite group (Waukara massif) | Biotite granite | Fine grained leucocratic rock | Principal minerals are orthoclase (somewhat zoned), subhedral twinned plagioclase (oligoclase to andesine) and quartz. Biotite (in part altered to chlorite) is the only ferromagnessian in this rock. There is some magnetite, apatite and sphene. Modal ratio of constituent is orthoclase > plagioclase | |
| II-B-2A | Saluwa | Granite group (Waukara massif) | Hornblende Diorite | Fine grained melanocratic rock | More than 70% of this rock is hornblende (in most part altered to chlorite). Another principal minerals are plagioclase (andesine) and orthoclase. | |
| II-B-2B | Saluwa | Granite group (Waukara massif) | Hornblende biotite quartz diorite | Medium grained mesocratic rock showing somewhat gneissose texture. | Plagioclase (andesine) ≫ biotite > hornblende > quartz is the modal ratio. Plagioclase (in euhedral to subhedral shape) shows albite twinning and its crystal length is 1 cm ±. Strained quartz is embedded in anhedral form. | |
| II-B-3 | Namo | Lariang river schist | Biotite schist | Reddish brown banded rock. | Melanocratic band, chiefly composed of flakes of biotite and leucocratic band which is made up of quartz and plagioclase (andesine). A little magnetite and chlorite are in melanocratic band. | See PL 2 |
| II-B-4 | Namo | Granite group (Waukara massif) | Biotite granite | Fine grained leucocratic rock. Its apparence is very similar to that of I-5. | Equigranular holocrystalline rock. Zoned oligoclase to andesine, orthoclase, quartz and biotite are the principal minerals. Accessories are apatite, magnetite and well formed allanite. | |
| II-C-4 | Balongga | Granite group (Waukara massif) | Biotite schist | Fine grained, leucocratic rock. | In feldspar, main constituent mineral, plagioclase is richer than orthoclase. So, the accurate name of this rock is adamellite. Mafic mineral is only biotite. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| II-C-6 | Balongga | Granite group (Waukara massif) | Hornblende biotite granite | Coarse grained feldspar crystal is characteristic. Generally coarse grained, holocrystalline rock. | The main constituents of this rock, are orthoclase (microcline) and plagioclase (andesine) which shows more than 1 cm large crystal. Hornblende and biotite are rich in this rock. Other accessories are little apatite and titanite. | |
| II-D-2 | Sidondo | Palu river schist | Biotite quartz schist | Grayish black colored rock. Brownish biotite band is observed. | Quartz and biotite show banded texture and definite arrangement. Also sulfide mineral and ferrous oxide altered from the former show definite arragement. | |
| II-D-5 | Pasaku | Grante group (Waukara massif) | Hornblende biotite quartz diorite | Holocrystalline, medium grained, massive rock | It consists chiefly plagioclase, biotite, hornblende and intersertal quartz. Plagioclase shows lamella twinning and zonal structure. Accessories are titanite and epidote. | |
| II-D-6 | Pasaku | Palu river schist | Biotite schist | Compact schistose rock showing banded structure of grayish black and grayish green. | In this rock, crystals show definite arrangement. Quartz, plagioclase (showing lamella twinning), biotite, clinopyroxene, sulfide minerals are recognized in fine part and coarse part. Also seggregations of quartz and plagioclase, biotite, clinopyroxene are observed. Quartz vein of coarse crystal is observed including clinopyroxene. | |
| II-D-7 | Bangga | Rhyolite group | Felisic rhyolite | Grayish compact part and porous part show zonal arrangement which suggest lava. | It shows flow texture consisting of very little phenocryst and much groundmass. Phenocryst is very small size of plagioclase. Groundmass is quartz feldspathic of 0.5 to 1.0 mm long, showing micrographic to micro-ophitic texture in some part. | |
| III-1A | Au | Andesite group | Hornblende biotite andesitic tuff breccia | Size of breccia is several mm to several cm, showing blackish red to reddish gray color. Cementing materials are yellowish. | Accidental breccia of plutonic rock, namely, granite, pyroxenite, and essential breccia of andesitic rock, namely, hornblende, biotite andesite, porous pumice fragment, glassy hornblende andesite fragment. (the last is accidental) Cementing material is volcanic ash including plagioclase and hornblende. | |
| III-2A | Au | Rompo river schist | Chlorite quartz schist | Dark green colored, compact schistose rock. White colored vein intrudes in this rock. | Main components are quartz, chlorite, epidote and carbonate. Quartz shows lenticular form and definite orientation. Also comparatively large crystal aggregation is observed. Fiberous chlorite, granular or veinlet-like epidote, fine grained calcite arrange regularly. Calcite veinlet is observed. | |
| III-2 | Au | Rompo river schist | Epidote chlorite quartz schist | Grayish black colored compact rock. Schistosity develops in some parts. | Quartz, plagioclase, chlorite, epidote, sulfide and carbonate arrange at definite direction. Moreover carbonate vein including quartz is observed. Quartz shows lenticular small flakes, plagioclase carlsbad and albite twinning. Cholrite is observed intersertally. | |

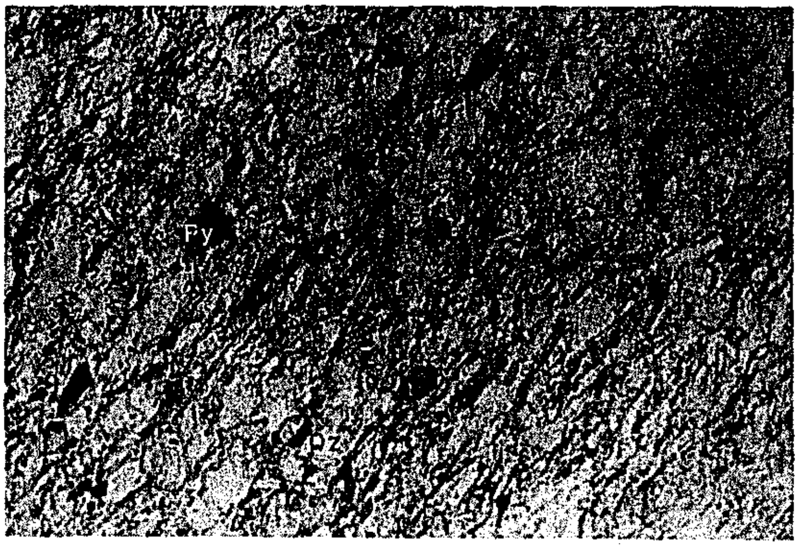
| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| III-3 | Au | Pyroxene andesite | Pyroxene andesite | Dark green, porphyritic massive rock. | It shows porphyritic texture. Phenocryst consists of plagioclase, clinopyroxene, olivine and opaque minerals. Plagioclase includes chlorite, pyroxene and in some part, sericite along the cleavage. Much clinopyroxene and little olivine is observed. Almost all part of opaque minerals are magnetite, some part of which altered to limonite. Groundmass is plagioclase lath, granular pyroxene, which changes to chlorite in part, fine grained magnetite and chlorite. | |
| III-4 | Au | Rompo river schist | Epidote chlorite quartz schist | Dark green colored compact hard rock. In some part, schistose or brecciated. | Quartz, epidote, chlorite, calcite and little opaque mineral arrange at definite direction, showing schistose texture. Quartz shows irregular form, plagioclase, carlsbad twinning and chlorite, green patch. Calcite vein shows cross intrusion to the schistosity. | |
| III-5 | Sabulu | Rompo river schist | Epidote chlorite quartz schist | Dark green compact rock. White colored veinlet is observed. | Quartz, feldspar, chlorite, epidote and opaque minerals are main constituents, which shows lenticular or irregular form, and plagioclase has carlsbad twinning. Opaque mineral which arranges parallel to schistosity is sulfide mineral. Carbonate vein and quartz vein are seen at any place. | |
| III-6 | Tuare | Karangana river formation | Carbonatized chert | White colored siliceous rock which is intruded by carbonate network-like vein | Extremely fine grained quartz (0.02 mm) is the main component. Fine grained carbonate (0.01 mm) mixes to the quartz grain. Also medium grained carbonate network is recognezed all over the rock. | |
| III-9 | Kagero | Gabbro group | Hornblende gabbro | Grayish black colored compact rock | Hornblende, plagioclase, titanite and opaque mineral compose this rock. Hornblende is green colored common hornblende and anhedral (rounded in part) plagioclase shows carlsbad and albite twinning. Opaque mineral is sulfide. | |
| III-11-B | Rundo | Granite group (Nokila laki massif) | Biotite granite | Holocrystalline, medium granied leucocratic rock | Quartz is usually interstitial and orthoclase has large crystal of carlsbad twinning or perthitic texture in part. Plagioclase is albite showing lamella twinning. Other main component is biotite and accessories are apatite and titanite. | |
| III-12 | Pada | Dolerite group | Hornblende dolerite | Grayish black colored compact hard rock | Phenocryst consists of micro-phenocryst of plagioclase and shows porphyritic texture. Plagioclase shows carlsbad twinning. Groundmass is plagioclase lath, hornblende and magnetite, showing intergranular texture. | |
| III-12B | Pada | Dolerite group | Hornblende dolerite | Grayish black colored compact rock | Details are as similar as III-12. But grain size is somewhat larger than III-12. Texture is from intergranular to gabbroic one. | |
| III-14 | Pada | Karangara river formation | Sandstone | Dark grayish black colored compact rock | Coarse grained and fine grained part show alternated layer. Coarse part consists of much amount of quartz and chlorite, little amount of plagioclase, hydro-mica, pyroxene and sulfide. Fine part is mainly quartz and pyroxene. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| III-20 | Kato | Rompo river schist | Sericite chlorite quartz schist | Gray colored micro-folded Schistose rock | This rock consists of fine grained or medium grained quartz, fiberous sericite and chlorite. All of them show schistose texture. Quartzose part and sericite chlorite rich part show banded texture. | |
| III-21 | Kato | Rompo river schist | Sericite chlorite quartz schist | Grayish white and grayish black colored parts show banded texture. | It consists quartz, sericite and chlorite. Quartz is equigranular in general, sericite is fiberous and chlorite is combined with quartz especially. Quartzose part and mafic part show banded texture. | |
| III-22 | Kato | Andesite group | Hornblende andesite | Grayish white colored porphyritic rock. Phenocryst of white feldspar and black needle-like mineral are observed. | Phenocryst consists of plagioclase, hornblende and opaque mineral. Plagioclase is altered to chlorite and carbonate in general. Hornblende is also altered to chlorite, titanite and carbonate. Opaque mineral is sulfide. Groundmass shows spherulitic texture and consists of micrographic intergrowth of quartz and feldspar. | |
| III-24 | Kato | Gabbro group | Hornblende gabbro | Gray to black colored compact rock. Grayish white veinlet is observed commonly as reticulated vein. | This is holocrystalline rock including much subheclral little lamella twinned plagioclase and titanite. Epidote veinlet is observed commonly. | |
| III-25 | Kato | Granite group (Nokila laki massif) | Hornblende biotite granite | Holocrystalline leucocratic rock | It consists of quartz, orthoclase, plagioclase, biotite hornblende, titanite and opaque mineral. Quartz is observed interstitially as fine crystal and orthoclase shows comparatively coarse grained, carlsbad twinning. Plagioclase is altered to sericite in part, and biotite to chlorite and titanite mostly. Chlorite veinlet is abundant making network. | |
| III-26 | Torro | Sopu river gneiss | Biotite granitic gneiss | Holocrystalline, gneissose rock | It consist chiefly much quartz, lamella twinned plagioclase, biotite, little orthoclase and sphene as inclusion into biotite. All of them show definite orientation. | |
| III-27 | Torro | Rompo river schist | Biotite chlorite bearing sericite quartz schist | Grayish white and grayish black colored part show banded texture. | Main constituents are irregular formed quartz, biotite.fibrous sericite, chlorite, sulfide and little lamella twinned plagioclase. Chlorite network is observed commonly. | |
| IV-2 | Namo | Gabbro group | Augite hornblende microgabbro | Mediumgrained, holocrystalline compact rock | Plagioclase, hornblende, augite, titanite and opaque mineral are consitituents. The most abundant is hornblende showing subhedral to granular form. Plagioclase shows subbedral to fine grained form, and augite is usually anhedral. Opagne mineral is both oxide and sulfide. | |

| Sample No | Location | Formation or group name | Rock name | Macroscopic observation | Microscopic observation | Remarks |
|---|---|---|---|---|---|---|
| IV-3 | Namo | Ultrabasic rock | Chromite bearing pyroxenite | Dark grayish green colored, holocrystalline rock. | Bronzite of 2-5 mm size is the main component. A little amount of olivine and chromite is observed. Serpentine is recognized in bronzite and olivine as network. Few crystal of magnetite is seen. | see PL 4 |
| IV-4 | Kalamea | Gabbro group | Hornblende gabbro | Dark gray, holocrystalline rock. | Plagioclase and augite show micrographic intergrowth including compartively much sulfide and apatite. | |
| IV-5 | Rio | Palu river schist | Sericite chlorite quartz phyllite | Grayish black colored, fragile and schistose rock | It consists of lenticular quartz, fiberous chlorite, sericite and sulfide. Carbonate and quartz veinlet are common all over the rock. | |
| IV-6 | Rio | Dacite group | Biotite dacite | Somewhat melanocratic, compact hard rock | This shows porphyritic texture. As phenocryst, little quartz, zoned biotite which altered to chlorite and carbonate and plagioclase are observed. Sulfide and carbonte are seen also. Groundmass consist of mozaic quartz and plagioclase, chlorite, biotite and sulfide. | |
| IV-7 | Pakuli | Granite group (Nokila laki massif) | Biotite granodiorite | Holocrystalline, leucocratic rock | Main constituents are interstitial quartz, perthitic orthoclase, plagioclase, biotite, much apatite, sulfide and carbonates. Also observed veinlet of carbonate which is altered from plagioclase. | |
| (Polished Section) | | | | | | |
| II-5 | Bakubakuru | Granite group (Nokila laki massif) | Biotite sheared granite | | Massive pyrite about 100 μ is observed in common. Granular zincblende, covellite and chalcopyrite show poor existence. Molybdenite is recognized by the fluorescent X-ray analysis. | |
| II-6 | Berdikari | Palu river schist | Garnet sillimanite biotite hornfels | | Very fine grained pyrite and zincblende of 10 to 30 μ are observed but their amounts are little. | |

Remarks : In the above description, quartz and crystobalite are treated as same.

PL 1. Slate (Sample No. I-9)



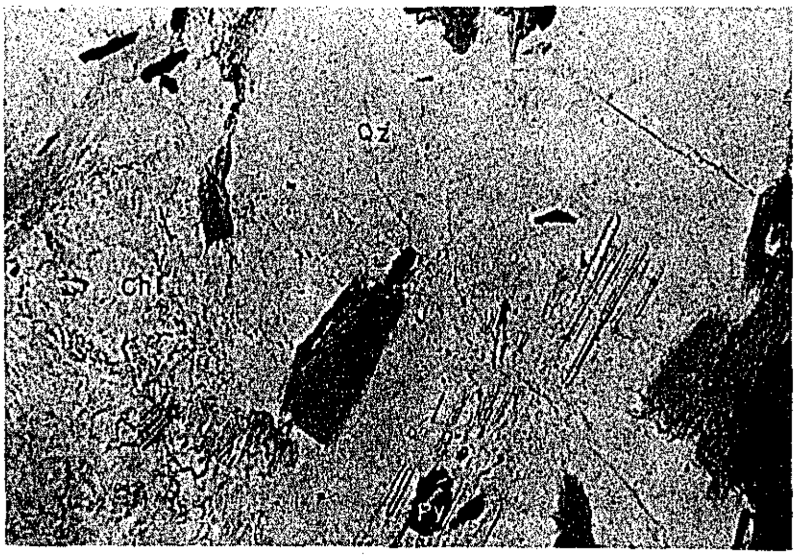

0 0.1 mm

Nicol not crossed

Pl : Plagioclase Qz : Quartz

Ser: Sericite Py : Pyrite

PL 2. Biotite Schist (Sample No. II-B-3)




0 0.1 mm

Nicol not crossed

Qz : Quartz Chl : Chlonite

Biot: Biotite Py : Pyrite

PL 3. Sericite Phyllite (Sample No. II-19)


0 0.1 mm

Nicol crossed

Qz : Quartz

Ser: Sericite

PL 4. Pyroxenite (Sample No. IV-3)

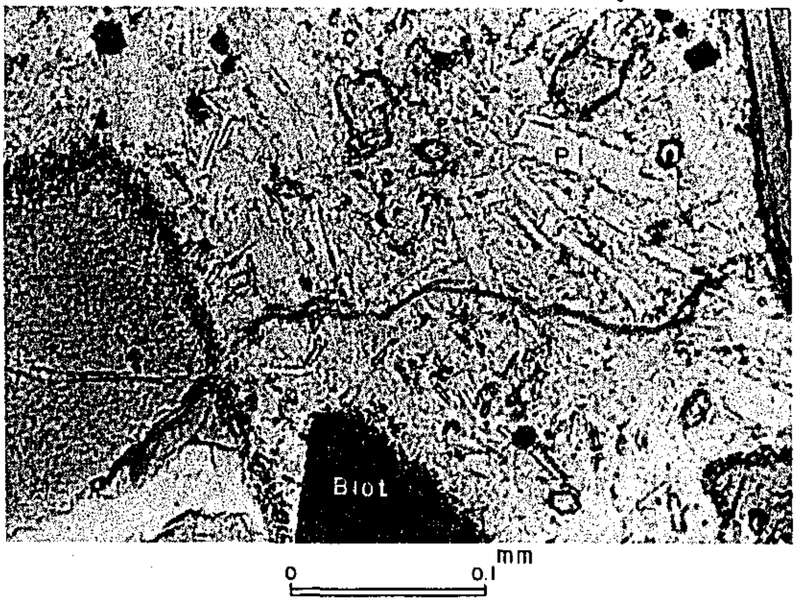

0 0.1 mm

Nicol not crossed

Brz Bronzite Mt : Magnetite

Serp Serpentine

PL 5.  Hornblende Biotite and Esite (Sample No. I-14)



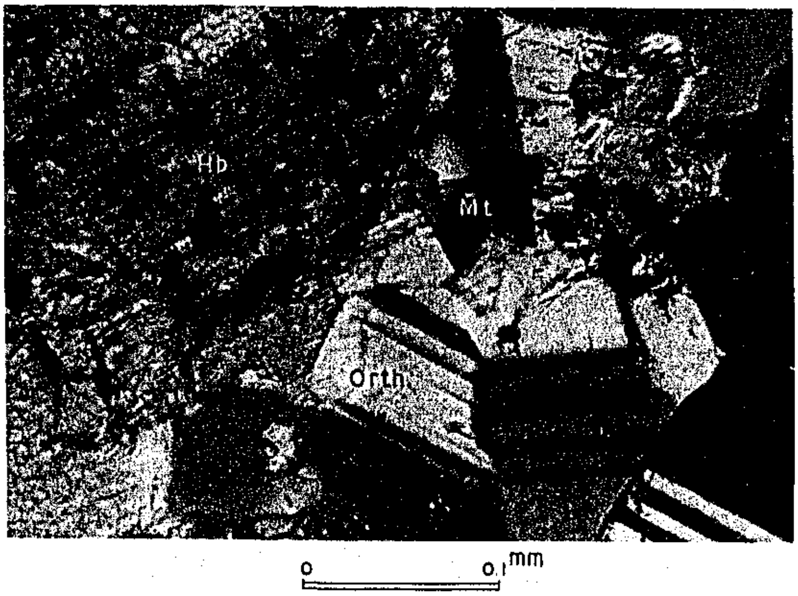

Nicol not crossed

Pl : Plagioclase

Hb: Hornblende

Biot: Biotite

PL 6.  Hornblende Granite (Sample No. II-23)




Nicol crossed

Orth : Or thoclase

Hb : Hornblende

Mt : Magnetite

TABLE 4 List of mineral resources.

(In the survey area)

| Name | Location | Country rock | Alteration | Scale & Orientation | | Ore mineral | Gangue mineral | Explanation & Remarks |
|---|---|---|---|---|---|---|---|---|
| Sopu river disse-<br>minated zone | Upper stream of<br>the Sopu | Biotite granite<br>and biotite<br>gneiss<br>(at the margin<br>of granite) | Contact metamor-<br>phism is occured<br>at the margin of<br>granite. No argi-<br>llaceous alteration | Confirmed scale<br>E-W direction 1 KM<br>N-S direction 2 KM<br>Presumed scale<br>E-W direction over<br>1 KM<br>N-S direction over<br>15 KM | Dissemination into<br>the country rock | Pyrite<br>Chalcopyrite<br>Zincblende<br>Covellite<br>Molybdenite<br>Pyrrhotite | —— | Contents of sulfide minerals are ex-<br>tremely low but this deposit has<br>possibility of porphyry copper type ore<br>deposit. |
| Masewo disse-<br>minated zone | Masewo along<br>the Karangana | Slate | Argillaceous<br>alteration is ob-<br>served in vein | Strike N $5^{o}$E<br>Dip $50^{o}$W<br>Width 1 m<br>Extension is not able<br>to follow | Hydrothermal<br>vein | Pyrite<br>Chalcopyrite<br>Zincblende | Chlorite<br>Sericite | As the scale is small and quality is<br>low, it is estimated to have less<br>economic value. |
| Banas laterite<br>deposit | Near Banas<br>along the<br>Karangana | Biotite<br>andesite | Weathering | From several to<br>several tens meters<br>Scattered in country<br>rock | Eluvial deposit | Heavy<br>minerals<br>Limonite | —— | Economically this is estimated<br>very low. |
| Towulu muscovite<br>deposit | Towulu along<br>the Lariang | Biotite schist | Chloritization<br>Silicification<br>(in parts) | Width of quartz vein<br>5 - 10 cm width,<br>of miscovite platy or<br>massive part 1-2 cm | In quartz vein<br>(parallel to<br>schistosity)<br>Presumed to be<br>pegmatitic vein | Muscovite | Biotite<br>Quartz<br>Chlorite<br>Plagioclase | It is said that this deposit was<br>explored in the past. |
| Lariang petroleum<br>deposit | Near the mouth<br>of the Lariang | By the lack of the field survey and condition of the method, details are uncertain. | | | | | | This deposit was explored and mined<br>in the past in a small scale. |

(Out of the survey area)

| Name | Location | Country rock | Alteration | Scale & Orientation | Occurence | Ore mineral | Gangue mineral | Explanation & Remarks |
|---|---|---|---|---|---|---|---|---|
| Uwewla river deposit | Along Uwewla river of Silae at 10 km north-west from Palu. 290 m from sea level | Granite | Silicification | Width 30 - 80 cm (sheared zone) Strike N40°W - 50°W Dip 15° -30'SW Extension 7 m along the strike | Fissure-filling vein (in the sheared zone of granite) | Galena (con-centrated as patch like from) Zinc Pyrite | Quartz, Clay minerals | |
| Wani disse-minated copper deposit | Near Wani, at the eastern shore of the Palu bay | Diorite | Argillaceous alteration Silicification | Strike N 40°E Dip 35°NW Scale width 5 m Extension 40 - 50 m | Uncertain | Pyrite (chalco-pyrite is not observed) | Clay minerals Quartz | |
| Saum parigi copper deposit | Saum Parigi at 7.5 km Southwest from Palu | Slate Phyllite (in part) | Uncertain | Width 0.5 cm | Veinlet in slate | Chalcopyrite Malachyte | Quartz | Only one boulder is observed. This is the deposit situated at the west side of Fossa Sarasina. |

TABLE 5 Chemical assay

| Sample No | Location | Rock name | Copper Contents per cent | Lead Contents per cent | Zinc Contents per cent | Sulfur Contents per cent | Remarks |
|---|---|---|---|---|---|---|---|
| II - 5 | Bakubakuru | Biotite sheared granite | 0.01 | 0.01. | 0.01 | 0.29 | Contact zone with crystalline schist |
| II - 6 | Berdikari | Garnet sillimanite biotite hornfels | 0.01 | 0.01 | 0.01 | 0.15 | Contact zone with gneiss |
| II - 7 | Berdikari | Gneissose biotite granite | 0.01 | 0.01 | 0.01 | 0.02 | |
| II - 11 | Berdikari | Garnet biotite granodiorite | 0.01 | 0.01 | 0.01 | 0.10 | |
| II - 12 | Berdikari | Biotite hornblende gneissose granite | 0.08 | 0.01 | 0.01 | 4.10 | |
| II - 14 | Berdikari | Biotite gneissose granite | 0.01 | 0.01 | 0.01 | 0.68 | |
| II - 15 | Upper stream of the Sopu | Sand | nd | nd | nd | 0.02 | Hot spring deposit |
| I - 8 | Masewo | Slate | 0.18 | 0.10 | 0.25 | 6.11 | |

Remarks : nd means unenforcement

TABLE 6 X - ray differactive analysis

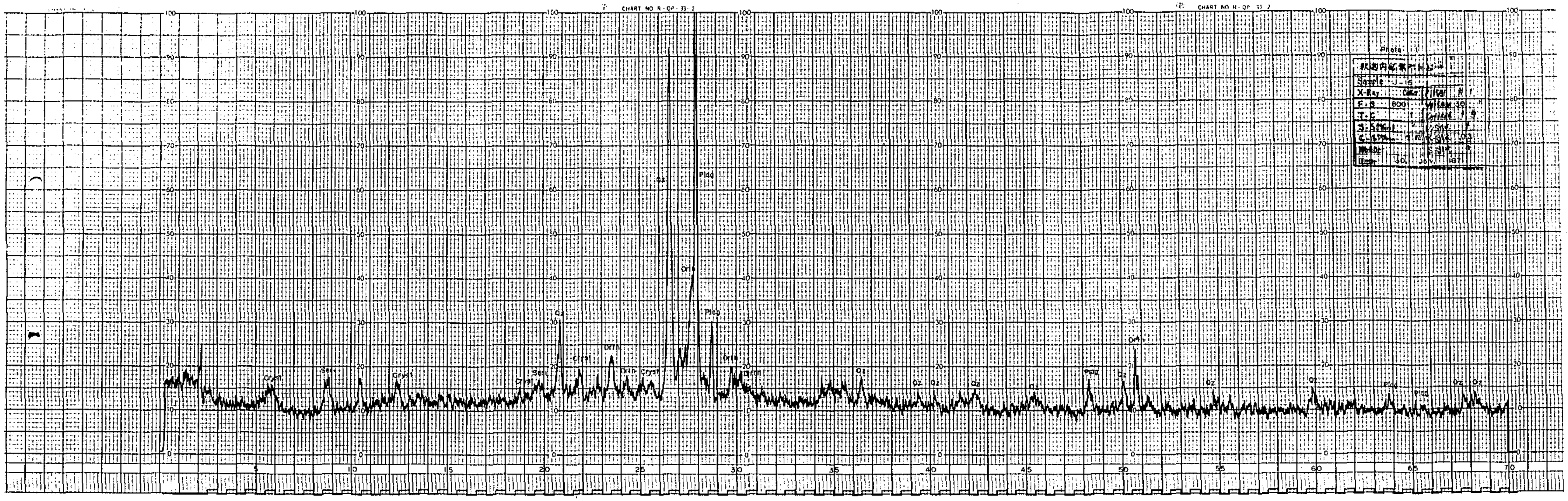
Mineral Composition by X-ray diffractive analysis

| Group | Sample No | Location | Rock Name | Clay mineral: Kao | Pyrophy | Halloy | Vermi | Mont | Seri | 1 M | 2 M | Chl | Hyd | Mix | Zeolite: Mor | Anal | Clip | Silica: Qz | Cryst | Felds: Plag | Orth | Sulfate: Gyp | Anhy | Carb: Cal | Sulfide: Py | Gal | Sph | Biot | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluvium | I - 1 | Gimpu | Silt (Quaternary) | | | | | | + | | | | | | | | | ++ | + | ++ | + | | | | | | | | |
| | I - 15 | Manu | Sand (Quaternary) | | | | | | + | | | | | | | | | ++ | + | ++ | + | | | | | | | | |
| | II - 15 | Berdikari | Sand (Quaternary) | | | | | | | | | | | | | | | +++ | + | ++ | +++ | | | | | | | | Hot spring deposit |
| Sedimentary rock including pyroclastics | II - 27 | Rio Manta | Siltstone (Doda formation) | | | | | | +△ | | | +△ | | | | | | + | | | | | | | | | | | |
| | I - 31 | Kodja | Rhyolitic tuff (Rhyolite group) | | | | | | | | | + | | | | | | ++ | + | ++ | + | | | | | | | | |
| | I - 39 | Kanuna | White clayey rock (Karangana river formation) | +? | | | | | + | | + | | | | | | | ++ | | | | | | | | | | | |
| | I - 28 | Tompi | Sheared quartzite (Karangana river formation) | | | | | | | | | | | | | | | +++ | + | ++ | + | | | | | | | | |
| Metamorphic rock | II - 22 | Rio | Argillaceous phyllite (Palu river schist) | ++△ | | | | | | | | | | | | | | +++ | | | | | | | | | | | |
| | II-B-3 | Namo | Biotite schist (lariang river schist) | | | | | | | | | | | | | | | +++ | + | ++ | + | | | | | | | +++ | |
| | III-16 | Pada | Muscovite schist (Poso schist) | +++ | | | | | ++ | | | ++ (Ferrous) | | | | | | +++ | + | ++ | ++ | | | | | | | | |
| | II - 6 | Berdikari | Garnet sillimanite biotite hornfels (Palu river schist) | | | | | | | | | | | | | | | +++ | | ++ | ++ | | | | | | | ++ | |
| Granite | I - 5 | Mapahi | Biotite granite (Nokila laki massif) | | | | | | | | | | | | | | | +++ | + | +++ | +++ | | | | | | | +++ | |
| | II-B-1 | Saluwa | Biotite granite (Waukara massif) | | | | | | | | | | | | | | | +++ | + | +++ | +++ | | | | | | | ++ | |
| | II-B-4 | Namo | Biotite granite (Waukara massif) | | | | | | | | | | | | | | | +++ | + | +++ | +++ | | | | | | | ++ | |
| | II-C-4 | Balongga | Biotite granite (Waukara massif) | | | | | | | | | | | | | | | +++ | | +++ | +++ | | | | | | | ++ | |
| | III-11-B | Rundo | Biotite granite (Nokila laki massif) | | | | | | | | | | | | | | | +++ | + | +++ | +++ | | | | | | | | |
| | II-11 | Berdikari | Garnet biotite granite (Nokila laki massif) | | | | | | + | | | | | | | | | +++ | + | +++ | ++ | | | | | | | | |
| | II-5 | Bakubakuru | Biotite sheared granite (Nokila laki massif) | + | | | | | | | | + | | | | | | +++ | | ++ | ++ | | | | | | | ++ | |
| | II-14 | Berdikari | Biotite gneissose granite (Nokila laki massif) | ++? | | | | | +++ | | | ++ (Ferrous) | | | | | | +++ | | | | | | | | | | | |
| | II-D-5 | Pasaku | Hornblende biotite quartz diorite (Waukara massif) | | | | | | | | | | | | | | | +++ | + | +++ | ++ | | | | | | | +++ | |
| | II-17 | Baluase | Hornblende biotite granite (Waukara massif) | | | | | | + | | | | | | | | | ++ | + | +++ | ++ | | | | | | | + | |
| | II-C-6 | Balongga | Hornblende biotite granite (Waukara massif) | ++△ | | | | | | | | | | | | | | ++ | + | +++ | ++ | | | | | | | ++ | |
| | II-23 | Rio | Hornblende granite (Rio massif) | | | | | | | | | | | | | | | ++ | | ++ | +++ | | | | + | | | | |

Remarks

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kao : Kaoline | Halloy : Halloysite | Seri : Sericite | 2 M : 2 M peak type of seritite | Hyd : Hydromica | Mor : Mordenite | Clip : Clinoptilolite |
| Pyrophy : Pyrophyllite | Vermi : Vermiculite | 1M : 1 M peak type of sericite | Che : Chlorite | Mix : Mixed layer minerals | Anal : Analcite | Qz : Quartz |
| Cryst : Crystobalite | Felds : Feldspar | Anhy : Anhydrite | Cal : Calcite | Gal : Galena | Biot : Biotite | |
| Plag : Plagioclase | Gyps : Gypsum | Carb : Carbonate | py : Pyrite | Sph : Sphalerite | | |

+++ abundant ++ common + little △ wide peak (showing ill crystallization) ? uncertain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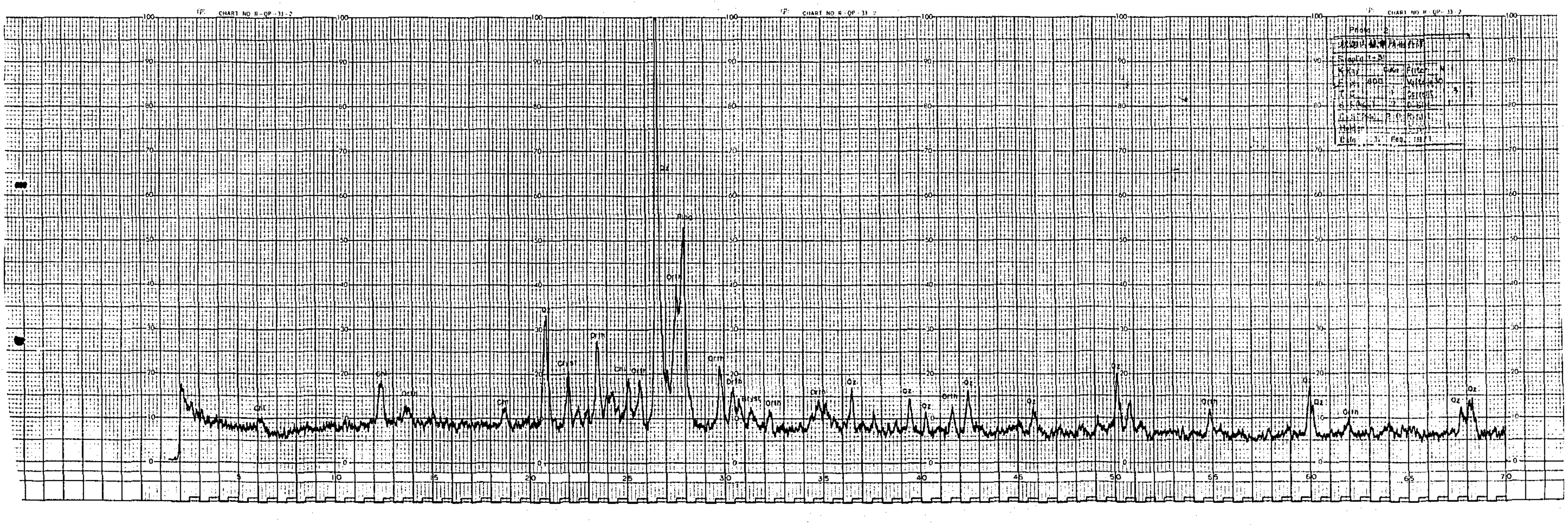
T.C 1
Qz
Plag
Orth
Cryst
Ser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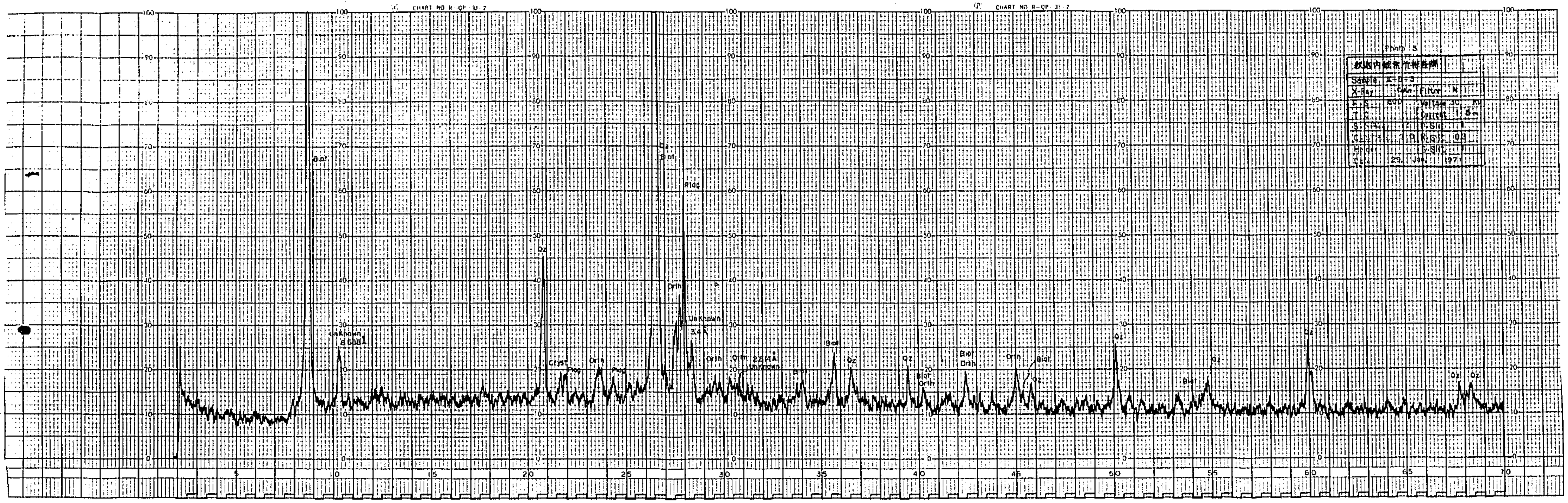
Plag
Orth
Cryst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Current
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1971
Biot
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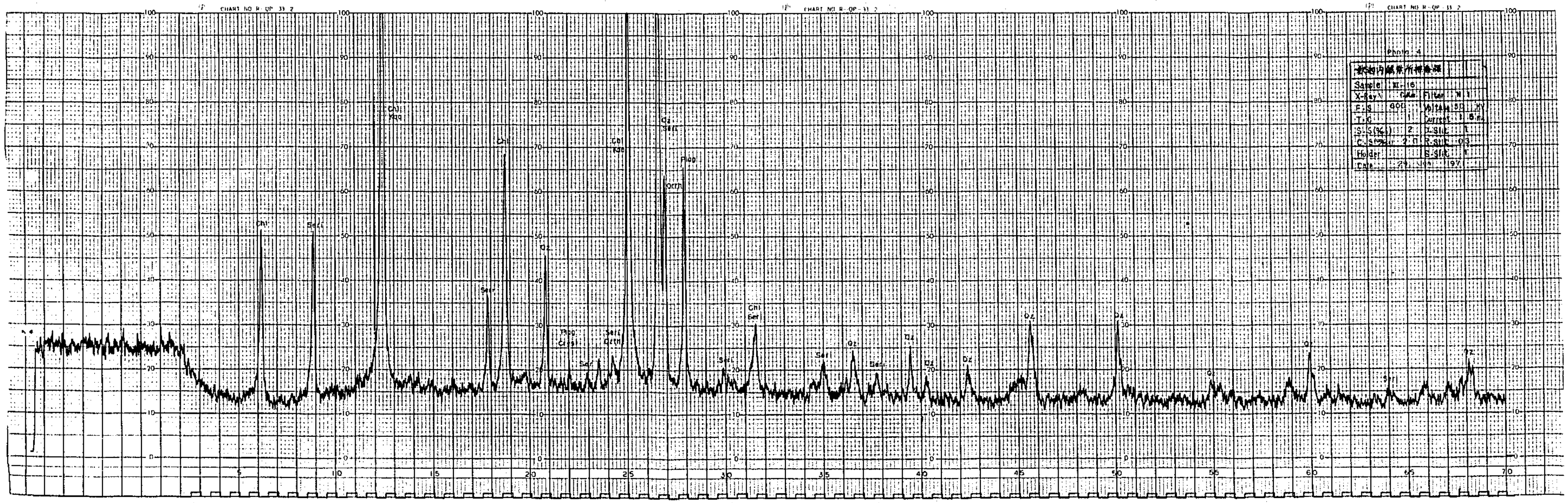
Cryst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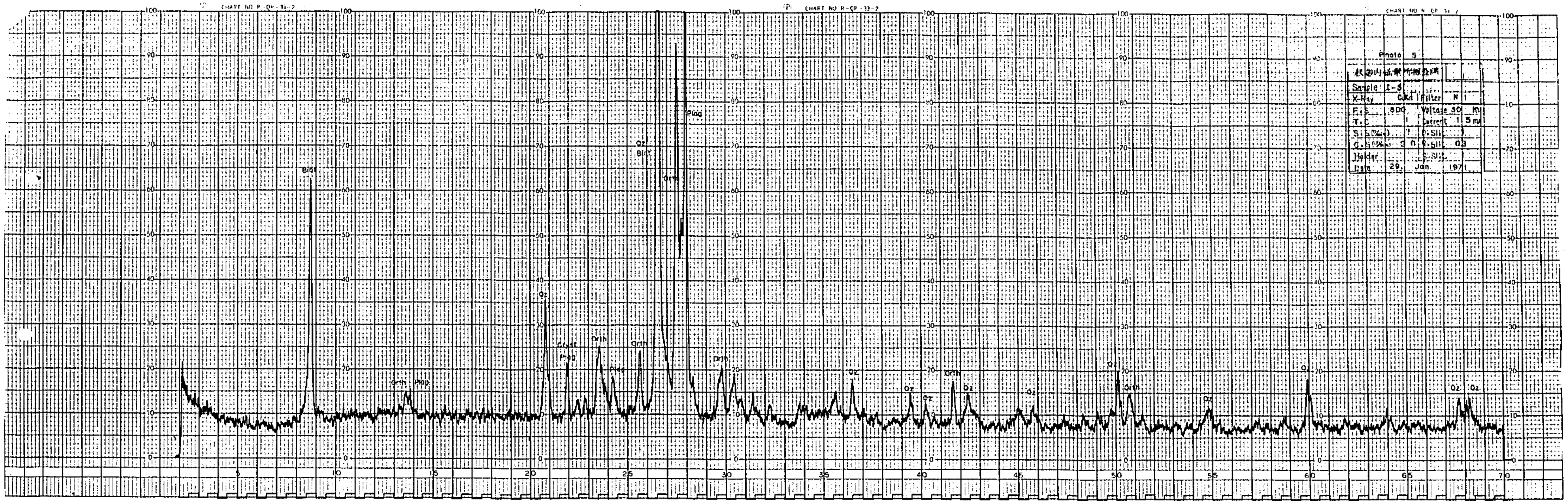
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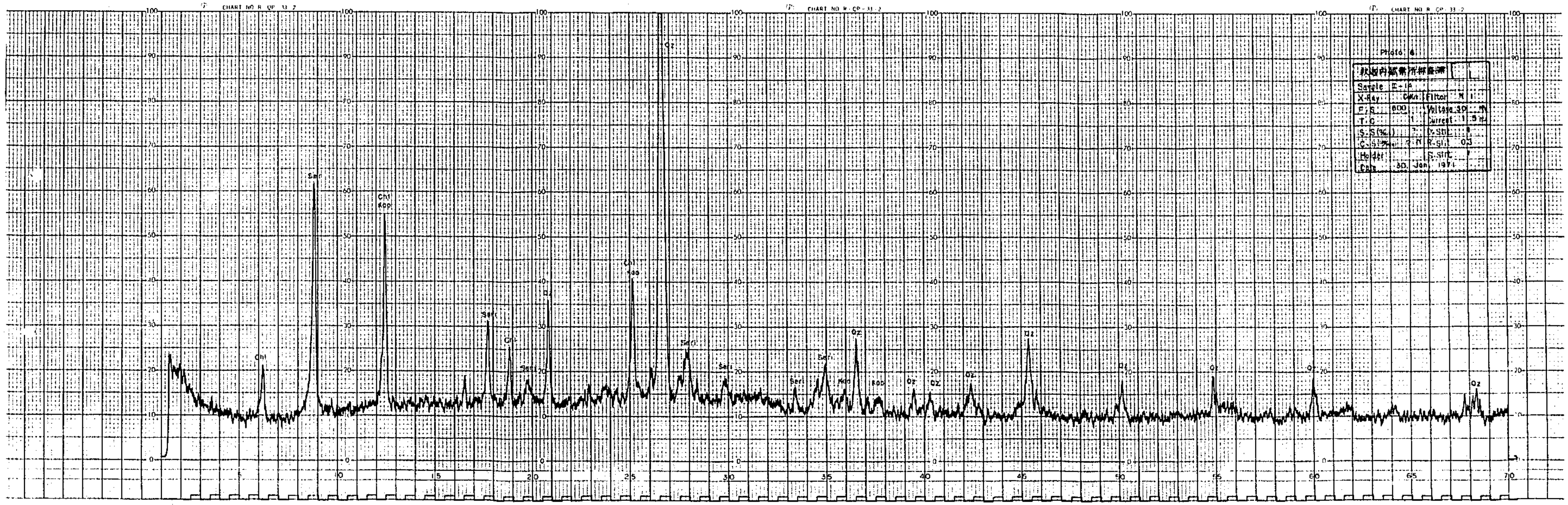
Date 29, Jan 1971
Qz
Orth
Plag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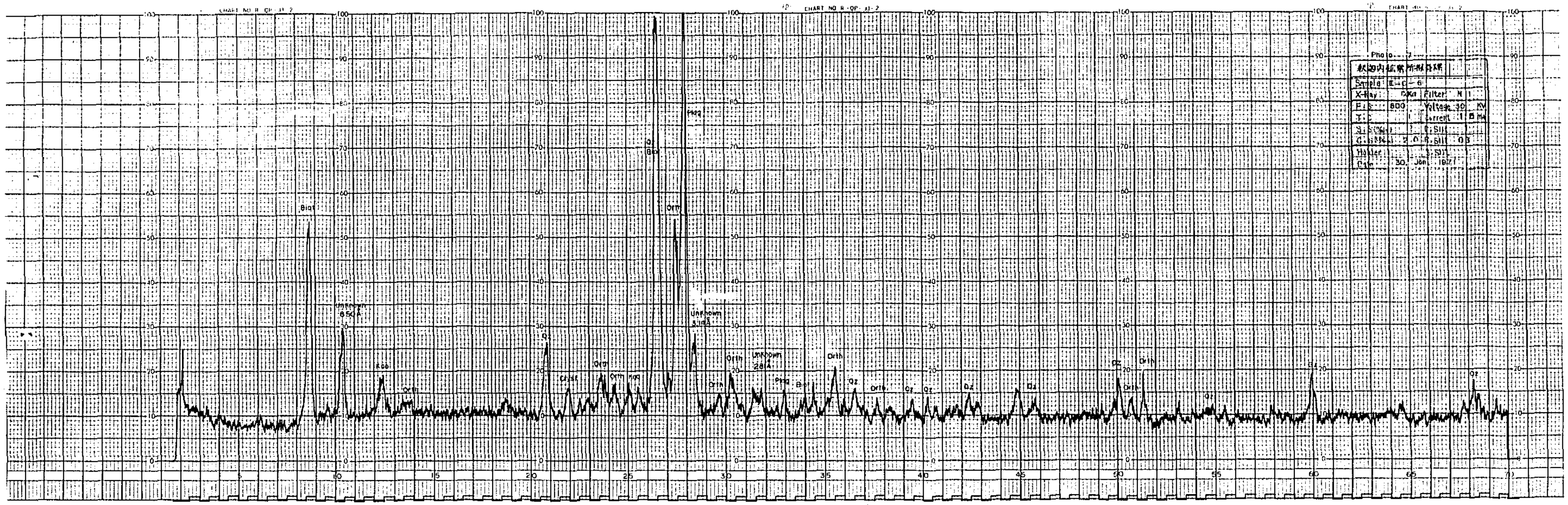
Date 30, Jan 1971
Ser
Chl
Qz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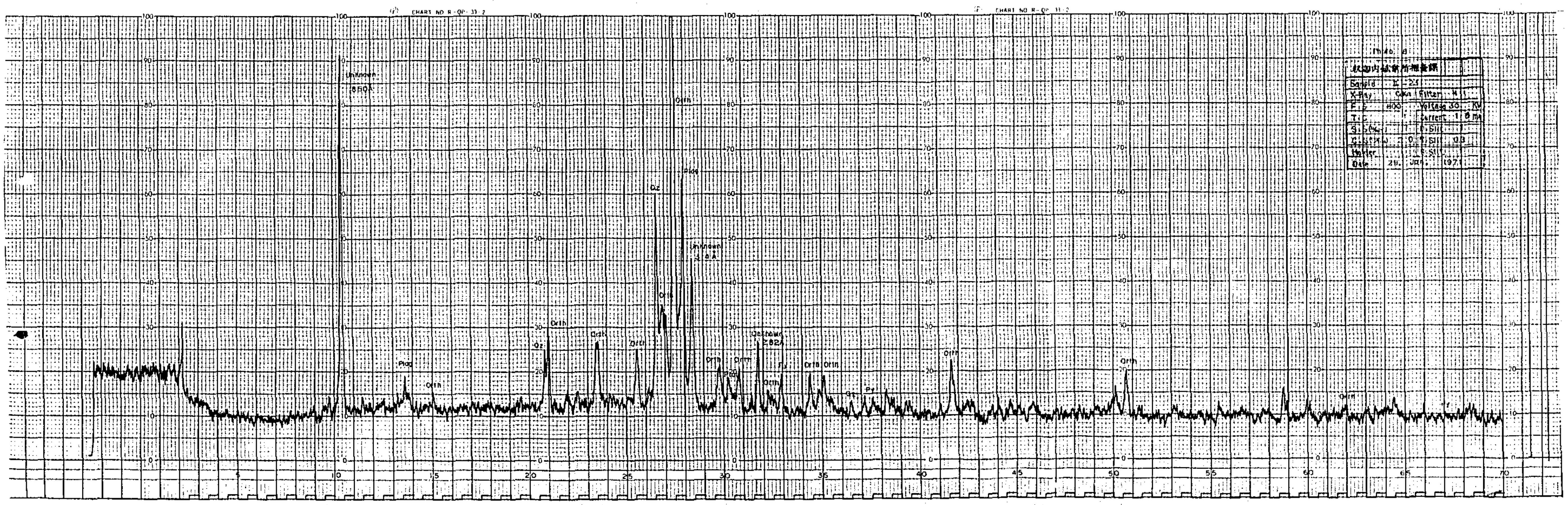
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Plag
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Date

# TABLE 7 Stratigraphical Relation Map

| Geological Age. | | Previous definition ( by Bemmelen etc ) Stratigraphy | Previous definition ( by Bemmelen etc ) Rock facies | Stratigraphy | Rock facies |
|---|---|---|---|---|---|
| Quaternary | Recent | Alluvium | Consolidated sediments | Quaternary deposits | Unconsolidated sediments |
| Quaternary | Pleistocene | Borupu tuff | Acidic tuff | { Alluvium, Lake deposit, Terrace deposit, Fan deposit, Talus deposit | { Sand, Gravel, Silt, Mud |
| Tertiary | Pliocene | Celebes molasse / Mamudju- Doda embayment marine sediment | Conglomerate sandstone shale etc / Sandy shale limestone etc | ① Doda Formation ④ ③ ② Andesite Dacite Ryolite group | Sandstone Conglomerate Siltstone / Andesite Dacite Rhyolite |
| Tertiary | Miocene | Sediments in Tawaëlia graben | Conglomerate shale dacite andesite lava mylonite | ⑤ Basic gneous rock group ⑧ Granite groupe / ⑥ ⑦ Palu river Rompo river schist | Kentallenite Dolerite Gabbro Pyroxenite Granite Granodiorite Diorite Quartz diorite |
| Tertiary | Oligocene | Grainte instrusion / Volcanic pyroclastic layer | Volcanic pyroclastic rock / Granite | | |
| Tertiary | Eocene | | | | |
| Tertiary | Paleogene | Tinombo formation Limestone layer | Phyllitic shale Graywacke Conglomerate Limestone Glaucophane schist | ⑨ Karangona river formation | Slate Sandstone Chert Basic tuff Conglomerate Limestone |
| Mesozoic | | Mesozoic sedimentary rocks | Chert Radiolarite | ⑩ | |
| Paleozonic | | Metamorphic rock | Amphibole epidote facies Granulite facies schist & gneiss | Poso schist Sopu river gneiss Lariang river schist | Muscovite quartz schist Biotite gneiss Biotite schist |

**Stratigraphical relation**

①② Disconformable with Quaternary desposit

③ Relation is uncertain, presumed to be the same age

④ Disconformable

⑤ Small intrusive body in granite or slate

⑥ Schist shows roof- pending in granite or xenolith in granite

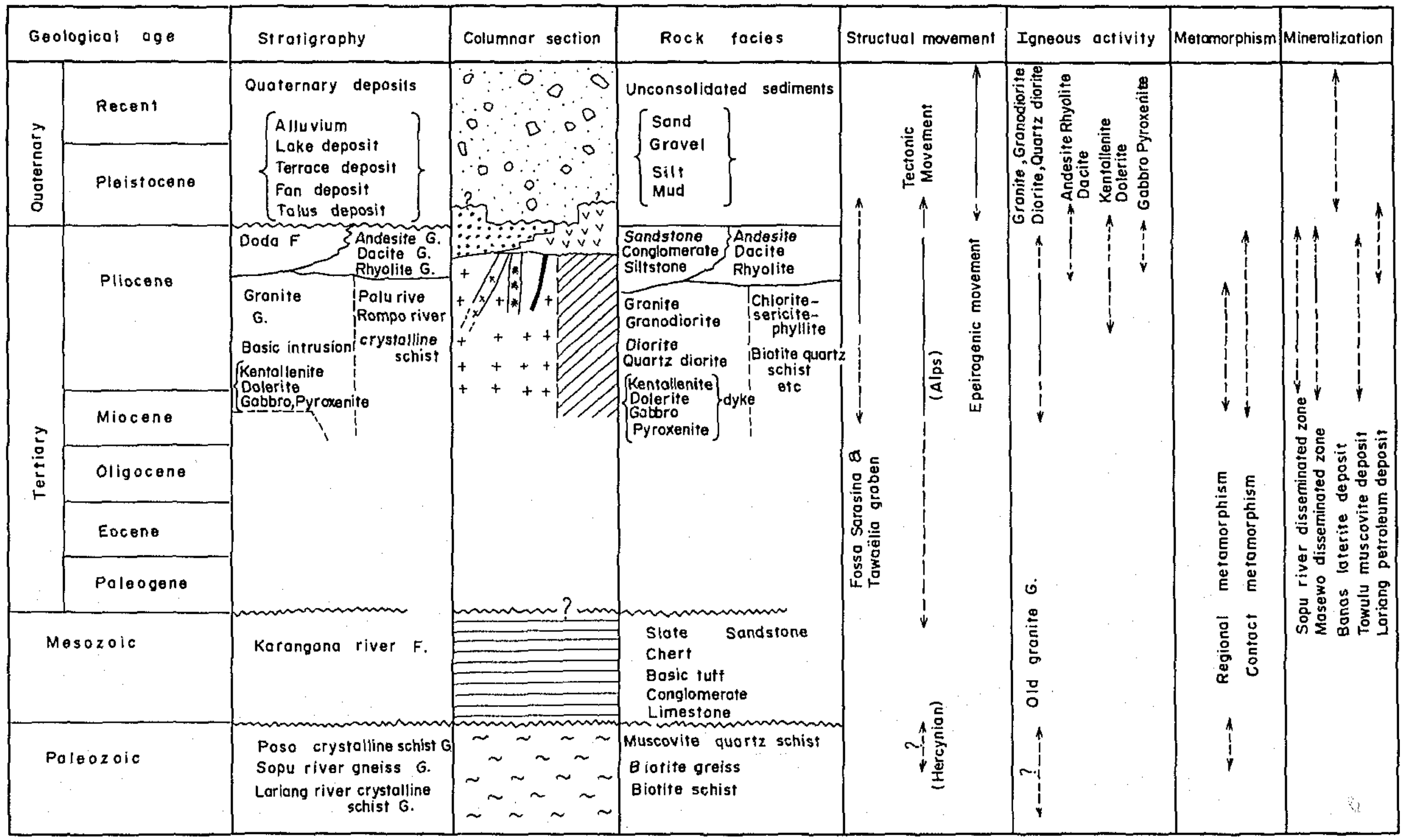
⑦ Age of these schist are unknown but suffered granitic intrusion

⑧ Miocene-pliocene intrusion as batholithic body

⑨ Disconformable

⑩ Disconformity or fault

TABLE 8-1 Compiled columnar section map




*Remarks* :

F : Formation
G : Group
? : Uncertain
~~~~ Disconformity
----- Unknown relation
~~~~

Table 8-2 Compiled columnar section map

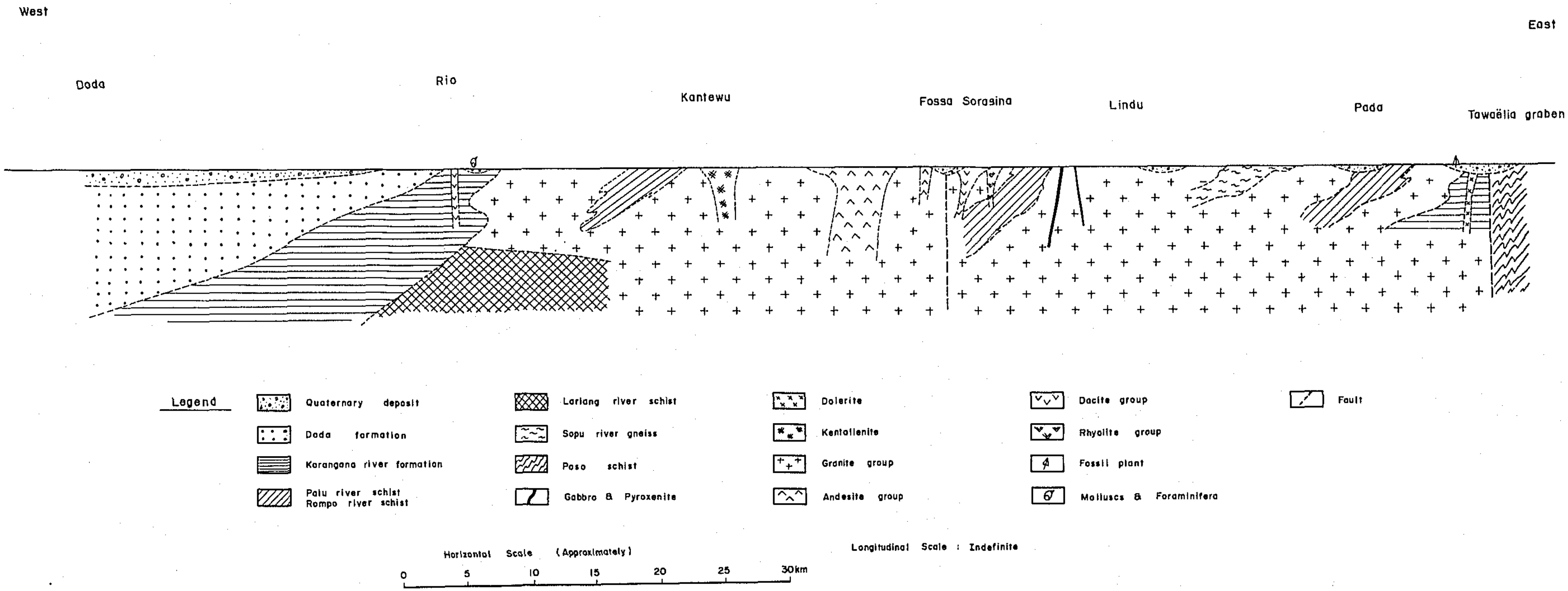


TABLE 9 List of Sample

| Sample No | Location *1 | Formation or group name | Rock name *2 | Determination of Fossil | Manufacture of Thin section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks *3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Susceptibility | Remnant magnetism | | |
| I - 1 | Gimpu (the Karo) | Alluvium | Silt | | | | * Y | | | | | | |
| I - 2 | South of Gimpu (the Karo) | Rhyolite group | Rhyolitic tuff | | Y | | | | | | | Y | |
| I - 3 | South of Gimpu (the Karo) | Granite group | Hornblende biotite granite | | Y | | | | | | | Y | |
| I - 5 | Mapahi (the Karangana) | Granite group | Biotite granite | | Y | | Y | | Y | Y | Y | | X-ray chart |
| I - 6 | Banas (the Karangana) | Andesite group | Hornblende biotite andesite | | Y | | | | | | | Y | |
| I - 7 | Masewo (the Karangana) | Karangana river formation | Biotite hornfels | | Y | | | | | | | Y | |
| I - 8 | Masewo (the Karangana) | Karangana river formation | Slate | | | | | Y | | | | Y | Ore sample |
| I - 9 | Mamu (the Karangana) | Karangana river formation | Slate | | Y | | | | | | | Y | |
| I - 10 | Kalamanta (the Karangana) | Dacite group | Dacitic tuff breccia | | Y | | | | | | | Y | |
| I - 12 | Kalamanta (the Karangana) | Doda formation | Sandstone | | Y | | | | | | | Y | |
| I - 13 | Kalamanta (the Karangana) | Andesite group | Hornblende biotite andesite | | Y | | | | | | | | |
| I - 14 | Kalamanta (the Karangana) | Andesite group | Hornblende biotite andesite | | Y | | | | | | | | |
| I - 15 | Mamu (the Karangana) | Alluvium | Sand | | | | Y | | | | | | X-ray chart |
| I - 18 | Banas (the Karangana) | Andesite group | Crushed biotite andesite | | Y | | | | | | | Y | |
| 1 - 20 | Banas (the Karangana) | Karangana river formation | Sandstone | | | | | | | | | Y | |
| I - 21 | Banas (the Karangana) | Andesite group | Hornblende biotite andesite | | Y | | | | | Y | Y | Y | |

*1 ( ) shows the basin of river.
*2 rock name is determined microscopically or macroscopically
*3 Fossil samples, Ore samples are shown in this column.
*Y Shows offirmation.

| Sample No | Location * 1 | Formation or rock group name | Rock Name * 2 | Determination of Fossil | Manufacture of Thin section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks * 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Susceptibitity | Remnant magnetism | | |
| I - 22 | Mapahi (the Karangana) | Granite group | Hornblende biotite quartz diorite | | Y | | | | | | | Y | |
| I - 23 | Banas (the Karangana) | Karangana river formation | Limestone | | Y | | | | | | | Y | |
| I - 24 | Banas (the Karangana) | Karangana river formation | Hornblende biotite hornfels | | Y | | | | | | | Y | |
| I - 25 | Banas (the Karangana) | Granite group | Hornblende biotite quartz diorite | | Y | | | | | | | Y | |
| I - 26 | Tompi (the Lariang) | Andesite group | Augite biotite andesite | | Y | | | | | | | Y | |
| I - 27 | Tompi (the Lariang) | Karangana river formation | Limestone | | Y | | | | | | | Y | |
| I - 28 | Tompi (the Lariang) | Karangana river formation | Sheared quartzite | | Y | | Y | | | | | Y | |
| I - 29 | Kodja (the Lariang) | Lariang river schist | Biotite schist | | Y | | | | | | | | |
| I - 31 | Kodja (the Lariang) | Rhyolite group | Rhyolitic tuff | | Y | | Y | | | | | Y | X-ray chart |
| I - 32 | Lonebasa (the Lariang) | Granite group | Hornblende biotite granite | | Y | | | | | | | Y | |
| I - 33 | Lonebasa (the Lariang) | Karangana river formation | Biotite phyllite | | Y | | | | | | | | |
| I - 34 | Kantewu (the Laraing) | Andesite group | Andesitic breccia | | Y | | | | | | | Y | |
| I - 35 | Kantewu (the Lariang) | Kentallenite | Kentallenite | | Y | | | | | | | | |
| I - 36 | Kantewu (the Lariang) | Kentallenite | Kentallenite | | Y | | | | | | | Y | |
| I - 37 | Onu (the Lariang) | Karangana river formation | Chlorite sericite schist | | Y | | | | | | | | |
| 1 - 38 | Lawe (the Lariang) | Karangana river formation | Slate (alternated with sandstone) | | | | | | | | | Y | |
| 1 - 39 | Kanuna (the Lariang) | Karangana river formation | white clayey rock | | | | Y | | | | | Y | |
| 1 - 40 | Kanuna (the Lariang) | Karangana river formation | Basic tuff | | Y | | | | | | | Y | |
| 1 - 41 | Siwagi (the Lariang) | Karangana river formation | Sandstone | | | | | | | | | Y | |
| 1 - 42 | Towulu (the Lariang) | Lariang river schist | Suscovite bearing biotite schist | | Y | | | | | | | Y | Ore sample |
| 1 - 43 | Mapahi (the Karangana) | Granite group | Riotite granite | | Y | | | | | | | Y | |

| Sample No | Location *1 | Formation or rock group name | Rock Name * 2 | Determination of Fossil | Manufacture of Thin Section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks * 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Suscep-tibitity | Remnant magnetism | | |
| II - 1 | Bora (the Palu) | Granite group | Biotite Granite | | Y | | | | | | | Y | |
| II - 2 | Bora (the Palu) | Palu river formation | Hornblende chlorite schist | | Y | | | | | | | Y | |
| II - 3 | Bora (the Palu) | Palu river formation | Epidote bearing phyllite | | Y | | | | | | | | |
| II - 4 | Bora (the Palu) | Granite group | Biotite granite | | Y | | | | | | | Y | |
| II - 5 | Bakubakuru (the Palu) | Granite group | Biotite sheared granite | | Y | Y | Y | Y | Y | Y | Y | Y | |
| II - 6 | Berdikari (the Sopu) | Palu river schist | Garnet sillimanite biotite hornfels | | Y | Y | Y | Y | Y | Y | Y | Y | |
| II - 7 | Berdikari (the Sopu) | Granite group | Gneissose biotite granite | | Y | | | Y | | | | Y | |
| II - 8 | Berdikari (the Sopu) | Granite group | Biotite granite | | Y | | | | | | | Y | |
| II - 9 | Berdikari (the Sopu) | Sopu river gneiss | Garnet sillimanite biotite gneiss | | Y | | | | | | | Y | |
| II - 10 | Berdikari (the Tongoa) | Granite group | Biotite granodiorite | | Y | | | | | | | Y | |
| II - 11 | Berdikari (the Tongoa) | Granite group | Garnet biotite granodiorite | | Y | | Y | Y | | | | Y | |
| II - 12 | Berdikari (the Tongoa) | Granite group | Biotite hornblende gneissose granite | | Y | | | Y | | | | Y | Ore Sample |
| II - 13 | Berdikari (the Tongoa) | Granite group | Biotite granite | | Y | | | | | | | Y | |
| II - 14 | Berdikari (the Sopu) | Granite group | Biotite gneissose granite | | Y | | Y | Y | | | | Y | |
| II - 15 | Berdikari (the Sopu) | Alluvium | Sand | | | | Y | Y | | | | Y | Hot spring deposit |
| II - 16 | Baluase (the Palu) | Granite group | Hornblende biotite granite | | Y | | | | | | | Y | |
| II - 17 | Baluase (the Palu) | Grante group | Hornblende biotite granite | | | | Y | | | | | Y | |
| II - 18 | Baluase (the Palu) | Granite group | Biotite granodiorite | | Y | | | | | | | Y | |
| II - 19 | Waukara (the Lariang) | Palu river schist | Sericite phyllite | | Y | | | | | | | Y | |
| II - 20 | Waukara (the Lariang) | Palu river schist | Sericite phyllite | | | | | | | | | Y | |
| II - 21 | Waukara (the Lariang) | Palu river schist | Felsic aggregate | | Y | | | | | | | Y | |

| Sample No. | Location * 1 | Formation or rock group name | Rock Name * 2 | Determination of Fossil | Manufacture of Thin Section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks * 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Susceptibility | Remnant magnetism | | |
| II - 22 | Rio (the Rio) | Palu river schist | Argillaceous phyllite | | | | Y | | | | | | |
| II - 23 | Rio (the Rio) | Granite group | Hornblende granite | | Y | | Y | | | | | Y | X --ray chart |
| II - 24 | Rio Pontroveti (the Rio) | Doda formation | Siltstone | Y | | | | | | | | Y | Fossil sample |
| II - 25 | Rio manta (the Rio) | Granite group | Hornblende granite | | Y | | | | | | | Y | |
| II - 26 | Rio manta (the Rio) | Karangana river formation | Biotite hornfels | | Y | | | | | | | Y | |
| II - 27 | Rio manta (the Rio) | Doda formation | Siltstone | Y | | | Y | | | | | Y | Fossil sample |
| II - 28 | Rio manta (the Rio) | Rhyolite group | Glassy rhyolite | | Y | | | | | | | Y | |
| II - 29 | Rio manta (the Rio) | Karangana river formation | Siliceous slate | | | | | | | | | Y | |
| II - 30 | Rio manta (the Rio) | Dacite group | Hornblende dacite | | Y | | | | | Y | Y | Y | |
| II - 31 | Rio manta (the Rio) | Doda formation | Conglomerate | | | | | | | | | | |
| II-A-1 | Saluwa (the Palu) | Granite group | Biotite granite | | Y | | | | | Y | Y | Y | |
| II-A-2 | Saluwa (the Palu) | Palu river schist | Biotite schist | | Y | | | | Y | Y | Y | Y | |
| II-B-1 | Saluwa (the Palu) | Granite group | Biotite granite | | Y | | Y | | | Y | Y | Y | |
| II-B-2A | Saluwa (the Palu) | Granite group | Hornblende diorite | | Y | | | | | | | | |
| II-B-2B | Saluwa (the Palu) | Granite group | Hornblende diorite | | | | | | | | | Y | |
| II-B-3 | Namo (the Pebatua) | Lariang river schist | Biotite schist | | Y | | Y | | | Y | Y | Y | X - ray chart |
| II-B-4 | Namo (the Pebatua) | Granite group | Biotite granite | | Y | | Y | | | | | Y | |
| II-C-4 | Balongga (the Ombi) | Granite group | Biotite granite | | Y | | Y | | | | | Y | |
| II-C-6 | Balongga (the Ombi) | Granite group | Hornblende biotite granite | | Y | | Y | | | Y | Y | Y | X- ray chart |
| II-D-2 | Sidondo (the Palu) | Palu river schist | Biotite quartz schist | | Y | | | | | | | Y | |
| II-D-5 | Pasaku (the Palu | Granite group | Hornblende biotite quartz diorite | | Y | | Y | | | | | Y | |
| II-D-6 | Pasaku (the Palu) | Palu river schist | Biotite schist | | Y | | | | | | | Y | |
| II-D-7 | Bangga (the Palu) | Rhyolite group | Felsic rhyolite | | Y | | | | | | | Y | |

| Sample No | Location * 1 | Formation or rock group name | Rock Name * 2 | Determination of Fossil | Manufacture of Thin Section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks * 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Susceptibility | Remnant magnetism | | |
| III-1 | Au (the Lariang) | Andesite group | Hornblende biotite andesitic tuffbrecca | | Y | | | | | | | | |
| III-1-A | Au (the Lariang) | Andesite group | Hornblende biotite andesitic tuff breccia | | Y | | | | | | | Y | |
| III-2 | Au (the Lariang) | Rompo river schist | Epidote chlorite quartz schist | | Y | | | | | | | | |
| III-2A | Au (the Lariang) | Rompo river schist | Chlorite quartz schist | | Y | | | | | | | | |
| III-3 | Au (the Lariang) | Andesite | Pyroxene andesite | | Y | | | | | | | Y | |
| III-4 | Au (the Lariang) | Rompo river schist | Epidote chlorite schist | | Y | | | | | | | | |
| III-5 | Sabulu (the Lariang) | Rompo river schist | Epidote chlorite quartz schist | | Y | | | | | | | Y | |
| III-6 | Tuare (the Lariang) | Karangana river formation | Carbonatized chert | | Y | | | | | | | | |
| III-7 | Tuare (the Lariang) | Karangana river formation | Hornfels | | | | | | | | | Y | |
| III-9 | Kagero (the Lariang) | Gabbro group | Hornblende gabbro | | Y | | | | | | | | |
| III-10 | Rundo (the Panpolea) | Granite group | Biotite granite | | | | | | | | | Y | |
| III-11B | Rundo (the Panpolea) | Granite group | Biotite granite | | Y | | Y | | Y | Y | Y | Y | |
| III-12 | Pada (the Banbuno) | Dolerite group | Hornblende dolerite | | Y | | | | | | | | |
| III-12B | Pada (the Barbuno) | Dolerite group | Hornblende dolerite | | Y | | | | | | | | |
| III-14 | Pada (the Marei) | Karangana river formation | Sandstone | | Y | | | | | | | | |
| III-15 | Pada (the Marei) | Poso schist | Muscovite sericite schist | | | | | | | | | | |
| III-16 | Pada (the Boro) | Poso schist | Muscovite sericite schist | | | | Y | | | | | | X-ray chart |
| III-17 | Pada (the Boro) | Poso schist | Muscovite sericite schist | | | | | | | | | Y | |
| III-17B | Pada (the Boro) | Poso schist | Muscovite sericite schist | | | | | | | | | | |
| III-18 | Bomba (the Banbuno) | Karangana river formation | Sandstone | | | | | | | | | Y | |

| Sample No | Location * 1 | Formation or rock group name | Rock name * 2 | Determination of Fossil | Manufacture of Thin Section | Manufacture of Polished Section | Analysis by X - ray | Chemical Assay | Dating by K - A method | Magnetic Measurement | | Presented with report | Remarks * 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Susceptibility | Remnant magnetism | | |
| III-19 | Torire (the Tawaelia) | Lake deposit | Mud | Y | | | | | | | | | |
| III-20 | Kato (the Rompo) | Rompo river schist | Sericite chlorite quartz schist | | Y | | | | | | | | |
| III-21 | Kato (the Rompo) | Rompo river schist | Sericite chlorite quartz schist | | Y | | | | | Y | Y | Y | |
| III-22 | Kato (the Rompo) | Andesite group | Hornblende andesite | | Y | | | | | | | | |
| III-23 | | | | | | | | | | | | | |
| III-24 | Kato (the Rompo) | Gabbro group | Hornblende gabbro | | Y | | | | | | | | |
| III-25 | Kato (the Rompo) | Granite group | Hornblende biotite granite | | Y | | | | | | | Y | |
| III-26 | Torro (the Palu) | Sopu river gneiss | Biotite granitic gneiss | | Y | | | | | | | | |
| III-27 | Torro (the Palu) | Rompo river schist | Sericite quartz schist | | Y | | | | | | | Y | |
| IV-2 | Namo (the Palu) | Gabbro group | Augite hornblende microgabbro | | Y | | | | | | | Y | |
| IV-3 | Namo (the Palu) | Ultrabasic group | Pyroxenite | | Y | | | | | | | Y | |
| IV-4 | Kalamea (the Bomba) | Gabbro group | Hornblende gabbro | | Y | | | | | | | | |
| IV-5 | Rio (the Watapusampu) | Palu river schist | Sercite chlorite quartz phyllite | | Y | | | | | | | | |
| IV-6 | Rio (the Watapusampu) | Dacite group | Biotite dacite | | Y | | | | | | | Y | |
| IV-7 | Pakuli (the Palu) | Grnaite group | Biotite granodiorite | | Y | | | | | | | | |