REPORT ON GEOLOGICAL SURVEY OF CENTRAL SULAWESI, INDONESIA

Vol. VI

SUMMARY AND CONCLUSION

JUNE 1973

METALLIC MINERALS EXPLORATION AGENCY

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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PREFACE

The Government of Japan, intending to perform geological and other related surveys, in response to the request by the Republic of Indonesia, for the purpose of confirming the potentialities of occurrence of mineral resources in Block No. 4 Area located in the central region of Sulawesi Island, delegated the implementation of such surveys to the Overseas Technical Cooperation Agency. This Agency, in turn, requested Metallic Minerals Exploration Agency of Japan to carry out the said surveys in view of the project touching, in particular, specialized fields such as geology and mineral resources surveys.

This year was the last to complete a series of surveys extending over three years, and for this, a survey team was formed consisting of 17 members headed by Mr. Toshio Wakiyama, Chief of Planning Section, Overseas Dept., Metallic Minerals Exploration Agency, and was dispatched to Indonesia for a period from September 12, 1972 to February 3, 1973. The surveys at site were completed as planned with cooperation extended by agencies concerned of the Government of the Republic of Indonesia.

The Report comprises the results of the third year surveys and the generalization of those obtained through the period of three years.

In conclusion, I wish to express my heartfelt appreciation for all that has been dedicated to the completion of the surveys by agencies concerned of the Government of the Republic of Indonesia, the Ministry of International Trade and Industry, the Ministry of Foreign Affairs, Metallic Minerals Exploration Agency and each corporation concerned.

June, 1973

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

LETTER OF TRANSMITTAL

June 27, 1973

Mr. Yasuaki Hiratsuka
President
Metallic Minerals Exploration Agency of Japan

Dear Sirs :

Re : Survey Reports

It gives us much pleasure to inform you that we have completed the preparation of a set of reports on the basic surveys for development of mineral resources in Sulawesi area of the Republic of Indonesia and are submitting them herewith for your perusal.

The survey was the first action of a series of technical cooperation intended for mineral resources development in developing nations and has become a memorable project that is long inscribed in the mind of all personnel engaged in the survey.

Over a period of three years commencing with 1970, many and varied kinds of prospecting methods have been employed in the survey seeking areas having occurrence of mineral resources such as, on the basis of geological surveys, geochemical survey, airborne magnetic survey, photogeological survey, two kinds of geophysical survey, drilling exploration and preparation of topographic maps. Resorting to such methods to their full extent, we were able to conduct detailed surveys for a promising area selected out of the first year's survey area of 14, 160 square km which was squeezed to concentrate on 4, 600 square km in the second year and 35 square km in the third year. The past survey data and information on mineral resources available prior to our survey were extremely limited, and therefore it goes without saying that data obtained in the reported survey will prove to be most valuable and important.

It is detected through the survey that granite accompanies mineralization and several mineralized areas are located in the survey areas. Such mineralized areas may not be capable of development in their present condition, but it is most probable that they may be further more developed by future explorations. Also the fact that such mineralized areas present the nature similar to porphyry copper type ore deposits is believed to provide a significant key to the performance of exploration of deposits of the area in the future.

The survey area comprises steep topography, thick jungles and major parts rarely inhabited, causing us much more difficulties than expected in the supply of materials, food and other goods, in transportation, communication and maintenance of health. However, it was an unexpected pleasure of all that we could get over these difficulties through the unremitting toils and assistance given by officials and people concerned in the locality, enabling us to complete the survey as originally planned.

Nikko Exploration and Development Co., Ltd. and Kokusai Aerial Co., Ltd. assumed to undertake the survey works upon instruction of Overseas Technical Cooperation Agency and Metallic Minerals Exploration Agency, and the former company took charge of Volumes I, IV, V, and VI of the reports and the latter company Volumes II and III.

We feel greatly indebted to officials and people of Indonesia, interalia Ministry of Mines, Geological Survey of Indonesia and Provincial Government of Central Sulawesi, and Japanese Embassy in Indonesia, Jakarta Office of Overseas Technical Cooperation Agency, Jakarta Office of Sumitomo Shoji Kaisha, Ltd. for enormous cooperation and assistance furnished in carrying out the surveys.

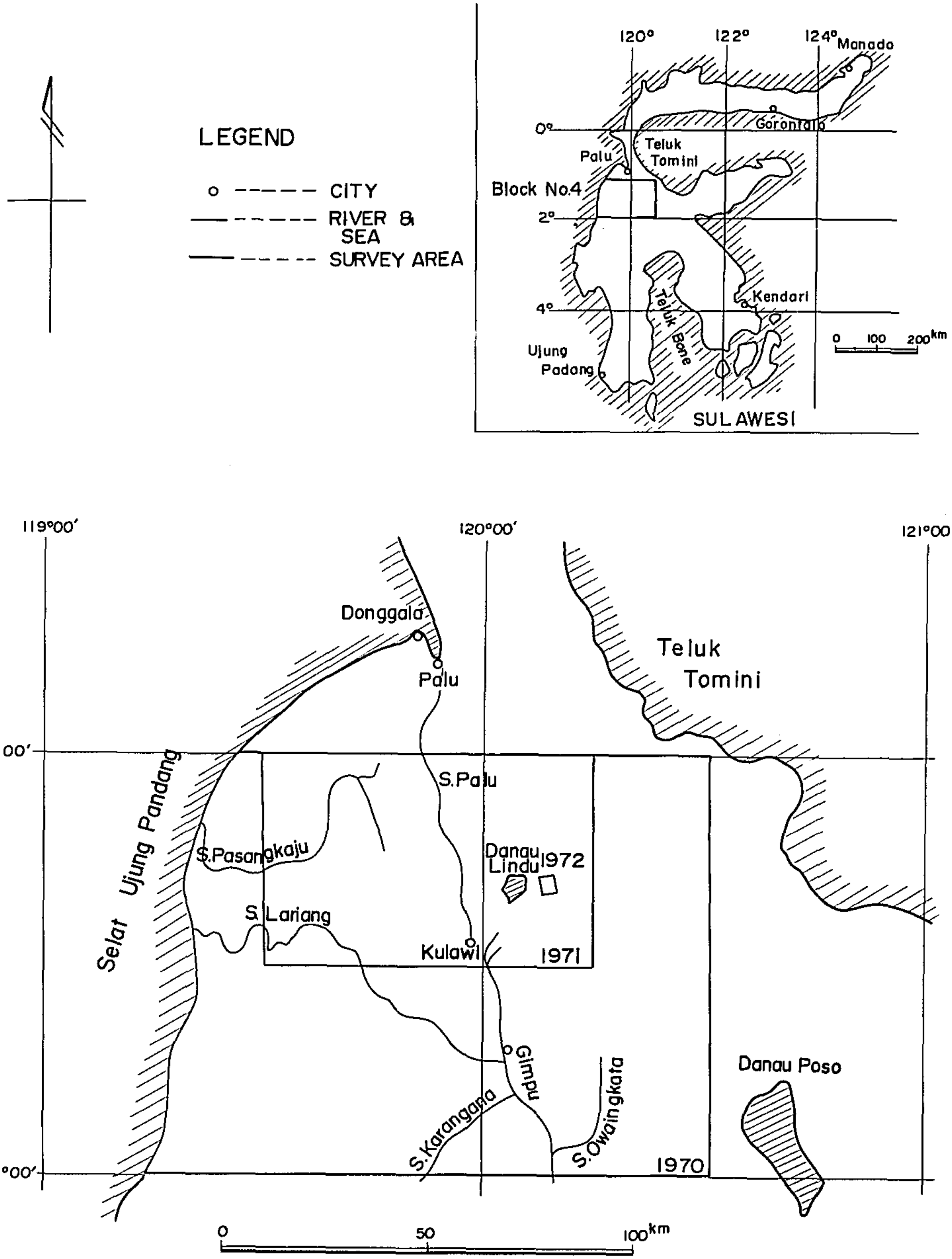
Further, we highly appreciate valuable guidance given through all phases of the survey by Japanese government authorities especially by Ministry of Foreign Affairs, Ministry of International Trade and Industry, Overseas Technical Cooperation Agency and Metallic Minerals Exploration Agency, and owe much to Tokyo University, Hokkaido University, Tohoku University, Akita University and Geological Survey of Japan for all instructive information given concerning the survey and also for great assistance extended by consulting firms such as Sumitomo Consultant Co., Ltd. and by Sumitomo Shoji Kaisha, Ltd. and Asahi Helicopter Co., Ltd.

Here, it is specifically mentioned as a token of profound gratitude that the surveys successfully conducted for the last three years have been in a great measure attributable to the esteemed efforts made by all parties named above.

Yours sincerely,

Masao Nakamura
President
Nikko Exploration and
Development Co., Ltd.

KEY MAP AND LOCATION MAP



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SUMMARY

The reported survey was conducted for the purpose of selecting areas having high potentialities of occurrence of mineral resources out of No. 4 Block in Sulawesi Island and for clarifying the mode of their occurrence. The surveying methods employed were geological survey, airborne magnetic survey, photogeological survey, aerophotographing and control point surveying in the year of 1970, geological survey and geochemical survey in 1971 and geological survey, geochemical survey, geophysical surveying (EM and IP methods) and drilling exploration in 1972.

The geology of the surveyed area consists of Quaternary formation, Tertiary sedimentary formation, sedimentary rocks such as slate formation, etc. presumed to be Mesozoic, igneous rocks intruded or erupted from the later period of Neogene to the beginning of Quaternary such as granite, kentallenite, gabbro, dolerite, andesite, dacite, etc. and metamorphic rocks of unkown period such as crystalline schist, gneiss, etc. Predominant among these is granite occupying approximately half the area, and extensively distributed in the west coast area and along the Palu river is Quaternary formation.

Major geological structures controlling the surveyed area are Tawaëlia graben (N-S direction) as seen in the eastern area of the country and Fossa Sarasina (NNW-SSE direction) as seen in the central area, and distribution of each formation is approximately in parallel with the said directions. Also the distribution of most of igneous rocks has close bearing on the two grabens, especially the latter. It is presumed that these grabens might have been formed over a very long period and the formation was judged to have been completed at the final period of Tertiary.

In the survey conducted in the first year or 1970 were observed disseminated areas consisting mainly of pyrite on the upper stream of the Sopu river and near Masewo of the Karangana river. Also granite, especially its periphery was found to be interesting as a place of good potentiality of deposit occurring. Based on these findings, out of the area surveyed in the first year was selected an area covering 4, 600 square km extending from 119°30' to 120°15' east longitude and 1° to 1°30' south latitude as having high potentiality of mineral deposits.

The purpose of the survey in the second year or 1971 was to conduct geological survey and geochemical survey on the said area of high potentiality to clarify the mode of occurrence of mineralized areas. As a result of the geological survey conducted, mineralized areas mainly of pyrite were located in S. Bomba and Rio districts. Comparing with the results of geochemical survey, S. Bomba district was judged to have higher potentiality and Rio mineralized area was ranked next to the former.

The survey in 1972 was conducted to have the details of mineralized area made clear in S. Bomba covering 35 square km. The geological survey was able to confirm the mineralization in S. Webose as principal mineralized area situated on the middle stream of the Webose river. This mineralized area, 1 km in width extending 3 km in NW-SE direction, consists mainly of pyrrhotite accompanying pyrite and a small quantity of chalcopyrite, and the mineralization is presumably due to granite intrusion. Studies made together with the results of drilling exploration conducted to investigate the underground of the mineralized area reveal a poor possibility of developing into a workable deposit with very low content of copper (0. 04 % in Cu content) although it has an extensive metamorphosed area.

Anomalies indicated by geophysical survey prove to be corresponding with the area of mineralization, but geochemical survey fails to show a clear anomalous area and the results fall short of clarifying the mineralized area.

However, the reported survey has served to clarify the geological and deposit conditions of Block No. 4 area of Sulawesi which was hitherto left unexplored with only limited data available and has located mineralized areas having nature similar to porphyry copper type ore deposit. All these results obtained are considered to provide an important guideline for the future exploration in the area.

PART I

INTRODUCTION

1. Purpose of Survey

The purpose of this survey is to confirm the possibilities of occurrence of mineral resources in Block No. 4 area of Sulawesi Island and clarify the scale and conditions of ore deposits in areas of high potentiality selected out of the said Block by employing efficient and appropriate surveying methods of various kinds.

The results of the survey conducted over the last three years are summarized hereunder.

Table 1. Scope of the Surveys from 1970 to 1972

1970

Location	Methods	Amount of Works	Number of Personnel	Period of Field Survey
Northern Extremity : 1°S Southern Extremity : 2°S Eastern Extremity : 120°28'27.99"E Western Extremity :Western Coastal line	Geological Survey	Square measure : 14,160 km^2	Managing & Planning Japanese team 5 Indonesian team 1	From 26, Sep. 1970 To 25, Nov. 1970
	Photogeo-logical Survey		Geological Survey Photogeological Survey Japanese team 7 Indonesian team 3	
	Airborne Magnetic Survey		Airborne Magnetic Survey Japanese team 1	
	Aero Photographing		Control Points Survey Japanese team 4 Indonesian team 1	
	Control Points Survey			
see Geological Survey, 1971	Topographic Mapping (in the area of 1971)	Square measure : 4,600 km^2	Supply & Transportation Indonesian team 1	

1971

Location	Methods	Amount of Works	Number of Personnel	Period of Field Survey
Northern Extremity : 1°S Southern Extremity : 1°30'S Eastern Extremity : 120°15'E Western Extremity : 119°30'E	Geological Survey	Square measure : 4, 600 km^2	Managing & Planning Japanese team 5 Indonesian team 1	From 10, Nov. 1971 To 21, Dec. 1971
	Geochemical Survey	Number of analysed samples : 3, 749	Geological Survey Geochemical Survey Japanese team 13 Indonesian team 6	
see Geological Survey,1970	Topographic Mapping (in the area of 1970)	Square measure : 14, 160 km^2	Supply & Transportation Japanese team 1 Indonesian team 1	

1972

Location	Methods	Amount of Works	Number of Personnel	Period of Field Survey
A. Lat. 1°17'00"S Log.120°12'40"E B. Lat. 1°21'12"S Log.120°10'44"E C. Lat. 1°20'41"S Log.120°13'22"E D. Lat. 1°17'38"S Log.120°10'06"E bounded by those four points	Geological Survey	Square measure : 35 km^2	Managing & Planning Japanese team 7 Indonesian team 1	From 22, Sep. 1972 To 29, Jan. 1973
			Geological Survey Japanese team 2 Indoensian team 1	
	Geochemical Survey	Number of analysed samples : 775	Geochemical Survey Japanese team 1 Indonesian team 1	
	Geophysical Survey (EM Vertical Loop Method)	Square measure : 35 km^2 Total line kilo meters surveyed : 78.0 km	Geophysical Survey Japanese team 6 Indonesian team 2	
S. Webose area	Geophysical Survey (EM Horizon-tal Loop Method)	Square measure : 2.5 km^2 Total line kilo meters surveyed : 16.4 km		

(cont'd)

Location	Methods	Amount of Works	Number of Personnel	Period of Field Survey
S. Webose area	Geophysical Survey (IP Method)	Square measure : 10 km^2 Total line kilo meters surveyed : 22.0 km		
	Drilling Exploration	3 holes Total length : 390 m	Drilling Exploration Japanese team 3 Indonesian team 2	
			Supply & Transportation Indonesian team 1	

2. Survey Personnel

Names of personnel engaged in the survey are as shown in Table 2.

Table 2. Survey Personnel from 1970 to 1972

1970

Managing and Planning	Hisashi Takahashi	Metallic Minerals Exploration Agency
	Jiro Komai	Metallic Minerals Exploration Agency
	Yasushi Kambe	Metallic Minerals Exploration Agency
	Hironao Suzuki	Overseas Technical Cooperation Agency
	R. Sakamto	Geological Survey of Indonesia
	Toru Ohtagaki	Nikko Exploration and Development Co., Ltd.
Geological Survey (including Photogeology)	Naoki Kobayashi	Nikko Exploration and Development Co., Ltd.
	H. M. Untung	Geological Survey of Indonesia
	Hiroyuki Fujioka	Nikko Exploration and Development Co., Ltd.
	Hajime Takahashi	Nikko Exploration and Development Co., Ltd.
	Koichi Shinoda	Nikko Exploration and Development Co., Ltd.
	A. M. Harahap	Geological Survey of Indonesia
	Yoshinori Wataya	Nikko Exploration and Development Co., Ltd.
	Masakazu Kawai	Nikko Exploration and Development Co., Ltd.
	Hiroshi Fuchimoto	Nikko Exploration and Development Co., Ltd.

	Suhardjono	*Geological Survey of Indonesia*
Control Points Survey	Fumito Jono	Kokusai Aerial Surveys Co., Ltd.
	Untung Paiman	Geological Survey of Indonesia
	Tetsuo Shimizu	Kokusai Aerial Surveys Co., Ltd.
	Katsuyuki Kasai	Kokusai Aerial Surveys Co., Ltd.
	Shiro Horibe	Kokusai Aerial Surveys Co., Ltd.
Supply and Transportation	Yang Sumolang	Geological Survey of Indonesia

1971

Managing and Planning	Hisashi Takahashi	Metallic Minerals Exploration Agency
	Yasushi Kambe	Metallic Minerals Exploration Agency
	Hironao Suzuki	Overseas Technical Cooperation Agency
	Hardjono	Geological Survey of Indonesia
	Toru Ohtagaki	Nikko Exploration and Development Co., Ltd.
	Toshio Anzai	Nikko Exploration and Development Co., Ltd.
Geological & Geochemical Survey	Takashi Ono	Nikko Exploration and Development Co., Ltd.
	O. Butarbutar	Geological Survey of Indonesia
	Mitsugu Nakamura	Nikko Exploration and Development Co., Ltd.

Koichi Shinoda	Nikko Exploration and Development Co., Ltd.
Hanafi Harahap	Geological Survey of Indonesia
Akitsura Shibuya	Nikko Exploration and Development Co., Ltd.
Hiroshi Fuchimoto	Nikko Exploration and Development Co., Ltd.
U. Djumarna	Geological Survey of Indonesia
Eiji Hashimoto	Nikko Exploration and Development Co., Ltd.
Hajime Takahashi	Nikko Exploration and Development Co., Ltd.
Supardi	Geological Survey of Indonesia
Atsuo Sasaki	Nikko Exploration and Development Co., Ltd.
Hiroaki Miyazaki	Nikko Exploration and Development Co., Ltd.
Hiroshi Miyajima	Nikko Exploration and Development Co., Ltd.
D. Sihotang	Geological Survey of Indonesia
Fumio Fukazawa	Nikko Exploration and Development Co., Ltd.
Akio Shida	Nikko Exploration and Development Co., Ltd.
Erdita Dipura	Geological Survey of Indonesia
Shoji Uchiyama	Nikko Exploration and Development Co., Ltd.

Supply and Transportation	Nobuaki Kainuma	Nikko Exploration and Development Co., Ltd.
	E. Tjetje	Geological Survey of Indonesia

1972

Managing & Planning	Toshio Wakiyama	Metallic Minerals Exploration Agency
	Yasushi Kambe	Metallic Minerals Exploration Agency
	Michihisa Shimoda	Overseas Technical Cooperation Agen
	Hardjono	Geological Survey of Indonesia
	Toru Ohtagaki	Nikko Exploration and Development Co., Ltd.
	Tomio Saeki	Nikko Exploration and Development Co., Ltd.
Geological Survey	Takashi Ono	Nikko Exploration and Development Co., Ltd.
	Erdita Dipura	Geological Survey of Indonesia
	Akitsura Shibuya	Nikko Exploration and Development Co., Ltd.
Geochemical Survey	Tetsuo Takagi	Nikko Exploration and Development Co., Ltd.
	Harwidjaja	Geological Survey of Indonesia

Geophysical Survey	Katsunosuke Wani	Nikko Exploration and Development Co., Ltd.
	Narzuki Sani	Geological Survey of Indonesia
	Wahju Sunoto	Geological Survey of Indonesia
	Teruo Ohashi	Nikko Exploration and Development Co., Ltd.
	Kiyoshi Kawasaki	Nikko Exploration and Development Co., Ltd.
	Yukio Tomikawa	Nikko Exploration and Development Co., Ltd.
	Katsuro Sato	Nikko Exploration and Development Co., Ltd.
	Tomohiro Narita	Nikko Exploration and Development Co., Ltd.
Drilling Exploration	Koichi Namiki	Nikko Exploration and Development Co., Ltd.
	Dudung Tarjono	Geological Survey of Indonesia
	Ikin	Geological Survey of Indonesia
	Takashi Kakishita	Nikko Exploration and Development Co., Ltd.
	Sunao Umemoto	Nikko Exploration and Development Co., Ltd.
Supply & Transportation	Nana Prijatna	Geological Survey of Indonesia

3. Location

The surveyed area is located at the central part of Sulawesi Island and is in both Central and South Sulawesi States. The capital of Central Sulawesi State is Palu city, which is about 10 km from the northern end of the surveyed area. Base camp was established in this city.

4. Access

Air route is usually used for transportation between Jakarta and Palu city, via Balikpapan or Ujun Pandang and the flight time is about six hours.

Travel by jeep is possible from Palu city to Kulawi which is in the center of the surveyed area. Ox cart is used from Kulawi to Gimpu or from Bora in the northwestern part of the area to Berdikari of Palulu county. There are some foot paths, but they are generally not developed. Boats can be used for communication to the west coast and also in Lindu lake, in the lower part of Lariang and Pasangkaju rivers.

5. 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) Tawaëlia 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.

In the central mountain district, high peaks of about 2, 500 m are seen continously, and steep slopes are observed especially at the eastern slant.

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 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.

Tawaëlia graben district is a plateau with the altitude of 600 - 800 m extending from north to south. Different from Fossa Sarasina, this graven does not show abrupt changes in the topography.

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

In the survey area, rivers show a complicated drainage pattern 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 Tawaëlia graben, flowing into the Tomini 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.

6. Climate

The area belongs to the tropical pluvial climatic zone and the year is divided into east monsoon season of May to October and west monsoon season of November to April. The rain is concentrated in the west monsoon season. In the coastal areas the average temperature is 25°C and humidity 80 per cent, but in the mountainous areas the temperature sometimes drop down to little over 10°C, and thunder is common.

Vegetation is very dense and most of the area is virgin jungle. In parts of the mountain regions, primitive agriculture is being done and rice paddies, coconuts, bananas and coffee are grown in the alluvial plains.

PART II GEOLOGY

1. Outline of Geology

In the surveyed area, granitic rocks which intruded in the late Tertiary to Pleistocene epoch is widely distributed, and Paleozoic and Mesozoic metamorphic rocks occur in roof pendant form, Neogene Tertiary formations and Quaternary alluvium overlies these geologic units locally. The geologic structure of this area is controlled by the two tectonic lines called Tawaëlia graben in the eastern part and Fossa Sarasina graben (Palu fault) in the central part, the former with N-S trend and the latter with NNW-SSE trend.

The stratigraphic correlation used in fiscal 1970, 1971, and 1972 are shown in Table 3. The determination of the geologic age and the stratigraphic relationship is very difficult in this area as there are no fossil occurrence with the exception of Tertiary formations and also because of the wide distribution of igneous rocks. Here the lithology will be explained using the geological survey, photogeological survey and airborne magnetic survey.

Table 3. Nominal Correlation of Strata from 1970 to 1972

Survey Area of 1970	Survey Area of 1971	Survey Area of 1972
Alluvium	Alluvium	Alluvium
Doda formation	S. Tinauka formation	S. Tinauka formation
Karangana river formation	S. Pakawa --------- formation (phyllite)	(not distributed)
Palu river crystalline schist & phyllite group	Sidondo schist	
Rompo river crystalline schist group	S. Rompo schist	S. Rompo schist
	(cont'd)	

Lariang river crystalline schist group	Towulu schist	(not distributed)
Sopu river gneiss group	G. Nokila laki gneiss	G. Nokila laki gneiss leucocratic / melanocratic
Poso crystalline schist	(not distributed)	(not distributed)

2. Geology

2-1 Poso Crystalline Schist

Type locality : Along the road leading eastward from Bomba and Pada villages.

Distribution : It is distributed in a narrow N-S zone in the eastern part of the Tawaëlia graben.

Lithology and composition : This is muscovite-quartz schist forming greenish white bodies with schistose microfolds, and has muscovite caused a luster. Quartz and muscovite are the major components and small amounts of sphene and sulphide minerals are contained.

Relation to other formations : The relation to other geological units are not known as the distribution of this rock is limited and is intersected by the faults of the Tawaëlia graben.

2-2 G. Nokila laki Gneiss

Distribution : It is distributed in N-S direction from Matave to Siroa on the right bank of the Palu river, and also in NW-SE direction from Lindu lake to Nakila laki mountain. It overlies granitic bodies as roof pendant. Thickness reaches to 1500 - 2500 + meters.

Lithology and composition : This rock is divided into granitic gneiss and biotite-amphibole gneiss.

1) Granitic gneiss : This rock is located at the right bank of the Palu river and is identified as injection gneiss. The constituent minerals are similar to those of granite and diorite the major mafic minerals being biotite with smaller amounts of amphibole and pyroxene. The salic minerals are orthoclase, plagioclase and quartz. It generally shows weak gneissosity.

2) Biotite-amphibole gneiss : The gneissose structure of this rock is more pronounced than that of the granitic gneiss and also this contains of more mafic minerals. This rock is divided into melanocratic and leucocratic gneisses from the biotite content with the former occupying apparent higher stratigraphic horizon and the latter lower horizon. They both contain large amounts of plagioclase and quartz with sphene and apatite as the common accessories.

Relation with other formations : This rock is greatly disturbed by the intrusion of the granitic bodies and also it occurs within granitic bodies as xenoliths, thus it is probably older than granite. There are, however, cases where granitic gneiss turns gradually into granite.

2-3 Towulu Schist

Distribution : It is elongated in NW-SE direction (30 x 6-7 km) and distributed in a lens shape.

Lithology and Composition : The major rock of this unit is biotite schist and gneissose schist occurs in some parts.

Relation to other formations : The schist bounds on slate with fault, and it is intruded with granite and the stratigraphy is not clear. But it is most likely that metamorphism took place simultaneously with G. Nokila laki gneiss and the degree of metamorphism is higher than that of the S. Rompo schist.

2-4 S. Rompo schist

Distribution : This rock is distributed as a roof pendant over granitic bodies in an area of 25 km x 25 km in the vicinity of the Rompo river in the central part of the eastern ranges. This unit was found bounded with faults within the G. Nokila laki gneiss by the survey in 1972.

Lithology and composition : The major part of this unit consists of black to dark gray amphibole schist with intercalation of quartz schist. Under the microscope, the major constituent minerals are hornblende and feldspar and it occasionally contains biotite, pyroxene, and chlorite. The metamorphic degree is somewhat higher than the Sidondo schist and seems to contain more green minerals.

Relation to other formations : This rock is intersected by granite, bounds on gneiss with faults and is overlain unconformably by Tertiary S. Tinauka formation.

2-5 Sidondo Schist

Distribution : This rock is distributed in N-S direction along the Palu river.

Lithology and composition : The major part of this unit consists of biotite-quartz schist and biotite schist with intercalations of slate and phyllite. It is hard and fine-grained, and has clear schistosity, but lineation is generally not observed. The major constituent minerals of biotite-quartz schist are biotite and quartz with sericite, chlorite, muscovite, calcite and carbonaceous material as accessory minerals.

Relation to other formations : As this rock often occurs as xenoliths in granites, it is older than granitic rocks.

2-6. S. Pakawa Formation

Distribution : Widely distributed in N-S direction from the midstream of the river Karangana and of the river Lariang to Rio district in the central range. N-S distribution of this formation is observed also in the southern part of Tawaëlia graben.

Lithology and composition : The major lithology of this formation is slate with intercalations of sandstone, limestone, tuff, and chert. Some parts of the slate is altered to phyllite.

1) Slate : This rock is black, hard, and compact. The major constituent mineral is angular quartz with some plagioclase and carbonaceous material. Secondary minerals are sericite and chlorite. A small amount of pyrite is observed.

2) Sandstone : This is a brittle coarse-grained, yellowish brown sandstone intercalated in slate. The rock is composed of poorly sorted plagioclase, quartz, chlorite and a small amount of biotite and magnetite. This turns gradually into slate with graded bedded structure.

3) Limestone : This is found as boulders near Omu half way down the Lariang river and also near Banas of Karangana river and is considered to occur as an intercalation of the slate. It is grayish white to yellowish white and some have siliceous parts consisting of very fine calcite and quartz under the microscope.

4) Basic tuff : This tuff is found near Momi of the midstream of the Lariang river. It is

reddish brown and phenocrysts of chlorite and plagioclase are observed and the matrix is glassy.

5) Sericite-chlorite schist and biotite phyllite : These show almost the same distribution as the basic tuff and is brittle with phyllitic structure. It consists of biotite with minor contents of sericite, chlorite and quartz.

6) Chert : This occurs only as xenoliths in granite at the western part of Gimpu of the Lariang river. It is white and hard. The constituent minerals are minute grains of quartz, with mixture of carbonate minerals sometimes with network like texture.

7) Conglomerate : This is an intraformational conglomerate underlying slate formation at the Marei river. The pebbles are quartzite, sandstone, and limestone. The maximum pebble is about 10 cm and is well rounded, the matrix is sandy.

Relation to other formations : Near the Karangana river, this formation is intruded by granite and andesite and bounds on Tawulu schist with fault. It is overlain unconformably by S. Tinauka formation in the downstream area of the Lariang river. Near the Marei river, the eastern end is intersected by Tawaëlia graben and in the western side it is intruded by granite.

2-7 S. Tinauka Formation

Distribution : This formation is distributed widely near Lindu lake, along the Palu river, from the Lariang river to the Rio district in the central western piedmont of the central ranges. The thickness is 500 m + in the vicinity of the Tinauka river and is 50 m - 200 m ± along the Palu river.

Lithology and composition : This formation consists of normal sediments * which is distributed from the Rio river to the Lariang river, and of acidic pyroclastics distributed in the northern part of Lindu lake and along the Palu river.

(1) Normal sediments : These are sandstone, conglomerate, and silt, they are generally soft and unaltered.

1) Sandstone : Sandstone is distributed in upstream of the Rio district and Karangana rivers, it is yellowish brown, brittle and its grain size often changes. It is mainly alternation of coarse-grained and fine-grained parts. The minerals are quartz with a small amount of feldspar amphibole, magnetite, and clay minerals (chlorite, sericite).

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* Nonpyroclastic sedimentary rocks

2) Conglomerate : Conglomerate is distributed around the Rio district, and Pakuli of the Palu river. The former conglomerate has similar matrix to the above mentioned sandstone and has only rounded pebbles of maximum 10 cm in diameter. Pebbles are composed of granite, slate, and sandstone, etc. The latter conglomerate is yellowish brown in color and compact and pebbles are of maximum 30 cm or more in diameter and are rounded, subangular and angular pebbles. The amount of matrix is small.

3) Silt stone : This is intercalated in sandstones around the Rio district and changes gradually from the above mentioned sandstone.

(2) Pyroclastic rocks : The major constituent of these rocks is dacitic and rhyolitic tuff,while minorly tuff breccia. They are generally soft, white and contains some green minerals (mostly chlorite). The breccias in the tuff breccia are mostly sandstone, slate and schists.

Relation to other formations : This formation unconformably overlies all other formations and granitic bodies with the exception of the alluvium deposits.

2-8 Alluvial Deposits

Alluvial deposits in this area are distributed as fans of the rivers flowing west and the down stream of the Palu river, alluvium plain deposits, small terraces along the Sopu river, talus deposits, coastal plain deposits in the downstream of the Pakawa river, and lacustrine deposits near Lindu lake. They are mostly alternating beds of sand, gravel, and silt.

2-9 Igneous Rocks

1) Granitic rocks

The granitic rocks occupy more than half of this area and they are largely divided into, Rio granite (around the Rio district), G. Tangkulowi granite (along the left bank of the Palu river), and Lindu granite (from the Sopu river to the Lindu lake). All of these granitic bodies have elongated form trending N-S. The granitic rocks are divided into biotite granite, biotite-amphibole granite, and amphibole granite, and they are all distributed commonly throughout the area. Also granodiorite, adamellite, quartz diorite, and monzonite are found locally. The major mineral constituents are plagioclase, orthoclase, quartz, biotite, and amphibole with sphene, magnetite, and hematite as the accessory minerals. Pyrite is often contained in the Lindu and Rio granites.

The K-Ar dating showed the rocks to be of 4.80 - 1.62 $\times 10^6$ years in age and it is inferred that the intrusion took place during late Tertiary to Pleistocene.

2) Ultrabasic rocks

These intruded as small dikes after the formation of the granite bodies and locates at the eastern part of the survey area. It is somewhat argillitized and consists of clinopyroxenes of 2 - 5 mm with a small amount of olivine. Chromite is associated in some places and serpentinization is observed.

3) Gabbro

Gabbro occurs as small stocks of 2 - 3 m in width within granitic bodies in the eastern mountain range. It is melanocratic, mediumgrained, compact, and holocrystalline and contains a large amount of amphiboles, plagioclase, and sphene.

4) Dolerite

Dolerite intrudes into slate as dyke of 2 x 4 km at midstream of the Lariang river. It is grayish black, compact, and consists mainly of oligoclase and hornblende. The rock is equigranular and contains a large amount of magnetite.

5) Kentallenite

This rock occurs as two intrusive bodies of about 5 km in diameter near Kantowu at midstream of the Lariang river. Orthoclase, oligoclase or andesine, augite (diallage), pyroxene and biotite are major constituents and apatite is found as accessory mineral. This rock is considered to be a plutonic facies with simultaneous intrusion as dolerite.

6) Andesite

Andesite occurs as dykes elongated in N-S direction with 2 - 3 km in width along the eastern bank of the Karangana river, and also as small dykes along the Fossa Sarasina and is distributed in several localities as andesitic pyroclastic rocks.

It is classified into (a) hornblende-biotite andesite, (b) amphibole-biotite andesite, and (c) amphibole andesite.

7) Rhyolite

Rhyolitic tuff and lava are found in the surveyed area. Tuff is distributed in narrow areas along the Fossa Sarasina and is pale green and compact. The constituent minerals of tuff are quartz, orthoclase, plagioclase, biotite, and amphibole. Lava occurs as a flow of 10 m wide at the midstream of the Palu river and is grayish black and shows flow structure. It has a small amount of phenocryst of plagioclase. The rock is rich in glassy groundmass.

3. Geologic Structure

3-1 Outline

The geologic structure of this area is largely controled by the widely distributed granitic bodies and by the rupture graben of N-S trend called Tawaëlia and Fossa Sarasina. The metamorphic rocks are distributed in the direction of the fracture zone and form roof pendant over the granites.

The intrusive bodies such as granites are also closely related to these tectonic lines and are distributed in N-S to NNE-SSW direction.

The only fold structure confirmed is a small repetition of small synclines in slate.

3-2. Faults

It was inferred from the distribution of the geological formations, results of photogeology and airborne magnetic survey, that Tawaëlia graben trended in N-S direction from the Tawaëlia river to the Marei river. The situation is similar with the Fossa Sarasina, fault topography is observed along the Palu river and thus the existence of the graben was inferred. The strike of the Fossa Sarasina is N20°W - S20°E and is oblique to the faults forming the Tawaëlia graben. But as the intersection of the two faults is out of the surveyed area, the relation of the two faults is not clear.

The lineation interpreted from aerial photographs show that NW-SE and NE-SW directions are prominent for both fault lineaments and fracture lines. The faults of this area were largely divided into the following two series by the detailed geological survey of 1972.

1) A series of faults in with NNW-SSE strike and those in direction normal to these.

2) A series of faults with NWW-SEE strike and those in direction normal to these.

3-3 The Structure of Metamorphic and Sedimentary Rocks

The metamorphic rocks of this area are elongated in NNW - SSE direction reflecting the direction of the two rupture graben. On the other hand, the G. Nokila laki gneiss and S. Rompo schist which is distributed in the eastern range show various schistosity from N-S to NWW - SEE because of the granitic intrusion and the prominent disturbance. Several synclinal structures were observed in the slate of S. Pakawa formation. The dip is generally in the range of 30° - 60°, but the S. Tinauka formation has a very low dip which suggests the difference of the geologic age and sedimentation.

4. Geologic History

There are no occurrence of fossils from the metamorphic rocks and slates with the exception of Neogene Tertiary S. Tinauka formation. And because of the tectonic movement caused by the intrusion of granitic rock bodies after Neogene Tertiary, the geologic structure before that time is extremely disturbed.

The basement rocks of this area is made of various metamorphic rocks. Of these metamorphic rocks, G. Nokila laki gneiss and Towulu schist are highly metamorphosed while S. Rompo schist and Sidondo schist have somewhat lower metamorphic degree. The slate bed of the S. Pakawa formation is considered to be younger than the gneiss and schists from the distribution and lithology, but the age is not clear.

A large scale tectonic movement related to the "Celebes orogeny" occurred from the late Tertiary to Pleistocene.

Series of tectonic lineations in N-S direction were developed in relation to these movement and the intrusion of granitic bodies began. Fossa Sarasina (Palu fault) was formed at this period and the basement rocks were incorporated into the granitic bodies. The intrusion of ultrabasic rocks, gabbro, dolerite began along both Fossa Sarasina and Tawaëlia tectonic lines, and silt, sand, and gravel deposits in the depressions were formed by this movement. There was a relatively large uplifting movement in recent.

PART Ⅲ

EXPLORATION

The Sulawesi Island is divided into three large geologic units, namely, Palu zone, Poso zone, Kolonodale zone, from west to east.

The mineral deposits which are associated with ultrabasic rocks in the Sulawesi Island have been well-known as nickel and chromium resources. They are developed mostly in Kolonodale zone. In Palu and Poso zones, the great number of copper, lead, zinc, gold and iron sulphide mineral deposits have been reported and/or exploited, although any large deposits have been not confirmed yet. From the region of Tertiary formations, a small production of petroleum and natural gas were known in the past.

In the surveyed area, since it being situated in the Palu and Poso zones, the mineral deposits of copper, lead, zinc, gold and iron sulphide are expected to be newly discovered.

In the report Part II, are summarized the results of the three years' geological survey. On the basis of the results, the general remarks on the survey on the promising area will be given in Part III, with the summaries of results of the survey of the each year.

Chapter 1. Survey during Fiscal 1970

1-1 Alteration

Chloritization, sericitization, kaolinitization and carbonitization are the predominant alteration in the area. These alterations are, however, very weak.

1) Chloritization

Chloritization is extensive found in the Tertiary sedimentary rocks, slates, granite, volcanic rocks. The alteration is weak, and mafic minerals in the rocks are partly replaced by chlorite.

2) Sericitization

Sericitization is also common. But in almost all cases, secondary sericite is partially developed in the primary minerals.

3) Kaolinization

Kaolinization is common in the metamorphic rocks and granites. Usually it is local and weak.

4) Carbonitization

Extremely weak alteration is seen in slate, phyllite and granite. Usually it is recognized only under the microscope as veinlets.

1-2 Mineralization

1) Sulphide disseminated area in the basin of the Sopu river.

At the upper streams of the Sopu river, dissemination of sulphide mineral is recognized in the granite as well as in the gneiss, especially in the hornfels around the granite.

Microscopically pyrite and chalcopyrite, and molybdenite are observed in very small quantity. This area is extended from east to west over 1 km (uncertain). The boulders of the sulphide disseminated rocks of this type are distributed in the eastern part of Lindu lake. Seeing from this, the mineralized area is estimated to be extended over 15 km. Because of its very low quality, it can hardly be worked economically.

2) Sulphide disseminated area near Masewo of the Karangana river

A sulphide disseminated rock of vein form associated with clay is found in the slates. Major sulphide is pyrite and, accompanied with chalcopyrite and zinc-blende. Gangue minerals are chlorite, sericite, etc. The width of this vein is about 1 m, and the continuity of the vein cannot be recognized. Judging from its small dimension and very low metal contents, it has not economical value at present.

This vein is a sort of hydrothermal origin which was formed by post-igneous activity of the granite intrusion.

Besides these sulphide disseminated areas, sulphide minerals are uniformly dispersed in the each sample of rocks as seen under the microscope, but never concentrated to a considerable degree, nor to a profitable grade and dimension. These sulphide minerals are most probably the primary constituents of the host rocks. Several non-profitable muscovite veins are observed at some places in the area. There are some indications of laterization, but they are not promisible.

1-3 Relation between Mineralization and Geologic Structure

The sulphide mineralization is confined around the Sopu river, granitic bodies which are distributed along with the major structural trend of this district.

1-4. Summary and Conclusion in 1970

As the result of the survey, it was revealed that the areas of hornfels around the granite stocks are most promising of further prospecting, among which, the most significant one was denoted as the sulphide disseminated area along the Sopu river.

On the basis of these results and the information of the previous survey, the surveyed area of fiscal 1971 was selected and the methods of the survey was recommended.

Chapter 2. Survey during Fiscal 1971

2-1. Alteration

The alteration in the surveyed area is generally weak, and even in the mineralized areas, the remarkable alteration cannot be recognized. It comprises chloritization, sericitization, kaolinization, and carbonitization.

2-2. Mineralization

The following are the results of the survey.

1) S. Bomba mineralized area

The host rock of the S. Bomba mineralized area is the G. Nokila laki gneiss, biotite gneiss and biotite-amphibole gneiss. Granites intrude these rocks as small stocks. The sulphide mineralization takes place in the gneiss around the granite, mostly in the form of veinlets of several meters long. The main sulphide mineral is pyrite and, accompanied with a very small amount of chalcopyrite and sphalerite. The sulphur content of the ores is about 6 % at maximum, but mostly about 1 %. Copper and zinc contents are 0. 14 % and 0. 12 %, at maximum respectively.

2) Rio mineralized area

The Rio mineralized area, of which host rock is the slate of the S. Pakawa formation, is located around granite. This dissemination of sulphide minerals and their partial limonitization are the features of this area. The mineralized rocks in the areas is exposed sporadically extending to about 10 km in N - S direction. Pyrite and a small amount of pyrrhotite are the sulphide constituents.

2-3 Geochemical survey

Geochemical survey of this area was carried out with the purpose of extracting promising areas for metallic minerals deposits by clarifying the distribution of components in river sands and soil. The number of the analysed samples is 3749 of which 2990 are river sands and 759 are soil samples. The sampling density is 0. 8 samples per square kilometer.

In order to determine the indicator element, approximately 10 per cent of all samples were chosen at random from the total area and emission spectograph was taken for the following 20 elements : Co, Zr, Ti, Zn, Na, Cu, Ag, V, Al, Ni, Fe, Ga, Si, Mg, Cr, Pb, Mn, P, B and Mo. After consideration of various factors, Cu, Pb, and Zn were selected as the most efficient indicators.

One of the reasons for slecting the above three elements was the fact that the type of deposits which can be expected from this area was porphyry copper.

Atomic absorption method was adopted for the quantitative measurement of the indicators.

Analyses were done independently for the following three samples.

(1) River sands 50 - 100 mesh (abbreviated as C here after)

(2) River sands under 100 mesh (F)

(3) Soil (S)

Anomaly range of each component, Cu, Pb and Zn, was independently analysed. As a results of it, it is recognized that background of each component is various for rocks, and that background of Cu, Pb and Zn is 20 - 30 ppm, 10 - 20 ppm and 30 - 60 ppm respectively. Maximum content of Cu, Pb, and Zn as measured is 175 ppm, 153 ppm and 127 ppm respectively, and these values are smaller than expected. Seventeen anomalous areas were found from the study of the analytical data of the three kinds (C, F and S) of samples, which are shown in Table 4 and Fig. 4. On comparing the distributions of anomalous areas for each component with others, similar patterns of Cu and Zn were revealed but Pb behaves in somewhat different way. These anomalous areas are in many cases distributed around the granitic bodies, and are often accompanied with the areas of weak dissemination with pyrite.

The most remarkable anomalous area is that of Rio, and the anomalous areas of S. Marino and S. Bomba are promising.

2-4 Summary and Conclusion in 1971

The geochemical survey denoted 17 anomalous areas, among which, because of the distinct indication of mineralization, the S. Marino, Rio and S. Bomba areas were analysed in detail as the most promising ones by geological survey. The S. Bomba and Rio areas were confirmed their extensions by the geological method, and the S. Marino area was found as located on the northern extension of the Rio mineralized area. This accords well, on the whole, with the results of the geochemical and geological surveys.

Among these three, the S. Bomba mineralized area is the largest, of which only a small part was confirmed, giving the possibilities of finding the more strongly mineralized parts in the areas. The Rio mineralized area is of a smaller scale and lower in metal content. This seems less valuable than the S. Bomba mineralized area.

As a conclusion, the S. Bomba mineralized area were decided as first candicate, Rio mineralized area as second, for the more detailed survey area during the coming 1972.

Chapter 3. Survey during Fiscal 1972

The results of the survey on the respective subject are as follows.

3-1 Alteration

The alteration in the S. Bomba area was revealed only in the S. Webose district where the mineralized area called S. Webose mineralized area is located. In the S. Webose area, the subconcentric three zones of alteration were recognized. It follows as from core to envelope :

1) Quartz-sericite-potash feldspar zone

In this zone, the major secondary minerals are quartz and sericite which is altered from plagioclase and potash feldspar. Veinlets of laumontite and clinozoicite are common. Small amount of sulphide minerals is also found.

2) Sericite-chlorite zone

The alteration minerals of the rocks in this zone are sericite which is altered from plagioclase, chlorite from biotite or garnet. Besides these, the altered rocks contain pyrrhotite and chalcopyrite, the latter being more predominant in this zone than in the other zones. Chalcopyrite is very few in amount.

3) Chlorite-montmorillotite zone

Of chlorite and montmorillonite in this zone, chlorite is more abundant in the altered part from the metamorphic rocks and montmorillonite is predominated in the part inherited biotite granite.

In brief, the sulphide mineralization in the S. Webose mineralized area extends most distinctly in the zone (2).

3-2 Mineralization

From described above, it may be concluded that the area which deserves being called "mineralized area" seems to be limited to the S. Webose district. This mineralization assumes the form of disseminated bodies, films or veinlets of dispersed grains or crystals of iron sulphide minerals. They are associated with the minor amount of chalcopyrite. Magnetite, rutile and ilmenite are the other minor accessories. As iron sulphide minerals are enumerated pyrrhotite, pyrite and marcasite. The S. Webose mineralized area is 1 km in maximum width and 3 km in the largest extension with NW-SE trend and is located in the highly fractured zone. The grade of S. Webose mineralized mass are Cu,0. 01 - 0. 14 % (average 0. 04 %) and S, 0. 7 - 6. 8 % (average 2. 4 %).

3-3 Igneous Rock Related to Mineralization

The igneous rock which is closely related to the mineralization is biotite granite. It occurs as three stocks with dimension of 100 x 400 m or smaller. The dissemination of sulphide minerals and the hydrothermal alteration (sericitization and chloritization) are the features in some part of these granitic stocks. These rocks are midium-grained, holocrystalline. Judging from the fault pattern, the period of this granitic intrusion is considered as the later stage of the igneous activity of the granite which distributes elsewhere in this district.

3-4 Geochemical Survey

In order to locate the most promising area and to take its dimension, the geochemical survey was carried out in this year.

Copper was used as the indicator element on examination of the results of the survey during fiscal 1971, and soils were used as the samples to grasp the feature of the secondary dispersion of the indicator element. The number of sampling point was about 20 per square kilometer and the total of 775 samples from the area of 35 km^2 were analysed.

The samples were analysed by biquinoline colorimetry in the laboratory at the base camp. The accuracy of analysis is of ppm.

Anomalous area was found to be limited in the southern part of the S. Webose mineralized area.

It was shown, also, however, that the higher content of copper was not indicated particularly in the soils of the S. Webose mineralized area which was identified by the geological method. In all over the surveyed area, the copper content is generally low.

3-5. Geophysical Surveys

The geophysical surveys were carried out with two methods : electromagnetic and induced polarization methods. An electromagnetic survey was conducted over the whole survey district. Furthermore, an induced polarization survey was also applied to examine the S. Webose mineralized area which is the most promising area.

Table 4. List of Geochemical Anomaly Areas, 1971

Anomaly area	Area (km²)	Cu						Pb						Zn						Note
		F		C		S		F		C		S		F		C		S		
		A*	B**	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	
1. S. Sipangi	5 x 10	69	◎	50	○	65	○	44	◎	24	○	148	○	106	◉	105	○	-	-	
2. S. Marino	7 x 20	89	◉	60	◉	146	◎	72	◎	37	◎	75	○	106	◉	107	◉	110	○	
3. Rio	8 x 10	167	◉	175	◉	56	○	80	◎	64	◎	137	○	106	◎	101	○	65	○	
4. G. Waukara	4 x 8	71	○	63	○	321	○	-	-	30	○	89	○	106	○	98	○	127	○	
5. Baluase	6 x 17	38	◎	28	◎	-	-	110	◎	138	◎	47	◎	96	◎	80	◎	70	○	
6. Bangga	5 x 5	91	○	98	◎	-	-	60	○	33	-	-	-	69	○	69	◎	-	-	
7. Sidondo	6 x 15	*** -	-	46	○	-	-	153	◎	-	-	37	○	144	◎	90	◉	-	-	few S samples
8. Siroa	5 x 7	42	○	29	○	37	○	100	○	68	◎	90	○	109	○	105	○	103	○	
9. S. Manushi - S. Meno	7 x 10	30	○	32	○	**** ×	×	102	◉	75	◉	×	×	71	◉	58	○	×	×	no S sample
10. S. Sopu	4 x 8	82	○	61	○	×	×	-	-	-	-	×	×	82	○	61	○	×	×	no S sample
11. S. Matou	3 x 9	-	-	-	-	-	-	135	◎	96	○	48	○	-	-	-	-	-	-	no anomaly of Cu, Zn
12. S. Bomba	5 x 10	53	○	-	-	-	-	-	-	-	-	-	-	61	○	52	○	65	○	no anomaly of Pb
13. S. Lariang (1)	9 x 15	78	◉	60	◎	129	◎	159	○	26	◎	63	◉	82	○	93	◉	91	○	
14. S. Lariang (2)	5 x 7	-	-	-	-	-	-	30	◎	19	○	-	-	-	-	-	-	-	-	no anomaly of Cu, Zn
15. Matave	7 x 18	167	◉	31	○	66	○	-	-	67	◉	127	◎	-	-	61	○	76	◎	
16. S. Tumawu	4 x 7	59	○	25	○	-	-	-	-	46	◎	87	○	87	○	62	○	99	○	
17. Labua	7 x 10	57	○	43	○	99	○	40	○	58	○	48	○	49	○	58	○	48	○	

* A represents the maximum value of anomaly within each area

** B represents the number of anomalies within each area (○ : 1 to 5, ◎ : 6 to 10, ◉ : over 11)

*** - represents no anomaly area.

**** × represents no sample.

Electromagnetic survey

1) Survey method

In the electromagnetic survey we adopted two methods : vertical and horizontal loop methods, which belong to an inductive electromagnetic method.

In case of vertical loop method, the moving source in-line coil configuration was adopted as a reconnaissance survey, and the survey stations were planned to establish along roads, ridges and valleys. The coil separation was usually taken as 100 m, but sometimes the separation shrank to 50 m according to the terrain condition. On the other hand, in case of horizontal loop method, which is usually employed in a detailed survey, we took the horizontal coplanar coil separation with an interval of 60 m. We used here SE 600 Electromagnetic Horizontal Loop System, Scintrex Ltd., in the two methods above mentioned.

2) Survey results

In the vertical loop survey, dip angles of the magnetic field were measured. We call absolute values of dip angle more than 10 %, "dip angle anomaly". While, in case of horizontal loop method, in-phase and out-of-phase components are measured in %. The absolute values of in-phase components of 110 % or more and those of out-of-phase components of 10 % or more are adopted as anomalies against the electromagnetic background response.

Many anomalies were obtained from the survey with vertical loop method and we dealt with twelve significant anomalies among them. Most of the anomalies obtained in the survey are distributed in the northern part of the survey area. We notice a NW trend passing through anomalies, A, B, G, H, I, J and K.

Anomalies A and B are the most distinct and have extensive negative zones.

As survey results with horizontal loop method, many small-scale anomalous in-phase components were obtained. Relatively significant anomalies A_1 to A_4 were pointed out. The most obvious is Anomaly A_1 observed in the north end of Line G, having distinct positive-negative pattern. While, anomalies A_2 to A_4 are formed by dominant negative zones but no significant positive zones form counterparts to them.

Significant anomalous out-of-phase components were obtained as Anomalies A_1 to A_4 from the survey. Anomaly A_1, observed around Station No. 65 on Line 32, is the most obvious one and has a large-scale typical pattern. Anomalies A_2 and A_3, consisting of positive zones, are also pointed out to be significant. In the northern part of Line A, an extensive negative anomaly A_4 was observed.

The noteworthy anomalies A, B, C and D were observed in the survey with vertical loop method. The most distinct anomalies are Anomalies A and B, located around S. Webose mineralized area, trending to the NW direction. Anomaly C is expressed by a complex pattern. This may be caused by the complicatedly distributed mineralized zone. Anomaly D has a typical pattern, but we can not catch the whole extension beyond the end of the traverse line.

Remarkably anomalous in-phase components were represented as Anomalies A_1 and A_2. We presume that the corresponding mineralized zones may exist below them.

On the other hand, no obvious relation exists between out-of-phase anomalies and the other anomalies.

Induced polarization survey

1) Survey method

The induced polarization survey was carried out by means of the frequency domain method with the electrode separation 100 m and the co-efficients of the electrode separation n = 1, 2 and 3. The instruments used in the survey were Burr-Brown IP Receiver Model 9741 and Yokohama Electronics Laboratory IP Transmitter YNC 502.

2) Survey results

The survey results are expressed in forms as frequency effect FE %, apparent resistivity ρ ohm-m and metal conduction factor MCF. The most distinct anomalous FE zone, trending to the NW direction, extends over Lines D, E, F and G. The anomaly centering around Stations No. 3 - 4, Line D, has a tendency to continue to the above mentioned zone in the deep part.

Anomalous zone, trending in the E - W direction, was observed on Lines H, I and J. But we cannot expect that the anomaly extends to the deep part.

A high resistivity zone, more than 300 ohm-m, extends to the NW direction and partly corresponds to an extent of the FE anomaly. However, the relation between resistivity and FE is not always obvious there.

The most promising anomalous FE zone extends over Lines D, E, F and G. This zone coincides with S. Webose mineralized area and is presumed to express the mineralization concerned. It is also presumed on the basis of pattern analysis of computer models that the anomaly centering around Stations No. 3 - 4, Line D, is caused by a mineralized zone extending downwards but not horizontally. On the other hand, the FE anomaly observed on Line H, I and J, which is located at the extended part of S. Webose mineralized area, can not be supposed to express such a mineralization as S. Webose, because the pattern of the anomaly is different from that observed over S. Webose.

3-6 Drilling Exploration

The purpose of this drilling was to obtain the informations concerning the subsurface mineralization in the most promising S. Webose mineralized area. The depth of every three drill holes was 130 m.

Columnar section of the drilling cores are shown in Fig. 6.

1) DH-1

Under the surface soil, sand and gravel bed of about 10 m thick, leucocratic gneiss appear downward in the enumerated order. Strongly silicified zone exists at 107.5 m in depth and is followed upward by sericite-chlorite zone and chlorite-montmorillorite zone. Weakly silicified zone exists at the upper most part of the drill hole. Weak mineralization of sulphide minerals (mainly consisting of pyrite) are confined mostly in the silicified zones as well as in the sericite-chlorite zone, but the metal content of these rocks is low; less than 0. 01 % of Cu tenor and 0. 16 % of S one at the depth of 35. 0 m to 38. 0 m and less than 0.01% of Cu tenor and 0. 14 % of S one at the depth of 91. 0 m to 98. 0 m.

2) DH-2

Surface soil, sand and gravel beds are 10 m thick, followed by melanocratic gneiss reaching to the bottom. This gneiss is penetrated by biotite granite. Intensely silicified zone (101 - 107 m), sericite-chlorite zone and chlorite-montmorillonite zone appear upward in the enumerated order. Mostly in the silicified zone and in the sericite-chlorite zone, are observed the weak dissemination of sulphide minerals mainly consisting of pyrite.

The metal content is, however, extremely low as follows:

0. 02 % of Cu tenor and 1. 30 % of S at the depth of 67. 0 m to 71. 0 m, less than 0. 01 % of Cu tenor and 0. 28 % of S at the depth of 95. 4 m to 95. 8 m, less than 0. 01 % of Cu and 0. 19 % S at the depth of 125. 0 m to 130 m.

3) DH-3

Under the surface soil, sand and gravel beds of 6. 5 m thick, are melanocratic gneiss, biotite granite and biotite amphibole bearing quartz porphyry as arranged in the enumerated order. Melanocratic gneiss are penetrated by biotite granite elsewhere. The rocks of the upper part belong to the chlorite zone and the lower part to the chlorite-epidote zone (propylitization zone). Pyrite dissemination is observed elsewhere. Metal content is very low; less than 0.01 % of Cu and 0.33 % of S at the depth of 69.0 m to 75.0 m, and less than 0.01 % Cu and 0.09 % of S at the depth of 114.0 m to 115.0 m.

As the final results of drilling nothing but weakly mineralized rocks which are hardly workable, were obtained.

The results of the surveys for three years are summarized in Table 5.

Table 5 Results of the Surveys from 1970 to 1972

1970

Location	Methods	Amount of Works	Purposes	Results
Northern Extremity : 1°S Southern Extremity : 2°S Eastern Extremity : 120°28'27.99"E Western Extremity : Western Coastal Line	Geological Survey	Square measure : 14,160 km^2	To clarify the geology and geological structure of all over the survey area. Selecting the promising area. (Under 30% of the survey area.)	Promising areas for mineral resources are around the granite. Distribution of ore deposits is controled by the structure of the granite and principal geologic structure of this area. On the basis above mentioned, the survey area for 1971 was selected.
	Photogeological Survey			
	Airborne Magnetic Survey			
	Aero Photographing			
	Control Points Survey			
See Geological Survey, 1971	Topographic Mapping (in the area of 1971)	Square measure : 14,160 km^2		

1971

Location	Methods	Amount of Works	Purposes	Results
Northern Extremity : 1°S Southern Extremity : 1°30'S Eastern Extremity : 119°30'E Western Extremity : 120°15'E	Geological Survey	Square measure : 4,600 km^2	To clarify the geological conditions of mineralized area (Chosen in 1970, and to extract targets for surveys of the next year).	17 anomalous areas were found by geochemical survey. Based on geological and geochemical surveys, S. Bomba mineralized area was selected as the most promising, Rio mineralized area as the second for 1972.
	Geochemical Survey	Number of analysed samples : 3,749		
See Geological Survey, 1970	Topographic Mapping (in the area of 1970)	Square measure : 14,160 km^2		

1972

Location	Methods	Amount of Works	Purposes	Results
A. Lat:1°17'00"S Log:120°12'40"E B. Lat:1°21'12"S Log:120°10'44"E C. Lat:1°20'41"S Log:120°13'22"E D. Lat:1°17'38"S Log:120°10'06"E bounded by those four points	Geological Survey	Square measure : 35 km^2	To clarify the details of the mineralized area, namely, structure, relation to granitic intrusion, metamorphism.	S. Webose mineralized area extends 1 Km in width and 3 Km in length in the gneiss pyrrhotite dissemination and hydrothermal alteration were recognized. Mineralization has relation with small stocks of granite.
	Geochemical Survey	Number of analysed samples : 775		
	Geophysical Survey (EM Vertical Loop Method)	Square measure : 35 km^2 Total line kilometers surveyed : 780 km	To examine the indication for ore deposits.	The distinct anomalous area was found in the northern part of the survey area.
S. Webose area	Geophysical Survey (EM Horizontal Loop Method)	Square measure : 2.5 km^2 Total line kilometers surveyed : 16.4 km	Detailed survey for E.M (Vertical) anomalous area	The anomalies were observed at S. Webose area with accord to I.P. anomalies.
	Geophysical Survey (IP Method)	Square measure : 10 km^2 Total line kilometers surveyed : 22.0 km	Detailed survey for S. Webose mineralized area.	Distinct anomalies were obtained over the S. Webose mineralized area. Scale and forms of the above area were able to suggest.
	Drilling Exploration	3 holes Total length : 390 m	To clarify S. Webose mineralized area.	Alteration and mineralization were confirmed at each hole, but their grades were poor. maximum : Cu 0.02% S1.30%

PART Ⅳ

CONCLUSIONS

The most promising area within Block No. 4, Sulawesi which was extracted from the results of the surveys carried out during the period of 1970 - 1972 is the S. Webose mineralized area. Although the geological conditions of mineralization such as the kind of igneous rocks, alteration process related to mineralization strongly resembles those of porphyry copper mineralization, the copper content is very low (Cu 0. 04 per cent) and it does not seem to improve downward. Thus the results of the surveys were not encouraging for this particular area.

But recent studies show as a first approximation that western Sulawesi can be included in the zone of porphyry copper deposits from tectonic standpoint. Thus, our findings from the present survey and the fact that porphyry copper type mineralization was found in this area will be of significant contribution to the exploration of the surrounding areas.

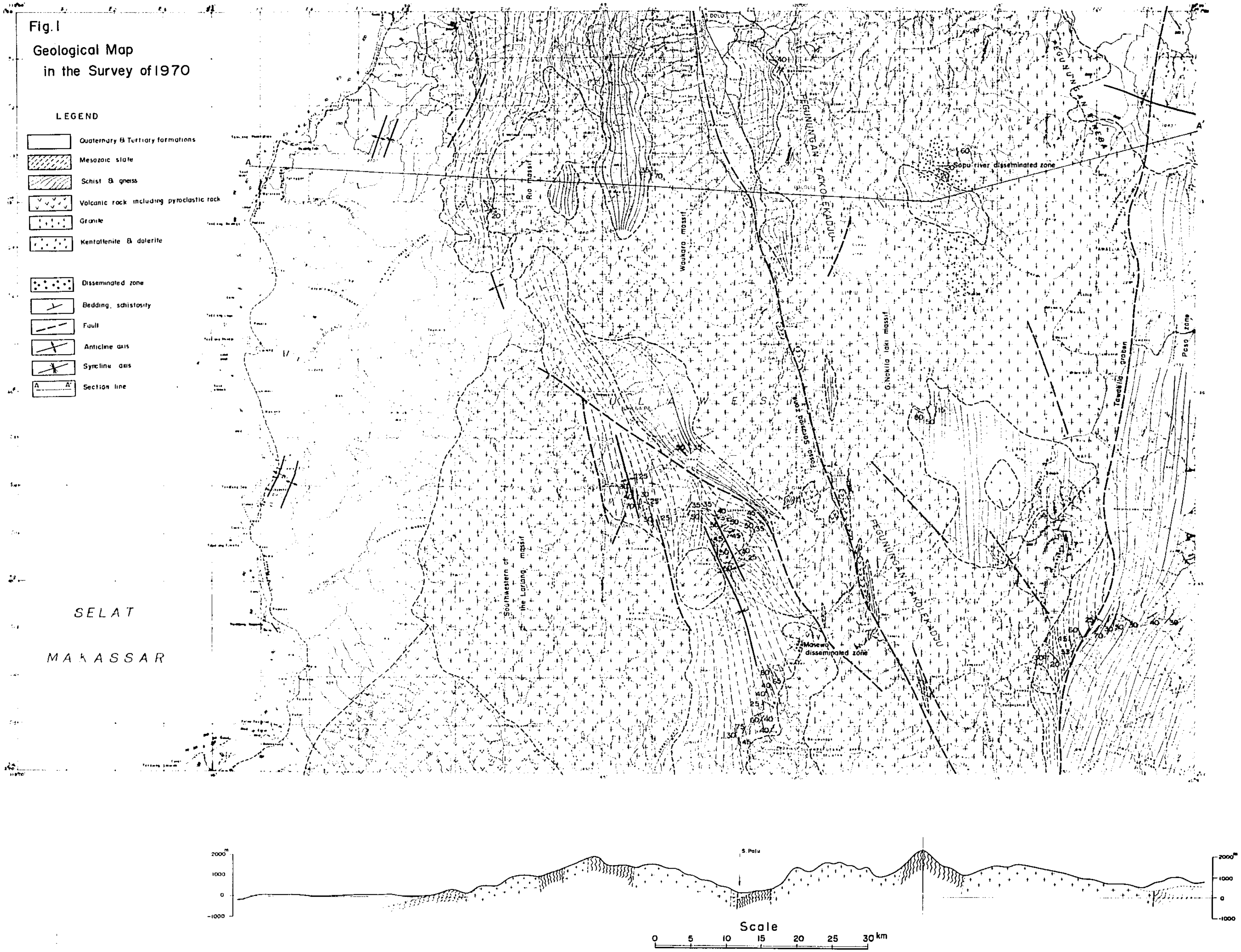

Fig. I
Geological Map
in the Survey of 1970

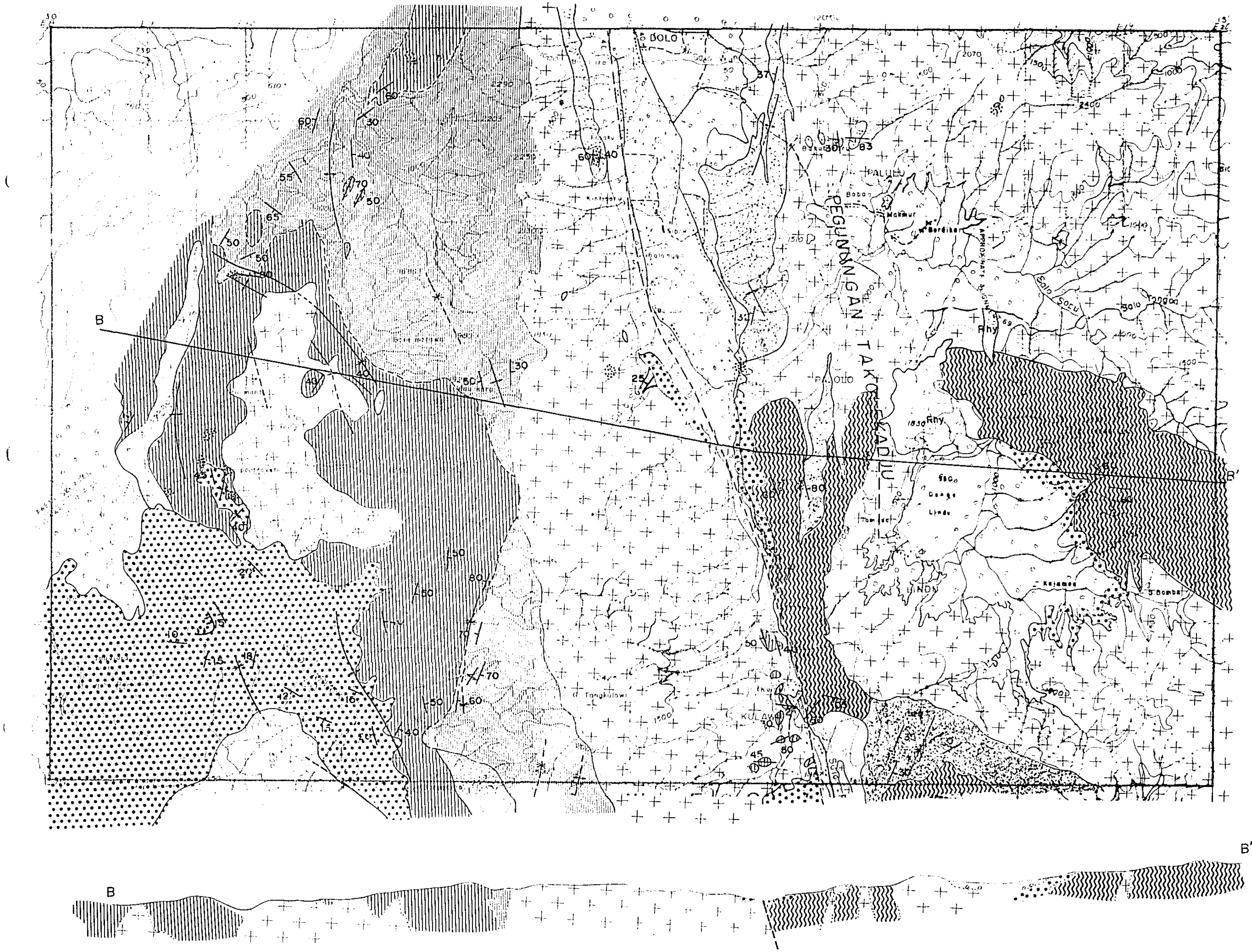

Fig.2 Geolo

LEG

Alluvium	Alluviu
Pliocene -Pleistocene	S. Tinauk Forn
Pre-Tertiary	S. Pakaw Forn
	Sidendo
	S. Rompo
	Towulu
	G. Nokild Gr
Intrusive rock	

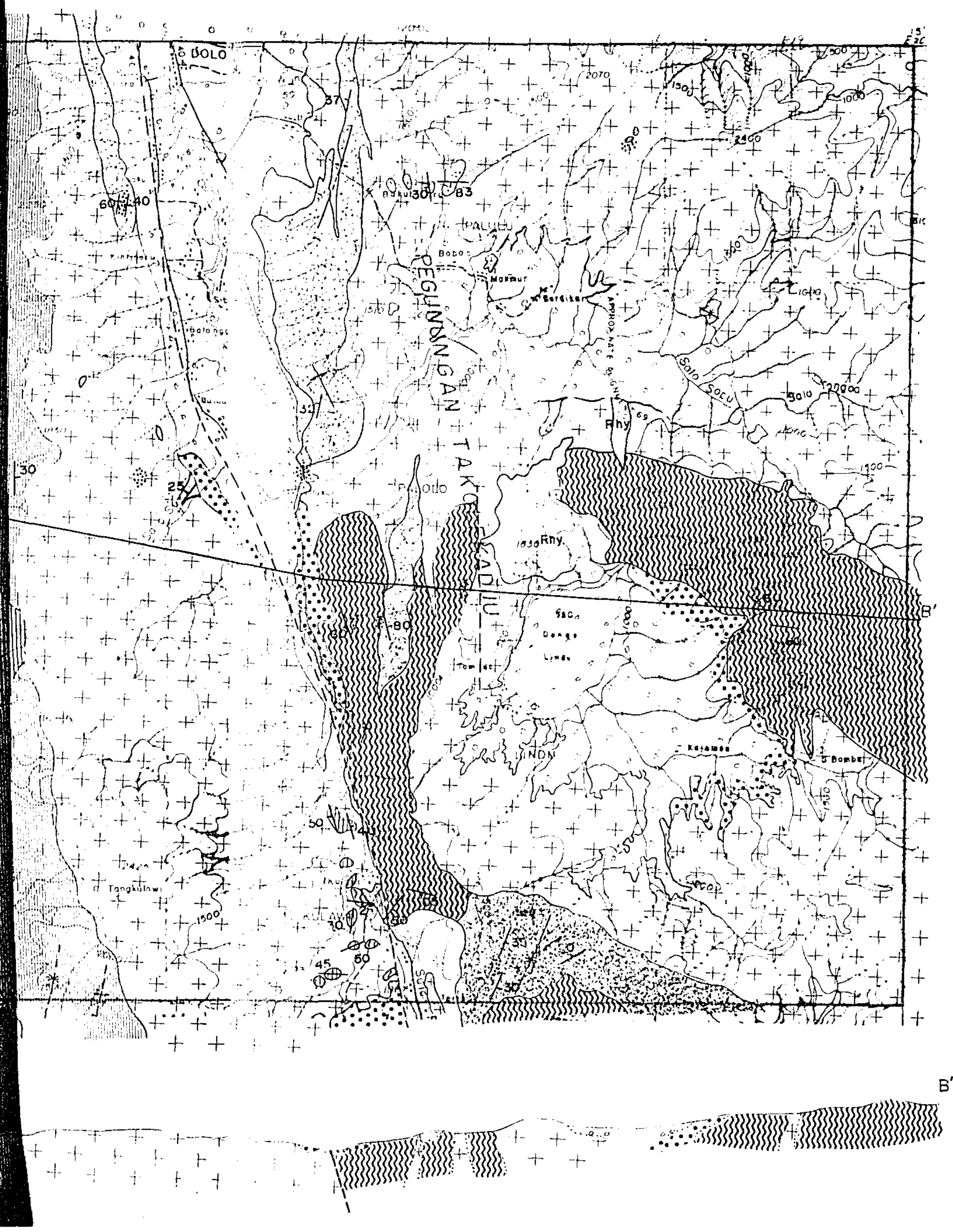

Fig.2 Geological Map in the Survey of 1971

LEGEND

Alluvium	Alluvium	Unconsolidated sediments (Silt, Sand, Gravel)
Pliocene -Pleistocene	S. Tinauka Formation	Rhyolite
		Clastic rocks (Siltstone, Sandstone, Conglomerate)
Pre-Tertiary	S. Pakawa Formation	Slate, Sandstone, Tuff, etc.
		Phyllite, etc.
	Sidende Schist	Biotite schist, etc.
	S. Rempe Schist	Biotite-epidote-chlorite schist, etc.
	Towulu Schist	Biotite schist, etc.
	G. Nokila laki Gneiss	Biotite gneiss, etc.
Intrusive rock		Granite
		Bedding, Schistosity
		Fault
		Synclinal / Anticlinal axis
		Mineralized zone
		Section line

Scale

0 10 20 30 40km

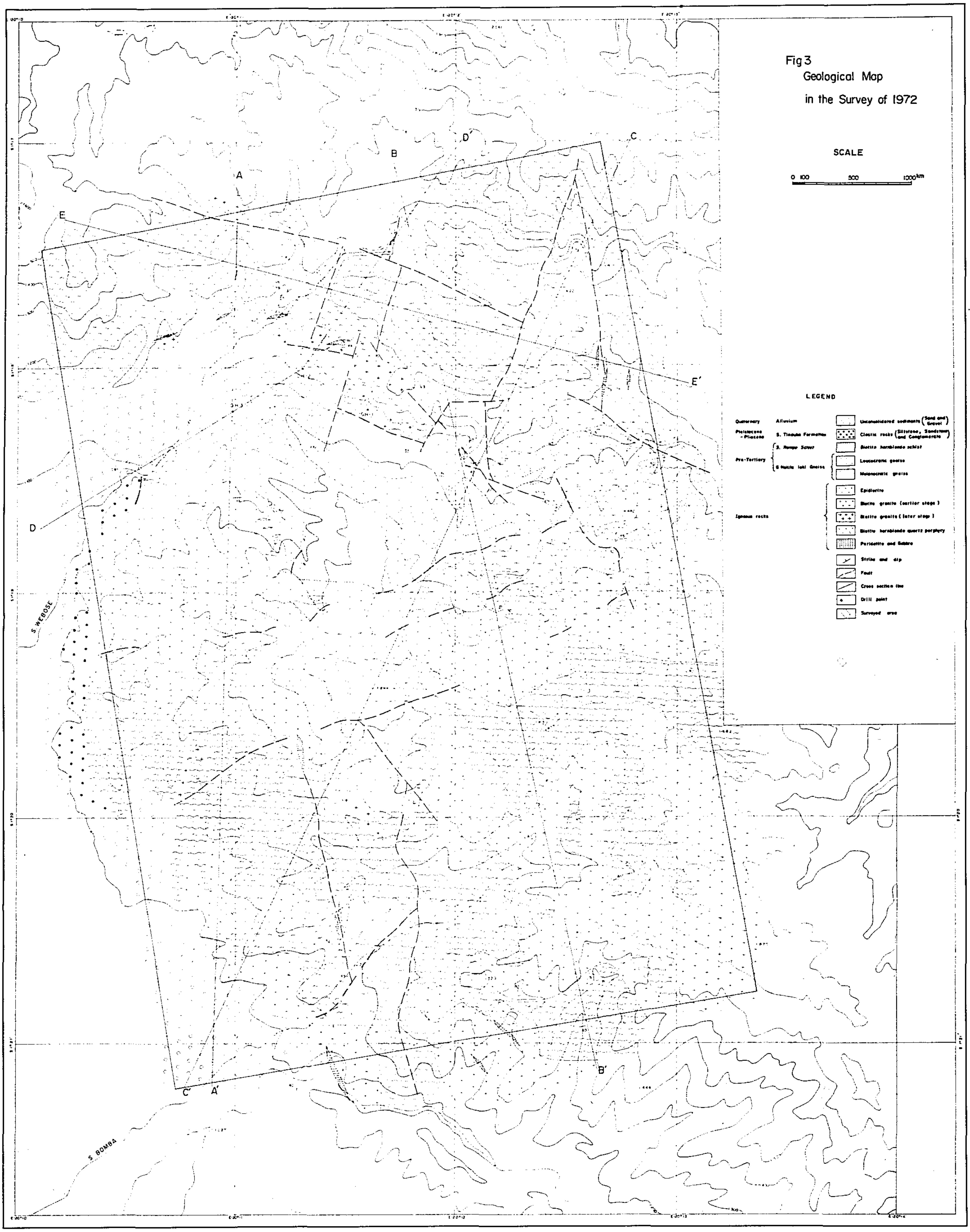

Fig 3 Geological Map in the Survey of 1972

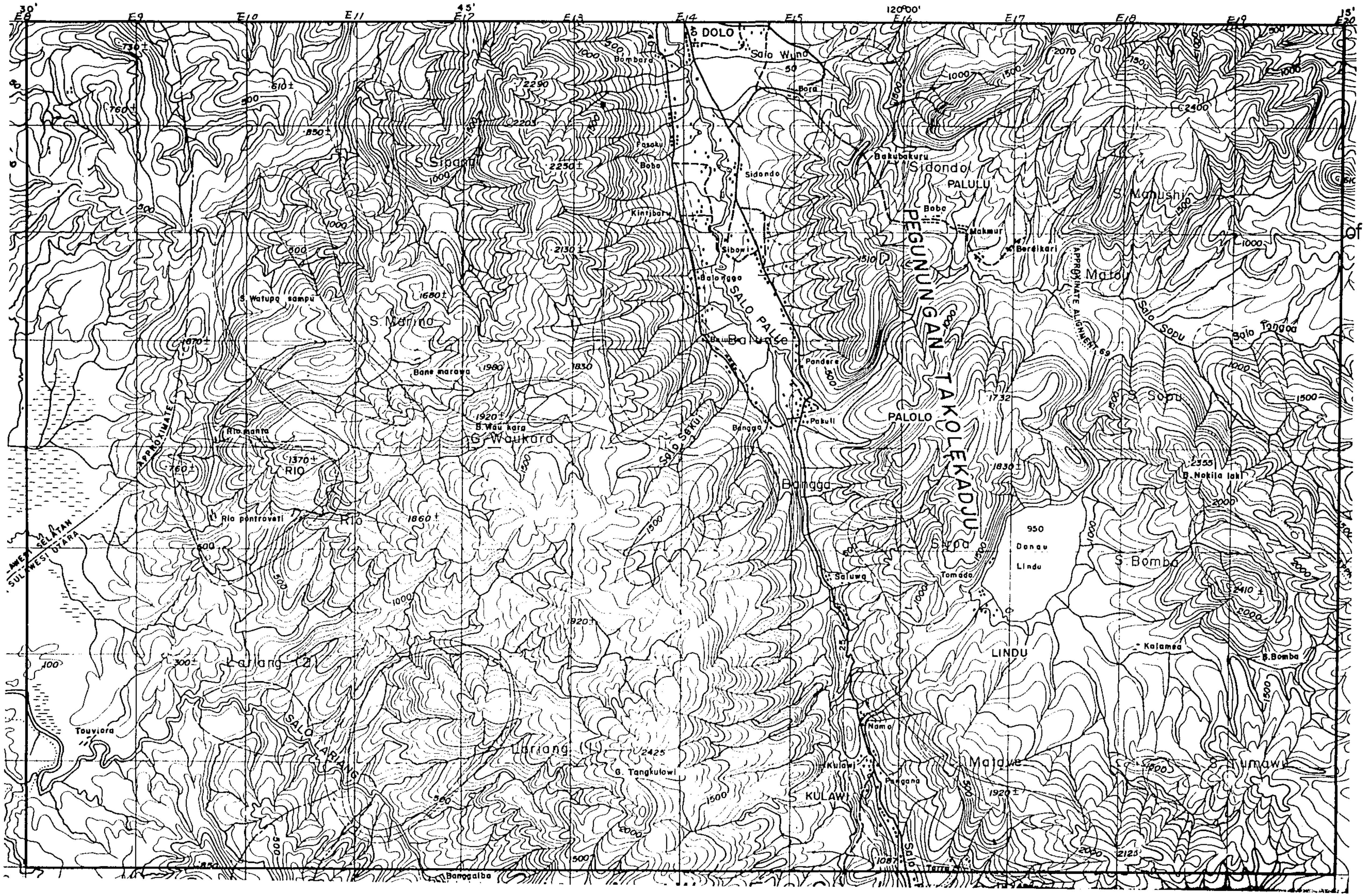

Fig 4

Location Map

of Geochemical Anomalous

LEGEND

Anomalous Area of

Anomalous Area of

Anomalous Area of

SCALE

0 10 20 30

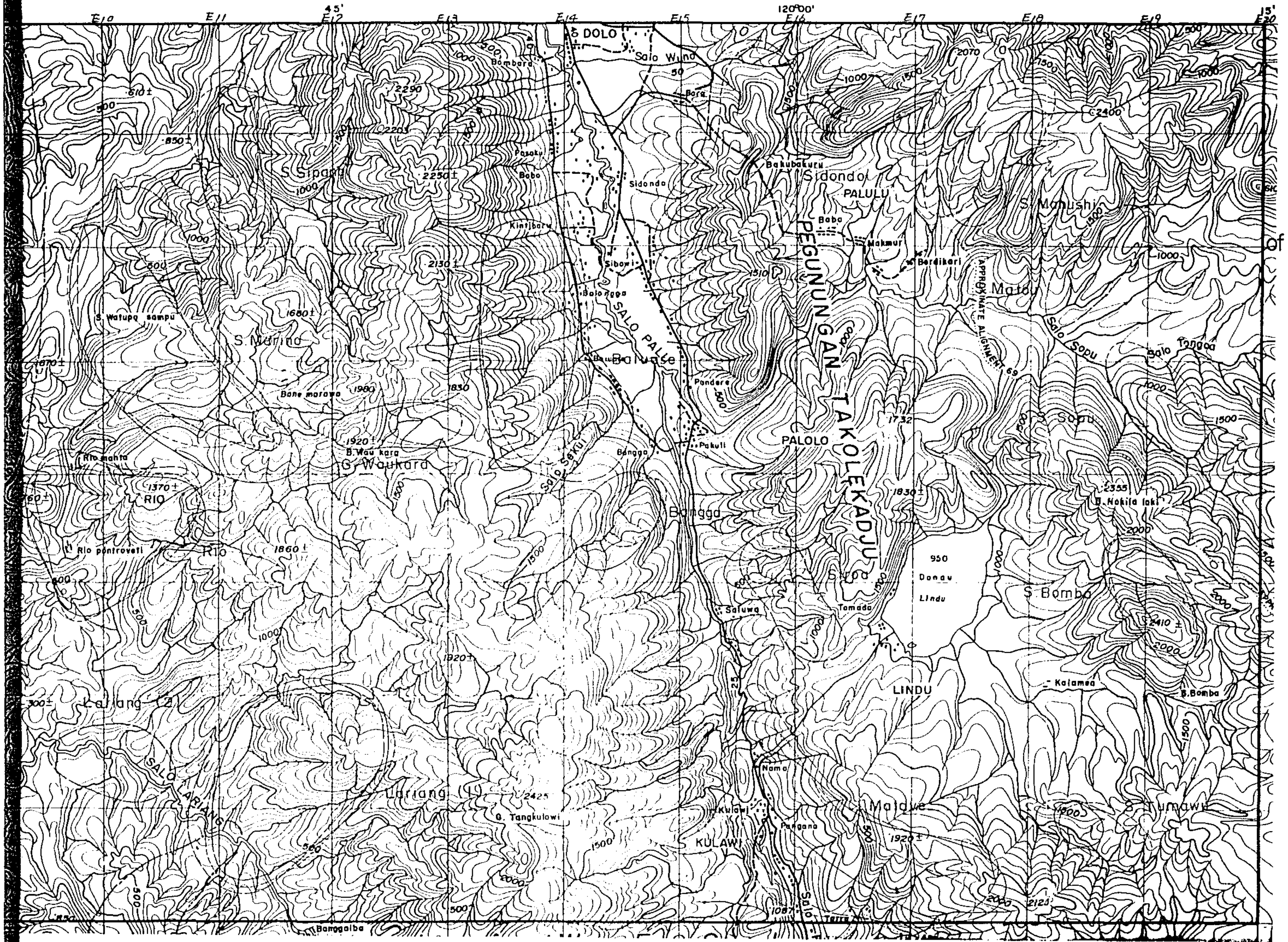

Fig 4

Location Map of Geochemical Anomalous Area, 1971

LEGEND

- Anomalous Area of Copper
- Anomalous Area of Lead
- Anomalous Area of Zinc

SCALE

0 10 20 30 40 km

Fig 5

Location Map of Geophysical (I.P. and E.M. methods) Anomalous Area, 1972

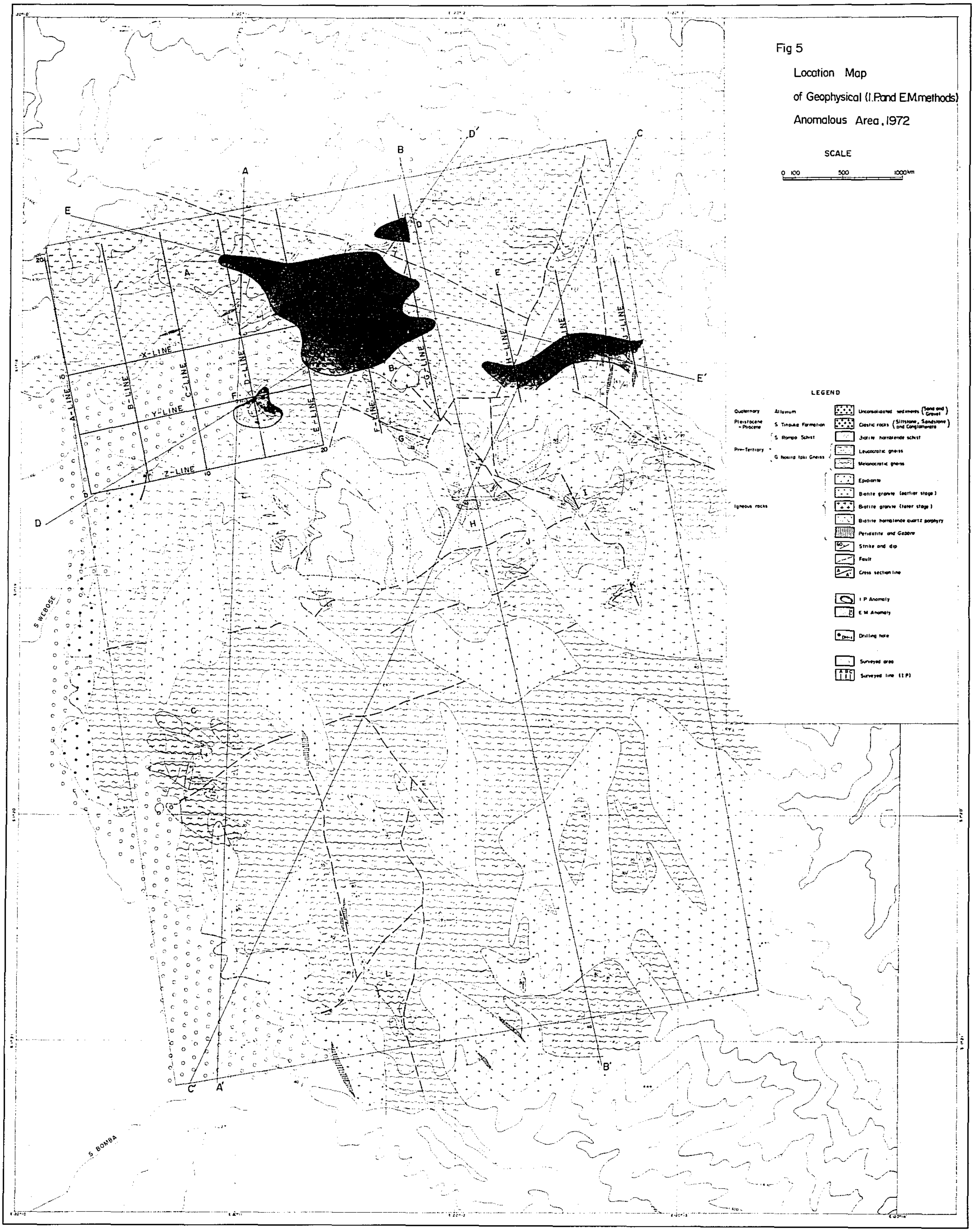

Fig. 6 Geological Column of Drilling Cores, 1972 Scale 1:500