REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE PEGUNUNGAN TIGAPULUH AREA, THE REPUBLIC OF INDONESIA

PHASE I

FEBRUARY 1990

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

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

The JICA and MMAJ sent to the Republic of Indonesia a survey team headed by Mr.Yoneharu Matano from October 10 to December 26, 1989.

The team exchanged views with the officials concerned of the Government of the Republic of Indonesia and conducted a field survey in the Pegunungan Tigapuluh area. After the team returned to Japan, further studies were made and the present report has been prepared.

We hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

February 1990

Dr.ADJAT SUDRADJAT
Director General of Geology
and Mineral Resources,
Ministry of Mines and Energy,
Republic of Indonesia

Kensuke YANAGIYA
President
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President
Metal Mining Agency of Japan

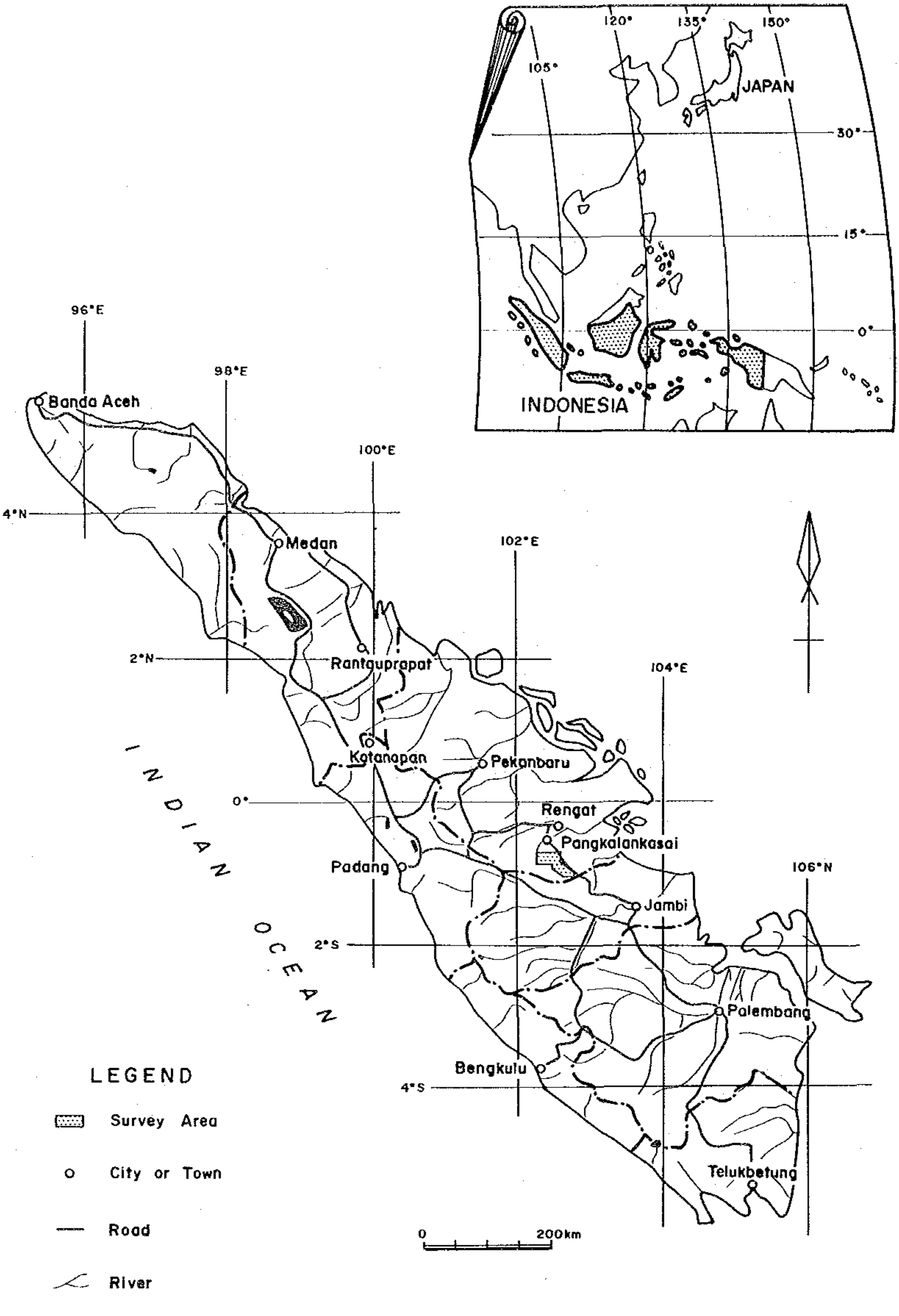

Fig.1-1 Index Map of the Survey area

Summary

The first phase survey of the Pegunungan Tigapuluh Project consisted of photogeologic interpretation, geological survey, geochemical prospecting and measurements of magnetic susceptibility and radioactivity.

The objective of the survey was the investigation and assessment of the prospectivity of the area. The amount of work carried out is as follows.

Photogeological
Interpretation area————1,000km²
Geological survey area————1,000km²
Traverse———— 539km
Geochemical prospecting
Stream sediments————1,019 samples
Panning———— 210 samples

The geology of the survey area is composed of Carboniferous - Permian metamorphic and sedimentary formations, Paleogene andesitic tuff, Neogene sedimentary rocks, Quaternary units and granitoids intruded the Carboniferous - Permian units.

The granitoids of the area are, porphyritic biotite granite, biotite granite, pegmatite and aplite. These all belong to the calc-alkali series and to the ilmenite series.

The geologic structure of the area is characterized by the intensely folded structure of the Paleozoic units and the faults which transect the Neogene strata. Many synclines - anticlines are observed in the Paleozoic strata and they are arranged in S form.

There are three major fault systems, namely NW-SE, NNW-SSE and NE-SW. The porphyritic biotite granite and the biotite granite tend to be aligned in NW-SE direction.

The mineralized zones of this area occur as network of tin-bearing quartz veins in pegmatites and leucocratic granites. These zones occur along the S.Isahan and S.Sikambu in the western part of the surveyed area. The line joining the two zones coincide with the direction of the arrangement of the granitic rocks.

The network veins consist of quartz, cassiterite, muscovite and arsenopyrite. The host rocks are greisenized with most of the potash feldspar and plagioclase muscovitized. These mineralized zones are chemically characterized by the content of rare metals such as Sn, W and Ce.

The geochemical prospecting of stream sediments revealed seven A-rank anomalous zones for Sn and one A-rank zone for other elements. Two of these Sn anomalous zones overlie the mineralized zone mentioned above where the Sn content of these anomalous zones ranges from 71 to 710 ppm.

The geochemical data of the panned samples showed eight A-rank anomalous zones for Sn of which two overlie the above mineralized zones.

Other than the mineralized zones, the zones which show anomalous values for both stream sediments and panned samples are; two Sn anomalous zones in the northwest extension of the known mineralized zones and one Sn zone each in the Neogene strata in the catchment of S.Antan and S.Endelang.

A tungsten anomalous zone was found near Bt.Kayumambang and a Nb and also a Li zone near porphyritic biotite granite body at S.Nibul.

As seen above, there are several localities in the survey area where the anomalies of both stream sediments and panned samples overlap. In the Paleozoic and granitic terrane, W, Nb and Li overlapping anomalies occur in the eastern part while the Sn overlapping anomalies occur in the west. Regarding relation between the granitoids and the overlapping anomalies, in the eastern part the anomalies occur in the porphyritic biotite granite zone while in the west there are several Sn anomalies in the leucocratic granite and pegmatite.

Since the Sn anomalies in the Neogene strata in the east is believed to be placer concentration and also since it is reasonable to consider their sources to be the granitoids in the Paleozoic units in the vicinity, the porphyritic biotite granite in the east has high resources potential for W, Nb, Ni mineralization followed by Sn mineralization. In the west, the granites have high Sn potential followed by W.

From the results reported above, the metal mineralization expected to be found in the survey area are;

① Sn, W, Ce-bearing primary mineralization

② primary mineralization containing various rare metals such as W , Nb and Li,

③ Sn placer concentration.

The areas found to be prospective for the above mineralization and the necessary prospecting methods are as follows.

(i) The area considered very prospective for the occurrence of primary Sn, W, Ce mineralization is the NW-SE extension of the known mineralized zones at S.Isahan and S.Sikambu. To the northwest of these zones, Sn geochemical anomalies are found and the possibility of the existence of mineralization similar to that of S.Isahan is high. Detailed geological survey and geochemical prospecting are recommended to be carried out and based on the detailed geological and geochemical information, drilling in prospective zones are recommended.

(ii) Although primary mineralization of rare metals such as W, Nb and Li were not found by the geological survey, their existence is inferred from geochemical considerations. Tungsten mineralization are expected near Bt.Kayumambang and Nb, Li mineralization are expected near the S.Nibul porphyritic biotite granite. In these areas detailed geological survey and geochemical prospecting are recommended in order to clarify the nature of mineralization.

(iii) Placer concentration of Sn and other metallic minerals have not been found during the geological survey. But their existence is inferred from the results of geochemical prospecting and the prospective areas are the Neogene zone along the S.Antan. Detailed geological survey and geochemical prospecting are recommended in order to assess the Sn placer concentration of the survey area

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PART I OVERVIEW

PART I OVERVIEW

Chapter 1 Introduction

1-1 Background and Objectives

The Indonesia-Japan Cooperative Mineral Exploration was carried out in five areas of the Republic of Indonesia: Sulawesi (1970-1972), Kalimantan (1974-1977), West Kalimantan (1979-1981), North Kalimantan (1982-1984) and South Sumatra areas (1985-1987). As a result of the exploration, a large amount of basic material regarding metallic mineral resource development was obtained. The exploration also contributed greatly to the technical improvement of the Geological Survey of Indonesia and the Directorate of Mineral Resources, as well as to the acquisition of geologic and mineral deposit data.

The Ministry of Mines and Energy of Indonesia planned to carry out mineral exploration in Pegunungan Tigapuluh area subsequent to South Sumatra, and requested the cooperation of the Japanese Government. In August 1989, the Japanese Government, complying with the request, dispatched a mission for project finding and scope of work headed by Kyoichi Koyama of the Metal Mining Agency of Japan to conduct a preliminary survey of the area. As a result of consultations with the Ministry of Mines and Energy of Indonesia, the counterpart of the Metal Mining Agency of Japan, an agreement was reached for cooperative exploration of the Pegunungan Tigapuluh area.

The major objectives of this exploration were to investigate and assess the potential of mineral resources in the Pegunungan Tigapuluh area, and to transfer exploration technology to the Indonesian counterpart during the course of the project.

1-2 Objective and Outline of Operation in the First Phase Survey

The survey area, 1,000 km² in size, is located in the central part of Sumatra and with the coordinates listed below.

1	0°43'23" S.	102°15'34" E.
2	0°53'42"	102°15'34"
3	0°53'42"	102°30'53"
4	0°55'55"	102°30'53"
5	1°03'16"	102°38'28"
6	1°03'16"	102°48'52"
7	1°01'00"	102°48'52"
8	0°50'25"	102°37'07"
9	0°43'23"	102°37'07"

Administration of the greater part of the area is under the jurisdiction of Riau Province, while the western end belongs under that of Jambi Province. The sphere of the survey area is shown in Figure 1-2.

The objective of the first phase is to extract zones with high probability of mineral occurrence by elucidating the geologic setting, the relationships between mineralization and geologic structures, between mineralization and granites, and the mode of occurrence of mineral deposits through geological survey and geochemical exploration of the Pegunungan Tigapuluh area.

The works conducted during the first phase were the study of existing material, photogeological interpretation, preparation of topographic maps, geological survey and geochemical prospecting, and measurements of magnetic susceptibility and radioactivity.

(1) Photogeological interpretation

Existing aerial photographs (scale 1:100,000) were used for photogeologic analysis. First, the photograph was covered with an overlay, and the drainage system was interpreted and superimposed on the photograph, thus producing the drainage system map. For geological interpretation, (i) the pattern and density of the drainage, resistance to weathering and erosion (relief, extent of erosion), valley profile, ridge shape and other topographic features, and (ii) photographic characteristics such as tone and texture were studied. On the basis of these details, the geological units and structural demarcations were defined and expressed on the drainage system map.

(2) Geological survey and geochemical exploration

The base camp was set up at Pangkalan Kasai, a village to the north of the survey area. In addition to this base camp, flying camps were utilized for durations of one to two weeks at a time. A series of 1:25,000 scale maps enlarged from the 1:50,000 scale topographic map compiled from the aerial photographs were used in the survey. When necessary, a route map was prepared by pacing or 50m tape with a clinometer.

Sampling for geochemical exploration was carried out concurrently with the geological survey, and under-80-mesh and panned samples were collected from the stream sediments. An average of two under-80-mesh samples per 1 km length, and one panned sample per 2.5 km length were taken along the survey route.

Samples were also collected from pits dug around outcrops showing mineralization to supplement geologic and mineral deposit samples.

Measurements of magnetic susceptibility and radioactivity were made at outcrops along the geological survey route.

The results of the geologic survey are expressed on a 1:50,000 scale map.

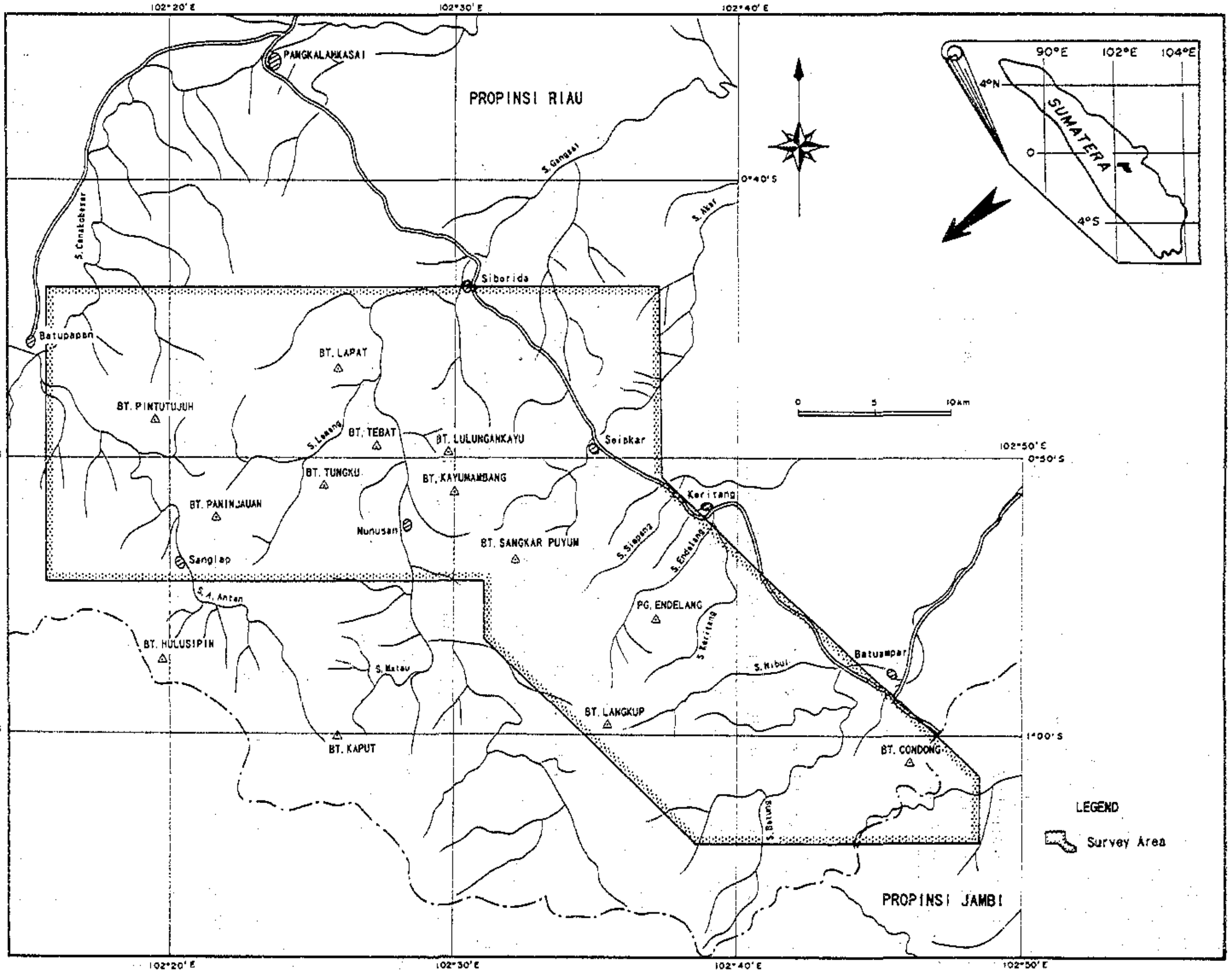


Fig.1-2 Location Map of the Survey area

(3) Amount of the survey in the first phase

content	Amount
Survey area	1,000km^2
Traverse length	539km
Rock samples	
Thin section	31pcs
X-ray diffractive analysis	31pcs
Absolute age determination	5pcs
Whole rock analysis	10pcs
Geochemical samples	
Stream sediment	1,019pcs(14 elements)
Pan concentrate	210pcs(14 elements)
Pitting	19.5m^3

1-3 Member of the First Phase Survey

(1) Mission for project finding and scope of work

(From 14 August 1989 to 27 August 1989)

【Indonesian members】

Dr.Adjat Sudrajat	Director General ; Directorate General of Geology and Mineral Resources, Department of Mines and Energy (DGGMR)
Salman Padmanagara	Director ; Directorate of Mineral Resources (DMR)
A. Machali Muchsin	Head ; Metallic Mineral Exploration Division (DMR)
Sunarya Johari	Chief ; Light and Rare Metals Section(DMR)
Nally Ahmad	Law Section(DGGMR)
Ratnawduri	Foreigen Bilateral Cooperation(DMR)

【Japanese members】

Kyouichi KOYAMA	Metal Mining Agency of Japan
Hideiku SHINOKAWA	Agency of Natural Resources and Energy
Hiroyasu KAINUMA	Japan International Cooperation Agency
Naoki SATO	Metal Mining Agency of Japan

(2) Suervey team

The survey of the first phase was carried out during the period from 26 September 1989 to 26 December 1989. Duration of the field survey and the organization of the survey team were as follows.

Duration of the study of existing material and photogeological interpretation in Japan

: From 26 September 1989 to 9 October 1989

Duration of the field survey

: From 10 October 1989 to 26 December 1989

【Indonesian members】

Sunarya Johari	(DMR)	Coordinator, Chief Geologist
Zamri Ta'in	(DMR)	Geologist
Endang Suwargi	(DMR)	Geologist
Karno	(DMR)	Geologist
Malik Manurung	(DMR)	Geologist
Sahala L. Gaol	(DMR)	Geologist
A. Said Ismail	(DMR)	Geologist
Zulkifli MD	(DMR)	Geologist

【Metal Mining Agency of Japan】

Masaharu TOYAMA	Coordinator

【Japanese members】

Yoneharu MATANO	(NED)	Team leader, Chief Geologist
Fukio KAYUKAWA	(NED)	Geologist
Hideya KIKUCHI	(NED)	Geologist
Tetsuo SATO	(NED)	Geologist and Photogeologist
Kenji SATO	(NED)	Geologist

note; DMR : Directorate of Mineral Resources

NED : Nikko Exploration and Development Co., Ltd.

Chapter 2 Geography of the Survey Area

2-1 Location and Access

The survey area is reached from Jakarta, the capital of Indonesia, by air to Padan, which is a city on the west coast of Sumatra 250 km due west of the survey area; from Padan, the travel on land for the distance of about 400 km takes about 10 hours. The road between Padan and Pangkalan Kasai (where the base camp was set up) is paved but passes over numerous bridges, allowing passage of only under-5-ton vehicles. Another means of access by air is from Palembang, a city in the southern part of Sumatra, to Rengat, a town adjacent to the survey area, but it cannot serve as a regular route because of the scarcity of flights (3 flights a week) and poor connection at Palembang.

The road within the survey area is one from Pangkalan Kasai to Jambi, the capital of Jambi Province, running between the northern end of the central part of the area and the northeastern end of the area. There is another road from Pangkalan Kasai to Batupapan, a village adjacent to the western end of the survey area. As both roads are unpaved, they become impassable, even by jeep, during the rainy season when the rivers overflow and the roads turn muddy. Two private roads for logging are being constructed by two forestry companies. It extends about 20 km along the southeastern end of the area and about 10 km in the northwestern part.

The survey area is accessible also by rivers. Two ton motorboats operate along the S.Cenakobesar at the western end of the area and its tributary, S.Antan, and also along the S.Gangsal in the central part of the area.

2-2 Topography and Drainage System

(1) Topography

The Republic of Indonesia consists of more than 13,600 islands with a total area of 1,900,000 km^2. In Sumatra, which includes the survey area, the Barisan Mountain Range forms the island's framework. It extends about 1,600 km in the NW-SE direction and comprises as many as 90 volcanoes higher than 2,500 m above sea level. The east side of the range gently decreases in elevation and is intervened by hilly land. Alluvial plains consisting of mangrove swamps are widely distributed along the coast.

The survey area corresponds to the northeastern part of the Pegunungan Tigapuluh isolated in the hilly region east of the Barisan Range. The greater part of the area is mountainous, 100 - 400 m in elevation. The highest peak, Bt.Kayumambang, 618 m in elevation, is located in the central part of the survey area. The northeastern part of the area is occupied by hills lower than 100 m and plains.

(2) Drainage system

The rivers in the survey area all flow in the NW or the NE direction since the area belongs to the northeastern Pegunungan Tigapuluh mountainland. Most of the rivers belong to the Retih drainage system, the western extremity of which is the S.Gangsal flowing through the western part of the area. These rivers join in the northeast of the area and flow into the South China Sea. The S.Antan flowing along the western tip of the area joins the S.Cenakobesar, which then joins the S.A.Batang Kuantan, and finally enters the South China Sea.

2-3 Climate and Vegetation

(1) Climate

As Indonesia belongs to the tropical rain forest climatic zone, it has two seasons, rainy and dry. In the dry season (April～October) the south east monsoon brings hot dry air from Australia, and in the rainy season the northeast monsoon brings wet air from the South China Sea, causing much rain fall. The climatic differences are most marked in the eastern region of Indonesia, while the climate in Sumatra varies less between the two seasons.

The monthly mean temperature, the maximum and minimum temperatures, the monthly mean humidity and the monthly mean precipitation for five years from 1984 to 1988 show below, recorded by the Japura Observatory 50 km NNW of the survey area.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Temperature (℃)	25.6	26.0	26.2	26.4	27.0	26.8	26.3	26.4	26.2	26.3	26.2	25.6	26.3
Maximum Temperature (℃)	33.0	34.3	34.4	34.0	34.6	34.4	33.6	34.4	34.2	34.5	34.0	35.0	
Minimum Temperature (℃)	18.1	18.6	17.6	17.4	16.6	17.2	17.0	16.4	19.0	19.2	19.1	18.4	
Mean Humidity (%)	87	85	86	86	85	85	85	82	85	86	85	86	85
Mean Precipitation (mm)	303	212	224	286	162	157	146	94	211	205	202	177	2,379

Location of the Japura Observatory : South Latitude 0°20′, East Longitude 102°19′, Sea level 19m

(2) **Vegetation**

The greater part of the mountainous area is covered by virgin tropical rain forests with trees often growing over 15 m tall and over 2 m in diameter. The lowland is mostly a shrub zone which had once been worked but subsequently neglected. Dry field rice cultivation by the slash-and-burn method is carried out in some parts of the lowland and also in the mountainous land along the rivers. Rubber trees under inadequate management are also found in the lowland.

Chapter 3 Available Geological Information

3-1 Outline of Past Geological Surveys

The geology of Sumatra, including the present survey area, was described by Van Bemmelen (1970). Geologic structures of Indonesia as a whole were reported by Hamilton (1978). As an unpublished reference, there is the geological map of Rengat (scale 1:250,000) produced by the Geological Research and Development Centre (1987). Tjia (1989) discussed the geotectonic history of the region from the north of the survey area to the Malay Peninsula.

Investigation of the geology and mineral deposits around the survey area was conducted in 1974～1975 by P.T.Timah collaborating with the Geological Survey of Indonesia (Subandoro et al.,1975). During the course of their investigation, cassiterite anomalies were discovered within the survey area by panning. During 1984～1986 the Directorate of Mineral Resources (D.M.R.) conducted a follow-up investigation of the cassiterite anomalies, and the results were reported by Harahap and Harmanto (1986) and Harmanto and Karno (1986). The important results of the investigation by D.M.R. are:

1) The Pegunungan Tigapuluh area is composed mostly of Triassic metamorphic rocks partly intruded by granites. Distribution of granites was observed in three districts.

2) Primary cassiterite mineralization was recognized in one of the three districts, the S.Isahan～S.Tulang district. Cassiterite mineralization was found in greisen, granites and the quartz veins occurring at the contact between granites and metasedimentary rocks.

3) In the S.Akar district, cassiterite was found by panning the stream sediments in the lower reaches of the granite distribution area.

3-2 General Geology of Central Sumatra

The geology and geotectonic history of the Pegunungan Tigapuluh area, including the present survey area in particular, were described by Van Bemmelen (1970) as follows.

"The pre-Tertiary System of this area consists of graywacke containing feldspar and fragments of quartzite. Zwierzycki (1930) assigned the graywacke to the Triassic system, but the result of structural analysis suggests the Jurassic period. The graywacke or pebbly graywacke is massive and contains fragments of schist, quartzite, limestone and granite. In the Cretaceous period this area became land due to the Sumatra Orogeny. Transgression advanced from

Oligocene to Miocene of the Tertiary period and quartz sandstone was formed. During the period from Pliocene to Pleistocene, the Pegunungan Tigapuluh mountainland emerged from the water."

Tjia (1989) summarized the geotectonic history of the Benton-Bengkalis Suture extending from the Malay Peninsula to the north of the Pegunungan Tigapuluh area, as below. "This suture line bounding the western tectonic province and the central tectonic province of the Malay Peninsula crosses the Strait of Malacca and continues to the Bengkalis depression. The recent oil exploration has revealed the existence of this Bengkalis depression which is traceable to the north of the Pegunungan Tigapuluh where the survey area is located. In the Cambrian - Early Permian period, the area west of the suture line was the peripheral region of Gondwanaland. This is supported by the Carboniferous to Early Permian glacial and marine sediments distributed in the western area. The eastern area is characterized by the Cathaysia flora.

Around the Middle Permian time, the western area separated from Gondwanaland, and in the Middle Triassic, it was sutured with the eastern area. The existence of the Late Triassic to Early Jurassic felsitic plutonic rocks in the western tectonic province of the Malay Peninsula indicates that the western area had been in the field of intensive compression since the Triassic period. Eastern Sumatra was in the compression field until Late Cretaceous, but it switched to the field of tension during the period from Late Cretaceous to Early Tertiary. In association with this shift, rifting took place along the fracture zone in the N-S direction. At the beginning of the Oligocene period, Sumatra returned to the field of compression, and strike-slip faults slipping rightward developed along the N-S fracture zone in Eastern Sumatra. In the Pliocene epoch, Sumatra was in the field of compression which produced NW-trending faults and folds."

Geological map of Central Sumatra is shown in Figure 1-3 (Hamilton,1978).

3-3 Geological Setting of Survey Area

The following summary of the geology of the survey area based on the geological map of Rengat (1:250,000, Geological Research and Development Centre, 1987).

The geology is composed of Carboniferous - Permian sedimentary rocks intruded by Jurassic granites; all are unconformably overlain by Tertiary sedimentary rocks and Quaternary sediments.

The Carboniferous - Permian sedimentary rocks are divided, by lithofacies into the Gangsal Formation, Pengabuan Formation and Mentulu Formation. The

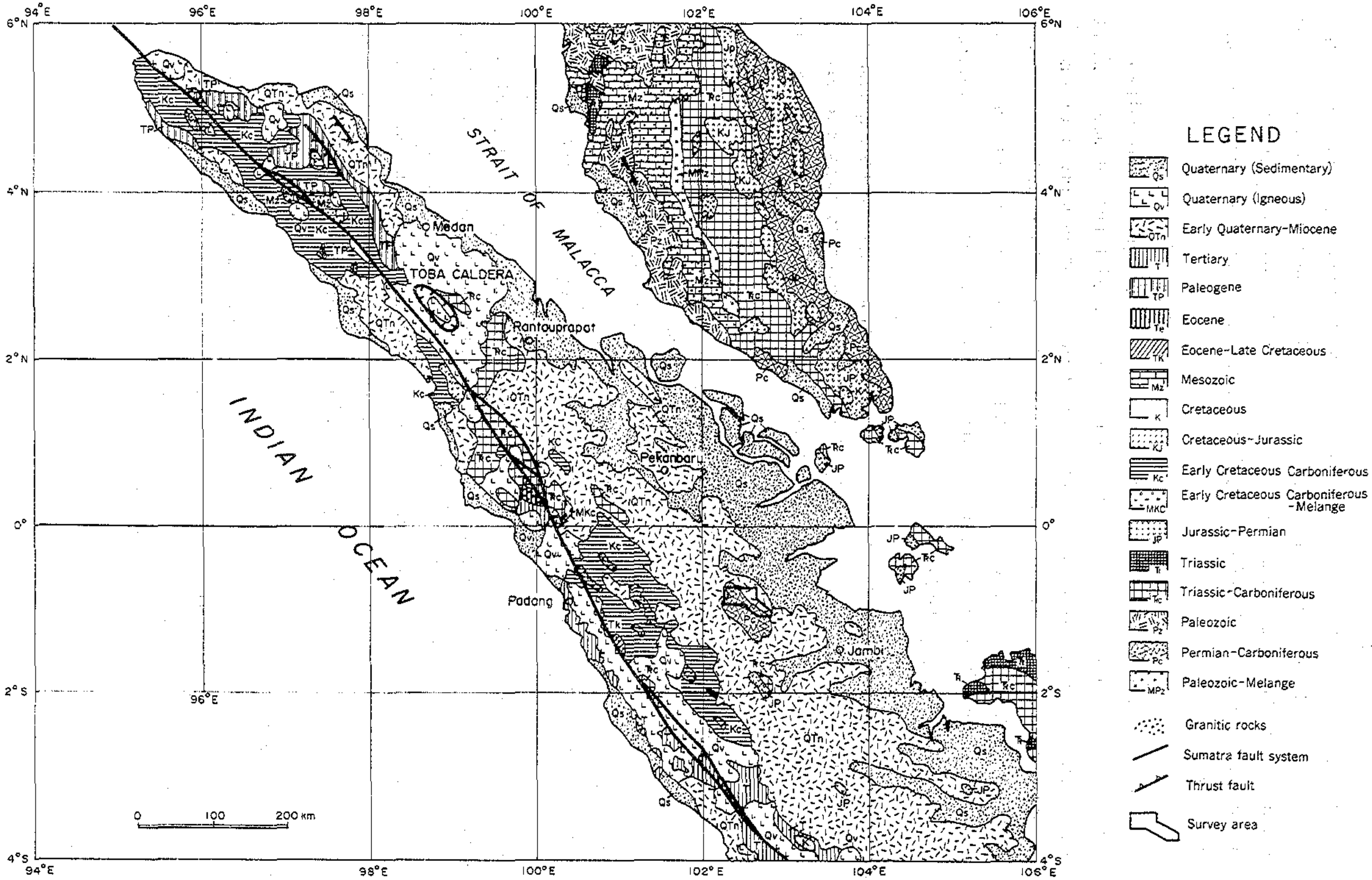


Fig.1-3 Geological Map of Central Sumatra

Gangsal Formation consists of shale, schist, metasandstone, limestone and quartzite. The Pengabuan Formation consists of lithic sandstone, metawacke and metasiltstone. The Mentulu Formation is subdivided into two members, one consisting of tuff and tuffaceous claystone and the other of graywacke and pebbly mudstone.

The Tertiary sedimentary rocks comprise, in ascending order, the Oligocene Kelesa Formation (polymictic conglomerate and pebbly sandstone), Miocene Lakat Formation (polymictic conglomerate, quartz sandstone and alternations of quartz sandstone and claystone), Tualang Formation (quartz sandstone and claystone), Gumai Formation (shale, claystone and sandstone), Miocene - Pliocene Bioni Formation (claystone-sandstone-shale-siltstone alternations), and Korinci Formation (tuffaceous sandstone).

Rocks intruding the pre-Tertiary System are granite, granodiorite, pegmatite and quartz porphyry. Their age is Early Jurassic as inferred from the age of the granite (180±7.0 Ma) on the geological map of Muarabungo adjacent to Rengat.

The survey area, with the exception of the northern and northeastern part, is composed of the pre-Tertiary System. As mentioned above, the occurrences of the Jurassic granites intruding the Carboniferous - Permian sedimentary rocks are known, and there are the geologic environments where the occurrence of the metallic mineralization accompanying the granite intrusion is expected.

According to Johari(1989), who discussed the possible occurrence of rare metal resources in Indonesia, existence of cassiterite and monazite is confirmed in and around the survey area. The tin placer deposit on Bangka Island, east of Sumatra, is accompanied by useful minerals such as monazite and xenotime as well as cassiterite. This fact suggests the occurrence of a pegmatite, greisen and metalliferous veins associated with the intrusion of granites.

3-4 Brief History of Mining in Survey Area

Within the survey area, no mines have been in operation. In the region from the north of the survey area to the Strait of Malacca, in several districts, oil in the Tertiary beds has been extracted. To the west of the survey area, exploration of Tertiary coal is in progress.

Chapter 4 Result of the Survey

4-1 Geologic Structure and Characteristics of Mineralization

The geology of the surveyed area consists of Carboniferous to Permian sedimentary rocks, Middle Jurassic to Early Cretaceous granitic rocks, Paleogene tuffs, Neogene sedimentary rocks and Quaternary sediments.

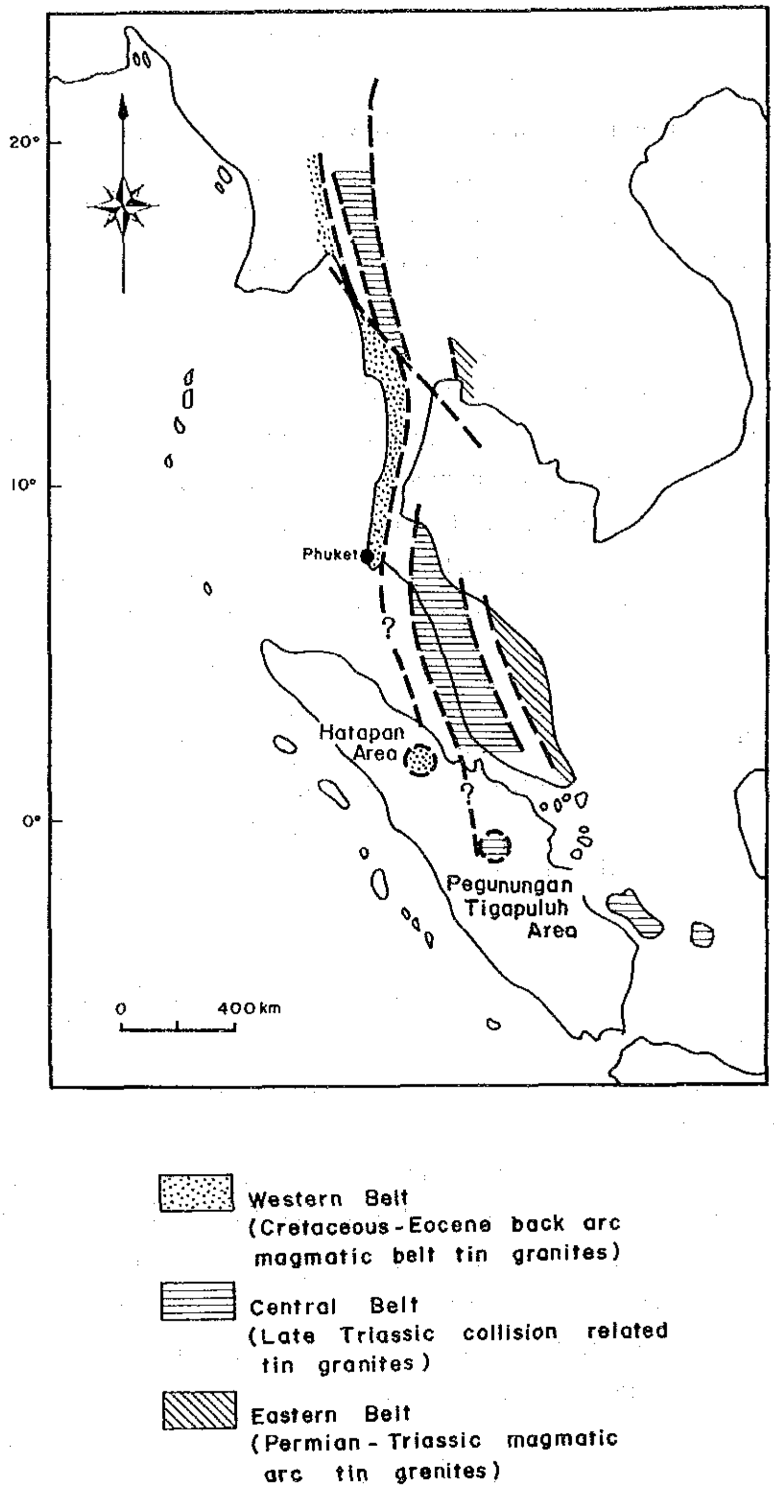
Regarding the granitic rocks of the survey area, their age of intrusion ranges from the Middle Jurassic to Early Cretaceous. The tin-bearing granitoids distributed in the western structural belt of Malay Peninsula, are of Late Triassic to Early Jurassic intrusion. These two plutonic rocks, therefore, have considerably close age of emplacement. Those granitic rocks of Malay Peninsula carry tin mineralization and placer tin deposits are distributed in the vicinity. These placer deposits also contain Nb, Ta and other rare earth elements.

The Carboniferous to Permian sedimentary rocks of the survey area can be construed to be of marine glacial origin, particularly the conglomeratic mudstone. Then the Paleozoic strata and the granitoids of the survey area can be correlated to those of the western structural belt of Malay Peninsula (Fig1-4).

The granitic rocks of the survey area belong to the calc-alkali series and the ilmenite series. The metal concentration expected to be associated with the ilmenite series granitoids are lithophile elements such as Sn, W, Be, Nb, Ta and Th (Ishihara, 1979).

The granitic rocks of the survey area can be classified into four groups by their lithology and chemistry. These are porphyritic biotite granite, biotite granite, pegmatite and aplite. The former two granites have wide distribution and exposures have been determined their age and chemical composition. Several bodies of both types are arranged in NW-SE direction. Their ages become younger northwestward. The biotite granite occurs to the west of the porphyritic biotite granite and is younger. The chemical composition of the porphyritic biotite granite does not change with age. The porphyritic type is considered, chemically, to be in a more advanced state of differentiation than the biotite granite in spite of the latter being younger in age.

If we consider the biotite granite to be a product of assimilation of the host rocks by the chemical composition during the magmatic differentiation process, and the small scale intrusive bodies of leucocratic granites and



(modified from Mitchell,1979)

Fig.1-4 Correlation of Granitoids between Malay Peninsula and the Survey area pegmatites of the western part to be the product of the final stages of differentiation, then the age and the process of differentiation agree well. The existence of small amounts of xenoliths of sandstone-like material in the biotite granite appears to substantiate the assimilation by magma.

Rare metal mineralization is expected to be associated with leucocratic granites and pegmatites of the final stages of magmatic differentiation. They exist as tin-bearing quartz veins of S.Isahan and S.Sikambu.

On the other hand, if we emphasize the chemical composition and consider the porphyritic biotite granite as a product of advanced stage of differentiation, the biotite granite as the product of assimilation as earlier, and if we consider the horizontal difference of the age to be caused by the change in regional stress field, then mineralization would be expected from all the granitic rocks of the survey area. This will be discussed in the next section with the results of the geochemical prospecting in mind.

Next, the relation between the geologic structure and mineralization will be considered. Photogeologic interpretation clarified the following points.

① Many of the lineaments in the pre-Tertiary zone trend in N-S and WNW-ESE directions.

② The granitic bodies are arranged in NW-SE direction.

Surface geological survey clarified the following points.

① In the Paleozoic Erathem, S-shape synclinal and anticlinal structures are developed from near Bt.Pintutujuh in the western part of the survey area to the southeastern part.

② There is a high possibility that a NNW-SSE to NW-SE trending graven or fracture zone, which formed during Late Cretaceous to Early Tertiary, underlies the Neogene zone along the S.Antan in the west and along the S.Gangsal in the central part of the survey area.

③ The NNW-SSE fault system which became active in Oligocene changed to vertical slip fault because of the block uplift of the Paleozoic strata and the granitic bodies which occurred from Miocene.

④ The granitoids with relatively large exposed areas are grouped into porphyritic biotite granite and biotite granite and the former bodies are arranged in NW-SE direction from the central part to the eastern part of the surveyed area whereas the latter granites are also arranged in the same direction from the western to the central part.

It is noted that the trend of the arrangement of the granitic bodies which were accompanied by mineralization is NW-SE. This direction coincides with the line joining the known Sn mineralized zones of S.Isahan and S.Sikambu.

Next the characteristics of mineralization will be considered.
In the S.Isahan and S.Sikambu Sn mineralized zones in the western part of the area, network of quartz veins is developed and the mineral paragenesis of the veins are, quartz-cassiterite-muscovite-tourmaline-arsenopyrite. Most of the potash feldspar and plagioclase of the host rocks, pegmatite or leucocratic granites, are muscovitized and it is believed that they underwent greisenization. The mineral paragenesis and the host rock alteration are similar to those of the Sn deposits in greisens and tin-bearing quartz veins of Thailand and China. The maximum grade of the tin-bearing quartz veins in the mineralized zones of the survey area is Sn 3.84%, W 0.07%, Ce 0.02%. The samples from 1 to 2m wide trenches cut in greisens and pegmatites containing quartz veins 0.2~0.5% Sn and 0.08%~0.24% Ce. Thus, these mineralized zones are characterized by content of rare metals such as Sn, W, Ce.

4-2 Geochemical Anomalies and Mineralization

The survey area was covered by geochemical prospecting using both stream sediments and panning. The collected samples were analyzed for fourteen rare metal elements.

From geochemical data on streams sediments, many Sn anomalous zones were extracted, and only two anomalous zones were extracted for Nb, W, Zr, Th, Ce, Y, U, Li. Classifying these zones resulted in seven A-rank zones for Sn and one for other elements. Two of the Sn A-rank anomalous zone correspond to known mineralized zones and the Sn content varies from 71 ~ 710 ppm. The elements such as W, Ce which were expected in the mineralized zone do not show anomalous values. Wolframite, a tungsten ore mineral, oxidized and decompose more rapidly than cassiterite and thus are concentrated in placer in very minor amount. Therefore, the analytical values of W may not reflect the mineralization accurately.

The results of the analysis of panned samples indicated eight A rank anomalous zones of which two correspond to known mineralized zones.

It is seen that geochemical anomalies were obtained for both stream sediments and panned samples at the known mineralized zones. Localities other the above known mineralized zones where both types of samples show anomalous geochemical values are, as shown in Fig.1-5, two Sn anomalous localities in the northwest extension of the known mineralized zones and one each in the Neogene of S.Antan and S.Endelang. One W anomalous zone near Bt.Kayumambang, one Nb and two Li zones were found near porphyritic biotite granite in S.Nibul. Aside from the absolute value of the anomalies, these zones can be considered with the same importance as the known mineralization in that they show anomalous values for both types of samples.

The distribution of the zones with overlapping anomalies of two types of samples that in Paleozoic and granitic terrane, W, Nb, Li anomalies occur in the eastern part and the Sn anomalies in the western part of the survey area. The type of granites associated is, in the east the porphyritic biotite granite with W, Nb, Li anomalies, and in the west, part of the Sn anomalies are associated with leucocratic granite or pegmatite. Although the anomalous zones do not occur in the granitic bodies, the source of Sn anomalies in the eastern Neogene strata is considered to be associated with granite.

Now, with the above facts in mind it is logical to consider that the eastern porphyritic biotite granite has high potential for W, Nb, Li mineralization followed by Sn concentration and thus is prospective for these rare metals, and that the western granite has high potential for Sn mineralization followed by W concentration and thus is prospective for tin.

4-3 Resource Potential for Rare Metal Elements

The mineralization expected to occur in the survey area from the result of geochemical prospecting are :

① Sn, W, Ce bearing primary mineralization,
② Primary mineralization of various rare metals such as W, Nb and Li,
③ Placer concentration of Sn.

The reserves and grades of these deposits will be clarified by further surveys. The resources potential revealed by the present survey is as follows.

① Primary mineralization of Sn, W, Ce

The known mineralized zones occur in small intrusive bodies such as stocks or cupolas of what is generally called pegmatite. The host rocks, pegmatites, are greisenized and the intensity of the alteration and the density of the quartz vein distribution in the network is proportional. The emplacement of these small intrusive bodies are inferred to be controlled by NW-SE trending line of weak structure. Therefore, the extension of the known mineralization in NW-SE direction is the most likely zone for locating the small intrusive bodies. Also in the extended zones, Sn anomalies have been detected and the possibility of Sn deposits occurring in these zones is high.

In the mineralized zones confirmed, most of the quartz vein network occur in pegmatite. But at S.Isahan, quartz-muscovite veins are found in Paleozoic strata.

The factors which control the size of the mineralized zones are considered to be ; the size of the intrusive bodies, the density of the quartz vein distribution in the network, the development of fractures at the contact with Paleozoic unit.

As seen in the Sn deposits of mineralization of Malaysia, Thailand, Banka island of Indonesia, the development of network (fractures) at the contact of Paleozoic units and the intrusive bodies would result in lager deposits in many cases.

② Primary mineralization of rare metals, W, Nb, Li

This type of mineralization was not found by geological survey. The existence of these inferred from the results of geochemical prospecting. It is expected that Nb, Li concentration would occur in greisen and W, Nb in quartz veins. The size and grade of these mineralized zones must be clarified by further prospecting.

③ Placer concentration of Sn

Placer concentration have not been found during geological survey. But the existence of these deposits is inferred from the results of geochemical prospecting and the probability of their existence is believed to be high.

Geochemical anomalies have been detected in rivers with the catchment in exclusively Neogene units, and anomalies were not detected in the upper reaches of these rivers where Paleozic strata are distributed. Thus the sources of these anomalies are in the Neogene formation. The highest anomaly of this type is found along the S.Antan where quartzose sandstone of the Neogene Empelu Formation is distributed. This sandstone probably occur burying old river beds, and there is a possibility of the tin-bearing sandstones similar to that in offshore South China burying submarine canyons.

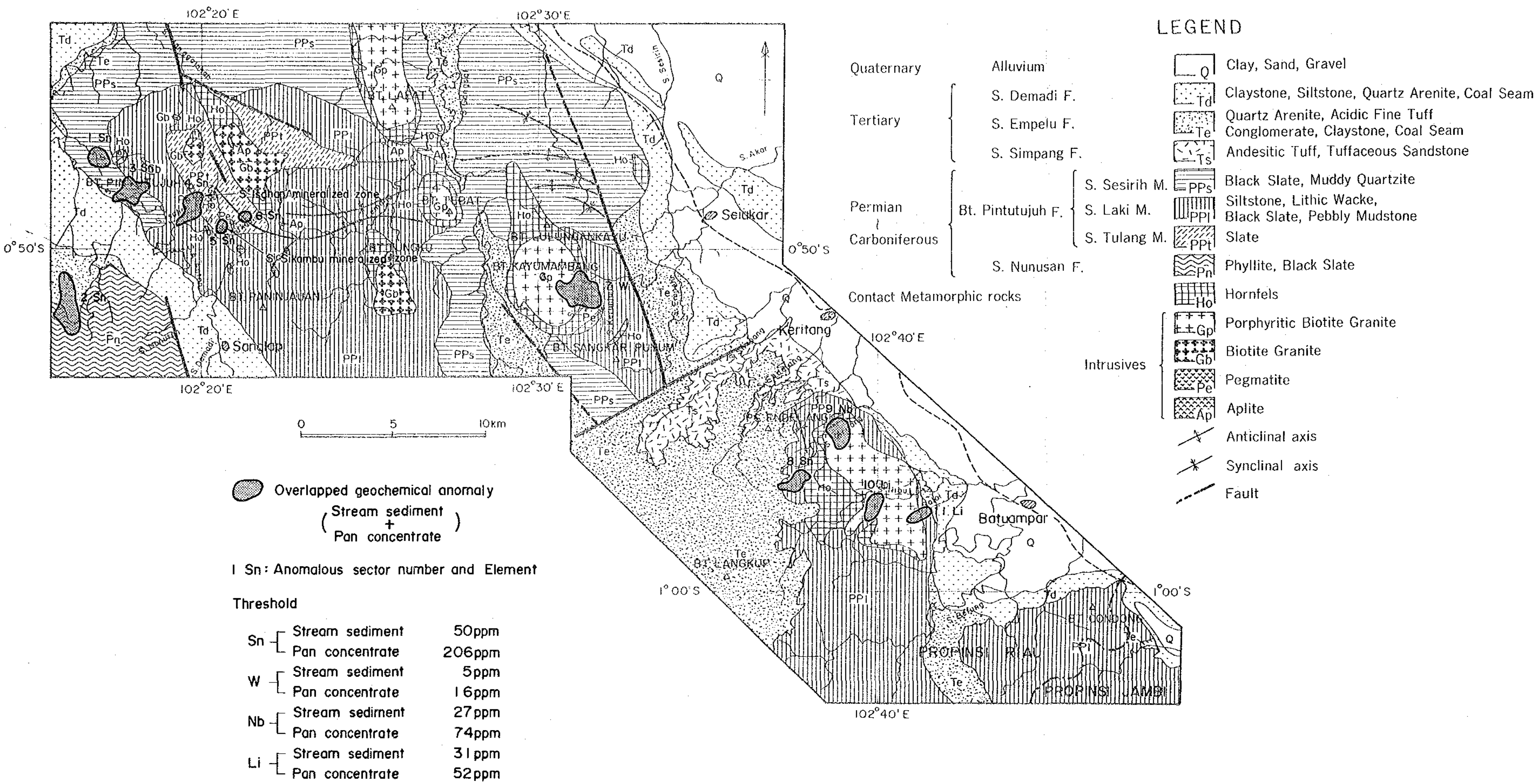


Fig.1-5 Generalized Map of the Survey Results

Chapter 5 Conclusion and Recommendation

5-1 Conclusion

During the course of the first phase of the Pegunungan Tigapuluh survey, photogeological interpretation, geological survey and geochemical prospecting were carried out with the following conclusions.

The geology of the survey area is composed of Carboniferous-Permian sedimentary rocks, Middle Jurassic to Early Cretaceous granitoids, Paleogene pyroclastic rocks, Neogene sedimentary rocks and Quaternary sedimentary rocks.

The granitoids distributed in this area are, from their lithology and chemical composition; porphyritic biotite granite, biotite granite, pegmatite (include leucocratic granite and pegmatite) and aplite. All of these rocks belong to the calc-alkali series and to the ilmenite series. The porphyritic biotite granite is in a more advanced stage of differentiation than the biotite granite. From the results of absolute age determination, geological survey and chemical analysis, it is inferred that the biotite granite intruded at a stage when the granitic magma differentiated and lithophile elements concentrated to a certain extent (porphyritic biotite granite), assimilation of surrounding rocks occurred and the CaO content increased.

The porphyritic biotite granite is arranged in the central to the eastern part while the biotite granite from the western to the central part of the survey area in NW-SE direction. This direction coincides with the line joining the two known tin mineralized zones.

The mineralized zones are the tin-bearing quartz vein network at S.Isahan and S.Sikambu in the western part of the area. The potash feldspar and plagioclase of the host pegmatite and leucocratic granite are mostly muscovitized and the rocks have been greisenized.

Assay of these mineralized zones show Sn 3.84%, W 0.07%, Ce 0.02% in the high grade part while samples containing quartz veins in leucocratic granites and pegmatite are Sn 0.2~0.5%, Ce 0.08%~0.24%. These zones are characterized by the content of rare metals such as Sn, W, Ce.

Geochemical prospecting by stream sediment and panned samples covered the whole survey area. The samples were analyzed for 14 rare metals.

Many Sn anomalous zones were extracted from stream sediments while only two zones were extracted for Nb, W, Zr, Th, Ce, Y, U, Li. Seven anomalous zones of

A-rank were delineated for Sn and one zone for other elements. Two of these Sn zones correspond to the known mineralized zones and the Sn contents of two zones are 71~710 ppm.

From geochemical data of the panned samples, eight anomalous zones of A-rank were delineated for Sn and two of these correspond to the known mineralized zones.

The known mineralized zones show geochemical anomalies both with stream sediment and panned samples. There are two Sn anomalous zones located in the northwest extension zone of the known mineralization and one Sn zone each in the Neogene zone along the S.Antan and S.Endelang which display anomalies for both types of samples. Also one W anomalous zone near Bt.Kayumambang, one Nb and two Li anomalous zones near the S.Nibul porphyritic biotite granite body which have anomalous values for both stream sediments and panned samples. These zones have similarity with the known mineralized zones in the overlap of anomalies by different methods regardless of the absolute value of the anomalies.

The distribution of the zones with overlapping anomalies of two type of samples that in Paleozoic and granitic terrane, W, Nb,Li anomalies occur in the eastern part and the Sn anomalies in the western part of the survey area. The type of granites associated are, in the east the porphyritic biotite granite with W, Nb, Li anomalies, and in the west, part of the Sn anomalies are associated with leucocratic granite or pegmatite. Although the anomalous zones do not occur in the granitic bodies, the source of Sn anomalies in the eastern Neogene strata is considered to be associated with granite.

It is thus conclude that the eastern porphyritic biotite granite has high potential for W, Nb, Li mineralization followed by Sn concentration and thus is prospective for these rare metals, and that the western granite has potential for Sn mineralization followed by W concentration and thus is prospective for tin.

From the results of geological survey and geochemical prospecting, it is expected that the survey area is prospective for the following types of mineralization.

① The zone prospective for primary Sn, W, Ce mineralization is the NW-SE extension of S.Isahan and S.Sikambu mineralized zones. Sn anomalies are detected in the extended zones and the probability of the existence of mineralization similar to that of S.Isahan is high.

② Primary mineralization of rare metals, W, Nb, Li was not found by geological survey. The existence of these mineralization is inferred from the results of geochemical prospecting. Tungsten-bearing mineralization is expected near Bt.Kyumambang and Nb, Li concentration near the S.Nibul porphyritic biotite granite.

③ Placer concentration were not found by geological survey. The existence of these concentration is inferred from the results of geochemical prospecting and the Neogene zone along S.Antan is prospective for this type of ore accumulation.

5-2 Recommendations for the Second Phase

The mineralization expected to occur in the survey area are concluded from the results of the first phase survey to be ;

① Primary mineralization of Sn, W, Ce,

② Primary mineralization of rare metals such as W, Nb, Li,

③ Placer concentration of Sn.

It is recommended that the following survey be conducted during the second phase for locating the mineralization associated with the intrusion of the granitoids and mechanical concentration of ore minerals supplied from the granitic rocks.

(1) Mineralization related to granitic intrusion.

① Along S.Isahan and vicinity

Tin- bearing quartz vein network is developed in pegmatite at S.Isahan and S.Sikambu.

It was shown by the study of geologic structure and geochemical prospecting that the possibility of these mineralized zones extending in NW-SE direction and other such zones occurring is high. It is recommended that detailed geological survey and geochemical prospecting be carried out in these zones followed by drilling.

② Bt.Kayumambang and vicinity

Tungsten anomalies were detected by geochemical prospecting during the present phase. It is recommended that detailed geological survey and geochemical prospecting be carried out in order to clarify the nature of mineralization of this anomalous zone.

③ Middle reaches of S. Nibul and vicinity

Anomalies for Nb and Li were detected at middle reaches of S.Nibul by geochemical prospecting during the present phase. It is recommended that detailed geological survey and geochemical prospecting be carried out in order to clarify the nature of the mineralization.

(2) Placer concentration

① Along S.Antan

Tin anomalies were detected by geochemical prospecting during the present phase. It is recommended that detailed geological survey and geochemical prospecting be carried out in order to evaluate the tin placer concentration.

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Photogeological Interpretation

1-1 Methods Used

The aim of photogeological interpretation is to obtain guidelines for geological survey and geochemical prospecting by elucidating the geologic units and the regional geologic structure of the survey area.

The aerial photographs used in the investigation were monochromatic prints of 1:110,000 scale. The number of photographs covering the survey area was 30. A list of the photographs used is laid out in the table below, and the orientation is outlined in Figure 2-1.

As the survey area is in to the tropical rain forest zone, it was presumed that a thick jungle covered the entire area. Therefore, of the elements ordinarily utilized to interpret lithologic division, geologic structure and other relevant features, special attention was paid to topographic features, texture, drainage pattern, drainage density, and linear structures.

Table 2-1 List of Aerial Photographs Used

Course No.	Photo No.	Number of Prints
R38/8344	158-163	6
R39/8331	38- 42	5
R39/8350	45- 49	4
R40/8350	115-112	8
R41/8360	41- 46	6

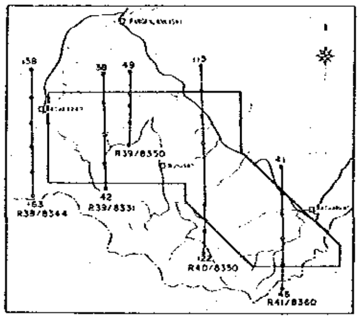


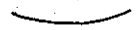
Fig.2-1 Orientation Map of Aerial Photographs

1-2 Results of Photogeological Interpretation

(1) Geologic units

From the results of photogeological interpretation, the geology of the survey area was divided into eight geologic units, as shown in Table 2-2 and Figure 2-2. They comprise clastic rocks (six units), an intrusive rock unit, G, and an unconsolidated clastics unit, Q. By referring to the existing material, the clastic rocks can be subdivided into Paleozoic units, P_1, P_2 and H, and Tertiary units, T_1, T_2 and T_3.

Table 2-2 Results of Photogeological Interprétation

Characteristics / Units	Photo-characteristics		Morphological Expression					Interpretation
			Drainage		Landform			
	Texture	Vegetation	Pattern	Density	Cross Section	Resistance	Surface	
Q	Very Fine	Glass Land Low	Meandering	Low		Very Low	Smooth Horizantal	Unconsolidated Deposits
T_3	Fine to Medium	Low	Meandering	Low		Low	Horizantal to Gentle	Fine to Medium Grained Clastic Rock
T_2	Fine	Low	Meandering	Low		Very Low	Horizantal	Fine Grained Clastic Rock
T_1	Medium to Coarse	Low to High	Subdendritic	Medium to Low		Moderate	Moderate	Medium to Coarse Grained Clastic Rock
P_2	Coarse	High	Subdendritic	Very High		High	Rather Steep	Very Hard Clastic Rock
P_1	Medium to Coarse	High	Subdendritic	Moderate to High		Moderate to High	Moderate to Steep	Hard Clastic Rock
G	Smooth	Moderate	Subradial	Moderate		High	Gentle	Granitic Rock
H	Coarse	High	Subdendritic to Subrectangular	High		Very High	Steep	Very Hard Rock (Hornfelsic)

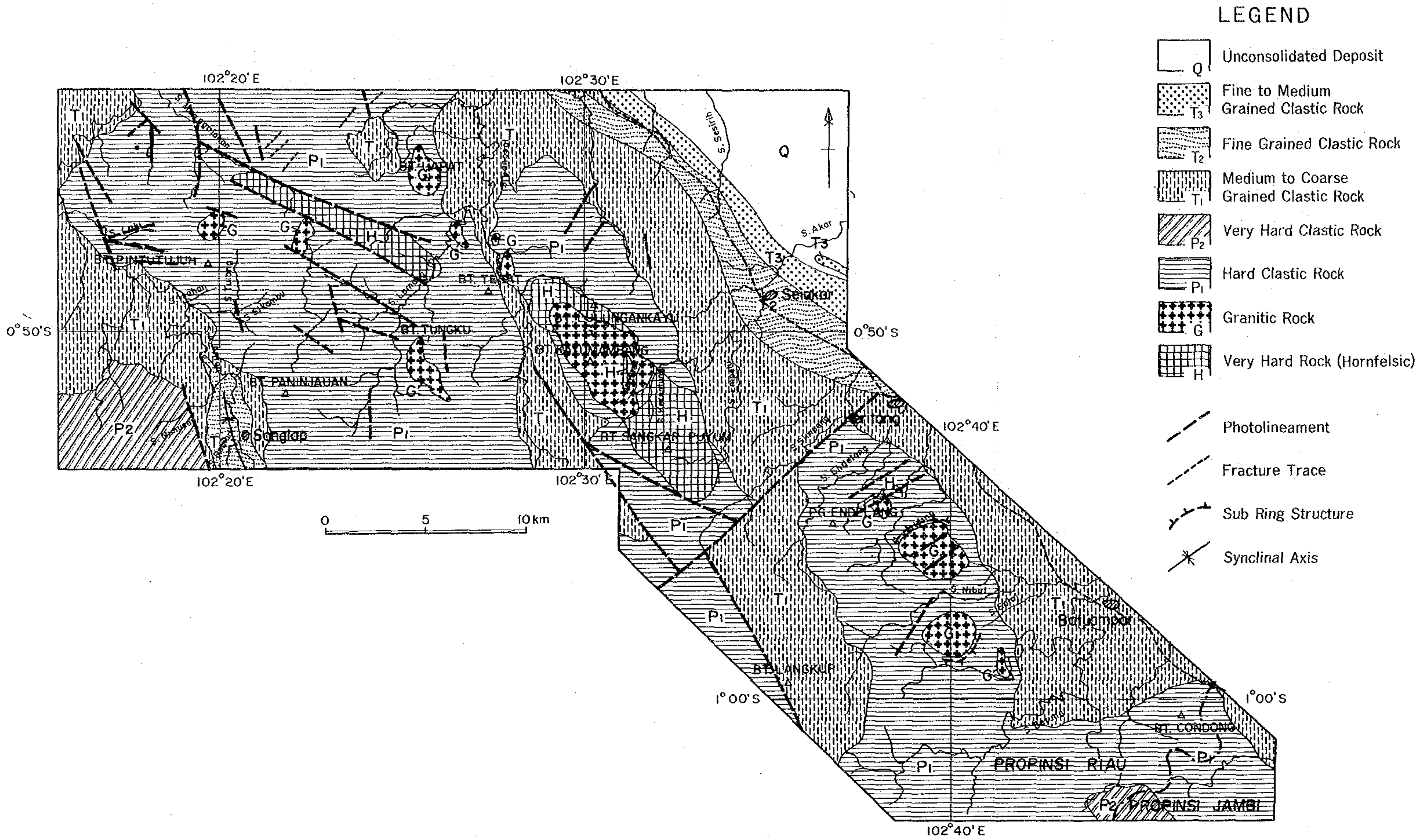


Fig.2-2 Photogeological Interpretation Map

① Unit P_1

This unit is extensively distributed between S.Gangsal and S.Antan, east of S.Antan, and also in the southeastern part of the survey area. It has the widest distribution of all the eight units. In the Unit P_1, subdendritic drainage system is developed with medium to high density, indicating that this unit has relatively low resistance to weathering and erosion compared with others.

From the above characteristics, it is judged that Unit P_1 is composed of hard clastic rocks.

② Unit P_2

This unit constitutes the mountainland west of S.Antan in the southwestern part of the survey area. It is distributed also in the southeastern end of the area, though on a smaller scale. The area occupied by this unit is extremely small. Drainage system of a subdendritic pattern with unusually high density is developed, suggesting the high resistance of this unit. Another characteristic of the unit is mountainside slopes very steep compared to Unit P_1.

This unit is inferred to be composed of clastic rocks harder than those of Unit P_1. The relationship between Units P_1 and P_2 is not known as they are not in direct contact.

③ Unit H

Unit H is distributed in the northwest and southeast extensions of Unit G around Bt.Kayumambang in the central part of the area. In the eastern part, it occurs on a small scale northeast of Pg.Endelang, in the central to northwestern parts, its distribution is elongated in WNW-ESE direction.

Subrectangular to subdendritic drainage system of high density is developed in Unit H, indicating the highest resistance of the units in this area. This unit is characterized also by steeper mountain slopes than Unit P_1. Since Unit H is locally in direct contact with Unit G, which is assumed to be granitic, it is probable that Unit P_1 became the hornfelsic Unit H through thermal metamorphism.

④ Unit T_1

This unit occurs along S.Antan in the area's western part, along S.Gangsal in the central part, in the northeastern and southeastern hills, and also around Bt.Langkup. Its distribution is next to Unit P_1 in areal extent.

The medium to low density distribution of the subdendritic drainage system shows that Unit T_1 has a moderate resistance among the units of this area. This unit is also characterized by gentle mountain slopes and by medium-to-coarse-grained texture.

Unit T_1 appears to consist of somewhat soft and medium-to-coarse-grained clastic rocks. It may have an unconformable relationship with the underlying units (P_1, P_2).

⑤ Unit T_2

This unit is distributed in the northeastern part of the area on the northeast side of Unit T_1. It occurs also in the upper reaches of S.Antan in the western part.

Meandering drainage system of low density is developed, showing the very low resistance of this unit. The unit is also characterized by the generally flat ground surface and by the fine-grained texture.

Unit T_2 is judged to be composed of soft and fine-grained clastic rocks. Its relationship with the underlying Unit T_1 is thought to be conformable.

⑥ Unit T_3

This extends in NW-SE direction as a long and narrow distribution on the northeast side of Unit T_2 in the northeastern part of the area. Development of meandering drainage system with low density indicates the low resistance. Also, this unit is characterized by the generally flat or gentle relief and fine-to-medium-grained texture.

This unit is probably composed of soft and fine-to-medium-grained clastic rocks. Its has a seemingly conformable relationship with the underlying Unit T_2.

⑦ Unit Q

This unit is distributed only at the northeastern end of the area. Development of meandering drainage system with low density is indicative of very low resistance. Other characteristics are the flat and smooth topography and the very fine-grained texture.

This unit is inferred to be composed of unconsolidated clastics.

⑧ Unit G

This unit is distributed widely around Bt.Kayumambang in central part of the area. It occurs distributed also in four localities northeast of Bt.Kayumambang, four localities around Pg.Endelang in the southeastern part of the area, and also at Bt.Tungku in the central south section of the area, though all on a small scale.

Drainage system of a subradial pattern of moderate density are developed, indicating the high resistance of the unit. The unit is also characterized by the dome-like mountain slopes and by smooth texture. The distribution in the southeastern part between S.Keritang and S.Nibul shows, in part, a subannular structure at the boundary with the surrounding unit.

From the fact that Unit H occurs around it and that subannular structure is observed, as well as from the drainage pattern and topographic features, it is inferred that Unit G is composed of granitic rocks which intrude Unit P_1.

(2) Geologic structure

Bedding is not recognized in any of the units of clastic rocks. Thus, rocks constituting these units are massive, and hence the presence or absence of fold structures remains unknown. Photolineaments representing fault and fractured zones and fracture traces indicative of joints or small fissures are observed in the survey area. A small-scale synclinal structure is inferred from the distribution mode of the units.

① Lineaments

A total of 35 lineaments are recognized throughout the survey area. Of these, 28 are developed in Units P_1, H and G; seven are found in Unit T_1 or distributed across Unit T_1 and underlying units.

Regarding the direction of these lineaments, N-S to NNW-SSE systems are found to be dominant. In terms of occurrence, lineaments are concentrated in Unit P_1 zone at the western end. Examination of the extension of each lineament revealed that those longer than 10 km trend in NNW-SSE to WNW-ESE directions.

② Fracture traces

Seven fracture traces with NE-SW trend extending for one kilometer or so, are found only in unit P_1 in the northern part of the area.

③ Synclinal structure

A synclinal structure with a NNW-SSE axis is inferred to occur in Unit T_2, from the unit's mode of distribution along S.Antan in the southwestern part of the area.

1-3 Discussions

As mentioned in Chapter 3 of Part I, there is a good potential regarding mineralization associated with the granitic rocks intruding into the Paleozoic units in this survey area.

From the results of photogeological interpretation, the following are concluded.

① The directions of photolineaments recognized within the the pre-Tertiary system are mostly N-S and WNW-ESE.

② Unit G, most likely to be granitic rocks, extends in the NW-SE direction. If the NE-SE lineament along S.Simpang in the eastern part of the survey area is regarded as a left-lateral strike-slip fault, the reconstruction shows that nine G units are arranged in virtually a straight line extending from Bt.Lapat in the midnorthern section of the survey area to south of S.Nibul in the eastern part. The G units are also aligned in the same direction from Bt.Pintutujuh in the west to Bt.Tungku. Considering the above, the direction of the structurally weak lines at the time of the intrusion of the granitic rocks must have been in the NW-SE direction.

Chapter 2 Geological Survey

2-1 Survey Method

This is the first phase of the Cooperative Mineral Exploration of the Pegunungan Tigapuluh area, Indonesia. The first phase operations comprised geological survey and geochemical prospecting, based on analysis of existing geological information and photogeological interpretation, through which the geological setting of the survey area was defined.

Prior to the field work, a 1:50,000 scale topographic map was prepared from the aerial photographs used in the photogeological interpretation. The 1:50,000 topographic map was enlarged to the scale of 1:25,000 for field use. The geological survey was conducted on the basis of these maps. The mineral showings were studied in detail so as to elucidate the mineralization and alteration.

A total of 539 km was explored, and the geology was compiled into a 1:50,000 map. The number of samples collected in the present investigation is 1,019 stream sediment samples, and 210 panned concentrates, and, 31 thin sections were made, 31 samples were studied by X-ray diffraction analysis, 5 samples were dated by K-Ar method, 10 samples were analyzed for whole rock, and 21 samples were assayed.

2-2 Outline of Geology

The geology of the survey area consists of Carboniferous - Permian, Tertiary and Quaternary Systems, and granitic rocks intruded into the Carboniferous - Permian.

The Paleozoic is divided into the S.Nunusan Formation and Bt.Pintutujih Formation. The S.Nunusan Formation is composed of phyllite derived from pelitic rock, and black slate. The Bt.Pintutujuh Formation is, for the most part, black slate which can be subdivided by lithofacies into the S.Tulung, S.Laki and S.Sesirih Members. A direct relationship between the S.Nunusan Formation and the Bt.Pintutujuh Formation is not observed in the outcrops, but the two formations are clearly different in the extent of slaty cleavage development.

The granitic rocks intruding into the Paleozoic are classified by lithofacies into porphyritic biotite granite, biotite granite, pegmatite and aplite. The times of their intrusion range from the Dogger Stage of the Jurassic to the Neocomian Stage of the Cretaceous Period. Due to the intrusion of these rocks, the Carboniferous - Permian sedimentary rocks underwent contact metamorphism and altered into hornfels.

Unconformably covering all these rocks, the Paleogene System consisting of andesitic tuff is distributed within a limited zone. In an unconformable relationship with the Paleogene System, the Neogene System, consisting of quartzose arenite and claystone, is distributed in various places.

The geologic structure of the survey area is characterized by numerous Paleozoic folds and faults cutting the Neogene System. A large number of synclinal and anticlinal structures observed in the Paleozoic formations show an S-shape arrangement. The faults are those of NW-SE, NNW-SSE, and NE-SW systems. Each type of granitic rock shows a tendency to align in the N-S direction.

Figure 2-3 shows the geology and geological section, and Figure 2-4 shows the stratigraphy and the outline of igneous activity in the survey area.

2-3 Stratigraphy

(1) S.Nunusan Formation

This formation is distributed only in the western part of the survey area. Its type locality is S.Nunusan, a tributary of S.Antan.

The formation is composed of very hard black, grayish black or grayish olive phyllite, and black slate which easily exfoliates into thin plates. The black slate resembles the black slate of the overlying Bt.Pintutujuh Formation, but is distinguished from the latter by the general hardness and the marked development of platy cleavage.

This is the lowermost formation in the area, and its thickness is over 500 m. The formation is correlated with the S.Gangsal Formation of the Rengat geological sheet.

(2) Bt.Pintutujuh Formation

This formation is divided by lithofacies into three members, namely, the S.Tulang, S.Laki and S.Sesirih Members, in ascending order. Outcrops in which the three members can all be observed together are found in the area between S.Antan west of Bt.Pintutujih, and S.Tulang.

① S.Tulang Member

This member is distributed only in the upper reaches of S.Tulang, east of Bt.Pintutujuh. It consists of dark greenish gray to gray massive slate, which, when weathered, turns to soft gray shale or claystone. Schistosity is

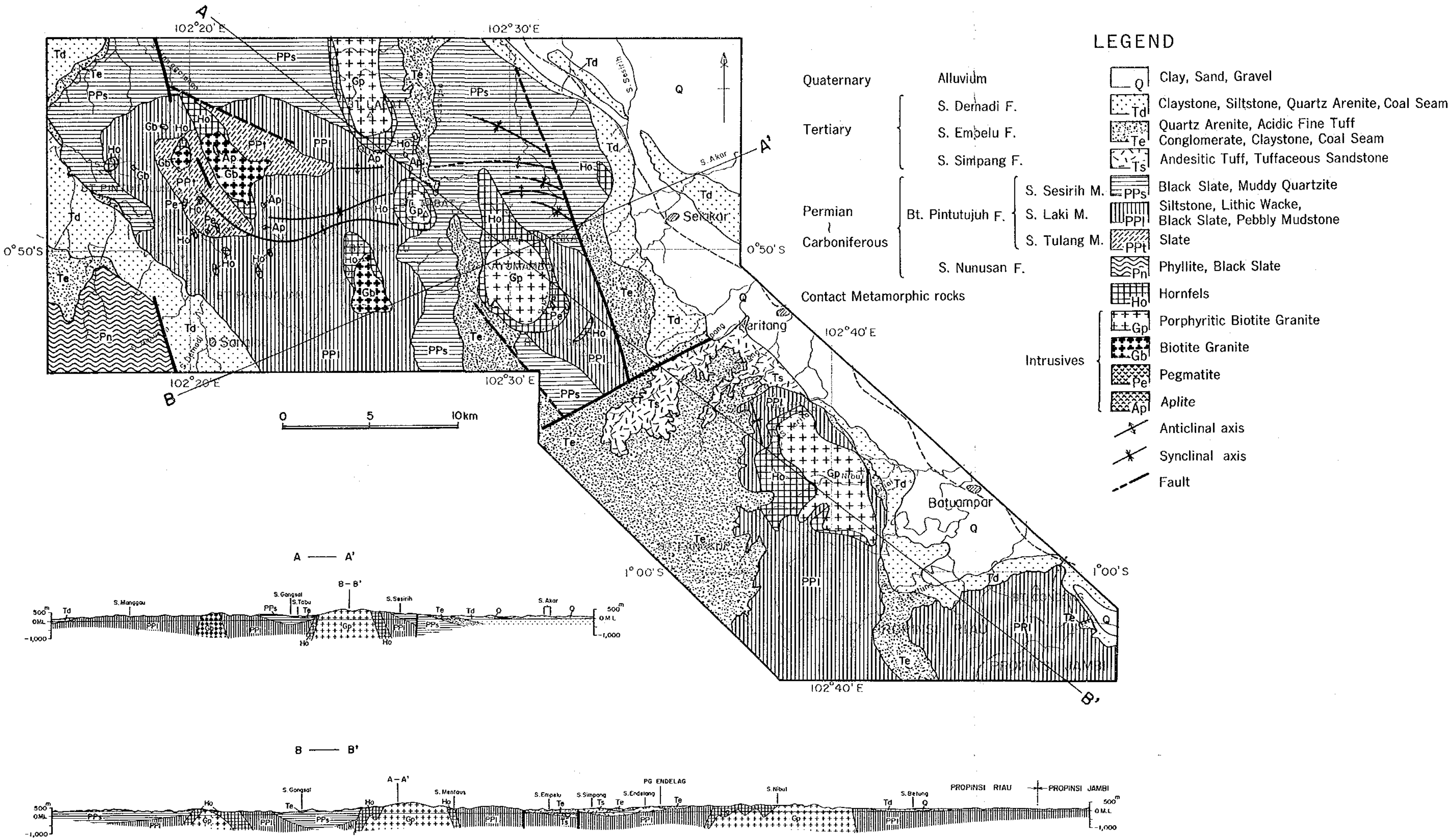


Fig.2-3 Geological Map

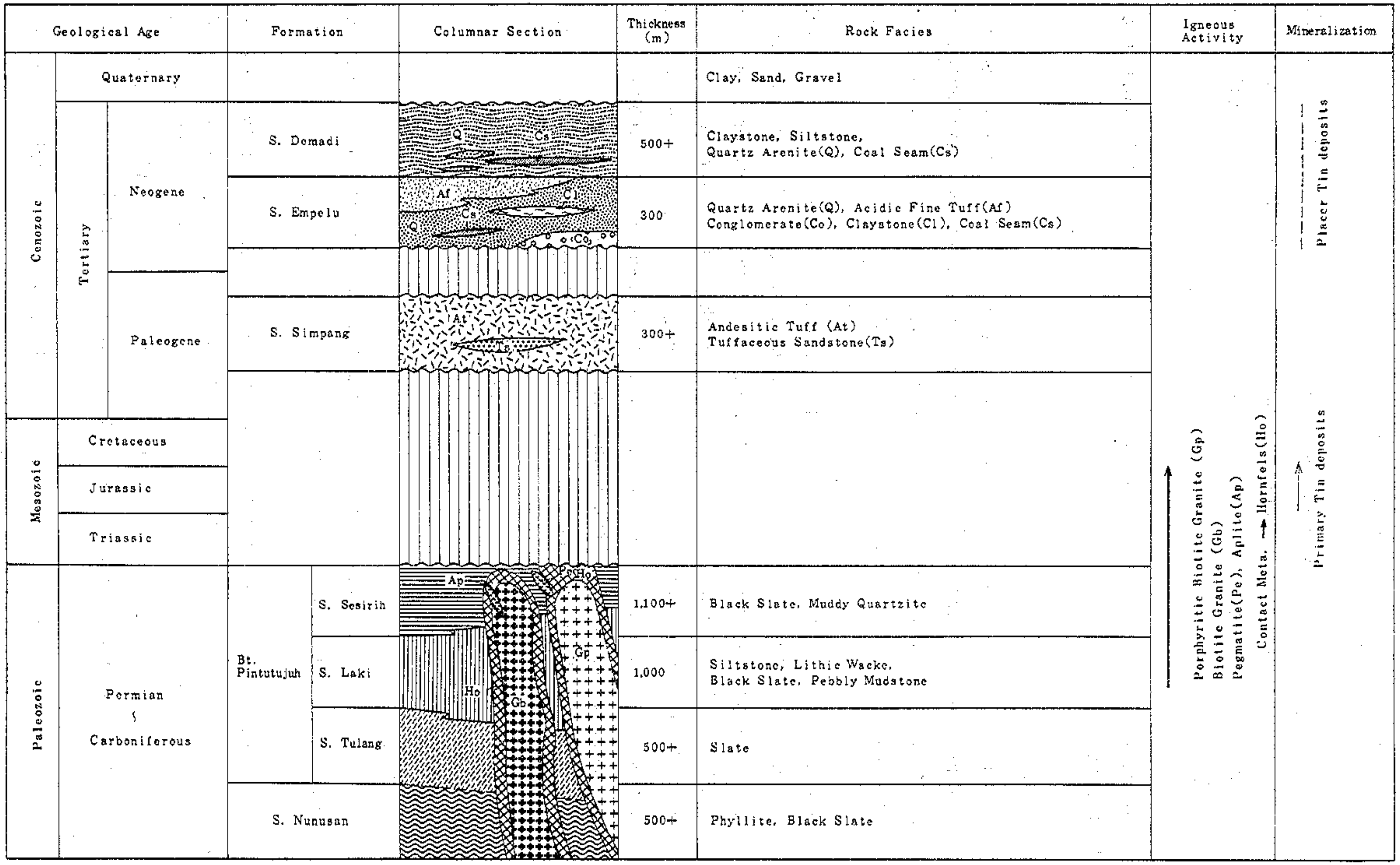


Fig.2-4 Schematic Column of the Survey area

recognized in some parts but slaty cleavage is rare.

Its relationship with the underlying S.Nunusan Formation is not known since the two are not in direct contact, but they are probably in a fault contact, as will be described later. The thickness of this member is estimated to be over 500m.

The S.Tulang Member is correlated with a section of the Muntulu Formation of the Rengat sheet.

② S.Laki Member

In the western part of the present area, the S.Laki Member encompasses the underlying S.Tulang Member. In the central part, it is distributed in the NW-SE direction southeast of Bt.Kayumembang, and in the east, its distribution extends widely from Pg.Endelang to the south.

This member consists chiefly of gray, dark gray, or rarely dark greenish gray siltstone and lithic wacke, intercalated with black mudstone and black slate. It is generally massive, and bedding is rare. It often contains fragments with 1~3 mm diameter, of pelitic rocks and quartzite, quartz grains and feldspar fragments. In the upper reaches of S.Laki and in the lower reaches of S.Tulang, this member contains subangular to subround of pebbles to granules of pelitic rocks and quartzite, in addition to rock and mineral fragments. When weathered, the rocks of this member become very soft.

The member, 1,000 m thick, is correlated with a part of the Muntulu Formation of the Rengat sheet.

③ S.Sesirih Member

This member is distributed from the western to central parts of the area, encompassing the underlying S.Laki Member.

The constituents are black mudstone and slate. It is generally massive, cleavage is not developed, and bedding is virtually unrecognized. Sometimes the lithofacies becomes silty or sandy in part. To the west of Bt.Pintutujuh, the member is intercalated with gray pelitic quartzite. When weathered, the mudstone and slate become gray soft rocks.

The S.Sesirih Member has a thickness of 1,100 m and is correlated with a section of the Muntulu Formation of the Rengat sheet.

(3) S.Simpang Formation

The formation consists chiefly of andesitic tuff, with some sandstone. It is distributed only in the vicinity of S.Endelang in the eastern part of the survey area.

The tuff presents a generally yellowish green homogeneous lithofacies, but sometimes contains a small amount of andesite fragments. No bedding is recognized. The tuff is consolidated to a moderate degree, and joints are developed.

The sandstone occurring as thin intercalations in the tuff is a medium-grained rock composed of grains cognate with the tuff.

The thickness of the S.Simpang Formation is estimated to be about 300 m. The formation is in fault contact with the underlying Bt.Pintutujih Formation.

This formation is inferred to be Paleogene because; its constituents are more consolidated than the rocks of the overlying Miocene Series, and andesitic volcanic activity is known to have taken place in South Sumatra from the Oligocene to Miocene (Van•Bemmelen, 1970).

(4) S.Empulu Formation

This formation is distributed widely along the S.Gangsal and from Pg.Endelang toward the southwest. It also occurs in direct contact with the outer margin of the Paleozoic.

It consists chiefly of grayish white or gray quartzose arenite and fine-grained white acid tuff. These rocks are not very consolidated.

The arenite varies in grain size from fine to coarse, its greater part being composed entirely of quartz grains. Bedding is well developed. The arenite is intercalated with yellowish gray claystone 10~30 cm thick, and occasionally with a coal seams whose maximum thickness is 1.5 m.

The lowermost part of the formation contains large quantities of fine angular gravels of vein quartz and a small quantity of fine subrounded gravels of siltstone. Conglomerate with a matrix of quartz sand is developed in this part.

The tuff is composed of fine fragments of acid glass, and no bedding is recognized. This rock is widely distributed in the area centering in the upper reaches of S.Endelang.

The S.Empulu Formation has a thickness of 300 m. It is correlated with the Lakat Formation of the Rengat sheet, being the Early Miocene sediment.

(5) S.Demadi Formation

This formation is distributed along S.Antan in the west, and to the northeast of the S.Empulu Formation in the eastern part of the survey area. It rests conformably on the underlying S.Empulu Formation.

The chief constituents are claystone and siltstone. The lower part is intercalated with quartzose arenite and coal seams. The claystone is gray to dark gray, the siltstone is grayish yellow, and the both are soft. The siltstone often shows distinct bedding planes. The quartzose arenite intercalated in the lower part is medium to coarse grained, and generally occurs as thin layers. Coal is found in several horizons but coal seams are thin, mostly around 1 m in thickness. The coal is of low quality, being muddy in many parts.

This formation has a thickness exceeding 500 m. It is Early to Middle Miocene sediment, and is correlated with the Tualang Formation and the Gemai Formation of the Rengat sheet.

2-4 Intrusive Rocks

The intrusive rocks distributed in the present area are granitic rocks comprising porphyritic biotite granite, biotite granite, pegmatite and aplite, which intruded into the Paleozoic.

(1) Porphyritic biotite granite

The distribution of this rock are as follows: 6 x 2 km extending northward from Bt.Lapat in the mid-northern part of the survey area ; 5 x 4 km around Bt.Kayumambang in the central part ; 2 x 1 km around Bt.Tebat ; and 4 x 3 km centered around the middle reaches of Nibul River in the east.

The porphyritic biotite granite is characterized by columnar or rhombic megaphenocrysts of potash feldspar. In some parts, the megaphenocrysts make up more than 60 percent by volume ratio. They often contain medium to fine-grained phenocrysts of biotite. The principal rock-forming minerals, excluding the potash feldspar megaphenocrysts, are quartz, potash feldspar, plagioclase and biotite. Under the microscope, aside from megaphenocrysts, these minerals show an equigranular structure. The potash feldspar and plagioclase are saussuritized.

By K-Ar dating(Table 2-4), the porphyritic biotite granite from the middle reaches of Nibul River was determined to be the Dogger (167 ± 4 Ma) of the Jurassic Period, and the granite at Bt.Kayumambang showed Jurassic Malm age (143 ± 3 Ma). In the north of Bt.Legat, the age was determined to be Neocomian (134 ± 3 Ma) of the Cretaceous Period. Thus, the age of the porphyritic biotite granite tends to become younger from the south to north.

(2) Biotite granite

This rock constitutes Bt.Tungku in the central part. Four bodies of the rock occur to the east and north of Bt.Pintutujuh in the western part of the survey area.

The principal rock-forming minerals are quartz, potash feldspar, plagioclase, biotite and hornblende. Under the microscope, these minerals show an equigranular or glomeroporphyritic structure. The potash feldspar and plagioclase are saussuritized.

K-Ar dating revealed the age of this rock, in the north of Bt.Pintutujuh in the western part, to be Neocomian (128 ± 3 Ma) of the Cretaceous Period.

(3) Pegmatite and aplite

Pegmatite occurs as small-scale intrusive bodies in the upper reaches of S.Isahan in the western part, along S.Sikambu, along S.Keruntung, a tributary of S.Akar, and along S.Mentaus in the eastern part of the survey area. In the west, the bodies are round about 100 m in diameter, or oval of about 100 x 200 m, and in the eastern part, the rocks occur as dikes 1~5 m wide.

Aplite is distributed as small dikes, 3~5 m wide, occurring within the medium-grained biotite granite east of Bt.Pintutujuh in the west, and within the Paleozoic in the upper reaches of S.Lemang and around S.Mentaus. Large quantities of aplite boulders are found to the west of Bt.Tungku, and to the south of Bt.Lapat. Aplite also occurs as small stocks near the mouth of S.Lemang.

The principal rock-forming minerals of the pegmatite are quartz, potash feldspar and plagioclase, accompanied by a small amount of muscovite. Under the microscope, the rock shows a graphic structure, a pegmatitic structure, or an equigranular structure. The potash feldspar and plagioclase are saussuritized. Around S.Isahan and S.Sikambu in the west, the rock has a lithofacies that may

Table 2-3 Results of Microscopic Observation of the Thin Section

Sample No.	Locality	Rock Name	Texture	Phenocryst								Alteration
									Qz	Af	Pl	Bi Mu Ho Ep Fe
A7	S. Tabuh	Gr	Equi	○	◎	△	○				△	Bi→Ch, Pl→Se
AR18	S. Manggojahan	Gr	Equi	◎	○	○	○				△	Bi→Ch, Se
A20	ditto	Gd	Equi	○	○	○	◎		△		△	Bi→Ch, Se, Ho→Cb
A25	ditto	Gd	Glom	○	○	○	◎		○		△	Bi→Ch, Se, Ho→Ch
A28	S. A. Muara	Gd	Equi	○	◎	○	○		△		•	
CR10	S. Keruntung	Pe	Grap	○	◎	△		•				Pl→Se
CR13	S. Mentaus	Gr	Grap	◎	◎	△	△				△	Bi, Pl→Se
CR14	ditto	Pe	Pegm	○	◎							Af→Se
CR16	ditto	Gr	Equi	◎	○	△	○				•	Bi→Ch, Se
CR18	ditto	Gr	Porp	○	△	△	◎		△			Ho→Ch
CR25	S. Nibul	Gr	Equi	◎	○	○	○				△	Bi→Ch, Se
CR28	ditto	Gr	Equi	○	◎	△	○				△	Bi→Ch
CR35	S. Tulang	Gd	Equi	○	○	○	○		○		△	Bi→Se, Ch, Ho→Ch
CR38	ditto	Gd	Equi	○	○	○	○		○		•	Bi→Se, Ch, Ho→Ch
CR45	S. Isahan	Gr	Pegm	△	◎	△						Af→Mu, Mf→Fe
CR49	ditto	Gr	Grap	○	◎	△					•	Af, Pl→Mu
CR51	ditto	Gr	Equi	◎	◎	△						Af, Pl→Mu
CR56	S. Sikambu	Gr	Equi	○	◎	△		○			△	Af, Pl→Se
DR1	S. Lemang	Qv~Ap		◎				△	•	•	△	
DR2	S. Penal	Qv~Ap		◎			•	•	•			
DR7	S. Tualang	Qv~Ap		◎	△			•		•		
DR38	S. Akar	Gr	Equi	△	○	○	○				△	Bi→Ch
ER17	S. Nibul	Gr	Equi	○	○	○	○					Bi→Ch

Sample No.	Locality	Rock Name	Texture	Mineral Chip									Matrix	Altered or Metamor. Mineral								
				Qz	Af	Pl	Bi	Mu	Ho	Py	Mf	Fe	Se	Qz	Af	Pl	Bi	Mu	Ho	Ch	An	Fe
AR27	S. A. Muara	Ho	Horn	○					○								○			◎		○
CR34	S. Tulang	Ho	Porp	○		△	△	○									•		•			
DR20	S. Sepegas	Ss		◎									◎									
ER1	S. Sesirih	Ph	Cata	◎	△	△	○	◎		△							△	△		◎		
ER4	ditto	Ho	Cata	◎	△	△												◎		◎		
ER6	ditto	Ho	Pobl	○	△	△	○	○									○	○		○	○	
ER7	S. Usul	Gn	Cata	◎	△	○	○		○								○	○			△	
ER11	S. Selensen	Ho	Schi											△	△	△	○	○		○		△

Abbreviations

Texture
- Equi; Equigranular
- Glom; Glomeroporphyritic
- Grap; Graphic
- Pegm; Pegmatitic
- Porp; Porphyritic
- Cata; Cataclastic
- Pobl; Porphyroblastic
- Schi; Schistose

Rock Name
- Gr ; Granite
- Gd ; Granodiorite
- Pe ; Pegmatite
- Qv ; Quartz vein
- Ap ; Aplite
- Ho ; Hornfels
- Ss ; Sandstone
- Ph ; Phyllite
- Gn ; Gneiss

Mineral
- Qz; Quartz
- Af; Alkali feldspar
- Pl; Plagioclase
- Bi; Biotite
- Mu; Muscovite
- Ho; Hornblende
- Ep; Epidote
- Fe; Iron minerals
- Py; Pyrite
- Mf; Mafic minerals
- Se; Sericite
- Ch; Chlorite
- An; Andalusite

Table 2-4 Results of K-Ar Dating

Sample No.	Locality	Rock Name	Sample Type	Potassium (k wt%)	Rad. ^{40}Ar (10^{-6}cc/g)	K-Ar age (Ma)	Air cont. (%)	Remarks Alt. deg.
A20	S. Manggajahan	Bi-Gr	Whole rock	3.02	15.5±0.2	128±3	3.2	1
				±0.06	15.4±0.2	127±3	3.3	
A28	S. Muara	Por-Gr	Whole rock	3.40	18.5±0.2	135±3	2.7	1
				±0.07	18.2±0.2	133±3	2.3	
CR38	S. Tulang	Bi-Gr	Whole rock	3.22	14.1±0.2	109±3	4.6	2
				±0.06	14.3±0.2	111±3	4.8	
DR38	S. Mentaus	Por-Gr	Whole rock	3.70	21.4±0.2	144±3	1.9	1
				±0.07	21.2±0.2	142±3	1.8	
ER17	S. Salai	Por-Gr	Whole rock	3.46	23.3±0.2	166±3	1.8	1
				±0.07	23.5±0.2	167±3	1.5	

Bi-Gr : Biotite Granite, Por-Gr : Porphyritic Biotite Granite

Alt. deg. : 1 -- Fresh or Altered worm-eaten like or along cleavages

2 -- Altered mafic minerals partly

indicate leucocratic granite or granite, but along S.Akar in the east, only pegmatite is distributed. In order to distinguish these pegmatitic rocks from the above-mentioned biotite granite, they are collectively called pegmatite hereafter.

Aplite is made up chiefly of equigranular quartz, potash feldspar, plagioclase and muscovite. In the west of Bt.Tungku and the south of Bt.Lapat, the rock shows mode of occurrence of aplite, but it contains only very minute amount of biotite, muscovite, hornblende and alleanite which indicates the characteristics of high-temperature quartz vein.

(4) Chemical composition

Ten samples each were collected from porphyritic biotite granite and biotite granite, and analyzed for 13 major components and for fluorine as a trace component. The results of analysis and the weight ratios of C.I.P.W.norm minerals are given in Table 2-5. The granitic rocks of the present area classified by the quartz - potash feldspar - plagioclase norm weight ratio are plotted in the granite and granodiorite domain, as shown in Figure 2-5. When classified by lithofacies, the porphyritic biotite granite is plotted in the granite domain, and the biotite granite falls in the domain that astrides the granodioritic granite domain and the granodiorite domain.

In the differentiation index (Table 2-5, D.I.), the porphyritic biotite granite shows values over 83 percent, while the biotite granite has lower values, 58~70 percent. The tin-bearing granitic rocks of the Hatapan area of North Sumatra were compared with the granitic rocks of the present area by their SiO_2 content and differentiation index. The result revealed that the former with, 73~77 percent SiO_2 content and over 92 percent D.I., are more advanced in differentiation than the later, less than 73 percent SiO_2 and less than 85 percent D.I.

For comparison of the alkali-lime contents, the alkali-lime ratios of the respective rocks are shown in Figure 2-6. It is seen in the figure that the porphyritic biotite granite shows a trend of $K_2O > Na_2O > CaO$, whereas that of the biotite grnite is $K_2O \fallingdotseq CaO > Na_2O$, indicating that it is rich in CaO. The distributions of the tin-bearing granite of Thailand (Ishihara et al., 1980) and of the granite of North Sumatra's Hatapan area are also shown in the same figure. Concerning the distribution, the porphyritic biotite granite of the present area is distributed adjacent to the former two granites, but the distribution of the biotite granite is distinctly separate from them.

Table 2-5 Whole Rock Analysis and CIPW Norms

Sample No.	A-7	A-18	A-20	A-25	A-28	CR-28	CR-35	CR-38	DR-38	ER-17
Locality	Bt. Kayu-manbang	S. Mangga-jahan	S. Mangga-jahan	S. Mangga-jahan	S. Muara	S. Nibul	S. Tulang	S. Tulang	S. Mentaus	S. Salai
Rock Name	Por-Gr	Bi-Gr	Bi-Gr	Bi-Gr	Por-Gr	Por-Gr	Bi-Gr	Bi-Gr	Por-Gr	Por-Gr
SiO_2	71.81	66.47	64.12	63.08	72.88	71.94	61.11	65.36	71.86	70.66
TiO_2	0.33	0.54	0.59	0.67	0.26	0.30	0.70	0.49	0.33	0.27
Al_2O_3	13.98	15.33	15.37	15.42	13.88	13.97	15.58	15.00	14.08	14.59
Fe_2O_3	0.24	0.90	1.24	1.26	0.50	0.83	1.38	0.91	0.80	0.75
FeO	2.35	4.12	4.60	5.11	2.11	2.29	5.48	4.07	2.32	2.43
MnO	0.05	0.08	0.10	0.12	0.05	0.05	0.11	0.09	0.06	0.08
MgO	0.72	1.18	1.98	2.20	0.55	0.62	2.56	1.81	0.66	0.55
CaO	1.57	3.32	4.07	4.46	1.59	1.86	4.87	3.50	2.06	1.47
Na_2O	2.73	2.38	2.46	2.34	3.05	2.87	2.34	3.07	3.03	2.81
K_2O	4.96	4.10	3.78	3.68	4.39	4.73	3.54	4.08	4.57	5.59
P_2O_5	0.22	0.26	0.25	0.28	0.17	0.22	0.28	0.22	0.20	0.23
BaO	0.04	0.12	0.08	0.10	0.03	0.05	0.09	0.08	0.03	0.06
LOI	0.96	1.11	1.01	0.99	0.44	0.74	1.54	1.23	0.16	0.68
Total	100.20	100.30	100.10	100.20	100.10	100.70	100.20	100.30	100.40	100.40
F(ppm)	530	600	510	640	410	780	650	540	630	800
Q	31.47	26.04	21.36	19.95	33.18	31.45	17.04	19.73	30.48	27.99
C	1.79	1.56	0.43	0.15	1.63	1.27	0.00	0.00	0.88	1.79
or	29.31	24.23	22.34	21.75	25.95	27.95	20.92	24.11	27.01	33.04
ab	23.09	20.13	20.80	19.79	25.79	24.27	19.79	25.96	25.62	23.76
an	6.36	14.78	18.57	20.31	6.79	7.80	21.56	15.10	8.92	5.80
di-wo	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.35	0.00	0.00
di-en	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00
di-fs	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.20	0.00	0.00
hy-en	1.79	2.94	4.93	5.48	1.37	1.54	6.23	4.36	1.64	1.37
hy-fs	3.67	6.08	6.64	7.46	3.12	3.11	7.79	5.88	3.16	3.55
mt	0.35	1.31	1.79	1.83	0.73	1.21	2.00	1.31	1.16	1.09
il	0.63	1.03	1.12	1.27	0.49	0.57	1.33	0.93	0.63	0.51
ap	0.52	0.62	0.59	0.66	0.40	0.52	0.66	0.52	0.47	0.54
Total	98.96	98.69	98.56	98.64	99.43	99.68	97.97	98.60	99.97	99.43
D. I.	83.87	70.40	64.50	61.49	84.92	83.67	57.75	69.80	83.11	84.79
$\frac{Al_2O_3}{(CaO+Na_2O+K_2O)}$	1.10	1.07	0.99	0.97	1.10	1.06	0.94	0.95	1.03	1.09

The S-type, I-type, magnetite series and ilmenite series divisions of granite is used for clarifying the nature of the material which generates the felsitic magma to produce granite. On the ACF diagram (Fig.2-7) used to discriminate between S-type and I-type, the porphyritic biotite granite is situated along the boundary of both types and in the S-type zone, while the biotite granite is distributed on the boundary and in the I-type zone.
On the C/ACF-$Al_2O_3/(CaO+Na_2O+K_2O)$ diagram (Fig.2-8), both granites are roughly regarded as I-type. For the $Al_2O_3/(CaO+Na_2O+K_2O)$ molar ratio, the porphyritic biotite granite shows values larger than 1, which suggests that the rock crystallized out of a peraluminous magma, but the values for the biotite granite are under 1, indicating a different composition of the magma.

On the Fe^{2+}/Fe^{3+} - SiO_2 diagram (Fig.2-9) used to discriminate between magnetite series and ilmenite series, all the granitic rocks of the present area belong to the ilmenite series.

The fluorine contents are in the range of 410~800 ppm. These values are low, in both maximum and mean values, as compared with those of the Hatapan granite (350~6,050 ppm) and the Kinta Valley granite of Indonesia (300~5,700 ppm).

2-5 Geologic Structure

The geologic structure of the present area is characterized by numerous Paleozoic fold and gently dipping Tertiary System. The faults cutting the Paleozoic and the Tertiary Systems are those of the NW-SE, NNW-SSE and NE-SE systems. There is a trend for the NW-SE system to be cut by the NNW-SSE system which is itself cut by the NE-SE system.

(1) Fold structure

The Paleozoic structure in the present area is unclear in most cases because of the indistinct bedding of all formations. However, in the western part of the area, some parts of the Paleozoic show a distinct bedding, as observed in the vicinity of Bt.Pintutujuh to Bt.Tebat and in the north of Bt.Kayumambang. In such bedded parts several synclinal and anticlinal structures are observed. The wavelength of those folds is around one kilometer, and the direction of the fold axis is NW-SE in the vicinity of Bt.Pintutujuh, and E-W around Bt.Tebat and in the north of Bt.Kayumambang. In the northeast of Bt.Kayumambang, the direction changes to NW-SE. To the east of Bt.Endelang in the eastern part of the area, a synclinal structure with a N-S axis is recognized. From the above, it is concluded that synclinal and anticlinal structures are distributed in an S-shape.

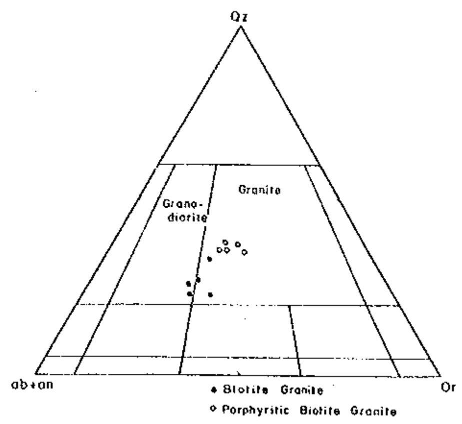


Fig.2-5 Quartz-Potash feldspar-Plagioclase Diagram

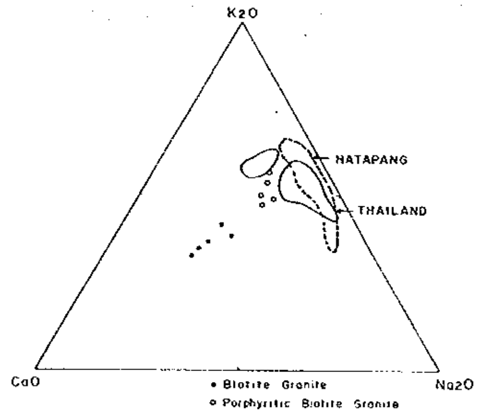


Fig.2-6 Alkali-Lime Ratio Diagram

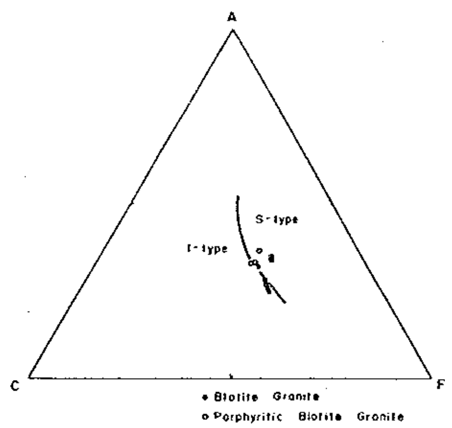


Fig.2-7 ACF Diagram

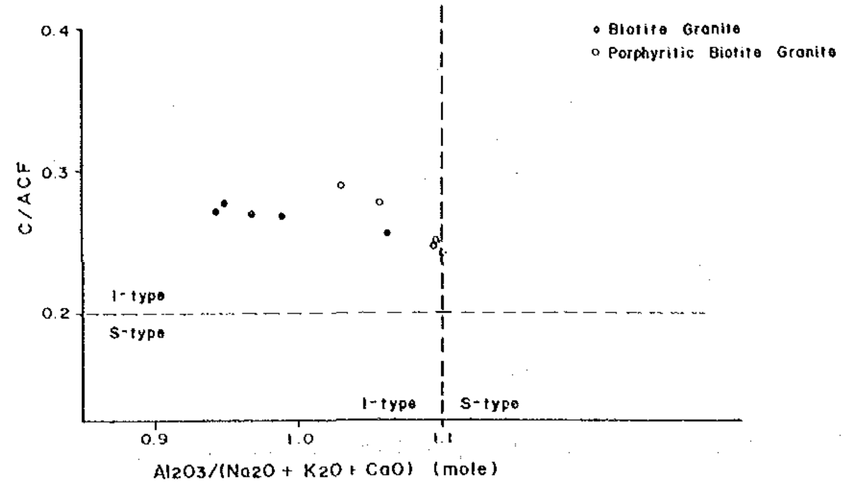


Fig.2-8 $C/ACF-Al_2O_3/(CaO+Na_2O+K_2O)$ Diagram

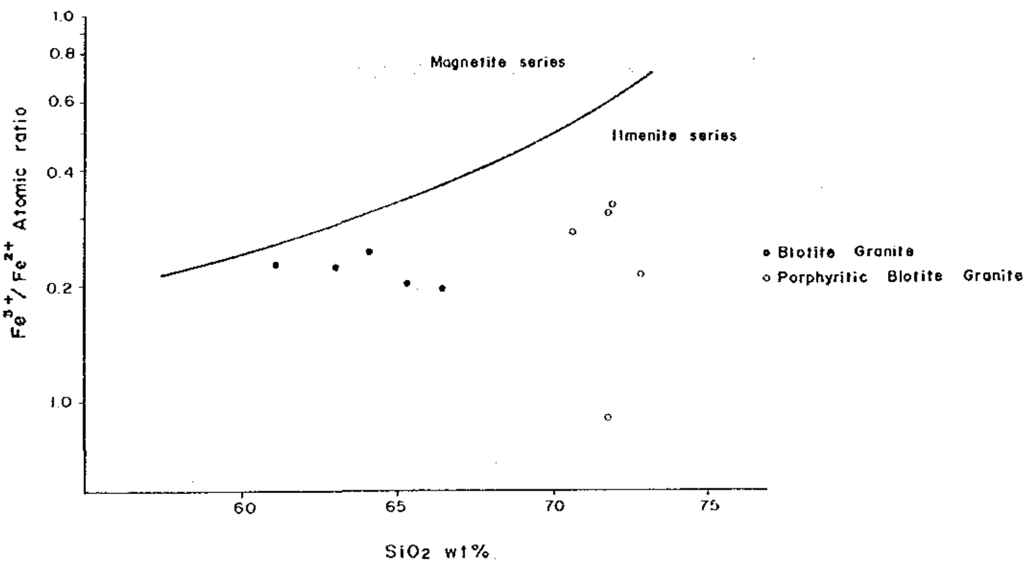


Fig.2-9 Fe^{2+}/Fe^{3+} - SiO_2 Diagram

The Neogene System shows only a gently dipping structure, but near the boundary with the Paleozoic, the dip becomes steeper (15°~45°) regardless of the locality. The steep dip may reflect the block uplift of the Paleozoic which occurred from the Miocene.

(2) Fault

Faults of the NW-SE system are found only along the upper reaches of S.Manggajahan in the western part of the area. Faults of the NNW-SSE system are distributed along the upper reaches of S.Antan, along the lower reaches of S.Manggajahan, and along the upper reaches of S.Tulang in the western part. They are also distributed along the upper reaches of S.Gangsal in the central part, and from S.Sesirih to the east of Bt.Kayumambang in the eastern part of the area. Formation up to the Neogene strata have been displaced by these faults. The NE-SW faults distributed in the south of Bt.Kayumambang have also displaced the Neogene System.

The geotectonic history of East Sumatra has been mentioned in Chapter 3 of Part I. According to Tija (1989), East Sumatra was under the compression field until the Late Cretaceous, but from then to the Early Tertiary, it become a tensional field, and a rift valley was formed along the N-S fracture. From the Oligocene to Pliocene, Sumatra again became a field of compression, and strike-slip faults developed.

Based on the above analysis, the faulting of the area is interpreted as follows. In the Tertiary System along S.Antan in the west and along S.Gangsal in the central area, the latent existence of a rift valley or a fracture zone formed between the Late Cretaceous and Early Tertiary is highly possible. From Oligocene, the NNW-SSE faults became active, and from the Miocene, they began to present the aspect of dip-slip faults accompanying the block uplift of the Paleozoic. The faults of the NE-SW system may be considered as those with a strong strike-slip element which became active after the development of NNW-SSE faults.

(3) Arrangement of intrusive rocks

The porphyritic biotite granite is distributed in the NW-SE direction from Bt.Lapat in the midnorthern area to Bt.Kayumambang. In the south, separate bodies of this rock are distributed along the middle reaches of S.Nibul, separated by the above-mentioned NE-SW faults. If the NE-SW faults are regarded as left-lateral faults and are moved 7 km in the strike direction, it is found that four bodies of porphyritic biotite granite are arranged in a straight line in the NW-SE direction.

The biotite granite in the western part of the area is arranged in the NW-SE direction, although it is slightly different from the above direction.

Along the upper reaches of S.Isahan and along S.Sikambu in the west, tin-bearing pegmatite is distributed. The line connecting these two localities coincides with the above-mentioned direction of the arrangement of the porphyritic biotite granite.

2-6 Mineralization and Associated Alteration

It was mentioned in the previous section that the granitic rocks of the survey area belonged to the calc-alkali series and also to the ilmenite series.

These granitoids are known to be accompanied by Sn, W, Be, Nb, Ta, Th oxide mineralization (Ishihara ,1979).

With the above in mind, the mineral showings of the survey area (Fig.2-10) are classified into following five groups by the host rocks and the mineral assemblages.

① Pegmatites and associated quartz-muscovite-tourmaline veins.
② Quartz veins in granites.
③ Quartz veins in Paleozoic strata.
④ Silicified and argillized zones.
⑤ Coal in Neogene strata.

Of the above, four mineral showings, which were considered to be particularly closely related to the granitic bodies, were selected and their state of mineralization was examined by pitting.

(1) Pegmatites and associated quartz-muscovite-tourmaline veins.

These veins occur in the upper reaches of S.Isahan and along S.Sikambu in the western part of the survey area, and along the S.Akar and S.Mentaus in the eastern part.

① Upper reaches of S.Isahan

Pegmatite outcrops are observed at three localities within a distance of 120m and network of 1 to 40cm wide quartz veins are exposed (Fig.2-11). The quartz veins contain cassiterite, muscovite, tourmaline, arsenopyrite, pyrite and minor amount of beryl. Cassiterite occurs mostly as independent lumps of 1 x 1cm to 5 x 5cm in the central or marginal parts of the veins. In rare cases, cassiterite occurs with sericite. Arsenopyrite veins with 1cm width transect the quartz veins in some places. One to 5cm wide muscovite-

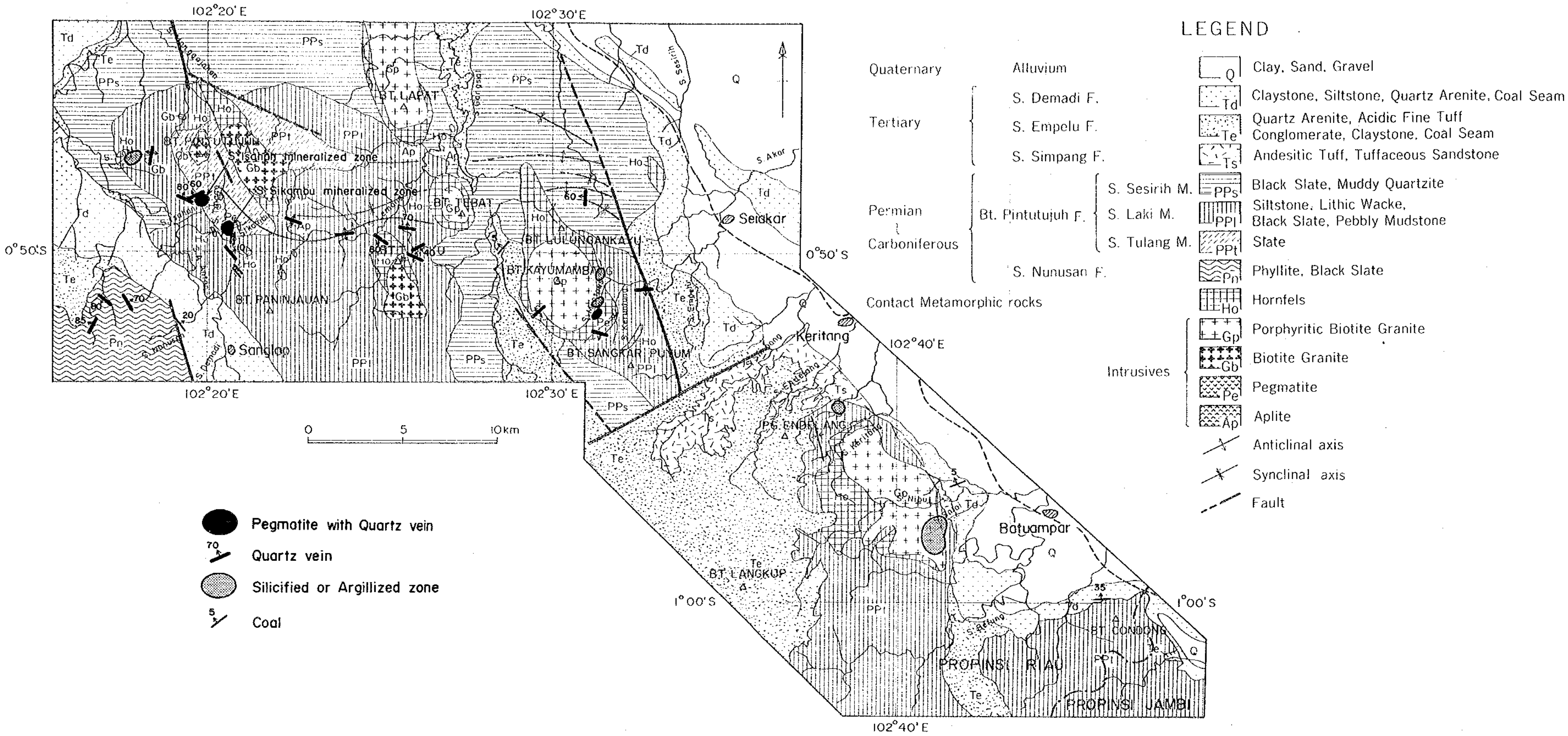


Fig.2-10 Mineral Showings Map

kaolinite-potash feldspar zone is often formed in the marginal parts of wide quartz veins. Quartz-muscovite veins with 10cm width occur in the slate which is in direct contact with the pegmatite.

In the pegmatite, most of the potash feldspars and plagioclase are muscovitized and minor amounts of kaolinite and beryl are observed and the body is generally tinted by iron oxides. The slate in contact with pegmatite is bleached to grayish white and X-ray diffraction identified quartz-kaolinite-sericite paragenesis.

The muscovitization in the pegmatite is probably the product of greisenization, but regarding kaolinite, it is not clear whether it was formed by greisenization, hydrothermal alteration or weathering, because there are cases when quartz-tourmaline-cassiterite veins are accompanied by kaolinitization in cornwall, England.(Bray,1983).

② S.Sikambu

There are two pegmatite bodies with dimensions in the order of 100 x 200m and 50 x 50m respectively. There are five quartz veins with width ranging from 2 to 20cm in the pegmatite bodies.

These veins contain cassiterite, muscovite, tourmaline and arsenopyrite. The muscovite occurs in the marginal parts of the veins. The mode of occurrence of these minerals are similar to that of mineralized zone of S.Isahan. The host rock underwent muscovitization and kaolinitization, but the alteration is weaker than at the S.Isahan mineralized zone and most of the potash feldspar and plagioclase remain intact.

③ S.Akar

There is a 1cm wide quartz vein and a 1mm wide muscovite vein which transects the quartz vein. These veins occur in a 2m wide pegmatite body which intruded into hornfels. A part of the potash feldspar of the host rock is sericitized.

④ S.Mentaus

A network of 1cm wide quartz-tourmaline veins and a quartz-muscovite veinlet which cuts through the network occur in a 1m wide pegmatite in hornfels.

(2) Quartz veins in granites

These veins are distributed in the upper reaches of S.Laki in the western part of the survey area and southwest of Bt.Kayumambang in the central part.

Quartz -potash feldspar - pyrite veins with 10cm width occur in biotite granite at the upper reaches of S.Laki. The host rock is intensely sericitized and a large amount of pyrite dissemination is observed.

Quartz-kaolinite-sericite veins with 30cm width occur in porphyritic biotite granite in a locality southwest of Bt.Kayumambang.

(3) Quartz veins in paleozoic strata

Quartz veins with more than 10cm in width occur at ; branch of S.Antan in the western part of the survey area, along S.Lemang and S.Sesirih in the central part and S.Akar in the eastern part. These veins are all less than 60cm wide with irregular width and are not continuous.

The major mineral paragenesis of the veins is ; quartz-pyrite, quartz-tourmaline and quartz-muscovite-pyrite.

Many boulders of these quartz veins are observed along the rivers in Paleozoic regions.

(4) Silicified and argillized zones

These alteration zones occur in the Paleozoic strata at; along S.Peseman and to the south of this river in the western part of the survey area, and along S.Mentaus and to the east of Bt.Endelang in the eastern part.

Network of pyrite veins are developed in these silicified and argillized zones. The alteration zones consist of quartz and minor amount of sericite.

A similar argillized vein is observed along the branch of S.Antan in the west. This vein consists of 10cm wide gray clay and pyrite.

Also along the S.Salai in the east, porphyritic biotite granite is argillized in a zone extending 500 x 1,500m wherein network of pyrite veins and pyrite dissemination are developed. The biotite and plagioclase of the host rock are altered to kaolinite and sericite.

(5) Coal in Neogene strata

Coal seam outcrops were found in several localities in the Neogene formations. The thickness of the seams range from 30cm to 3m and it is seen, by unaided eyes, that the coal contains clay and the grade is not high.

(6) Pitting

Pits were dug near pegmatite and near the quartz-muscovite-tourmaline vein exposures in the pegmatites, and also near the exposures of silicified and argillized rocks.

These pits were 3 to 4.5m deep and the purpose was to confirm the extent of mineralization and alteration. The location of the pits and their targets are listed below (Figs. 2-12,2-13,2-14,2-15).

Pit No.	Location	Depth	Objectives
No. 1	Eastern, S. Salai	3.0m	pyrite net work in argillized porphyritic biotite granite
No. 2	Eastern, S. Mentaus	4.5m	pegmatite
No. 3	Western, S. Sikambu	3.0m	quartz-muscovite-tourmaline veins in pegmatite
No. 4	Western, S. Sikambu	3.0m	quartz-muscovite-tourmaline veins in pegmatite
No. 5	Western, S. Isahan	3.0m	quartz-muscovite-tourmaline veins in pegmatite
No. 6	Western, S. Isahan	3.0m	quartz-muscovite-tourmaline veins in pegmatite

① Pit No.1

This pit is located 50m south of the argillized porphyritic biotite granite outcrop. Weathered porphyritic biotite granite was confirmed by this pit. Network of veins, similar to those in the outcrop is developed, but pyrite is altered to limonite.

② Pit No.2

This pit is located 30m southwest of pegmatite outcrop. Strongly weathered lithic wacke was encountered, but it is not mineralized.

③ Pit No.3

This pit was dug 50m southeast of the pegmatite exposure. The purpose of this pit was to confirm the extent of the pegmatite body and to clarify the conditions of the quartz veins. Weathered gray slate breccias occurred between the surface and the bed rock. The rock is slate. Mineralization was not observed.

④ Pit No.4

This pitting was done 100m northwest of pit No.3 with the same purpose. Greisenized pegmatite and brecciated vein quartz were found between the surface and the bed rock. The rock is lithic wacke, but mineralization was not observed.

⑤ Pit No.5

This pit is located 130m southeast of the pegmatite exposure. The purpose of this pit was to clarify the extent of pegmatite body and the mineralization. Soil and brecciated lithic wacke occur from the surface to the bed rock. The bed rock is weathered lithic wacke and mineralization was not observed.

⑥ Pit No.6

This pit is located 50m northwest of the pegmatite outcrop. It was worked with the same purpose as Pit No.5. Soil and weathered and brecciated pegmatite occur from the surface to the bed rock. The bed rock is lithic wacke, but there is no evidence of mineralization.

The bottom 1m of all pits was systematically sampled and analyzed and the results are laid out below.

Pit No.	Au (ppb)	Ag (ppm)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
1	7	<0.2	1	33	17.0	3	5000	10800	63.0	485	135	16.0	83	100
2	2	0.3	1	35	8.0	8	205	4750	78.0	290	68	21.0	66	130
3	7	0.2	14	20	<1.0	60	225	8050	26.0	290	97	<1.0	114	94
4	20	<0.2	8	23	<1.0	45	220	8900	51.0	295	96	17.0	85	90
5	10	<0.2	11	26	<1.0	12	275	10700	43.0	105	39	9.0	16	40
6	32	<0.2	<1	20	15.0	9	105	345	130.0	185	180	20.0	29	56

The following was clarified from pitting.

① It was expected that the pegmatite of S.Isahan would extend continuously in the same NW-SE direction as the host granitic body, but the pegmatite consists of two small stocks whose size is at most 80 x 40m.

② It was confirmed that the pegmatite body at S.Sikambu extends continuously from the outcrop northwestward toward S.Tulang, but mineralization was not observed. Considering the conditions of the exposures, the density of quartz vein distribution of this pegmatite body is considered to be lower than that of S.Isahan.

(7) Discussions

Twenty-one samples were collected from mineral showings and analyzed for the following 15 elements Au, Ag, Sn, Nb, Ta, W, Zr, TiO_2, Th, Ce, Y, Li, La, MnO and total Fe (Table 2-6). Of these elements, Sn, W and Ce contents are note worthly.

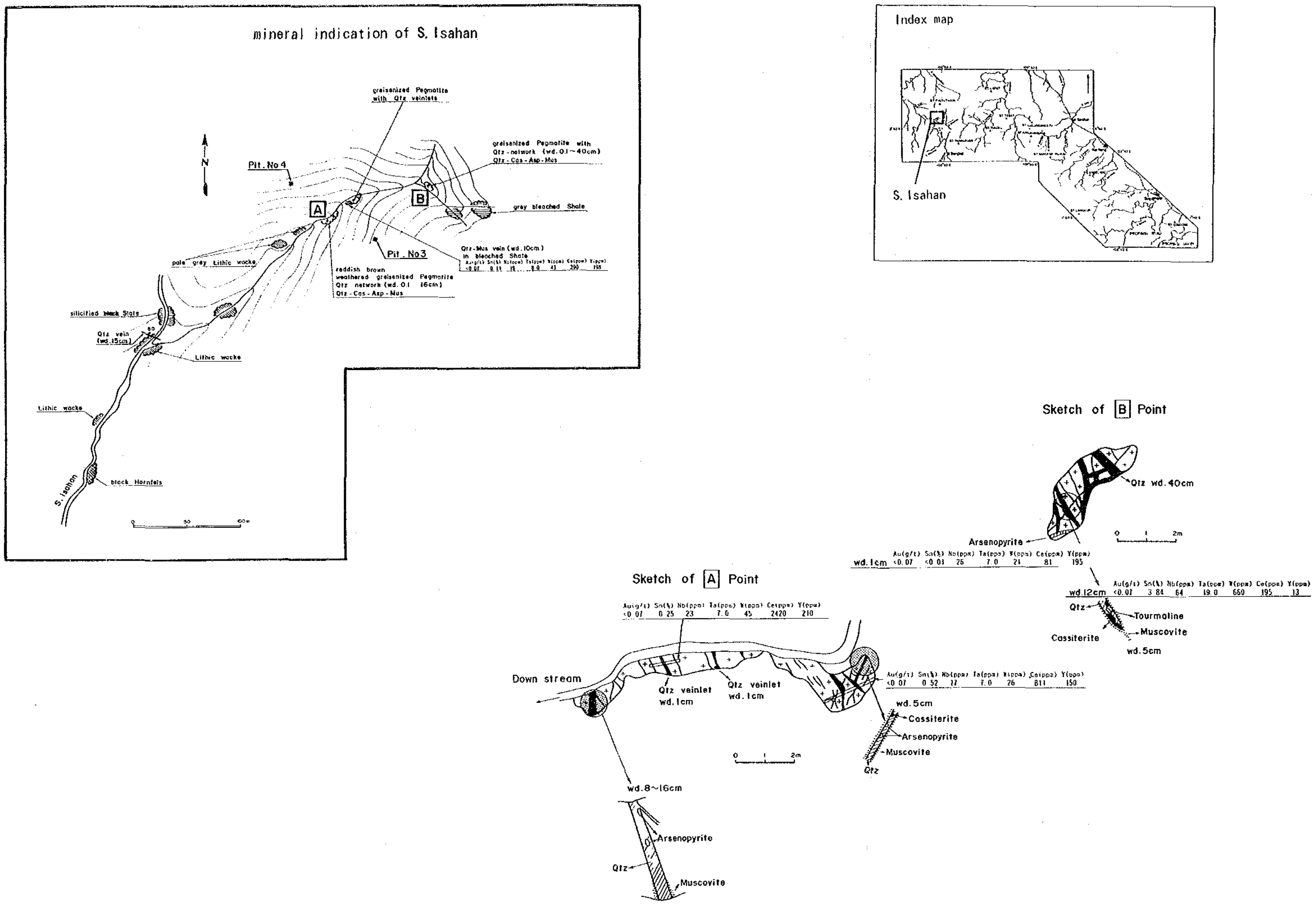
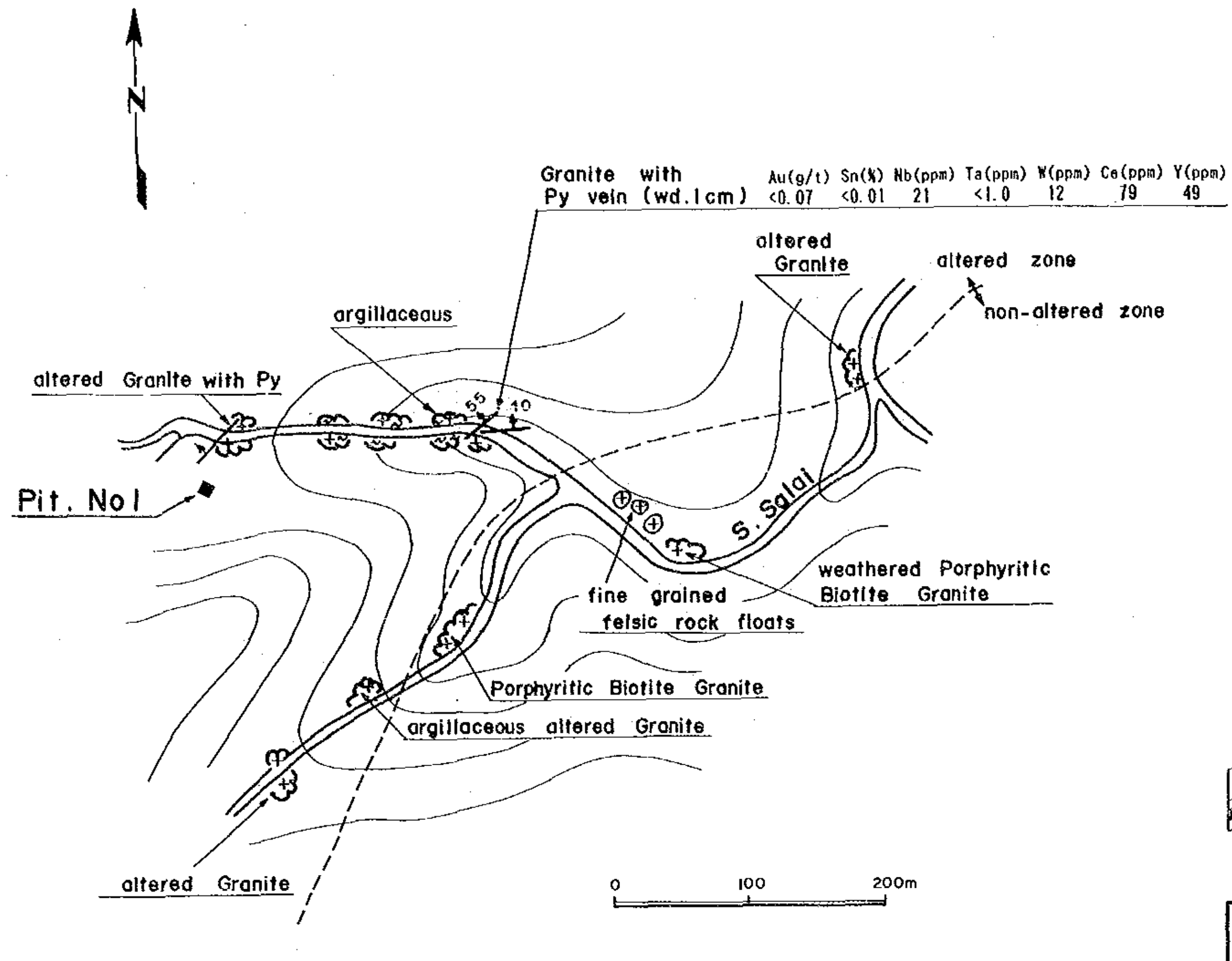
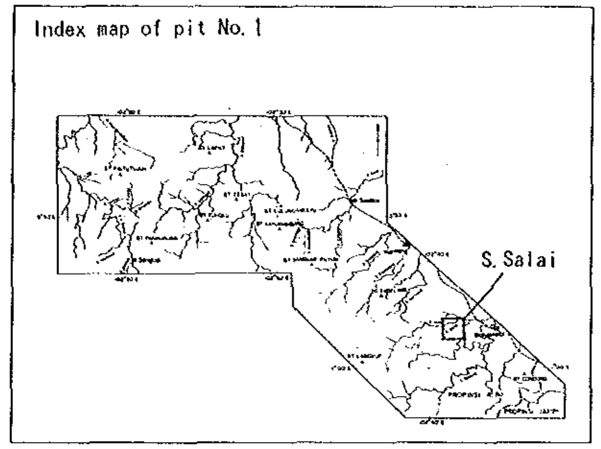


Fig.2-11 Sketch of the Mineralized zone at S.Isahan





	Au(ppb)	Ag(ppm)	Sn(ppm)	Nb(ppm)	Ta(ppm)	W(ppm)	Zr(ppm)	Ti(ppm)	Th(ppm)	Ce(ppm)	Y(ppm)	U(ppm)	Li(ppm)	La(ppm)
Pit. No1	7	<0.2	1	33	17.0	3	5000	10800	63.0	485	135	16.0	83	100

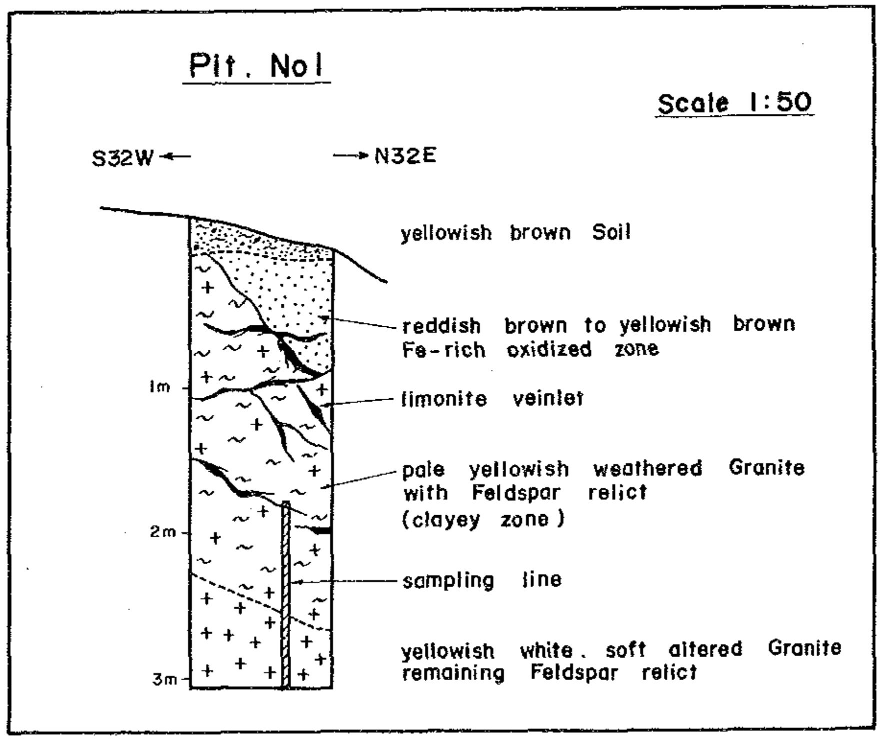
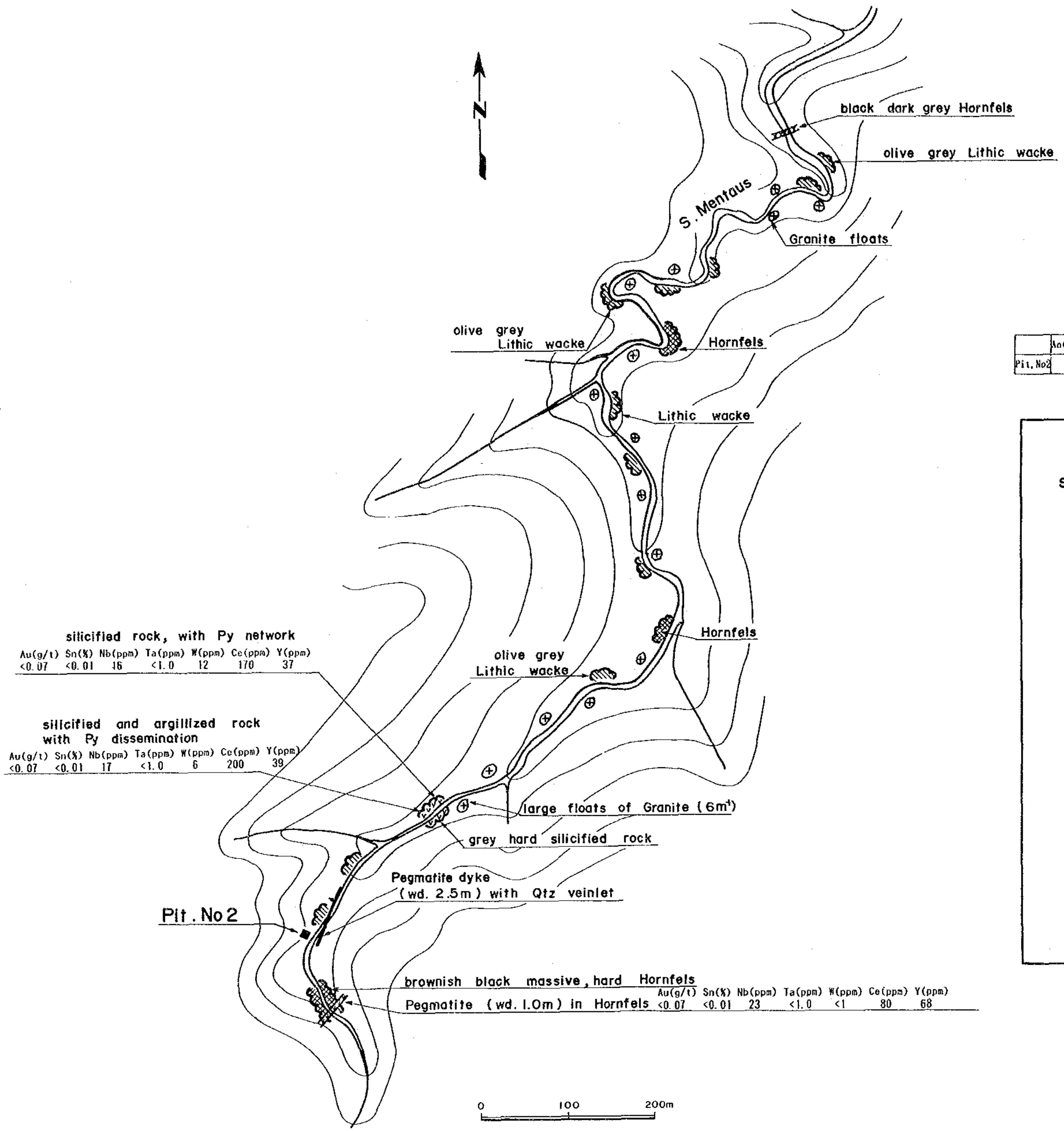
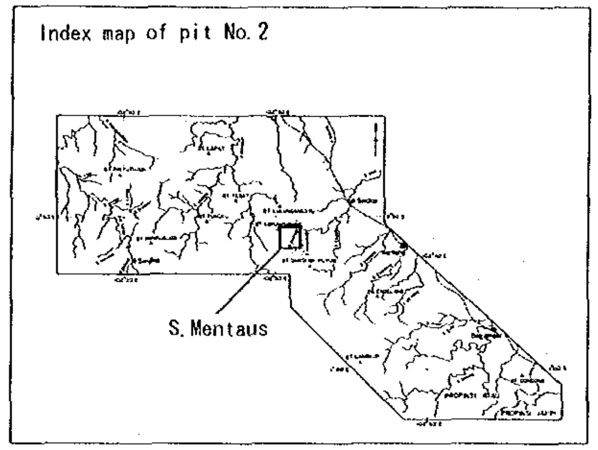


Fig.2-12 Location Map and Sketch of Pit No.1





	Au(ppb)	Ag(ppm)	Sn(ppm)	Nb(ppm)	Ta(ppm)	W(ppm)	Zr(ppm)	Ti(ppm)	Th(ppm)	Ce(ppm)	Y(ppm)	U(ppm)	Li(ppm)	La(ppm)
Pit, No2	2	0.3	1	35	8.0	8	205	4750	78.0	290	68	21.0	66	130

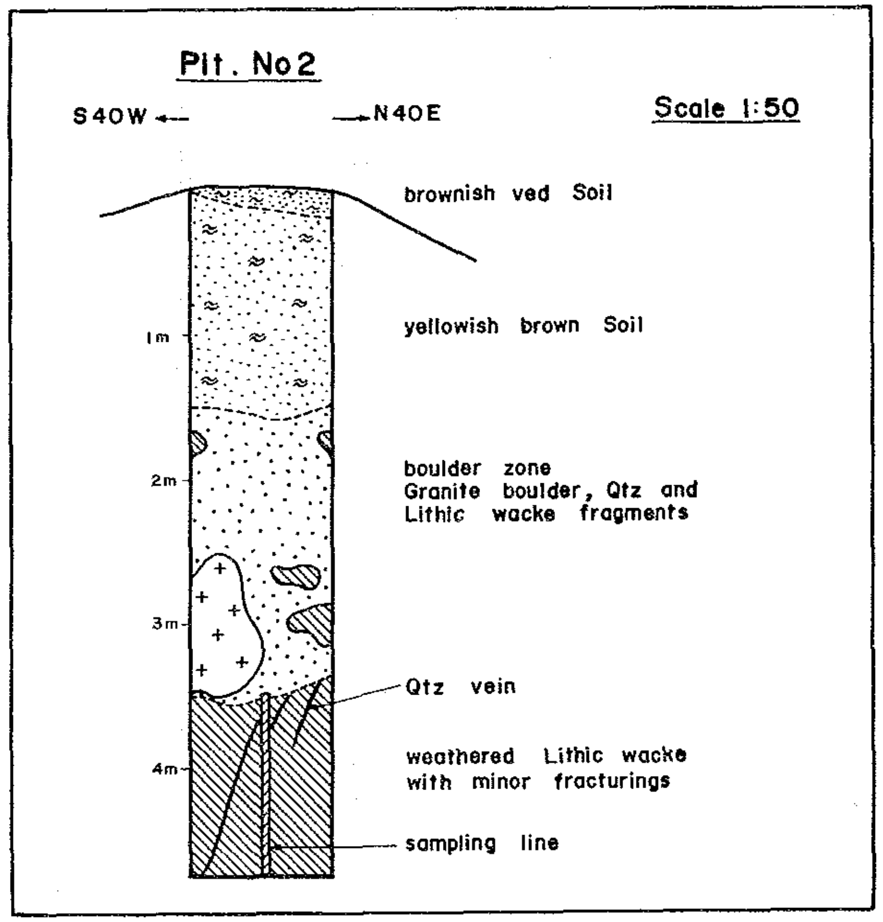
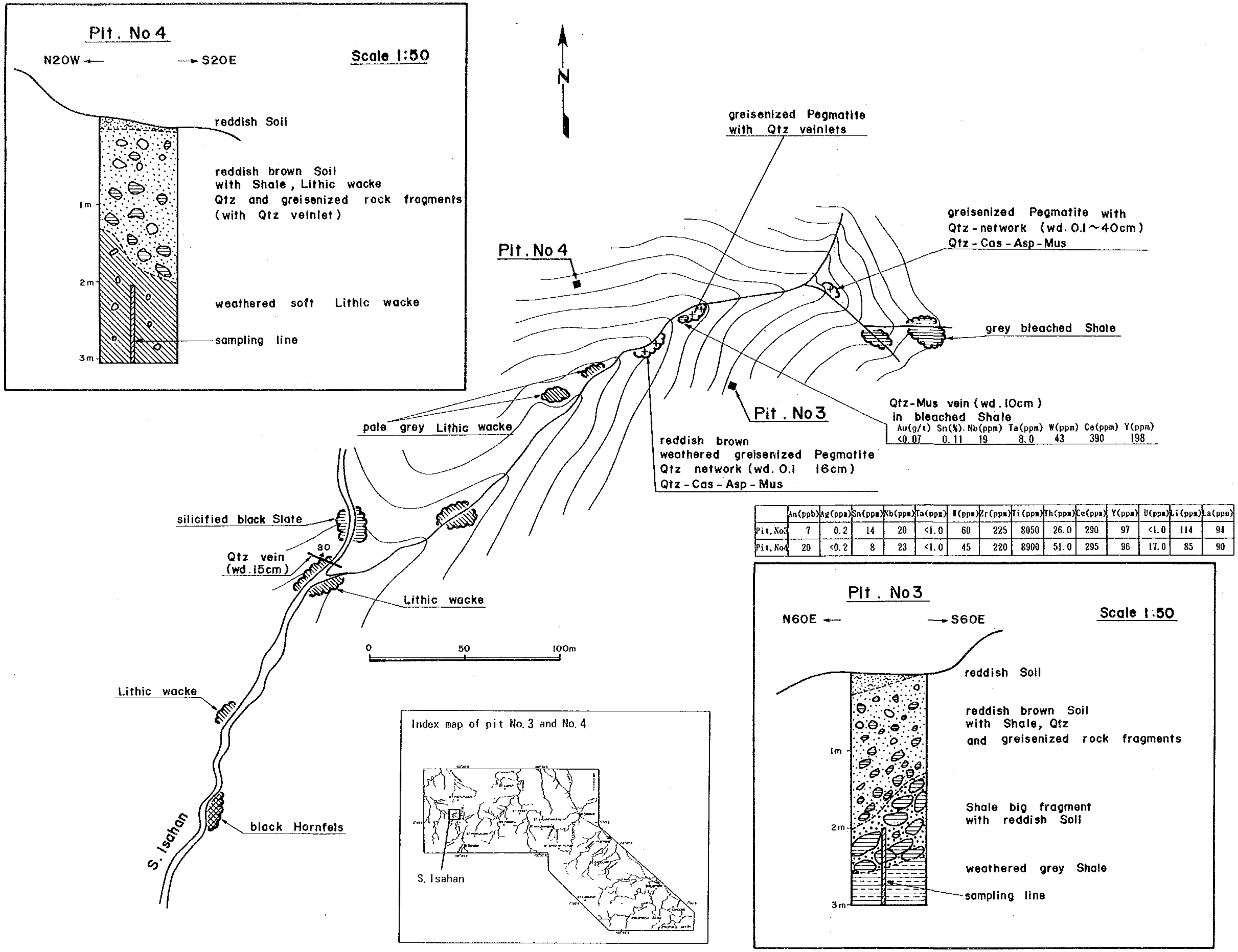
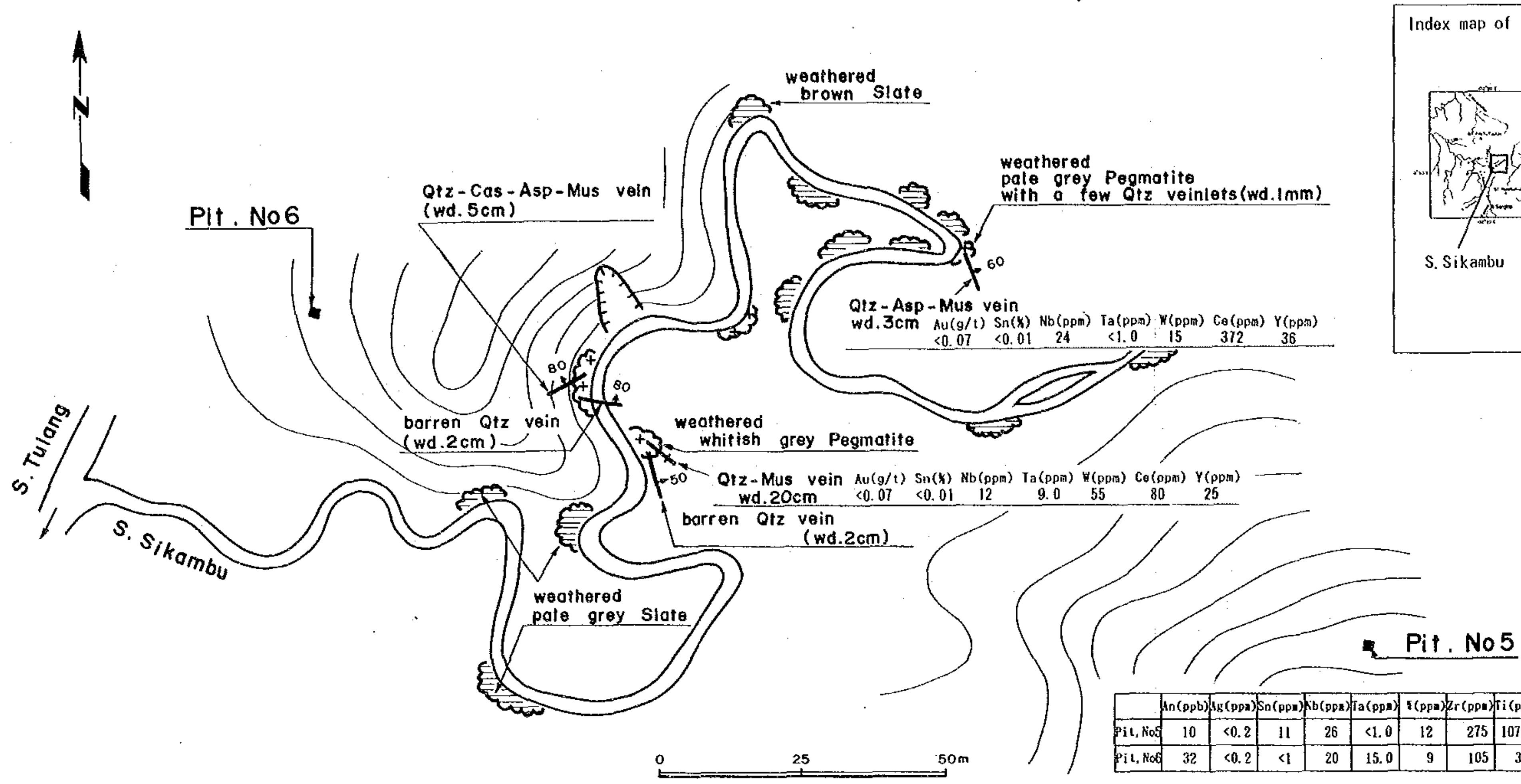


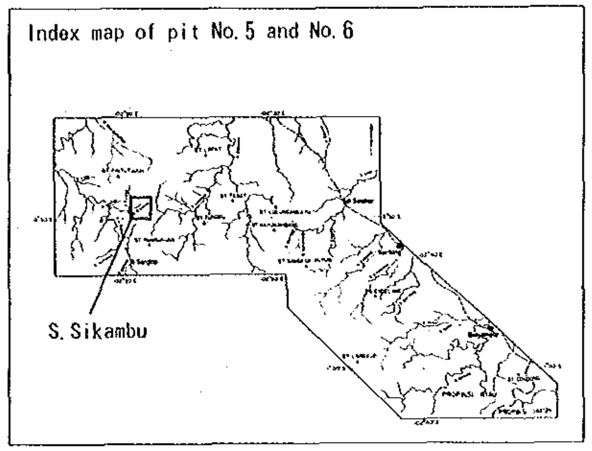
Fig.2-13 Location Map and Sketch of Pit No.2



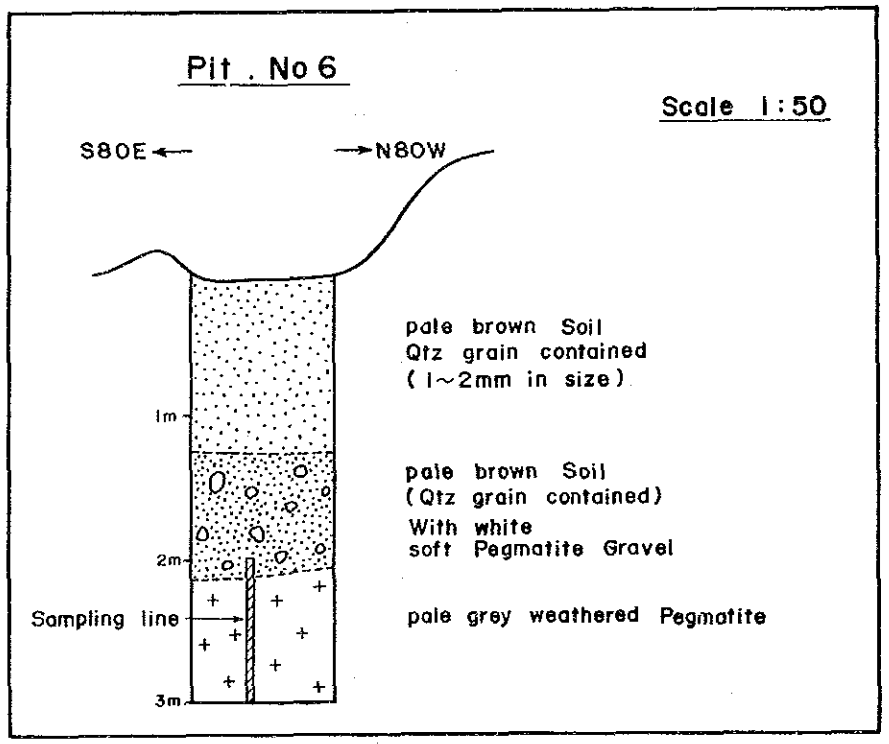
	Au(ppb)	Ag(ppm)	Sn(ppm)	Nb(ppm)	Ta(ppm)	W(ppm)	Zr(ppm)	Ti(ppm)	Th(ppm)	Ce(ppm)	Y(ppm)	U(ppm)	Li(ppm)	La(ppm)
Pit, No3	7	0.2	14	20	<1.0	60	225	8050	26.0	290	97	<1.0	114	94
Pit, No4	20	<0.2	8	23	<1.0	45	220	8900	51.0	295	96	17.0	85	90

Fig.2-14 Location Map and Sketch of Pit No.3 and No.4





	Au(ppb)	Ag(ppm)	Sn(ppm)	Nb(ppm)	Ta(ppm)	W(ppm)	Zr(ppm)	Ti(ppm)	Th(ppm)	Ce(ppm)	Y(ppm)	U(ppm)	Li(ppm)	La(ppm)
Pit, No5	10	<0.2	11	26	<1.0	12	275	10700	43.0	105	39	9.0	16	40
Pit, No6	32	<0.2	<1	20	15.0	9	105	345	130.0	185	180	20.0	29	56



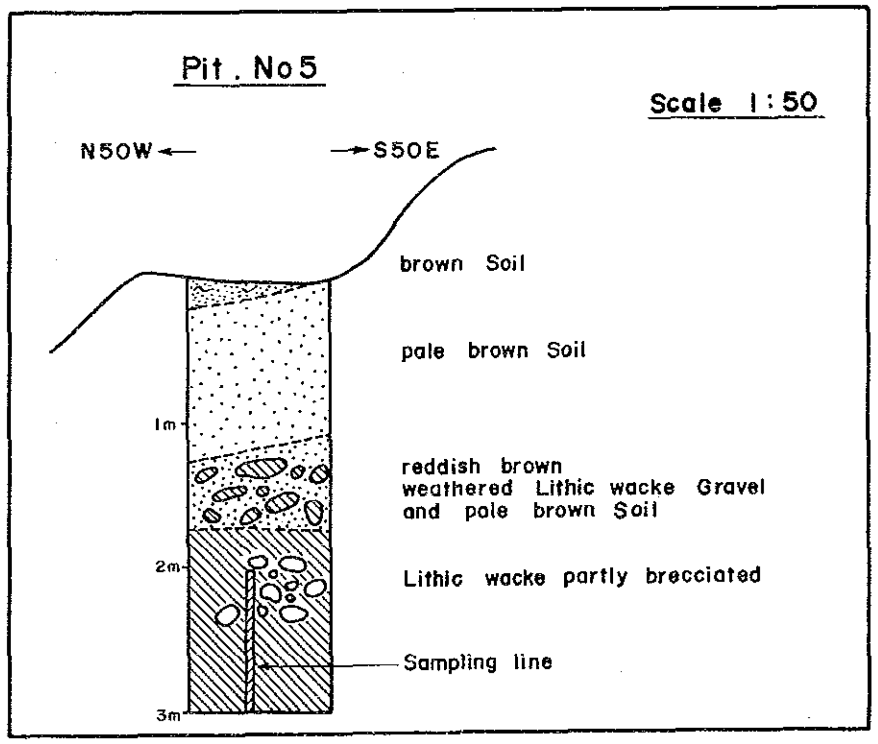


Fig.2-15 Location map and Sketch of Pit No.5 and No.6

Table 2-6 Result of Chemical Analysis of Rock Samples

Sample No.	Location	Sample name	Au (g/t)	Ag (g/t)	Sn (%)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	TiO_2 (%)	Th (ppm)	Ce (ppm)	Y (ppm)	Li (%)	La (ppm)	MnO (%)	Fe (%)
C02	S.Lenang	Qtz.vein in the Paleozoic	<0.07	<0.5	<0.01	14	<1.0	<1	84	0.38	12.0	90	21	<0.01	45	0.06	2.77
CR11	S.Mentaus	Silicified rock	<0.07	<0.5	<0.01	16	<1.0	12	115	0.46	13.0	170	37	<0.01	36	<0.01	2.95
CR12	S.Mentaus	Silicified rock	<0.07	<0.5	<0.01	17	<1.0	6	140	0.52	9.0	200	39	<0.01	61	0.01	3.07
CR14	S.Mentaus	Pegmatite with Qtz veinlet	<0.07	<0.5	<0.01	23	<1.0	<1	50	0.03	8.0	80	68	<0.01	36	0.01	0.81
CR20	S.Akar	Qtz.vein with Py spot	<0.07	<0.5	<0.01	7	6.0	<1	11	<0.02	<1.0	250	<1	<0.01	31	0.01	2.45
CR21	S.Keruntung	Qtz.vein with Py	<0.07	<0.5	<0.01	8	<1.0	9	22	0.06	<1.0	60	5	<0.01	<1	0.03	5.14
CR31	S.Salai	Por.Bi.Granite with Py dis	<0.07	<0.5	<0.01	21	<1.0	12	115	0.26	33.0	79	49	<0.01	85	0.01	1.08
CR32	S.Salai	Por.Bi.Granite with Py net	<0.07	<0.5	<0.01	19	<1.0	<1	135	0.20	29.0	191	37	<0.01	20	0.01	7.29
CR41	S.Pesenan	Qtz.vein	<0.07	<0.5	<0.01	12	<1.0	<1	90	0.28	11.0	121	19	<0.01	59	0.06	3.19
CR42	S.Pesenan	Silicified rock with Py net	0.21	0.8	<0.01	15	<1.0	<1	95	0.24	<1.0	203	27	<0.01	21	<0.01	5.29
CR44	S.Isahan	Greisen in shale	<0.07	0.5	0.11	19	8.0	43	46	0.10	24.0	390	198	<0.01	49	0.04	3.57
CR46	S.Isahan	Qtz.vein with cassiterite	<0.07	<0.5	3.84	64	19.0	660	16	0.02	<1.0	195	13	<0.01	<1	0.03	1.09
CR48	S.Isahan	Arsenopyrite vein	<0.07	<0.5	<0.01	26	7.0	21	68	<0.02	18.0	81	195	<0.01	<1	<0.01	5.48
CR50	S.Isahan	Greisenized granite	<0.07	1.0	0.25	23	7.0	45	44	<0.02	31.0	2420	210	<0.01	<1	0.04	2.77
CR52	S.Isahan	Greisenized granite	<0.07	1.0	0.52	17	7.0	26	34	<0.02	16.0	811	150	<0.01	<1	0.01	1.00
CR58	S.Sikambu	Qtz.vein with Arsenopyrite	<0.07	0.5	<0.01	24	<1.0	15	40	0.06	24.0	372	36	<0.01	29	0.08	3.69
CR64	S.Sikambu	Qtz.vein with Muscovite	<0.07	<0.5	<0.01	12	9.0	55	13	<0.02	<1.0	80	25	<0.01	<1	0.02	0.92
D07	S.Balui	Silicified rock with Py	<0.07	<0.5	<0.01	13	7.0	<1	105	0.28	10.0	98	21	<0.01	<1	<0.01	2.20
D08	S.Matah	Clay vein with Py	<0.07	<0.5	<0.01	15	<1.0	<1	160	0.46	11.0	162	56	<0.01	90	0.02	6.09
ER16	S.Laki	Qtz.vein in the Bi.granite	<0.07	0.8	<0.01	23	<1.0	6	57	<0.02	28.0	616	27	<0.01	87	<0.01	1.27
EX1	S.Sesirib	Qtz.vein in the paleozoic	<0.07	<0.5	<0.01	7	6.0	<1	10	<0.02	<1.0	24	<1	<0.01	50	0.02	1.20

The analysis of samples from the cassiterite-bearing quartz veins in the S.Isahan pegmatite showed 3.84 percent Sn and 0.07 percent W and other samples which are mixtures of the pegmatite and quartz vein from the same locality contained 0.08 to 0.24 percent Ce.

Principal component analysis were carried out on the geochemical data of Table 2-6 in order to clarify the characteristics of mineralization. Of the first principal component, Sn, Nb, Ta, W, Ce show large negative values. In the second principal component, Zr, Th, Y show large positive values and in the third principal component, Au, Ag show large positive values. The first principal component is interpreted as the factor representing mineralization accompanying ilmenite series granitic rocks.

The data of the samples from S.Isahan and S.Sikambu show a high negative factor score for the first principal component. Also the quartz vein samples from biotite granite of S.Laki show high negative factor score for the first principal component. This fact is interesting because it indicates that the quartz veins of both S.Laki and S.Isahan were formed by the same type of mineralization.

From the data obtained regarding mineralization and alteration, the metal concentration expected in this survey area is Sn, W, Ce-bearing pegmatite and quartz veins in pegmatite. The quartz veins are found in S.Isahan and

S.Sikambu. If the density of quartz veins in pegmatite can be the measure of intensity of mineralization, the mineralization is most intense in the exposures of S.Isahan followed by S.Sikambu.

Table 2-7 Eigenvectors of Principal Component Analysis with the Geochemical Data of the Rock Samples Analysis

	EIGENVECTORS			
	1	2	3	4
Au	0.10	0.04	0.67	-0.11
Ag	-0.22	0.25	0.48	0.29
Sn	-0.41	0.11	-0.02	0.07
Nb	-0.23	0.32	-0.16	-0.25
Ta	-0.38	-0.17	-0.01	-0.15
W	-0.39	0.11	-0.16	-0.10
Zr	0.28	0.41	-0.04	-0.21
TiO_2	0.35	0.20	-0.11	-0.05
Th	0.05	0.45	-0.26	0.06
Ce	-0.23	0.34	0.23	0.33
Y	-0.11	0.47	-0.07	-0.18
La	0.32	0.07	-0.05	0.32
MnO	-0.08	-0.02	-0.31	0.70
Fe	0.22	0.17	0.14	0.15
Eigen	4.27	3.41	1.62	1.19
Propo.	0.30	0.24	0.12	0.08
Cum. prop	0.30	0.55	0.66	0.75

2-7 Granites-Geologic Structure-Mineralization

The intrusive rocks in the survey area are porphyritic biotite granite, biotite granite, pegmatite and aplite, all in Paleozoic strata. The chemical data and the age have been determined for the porphyritic biotite granite and biotite granite, thus the relation between these rocks and mineralization will be considered below.

The age of the porphyritic biotite granite is determined to be Middle Jurassic to Early Cretaceous. The biotite granite, on the other hand, is Early Cretaceous. Therefore, if these two types of granites were products of a series of activity of the same magma, the nature of the magma changed after the formation of the porphyritic granite and subsequently formed the biotite granite. From the chemical analysis of the major components, the porphyritic biotite granite has higher degree of magmatic differentiation compared to the biotite granite.

One interpretation of this seemingly contradicting phenomenon is that after the solidification of the porphyritic biotite granite, the differentiated magma assimilated the rocks in the vicinity thus changing its composition toward granodioritic composition.

The mineralization observed in the survey area is that of Sn, W, Ce. These generally are associated with activities of ilmenite series granitoids. From this point of view, both types of granites can host the mineralization of the area.

Their differentiation index and alkali/calcium ratio, however, show that the porphyritic biotite granite is a more likely host compared to the tin-bearing granites in other areas. On the other hand, tin mineralization occurs in closer proximity to the biotite granite, at least on the surface, and thus the possibility of this type of granite being the source of the mineralization cannot be denied. The relationship between the tin mineralization and the granite types will be considered comprehensively in the next chapter including the results of the geochemical prospecting.

There are evidences regarding the relation between geologic structure and mineralization. Structurally weak lineation of the survey area, where granitoids intruded during Jurassic to Cretaceous, is manifested by the arrangement of the granitic intrusion. Naturally, the mineralization associated with the granitic intrusion is expected to be controlled by this structurally weak zone.

This structural control is manifested as the following phenomena. The line connecting the mineral showings at the upper reaches of S.Isahan and S.Sikambu in the western part of the area coincides with the alignment of the granitic rocks. Also, the quartz vein in the biotite granite, which was mentioned in the section on mineralization and alteration, are situated at the extension of a line joining the above two mineral showings.

The above is considered to be an indication of the fact that the stress field which controlled the area at the time of the solidification of the granitic rocks also existed during mineralization.

Chapter 3 Geochemical Prospecting

3-1 Geochemical Prospecting with Stream Sediments

Geochemical prospecting using stream sediments was carried out with the purpose of obtaining clues for discovering new mineralized zones which would otherwise be undetected by geological survey, as well as for clarifying the extension of known mineral occurrences through geological survey. Geochemical prospecting was carried out parallel with the geological survey.

(1) Sampling and analysis

Fine sands of -80 mesh were sampled from sediments near the riverbanks where the rivers were wide and deep, and from faster-flowing midstream where the rivers were narrow and shallow. The number of samples collected was 1,019, which corresponds to a density of approximately one sample/km^2.

The samples, after being air-dried in the field, were analyzed at Chemex Lab. Inc. of Canada, for 14 elements: Au, Ag, Sn, Nb, Ta, W, Zr, Ti, Th, Ce, Y, U, Li and La. The methods of analysis and the limits of detection are given below.

Element	Digestion and Method	Lower Limit	Upper Limit
Au	Fuse 10g sample, Neutron activation encapsulation and irradiation	1ppb	10,000ppb
Ag	HNO_3-aqua regia digest. Atomic Absorption	0.2ppm	100ppm
Sn	NH_4I sublimation extrac. Atomic Absorption	2ppm	1,000ppm
Nb	X-ray fluorescence	5ppm	10,000ppm
Ta	Neutron activation encapsulation and irradiation	2ppm	10,000ppm
W	K pyrosulfate fusion Colorimetric test	2ppm	1,000ppm
Zr	X-ray fluorescence	5ppm	10,000ppm
Ti	Induced coupling plasma	100ppm	10,000ppm
Th	Neutron activation encapsulation and irradiation	1ppm	1,000ppm
Ce	Neutron activation encapsulation and irradiation	2ppm	10,000ppm
Y	X-ray fluorescence	5ppm	10,000ppm
U	Neutron activation encapsulation and irradiation	1ppm	1,000ppm
Li	$HClO_4$-HNO_3-HF digestion Atomic Absorption	1ppm	1,000ppm
La	Neutron activation encapsulation and irradiation	1ppm	1,000ppm

(2) Results of data processing

① Method of analysis

It is known that the distribution of geochemical data, especially that of minor elements belonging to a certain population, generally shows a close approximation to logarithmic normal distribution. In the present analysis, therefore, the natural logarithms of the respective analytical values were used in the calculation of statistical amounts. When the analytical values were less than the detection limit, a value half that of the lower limit was substituted in the calculation.

② Basic statistical values

In Table 2-8 are shown the geometric means and the maximum and minimum values of each element, and the proportion of samples showing values less than the lower detection limit for total samples. The abundance of elements in crustal rocks (Mason, 1966) are also given for reference.

The maximum value of each element is divided by its crustal abundance and the result is considered to represent the element's degree of concentration. Sn is found to have the highest concentration, followed by Zr, U and Th, while low degrees of concentration are noticed for Ti, Li, Y and Ag.

The frequency of samples with values less than the detection limit is high for Au, Ag and W, accounting for more than two-thirds of the total. Particularly Ag, with its value lower than the lower limit in almost all samples, is excluded from consideration.

Table 2-8 Basic Statistics of Stream Sediment samples

	Au (ppb)	Ag (ppm)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
Logarithmic Mean	<1	<0.2	2	16	8	<2	629	4019	12	71	17	4	11	27
Max.	57	0.5	875	45	31	22	10300	23700	220	680	360	165	47	360
Min.	<1	<0.1	<1	9	<1	<2	90	830	<1	<1	<1	<1	2	<1
Number of under detection limit(%)	75	99	32	0	8	75	0	0	6	4	2	25	0	14
Average amounts of the elements in Crustal rocks	4	0.07	2	20	2	1.5	165	4400	7.2	60	33	1.8	20	30
Concentrated degree	14	7	438	23	16	15	62	5	31	11	11	92	2	12

Since the samples were collected from stream sediments, they are considered to contain geochemical information reflecting the geology of the source areas. The rocks of the source areas of the samples vary greatly, and this causes considerable uncertainty in the lithology and their distribution frequency. Accordingly, in the present analysis, the geology was divided into four units, namely, the Paleozoic, Cenozoic, granitic unit, and hornfels, so as to grasp the general relationship between the analytical values and the geology. Assuming that the geologic unit which is distributed in the proximity of the sampling sites is the unit that constitutes their source, the geometric means for each unit was obtained (Table 2-9).

Table 2-9 Geometric Mean of Each Geological Unit with Stream Sediment Samples

	Au (ppb)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
Paleozoic	0.7	1.4	15.6	7.2	1.2	571	4465	11.5	75	18	2.9	11.9	26.8
Cenozoic	0.7	5.4	15.1	11.2	1.4	667	3485	10.6	59	14	4.1	9.3	25.8
Granites	1.1	2.7	25.3	5.1	4.5	1126	3755	20.8	133	47	13.3	22.6	38.9
Hornfels	0.9	1.7	15.7	8.4	1.3	582	3884	10.2	70	17	3.8	12.4	27.6

In the granitic unit, one of the four geologic units, the highest geometric means are shown by 10 elements: Au, Nb, W, Zr, Th, Ce, Y, U, Li and La. In the Cenozoic unit, Sn and Ta are the highest, and in the Paleozoic, Ti. Among these elements, Sn, W, Y and U have maximum mean values larger than twice the average values of other geologic units. The difference of average values among different units is small in Au, Nb, Zr, Ti and La.

③ Frequency distribution of analytical values

The frequency distribution of analytical values is shown in Fig. 2-16. Nb, Zr, Ti, Y, U and Li are the elements with close-to-normal distribution. Ta, Ce and La are distributed with the highest value of their frequency positioned a little to the right, while Sn has its highest frequency somewhat left from the center. Au, Ag and W present an L-shape distribution, as many of their values are less than the lower detection limit.

④ Correlation among elements

Table 2-10 shows the correlation coefficients of all the samples.

Correlation coefficient values larger than 0.5 are found in the combinations of Nb-Ti and Nb-Th-Y. The elements with coefficients of correlation of only − 0.3～0.3 with other elements are Au, Ag, Sn and La.

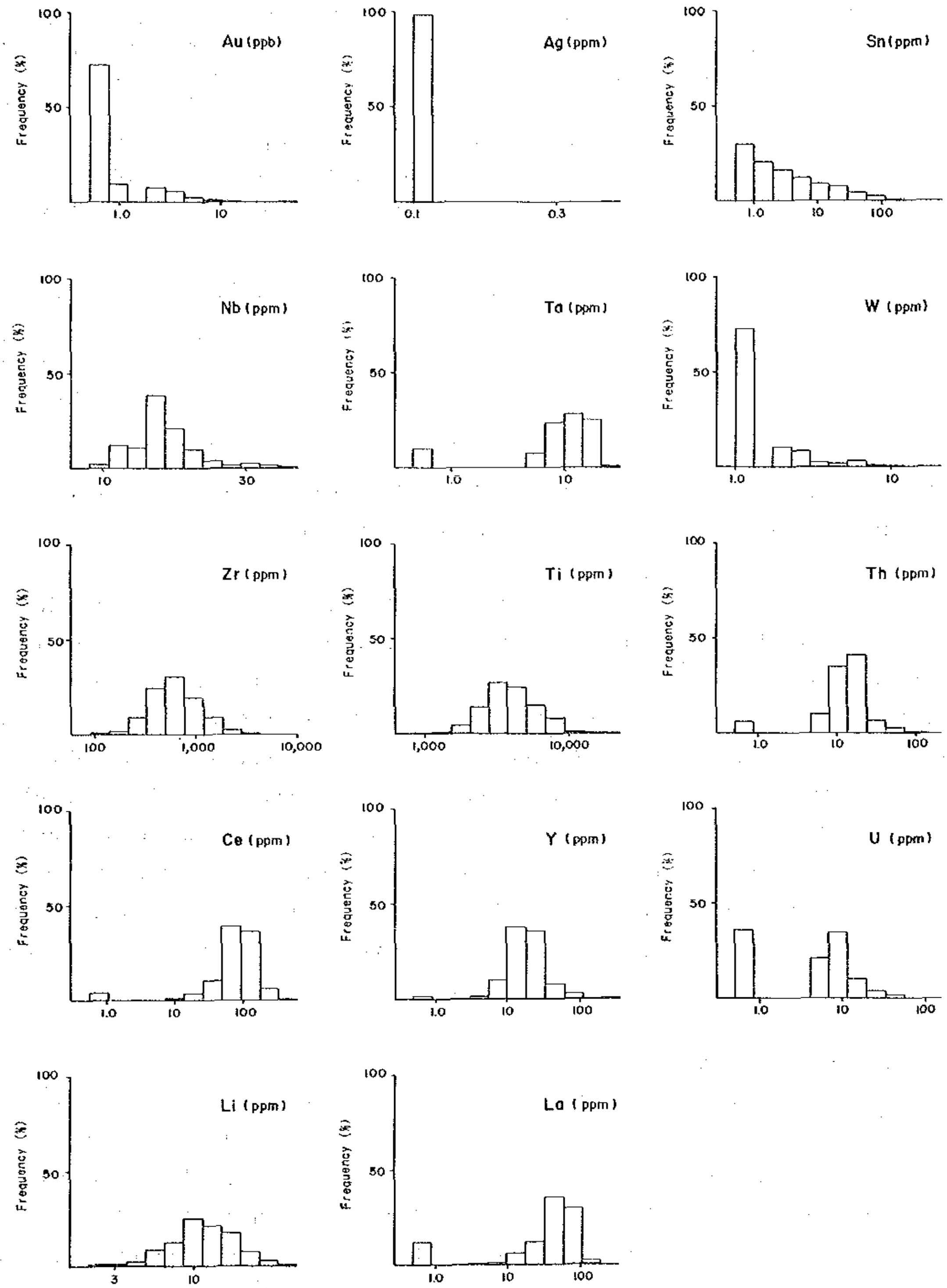


Fig.2-16 Histogram of 14 Elements with Stream Sediment Samples

Table 2-10 Correlation Matrix of Stream Sediment Samples

	Au	Ag	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	-0.02	-0.05	0.08	-0.14	0.09	0.03	0.03	-0.07	0.09	0.03	-0.08	0.02	0.06
Ag		1.00	0.03	0.05	0.01	-0.02	0.05	0.05	0.06	0.03	0.06	0.05	0.06	0.02
Sn			1.00	-0.06	0.12	0.18	0.26	-0.14	0.04	-0.00	0.04	0.11	-0.05	0.03
Nb				1.00	-0.21	0.48	0.45	0.53	0.50	0.39	0.67	0.25	0.46	0.26
Ta					1.00	-0.02	0.08	-0.21	0.02	-0.15	-0.22	0.20	-0.25	-0.06
W						1.00	0.32	0.03	0.25	0.16	0.37	0.30	0.31	0.08
Zr							1.00	0.27	0.33	0.41	0.41	0.27	0.02	0.19
Ti								1.00	0.38	0.34	0.48	0.01	0.31	0.23
Th									1.00	0.23	0.50	0.33	0.35	0.15
Ce										1.00	0.43	0.05	0.25	0.07
Y											1.00	0.24	0.65	0.21
U												1.00	0.19	0.04
Li													1.00	0.12
La														1.00

The correlation coefficients of elements, except Ag, in each of the above-mentioned geologic units are given in Table 2-11.

In granitic zones, high correlation coefficients (over 0.5) occur in the following combinations ; Nb-W-U, Nb-Zr-Ti-Ce, Nb-Th-Y, Nb-W-Li, W-Y-U, Zr-Th-U, W-Th-Li, and Ce-U. In hornfels zones, high values are present in the combinations of Nb-W-Y, Nb-Th-Y-Li, Nb-Ti-Th-Y, Ce-U and Y-U. In Paleozoic zones, Nb-Ti-Y and Y-Li are the combinations showing high values. In Cenozoic zones, combination of high coefficients are Nb-Zr, Nb-Ti, Nb-Y and Y-Li. From these combinations in each geologic unit, it is found that the correlation coefficient decreases in the order of granitic zones-hornfels-Cenozoic-Paleozoic. This order can be explained by the fact that the granitic rocks contain small amounts of elements with high correlation coefficients, hornfels is distributed around the granitic rocks, the Cenozoic is composed of granitic rock, hornfels and Paleozoic rock clastics.

⑤ Multivariate analysis

To summarize the significance of geochemical data and to facilitate the geology-mineralization correlation and the interpretation of these data, printcipal component analysis were carried out for 13 elements, excluding Ag. Although calculation of all 13 principal components could be made, four principal components that were statistically significant (the ones having eigenvalues over 1.0) were chosen, and their eigenvectors, factor loading values, eigenvalues, proportion and cumulative proportion were obtained, as shown in Table 2-12.

Table 2-11 Correlation Matrix of Each Geological Unit with Stream Sediment Samples

Paleozoic Zones

	Au	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	0.01	-0.01	-0.12	0.04	0.02	0.06	-0.07	0.10	-0.01	-0.11	-0.06	0.05
Sn		1.00	-0.13	-0.02	0.07	0.10	-0.13	-0.09	-0.02	0.00	-0.02	0.00	0.04
Nb			1.00	-0.24	0.27	0.26	0.68	0.45	0.32	0.65	0.10	0.30	0.26
Ta				1.00	-0.14	0.08	-0.27	-0.03	-0.15	-0.30	0.17	-0.22	-0.09
W					1.00	0.05	0.08	0.13	0.09	0.16	0.06	0.14	0.04
Zr						1.00	0.31	0.18	0.39	0.27	0.13	-0.16	0.17
Ti							1.00	0.39	0.35	0.59	0.06	0.29	0.25
Th								1.00	0.19	0.39	0.20	0.27	0.11
Ce									1.00	0.39	0.00	0.09	0.05
Y										1.00	0.11	0.61	0.20
U											1.00	0.12	0.01
Li												1.00	0.08
La													1.00

Cenozoic Zones

	Au	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	0.01	0.07	-0.08	0.06	0.03	0.13	-0.08	0.04	0.03	-0.09	0.04	0.02
Sn		1.00	-0.01	0.06	0.17	0.36	0.02	0.14	0.10	0.15	0.13	0.12	-0.01
Nb			1.00	-0.16	0.17	0.51	0.59	0.48	0.41	0.66	0.08	0.25	0.27
Ta				1.00	0.16	-0.01	-0.15	0.10	-0.16	-0.17	0.33	-0.25	-0.06
W					1.00	0.22	0.05	0.12	0.09	0.20	0.21	0.13	0.05
Zr						1.00	0.41	0.40	0.38	0.46	0.24	0.02	0.16
Ti							1.00	0.29	0.29	0.49	-0.06	0.25	0.25
Th								1.00	0.19	0.49	0.39	0.25	0.13
Ce									1.00	0.42	0.00	0.29	0.08
Y										1.00	0.12	0.59	0.27
U											1.00	0.03	0.04
Li												1.00	0.13
La													1.00

Granite Zones

	Au	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	-0.24	0.12	-0.14	0.09	-0.11	-0.05	-0.00	0.01	0.14	0.08	0.16	0.12
Sn		1.00	-0.21	0.45	-0.02	0.24	0.02	0.19	0.03	0.01	0.05	-0.40	0.10
Nb			1.00	-0.00	0.61	0.60	0.73	0.59	0.61	0.54	0.60	0.69	0.39
Ta				1.00	0.11	0.41	0.17	0.21	0.33	0.01	0.32	-0.13	-0.01
W					1.00	0.40	0.40	0.50	0.46	0.51	0.57	0.60	0.13
Zr						1.00	0.57	0.62	0.76	0.47	0.68	0.15	0.26
Ti							1.00	0.49	0.56	0.45	0.45	0.43	0.25
Th								1.00	0.44	0.50	0.66	0.52	0.40
Ce									1.00	0.40	0.58	0.26	0.22
Y										1.00	0.54	0.45	0.16
U											1.00	0.45	0.37
Li												1.00	0.22
La													1.00

Hornfels Zones

	Au	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	-0.32	-0.18	-0.24	-0.22	-0.03	-0.32	-0.31	0.05	-0.41	-0.40	-0.42	0.09
Sn		1.00	0.22	0.03	0.45	0.36	0.08	0.25	-0.02	0.35	0.34	0.20	0.14
Nb			1.00	0.00	0.56	0.46	0.66	0.57	0.48	0.64	0.29	0.52	0.21
Ta				1.00	0.17	0.15	0.09	0.17	-0.06	0.08	0.24	0.10	0.13
W					1.00	0.46	0.29	0.35	0.21	0.50	0.44	0.44	0.15
Zr						1.00	0.11	0.23	0.49	0.41	0.20	-0.06	0.25
Ti							1.00	0.68	0.40	0.63	0.24	0.62	0.06
Th								1.00	0.26	0.69	0.37	0.57	0.11
Ce									1.00	0.42	0.03	0.17	0.02
Y										1.00	0.52	0.72	0.02
U											1.00	0.50	-0.09
Li												1.00	0.03
La													1.00

Table 2-12 Results of Principal Component Analysis with Stream Sediment Samples

	1		2		3		4	
	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading
Au	0.04	0.08	-0.20	-0.26	-0.49	-0.53	0.46	0.48
Sn	0.03	0.06	0.44	0.57	-0.32	-0.34	0.16	0.17
Nb	0.43	0.85	-0.06	-0.07	0.00	0.00	0.02	0.02
Ta	-0.11	-0.22	0.51	0.66	0.08	0.09	-0.27	-0.29
W	0.27	0.53	0.26	0.33	-0.01	-0.02	0.51	0.54
Zr	0.29	0.58	0.31	0.40	-0.43	-0.46	-0.21	-0.22
Ti	0.31	0.62	-0.28	-0.36	-0.03	-0.03	-0.40	-0.42
Th	0.33	0.66	0.14	0.18	0.25	0.27	-0.20	-0.21
Ce	0.28	0.56	-0.09	-0.12	-0.31	-0.34	-0.14	-0.15
Y	0.43	0.86	-0.07	-0.09	0.09	0.10	0.05	0.06
U	0.19	0.37	0.44	0.57	0.30	0.32	0.10	0.10
Li	0.32	0.64	-0.19	-0.24	0.38	0.42	0.30	0.31
La	0.16	0.32	-0.05	-0.07	-0.24	-0.26	-0.25	-0.27
Eigen	3.91		1.68		1.16		1.10	
Propo.	0.30		0.13		0.09		0.08	
Cum. prop	0.30		0.43		0.52		0.60	

Using factor loading, which represents the correlation between the principal component and the geochemical data, the characteristics of the four principal components can be described as follows.

The 1st principal component:

The highest values of positive correlation are shown by Nb and Y; ranked next are W, Zr, Ti, Th, Ce and Li. Au, Sn and Ta have no correlation with the 1st principal component. Elements having positive values in the factor leading, are often associated with granitic rocks, particularly pegmatite. Hence this principal component is interpreted to indirectly point to granitic rocks. Samples having factor scores of 2.0 or over are numerous in the vicinities of porphyritic biotite granite, such as around Bt.Lapat and Bt.Kayumambang and along S.Nibul. Nb and Ta are alike in geochemical property and generally show similar behavior, but in the survey area Nb behaves rather like Y, differing from Ta. In the granitic rocks of the area, the existence of some minerals with the Nb-Y combination is possible.

The 2nd principal component:

Positive values are shown by Sn, Ta and U. These were obtained from elements, except Au, which show no correlation with other elements in the 1st principal component. The meaning of this principal component cannot be explained geologically.

The 3rd principal component:

Au shows a negative value. This composition is probably the information on Au that was not obtained from the 1st and 2nd compositions.

The 4th principal component:

Au and W show positive values. The information on W, whose behavior is different from Nb and Y, was obtained, so that this composition may be the information on Au and W, showing similar behavior.

(3) **Geochemical anomalies and anomalous zones**

① Threshold setting

As mentioned earlier, the mean value of elements of samples from different geologic units vary significantly. Different from the geochemical prospecting using rock samples, it is not easy to define the geologic units as the sources of the samples or the proportion of their constituents when many geologic units constitute the source zone. If high-grade samples such as Sn occur on the downstream side of the border area of geologic units, artificial division of geologic units is apt to lead to an erroneous conclusion. For example, the occurrence of tin has been confirmed in the known mineralized zone, the samples collected in the down stream side of this zone showed the highest tin content in spite of the fact that the sampling sites were in the Paleozoic zone. In the present analysis, therefore, all the samples were treated collectively, without setting thresholds for the geologic units of the source zone, and twice the standard deviation added to the average value of each element was regarded as an anomaly. The thresholds of the respective element are given in Table 2-13.

Table 2-13 List of Threshold for Geochemical Anomaly with Stream Sediment Samples

Au (ppb)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
4	50	27	64	5	2048	9984	73	652	79	58	31	606

② Extraction of geochemically anomalous zone

When samples from more than two adjacent sites contain anomalous amounts of the same elements, that area was delineated as the geochemically anomalous zone of those elements. Where the anomalous zones of plural elements overlap, they are treated as one zone. As for Sn, however, it may show anomalous values at only one site downstream of the known mineralization; in such a case, even the single site was regarded as an anomalous zone.

③ Distribution and assessment of geochemically anomalous zones

geochemical anomalous zones are extracted the survey area (Table 2-14 and Fig. 2-17). There are 25 anomalous zones for Sn alone, three zones for a few elements such as Nb and Li, and two zones for numerous elements such as Nb, W, Ce and Y. These zones are divided into two ranks, A and B, according to the value of the anomaly. For Sn, the zones with values larger than twice the threshold are assigned A rank, and those with less values B rank. For other elements, ranking of anomalous zones was made by taking into account the number of elements with anomalous values and the number of samples. When thus ranked, there are seven A-rank anomalous zones for Sn and one for other elements. Of these seven A-rank Sn anomalous zones, five are in the western part of the survey area and two in the eastern part. A-rank anomalous zones of other elements are distributed in the north of Bt.Lapat in the central part of the area

The characteristic features of A-rank anomalous zone are as follows.

S. Antan (No.2)

Anomalous values of Sn (83～120 ppm) were detected in three localities. The anomalous zone is composed of the Paleozoic Bt.Pintutujuh Formation. No mineralization of tin or any other elements has been confirmed.

S. Antan (No.4)

Anomalous values of Sn (100～170 ppm) are distributed in four localities. The zone is composed of the Neogene Demadi Formation. No mineralization of tin or other elements has been confirmed in the zone.

S. Antan (No.5)

Anomalous values of Sn (58～170 ppm) are distributed in four localities. The zone is composed of the Neogene S.Empulu Formation.

S. Isahan (No.9)

Anomalous values of Sn (71～330 ppm) were found in three localities. In the zone, the Paleozoic Bt.Pintutujuh Formation and intruding pegmatite are

Table 2-14 List of Geochemical Anomalous Zones with Stream Sediment Samples

No.	Location	Number of anomalous samples	Anomalous elements and the range	Rank
1	S. Cenakobesar	1	Sn:88ppm	B
2	S. Antan	3	Sn:83-120ppm	A
3	Tributary of S. Antan	1	Sn:100ppm	B
4	S. Matah	4	Sn:100-170ppm	A
5	Tributary of S. Antan	4	Sn:58-170ppm	A
6	Tributary of S. Antan	3	Sn:83-95ppm	B
7	S. Antan	1	Sn:60ppm	B
8	S. Antan	1	Sn:180ppm	A
9	S. Isahan	3	Sn:71-330ppm	A
10	S. Tanau	1	Sn:69ppm	B
11	S. Nunusan	1	Sn:54ppm	B
12	S. Sikambu	1	Sn:710ppm	A
13	S. Sikambu	1	Sn:94ppm	B
14	S. Tulang	1	Sn:60ppm	B
15	S. Tulang	1	Sn:54ppm	B
16	S. Muara	5	Nb:27-44ppm Th:91-125ppm U :83-165ppm W :11-17ppm (Ce:680ppm) (Sn:220ppm) Zr:2,450-10,300ppm Y :210-360ppm	A
17	S. Muara	1	Sn:80ppm	B
18	Tributary of S. Gangsal	1	Sn:95ppm	B
19	Bt. Kayumambang	9	Nb:31-33ppm Y :79-130ppm (U:64ppm) W :11-22ppm Li:37-47ppm (Th:85ppm)	B
20	Tributary of S. Empelu	1	Sn:75ppm	B
21	S. Empelu	2	Sn:87-130ppm	A
22	Tributary of S. Empelu	1	Sn:66ppm	B
23	Tributary of S. Endelang	1	Sn:52ppm	B
24	Tributary of S. Endelang	1	Sn:78ppm	B
25	S. Keritang	1	Sn:140ppm	A
26	S. Keritang -- S. Nibul	18	Nb:27-45ppm (Zr:2,200-4,300ppm) (W :9ppm)	B
27	Tributary of S. Nibul	5	Nb:36-45ppm (Y :85ppm) Li:32-36ppm	B
28	S. Salai	5	Nb:28-33ppm Y :85-90ppm Li:32-39ppm	B
29	South of Batuampar	1	Sn:96ppm	B
30	West of Bt. Condong	1	Sn:60ppm	B

distributed. Tin mineralization occurs in this zone.

S. Sikambu (No.12)

A Sn anomalous value (710 ppm) was found at one localities. The Paleozoic Bt.Pintutujuh Formation and pegmatite intruding it are distributed in the zone. Tin mineralization occurs just upstream of the sampling site.

North of Bt.Lapat (No.18)

Anomalous values of Nb (27～44 ppm), W (11～17 ppm), Zr (2,450～10,300 ppm), Th (91～125 ppm), Y (21～360 ppm) and U (83～145 ppm) were found in five localities. Anomalies of Sn (220 ppm) and Ce (680 ppm) are recognized in parts of the zone. The zone is composed of porphyritic biotite granite. No mineralization has been confirmed by geological survey.

S. Empulu (No.21)

Sn anomalies (87～130 ppm) were detected in two localities. The zone is composed of the Neogene S.Empulu Formation and the Paleozoic Bt.Pintutujuh Formation. Tin mineralization has not been confirmed in this zone.

S. Endelang (No.25)

A Sn anomaly (140 ppm) was found in one localities. The zone is composed of the Paleozoic Bt.Pintutujuh Formation. Tin mineralization has not been confirmed in this zone.

The S. Antan should also be mentioned as a zone where many of the B-rank zones occur in the vicinity of the A-rank anomalous zones. They are divided into two groups according to the geology of their respective catchment zones. One group is represented by the B-rank anomalous zones in the Pre-Tertiary System. They comprise No.7 and No.8 anomalous zones located in the northwest extension of a line connecting the above-mentioned S.Sikambu Basin and S.Isahan Basin. The other group comprises those in the Neogene System, as represented by anomalous zones No.3, No.6 and No.10.

3-2 Geochemical Prospecting with Panned Concentrates

The purpose of the geochemical prospecting with panned concentrates is similar to that with stream sediments, but special attention is paid to the rare metal contents in concentrated heavy minerals. Thus, in order to extract mineralized zones of rare metals heavy minerals, the geochemical prospecting with panned concentrates was carried out parallel with stream sediment prospecting.

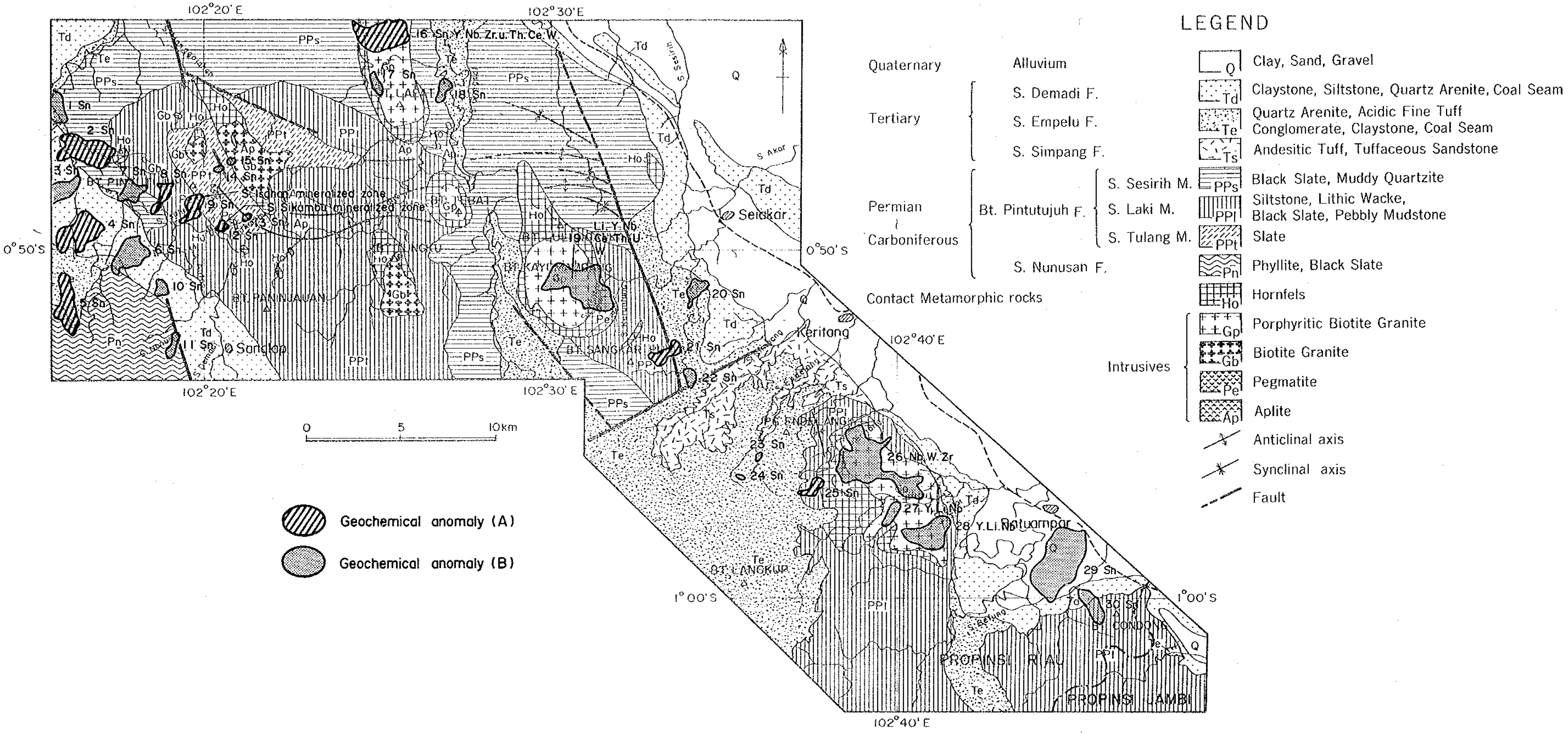


Fig.2-17 Compiled Map of Geochemical Anomalous Zones with Stream Sediment Samples

(1) Sampling and analysis

It was planned to collect samples from the sediments enriched in heavy minerals directly on exposed rocks in rivers, but as the exposures were scarce and no suitable sites for sampling were available, the sands from sites with rapid flow were collected for panning.

Since the elements to be analyzed were as many as 14 and they contained rare earth elements, about 100 g of samples including spare samples was required. Therefore, 10 litre of sands was collected by a shovel, so as to finally obtain 100g for panning.

As the sampling was done by five teams, the sample's weight (degree of enrichment of panned concentrate) varied from team to team and from sample to sample. Accordingly, in the statistical treatment the analytical values were converted into the values for the weight of 100g. The number of samples collected was 210, which corresponds to a sampling density of approximately 0.2 sample/km^2.

The samples were air-dried in the field and were chemically analyzed at Chemex Lab. Inc. of Canada. The analysed elements and the lower and upper detection limits are the same as those of the stream sediments.

(2) Statistical processing

① Method of analysis

After the geochemical data were weighted with the sample weight, the values were converted to natural logarithms and statistical amounts were calculated. When the chemical data were below the lower detection limit, half of the latter value was substituted and when they were over the upper limit of detection, twice the latter value was substituted in the calculation.

② Basic statistical values

Table 2-15 shows the geometric mean, the maximum and minimum values of all the samples. A total of stream sediment and panned 192 samples were collected from the same sites. The average values of the samples of the two groups and their ratio between the two groups are given in Table 2-16. When the geochemical data (average values) of the panning samples were divided by those of the stream sediment samples and the resultant value was taken as the degree of concentration by panning, it showed that the degree of concentration was highest for Sn, being 6.7 times, followed by 1.5～2 times for W and Ce. Other elements ranged from 0.8 to 1.5 times, which indicates little concentration as far as the average values are concerned.

Table 2-15 Basic Statistics of Panned Samples

	Au (ppb)	Ag (ppm)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
Logarithmic Mean	<1	<0.2	19	22	9	2	918	5385	15	107	22	4	7	41
Max.	270	0.5	3400	176	67	120	43260	48720	395	2814	441	126	74	1386
Min.	<1	<0.1	<1	3	<1	<2	73	420	<1	<1	<1	<1	<1	<1

Table 2-16 Comparison of Stream Sediment and Panned Samples in Same Sites

	Au (ppb)	Ag (ppm)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
Stream sediments(A)	0.74	0.10	2.70	15.9	9.7	1.4	650	3861	11.8	69.7	16.4	4.2	10.9	33.0
Pan concentrate(B)	0.79	0.12	18.52	21.4	9.1	2.4	916	5282	14.5	106.5	21.9	3.5	7.2	39.6
B/A	1.1	-	6.7	1.3	0.9	1.7	1.4	1.4	1.2	1.5	1.3	0.8	0.8	1.2

③ Correlation among elements

Table 2-17 shows correlation coefficients of all samples. The combinations having over 0.5 correlation coefficients are Nb-W, Nb-Zr-Ti-Y, Zr-Th-Ce-Y, Zr-Th-Y-U, Nb-Ti-Ce, Nb-Li and Y-La. Correlation among these elements is higher than at of the stream sediments. This is perhaps explained by the fact that the catchment areas of the panned samples are nearly five times larger than those of the stream sediments, and consequently the samples for panning came to show more mixed composition on the average, resulting in the higher correlation.

Table 2-17 Correlation Matrix of Panned Samples

	Au	Sn	Nb	Ta	W	Zr	Ti	Th	Ce	Y	U	Li	La
Au	1.00	0.15	0.46	0.14	0.22	0.38	0.48	0.19	0.26	0.29	0.14	0.37	0.17
Sn		1.00	0.26	0.12	0.34	0.38	0.18	0.34	0.38	0.37	0.38	-0.01	0.19
Nb			1.00	0.33	0.59	0.63	0.88	0.48	0.48	0.56	0.39	0.61	0.42
Ta				1.00	0.12	0.32	0.19	0.06	0.18	0.03	0.27	0.12	0.04
W					1.00	0.38	0.40	0.42	0.29	0.42	0.45	0.49	0.23
Zr						1.00	0.69	0.63	0.73	0.64	0.56	0.18	0.49
Ti							1.00	0.48	0.53	0.54	0.30	0.48	0.46
Th								1.00	0.65	0.69	0.52	0.24	0.44
Ce									1.00	0.58	0.42	0.16	0.39
Y										1.00	0.56	0.33	0.54
U											1.00	0.20	0.25
Li												1.00	0.14
La													1.00

(3) Geochemical anomalies and anomalous zones

① Threshold setting

Geochemical data exceeding the sum of the average value and twofold standard deviation were taken as geochemically anomalous values, same as in the case of the stream sediments. However for Sn, which showed 1,600 ppm in the sample collected 300 m downstream of the known mineralized zone (S. Sikambu), the value obtained by adding the twofold standard deviation to its average value was too high (2,183 ppm) for a threshold. So, the average value plus the standard deviation, over 206 ppm, was regarded as geochemical anomaly. The thresholds of the respective elements are given in Table 2-18.

Table 2-18 List of Threshold for Geochemical Anomaly with Panned Samples

Au (ppb)	Sn (ppm)	Nb (ppm)	Ta (ppm)	W (ppm)	Zr (ppm)	Ti (ppm)	Th (ppm)	Ce (ppm)	Y (ppm)	U (ppm)	Li (ppm)	La (ppm)
7	206	74	78	16	6974	20719	289	1240	216	72	52	1290

② Geochemically anomalous zones

In the geochemical prospecting by panned concentrates, the density of sampling is lower than stream sediments. Therefore, if a certain element showed an anomalous value, the catchment area of that element was taken as the zone of geochemical anomaly.

③ Distribution and assessment of geochemically anomalous zones

Thirty-six anomalous zones were extracted in the survey area (Table 2-19 and Fig. 2-18). Anomalous zones with only Sn are 15; anomalous zones with Sn accompanied by one or two other elements such as Au, Nb, W, Zr and Li, are nine; anomalous zones of only Au are two; those with only W are four; those with only Zr are two; those of Li alone are two; anomalous zone of Nb-W-Li is one and multielement anomalous zone is one.

Those anomalous zones were classified into A rank and B rank based on the value of anomaly. There are 11 areas of A-rank anomaly, which are summarized as follows.

Table 2-19 List of geochemical Anomalous Zones with Panned Samples

No.	Location	Number of anomalous samples	Anomalous elements and the range	Rank
1	Tributary of S. Cenakobesar	1	Sn:263ppm	B
2	S. Antan	1	Au:72ppb Sn:2,000ppm	A
3	Tributary of S. Antan	1	Au:6ppm Ti:40,640ppm	B
4	Tributary of S. Antan	2	Sn:210-608ppm	B
5	S. Antan	3	Sn:236-566ppm	B
6	S. Isahan	1	Sn:3,400ppm W:17ppm	A
7	S. Tulang — S. Sikambu	2	Sn:600-1,600ppm	A
8	S. Tulang	1	W :25ppm	B
9	S. Manggajahan — Bt. Lapat	3	Sn:1,100-1,600ppm	A
10	Bt. Lapat	1	Au:13ppb Sn:931ppm	B
11	Bt. Lapat	2	Sn:285-360ppm	B
12	Tributary of S. Lemang	1	Sn:510ppm	B
13	Tributary of S. Tamberan	1	Sn:537ppm	B
14	Tributary of S. Lemang	1	Sn:220ppm	B
15	S. Gangsal	1	Sn:220ppm	B
16	Bt. Kayumambang	1	W :9ppm	B
17	Bt. Kayumambang	1	Sn:300ppm	B
18	S. Tabu	3	Sn:300-1,400ppm W :9-16ppm	A
19	Bt. Kayumambang	1	Sn:1,056ppm Nb:77ppm	A
20	S. Mentaus	1	Sn:2,500ppm Nb:100ppm	A
21	Tributary of S. Gangsal	1	Sn:400ppm	B
22	Tributary of S. Gangsal	1	Au:96ppb	B
23	S. Akar	1	Sn:2,600ppm	A
24	S. Talang Lakat	1	Zr:9,200ppm	B
25	S. Empelu	1	Sn:714ppm Nb:176ppm Zr:43,260ppm Ti:48,720ppm Th:395ppm Ce:2,814ppm Y :441ppm U :126ppm La:1,386ppm	A
26	S. Empelu	1	Sn:1,159ppm Li:61ppm	A
27	S. Selanama	1	Sn:2,989ppm Zr:15,708ppm Ti:26,355ppm	A
28	S. Keritang	1	Sn:594ppm	B
29	S. Keritang	1	Nb:78ppm W :23ppm Li:68ppm	B
30	S. Keritang	2	W :18-42ppm	B
31	S. Keritang	1	Sn:336-384ppm	B
32	Tributary of S. Nibul	1	Li:57ppm	B
33	S. Salai	1	Li:74ppm	B
34	Southwest of Batuampar	1	Zr:7,854ppm	B
35	S. Gangsal	1	Au:270ppb	B
36	S. Keritang	1	W :15ppm	B

S.Antan (No.2)

Au anomaly (72 ppm) and Sn anomaly (2,000 ppm) were detected in one locality. The catchment area is composed of the Paleozoic Bt.Pintutuuh Formation. This zone overlaps with part of the A-rank anomaly zone by the stream sediments.

S.Isahan (No.6)

Sn anomaly (3,400 ppm) and W anomaly (2,000 ppm) occur in one locality. The catchment area has tin mineralization which overlaps with the A-rank anomaly zone by the stream sediments.

S.Tulang and S.Sikambu (No.7)

Sn anomaly (600~1,600 ppm) is found in two localities. Tin mineralization occurs in the S.Sikambu, and it overlaps with the A-rank anomaly zone by the stream sediments.

West of Bt.Lapat (No.9)

Sn anomaly (1,199~1,600 ppm) was detected in three localities. The Paleozoic Bt.Pintutujuh Formation and porphyritic biotite granite and biotite granite intruding the former are distributed in the catchment area. The geochemical prospecting with stream sediments in this area failed to detect any anomalies of Sn or other elements.

West of Bt.Kayumambang (No.18)

Sn anomaly (300~1,400 ppm) and W anomaly (16~22 ppm) were obtained from three localities. This zone is composed of porphyritic biotite granite. Part of the anomalies overlaps with the A-rank anomaly zone (W) by the stream sediments.

East of Bt.Kayumambang (No.19)

Sn anomaly (1,056 ppm) and Nb anomaly (77 ppm) were detected from one locality. Distributed in the catchment zone are porphyritic biotite granite, Bt.Pintutujuh Formation and hornfels. The anomalous zone partly overlaps with the A-rank anomaly (Nb) by the stream sediments.

S.Mentaus (No.20)

Sn anomaly (2,500 ppm), W anomaly (100 ppm) were obtained from one locality. The geology of the catchment zone is similar to that of the No.19 anomalous zone. Part of the anomalous zone in this area overlaps with the anomalous zone (Nb, W) by the stream sediments.

S.Akar (No.23)

Sn anomaly (2,000 ppm) was detected in one locality. The catchment zone is composed of the Paleozoic Bt.Pintutujuh Formation, the Neogene S.Empulu and S.Demadi Formation. The anomalous zones overlaps partly with the B-rank anomalous zones by the stream sediments.

S.Empulu (No.25)

Anomalous values of Sn (714ppm), Nb (176 ppm), Zr (43,260 ppm), Ti (48,720 ppm), Th (395 ppm), Ce (2,814 ppm), Y (441 ppm), U (126 ppm) and La (1,386 ppm) were detected in one locality. The catchment zone is composed of the Neogene S. Empulu Formation. The anomalous zones does not overlap with that by the stream sediments.

S.Empulu (No.26)

Sn anomaly (1,159 ppm) and Li anomaly (61 ppm) were detected in one locality. The catchment zone is composed of the Paleozoic Bt. Pintutujuh Formation and the Neogene S.Empulu Formation. The anomalous zones in this zone does not overlap with that of the stream sediments.

North of S. Simpang (No.27)

Anomalous values of Sn (2,989 ppm), Zr (15,708 ppm) and Ti (26,355 ppm) were obtained from one locality. The catchment zone is composed of the Quaternary system and the Neogene Empulu Formation. The anomalous zone does not overlap with that of the stream sediments.

There are other B-rank anomalous zones of panned samples, such as No.4 (Sn), No.11 (Sn) and No.32 (Li), which are overlapping with the A- or B-rank anomalous zones of the stream sediments.

3-3 Correlation Between Geochemical Anomalies and Mineralization-Alteration

Relation with mineralized and altered zones are established for A-rank anomalous zones of both stream sediments and panned concentrates at S.Isahan (Sn mineralization) and S.Sikambu (Sn mineralization), and for B-rank zone of stream sediments at S.Salai (argilluzation). According to the result of assay of samples from the tin mineralized zone in S.Isahan and S.Sikambu, Sn is the only element which shows high values in the zone. This is concordant with the high anomalous values of Sn obtained by the geochemical prospecting. In the anomalous zone (Y, Nb, Li) of S.Salai, the contents of Li in the argillized rocks are often less than the detection limit (0.01%), and the values of Nb and Y are close to the crustal abundance. Geochemical anomalous values of elements

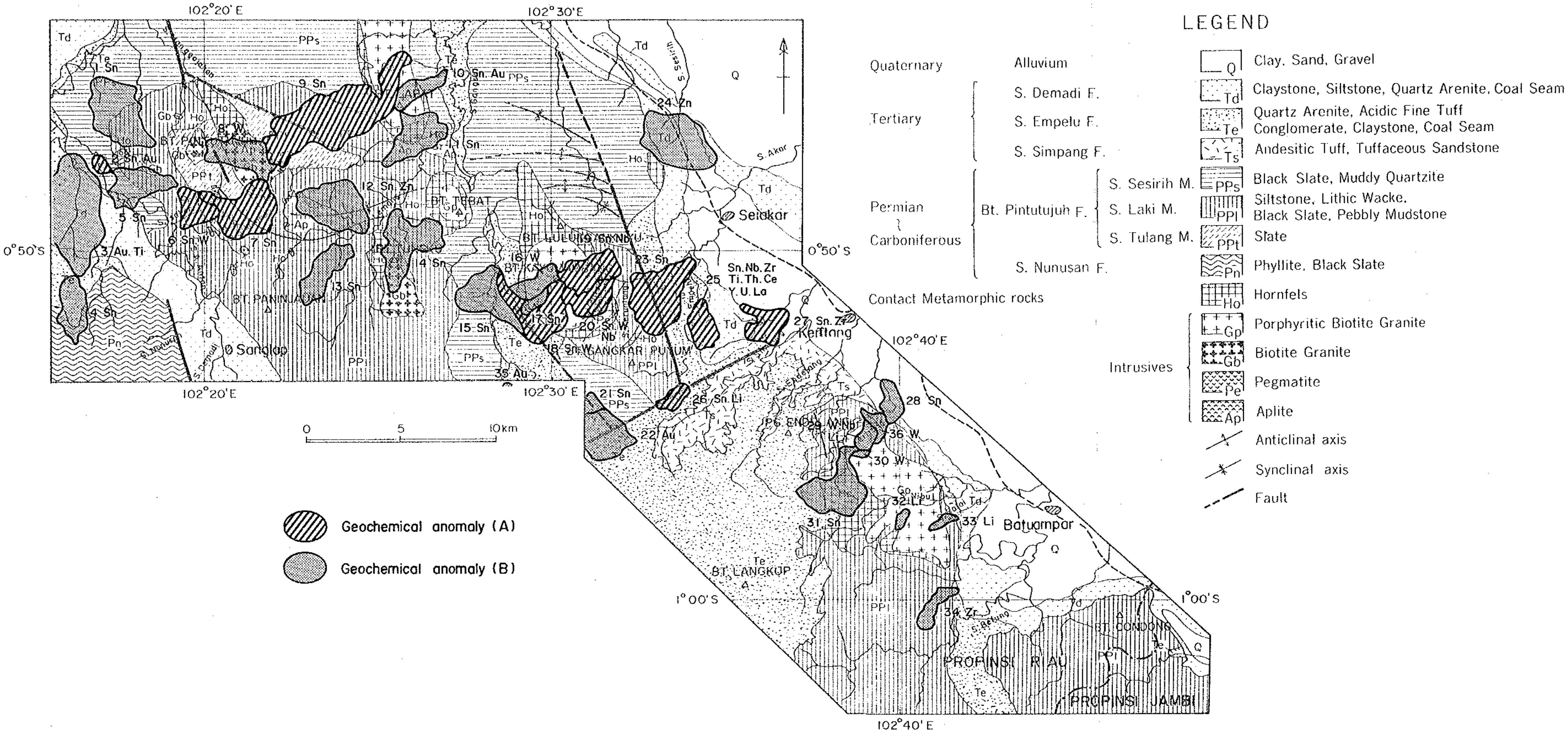


Fig.2-18 Compiled Map of Geochemical Anomalous Zones with Panned Samples

are generally similar to, or three times larger than the crustal abundance. The contents of these elements in the surrounding rocks is not clear, but in the case of the stream sediment samples their high contents compared with those of *other localities may reflect the influence of the argillized rock.*

All other anomalous zones have no mineralization in their catchment zones. Other than the anomalous zones with the Paleozoic or granitic units in their source, a noteworthy anomalous zone is a group of anomalies with Neogene catchment.

The primary mineralization recognized in the survey area are mostly associated with the intrusion of granitic rocks, and they are hosted by granitic rocks or Paleozoic rocks. The Neogene System is distributed unconformably overlying the Paleozoic and granitic rocks. Consequently, the clastics that make up the Neogene System contain the substances supplied from the granitic rocks distributed within the survey area. The alluvial deposits in Malaysia and Australia are known to contain concentrated Sn, Nb, Ta, Y, Ce, Zr and Ti. Certain minerals in the primary mineralized zones or granitic rocks of the present survey area are capable of forming alluvial deposits, if they are heavy minerals with strong resistance to weathering, even though their amounts might be small. In the respect, the stream sediment survey revealed that there are nine A- and B-rank Sn anomalies with Neogene catchment. This is interpreted to suggest the possibility of older alluvial concentration within the Neogene System.