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

PHASE II

FEBRUARY 1991

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to a request extended by the Government of the Republic of Indonesia, agreed to conduct a metallic mineral exploration survey in Pegunungan Tigapuluh Area, and commissioned its implementation to the Japan International Cooperation Agency.

The agency, taking into consideration the importance of the technical nature of this survey, sought the cooperation of the Metal Mining Agency of Japan in order to accomplish the contemplated task.

The Government of the Republic of Indonesia appointed the Directorate of Mineral Resources to execute the survey as counterpart to the Japanese team. The survey is being carried out jointly by experts from both Governments.

The second phase of the collaboration survey consists of geological, geochemical and drilling explorations for metallic minerals.

This report summarizes the results of the second phase of the survey, and will later form a portion of the final report on the results obtained through the survey.

We wish to take this opportunity to express our gratitude to all sides concerned in the execution of the survey.

February 1991

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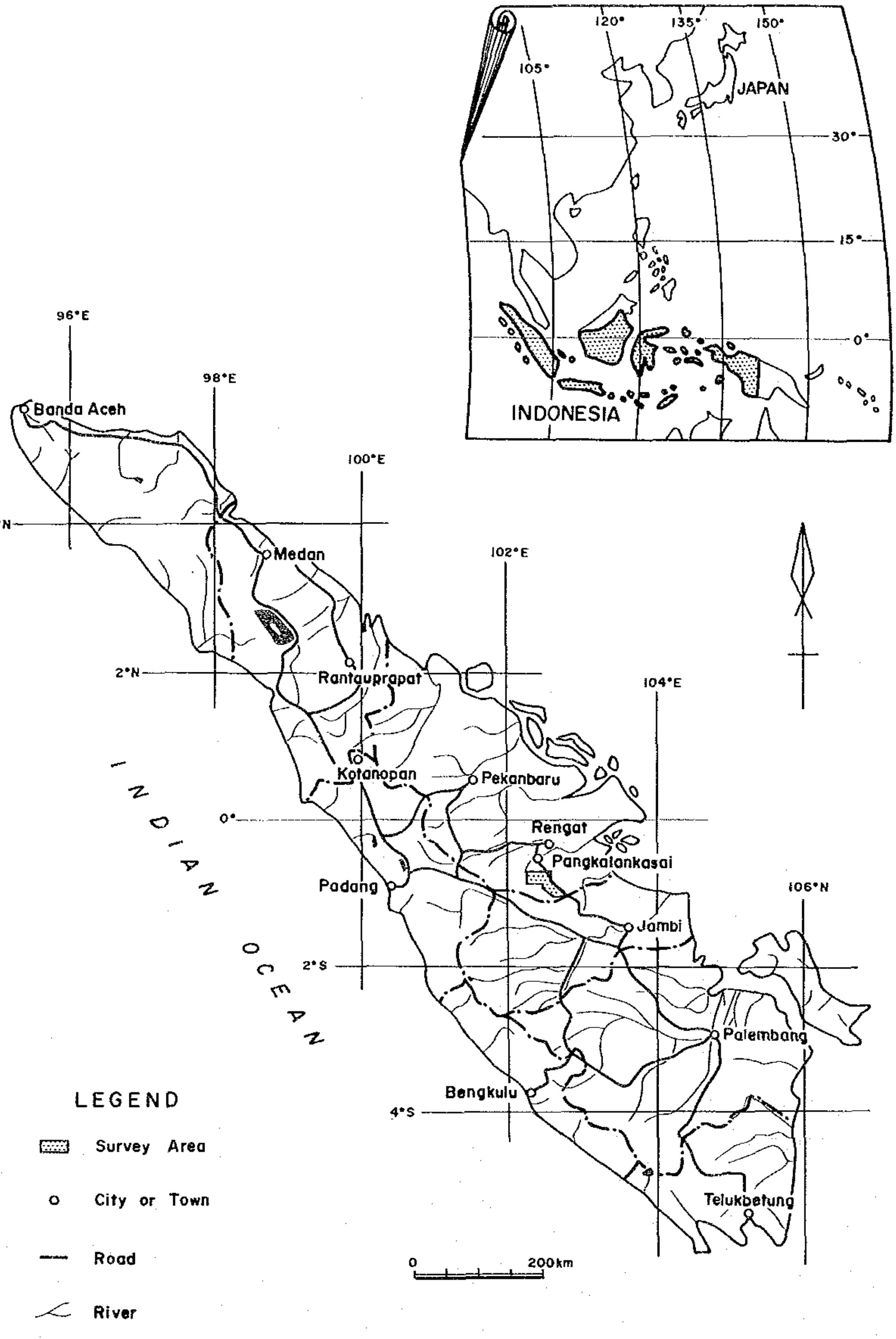

Fig.1-1 Index Map of Survey Area

SUMMARY

This phase corresponds to the second year of the cooperative mineral exploration programme in the Pegunungan Tigapuluh area. Geological survey, geochemical exploration and drilling exploration were carried out for the purpose of evaluating the potential of mineral resources in the Bt.Pintutujuh area by clarifying the geology of the area. The work carried out during the present phase is summarized as follows.

Geological survey	Survey area	70 km²
	Total length of traverse	220 km
Geochemical exploration	Stream sediments	312 pcs
	Panned concentrates	53 pcs
	Soil samples	600 pcs
Drilling exploration	Number of Holes	6 hls
	Total length	606.0 m

The geology in the Bt.Pintutujuh area is composed of Carboniferous to Permian sedimentary strata, Jurassic to Early Cretaceous granitic rocks and Neogene sedimentary strata. The granitic rocks distributed in the area are, from their lithology and chemical composition, classified into biotite granite, leucocratic granite and aplite. They belong to the ilmenite series of granitoids. It is considered that the leucocratic granite is the intrusive facies of granite, and thus it is inferred that the porphyritic biotite granite which is distributed in the area of the first phase survey, exist beneath the leucocratic granite without surface exposures. Fault systems with WNW-ESE and NNW-SSE trends are developed in the survey area. The distribution of the leucocratic granites which host the known tin mineralization are predominantly arranged in approximately WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang. The small bodies of leucocratic granite near S.Sikambu are distributed in approximately NNW-SSE direction. These facts indicate that the intrusion of the leucocratic granite bodies was controlled by the structure which was parallel to the fault system.

The entire survey area of this phase was covered by geochemical exploration using stream sediments and panned concentrates. In addition, soil geochemical survey was carried out over an area of 6 km^2 in which the known mineralized zones were located. Six elements, Au, Sn, W, Th, Ce and U, were analysed.

From the stream sediment geochemistry, six A-rank anomalous zones of

Sn or the combination of Sn and other elements were delineated. These zones are distributed in the central part of the survey area extending approximately in the WNW-ESE direction. Two of them correspond to the known mineralized zones.

Survey of panned concentrates indicated four A-rank anomalous zones in the survey area. The A-rank anomalous zones of both stream sediments and panned concentrates overlap at five localities; S.Pinang, S.Isahan (tin-mineralized zone), branches of S.Tulang (leucocratic granite), lower reaches of S.Sikambu (tin-mineralized zone), and branches of S.Sikambu (leucocratic granite). Either leucocratic granite or tin mineralization in the leucocratic granite are distributed in four of the five localities excluding S.Pinang.

From the soil geochemistry, three anomalous zones were identified; one extending from the upper reaches of S.Isahan to S.Tulang in approximately WNW-ESE direction, the middle reaches of S.Isahan, and the junction of S.Sikambu and S.Tulang.

The elements which constitute A-rank anomalous zones for both stream sediments, panned concentrates and soil anomalies are Sn and W. All these geochemical surveys showed a trend of anomalous zones arranged or extending in the WNW-ESE direction. It coincides with one of the directions which controlled the intrusions of leucocratic granite.

Mineralization is composed of small veins and dissemination in the S.Isahan and S.Sikambu tin-mineralized zones. Quartz is the major constituent mineral in veins. Pyrite, muscovite, tourmaline, calcite and arsenopyrite are associated with quartz in decreasing order. Cassiterite and molybdenite are very seldom found in veins. The sequence of mineralization, which is inferred from the relations of the veins, is quartz-potassium feldspar- tourmaline- muscovite- pyrite- arsenopyrite (-cassiterite or-molybdenite), quartz-potassium feldspar-pyrite, quartz-pyrite and calcite-quartz-pyrite.

Cassiterite, pyrite, tourmaline and muscovite are disseminated in the host rock. The major disseminated mineral is pyrite, and the distribution is limited to leucocratic granite. Cassiterite dissemination was only observed in the leucocratic granite at the S.Sikambu zone.

A total of six holes were drilled at the S.Isahan and S.Sikambu zones. These zones were extracted as being promising from the results of the geological and geochemical exploration mentioned above.

Assay results of drill cores are summarized as follows:

Au: Rather low grade in general, up to 0.07 g/t.
Sn: Up to 0.24 %. Most of them are less than 0.01 % (93 % of total samples).
W: All less than 0.01 %.
Th: ditto
Ce: All less than 0.02 %.
U: All less than 0.01 %.

Zones of the drill cores which contain more than 0.1 % Sn are as follows.

Hole No.	Depth(m)	Width	Sn(%)
MJIT-2	51.0-52.5	1.5m	0.24
(S.Sikambu)	55.5-57.0	1.5m	0.22

The average grade of the cores from MJIT-2, 7.5 m in total length from 49.5 m to 57.0 m including the above listed two samples, is 0.11 % Sn.

Based on the results of geological survey, geochemical exploration and drilling, cassiterite-bearing primary deposit are expected to occur in the survey area. The evaluation of resource potential of the survey area was carried out separately for the two parts, namely the S.Isahan and S.Sikambu zones where drilling exploration was conducted, and other zones.

【 S.Isahan and S.Sikambu 】

Drilling exploration showed that the tin mineralization could occur as either quartz-potassium feldspar-tourmaline-muscovite-pyrite-arsenopyrite-cassiterite veins or cassiterite dissemination in leucocratic granite. Leucocratic granite bodies which can be found to host mineralization cannot be expected to be very large, because it is the intrusive facies of porphyritic biotite granite. The data obtained and presently available is insufficient to conduct ore reserve calculation. However, since the grade exceeds 0.1 % Sn at only two points of MJIT-2 with width of 1.5 m and the maximum content is low at 0.24 % Sn, it is concluded that economically feasible deposits do not occur in the S.Isahan and S.Sikambu zones.

【 Other zones 】

The evaluation of the resource potential was carried out on the bodies of the soil geochemistry as follows.

The Sn geochemical anomalies ranging from 16 to 72 ppm were detected in the broad anomalous zone in the S.Isahan-S.Tulang zone (excluding the drill-tested area at the S.Isahan zone). These anomalous values are similar to the Sn content obtained from soil samples at the drilling sites. Leucocratic granite is distributed and tin mineralization can be expected in this zone. It is concluded from the values and the areal extent of the anomalies of the soil geochemical work that the grade and scale of the mineralization which can be expected here would be similar to those of the S.Isahan and S.Sikambu zones. Other soil anomalies are not of interest because they are either independent anomaly not overlapping with results of other methods or their areal extent is small.

Examination of geochemical anomalies other than those of soil is as follows.

A-rank geochemical anomalies of stream sediments and panned concentrates are obtained from only one locality, at the S.Pinang zone west of the S.Isahan mineralized zone. Anomalous values are distributed along the main stream of S.Pinang, which shows the possibility of mineralization in the upstream areas. The upper reaches of S.Pinang is located at the western extension of leucocratic granite developed between S.Isahan and S.Tulang, and distribution of leucocratic granite can be expected in this zone. It is concluded from the values of the anomalies of the stream sediment and panned concentrate geochemical works that the grade and scale of the mineralization which can be expected here would not exceed than those of the known tin-mineralized zones.

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PART 1 OVERVIEW

Chapter 1 Introduction

1-1 Background and Objectives

The Indonesia-Japan Cooperative Mineral Exploration has been carried out in five areas of the Republic of Indonesia - Sulawesi and other areas - since 1970. As a result of the exploration, a large amount of basic information regarding metallic mineral resource development was obtained. The exploration also contributed greatly to the technical progress of the Geological Survey of Indonesia and the Directorate of Mineral Resources, as well as to the acquisition and accumulation of knowledge regarding geology and mineral deposits of the country.

The Ministry of Mines and Energy of Indonesia planned to 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 headed by Kyoichi Koyama of the Metal Mining Agency of Japan for project-finding, discussing the scope of work and 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.

In 1989, preliminary investigation and the first phase field survey were carried out for the purpose of assessing the potential of mineral resources in the Pegunungan Tigapuluh area. The major works conducted during the first phase were photogeological investigation, geological survey, geochemical exploration and measurements of magnetic susceptibility and radioactivity.

In 1990, successive geological and geochemical survey continued on the Pegunungan Tigapuluh area. Efforts were concentrated on elucidating the relationship between mineralization and geologic structure and also between mineralization and igneous activity, extracting the promising zones, and evaluating the possibility of mineral occurrence of the zones in the area. A drilling programme was carried out during the year.

1-2 Conclusions and Recommendations of the First Phase Survey

1-2-1 Conclusions of the First Phase Survey

During the course of the first phase of the Pegunungan Tigapuluh survey, photogeological investigation, geological survey and geochemical exploration and some associated investigations were carried out with the following conclusions.

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

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 ilmenite series from their chemistry and magnetic susceptibility. 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 differentiation progressed 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 occurs in the central and the eastern part of the area, while the biotite granite in the western and the central part. Both are arranged in the NW-SE direction, which coincides with the line connecting the two known tin occurrences.

Tin mineralization is known at two localities in the western part of the area, S.Isahan and S.Sikambu. They show the features of cassiterite-bearing quartz vein network which is composed of quartz, cassiterite, muscovite, tourmaline and arsenopyrite. The potassium feldspar and plagioclase of the host pegmatite and leucocratic granite are mostly muscovitized and the rocks have been greisenized. Assay results of these mineralized zones are 3.84 % Sn, 0.07 % W, 0.02 % Ce in the high grade part, while those of the samples containing quartz veins in leucocratic granites and pegmatite are 0.2 to 0.5 % Sn, 0.08 to 0.24 % Ce. These zones are characterized by the content of rare metals such as Sn, W and Ce.

Geochemical survey by stream sediments and panned concentrates covered the whole survey area. The samples were analysed for 14 rare metal elements.

Many Sn anomalous zones were extracted from stream sediments, while only two zones were extracted for Nb, W, Zr, Th, Ce, Y, U and Li. Eight anomalous zones of A-rank were delineated for Sn, and one zone for other elements. Two of these Sn anomalies, which showed 71 to 710 ppm Sn, correspond to the known mineralized zones.

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

The known mineralized zones showed geochemical anomalies both with stream sediments and panned concentrates. There are also two Sn anomalous zones located in the northwestern extension of the known mineralization, and two Sn zones located in the Neogene strata along S.Antan and S.Endelang, which displayed anomalies for both types of samples. One W anomalous zone was found near Bt.Kayumambang and one Nb and two Li anomalous zones occur near the S.Nibul porphyritic biotite granite body. In these zones, both stream sediments and panned concentrates had anomalous metal contents. These zones are similar to the known mineralized zones in that the anomalies by different methods overlap, regardless of the absolute values.

From the results of the first phase geological and geochemical exploration, three types of metal concentration were identified to be prospective in the area. Those are: ① primary Sn, W and Ce mineralization, ② primary rare metal mineralization including W, Nb and Li, and ③ placer type Sn concentration.

① The zones prospective for primary Sn, W and Ce mineralization are the known zones and their NW-SE extensions of the S.Isahan and the S.Sikambu zones. Sn anomalies were obtained in the extended zones, which means that the possibility of finding mineralization similar to the S.Isahan is high.

② Although primary mineralization of rare metals (including W, Nb and Li) was not found by geological survey, the results of the geochemical survey in the first phase indicate the existence of these mineralization. Tungsten mineralization is expected near Bt.Kyumambang. Nb and Li concentration is also expected in the vicinity of the S.Nibul porphyritic biotite granite.

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

1-2-2 Recommendations for the Second Phase Survey

Three type of mineralization were expected to occur in the survey area from the results of the first phase exploration. It was recommended that the following survey be conducted during the second phase for locating the mineralization associated with the intrusion of the granitoids and the mechanical concentration of ore minerals supplied from the granitic rocks.

(1) Mineralization related to granitic intrusion.

① Bt.Pintutujuh area

Cassiterite-bearing quartz vein network is developed in the leucocratic granite at S.Isahan and S.Sikambu. It was shown by the study of the geologic structure and geochemical analysis that the possibility of these mineralized zones extending in the NW-SE direction and the existence of new mineralized zones is high. It was recommended that detailed geological survey and geochemical exploration be planned in these zones followed by drilling.

② Bt.Kayumambang and vicinity

Several tungsten anomalies were detected during the first phase. It was recommended that detailed geological and geochemical survey be carried out in order to clarify the nature of mineralization of this zone.

③ Along S. Nibul and vicinity

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

(2) Placer concentration

① Along S.Antan

Tin anomalies were detected in the area of Neogene strata along S.Antan. It was recommended that detailed geological and geochemical survey be carried out in order to evaluate the tin placer concentration.

1-3 Outline of the Second Phase Survey

1-3-1 Survey Area

The survey area, 70 km^2 in size, corresponds to the western part of the first phase survey area, and is surrounded by the coordinates listed below. Administration of the area is under the jurisdiction of the Riau Province. The survey area is shown in Figure 1-2.

①	0° 44' 52"S	102° 18' 02"E
②	0° 47' 08"S	102° 15' 46"E
③	0° 51' 40"S	102° 20' 17"E
④	0° 49' 23"S	102° 22' 34"E

1-3-2 Objectives

This phase corresponds to the second and final year of the cooperative mineral exploration programme in the Pegunungan Tigapuluh area. The major objectives in this phase are elucidating the relationship between mineralization and geologic structure and also between mineralization and igneous activity, and extracting the promising zones for future prospecting. A drilling programme is also included in this phase for evaluating the mineral occurrence in the selected zones.

1-3-3 Exploration Work

Geological survey, geochemical exploration, and a drilling programme were carried out during this year.

(1) 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 1:10,000 scale maps enlarged from the 1:50,000 scale topographic map compiled from the aerial photographs were used in the field. When necessary, a route map was prepared by pacing or with 50 m tape and a Brunton-type compass.

Geochemical samples of both under -80 mesh and panned stream sediments were collected concurrently during the geological survey. Additional soil samples of B-layer at the depth of 40 to 70 cm from the surface were collected systematically (100 m× 100 m grid pattern) for 6 km^2.

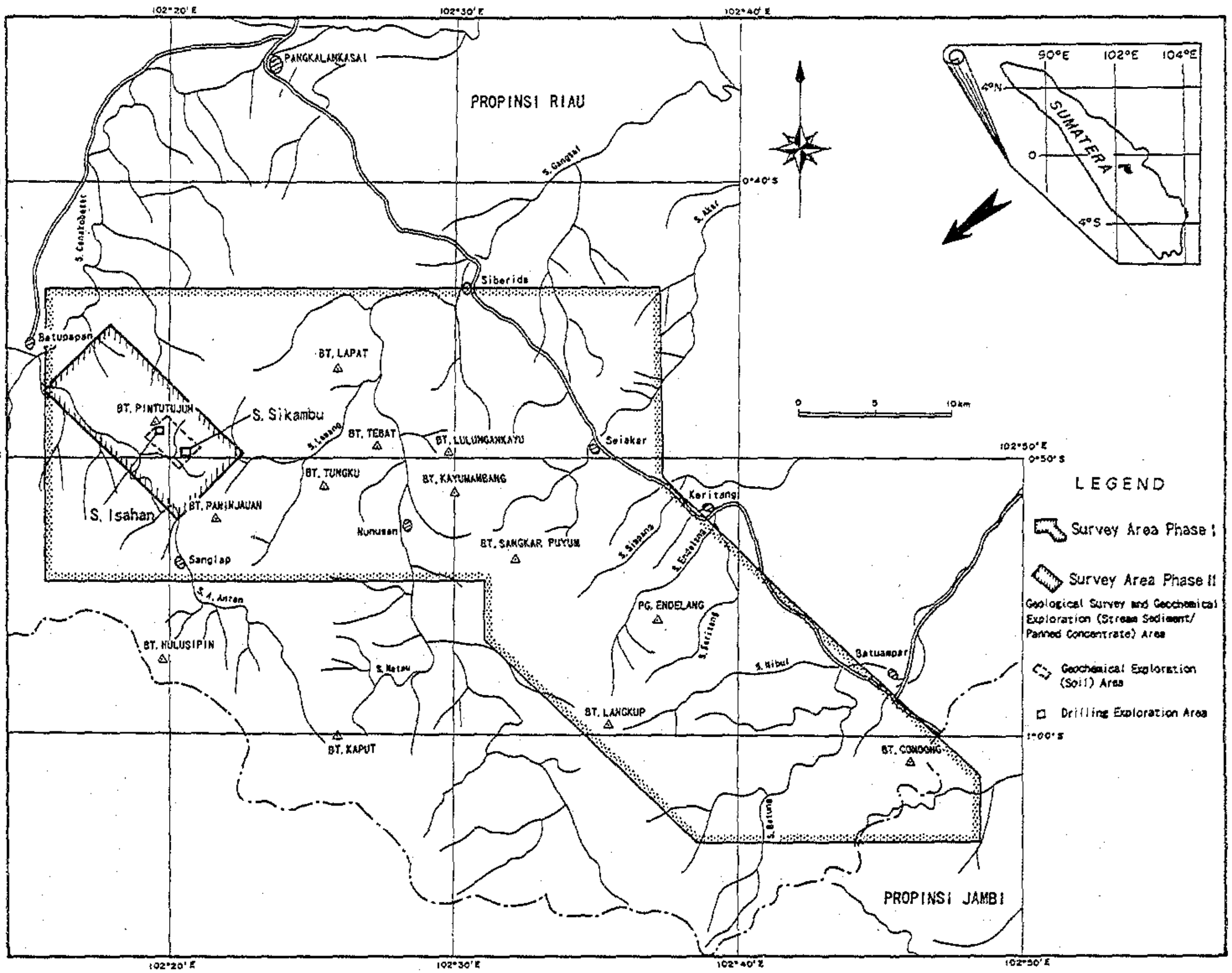


Fig.1-2 Location Map of Geological Survey, Geochemical Exploration and Drilling Exploration Areas

(2) Drilling

A programme of drilling composed of six diamond holes was carried out at selected sites of S.Isahan and S.Sikambu. Each hole was dug vertically to the average depth of 100 m by wireline method. Diameter of the holes was NQ or BQ size except in the shallower parts. Drilled cores were carefully investigated geologically, and the results were compiled on 1:200 scale columns. Colour photographs and thin sections were prepared from the cores. Microscopic observation of the polished sections and chemical analyses were conducted on the mineralized sections of cores.

(3) Content of the survey

The work carried out during the present phase is summarized as follows.

Geological survey and geochemical exploration	
Survey area	70 km^2
Total length of traverse	220 km
Rock samples	
Thin sections	20 pcs
X-ray diffraction analysis	20 pcs
Age determination	3 pcs
Whole rock analysis	10 pcs
Assay (6 elements)	5 pcs
Geochemical samples	
Stream sediments (6 elements)	312 pcs
Panned concentrates (6 elements)	53 pcs
Soil samples (6 elements)	600 pcs
Drilling	
Holes	6 hls
Total length	606.0 m
Rock samples	
Thin sections	21 pcs
Polished sections	11 pcs
X-ray diffraction analysis	5 pcs
Assay (6 elements)	209 pcs

1-3-4 Members of the Survey Team

[Metal Mining Agency of Japan]

Nobuyuki Masuda	Coordinator

[Survey Teams]

Indonesian members (D.M.R.)

Sunarya Johari	Coordinator
Zamri Ta'in	Geologist
Dwi Nugroho	ditto
Suhandi	Surveyer
Rukanda A.R.	ditto
Endang Suwargi	Geologist
Awan Rachman	Drilling engineer
Maman Suherman	ditto
Madiyanto	ditto

Japanese members (NED)

Yoneharu Matano	Team leader, Geologist
Tetsuo Sato	Geologist
Susumu Horiguchi	Drilling engineer
Souji Kannari	ditto
Jun-ichi Kato	ditto

note; D.M.R.: Directorate of Mineral Resources

N E D: Nikko Exploration and Development Co.,Ltd.

1-3-5 Duration of the Survey

Investigation of existing materials

From 6 July to 11 July 1990

Field work

Geological survey and geochemical exploration

From 12 July to 25 September 1990

Drilling

From 9 August to 27 November 1990

Additional survey

From 28 November to 11 December 1990

Laboratory work and report preparation

From 12 November 1990 to 20 February 1991

Chapter 2 Geography of the Survey Area

2-1 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 for 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 eastern side of the range is formed by gentle slopes which are intervened by hilly zones. Alluvial plains consisting of mangrove swamps are widely distributed along the coast.

The survey area corresponds to the northeastern part of the Pegunungan Tigapuluh area and is isolated in the hilly region east of the Barisan Range. The greater part of the area is mountainous, 100 to 350 m in elevation. The highest peak is 356 m in elevation, and is located in the central part of the survey area. Hills lower than 100 m in elevation are developed along S.A.Antan in the southwest of the area.

(2) Drainage system

Most of the drainage systems in the survey area, apart from some in the northeastern end, flow into S.Cenakobesar. Rivers in the north flow north to northwestward, while those in the southern part tend to flow west to southwestward. However, there are some exceptions such as S.Tulang, which is located in the east and flows southward. S.A.Antan, which forms the largest drainage system in the area, meanders and sometimes changes its course, as a whole it flows northwestward and into S.Cenakobesar at the northwestern part of the area. S.Cenakobesar, then, flows into S.A.Bantang Kuantan, and finally the South China Sea.

2-2 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 to October) the southeast 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 rainfall. The climatic differences are most marked in the eastern region of Indonesia. The southeast monsoon, however, brings wet air from the Indian Ocean to Sumatra and it results in lesser climatic changes between the seasons. Also in Sumatra, there are some decrease in rain fall from June to August, but there is almost no dry season.

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, recorded by the Japura Observatory 50 km NNW of the survey area, are shown below.

	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 19 m

(2) Vegetation

The greater part of the mountainous area is covered by virgin tropical rain forests with trees often growing over 20 m tall and over 2 m in diameter. These trees are densely surrounded by a cluster of shorter trees of about 10 m tall and 10 to 50 cm in diameter. It is dark inside such dense forests and a strobe light is always essential for taking photographs in these forests. In general, the undergrowth in the forest is not very thick and it is relatively easy to pass through by cutting grasses and creepers without mechanical aid.

The lowland is mostly composed of forests of lower trees about 10 m tall, which had once been worked and subsequently left neglected. Some of the hills along S.A.Anton produces dry field rice by the slash-and-burn farming.

Chapter 3 Geology of the Survey Area

3-1 Geology of Central Sumatra

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

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

The Carboniferous to Permian sedimentary strata are divided stratigraphically into the Gangsal Formation, Pengabuan Formation and Mentulu Formation. The 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 sequence comprises, 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 to Pliocene Bioni Formation (claystone-sandstone-shale-siltstone alternations), and Korinci Formation (tuffaceous sandstone).

The Jurassic to Cretaceous granitic rocks, composed of granite, granodiorite, pegmatite and quartz porphyry, intrude the pre-Tertiary Systems.

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

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 follows.

"This suture line bounding the western tectonic province and the central tectonic province of the Malay Peninsula crosses over the Strait of Malacca and continues to the Bengkalis depression. Recent oil exploration work has revealed the existence of this Bengkalis depression which is traceable to the north of the Pegunungan Tigapuluh area where the survey area is located. In Cambrian to Early Permian period, the area west of the suture line was the peripheral region of Gondwanaland. This is supported by the distribution of the Carboniferous to Early Permian glacial and marine

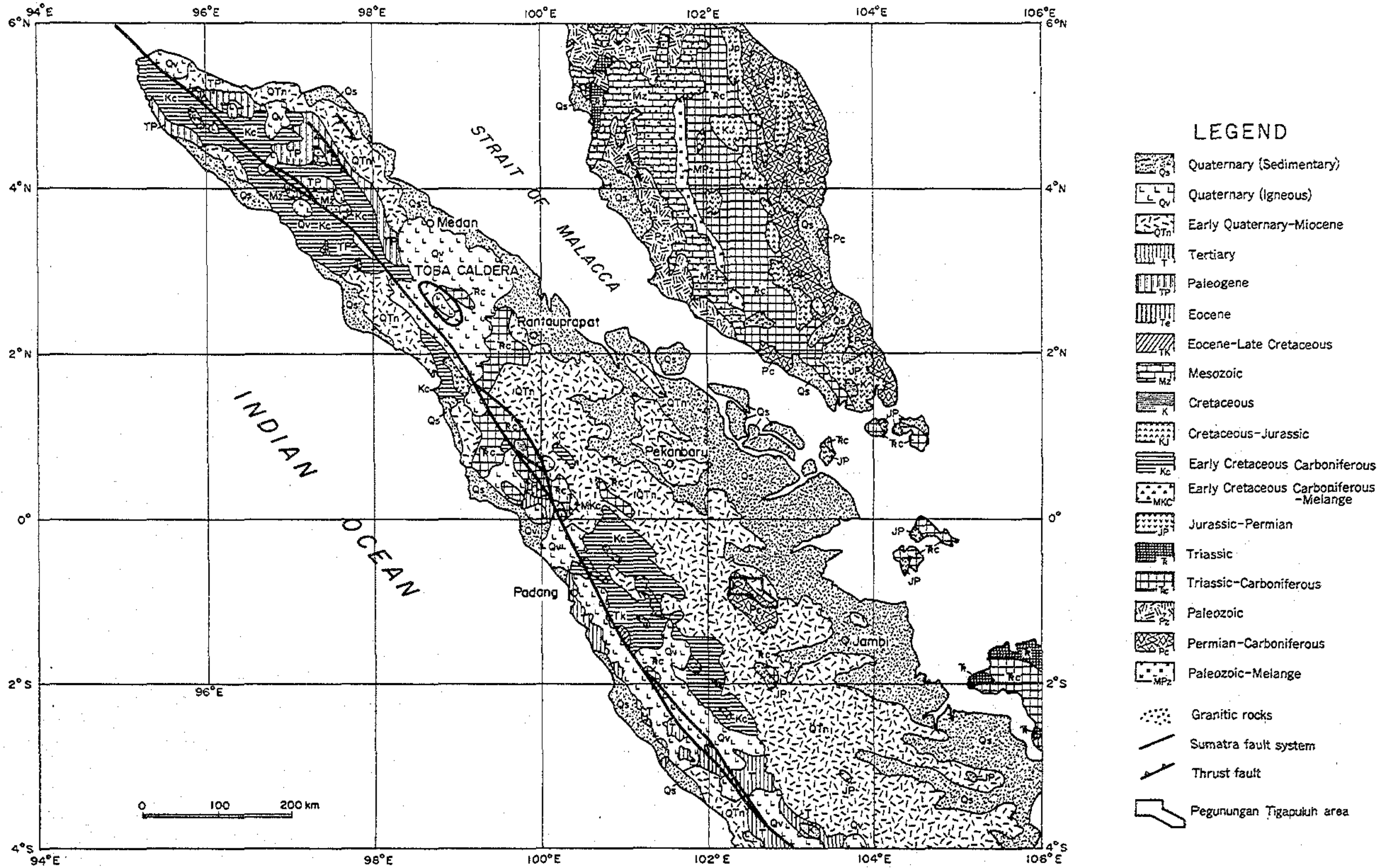


Fig.1-3 Geologic Map of Central Sumatra

sediments in the western area.

The eastern area is characterized by the occurrence of the Cathaysia flora. Around Middle Permian time, the western area was separated from Gondwanaland, and in Middle Triassic time, 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 Triassic period.

Eastern Sumatra was in the compression field until Late Cretaceous, then it switched to the field of tension during the period from Late Cretaceous to Early Tertiary. In association with this shift, formation of rift took place along the fracture zone in the N-S direction. At the beginning of Oligocene epoch, Sumatra returned to the field of compression, and strike-slip faults slipping right-ward developed along the N-S fracture zone in Eastern Sumatra. In Pliocene epoch, Sumatra was in the field of compression which produced NW-trending faults and folds."

3-2 Outline of Past Geological Investigation

The geology of Sumatra, including the present survey area, was described by van Bemmelen (1970). Geologic structure of Indonesia as a whole was reported by Hamilton (1978). As an unpublished reference, there is the geological map of Rengat (scale 1:250,000) prepared 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 during 1974 to 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 to 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 mainly 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 and quartz veins occurring in granites and at the contact between granites and metasedimentary rocks.

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

3-3 Geological Setting of the Survey Area

Major part of 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 to Permian sedimentary formations are known. This geological environments imply the possibility of occurrence of the metallic mineralization accompanying the granite intrusion.

Occurrences of cassiterite and monazite were confirmed in and around the survey area, according to Johari(1989) who discussed the rare metal resources in Indonesia. In addition to that, the existence of other types of deposit, such as pegmatite, greisen and metalliferous veins associated with intrusion of granites, is also possible in this area. This is suggested by the fact that the tin placer deposits of the Bangka Island, east of Sumatra, are accompanied by useful minerals such as monazite and xenotime as well as cassiterite.

3-4 Brief History of Mining in the Survey Area

Neither metallic nor non-metallic mines have been in operation within the survey area. Crude oil in the Tertiary beds has been extracted in several districts in the region from the north of the survey area to the Strait of Malacca. To the west of the survey area, exploration activities for Tertiary coal are in progress.

Chapter 4 Discussions

4-1 Characteristics of Geologic Structure and Mineralization and Factors which Control Mineralization

The geology of the Bt.Pintutujuh area is composed of the Carboniferous to Permian sedimentary strata, the Jurassic to early Cretaceous granitic rocks and the Neogene Tertiary sedimentary strata.

The granitic rocks in the area belong to the ilmenite series, based upon the results of the whole rock analysis carried out during this year and the results of magnetic susceptibility measured during the previous phase.

The granitic rocks of this area are classified into three groups, biotite granite, leucocratic granite and aplite, from their lithology and chemical composition.

The leucocratic granite hosts greisen whose radiometric age is Jurassic (160 to 150 Ma). This age is much closer to that of the porphyritic biotite granite (167 to 134 Ma), which was distributed in the area of the first phase survey, than that of the biotite granite (113 to 110 Ma) in the present survey area.

It is considered from the results of the geological survey and drilling exploration during this year that the leucocratic granite is an intrusive facies of granite. This fact and the age relationship, combined with the general phase relationship between muscovite granite and porphyritic biotite granite in Belitung, Indonesia (the muscovite granite is as the dyke facies of the porphyritic granite according to Schwartz, 1990), suggest the existence of porphyritic biotite granite intruded beneath the leucocratic granite.

During the first phase survey, it was considered from the spatial distribution of the granitic rocks that biotite granite is related to mineralization. However, the results of this year shows that the porphyritic biotite granite has much closer relationship to mineralization.

The relationship between geologic structure and mineralization has been studied as follows.

The photogeological interpretation carried out during the previous phase pointed out that the trend of the majority of lineaments in the pre-Tertiary units is in the WNW-ESE and NNW-SSE direction. The geological survey of the present phase survey indicated that the strike of the major faults is WNW-ESE and NNW-SSE. Regarding the distribution of leucocratic granites which host the known tin mineralization, they are predominantly arranged in the WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang. The exposures of granite dykes have E-W strike. The small bodies of leucocratic granite near S.Sikambu are distributed approximately in the NNW-SSE direction.

The characteristics of mineralization have been studied as follows.

Mineralization in the S.Isahan and S.Sikambu tin-mineralized zones resulted in veinlets and dissemination. Quartz is the major constituent of the veins followed by pyrite, muscovite, tourmaline, calcite and arsenopyrite in decreasing order. Cassiterite and molybdenite occur very sparsely in the veins. The sequence of mineralization, which are inferred from the mineralization of the veins, is quartz-potassium feldspar-tourmaline-muscovite- pyrite- arsenopyrite (-cassiterite or -molybdenite), quartz-potassium feldspar-pyrite, quartz-pyrite, calcite-quartz-pyrite.

Cassiterite, pyrite, tourmaline and muscovite are disseminated in the rock. Disseminated ore minerals are mainly composed of pyrite, and the distribution is limited in leucocratic granite. Cassiterite dissemination which can be observed by unaided eyes occur only in the leucocratic granite at the S.Sikambu zone.

The highest grade detected from cassiterite-bearing quartz vein outcrops is 3.84 % Sn, 0.07 % W and 0.02 % Ce. Samples from trenches 1 to 2 m in width which were excavated in the leucocratic granite contained 0.2 to 0.5 % Sn, and 0.08 to 0.24 % Ce.

Regarding drill cores, analysis showed that the contents of Au, W, Th, Ce and U are all low. The highest Sn content was 0.24 % and most of the samples contained less than 0.01 % (93% of all samples). One of the relatively high Sn zone (sampled 7.5 m in length from 49.5 m to 57.0 m in MJIT-2, leucocratic granite) contained an average 0.11 % Sn.

Phenocrysts of quartz, potassium feldspar, plagioclase and muscovite in the leucocratic granite are fractured and muscovite (sericite) or secondary fine quartz occur among the broken pieces. Greisen was observed in some of the drill holes both in S.Sikambu and S.Isahan. Kaoline was also detected as an alteration mineral. There is no distinct relation between the numbers of veins and alteration in leucocratic granite.

Muscovite (sericite), biotite, calcite or dolomite were observed in the matrices of Paleozoic siltstone, shale and pebbly siltstone. They are often bleached adjacent to quartz vein, producing fine-grained secondary quartz.

There is no clear relation between alteration and grades. High grade assay values were expected in greisen, but it showed no clear tendency of increase in the greisenized parts.

4-2 Geochemical Anomalies and Mineralization

Geochemical explorations of both stream sediments and panned concentrates covered the entire survey area of the present phase. In addition to that, soil geochemistry focusing on the area of 6 km^2 including the known mineralized zones was carried out on this year. Six elements, Au, Sn, W, Th, Ce and U, were analysed.

From the stream sediment geochemistry, six A-rank anomalies of Sn or the combination of Sn and other elements were picked up. These anomalies are distributed in the central part of the survey area arranged in approximately the WNW-ESE direction. Two of the anomalies correspond to the known mineralized zones. Three Sn-anomalies (70 to 400 ppm), two Au-anomalies (10 to 15 ppb) and five W-anomalies (7 to 32 ppm) were detected near the S.Isahan mineralized zone. One Sn-anomaly (710 ppm) was detected near the S.Sikambu mineralized zone.

Exploration by panned concentrates detected four A-rank anomalies in the survey area. They consist of ten Sn-anomalies (600 to >1,000 ppm), three W-anomalies (16 to 55 ppm) and one Th-anomaly (93 ppm) from the upper reaches of S.Isahan to the lower reaches of S.Sikambu. The S.Isahan and S.Sikambu mineralized zones are located in the area.

Overlap of A-rank anomalous zones of both stream sediments and panned concentrates was observed in the following five localities; S.Pinang, S.Isahan (tin-mineralized zone), the branches of S.Tulang (leucocratic granite), the lower reaches of S.Sikambu (tin-mineralized zone), and the branches of S.Sikambu (leucocratic granite). In these localities with the exception of S.Pinang, either leucocratic granite or tin mineralization in the leucocratic granite are found to occur (Fig.1-4).

From the soil geochemistry, three anomalies were identified; one extending from the upper reaches of S.Isahan to S.Tulang in approximately WNW-ESE direction (the S.Isahan-S.Tulang zone), the middle reaches of S.Isahan, and the junction of S.Sikambu and S.Tulang.

Of the above three soil anomalous zones, the S.Isahan-S.Tulang zone occupies the biggest area and Au, Sn and W-anomalies overlap. Au content is 10 to 65 ppb, Sn 16 to 72 ppm, and W 33 to 90 ppm. The S.Isahan tin-mineralized zone and three bodies of leucocratic granite are distributed in the zone. Approximately half of the above anomalous zone overlaps with either the A-rank stream sediment anomalous zone or the A-rank panned concentrate anomalous zone.

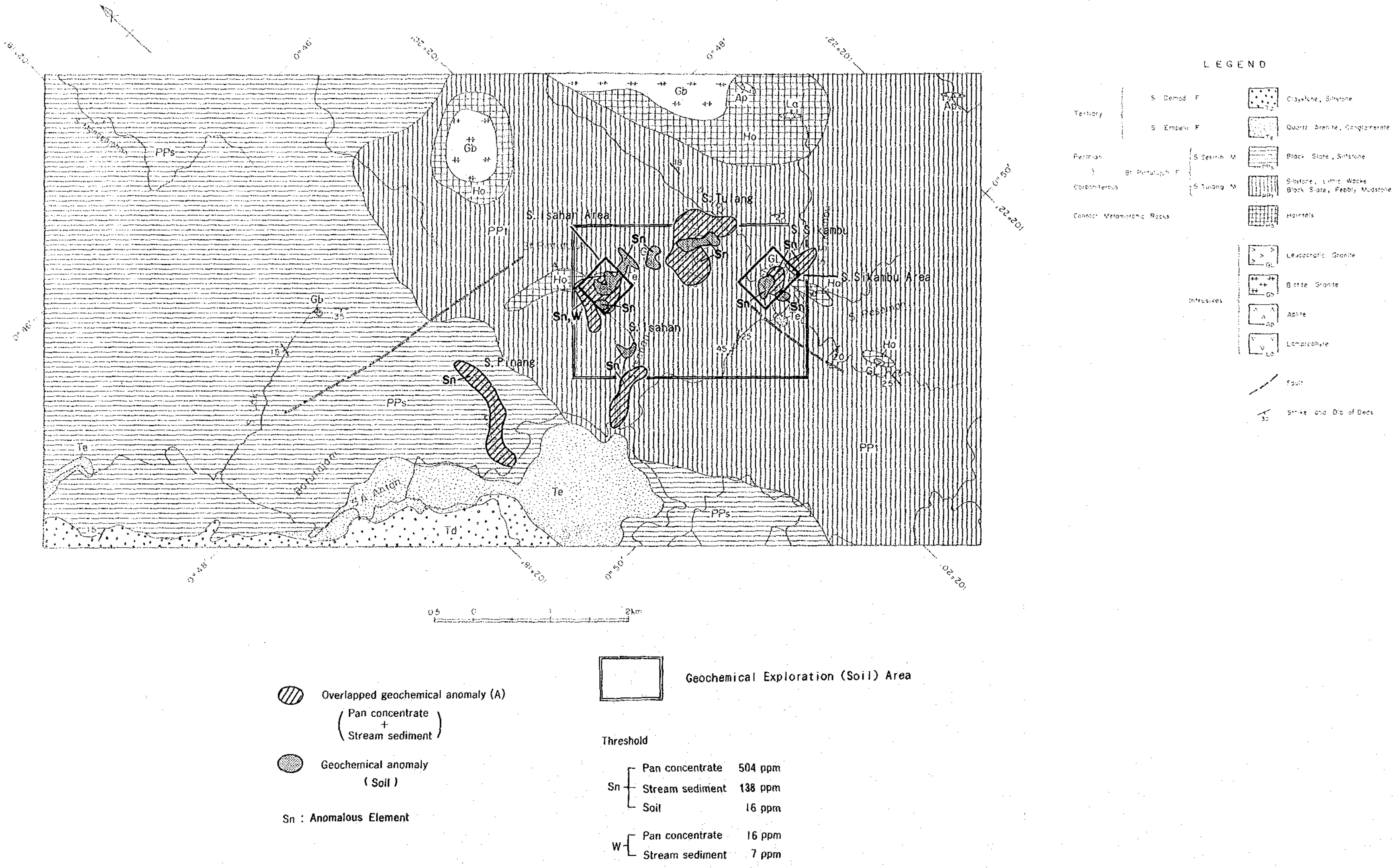


Fig.1-4 Generalized Map of Survey Results

The zone in middle reaches of S.Isahan is composed of three anomalies of Sn only (23 to 150 ppm) without overlap of other elements. Any mineralization or intrusive body is not recognized in the zone. No anomalous value is detected from panned concentrates.

There are Au and Sn anomalies distributed at the junction of S.Sikambu and S.Tulang. Au content is 10 ppb, and Sn 16 to 68 ppm. The S.Sikambu tin-mineralized zone and leucocratic granite are included in the zone.

The elements which constitute the A-rank anomalous zone in stream sediments/panned concentrates and soil anomalies are Sn and W. Thus the geochemical exploration results indicate the possibility of Sn-W mineralization in the survey area. All three geochemical methods showed the trend of anomalous zones arranged or extending in the WNW-ESE direction. This coincides with one of the directions which controlled the intrusions of leucocratic granite. Mineralization, thus, is assumed to be controlled by the structural trend of the same direction as well.

Statistical analysis of correlation coefficients of six elements -Au, Sn, W, Th, Ce and U- analysed in drilling exploration, showed that one of them, W-U, had the negative correlation. W has the tendency to have higher content in siltstone, while U has the high values in leucocratic granite. Tin-tungsten mineralization was expected to occur from the results of geochemical exploration in the survey area. Drilling results, however, showed that the mineralization which could be expected in the area was only tin mineralization.

4-3 Resource Potential

The study of resource potential of the survey area was carried out separately for two parts, namely the drill-tested zone of S.Isahan and S.Sikambu, and other zones.

【 S.Isahan and S.Sikambu 】

The element which can be expected to occur in the S.Isahan and S.Sikambu mineralized zones is Sn, from the results of geological and geochemical surveys and drilling. Drilling exploration showed that the ore grade tin mineralization could occur as either cassiterite-bearing quartz veins (whose mineral assemblage is quartz-potassium feldspar-tourmaline-muscovite-pyrite-arsenopyrite-cassiterite) or cassiterite dissemination in leucocratic granite. Leucocratic granite bodies which can be found to host mineralization cannot be expected to be very large, because it is the intrusive facies of porphyritic biotite granite. The data obtained and presently available is insufficient to conduct ore reserve calculation. However, since the grade exceeds 0.1 % Sn at only two points of MJIT-2 with width of 1.5 m and the maximum content is low at 0.24 % Sn, it is concluded that economically feasible deposits do not occur in the S.Isahan and S.Sikambu zones.

【 Other zones 】

Evaluation of the resource potential was carried out on the basis of the soil geochemistry as follows. The Sn geochemical anomalies ranging from 16 to 72 ppm were detected in the broad anomalous zone in the S.Isahan-S.Tulang zone (excluding the drill-tested area at S.Isahan). These anomalous values are similar to the Sn content obtained from soil samples at the drilling site. As leucocratic granite is distributed, tin mineralization can be expected in this zone. It is concluded from the values and the areal extent of the anomalies of the soil geochemical work that the grade and scale of the mineralization which can be expected here would be similar to those of the S.Isahan and S.Sikambu zones. Other soil anomalies are not of interest, because they are either independent anomalies not overlapping with results of other methods or their areal extent is small.

Examination of geochemical anomalies other than those of soil is as follows.

A-rank geochemical anomalies of stream sediments and panned concentrate are obtained in only one locality, at the S.Pinang zone west of the S.Isahan mineralized zone. Anomalous values are distributed along the main stream of S.Pinang, which shows the possibility of mineralization at the upper reaches. The upper reaches of S.Pinang is located at the western extension of leucocratic granite developed between S.Isahan and S.Tulang.

Chapter 5 Conclusions

5-1 Conclusions

During the course of the second phase survey of the Pegunungan Tigapuluh area, geological survey, geochemical exploration and drilling were carried out in the western part (Bt.Pintutujuh area) with an areal extent of 70 km^2. The conclusions which were obtained from the survey are as follows.

The geology in the Bt.Pintutujuh area is composed of Carboniferous to Permian sedimentary strata, Jurassic to Early Cretaceous granitic rocks and Neogene sedimentary strata.

The granitic rocks distributed in the area are classified into biotite granite, leucocratic granite and aplite from their lithology and chemical composition. They belong to the ilmenite series of granitoids.

It is considered that the leucocratic granite is the intrusive facies of granite, and thus it is inferred that the porphyritic biotite granite which is distributed in the area of the first phase survey, exist beneath the leucocratic granite without surface exposures.

Fault systems of WNW-ESE and NNW-SSE trends are developed in the survey area. From the distribution of the leucocratic granites which host the known tin mineralization, they are predominantly arranged approximately in the WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang. Some of the leucocratic granite dykes crop out with E-W strike. The small bodies of leucocratic granite near S.Sikambu are distributed approximately in the NNW-SSE direction. These facts indicate that the intrusion of the leucocratic granite bodies was controlled by the structure which was parallel to the fault system.

Mineralization is composed of small veins and dissemination in the S.Isahan and S.Sikambu tin-mineralized zones. Quartz is the major constituent mineral in veins. Pyrite, muscovite, tourmaline, calcite and arsenopyrite are associated with quartz in decreasing order. Cassiterite and molybdenite are very seldom found in veins. The sequence of mineralization, which is assumed from the vein mineralization, is quartz-potassium feldspar-tourmaline- muscovite- pyrite- arsenopyrite (-cassiterite or-molybdenite), quartz-potassium feldspar-pyrite, quartz-pyrite and calcite-quartz-pyrite.

Cassiterite, pyrite, tourmaline and muscovite are disseminated in the host rock. Dissemination of ore mineral is mainly composed of pyrite, and the distribution is limited in leucocratic granite. Cassiterite dissemination was only observed in the leucocratic granite at the S.Sikambu zone.

The highest grade detected from cassiterite-bearing quartz vein outcrops was 3.84 % Sn, 0.07 % W and 0.02 % Ce. Samples from trenches 1 to 2 m wide including the quartz veins in the leucocratic granite have composition ranging from 0.2 to 0.5 % Sn and 0.08 to 0.24 % Ce.

Whole survey area of this phase was covered by geochemical exploration using stream sediments and panned concentrates. In addition to that, soil geochemical survey was carried out over an area of 6 km^2 in which the known mineralized zones were located. Six elements, Au, Sn, W, Th, Ce and U, were analysed.

From the stream sediment geochemistry, six A-rank anomalous zones of Sn or the combination of Sn and other elements were delineated. These zones are distributed in the central part of the survey area extending approximately in the WNW-ESE direction. Two of them correspond to the known mineralized zones.

Survey of panned concentrates indicated four A-rank anomalous zones in the survey area. The A-rank anomalous zones of both stream sediments and panned concentrates overlap in five localities; S.Pinang, S.Isahan (tin mineralized zone), branches of S.Tulang (leucocratic granite), lower reaches of S.Sikambu (tin-mineralized zone), and branches of S.Sikambu (leucocratic granite). Either leucocratic granite or tin mineralization in the leucocratic granite are distributed in four of the five localities excluding S.Pinang.

Three anomalous zones were identified from the soil geochemistry; one extending from the upper reaches of S.Isahan to S.Tulang in approximately WNW-ESE direction (the S.Isahan-S.Tulang zone), the middle reaches of S.Isahan, and the junction of S.Sikambu and S.Tulang. Among the three soil anomalous zones, the S.Isahan-S.Tulang zone occupies the largest area (0.3 × 2 km).

The elements which constitute A-rank anomalous zones for both stream sediments, panned concentrates and soil anomalies are Sn and W. All these geochemical surveys showed a trend of anomalous zones arranged or extending in the WNW-ESE direction. It coincides with one of the directions which controlled the intrusions of leucocratic granite.

Assay results of drill cores are summarized as follows:

Au: Rather low grade in general, up to 0.07 g/t.
Sn: Up to 0.24 %. Most of them are less than 0.01 % (93 % of total samples).
W: All less than 0.01 %.

Th: ditto
Ce: All less than 0.02 %
U: All less than 0.01 %

Zones of the drill cores which contain more than 0.1 % Sn are as follows.

Hole No.	Depth(m)	Width	Sn(%)
MJIT-2	51.0-52.5	1.5m	0.24
(S.Sikambu)	55.5-57.0	1.5m	0.22

The average grade of the core from MJIT-2, 7.5 m in total length from 49.5 m to 57.0 m including the above listed two samples, is 0.11 % Sn.

The leucocratic granite is composed mainly of quartz, potassium feldspar, plagioclase and muscovite. Phenocrystals of these minerals are broken. Muscovite (sericite) is recrystallized in the matrix filling the void among the fragments of these phenocrysts. Secondary fine-grained quartz is also formed. Greisen was observed in some of the drill cores both in the S.Sikambu and S.Isahan zones. Kaoline was detected as an alteration product. There is no close relationship between the numbers of veins and the alteration in leucocratic granite.

Siltstone, shale and pebbly siltstone of the S.Tulang Member of the Paleozoic Bt.Pintutujuh Formation contain fragments of quartzite and quartz. They also contain muscovite, biotite, calcite or dolomite in the matrices. Parts of the rock adjacent to quartz veins are bleached, often containing secondary fine quartz.

There is no clear relation between alteration and grades. High grade assay values have been expected in greisen, but there is no clear tendency of the increase of grade in the greisenized parts. The type of ore deposit which are expected to occur in the survey area can be cassiterite-bearing primary deposit, based on the results of geological survey, geochemical exploration and drill. The possibility in each zone are summarized as follows.

【 S.Isahan and S.Sikambu 】

The element which can be expected to occur in the S.Isahan and S.Sikambu mineralized zones is Sn, from the results of geological and geochemical surveys and drilling. Drilling exploration showed that the ore garde tin mineralization could occur as either cassiterite-bearing quartz veins (whose mineral assemblage is quartz-potassium feldspar-tourmaline-muscovite-pyrite-arsenopyrite-cassiterite) or cassiterite dissemination in leucocratic granite. Leucocratic granite bodies which can be found to host mineralization cannot be expected to be very large, because it is the intrusive facies of porphyritic biotite granite. The data obtained and presently available is insufficient to conduct ore reserve calculation. However, since the grade exceeds 0.1 % Sn at only two points of MJIT-2 with width of 1.5 m and the maximum content is low at 0.24 % Sn, it is concluded that economically feasible deposits do not occur in the S.Isahan and S.Sikambu zones.

【 Other zones 】

Evaluation of the resource potential was carried out on the basis of the soil geochemistry as follows. The Sn geochemical anomalies ranging from 16 to 72 ppm were detected in the broad anomalous zone in the S.Isahan-S.Tulang zone (excluding the drill-tested area at S.Isahan). These anomalous values are similar to the Sn content obtained from soil samples at the drilling site. As leucocratic granite is distributed, tin mineralization can be expected in this zone. It is concluded from the values and the areal extent of the anomalies of the soil geochemical work that the grade and scale of the mineralization which can be expected here would be similar to those of the S.Isahan and S.Sikambu zones. Other soil anomalies are not of interest, because they are either independent anomalies not overlapping with results of other methods or their areal extent is small.

Examination of geochemical anomalies other than those of soil is as follows.

A-rank geochemical anomalies of stream sediments and panned concentrate are obtained in only one locality, at the S.Pinang zone west of the S.Isahan mineralized zone. Anomalous values are distributed along the main stream of S.Pinang, which shows the possibility of mineralization at the upper reaches. The upper reaches of S.Pinang is located at the western extension of leucocratic granite developed between S.Isahan and S.Tulang.

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Geological Survey

1-1 Survey Method

This phase was carried out during the second year of the cooperative mineral exploration programme in the Pegunungan Tigapuluh area, Republic of Indonesia. Geological survey was conducted in the area selected as a result of the work of the previous year and its objectives were to elucidate the relationship among mineralization, geologic structure and igneous activity, and to extract promising mineralized zones.

The base camp was established at Pangkalan Kasai located in the northern part of the survey area. Flying camps were also used for periods of one to two weeks. As for transportation, four-wheel drive vehicles between the base camp and the Batupapan village and boats with outboard motor from the village to the northwest were utilized. In the southeastern area, 4 WD vehicles were used where timber roads were usable.

The 1:50,000 scale topographic map, which was prepared during the previous year, was enlarged to 1:10,000 for field use. The mineral showings were studied in detail so as to elucidate the mineralization and alteration.

A total of 220 km was traversed, and the geology was compiled into a 1:25,000 map. The numbers of samples collected and prepared during the present investigation are; 20 for thin sections, 20 for X-ray diffraction analyses, 3 for age determination, 10 for whole rock analyses, and 5 for assaying.

1-2 Outline of Geology

The geology of the survey area consists of Carboniferous to Permian and Tertiary Systems, and granitic rocks intruded into the Carboniferous to Permian. The Paleozoic comprises the Bt.Pintutujuh Formation. It is composed of siltstone and black slate, and subdivided by lithofacies into the S.Tulang and S.Sesirih Members.

The granitic rocks intruding into the Paleozoic strata are classified by lithofacies into biotite granite, leucocratic granite and aplite. The biotite granite was intruded in Early Cretaceous. Due to the intrusion of these rocks, Carboniferous to Permian sedimentary strata underwent contact metamorphism and were altered to hornfels. Lamprophyre occurs in the southern part of this area.

The Neogene System, consisting of quartzose arenite and claystone, is distributed unconformably over these rocks.

Faults of WNW-ESE and NNW-SSE systems are recognized in this area.

Figure 2-1 shows the geology and geologic sections. Figure 2-2 shows the stratigraphy and outline of igneous activity in the survey area.

1-3 Stratigraphy

(1) Bt.Pintutujuh Formation

This formation is divided by lithofacies into two members; namely, the S.Tulang and S.Sesirih Members in ascending order. Outcrops of both members are observable in the area between S.A.Antan (west of Bt.Pintutujuh) and S.Tulang.

① S.Tulang Member

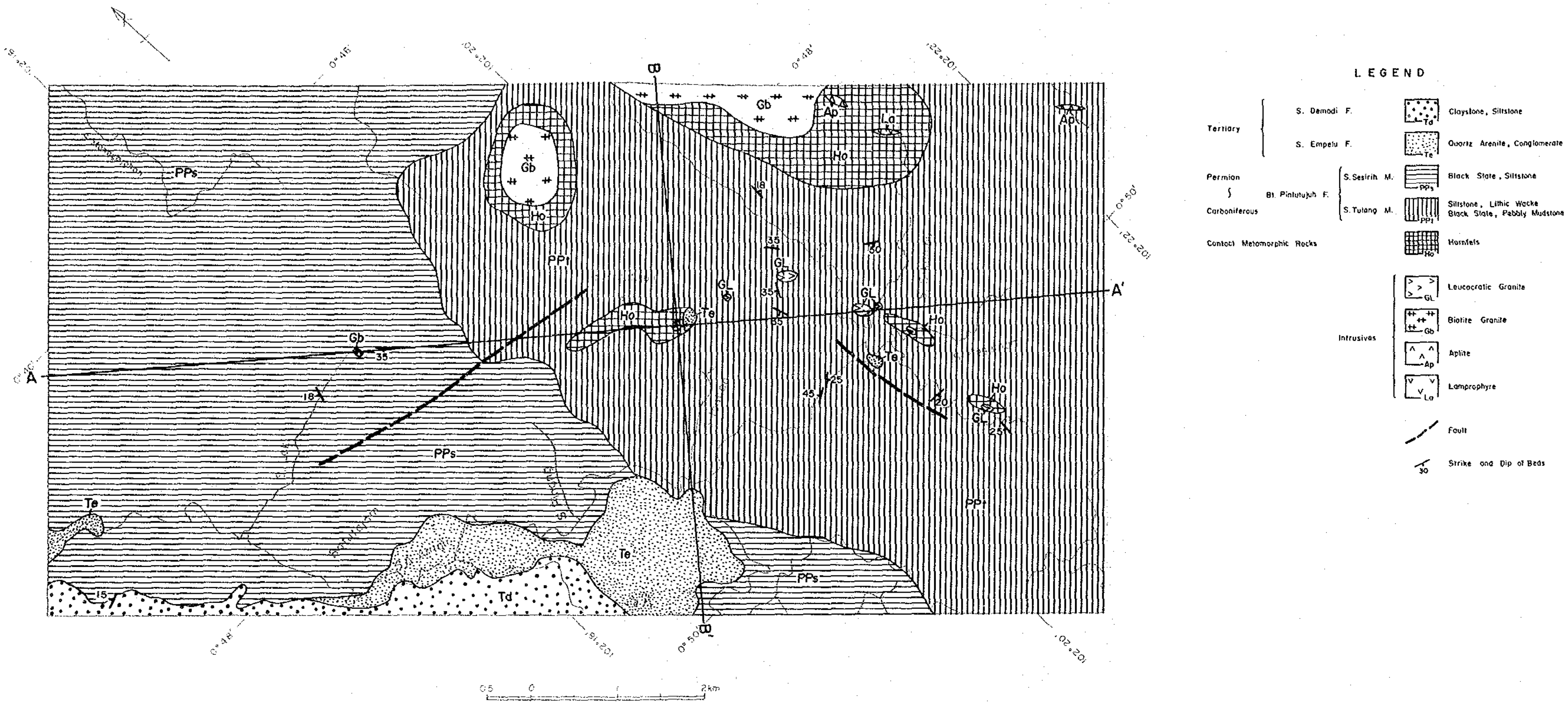
This member is widely distributed in the southeastern part of the area. It consists mainly of siltstone and lithic grey wacke of colours varying from grey, dark grey and dark greenish grey (rarely). Black mudstone or black slate are intercalated in the member. It is generally massive, and bedding is rarely developed. It sometimes contains various kinds of fragments of 1 to 3 mm diameter, such as pelitic rocks, quartzite, quartz grains and feldspar crystals. In the upper reaches of S.Laki and in the lower reaches of S.Tulang, this member contains subangular to subround 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, over 500 m thick, forms the lowest formation in the area and is correlated with a part of the Muntulu Formation of the Rengat sheet.

② S.Sesirih Member

This member is distributed in the northwestern part of the area. The constituents are black mudstone and slate. It is generally massive, and cleavage is not developed. The bedding is virtually unrecognized. Sometimes, the lithofacies partly becomes silty or sandy. To the west of Bt.Pintutujuh, the member is intercalated with grey pelitic quartzite. When weathered, the mudstone and slate become grey soft rocks. The S.Sesirih Member has a thickness of over 500 m, and is correlated with a section of the Muntulu Formation of the Rengat sheet.

(2) S.Empelu Formation

This formation is distributed somewhat widely along S.A.Antan. It is



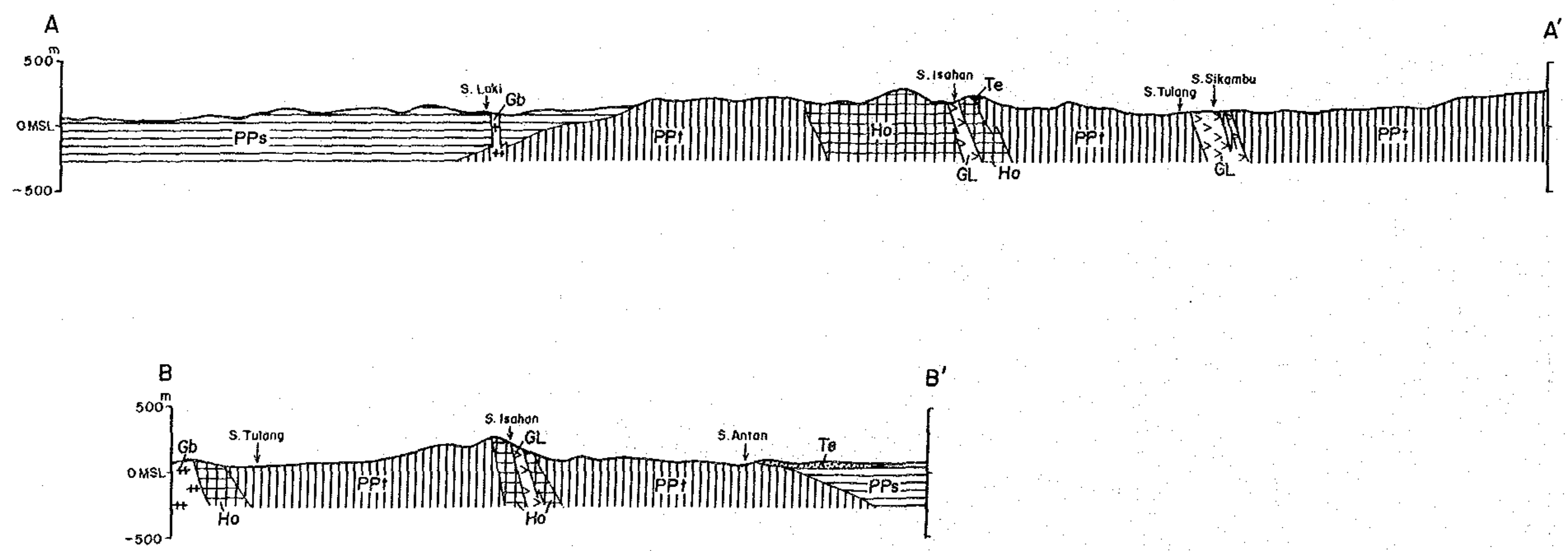


Fig.2-1 Geologic Map of Survey Area

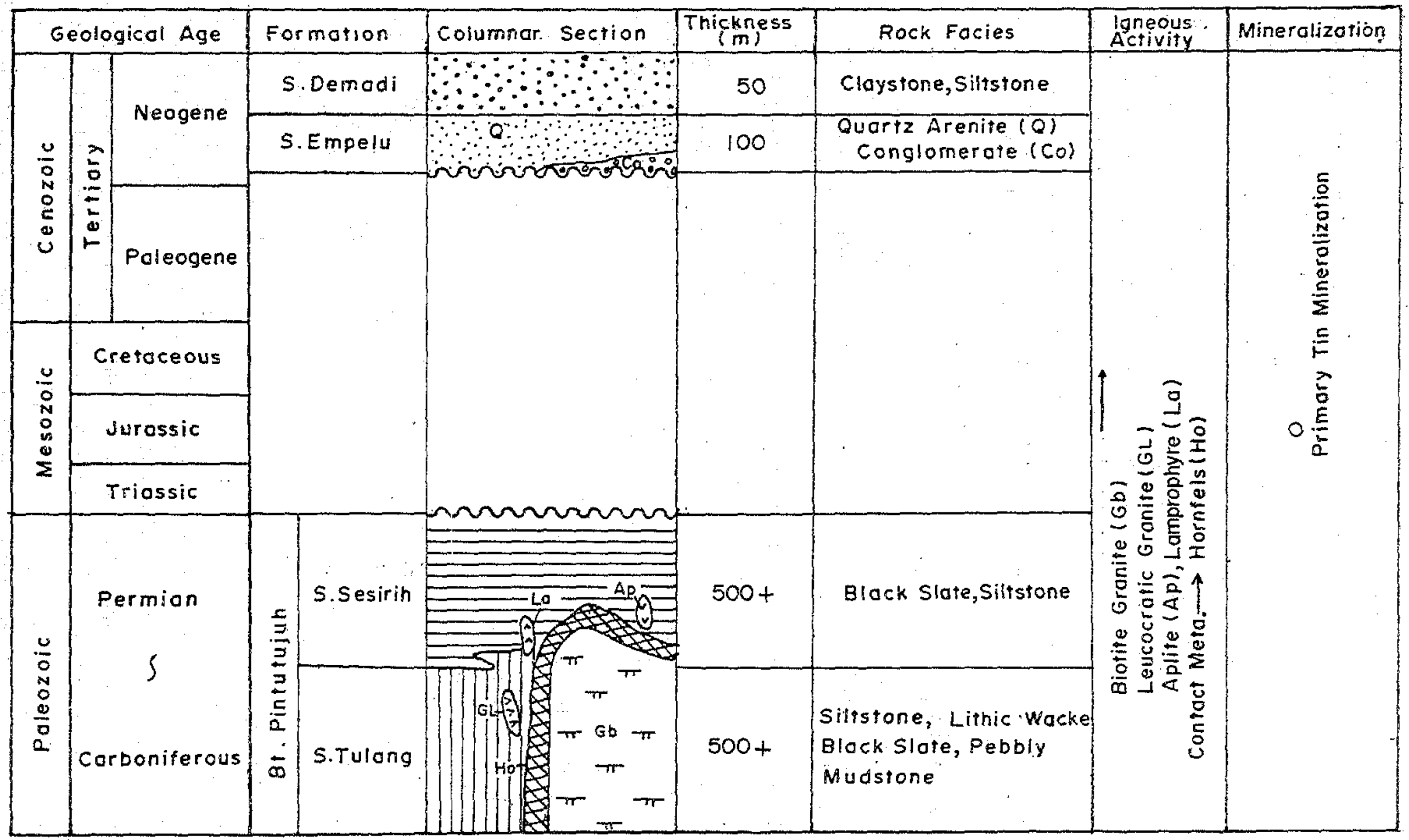


Fig.2-2 Schematic Geologic Column of Survey Area

also distributed in smaller scale at the upper reaches of S.Isahan, and at the junction of S.Tulang and S.Peseman. It consists mainly of greyish white or grey quartzose arenite. It is poorly 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 grey claystone of 10 to 30 cm thick. 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. It has a thickness of 100 m. It is correlated with the Early Miocene Lakat Formation of the Rengat sheet.

(3) S.Demadi Formation

This formation is distributed along S.Antan in the western margin of the area, resting conformably on the underlying S.Empelu Formation. The major constituents are claystone and siltstone. The lower part is intercalated with quartzose arenite. The claystone is grey to dark grey, while the siltstone is greyish yellow. 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. This formation has a thickness of 50 m. It is Early to Middle Miocene in age, and is correlated with the Tualang Formation and the Gemai Formation of the Rengat sheet.

1-4 Intrusive Bodies

The intrusive bodies distributed in the present area are granitic rocks comprising biotite granite, leucocratic granite, aplite and lamprophyre, which intruded into the Paleozoic strata.

(1) Biotite granite

Three bodies of biotite granite occur to the east and north of Bt.Pintutujuh.

The principal rock-forming minerals of this granite are quartz, potassium feldspar, plagioclase, biotite, hornblende and cummingtonite. Under the microscope, these minerals show equigranular or glomeroporphyritic texture. Potassium feldspar and plagioclase are saussuritized. Some biotite is altered to chlorite.

This rock intruded in Early Cretaceous (113 Ma) according to K-Ar dating.

(2) Leucocratic granite

Small bodies of the leucocratic granite are distributed in the upper reaches of S.Isahan, along S.Sikambu and S.Peseman. Outcrops of these bodies have oval shape of 100 m× 200 m in size, or form dykes of 1 m to 5 m in width. Principal minerals are quartz, potassium feldspar and plagioclase. Small amount of muscovite is associated. These minerals show graphic/ pegmatitic or equigranular texture under the microscope. Potassium feldspar and plagioclase are saussuritized.

Greisenization of the rock is observed at the upper reaches of S.Isahan and along S.Sikambu. These greisenized samples show the age of Middle Jurassic (160 to 150 Ma) from K-Ar dating. Thus the intrusion of this granite occurred prior to the Middle Jurassic.

(3) Aplite

Aplite occurs as small dykes along S.Lemang and S.Sikambu in the southeastern part of the area. The major constituents are quartz, potassium feldspar, plagioclase, muscovite and biotite, and they form graphic texture. Plagioclase is strongly saussuritized. Along S.Lemang, this shows transitional facies from aplite to high-temperature quartz vein, and the mineral composition changes to a large amount of quartz and a very small amount of plagioclase and potassium feldspar.

(4) Lamprophyre

The rock occurs as small dykes along S.Sikambu in the southern part of the area.

Principal constituent minerals are plagioclase, biotite, quartz and muscovite. Actinolite and calcite also occur in the rock as metamorphic or alteration products. It shows porphyritic texture in general, but sometimes have ophitic texture. Biotite contained in the rock shows characteristic plechroism (pale reddish brown to plain colour). These facts indicate that this rock was contact-metamorphosed into the amphibolite facies or epidote-amphibolite facies.

(5) Chemical composition

Three biotite granite samples, six leucocratic granite, and one lamprophyre, a total of ten samples were collected, and analysed for 13 major components and 13 trace elements (Tables 2-1 and 2-2).

The analytical results of the major elements and weight ratios of C.I.P.W. norm minerals are given in Table 2-1.

Table 2-1 Analytical Results of Major Elements and Weight Ratios of C.I.P.W. Norm Minerals of Intrusive Rocks

No.	FR-5	FR-7	FR-9	FR-14	FR-15	FR-16	FR-19	FR-27	GR-29	GR-63
Rock Name	La	La	Gl	Gl	Gl	Gl	Gl	Gl	Gb	Gb
SiO_2	47.32	59.27	71.28	76.26	63.65	73.11	69.36	74.17	63.12	60.07
TiO_2	0.63	0.84	0.01	0.01	<0.01	0.01	0.03	0.01	0.56	0.61
Al_2O_3	12.89	14.92	16.61	14.73	20.84	14.22	18.06	14.86	15.38	15.43
Fe_2O_3	0.86	1.31	0.51	0.06	0.53	1.10	0.09	0.00	1.11	1.49
FeO	6.60	6.05	0.36	0.22	1.17	0.57	0.52	0.20	4.05	5.08
MnO	0.13	0.14	<0.01	<0.01	0.08	0.01	0.02	<0.01	0.09	0.13
MgO	8.24	2.67	0.02	0.34	0.07	<0.01	0.04	0.20	1.95	2.74
CaO	6.80	4.98	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	3.95	4.60
Na_2O	2.68	2.12	0.11	<0.01	0.13	0.15	0.08	0.11	2.69	2.80
K_2O	1.41	3.64	6.12	3.65	7.93	8.58	4.75	6.98	4.38	3.49
P_2O_5	0.12	0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.11
BaO	0.07	0.12	0.05	0.04	0.08	0.04	0.04	0.04	0.12	0.11
LOI	9.07	1.22	4.30	3.72	3.37	1.97	5.48	2.70	1.27	1.59
Total	96.82	97.48	99.39	99.05	97.87	99.77	98.48	99.28	98.79	98.25
Q	0.00	15.52	47.09	61.60	31.60	39.33	50.27	46.36	17.47	14.10
C	0.00	0.00	9.81	10.77	12.05	4.69	12.79	7.13	0.00	0.00
or	8.33	21.51	36.17	21.57	46.87	50.71	28.07	41.25	25.89	20.63
ab	22.66	17.93	0.93	0.04	1.10	1.27	0.68	0.93	22.75	23.68
an	18.98	20.45	0.00	0.00	0.00	0.00	0.00	0.00	16.96	19.23
di-wo	5.83	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.77	1.20
di-en	3.62	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.57
di-fs	1.87	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.61
hy-en	12.16	6.12	0.05	0.85	0.17	0.01	0.10	0.50	4.50	6.25
hy-fs	6.29	8.20	0.23	0.35	1.85	0.14	0.87	0.36	5.35	6.72
ol-fo	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ol-fa	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mt	1.24	1.89	0.74	0.08	0.77	1.59	0.13	0.00	1.61	2.17
il	1.20	1.60	0.02	0.02	0.01	0.02	0.06	0.02	1.06	1.16
ap	0.28	0.47	0.01	0.01	0.01	0.01	0.01	0.01	0.28	0.26
Total	87.67	96.14	95.04	95.28	94.41	97.76	92.96	96.54	97.39	96.55
D.I.	30.99	54.96	84.19	83.21	79.57	91.31	79.02	88.54	66.11	58.41

Abbreviation

Gb:Biotite granite Gl:Leucocratic granite La:Lamprophyre

The C.I.P.W. norm figures of the leucocratic granite are plotted along a line between (quartz)-(orthoclase+albite) on the quartz-potassium feldspar-plagioclase norm weight diagram (Fig.2-3). Regarding the differentiation index (Table 2-1, D.I.), the biotite granite has values between 54 and 67%, whereas the leucocratic granite shows higher values between 79 and 92 %. This indicates that the latter is in a higher state of differentiation than the former.

As for the comparison of alkali-lime content, the alkali-lime ratios of the respective rocks are shown in Figure 2-4. It is seen from the figure that the leucocratic granite is characterized by its higher K_2O-content than the biotite granite.

The S-type/I-type and the magnetite series/ilmenite series divisions of granite are used for clarifying the nature of material which generates the felsitic magma to produce granite. The biotite granite is situated along the boundary of the S-type and I-type regions on the ACF diagram, while it is distributed in the I-type zone on the C/ACF-$Al_2O_3/(CaO+Na_2O+K_2O)$ diagram. On the Fe^{2+}/Fe^{3+}-SiO_2 diagram (used to discriminate between magnetite series and ilmenite series), the biotite granite belongs to the ilmenite series.

Table 2-2 Assay Values of Trace Elements Contained in Intrusive Rocks

Sample No.	Rock Name	F ppm	W ppm	Sn ppm	Li ppm	Rb ppm	Sr ppm	Ce ppm	Th ppm	Ta ppm	U ppm	Nb ppm	Y ppm	Zr ppm
FR-5	Gb	380	3	2	35	37	190	40	11.0	<2.0	2.4	11	23	89
FR-7	La	560	17	4	35	110	205	100	26.0	<2.0	4.4	15	48	185
FR-9	Gl	260	125	3	6	295	5	6	35.0	4.0	7.6	25	110	79
FR-14	Gl	1450	95	5	33	330	2	6	37.0	14.0	10.8	46	155	71
FR-15	Gl	1460	17	90	64	830	3	4	22.0	<2.0	10.4	24	240	76
FR-16	Gl	620	3	2	34	460	8	22	34.0	<2.0	8.0	16	110	73
FR-19	Gl	770	175	4	29	410	4	16	28.0	4.0	24.6	18	120	61
FR-27	Gl	1120	225	5	27	540	3	8	27.0	6.0	13.6	20	170	73
GR-29	Gb	530	<2	5	25	145	215	106	33.0	<2.0	7.4	16	41	150
GR-63	Gb	510	<2	3	23	123	215	64	24.0	<2.0	10.4	18	45	140

Abbreviation

Gb:Biotite granite Gl:Leucocratic granite La:Lamprophyre

Geometric mean, maximum and minimum values of the trace element content are shown in Table 2-3.

Table 2-3 Basic Statistics of Assay Values of Trace Elements Contained in Intrusive Rocks

	F ppm	W ppm	Sn ppm	Li ppm	Rb ppm	Sr ppm	Ce ppm	Th ppm	Ta ppm	U ppm	Nb ppm	Y ppm	Zr ppm
Geom. Mean	665	16	5	27	239	19	20	26	2	8.4	19	85	93
Max.	1460	225	90	64	830	215	106	37	14	24.6	46	240	185
Min.	260	<2	2	6	37	2	4	11	<2	2.4	11	23	61

Table 2-4 shows the matrix of correlation coefficients of all samples.

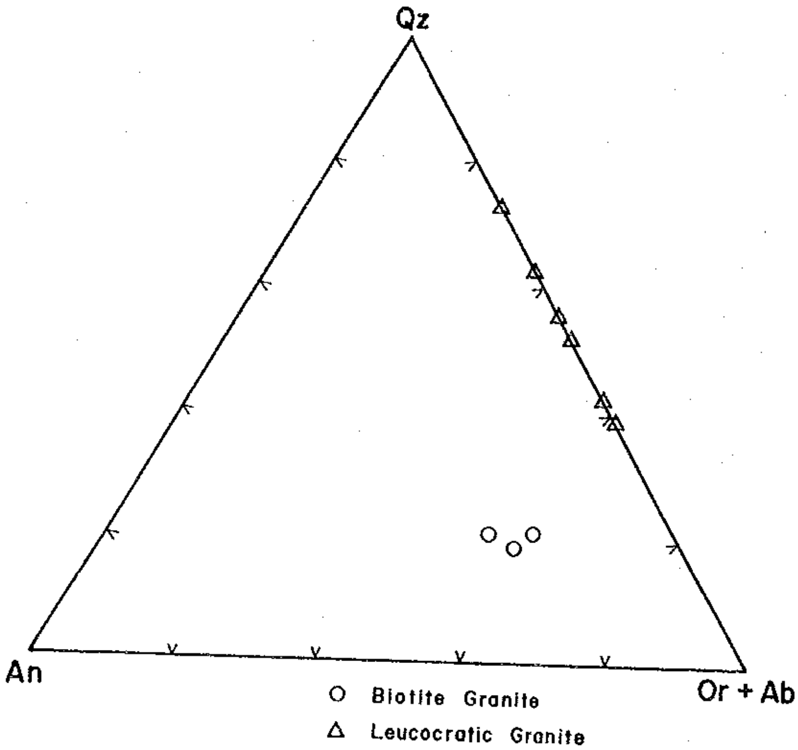


Fig.2-3 Quartz-Potassium Feldspar-Anorthite Diagram

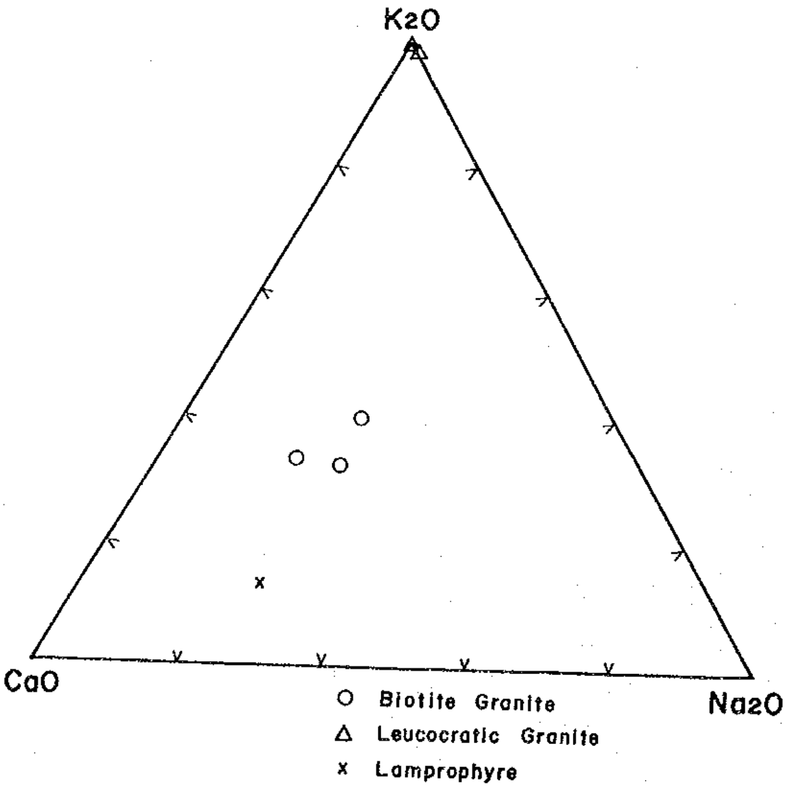


Fig.2-4 Alkali-Lime Ratio Diagram

Table 2-4 Correlation Coefficients of Assay Values of Trace Elements Contained in Intrusive Rocks

	F	W	Sn	Li	Rb	Sr	Ce	Th	Ta	U	Nb	Y	Zr
F	1.00	0.34	0.63	0.69	0.62	-0.56	-0.47	0.18	0.38	0.52	0.54	0.68	-0.36
W		1.00	0.15	-0.23	0.54	-0.77	-0.71	0.30	0.82	0.50	0.54	0.68	-0.60
Sn			1.00	0.48	0.55	-0.36	-0.47	-0.02	-0.07	0.27	0.34	0.57	-0.13
Li				1.00	0.09	0.03	0.07	-0.36	-0.29	-0.02	-0.13	0.09	-0.00
Rb					1.00	-0.86	-0.74	0.59	0.40	0.76	0.58	0.96	-0.60
Sr						1.00	0.93	-0.43	-0.70	-0.63	-0.69	-0.93	0.86
Ce							1.00	-0.21	-0.63	-0.44	-0.69	-0.86	0.83
Th								1.00	0.44	0.57	0.60	0.52	-0.08
Ta									1.00	0.51	0.75	0.55	-0.57
U										1.00	0.49	0.70	-0.47
Nb											1.00	0.70	-0.40
Y												1.00	-0.67
Zr													1.00

For the purpose of interpreting the geological and petrological significance of the values of trace elements more easily, the principal component analysis for thirteen trace elements was carried out. Although calculation of thirteen principal components has been conducted, three principal components that were statistically more meaningful (those with eigenvalues over 1.0) were chosen. Their eigenvectors, factor loadings, eigenvalues, proportions and cumulative proportions are shown in Table 2-5.

Table 2-5 Results of Principal Component Analysis of Assay Values of Trace Elements Contained in Intrusive Rocks

	1		2		3	
	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading
F	0.25	0.66	0.40	0.60	0.10	0.11
W	0.29	0.77	-0.21	-0.32	-0.24	-0.27
Sn	0.17	0.46	0.47	0.71	0.08	0.09
Li	0.00	0.01	0.61	0.92	-0.05	-0.06
Rb	0.33	0.89	0.11	0.16	0.20	0.22
Sr	-0.36	-0.97	0.03	0.05	0.16	0.18
Ce	-0.33	-0.88	0.01	0.01	0.31	0.35
Th	0.19	0.52	-0.26	0.39	0.63	0.72
Ta	0.27	0.74	-0.30	-0.46	-0.11	-0.13
U	0.28	0.74	-0.02	-0.03	0.31	0.35
Nb	0.29	0.79	-0.10	-0.14	0.19	0.21
Y	0.36	0.96	0.09	0.14	0.06	0.07
Zr	-0.28	-0.74	0.05	0.07	0.47	0.53
Eigen	7.23		2.26		1.27	
Propo.	0.56		0.17		0.10	
Cum. prop	0.56		0.73		0.83	

Using factor loadings, which represents the correlation between the principal component and the variable (assay value), and factor scores, the characteristics of the three principal components can be described as follows.

The first principal component: The leucocratic granite has positive factor score, and both biotite granite and lamprophyre show negative factor score. Trace elements such as F, W, Rb, Ta, U, Nb and Y have high positive factor loading, whereas Sr, Ce and Zr show high negative factor loadings. This component is interpreted statistically as the one which reflects petrological difference.

The second principal component: High positive values are shown by F, Sn and Li. The high positive factor scores are obtained from one sample of the leucocratic granite in the upper reaches of S.Isahan where cassiterite-bearing quartz vein is developed. This means that the component is related to the mineralization.

The third principal component: Th shows high value of factor loading, and lamprophyre has high positive factor score. This component is also interpreted as the one which shows petrological meaning.

Average contents of trace elements for each granite groups, and some analytical data of muscovite granite and biotite granite in Bilitung, Indonesia (Schwartz M.O. et al.,1990) are shown in the table below.

Rock	F (ppm)	W (ppm)	Sn (ppm)	Li (ppm)	Rb (ppm)	Sr (ppm)	Ce (ppm)	Th (ppm)	Ta (ppm)	U (ppm)	Nb (ppm)	Y (ppm)	Zr (ppm)
GL	816	54	6	26	449	4	9	30	3	11.5	23	145	72
GB	468	3	4	27	125	212	88	27	<2	7.0	16	45	157
BGM	3900	303	85	153	758	26	47	48	28	17	51	63	50
BGB	4500	23	28	100	567	10	<20	80	8	23	41	124	77

Abbreviation

GL:Leucocratic granite GB:Biotite granite

BGM:Bilitung muscovite granite BGB:Bilitung biotite granite

Comparing the leucocratic granite of the survey area to the Bilitung muscovite granite, the leucocratic granite shows distinctively lower values of F, W, Sn, Li, Sr, Ce and Ta than the Bilitung granite. Only the Y content of the former rock is higher than that of the latter. In case of biotite granites between both areas, lower values of F, W, Sn, Li, U and Y are found in the rocks in this area, while Sr and Ce values are higher than the

Bilitung rocks.

1-5 Geologic Structure

Two kinds of fault systems, the WNW-ESE system and the NNW-SSE system, are recognized in the survey area. None of the Paleozoic formations in the area shows clear bedding structure. This causes some difficulty in interpreting the geologic structure of this area.

(1) Faults

Faults of the WNW-ESE system are inferred to exist at the upper reaches of S.Laki. These faults were indicated in the photogeological analysis of the first phase. Faults of the NNW-SSE system, which were also inferred from geographic features, are recognized near the junction of S.Tulang and S.Peseman.

(2) Arrangement of intrusive rocks

The leucocratic granite is distributed in the WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang, and is also distributed approximately in the NNW-SSE direction from S.Tulang to S.Sikambu and S.Peseman. At the upper reaches of S.Isahan, distribution of hornfels extends in the WNW-ESE direction. These directions correspond to the trends of the fault system of this area.

1-6 Mineralization and Associated Alteration

Based on the results of the first phase survey, primary mineralization of Sn, W and Ce is expected to exist in the area. The mineral showings in the survey area (Fig.2-5) are summarized into the following three groups by host rocks and mineral assemblages.

(1) Cassiterite-bearing quartz vein networks in the leucocratic granite.
(2) Quartz veins in the biotite granite
(3) Quartz veins in the Paleozoic system

(1) Cassiterite-bearing quartz vein networks in the leucocratic granite

This type of mineralization occurs in western S.Isahan and S.Sikambu.

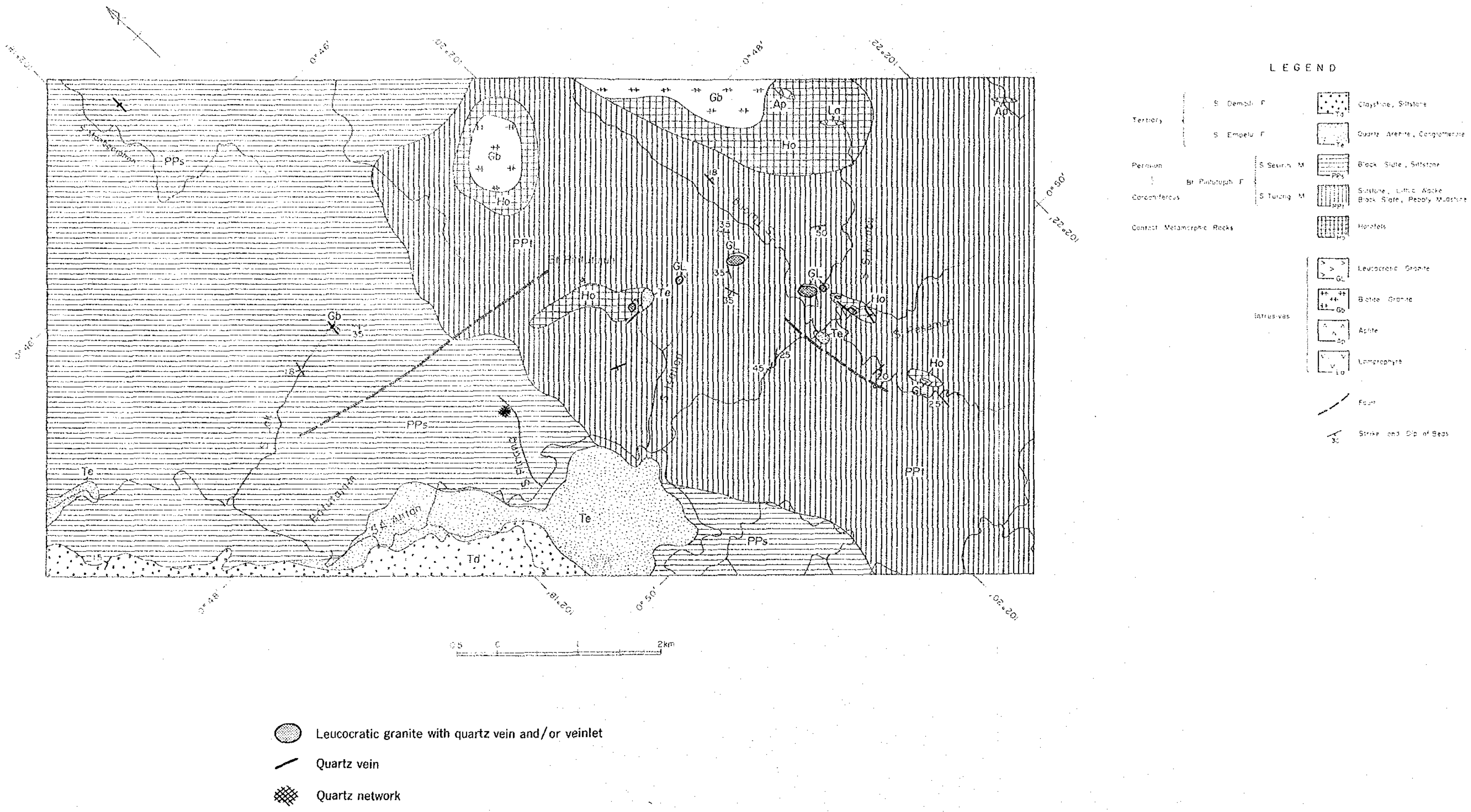


Fig.2-5 Distribution Map of Mineral Showings

① S.Isahan

Leucocratic granite outcrops are observed at three localities at the upper reaches of S.Isahan within a distance of 120 m, and networks of 1 cm to 40 cm wide quartz veins are developed in these granitic bodies (Fig.2-6). The quartz veins contain cassiterite, muscovite, tourmaline, arsenopyrite, pyrite and a minor amount of beryl. Cassiterite occurs mostly as independent lumps in the central or marginal parts of the veins. The size of these lumps is in the order of 1 cm×1 cm to 5 cm×5 cm. In rare cases, cassiterite is associated with sericite. Arsenopyrite veins with 1 cm width transect the quartz veins in some places. One to 5 cm wide muscovite-kaolinite-potassium feldspar zone is often found in the marginal parts of wide quartz veins.

Quartz-muscovite veins with 10 cm width occur in the slate which is in direct contact with the leucocratic granite.

Most of the potassium feldspar and plagioclase are altered to muscovite in the leucocratic granite. Kaolinite, beryl and limonite are observed in some cases. The rock forms dykes of 1 to 5 m in width.

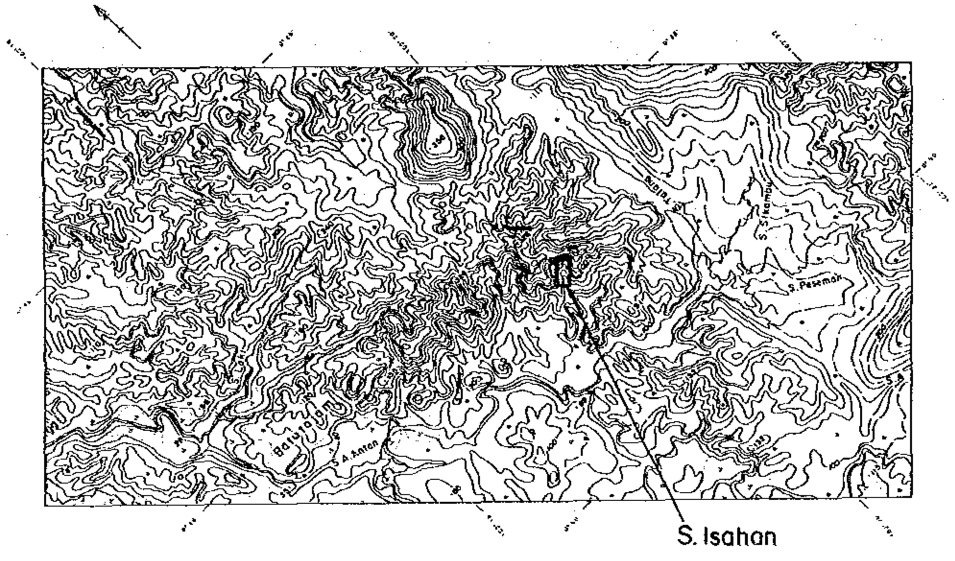
Siltstone and slate in contact with the leucocratic granite are bleached to greyish white, and X-ray diffraction identified quartz-kaolinite-sericite assemblage. Greisenization (silicified and muscovitized) is observed in siltstone near the contact of the leucocratic granite.

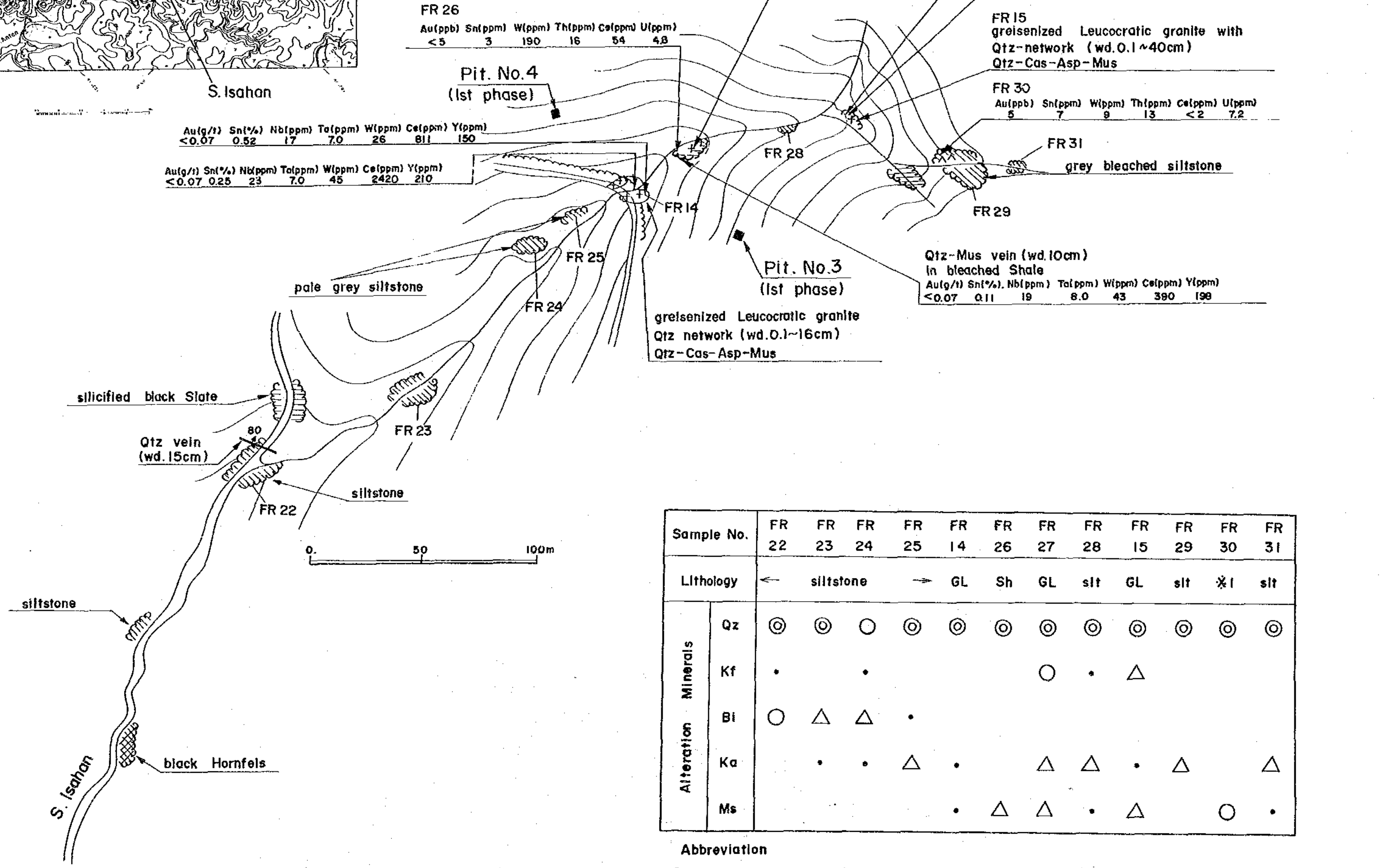
The muscovite in the leucocratic granite was concluded to be probably the product of greisenization. But it was left unclear in the course of the first year study whether the kaolinite was formed by hydrothermal alteration or weathering process. In this year, leucocratic granite and siltstone samples from the upper reaches of S.Isahan were collected and alteration minerals were identified by X-ray diffraction analysis. The results are; siltstone away from the leucocratic granite is metamorphosed into hornfels, a quartz-biotite-potassium feldspar is the major mineral assemblage in this zone, whereas the biotite disappears and kaolinite-muscovite begin to appear towards the leucocratic granite dykes (Fig.2-6). These facts indicate that the kaolinite is the product of hydrothermal alteration.

② S.Sikambu

Two bodies of leucocratic granite, a stock with the surface areal extent of 100 m×200 m and a thin dyke of about 1 m in width, are exposed (Fig.2-7). Five quartz veins, 2 to 20 cm wide, are recognized in the body. These veins contain cassiterite, muscovite, tourmaline and arsenopyrite, with muscovite in the marginal part of the veins. The mode of occurrence of the minerals is similar to that of the mineralized zone at the upper reaches of S.Isahan.

Index Map





Sample No.		FR 22	FR 23	FR 24	FR 25	FR 14	FR 26	FR 27	FR 28	FR 15	FR 29	FR 30	FR 31
Lithology		←	siltstone		→	GL	Sh	GL	slt	GL	slt	※1	slt
Alteration Minerals	Qz	◎	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Kf	•		•				○	•	△			
	Bi	○	△	△	•								
	Ka		•	•	△	•		△	△	•	△		△
	Ms					•	△	△	•	△		○	•

Abbreviation

Qz : Quartz
Kf : K-feldspar
Bi : Biotite
Ka : Kaoline
Ms : Muscovite

GL : Leucocratic granite
Sh : Shale
slt : Siltstone
※1 : Silicified rock

Fig.2-6 Sketch of S.Isahan Mineralized Zone

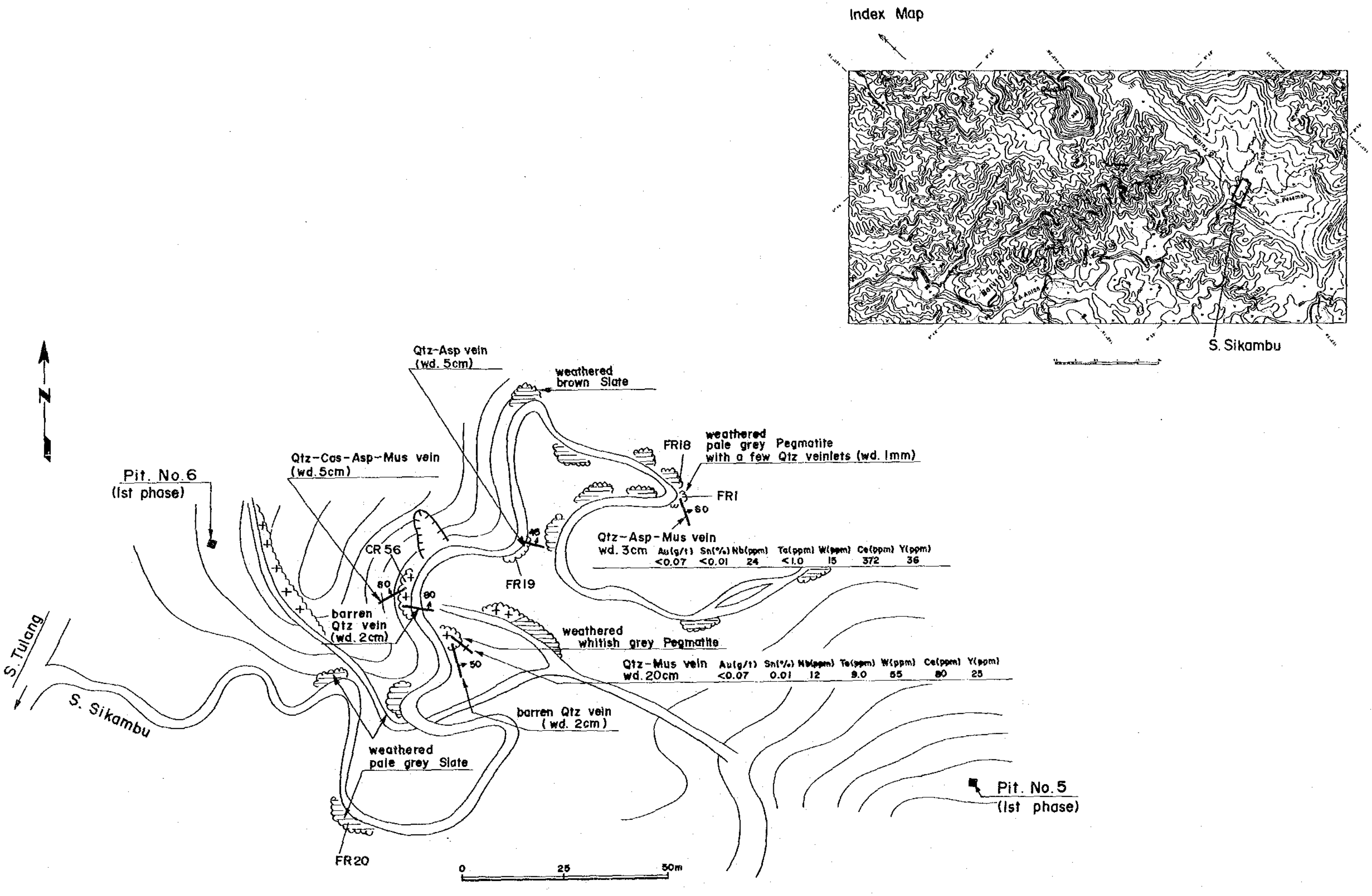


Fig.2-7 Sketch of S.Sikambu Mineralized Zone

The host rock underwent muscovitization and kaolinitization, but the alteration is weaker than at the S.Isahan mineralized zone and most of the potassium feldspar and plagioclase remain intact.

③ East of upper reaches of S.Isahan

A dyke with 1 to 2 m in width was discovered during the construction of drilling tracks. Quartz-muscovite veins of less than 1 cm in width were observed. The dyke rock itself are muscovitized and kaolinitized.

④ Branch of S.Tulang

Boulders of the leucocratic granite are distributed. They are sometimes muscovitized and kaolinitized, containing quartz-muscovite thin veins.

⑤ Branch of S.Sikambu and southward

Leucocratic granite boulders, which are muscovitized and kaolinitized, were observed in two localities.

(2) Quartz veins in the biotite granite

This type of mineralization occurs at the upper reaches of S.Laki. The biotite granite contains 10 cm wide quartz-potassium feldspar-pyrite veins. Strong sericitization and pyrite dissemination are observed.

(3) Quartz veins in Paleozoic strata

Quartz veins 10 to 20 cm wide occur at; a branch of S.Manggajohan in the northern area, S.Isahan, S.Sikambu and S.Peseman. All these veins have irregular width and are not continuous. The major mineral assemblages are; quartz-pyrite, quartz-tourmaline and quartz-muscovite-pyrite. Quartz-arsenopyrite vein networks were observed in S.Pinang. Boulders of quartz veins were often found at the banks in the Paleozoic region.

(4) Discussions

From the mineral showings mentioned previously, five samples were collected and analyzed for the following six elements; Au, Sn, W, Th, Ce and U (Table 2-6).

Table 2-6 Assay Values of Ore Samples

Sample No.	Location	Sample description	Au (ppb)	Sn (ppm)	W (ppm)	Th (ppm)	Ce (ppm)	U (ppm)
FR3	S.Sikambu	Qz-Ap-Ms vein	<5	56	3	3	2	1.0
FR13	S.Pinang	Qz-Ap network	20	4	3	6	24	0.8
FR26	S.Isahan	Silicified shale	<5	3	190	16	54	4.8
FR30	ditto	Sili-Ms rock	5	7	9	13	<2	7.2
GR14	Tri. of S.Antan	Qz vein	<5	73	16	10	30	0.8

All these samples were of low grade, and the results were rather disappointing. Mineralization of the survey area including the results of the previous phase can be summarized as follows.

Cassiterite-bearing quartz veins from the leucocratic granite at the upper reaches of S.Isahan contained 3.84 % Sn and 0.07 % W. Leucocratic granite samples including quartz veins (0.1 to 1 cm in width) from the same location contained 0.08 to 0.24 % Ce.

According to these analytical data, the metal concentration expected in the survey area is either dissemination of Sn, W and Ce minerals in the leucocratic granite or Sn, W and Ce-bearing quartz vein network in the leucocratic granite.

1-7 Granite - Geologic Structure - Mineralization

The intrusive rocks in the survey area are biotite granite, leucocratic granite, aplite and lamprophyre, all in the Paleozoic strata.

Results of K-Ar dating of the biotite granite show Early Cretaceous (128 to 110 Ma) age. The greisenized silicified-muscovitized rocks (drill core) from S.Isahan and from S.Sikambu, on the other hand, are Middle Jurassic (160 to 150 Ma) age. The biotite granite is, thus, interpreted to have formed after the mineralization. This is also supported by the evidence that the lamprophyre dykes are contact-metamorphosed.

The above indicates that the leucocratic granites distributed in S.Isahan and other areas are the intrusive facies of pre-Middle Jurassic igneous activity. It is also indicated that the porphyritic biotite granite (167 to 134 Ma) has the closest age relationship with the leucocratic granite among the granites distributed in the area surveyed during the previous year. Therefore, concealed bodies of porphyritic biotite granite which is directly related to mineralization can be expected below the leucocratic granite. The porphyritic biotite granite contains 73 to 77 % SiO_2 and its differential index is over 92 %. Thus, it has higher degree of magmatic differentiation compared to the biotite granite.

There are evidences regarding the relation between geologic structure and mineralization. Structurally weak lineation during Jurassic period in the survey area is manifested by the arrangement of the leucocratic granites which host mineralization. And the mineralization naturally is expected to be controlled by this structurally weak zone. The leucocratic granite bodies, from the upper reaches of S.Isahan to S.Tulang, are distributed approximately in the WNW-ESE direction. Strike measurements of the leucocratic granite dykes at the outcrops show the E-W direction. Distribution of the leucocratic granite from S.Sikambu towards the south is approximately in the N-S direction. These structures coincide with the direction of assumed faults at S.Laki and S.Tulang.

Chapter 2 Geochemical Exploration

2-1 Geochemical Exploration with Stream Sediments

Geochemical exploration using stream sediments was carried out for finding indications of mineralized zones which would otherwise be undetected by geological survey, as well as for clarifying the extension of mineral occurrences discovered by the previous survey. The work was conducted parallel with the geological survey.

(1) Sampling and chemical analysis

Fine sands of -80 mesh were sampled from sediments near the river banks where the rivers were wide and deep, and from faster-flowing midstream in cases when the rivers were narrow and shallow. 312 samples were collected. Combining with the samples collected from the area in the previous year, the number of samples totalled 415, which correspond to an approximate density of six samples per km^2.

The samples, after being air-dried in the field, were analysed at Chemex Lab. Inc. of Canada, for six elements; Au, Sn, W, Th, Ce and U. The methods of analysis and the limits of detection are given below.

Element	Digestion and Method	Lower Limit	Upper Limit
Au	Fuse 10g sample. Fire assay. Atomic Absorption	5ppb	10,000ppb
Sn	NH_4I sublimation extrac. Atomic Absorption	2ppm	1,000ppm
W	K pyrosulfate fusion Colorimetric test	2ppm	1,000ppm
Th	Neutron activation encapsulation and irradiation	1ppm	10,000ppm
Ce	Neutron activation encapsulation and irradiation	2ppm	10,000ppm
U	Neutron activation encapsulation and irradiation	0.2ppm	10,000ppm

(2) Results of data processing

① Method of statistical analysis

It is known that the distribution of geochemical data, especially that of minor elements belonging to a single population, generally shows close approximation to logarithmic normal distribution.

In the present analysis, following the previous year, the natural logarithms of the respective analytical values were used in the calculation of statistical amounts. The 103 data, which were obtained in the previous year, were taken into the current analysis. When the analytical values were less than the detection limit, a value half of the detection limit was substituted in the calculation.

② Basic statistical figures

Table 2-7 shows the geometric means and the maximum and minimum values of each element. The abundance of elements in crustal rocks (Mason, 1966) are also given for reference.

The geometric means show somehow similar values to the average abundance of crustal rocks.

Table 2-7 Basic Statistics of Assay Values of Stream Sediments

	Au (ppb)	Sn (ppm)	W (ppm)	Th (ppm)	Ce (ppm)	U (ppm)
Geometric Mean	<5	3	2	8	40	2.4
maximum	40	710	32	37	240	22
minimum	<5	<2	<2	<1	<2	<0.2
Average Abundance of Crustal Rocks	4	2	1.5	7.2	60	1.8

③ Frequency distribution of analytical values

The frequency distribution of analytical values is shown in Figure 2-8. Th, Ce and U are the elements which show the close-to-normal distribution. W pattern has the highest value of its frequency positioned to the left. The frequency distributions of Au and Sn are L-shaped, as many of their values are lower than the detection limit.

④ Correlation among elements

Table 2-8 shows the correlation coefficients of all the samples. Correlation coefficient values larger than 0.4 are found in the combination of Sn-W. The elements with low coefficient values of only -0.3 to 0.3 with other elements are Au, Th, Ce and U.

Table 2-8 Correlation Coefficients of Assay values of Stream Sediments

	Au	Sn	W	Th	Ce	U
Au	1.00	-0.11	0.27	0.18	-0.30	0.02
Sn		1.00	0.43	0.06	0.19	-0.01
W			1.00	0.24	-0.02	0.03
Th				1.00	0.12	0.12
Ce					1.00	0.06
U						1.00

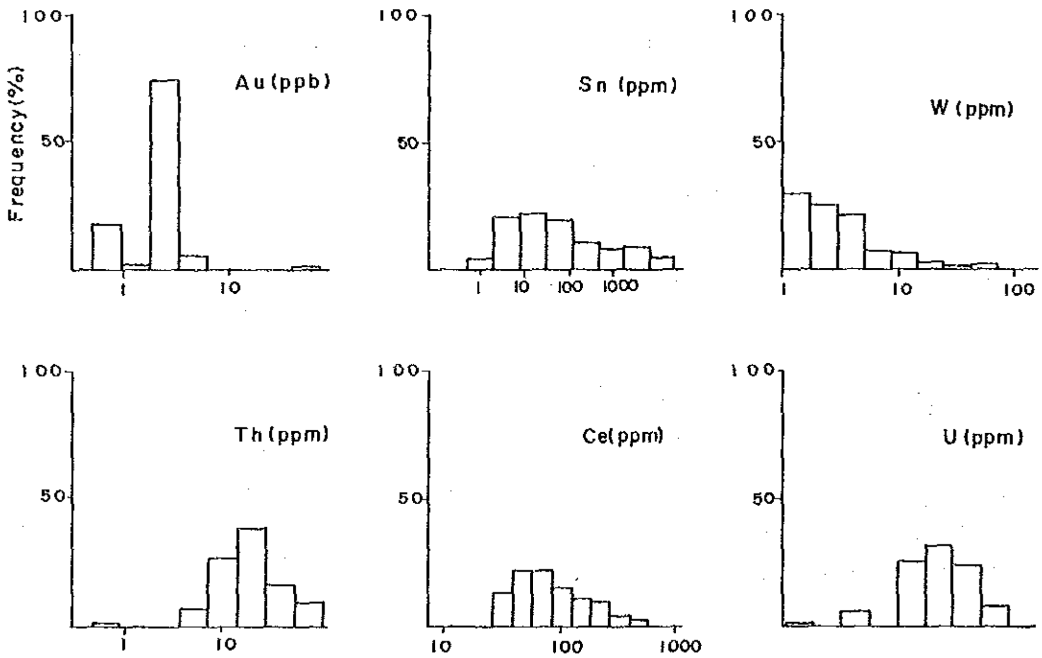


Fig.2-8 Histogram of Assay Values of Stream Sediments

⑤ Multivariate analysis

To summarize the significance of geochemical data and to facilitate the geology-mineralization correlation and the interpretation of these data, principal component analysis were carried out for six elements. Although calculation of all six principal components could be made, three principal components that were statistically significant (the ones having eigenvalues over 1.0) were chosen. Their eigenvectors, factor loading values, eigenvalues, proportions and cumulative proportions were obtained, as shown in Table 2-9.

Table 2-9 Results of Principal Component Analysis of Assay Values of Stream Sediments

	1		2		3	
	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading
Au	0.29	0.36	0.65	0.77	0.03	0.04
Sn	0.50	0.64	-0.38	-0.45	-0.37	-0.38
W	0.66	0.84	0.08	0.09	-0.23	-0.24
Th	0.44	0.56	0.06	0.07	0.47	0.50
Ce	0.10	0.13	-0.65	-0.77	0.23	0.24
U	0.13	0.16	-0.04	-0.04	0.73	0.76
Eigen.	1.61		1.41		1.09	
Propo.	0.27		0.23		0.18	
Cum.prop	0.27		0.50		0.68	

Using factor loading, which represents the correlation between the principal component and the variables (assay value), the characteristics of the three principal components can be described as follows.

The first principal component: The highest values are obtained from W, and next from Sn. These elements are the ones which are expected to be associated with tin mineralizations in this area. Hence, this principal component is interpreted to represent the mineralization. Samples having factor scores of 2.0 or over are distributed over the WNW-ESE elongated zones at the upper reaches of S.Isahan.

The second principal component: Positive values is shown by Au, and negative values by Ce and Sn. Geological significance of this component is not clear.

The third principal component: High positive value is obtained from U. There is no distinctive relationship between the localities of the high factor scores and geology. The significance of this component is also not clear.

(3) Geochemical anomalies and anomalous zones

① Threshold setting

Following the method employed in the previous year, 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 geometric mean value of each element was regarded as threshold. The thresholds of the respective elements are given in Table 2-10.

Table 2-10 Thresholds for Assay Values of Stream Sediments

Au (ppb)	Sn (ppm)	W (ppm)	Th (ppm)	Ce (ppm)	U (ppm)
9	69	7	36	161	10.7

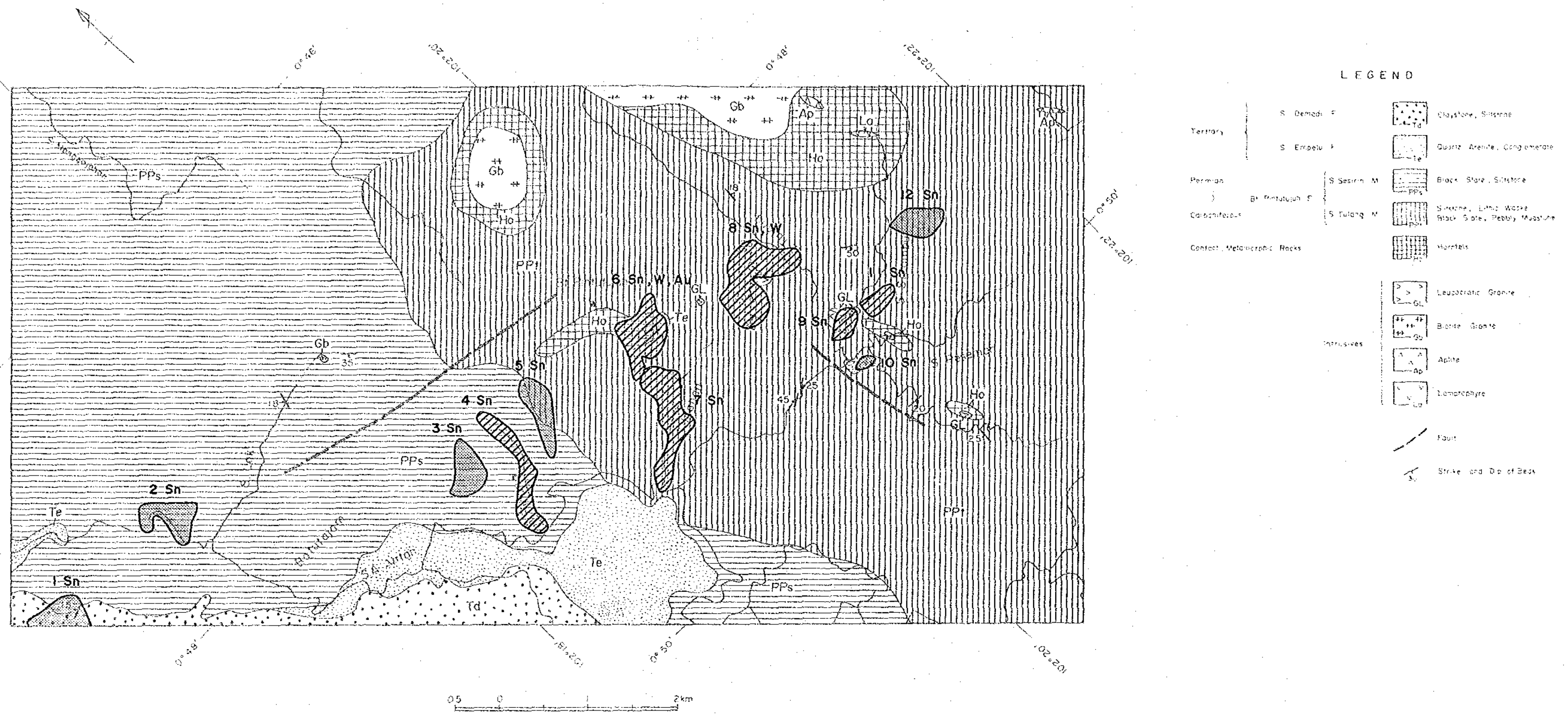
② Extraction of geochemically anomalous zones

When samples from more than two adjacent sites contain anomalous amounts of the same elements, that area was regarded as a geochemically anomalous zone of those elements. Where the anomalous zones of plural elements overlap, they were treated as one zone. Sn, however, sometimes shows 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 anomalies

Twelve anomalous zones were extracted in the survey area (Table 2-11 and Fig.2-9). There are ten anomalies for Sn alone, one for the combination of Sn and W, and another for Sn-W-Au. These zones were grouped into two ranks, A and B, according to the value of the anomaly. For Sn, the zones with values higher than twice the threshold were assigned A-rank, and those with lower values B-rank. For other elements, assigning ranks to anomalous zones was done by taking into account the number of elements with anomalous values and the number of samples. When thus ranked, there are six A-rank anomalous zones for Sn and one for other elements. A-rank anomalous zones are outlined as follows.

S.Pinang (No.4): Anomalous values of Sn (80 to 180 ppm) were detected in three localities. Geology of the drainage area is composed of Paleozoic strata. Quartz vein networks were observed with low contents of Sn.



Geochemical anomaly (A)

Geochemical anomaly (B)

1 Sn : Anomalous sector number and Element

Threshold

Au 9 ppb

Sn 69 ppm

W 7 ppm

No.	Location	Number of Anomalous Samplee	Anomalous Elements and Range	Rank
1	Tributary of S. Antan	1	Sn(120ppm)	B
2	S. Antan	1	Sn(83ppm)	B
3	Tributary of S. Antan	1	Sn(77ppm)	B
4	S. Pinang	3	Sn(80-180ppm)	A
5	Tributary of S. Antan	1	Sn(70ppm)	B
6	Upper reaches of S. Isahan	7	Sn(70-400ppm) W(7-32ppm), Au(10-15ppb)	A
7	Lower reaches of S. Isahan	5	Sn(71-330ppm)	A
8	Tributary of S. Tulang	4	Sn(230-290ppm) W(7-28ppm)	A
9	Lower reaches of S Sikambu	1	Sn(710ppm)	A
10	Tributary of S. Peseman	1	Sn(80ppm)	B
11	Tributary of S. Sikambu	1	Sn(290ppm)	A
12	Tributary of S. Sikambu	1	Sn(94ppm)	B

Fig.2-9 Distribution Map of Anomalous Zones Delineated by Stream Sediment Geochemical Exploration

Upper reaches of S.Isahan (No.6): There are three Sn anomalies (70 to 400 ppm), two Au anomalies (10 to 15 ppb) and five W anomalies (7 to 32 ppm). The zone is composed of the leucocratic granite and Paleozoic strata. This is called the S.Isahan tin-mineralization zone.

Lower reaches of S,Isahan (No.7): Anomalies of Sn (71 to 330 ppm) are distributed in five localities. The zone is composed of the Paleozoic formations. No mineralization is known in this zone.

Branches of S.Tulang (No.8): Two anomalies of Sn (230 to 290 ppm) and three of W (7 to 28 ppm) are distributed. The zone is composed of the leucocratic granite and the Paleozoic strata.

Lower reaches of S.Sikambu (No.9): There is only one anomaly of Sn (710 ppm) in the area. The zone is composed of the leucocratic granite and Paleozoic strata. This is called the S.Sikambu tin-mineralization zone.

Branch of S.Sikambu (No.11): One Sn anomaly (290 ppm) was obtained. The zone is composed of the leucocratic granite and Paleozoic strata. No mineralization is known in this area.

Table 2-11 Anomalous Zones Delineated from Stream Sediment Geochemistry

No.	Location	Number of Anomalous Samples	Anomalous Elements and Range	Rank
1	Tributary of S. Antan	1	Sn(120ppm)	B
2	S. Antan	1	Sn(83ppm)	B
3	Tributary of S. Antan	1	Sn(77ppm)	B
4	S. Pinang	3	Sn(80-180ppm)	A
5	Tributary of S. Antan	1	Sn(70ppm)	B
6	Upper reaches of S. Isahan	7	Sn(70-400ppm) W(7-32ppm), Au(10-15ppm)	A
7	Lower reaches of S. Isahan	5	Sn(71-330ppm)	A
8	Tributary of S. Tulang	4	Sn(230-290ppm) W(7-28ppm)	A
9	Lower reaches of S Sikambu	1	Sn(710ppm)	A
10	Tributary of S. Peseman	1	Sn(80ppm)	B
11	Tributary of S. Sikambu	1	Sn(290ppm)	A
12	Tributary of S. Sikambu	1	Sn(94ppm)	B

2-2 Geochemical Survey with Panned Concentrates

The purpose of the geochemical survey 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 heavy minerals including rare metals, this survey was carried out parallel with sampling of stream sediments.

(1) Sampling and chemical analysis

It was originally planned to collect samples from the sediments enriched in heavy minerals directly on exposed rocks in the 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 as many as six elements including rare earths were analysed, about 100 g of samples including spare samples were required. Therefore, 10 litre of sands was collected by a shovel, so as to finally obtain 100 g of panned concentrate.

Fifty-three panned concentrates were obtained. The total number of samples amounted to 72 including those collected in the previous year, and this corresponds to a sampling density of approximately 1 sample per km^2.

The samples were air-dried in the field and were chemically analysed 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 statistical analysis

The assay values were converted to natural logarithms, and statistical figures were calculated. Nineteen data taken in the previous survey in the area were included in the present calculation. 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 figures

Table 2-12 shows the geometric mean, the maximum and minimum values of all samples. Comparing the mean values of the panned concentrates to that of the stream sediments, the former is fifteen times as high in Sn content as the latter, while the other elements in the panned concentrates are up to twice as high. This fact indicates that the heavy minerals in the stream sediments contain only a significant level of Sn and the other elements are not concentrated in the heavy minerals.

Table 2-12 Basic Statistics of Assay Values of Panned Concentrates

	Au (ppb)	Sn (ppm)	W (ppm)	Th (ppm)	Ce (ppm)	U (ppm)
Geometric Mean	<5	46	3	18	81	3.4
Maximum	72	>1000	55	101	580	19
Minimum	<1	<2	<1	<1	26	<0.2
Geometric Mean of Stream Sediments	<5	3	2	8	40	2.4

③ Frequency distribution of assay values

Figure 2-10 shows the frequency distribution of assay values for each element. Th, Ce and U show close to the normal distribution. Sn and W patterns have the highest value positioned to the left from the center. The frequency distribution of Au is L-shaped, as many of their values are less than the lower detection limit.

④ Correlation among elements

Table 2-13 shows correlation coefficients of all samples. The combinations having over 0.5 correlation coefficients are Sn-W, Th-Ce and Ce-U. Correlation among these elements is sometimes higher than that of the stream sediments.

Table 2-13 Correlation Coefficients of Assay values of Panned Concentrates

	Au	Sn	W	Th	Ce	U
Au	1.00	-0.02	0.03	0.14	-0.27	-0.08
Sn		1.00	0.57	0.10	0.30	0.33
W			1.00	0.10	0.03	0.04
Th				1.00	0.63	0.42
Ce					1.00	0.53
U						1.00

⑤ Multivariate analysis

To summarize the significance of geochemical data and to facilitate the geology-mineralization correlation and the interpretation of these data, principal component analysis were carried out for the six elements. Although calculation of all six principal components could be made, three principal components that were statistically significant (the ones having eigenvalues over 1.0) were chosen. Their eigenvectors, factor loading values, eigenvalues, proportions and cumulative proportions were obtained, as shown in Table 2-14.

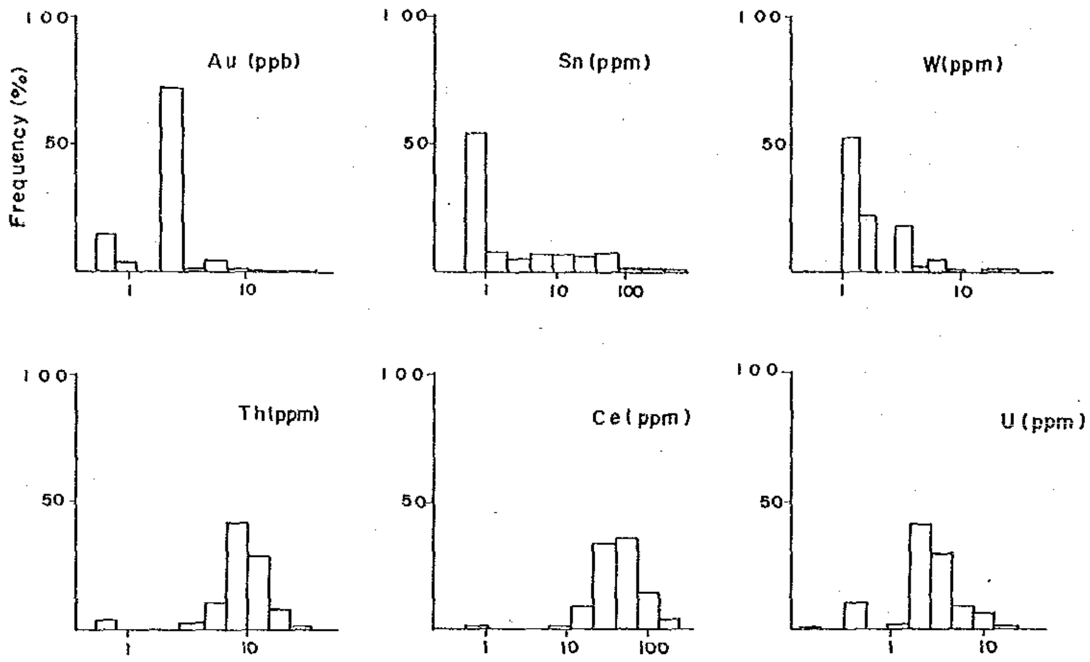


Fig.2-10 Histogram of Assay Values of Panned Concentrates

Table 2-14 Results of Principal Component Analysis of Assay Values of Panned Concentrates

	1		2		3	
	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading	Eigen-vector	Factor Loading
Au	-0.10	-0.15	0.14	0.16	0.90	0.95
Sn	0.40	0.60	0.56	0.66	-0.10	-0.10
W	0.24	0.36	0.70	0.82	0.02	0.02
Th	0.47	0.71	-0.28	-0.33	0.40	0.42
Ce	0.56	0.84	-0.28	-0.33	-0.12	-0.13
U	0.50	0.75	-0.17	-0.20	0.01	0.01
Eigen.	2.28		1.40		1.10	
Propo.	0.38		0.23		0.18	
Cum. prop	0.38		0.61		0.80	

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

The first principal component: Sn, Th, Ce and U show high positive values. Samples with factor scores over 2.0 were distributed in the zones between S.Laki and S.Antan, and at the branches of S.Tulang. They show no clear correspondence with geology. It is difficult to understand the significance of this principal component.

The second principal component: Sn and W show positive values. High factor scores were obtained from the upper reaches of S.Isahan. This is interpreted as the principal component related to the mineralization.

The third principal component: Au shows high positive values. Au has no close relationship with other elements, it shows its independent behavior.

(3) Geochemical anomalies and anomalous zones

① Threshold setting

Geochemical data exceeding the sum of the average value and twice the 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 calculated by adding the twice the standard deviation to its average value was too high (5,467 ppm) for a threshold. Thus, the average value plus the standard deviation, over 504 ppm, was regarded as geochemical anomaly. The thresholds of the respective elements are given in

Table 2-15.

Table 2-15 Tresholds for Assay values of Panned Concentrates

Au (ppb)	Sn (ppm)	W (ppm)	Th (ppm)	Ce (ppm)	U (ppm)
10	504	16	90	344	21.3

② Geochemically anomalous zones

Geochemically anomalous zones of panned concentrates were selected on the same bases as in the case of the stream sediments.

③ Distribution and assessment of anomalies

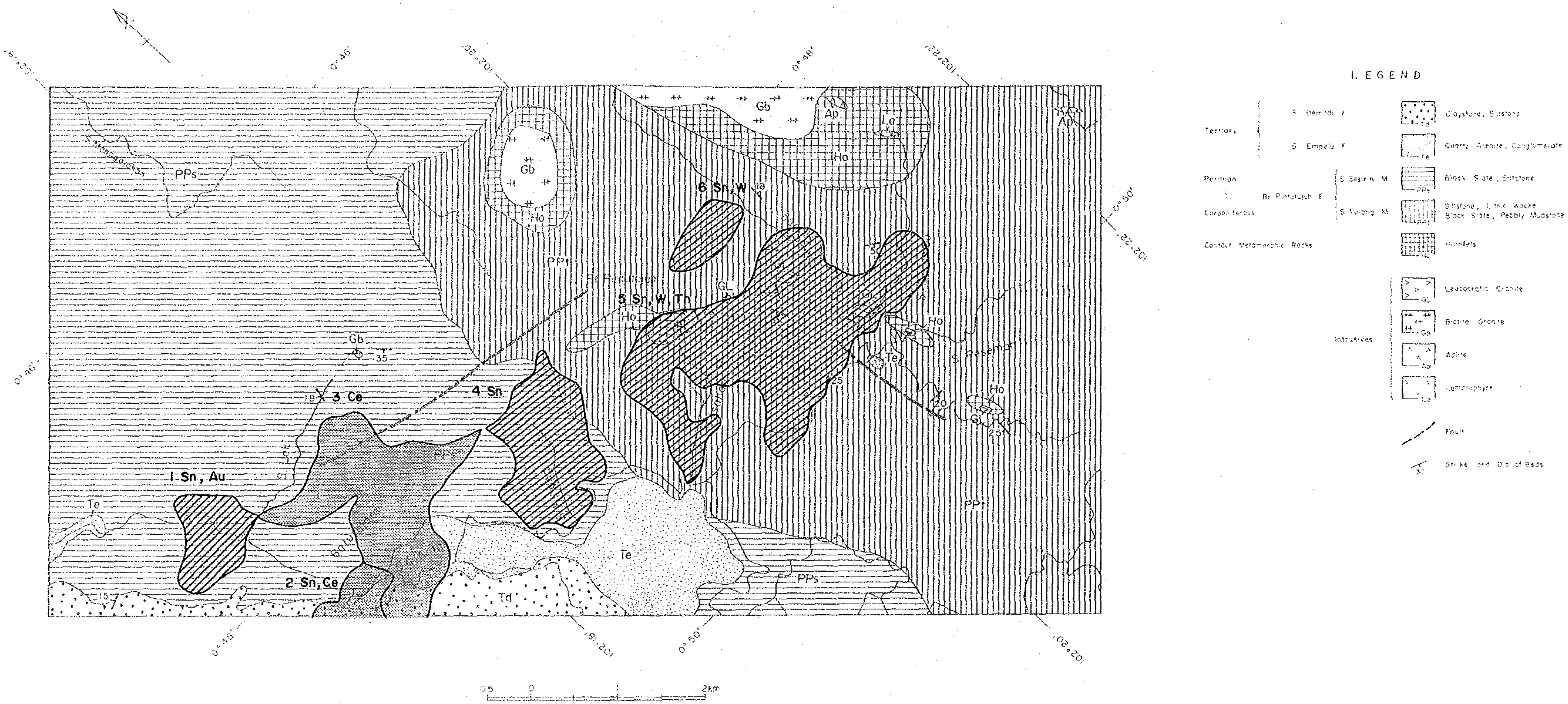
Six geochemical anomalous zones were extracted in the survey area (Table 2-16 and Fig.2-11). There are two zones with only Sn anomalies, four zones with anomalies of Sn accompanied by one or two other elements. They are classified into A-rank and B-rank based on the levels of anomaly. The A-rank anomalies are outlined as follows.

S.Antan (No.1): One Au anomaly (72 ppb) and one Sn anomaly (>1,000 ppm) were detected. The zone is composed of Paleozoic strata. The zone overlaps in part with a B-rank stream sediment anomaly.

S.Pinang (No.4): Three Sn anomalies (>1,000 ppm) were found. This is geologically situated in the Paleozoic area. The anomalies overlap partly with A-rank stream sediment anomalies.

From upper reaches of S.Isahan to lower reaches of S.Sikambu (No.5): Many anomalies were found in the area; ten Sn anomalies (600 to >1,000 ppm), three W anomalies (16 to 55 ppm) and one Th anomaly (93 ppm). The area is composed of the leucocratic granite and Paleozoic strata. The S.Isahan and S.Sikambu mineralized zones are situated in this area. Those anomalies and A-rank stream sediment anomalies overlap each other in some places.

Branch of S.Tulang (No.6): One Sn anomaly (>1,000 ppm) and one W anomaly (27ppm) were detected. The zone is composed of the Paleozoic strata. No mineralization was reported in the zone.



Geochemical anomaly (A)

Geochemical anomaly (B)

1 Sn : Anomalous sector number and Element

Threshold

Au	10	ppm
Sn	504	ppm
W	16	ppm
Th	90	ppm
Ce	344	ppm

No.	Location	Number of Anomalous Samples	Anomalous Elements and Range	Rank
1	S. Antan	1	Sn(> 1,000ppm). Au(72ppb)	A
2	S. Antan	1	Sn(560ppm). Ce(580ppm)	B
3	S. Laki and S. Antan	2	Ce(390-420ppm)	B
4	S. Pinang and tributary of S. Antan	3	Sn(> 1,000ppm)	A
5	S. Isahan- S. Tulang- S. Sikambu	9	Sn(600->1,000ppm) W(16-55ppm). Th(93ppm)	A
6	Tributary of of Tulang	1	Sn(>1,000ppm) W(27ppm)	A

Fig.2-11 Distribution Map of Anomalous Zones Delineated by Panned Concentrate Geochemical Exploration