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

CONSOLIDATED REPORT

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 survey was carried out for two years, from the first phase (from 1989 to 1990) to the second phase (from 1990 to 1991).

This is the final report compiled as the result of the two phases survey.

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

February 1991

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

Kensuke Yanagiya

Kensuke YANAGIYA
President
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President
Metal Mining Agency of Japan

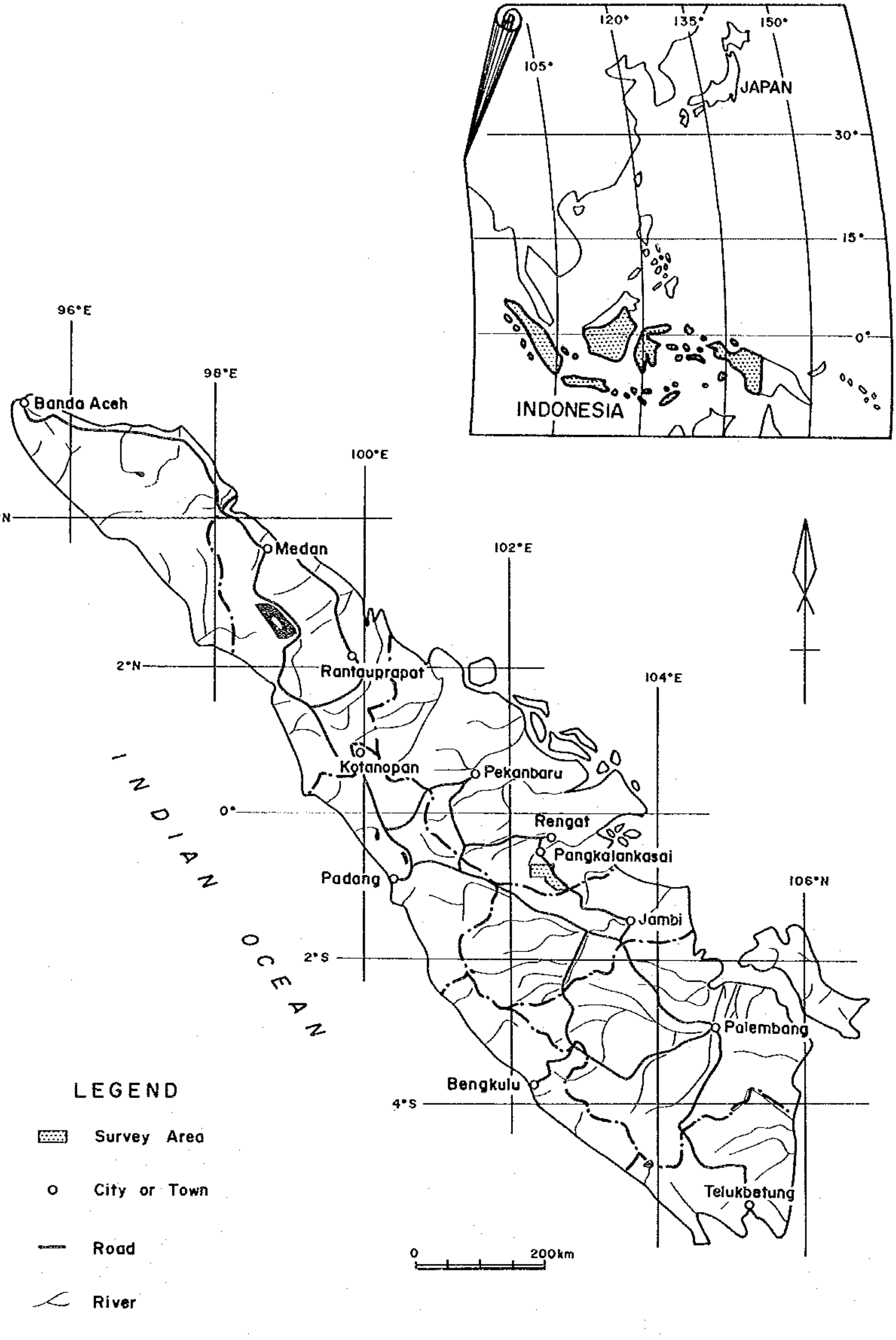

Fig.1-1 Index Map of Survey Area

SUMMARY

The report embodies the results of the works conducted during the two phases of the cooperative mineral exploration programme in the Pegunungan Tigapuluh area. The objective of the work is to evaluate the potential of mineral resources in the Pegunungan Tigapuluh area by clarifying the geology of the area.

During the first phase, geological survey and geochemical exploration were conducted in the Pegunungan Tigapuluh area. During the second phase, geological survey and geochemical exploration were carried out in the Bt.Pintutujuh area and drilling was carried out in the S.Isahan zone and S.Sikambu zone.

The results obtained are as follows.

1. Pegunungan Tigapuluh Area

(1) The geology of the Pegunungan Tigapuluh area is composed of Carboniferous to Permian sedimentary strata, Jurassic to Early Cretaceous granitic rocks, Paleogene tuffs, Neogene sedimentary strata and Quaternary sediments.

(2) The granitic rocks distributed in the area are, from their lithology and chemical composition, classified into porphyritic biotite granite, biotite granite, leucocratic granite, pegmatite and aplite. They belong to the ilmenite series of granitoids. The porphyritic type is considered, chemically, to be in a more advanced state of differentiation than that of bitite granite.

(3) The mineralized zones of this area occur as network of cassiterite-bearing quartz veins and cassiterite dissemination in leucocratic granite. These zones occur along the upper reach of S.Isahan and the lower reach of S.Sikambu in the western part of the survey area.

(4) The geochemical data of both stream sediments and panned concentrates shows six A-rank anomalous zones (Sn or Sn-W) which two overlie the above mineralized zones. Other than the mineralized zones, the zones which show A-rank anomalous values for both stream sediments and panned concentrates are found near the mineralized zones.

(5) The above six geochemical A-rank anomalous zones are arranged in the WNW-ESE direction. The structural weak lines in the WNW-ESE direction are

considered to control the mineralization in this area.

(6) Although rare earth (Nb, Ta, Ce, Y, La, etc.) bearing primary deposits were expected to occur in the Pegunungan Tigapuluh area, it is considered from the results of first phase survey that the mineralization expected to occur in this area is the Sn and W bearing primary mineralization. The zone prospective for this mineralization the is the Bt.Pintutujuh area.

2. Bt.Pintutujuh Area

(1) The granitic rocks distributed in the area are, from their lithology and chemical composition, classified into biotite granite, leucocratic granite and aplite. 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.

(2) Fault systems of WNW-ESE and NNW-SSE trends are developed in the survey area. The leucocratic granites which host the known tin mineralization are arranged approximately in the WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang.

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

(4) 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. 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.

(5) 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 considered that economically feasible deposits do not occur in the S.Isahan and S.Sikambu zones.

(6) The Sn geochemical anomalies ranging from 16 to 72 ppm were detected in the broad anomalous zone in the S.Isahan-S.Tulang area (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 site. As leucocratic granite is distributed and tin mineralization can be expected in this zone. It is considered from the values and the areal extent of the anomalies of the soil geochemical work that the grade and scale of the minaralization which can be expected here would be similar to those of the S.Isahan and S.Sikambu zones.

(7) A-rank geochemical anomalies of stream sediments and panned concentrates 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, and distribution of leucocratic granite can be expected in this zone. It is considered from the values of anomalies of the stream sediment and panned concentrate geochemical works that existence of deposits with the ore grade exceeding those of the known mineralized zones can not be expected.

(8) It is concluded from the results of these surveys that possiblity of existence of economically feasible deposits in the survey area is low.

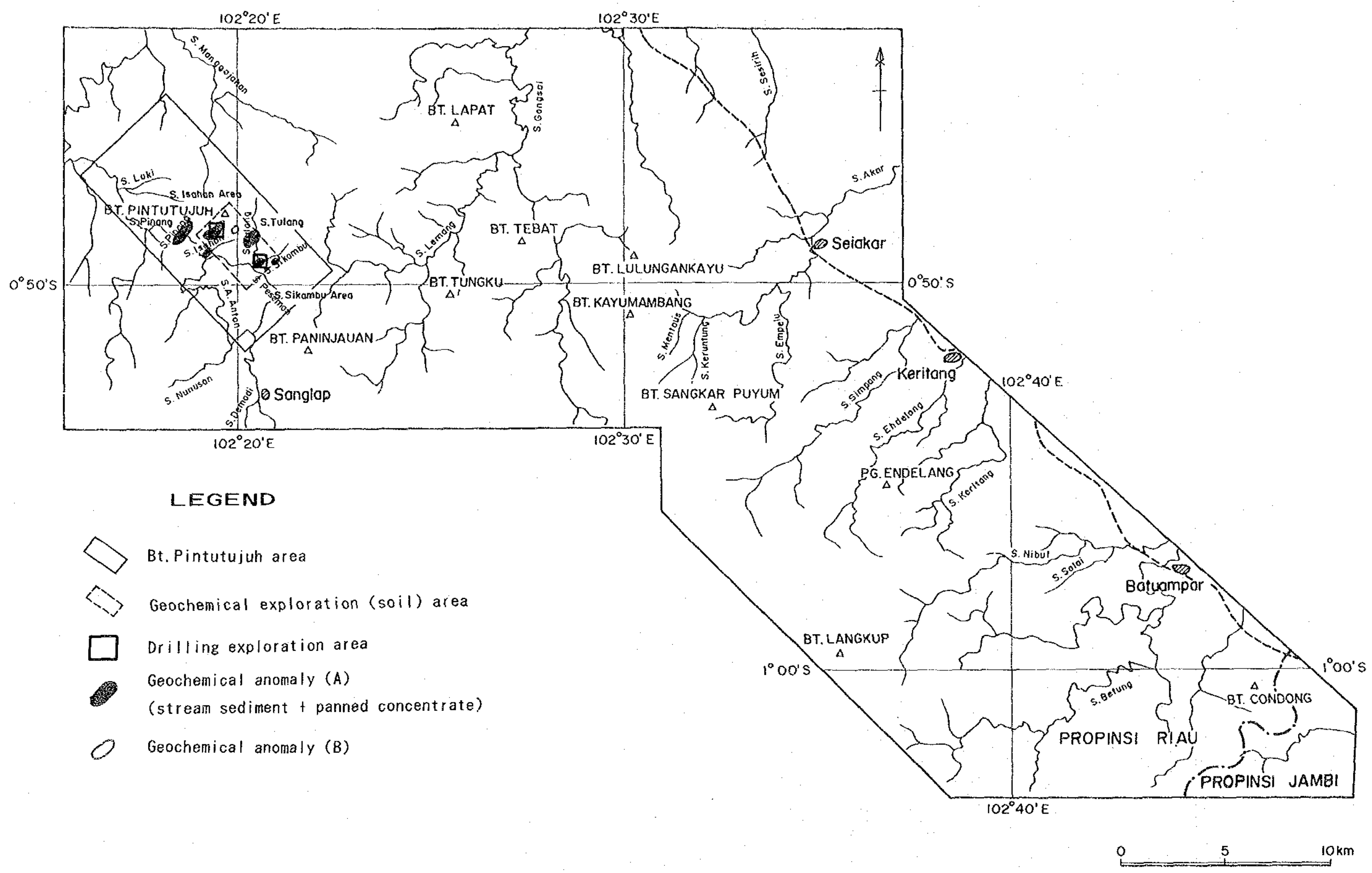

Fig.1-2 Generalized Map of Survey Results

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PART I OVERVIEW

PART I OVERVIEW

Chapter 1 Outline of the survey

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 the 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 with 1,000 km^2 areal extension. 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 Bt.Pintutujuh 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.

This report is final one concluding the results of these surveys conducted during 1989 to 1990. The flowsheet of this survey is shown in Figure 1-3.

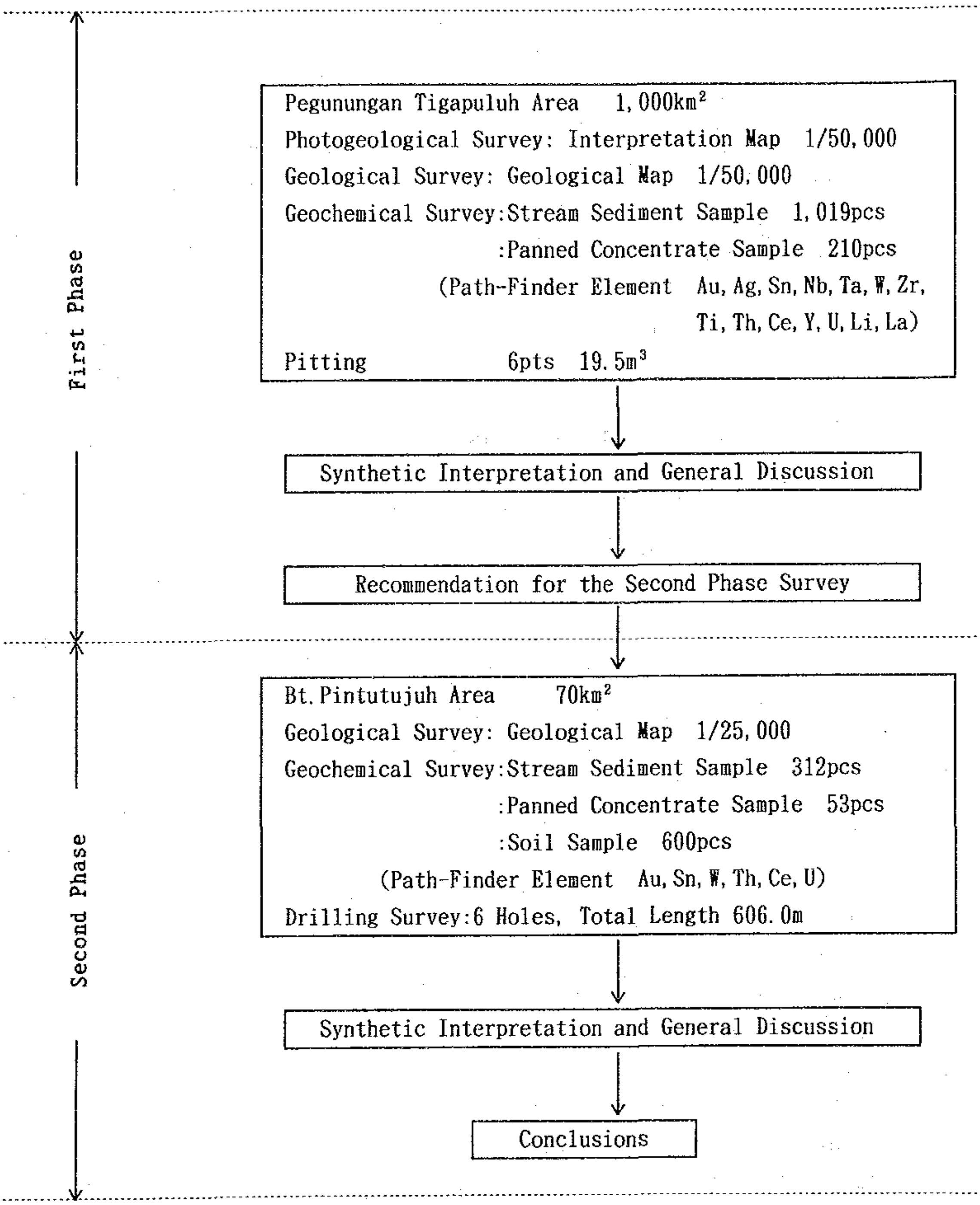


Fig.1-3 Flow Sheet of the Survey

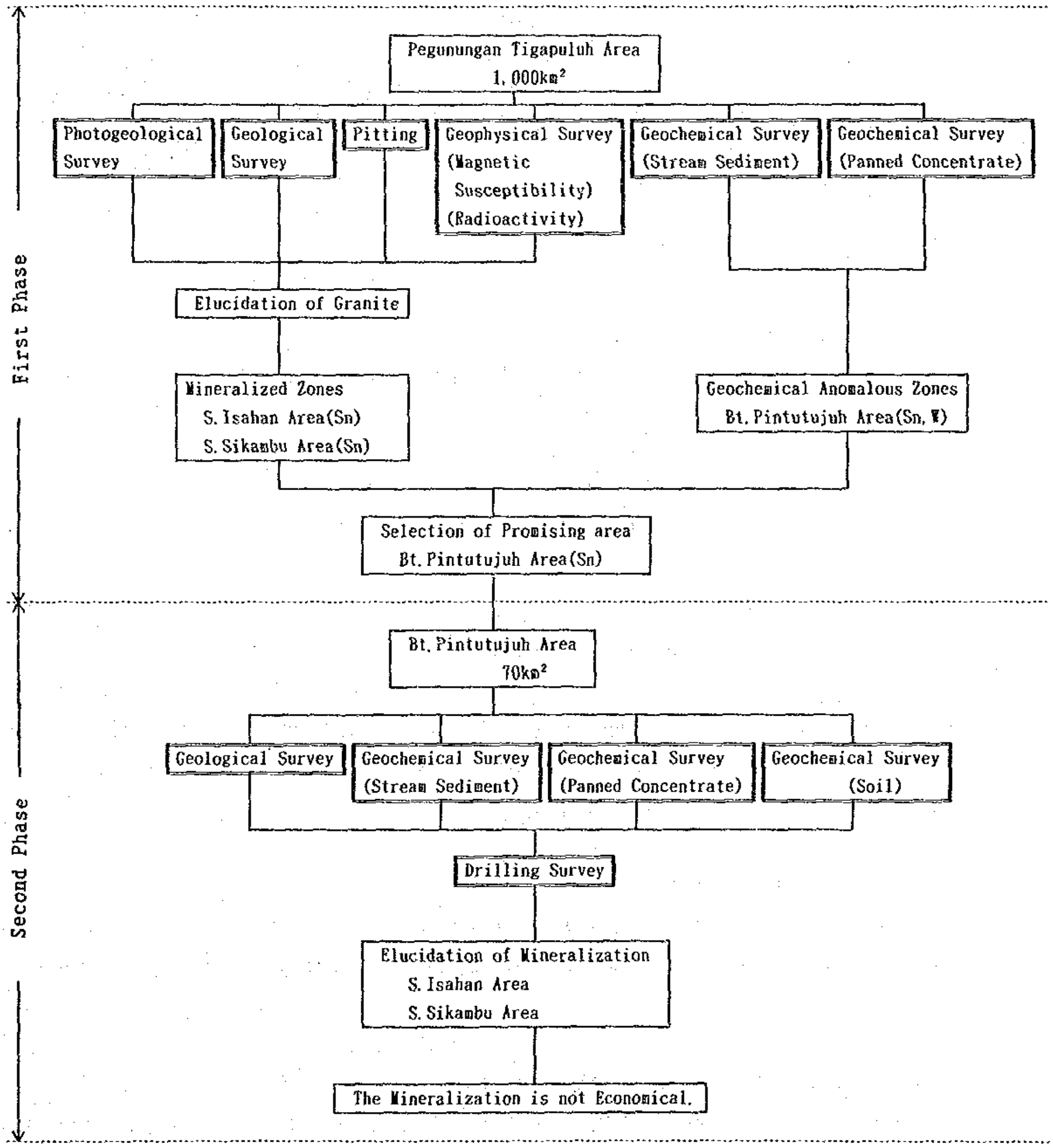


Fig. 1-4 Flow Sheet of Extracting the Promising Mineralized Zones

1-1 Survey Area and Objectives of the Survey

1-1-1 Location of Survey Area

The survey area is located to the south of central Sumatra as shown in Figure 1-1, and is surrounded by the coordinates listed below (Fig.1-5).

(1) Pegunungan Tigapuluh Area

South latitude	East longitude	South latitude	East longitude
0°43'23"	102°15'34"	1°03'16"	102°38'28"
0°43'23"	102°37'07"	0°55'55"	102°30'53"
0°50'25"	102°37'07"	0°53'42"	102°30'53"
1°01'00"	102°48'52"	0°53'42"	102°15'34"
1°03'16"	102°48'52"		

(2) Bt.Pintutujuh Area

South latitude	East longitude
0°44'52"	102°18'02"
0°47'08"	102°15'46"
0°51'40"	102°20'17"
0°49'23"	102°22'34"

1-1-2 Objectives

(1) Geological survey and geochemical exploration

The objectives of geological survey and geochemical exploration are elucidating the relationship between mineralization and geoligic structure and also between mineralization and granitic rocks, and extracting the promising zones for future prospecting.

(2) Drilling exploration

The objective of drilling exploration is to evaluate the mineral occurrence in the mineralized zones extracted by geological and geochemical survey.

1-2 Methods and Contents of the Survey

The survey methods are divided into geological survey, geochemical exploration, drilling and laboratory studies. The methods and contents of each phase are shown in Table 1-1.

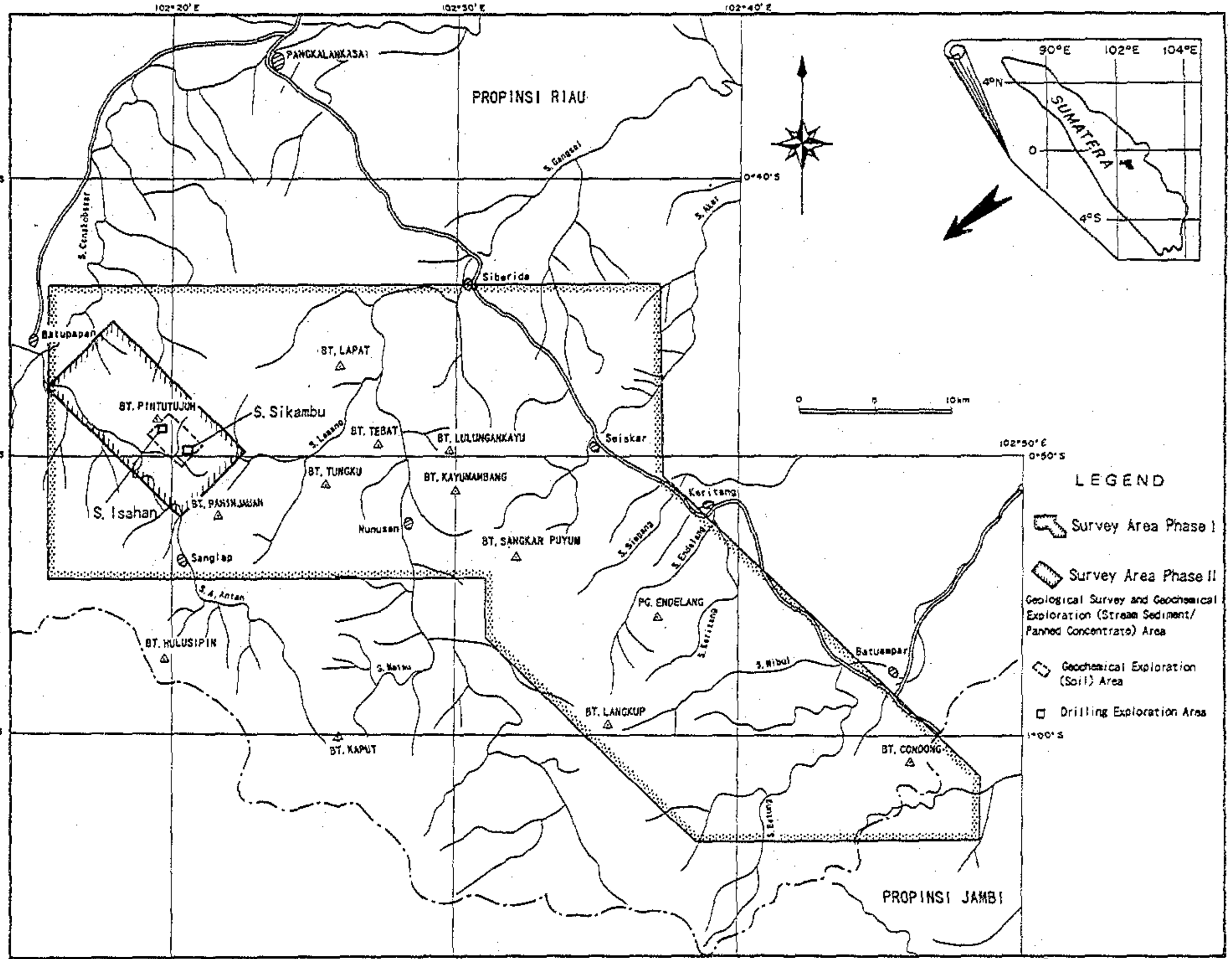


Fig.1-5 Location Map of Geological Survey, Geochemical Exploration and Drilling Exploration Areas

1-3 Survey Period and Organization of the Survey Team

The period of the field work and the organization of the survey team in each phase are shown in Table 1-2.

Table 1-1 Survey Methods and the Contents

Phase	Survey method	Area	Contents
Phase I	Photogeological Interpretation	P. Tigapuluh area	1,000 km²
	Geological survey	P. Tigapuluh area	1,000 km² (Geologic map, scale 1/50,000) Pitting (6 wells, 19.5m³)
	Geochemical exploration	P. Tigapuluh area	Stream sediments 1,019 pcs Panned concentrates 210 pcs (Au, Ag, Sn, Nb, Ta, W, Zr, Ti, Th, Ce, Y, U, Li, La)
	Mesurements of magnetic susceptibility and radioactivity	P. Tigapuluh area	
	Laboratory studies	Thin sections	31 pcs
		X-ray diffraction analysis	31 pcs
		Age determination	5 pcs
		Whole rock analysis	10 pcs (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, BaO, F, LOI)
		Assay of ore samples	21 pcs (Au, Ag, Sn, Nb, Ta, W, Zr, TiO_2, Th, Ce, Y, Li, La, MnO, Fe)
Phase II	Geological Survey	Bt. Pintutujuh area	70 km² (Geologic map, scale 1/25,000)
	Geochemical Exploration	Bt. Pintutujuh area	Stream sediments 312 pcs Panned concentrates 53 pcs Soil samples 600 pcs (Au, Sn, W, Th, Ce, U)
	Drilling	S. Isaban and S. Sikambu areas	6 holes (MJIT-1 to -6) Total length 606.0m
	Laboratory studies	Thin sections	40 pcs
		Polished sections	10 pcs
		X-ray diffraction analysis	20 pcs
		Age determination	3 pcs
		Whole rock analysis	10 pcs (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, BaO, F, LOI, Ce, Sr, Rb, Nb, Ta, Y, Zr, Sn, W, Th, U, Li)
		Assay of ore samples	5 pcs (Au, Sn, W, Th, Ce, U)
		Assay of boring cores	209 pcs (Au, Sn, W, Th, Ce, U)

Table 1-2 Duration of the Survey and Members of the Survey Team

Phase (Year)	Work	Duration	Name: Japanese side	Name: Indonesian side
Phase I (1989 - 1990)	Mission for project-finding and scope of work		Kyo-ichi KOYAMA (3) Hideiku SINOKAWA (1) Yasuhiro KAINUMA (2) Naoki SATO (3)	Dr. Adjat Sudrajat (4) Salman Padmanagara (5) A. Machali Muchsin (5) Sunarya Johari (5) Nally Ahmad (4) Ratnawidupi (5)
	Coordinate		Masaharu TOYAMA (3)	
	Geological Survey and Geochemical Exploration	1989. 10. 10 to 1989. 12. 26	Yoneharu MATANO (6) * Mikio KAYUKAWA (6) Hideya KIKUCHI (6) Tesuo SATO (6) Kenji SATO (6)	Sunarya Johari (5) * Zamri Ta'in (5) Endang Suwargi (5) Karno (5) Malik Manurung (5) Sahala L. Gaol (5) A. Said Ismail (5) Zulkifli MD. (5)
Phase II (1990~1991)	Coordinate		Nobuyuki MASUDA (3)	
	Geological survey and Geochemical exploration	1990. 7. 12 to 1990. 9. 25	Yoneharu MATONO (6) * Tesuo SATO (6)	Sunarya Johari (5) * Zamri Ta'in (5) Dwi Nugroho (5) Subandi (5) Rukanda A. R. (5)
	Drilling Exploration	1990. 8. 9 to 1990. 12. 11	Susumu HORIGUCHI (6) Souji KANNARI (6) Jun-ichi KATO (6)	Endang Suwargi (5) Awan Rachman (5) Maman Suherman (5) Mardiyanto (5)

[Note]

(1) : Ministry of International Trading and Industry (MITI)

(2) : Japan International Cooperation Agency (JICA)

(3) : Metal Mining Agency of Japan (MMAJ)

(4) : Directorate General of Geology and Mineral Resources (DGGMR)

(5) : Directorate of Mineral Resources (DMR)

(6) : Nikko Exploration & Development Co., Ltd. (NED)

* : Team leader

Chapter 2 Circumstance of the Survey Area

2-1 Access, Topography and Drainage System

(1) Access

The survey area is reached from Jakarta, the capital of Indonesia, by air to Padang, which is a capital of West Sumatra Province on the west coast of Sumatra 250 km due west of the survey area; from Padang, the travel on land for the distance of about 400 km takes about 10 hours. The road between Padang and Pangkalan Kasai (where the base camp was set up) is paved but passes over numerous bridges, allowing passage of only under-5-ton vehicles.

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

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

(2) Topography

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

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

(3) Drainage system

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

2-2 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) Vegitation

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 shrubs and bushes of 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 comprise, in ascending order, the Oligocene Kelesa Formation (polymictic conglomerate and pebbly sandstone), Miocene Lakat Formation (polymictic conglomerate, quartz sandstone and alternations of quartz sandstone and claystone), Tualang Formation (quartz sandstone and claystone), Gumai Formation (shale, claystone and sandstone), Miocene 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 1-6 (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 sediments in the western area.

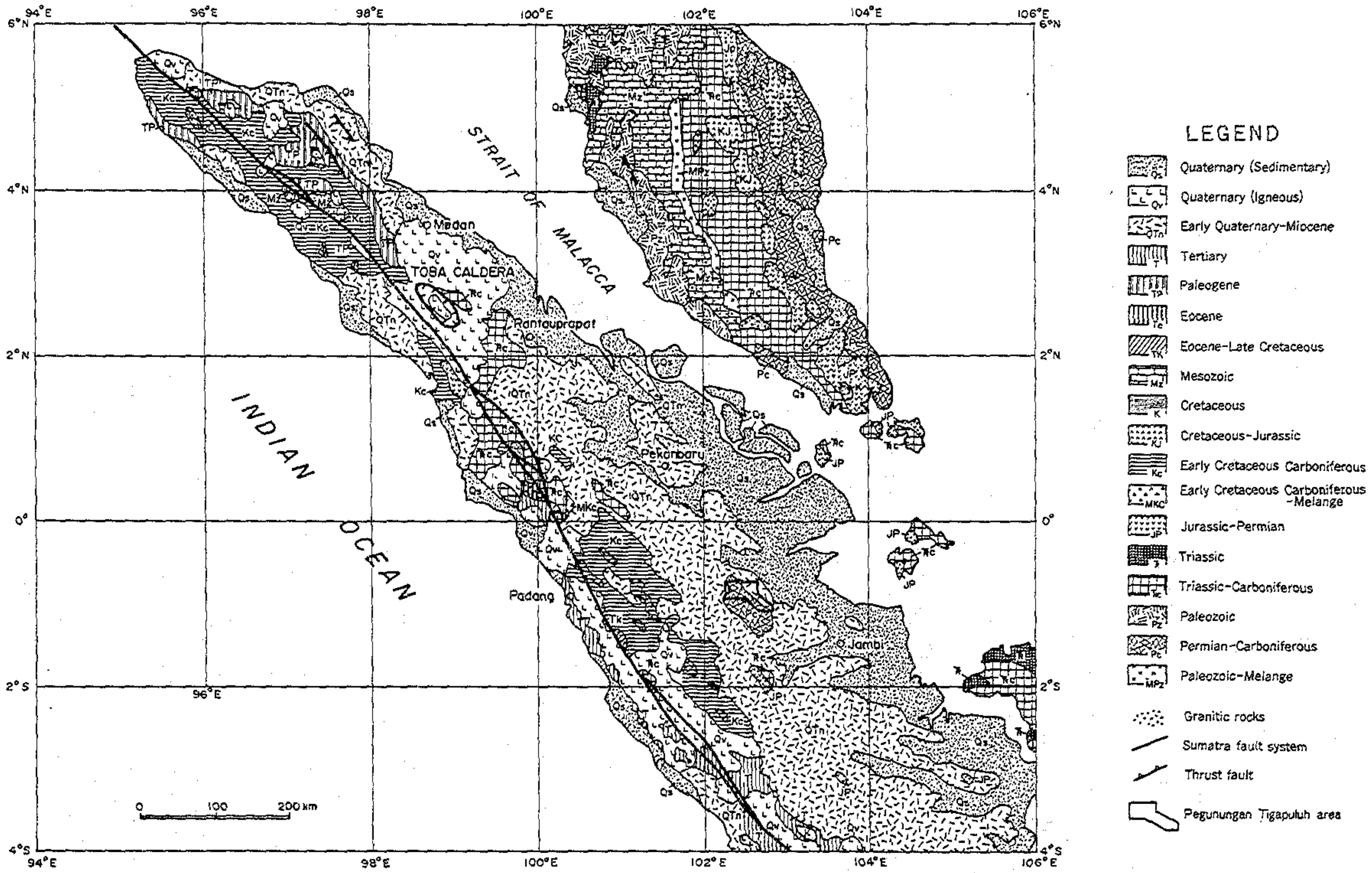


Fig.1-6 Geologic Map of Central Sumatra

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 felsic 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 Geological Setting of the Pegunungan Tigapuluh and Bt.Pintutujuh Areas

(1) Pegunungan Tigapuluh Area

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

The Paleozoic is divided into the S.Nunusan Formation and Bt.Pintutujih Formation. The S.Nunusan Formation is composed of phyllite and black slate derived from pelitic rock. The Bt.Pintutujuh Formation is composed of siltstone and black slate.

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

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

The geologic structure of the survey area is characterized by numerous

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

(2) Bt.Pintutujuh Area

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.

The granitic rocks intruding into the Paleozoic are classified by lithofacies into biotite granite, leucocratic granite and aplite. The biotite granite was intruded in Early Cretaceous.

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.

Cassiterite bearing quartz veinlets and cassiterite dissemination occur in leucocratic granite.

Chapter 4 Previous surveys

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).

Chapter 5 Conclusions

(1) Pegunungan Tigapuluh Area

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

The granitoids distributed in this area are classified into porphyritic biotite granite, biotite granite, leucocratic granite, pegmatite and aplite, from their lithology and chemical composition. All of these rocks belong to the ilmenite series from their chemical compositions and magnetic susceptibilities. The porphyritic biotite granite is in a more advanced stage of differentiation than the biotite granite.

The porphyritic biotite granite is arranged in the central to the eastern part while the biotite granite from the western to the central part of the survey area in NW-SE direction.

The mineralized zones are the cassiterite-bearing quartz vein network and cassiterite dissemination at the upper reaches of S.Isahan and the lower reaches of S.Sikambu in the western part of the area.

Six A-rank anomalous zones of stream sediments were delineated for Sn, two zones for Sn, W and Au and one zone for Nb, W, Zr, Th, Ce, Y, U, Li and Sn. Two of these nine zones correspond to the known tin-mineralized zones, with the Sn geochemical anomalies ranging from 70 to 710 ppm.

Four A-rank anomalous zones of panned concentrates were delineated for Sn, three zones for Sn and W or Au and three zones for Sn and Nb-W, Nb or Li and one zone for Sn,Zr and Li. Two of these eleven zones correspond to the known tin-mineralized zones.

The known mineralized zones show A-rank geochemical anomalies both with stream sediment and panned samples. There are four A-rank anomalous zones(Sn or Sn-W) located around the known mineralized zones.

These six A-rank geochemical anomalies are distributed approximately in the NNW-SSE direction. This fact indicates that the mineralization of this area was controlled by the weak structure line of NNW-SSE direction.

From the results of geological survey and geochemical exploration in the Pegunungan Tigapuluh area, primary Sn and W mineralization is prospective in the area. Primary Sn, W mineralization is expected in the Bt.Pintutujuh area.

(2) Bt.Pintutujuh Area

The geology of 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. It is considered that the leucocratic granite is the intrusive facies of granite, and thus it is inferred that the porphyritic biotite granite exist beneath the leucocratic granite without surface exposures.

Fault systems of WNW-ESE and NNW-SSE trends are developed in the survey area. The leucocratic granites which host the known tin mineralization, are arranged approximately in the WNW-ESE direction from the upper reaches of S.Isahan to S.Tulang.

Whole survey area of this area 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 analyzed.

The results of geochemical exploration using stream sediments and panned concentrates are already stated in (1) Pegunungan Tigapuluh Area.

Three anomalous zones were identified from the soil geochemistry; one extending from the upper reaches of S.Isahan to S.Tulang approximately in the 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 in the WNW-ESE direction. It coincides with the direction 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 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.

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 %

The leucocratic granite is composed mainly of quartz, potassium feldspar, plagioclase and muscovite. Phenocrysts 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 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. It is inferred that a leucocratic granite related to tin mineralization occur in there. But, judging from values of geochemical anomalies of stream sediments and panned concentrates, it is difficult that a mineralized zone with ore grade exceeding those of the known mineralized zones is expected to occur.

From the results of these surveys, it was clarified that possibility of existence of economically feasible deposits in the survey area is low.

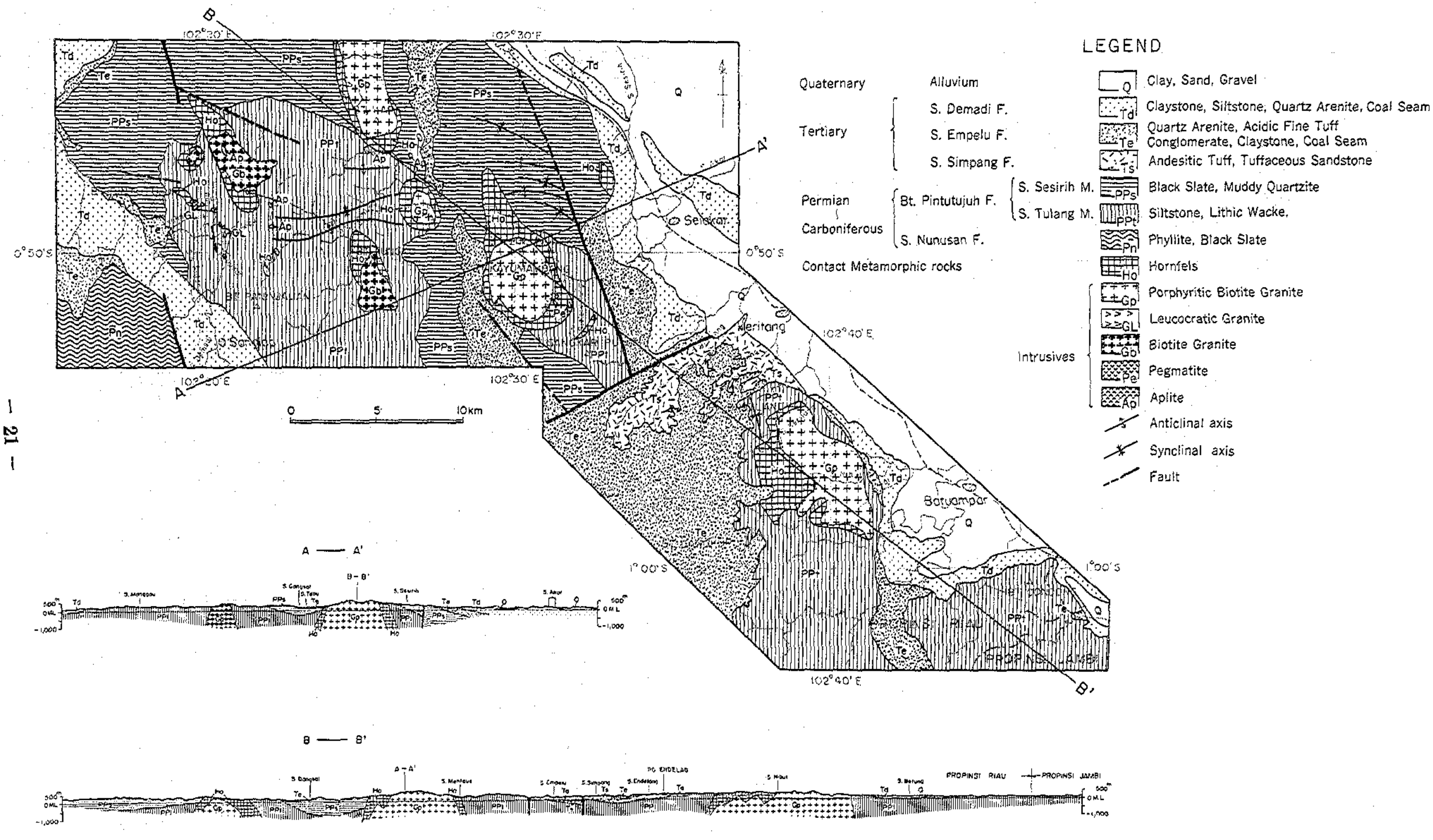


Fig.1-7 Geologic Map of Pegunungan Tigapuluh Area

Geological Age			Formation		Columnar Section	Thickness (m)	Rock Facies	Igneous Activity	Mineralization
Cenozoic	Quaternary						Clay, Sand, Gravel		
Cenozoic	Tertiary	Neogene	S. Demadi			500+	Claystone, Siltstone, Quartz Arenite(Q), Coal Seam(Cs)		
Cenozoic	Tertiary	Neogene	S. Empelu			300	Quartz Arenite(Q), Acidic Fine Tuff(Af) Conglomerate(Co), Claystone(Cl), Coal Seam(Cs)		
Cenozoic	Tertiary								
Cenozoic	Tertiary	Paleogene	S. Simpang			300+	Andesitic Tuff (At) Tuffaceous Sandstone(Ts)		
Mesozoic	Cretaceous								
Mesozoic	Jurassic								
Mesozoic	Triassic								
Paleozoic	Permian ∫ Carboniferous		Bt. Pintutujuh	S. Sesirih		1,100+	Black Slate, Muddy Quartzite	← Porphyritic Biotite Granite (Gp), Biotite Granite (Gb), Leucocratic Granite (GL), Pegmatite(Pe), Aplite(Ap), Contact Meta. → Hornfels(Ho)	○ Primary Tin deposits
Paleozoic	Permian ∫ Carboniferous		Bt. Pintutujuh	S. Tulang		1,000	Siltstone, Lithic Wacke, Black Slate, Pebbly Mudstone		
Paleozoic	Permian ∫ Carboniferous		S. Nunusan			500+	Phyllite, Black Slate		

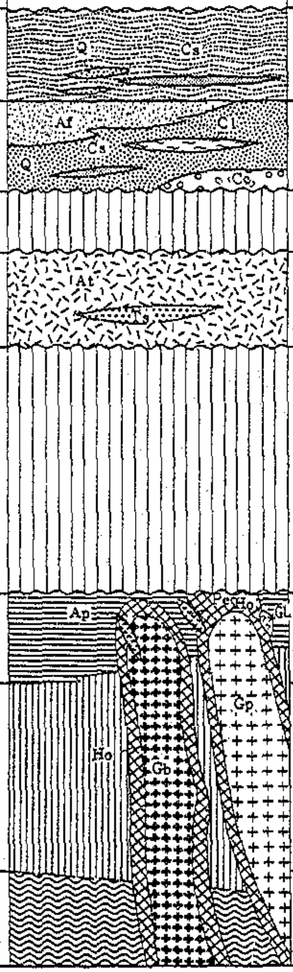
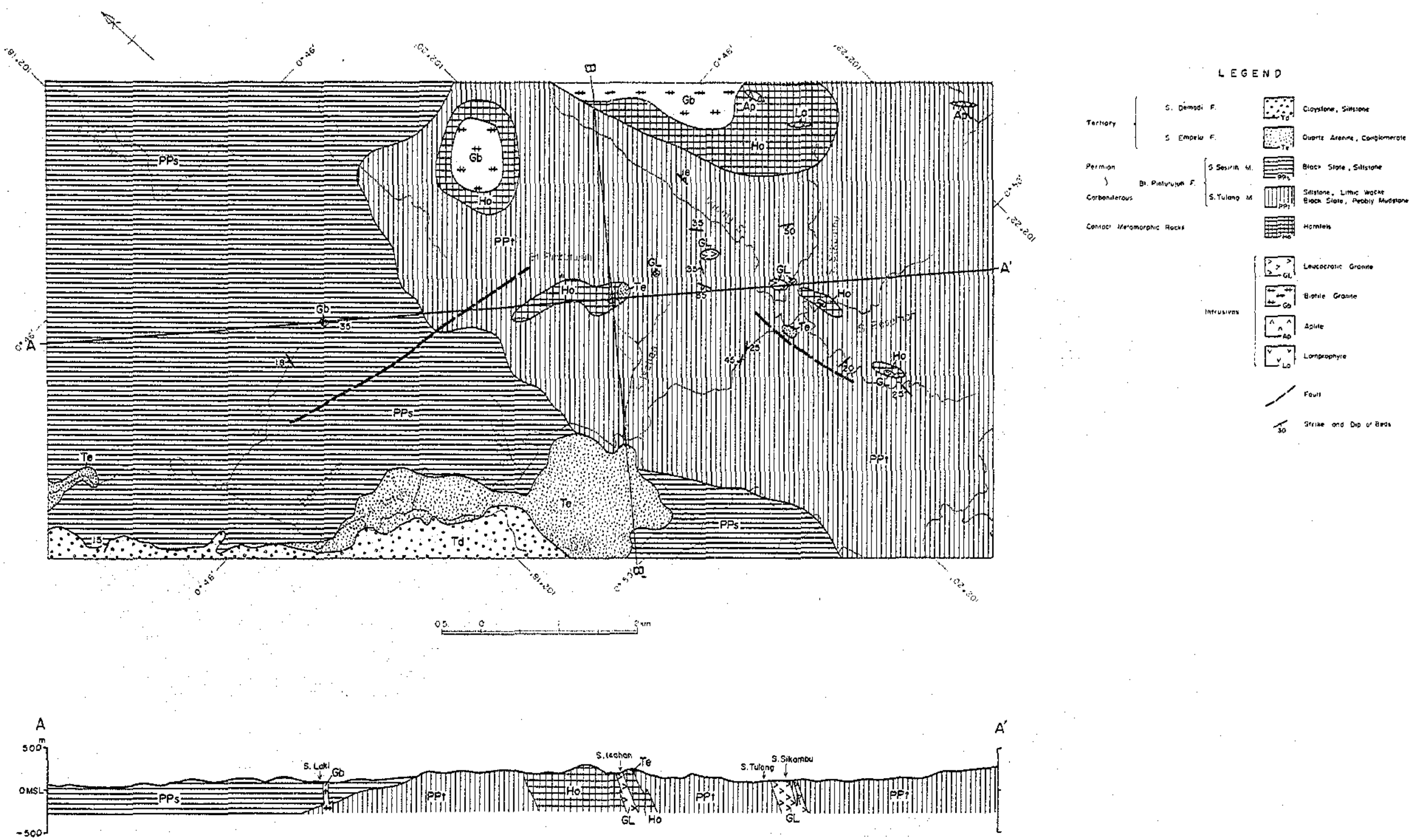


Fig.1-8 Schematic Geologic Column of Pegunungan Tigapuluh Area



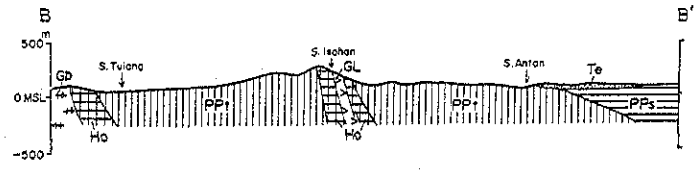


Fig.1-9 Geologic Map of Bt.Pintutujuh Area

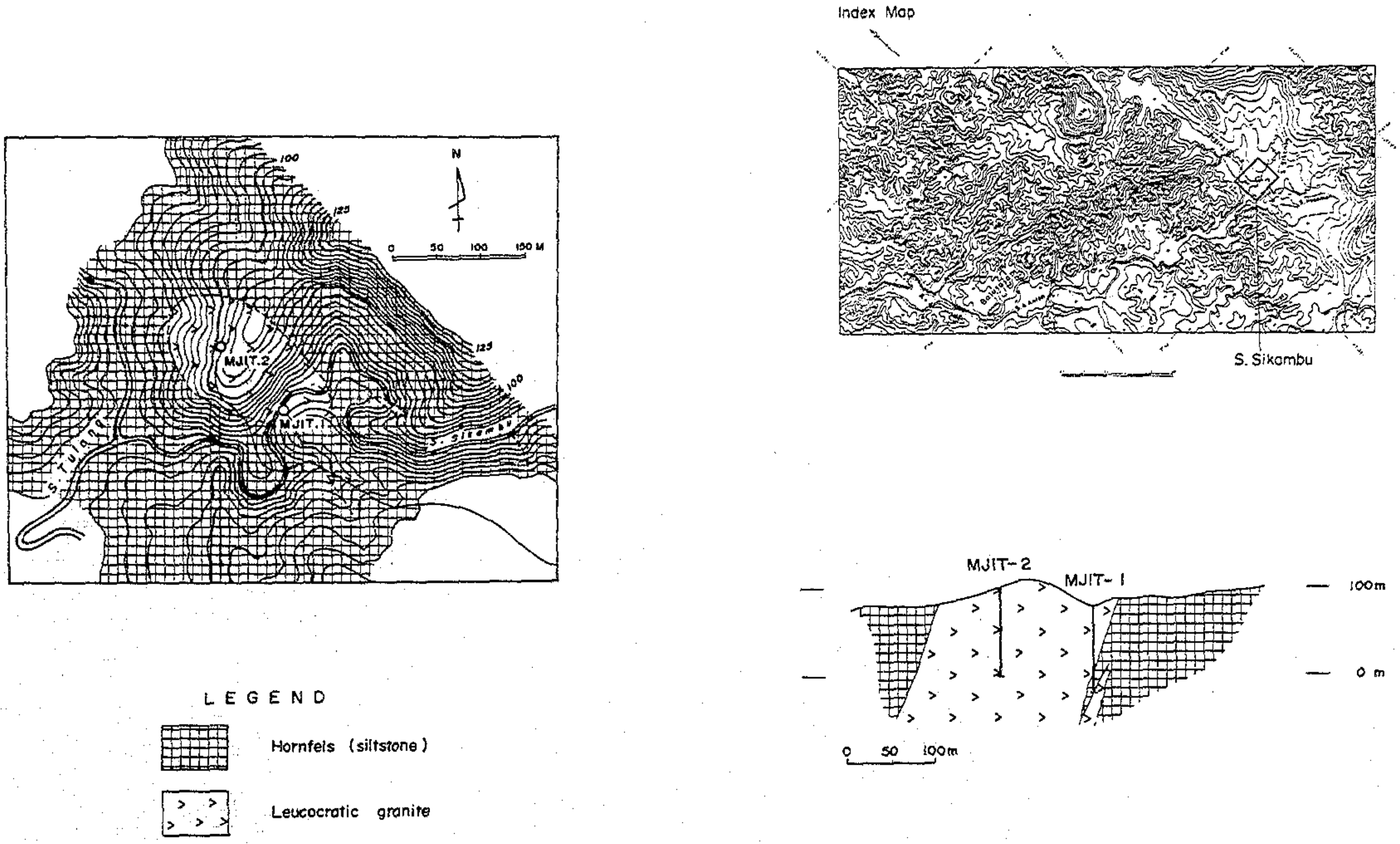


Fig.1-10 Map Showing Location of Drill Holes and Geology of S.Sikambu Zone

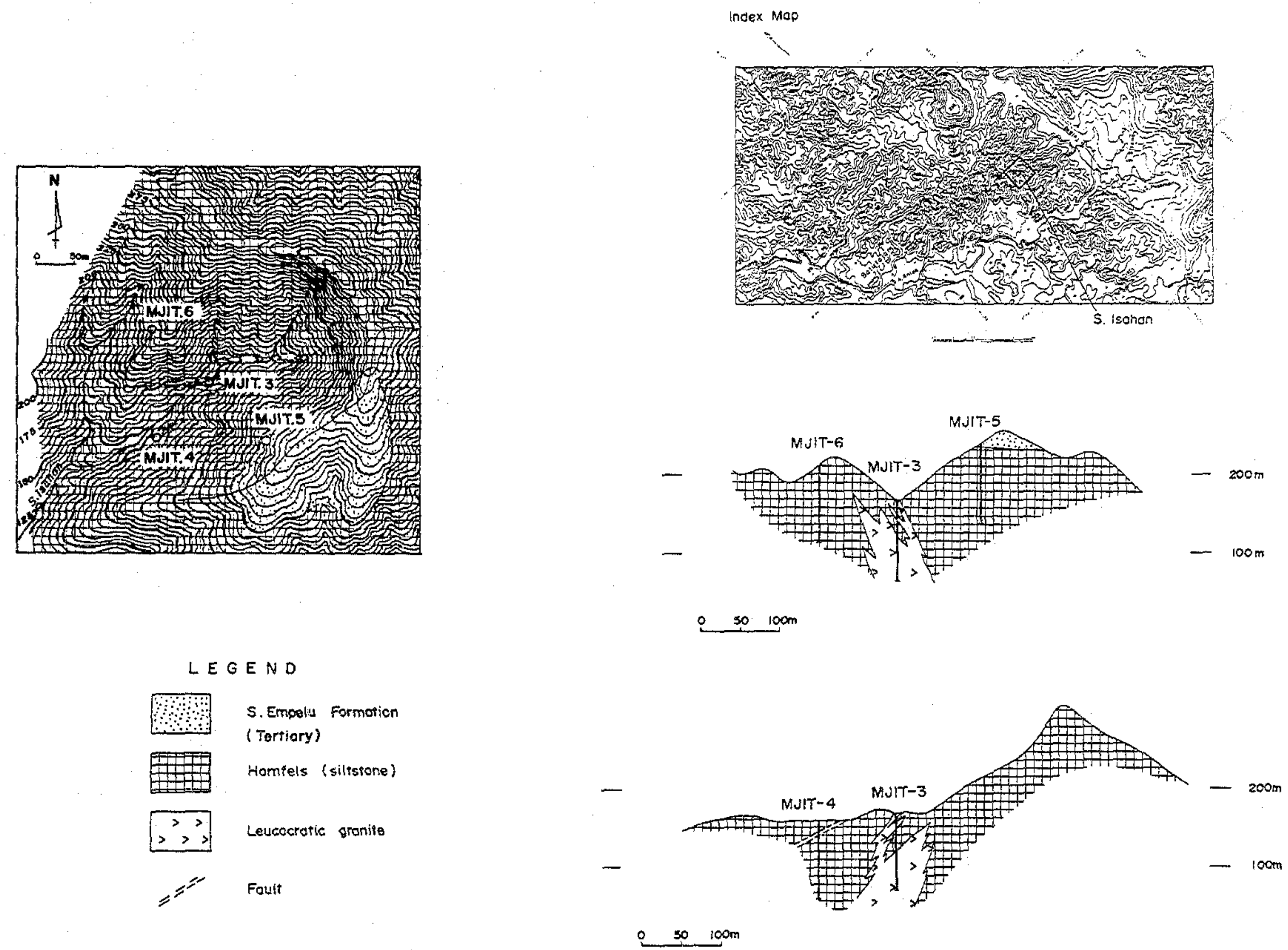


Fig.1-11 Map Showing Location of Drill Holes and Geology of S.Isahan Zone

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Pegunungan Tigapuluh Area

1-1 Photogeological Interpretation

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

The aerial photographs used in the investigation were monochromatic prints of 1:110,000 scale. The number of photographs covering the survey area was 30.

(1) Geologic units

From the results of photogeological interpretation, the geology of the survey area was divided into eight geologic units, as shown in Figure 2-1. They comprise clastic rocks (six units), an intrusive rock unit, G, and an unconsolidated clastics unit, Q. By referring to the existing material, the clastic rocks can be subdivided into Paleozoic units, P_1,P_2 and H, and Tertiary units, T_1, T_2 and T_3.

① Unit P_1

This unit is extensively distributed between S.Gangsal and S.A.Antan, east of S.Gangsal, and also in the southeastern part of the survey area. It has the widest distribution of all the eight units. It is judged that Unit P_1 is composed of hard clastic rocks.

② Unit P_2

This unit constitutes the mountainland west of S.A.Antan in the southwestern part of the survey area. It is distributed also in the southeastern end of the area, though on a smaller scale. The area occupied by this unit is extremely small. This unit is inferred to be composed of clastic rocks harder than those of Unit P_1.

③ Unit H

Unit H is distributed in the northwest and southeast extensions of Unit G around Bt.Kayumambang in the central part of the area. In the eastern part, it occurs on a small scale northeast of Pg.Endelang, in the central to northwestern parts, its distribution is elongated in WNW-ESE direction. Since Unit H is locally in direct contact with Unit G, which is assumed to be granitic rock, it is probable that Unit P_1 became the hornfelsic Unit H through thermal metamorphism.

④ Unit T_1

This unit occurs along S.Antan in the area's western part, along

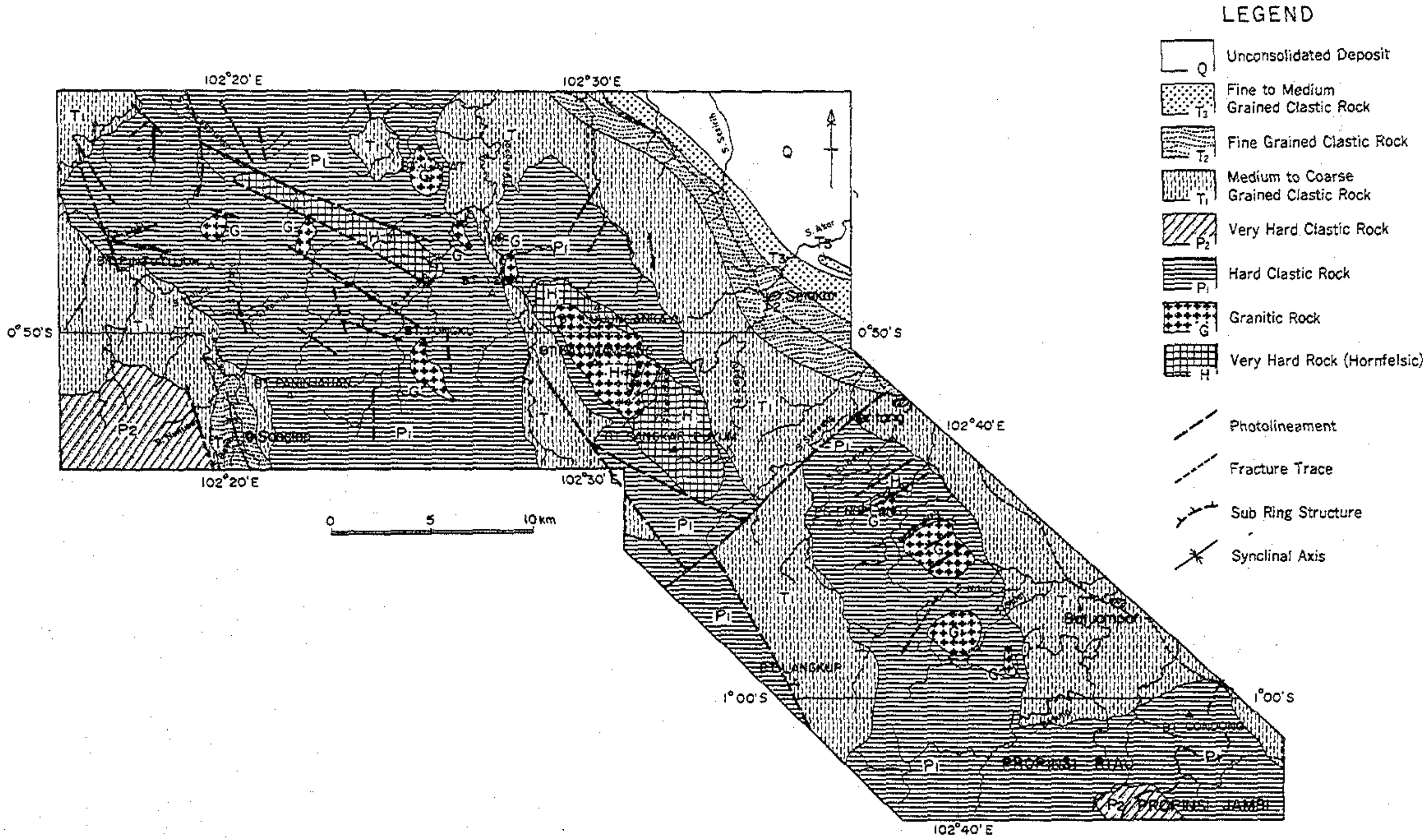


Fig.2-1 Photogeological Interpretation Map

S.Gangsal in the central part, in the northeastern and southeastern hills, and also around Bt.Langkup. Its distribution is next to Unit P_1 in areal extent. Unit T_1 appears to consist of somewhat soft and medium-to-coarse-grained clastic rocks. It may have an unconformable relationship with the underlying units (P_1, P_2).

⑤ Unit T_2

This unit is distributed in the northeastern part of the area on the northeast side of Unit T_1. It occurs also in the upper reaches of S.A.Antan in the western part. Unit T_2 is judged to be composed of soft and fine-grained clastic rocks. Its relationship with the underlying Unit T_1 is thought to be conformable.

⑥ Unit T_3

This extends in NW-SE direction as a long and narrow distribution on the northeast side of Unit T_2 in the northeastern part of the area. This unit is probably composed of soft and fine-to-medium-grained clastic rocks. Its has a seemingly conformable relationship with the underlying Unit T_2.

⑦ Unit Q

This unit is distributed only at the northeastern end of the area. This unit is inferred to be composed of unconsolidated clastics.

⑧ Unit G

This unit is distributed widely around Bt.Kayumambang in central part of the area. It occurs also in four localities northeast of Bt.Kayumambang, four localities around Pg.Endelang in the southeastern part of the area, and also at Bt.Tungku in the central south section of the area, though all on a small scale. From the fact that Unit H occurs around it and that subannular structure is observed, as well as from the drainage pattern and topographic features, it is inferred that Unit G is composed of granitic rocks which intrude Unit P_1.

(2) Geologic structure

Bedding is not recognized in any of the units of clastic rocks. Thus, rocks constituting these units are massive, and hence the presence or absence of fold structures remains unknown.

A total of 35 lineaments are recognized throughout the survey area. Of these, 28 are developed in Units P_1, H and G; seven are found in Unit T_1 or distributed across Unit T_1 and underlying units. Regarding the direction of these lineaments, N-S to NNW-SSE systems are found to be dominant. In terms of occurrence, lineaments are concentrated in Unit P_1 zone at the western end. Examination of the extension of each lineament revealed that those longer than 10 km trend in NNW-SSE to WNW-ESE directions.

1-2 Geological Survey

1-2-1 Outline of Geology

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

The Paleozoic is divided into the S.Nunusan Formation and Bt.Pintutujih Formation. The S.Nunusan Formation is composed of phyllite derived from pelitic rock and black slate. The Bt.Pintutujuh Formation consists chiefly of siltstone and black slate, which can be subdivided into the S.Tulung and S.Sesirih Members by their lithofacies.

The granitic rocks intruding into the Paleozoic are classified into porphyritic biotite granite, biotite granite, leucocratic granite, pegmatite and aplite by their lithofacies. The age of their intrusion ranges from Jurassic to Early Cretaceous. Due to the intrusion of these rocks, the Carboniferous to Permian sedimentary strata underwent contact-metamorphism and altered into hornfels.

Unconformably covering all these rocks, the Paleogene System consisting of andesitic tuff is distributed within a limited area. The Neogene System consisting of quartzose arenite and claystone overlies the Paleogene System with an unconformity, and is distributed in various places.

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

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

(1) S.Nunusan Formation

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

The formation is composed of very hard black, greyish black or greyish olive phyllite, and black slate which easily exfoliates into thin plates.

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

(2) Bt.Pintutujuh Formation

This formation is divided by lithofacies into two members; namely, the S.Tulang and S.Sesirih Members.

① S.Tulang Member

In the western part of the present area, this member is distributed at the vicinity of Bt.Pintutujuh. In the central part, it is distributed in the NW-SE direction southeast of Bt.Kayumambang, and in the east, its distribution extends widely from Pg.Endelang to the south.

This member consists chiefly of grey, dark grey, or rarely dark greenish grey siltstone and lithic wacke, intercalated with black mudstone and black slate. It is generally massive, and bedding is rare.

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

② S.Sesirih Member

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

The constituents are black mudstone and slate. It is generally massive.

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

(3) S.Simpang Formation

The formation consists chiefly of andesitic tuff, with some sandstone. It is distributed only in the vicinity of S.Endelang in the eastern part of the survey area. The thickness of the S.Simpang Formation is estimated to be approximately 300 m.

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

(4) S.Empelu Formation

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

It consists mainly of greyish white or grey quartzose arenite and fine-grained white acidic tuff. The arenite is intercalated with yellowish grey claystone 10~30 cm thick, and occasionally with a coal seams whose maximum thickness is 1.5 m. These rocks are not very consolidated.

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

(5) S.Demadi Formation

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

The main constituents are claystone and siltstone. The lower part is intercalated with quartzose arenite and coal seams.

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

1-2-2 Intrusive Rocks

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

(1) Porphyritic biotite granite

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

The porphyritic biotite granite is characterized by columnar or rhombic megaphenocrysts of potassium feldspar, its maximum size is 5 x 5 cm. In some parts, the megaphenocrysts make up more than 60 % by volume ratio. They often contain medium to fine-grained phenocrysts of biotite. The principal rock-forming minerals, excluding the potassium feldspar megaphenocrysts, are quartz, potassium feldspar, plagioclase and biotite. Under the microscope, aside from megaphenocrysts, these minerals show an equigranular structure. The potassium feldspar and plagioclase are saussuritized.

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

(2) Biotite granite

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

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

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

(3) Leucocratic granite

Small bodies of the leucocratic granite are distributed in the western part from the upper reaches of S.Isahan to S.Sikambu. 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.

(4) Pegmatite and aplite

Pegmatite occurs as small-scale intrusive bodies along S.Keruntung, a tributary of S.Akar, and along S.Mentaus in the eastern part of the survey area. the rocks occur as dikes 1 to 5 m wide. The principal rock-forming minerals of the pegmatite are quartz, potassium feldspar and plagioclase, accompanied by a small amount of muscovite. Under the microscope, the rock shows a graphic structure, a pegmatitic structure, or an equigranular structure.

Aplite is distributed as small dikes, 3 to 5 m wide, occurring within the medium-grained biotite granite east of Bt.Pintutujuh in the west, and within the Paleozoic in the upper reaches of S.Lemang and around S.Mentaus. Large quantities of aplite boulders are found to the west of Bt.Tungku, and to the south of Bt.Lapat. Aplite also occurs as small stocks near the mouth of S.Lemang. Aplite is made up chiefly of equigranular quartz, potassium feldspar, plagioclase and muscovite. In the west of Bt.Tungku and the south of Bt.Lapat, the rock shows mode of occurrence of aplite, but it contains only very minute amount of biotite, muscovite, hornblende and allanite which indicates the characteristics of high-temperature quartz vein.

(5) Chemical composition

Nineteen samples were collected from porphyritic biotite granite, biotite granite and leucocratic granite, and analyzed for 13 major components and for fluorine as a trace component.

The results of analysis and the weight ratios of C.I.P.W. norm minerals are given in Appendix Table 1 and 2. The porphyritic biotite granite, biotite granite and leucocratic granite of the present area classified by the quartz-alkali feldspar-anorthoclase norm weight ratio are plotted in the different domains, as shown in Figure 2-2.

In the differentiation index (D.I.), the leucocratic granite shows 79 to 91 %, the porphyritic biotite granite 83 to 85 %, while the biotite granite has lower values, 54 to 70 %. The cassiterite-bearing granitic rocks of the Hatapang area of North Sumatra were compared with the granitic rocks of the present area by their SiO_2 content and differentiation index. The result revealed that the former with, 73 to 77 % SiO_2 content and over 92 % D.I., are more advanced in differentiation than the later, less than 73 % SiO_2 and less than 91 % D.I.

For comparison of the alkali-lime contents, the alkali-lime ratios of the respective rocks are shown in Figure 2-3. It is seen in the figure that the leucocratic granite shows a trend of $K_2O \gg Na_2O > CaO$, the porphyritic biotite granite a trend of $K_2O > Na_2O > CaO$, whereas that of the biotite granite is $K_2O > CaO > Na_2O$, indicating that it is rich in CaO. The distribution of the cassiterite-bearing granite of Thailand (Ishihara et al., 1980) is also shown in the same figure. Concerning the distribution, the porphyritic biotite granite of the present area is distributed adjacent to the former granite, but the distribution of the leucocratic granite and the biotite granite is distinctly separate from them.

The S-type, I-type, magnetite series and ilmenite series divisions of granite is used for clarifying the nature of the material which generates the felsic magma to produce granite. On the ACF diagram (Fig.2-4) used to discriminate between S-type and I-type, the porphyritic biotite granite is situated along the boundary of both types and in the S-type zone, while the biotite granite is distributed on the boundary and in the I-type zone. On the C/ACF-$Al_2O_3/(CaO+Na_2O+K_2O)$ diagram (Fig.2-5), both granites are roughly regarded as I-type.

On the Fe^{2+}/Fe^{3+} - SiO_2 diagram (Fig.2-6) used to discriminate between magnetite series and ilmenite series, all the granitic rocks of the present area belong to the ilmenite series.

The fluorine contents are in the range of 410 to 1,460 ppm. These values are low, in both maximum and mean values, as compared with those of the Hatapan granites (350 to 6,050 ppm) and the Kinta Valley granites of Malaysia (300 to 5,700 ppm).

1-2-3 Geologic Structure

The geologic structure of the present area is characterized by numerous Paleozoic fold and gently dipping Tertiary System. The faults

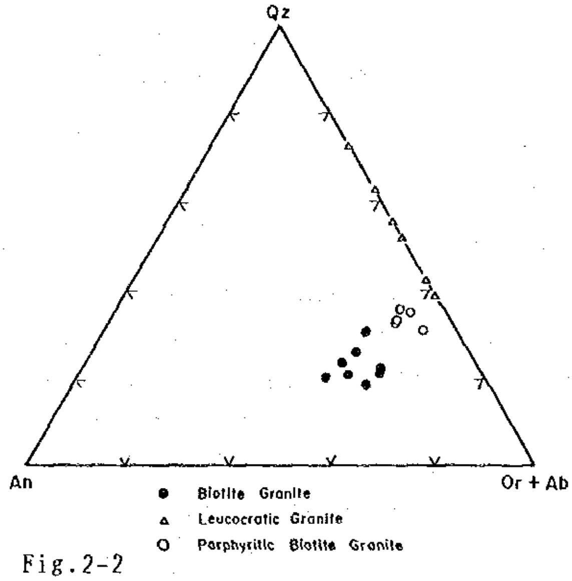


Fig.2-2
Quartz-Potassium
Feldspar-Anorthite Diagram

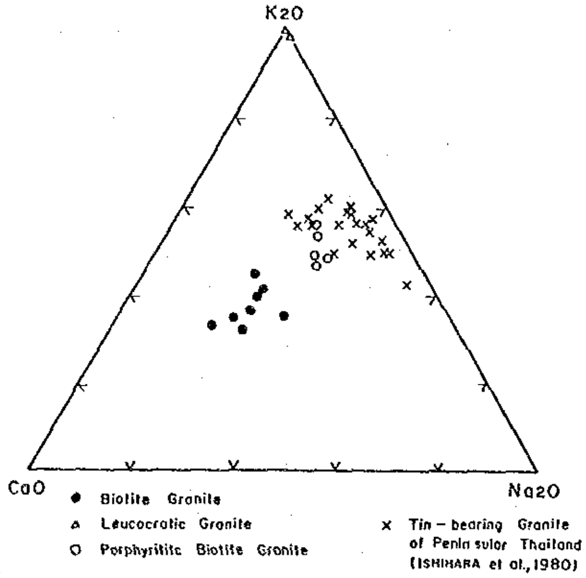


Fig.2-3 Alkali-Lime Ratio Diagram

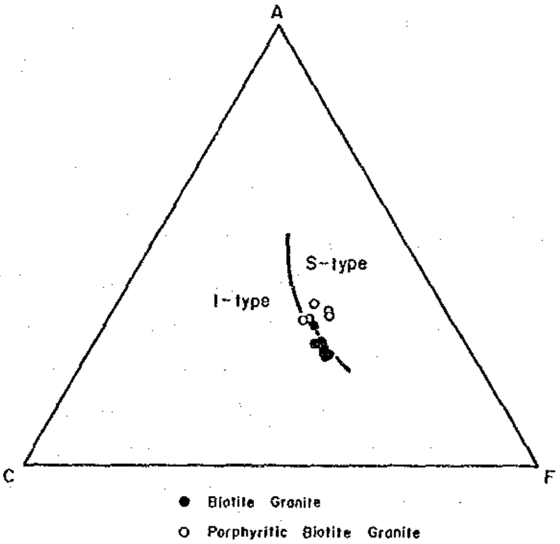


Fig.2-4 ACF Diagram

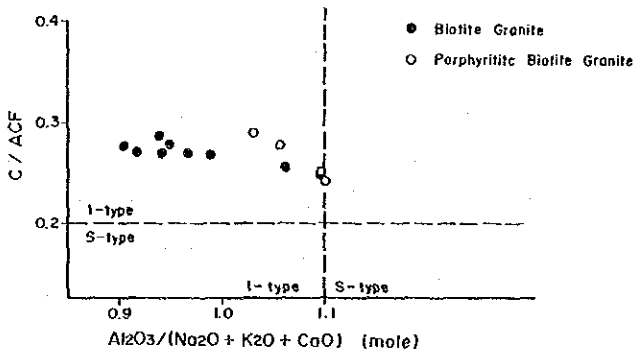


Fig.2-5
C/ACF-$Al_2O_3/(CaO+Na_2O+K_2O)$ Diagram

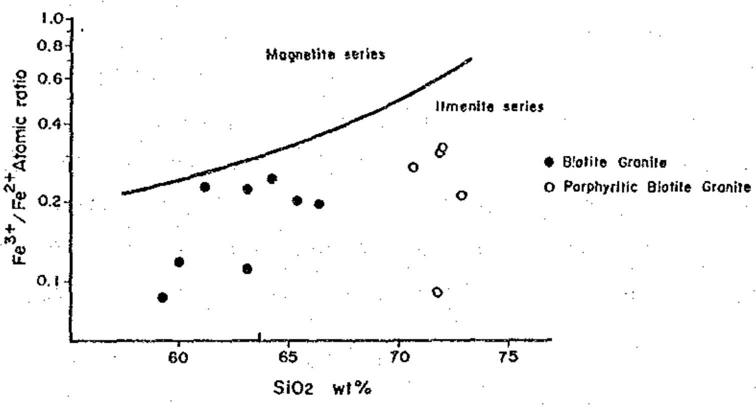


Fig.2-6 Fe^{2+}/Fe^{3+}-SiO_2 Diagram cutting the Paleozoic and the Tertiary Systems are those of the NW-SE, NNW-SSE and NE-SE systems. There is a trend for the NW-SE system to be cut by the NNW-SSE system which is itself cut by the NE-SE system.

(1) Fold structure

The Paleozoic structure in the present area is unclear in most cases because of the indistinct bedding of all formations. However, in the western part of the area, some parts of the Paleozoic show a distinct bedding, as observed in the vicinity of Bt.Pintutujuh to Bt.Tebat and in the north of Bt.Kayumambang. In such bedded parts several synclinal and anticlinal structures are observed. The wavelength of those folds is around one kilometre, and the direction of the fold axis is NW-SE in the vicinity of Bt.Pintutujuh, and E-W around Bt.Tebat and in the north of Bt.Kayumambang.

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

(2) Fault

Faults of the NW-SE system are found only along the upper reaches of S.Manggajohan in the western part of the area. Faults of the NNW-SSE system are distributed along the upper reaches of S.A.Antan and along the lower reaches of S.Manggajohan in the western part. They are also distributed along the upper reaches of S.Gangsal in the central part, and from S.Sesirih to the east of Bt.Kayumambang in the eastern part of the area. Formation up to the Neogene strata have been displaced by these faults. A WNW-ESE fault is distributed in the Paleozoic System of S.Laki.

Based on geotectonic history of East Sumatra (Tjia,1989), the faulting of the area is interpreted as follows. In the Tertiary System along S.A.Antan in the west and along S.Gangsal in the central area, the latent existence of a rift valley or a fracture zone formed between the Late Cretaceous and Early Tertiary is highly possible. From Oligocene, the NNW-SSE faults became active, and from the Miocene, they began to present the aspect of dip-slip faults accompanying the block uplift of the Paleozoic. The faults of the NE-SW system may be considered as those with a strong strike-slip element which became active after the development of NNW-SSE faults.

(3) Arrangement of intrusive rocks

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

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

1-2-4 Measurement of Magnetic Susceptibility and Radioactivity

It has been pointed out by Sano et al.(1988) and others that granites accompanied by tin and tungsten mineralization have relatively low magnetic susceptibility and high radioactivity. Granites are classified into the magnetite series and ilmenite series, by the relationships between the various constituent minerals and the mineralization and also between the granite-producing field (Ishihara, 1980), or into oxidized type and reduced type (Sato, 1988). These two series nearly correspond to the two types of granite (Sato, 1988). In order to determine to which of the two types the granites of the survey area belong, as well as to investigate their relationship to mineralization, measurements of their magnetic susceptibility and radioactivity were carried out. Measurements were also made on rocks other than granites for the purpose of clarifying whether or not the measurement of magnetic susceptibility and radioactivity can be useful for future exploration.

(1) Results of Measurement

Figure 2-7 is a correlation diagram of magnetic susceptibility and radioactivity values of all rocks, and figure 2-8 is that of only granitic rocks.

Magnetic susceptibility is very low in biotite granite, porphyritic biotite granite, pegmatite and aplite. Their values overlap each other in the correlation diagram. The magnetic susceptibility of granitic rocks, and sedimentary rocks and hornfels overlap on the correlation diagram. No distinct difference between the two groups is shown.

As for the γ-ray radioactivity, a tendency of intensity is in the order of porphyritic biotite granite > pegmatite-aplite ≒ biotite granite on the correlation diagram. For all rocks, some parts overlap but a general tendency shows granitic rocks higher than sedimentary rocks and hornfels on

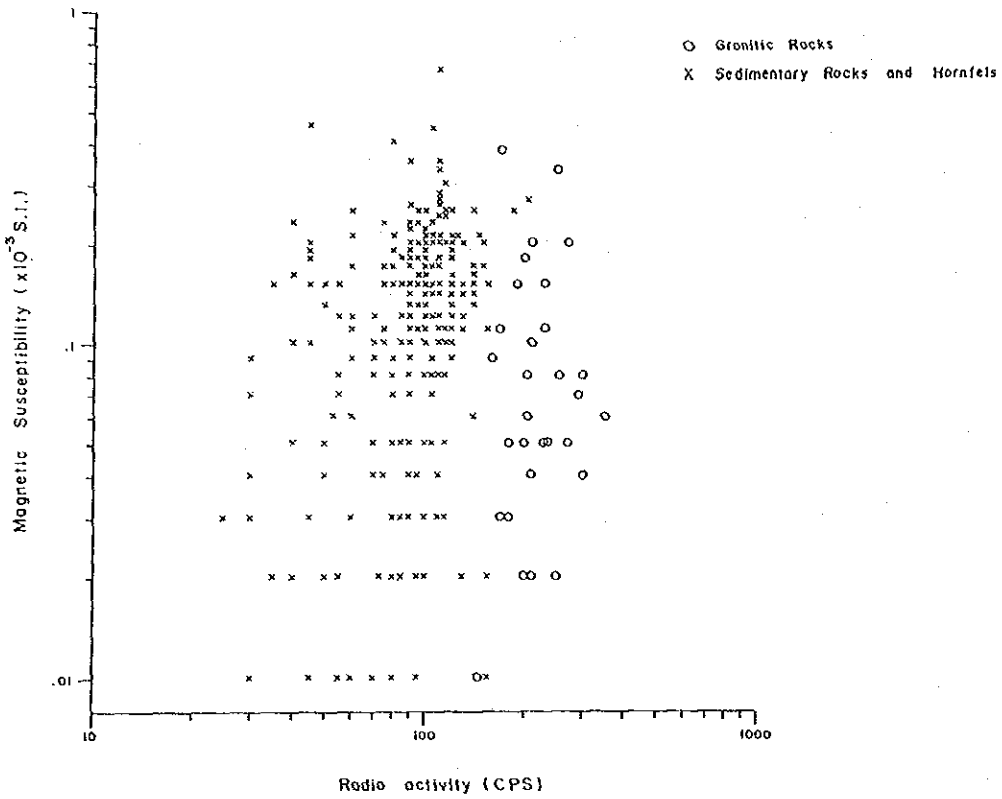


Fig.2-7 Correlation Diagram between Magnetic Susceptibility and Radioactivity of Whole Rocks

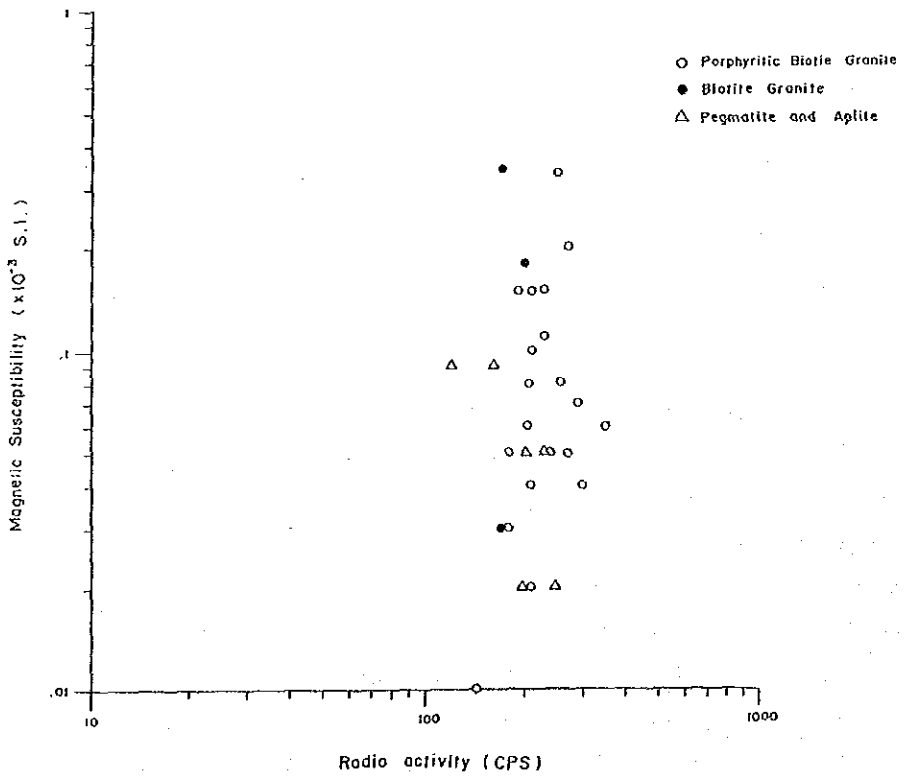


Fig.2-8 Correlation Diagram between Magnetic Susceptibility and Radioactivity of Granitic Rocks

the same diagram.

No correlation is found between magnetic susceptibility and intensity of radioactivity.

(2) Consideration

Granites are classified by their magnetic susceptibility and chemical composition of ilmenite; the ones having values larger than 3.5 x 10^3 S.I. are classified as oxidized type and those with lower values as reduced type (Sato, 1988).

From the results of the magnetic susceptibility measurements, the granitic rocks of the survey area showing values under 3.5 x 10^3 S.I. are assigned to the reduced type (granite of ilmenite series). This is concordant with the result of the analysis of major components of the above-mentioned granites.

Pegmatite and aplite were expected to show higher radioactive intensity, but the obtained values were similar to those of other granitic rocks. On the other hand, the comparison between the sediments・hornfels and the granitic rocks clearly revealed that the latter had higher values than the former, though the two groups partially overlap. This fact suggests that it is possible to make a distinction between the granitic rocks and the sediments・hornfels through the use of measured radioactivity values.

1-2-5 Mineralization and Associated Alteration

The mineral showings of the survey area (Figure 2-9) are classified into following five groups by the host rock and the mineral assemblages.

① Quartz-muscovite-tourmaline veins in leucocratic granite or pegmatite.
② Quartz veins in granites.
③ Quartz veins in Paleozoic strata.
④ Silicified and argillized zones.
⑤ Coal in Neogene strata.

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

(1) Quartz-muscovite-tourmaline veins in leucocratic granite or pegmatite

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

① Upper reaches of S.Isahan

This is explained in the Chapter 2.

② S.Sikambu

This is explained in the Chapter 2.

③ S.Akar

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

④ S.Mentaus

A network of 1cm wide quartz-tourmaline veins and a quartz-muscovite veinlet which cuts through the network occur in a 1m wide pegmatite in hornfels. The result of chemical analysis of these veins was not promising. It is found by pitting that there is no mineral showing at a point of 30 m southwestward from the outcrop.

(2) Quartz veins in granites

This type of mineralization occurs in the upper reaches of S.Laki in the western part of the survey area and southwest of Bt.Kayumambang in the central part.

Quartz-potash feldspar-pyrite veins with 10cm width occur in biotite granite at the upper reaches of S.Laki. The host rock is intensely sericitized and a large amount of pyrite dissemination is observed. The result of chemical analysis was of low grade except 0.06 % Ce.

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

(3) Quartz veins in paleozoic strata

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

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

The chemical analysis showed low grade in all veins.

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

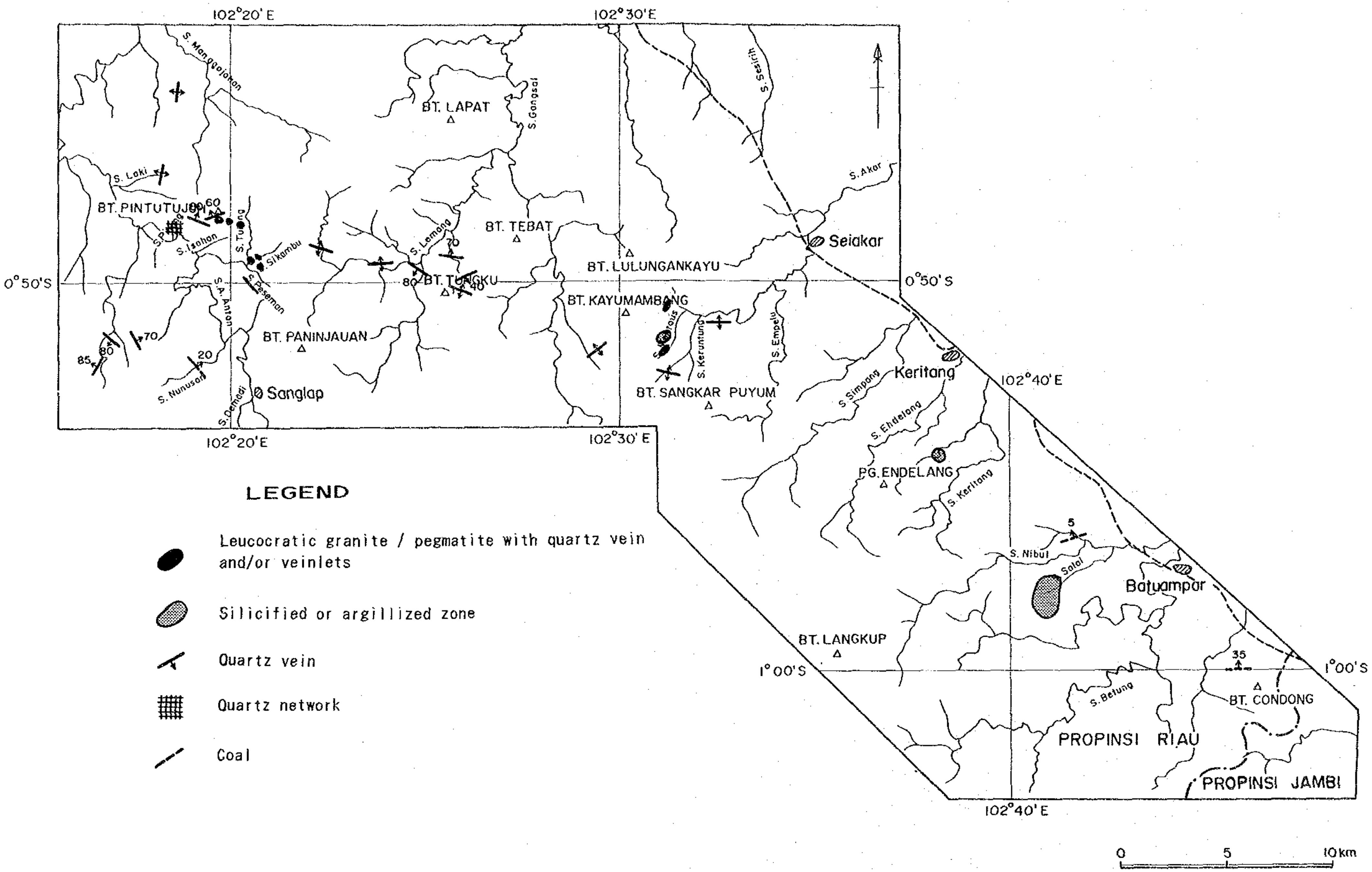


Fig.2-9 Distribution Map of Mineral Showings

(4) Silicified and argillized zones

These alteration zones occur in the Paleozoic strata along S.Mentaus and to the east of Pg.Endelang in the eastern part. Network of pyrite veins are developed in these silicified and argillized zones. The altered rocks consist of quartz and minor amount of sericite.

Also along the S.Salai in the east, porphyritic biotite granite is argillized in a zone extending 500 x 1,500m wherein network of pyrite veins and pyrite dissemination are developed. The biotite and plagioclase of the host rock are altered to kaolinite and sericite. At a point of 50 m southernward from the outcrops, network of veins was confirmed by a pit, similar to those in the outcrop, but the grade was low

(5) Coal in Neogene strata

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

1-2-6 Granites-Geologic Structure-Mineralization

The intrusive rocks in the survey area are porphyritic biotite granite, biotite granite, leucocratic granite, pegmatite and aplite, all in Paleozoic strata and belong to the ilmenite series of granitoids. These granitoids are known to be accompanied by lithophile elements -Sn, W, Nb, Ta, Th and etc.-.

The age of the porphyritic biotite granite is determined to be Middle Jurassic to Early Cretaceous. The biotite granite, on the other hand, is Early Cretaceous. The greisenized leucocratic granites that host the known mineralized zones are Middle Jurassic.

From these facts it is considered that the leucocratic granite controlled directly the occurrence of the mineralization. Therefore, the consideration that the leucocratic granite is the intrusive facies of porphyritic biotite granite, the age of the granitoids, the differential index and alkali-lime ratios show that porphyritic bitite granite indirectly controlled the distribution of the mineralized zones.

1-3 Geochemical Exploration

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

The samples of stream sediments were fine sands of -80 mesh and the number of samples collected was 1,109. The number of panned concentrates samples were 210. The samples were analyzed at Chemex Lab. Inc. of Canada, for 14 elements: Au, Ag, Sn, Nb, Ta, W, Zr, Ti, Th, Ce, Y, U, Li and La.

For delineating the geochemical anomalous zones the samples collected from the Bt.Pintutujuh area, 312 for stream sediments and 53 for panned concentrates, were combined with the above samples and were interpreted synthetically. The samples from the Bt.Pintutujuh area were analyzed for six elements: Au, Sn, W, Th, Ce and U.

1-3-1 Geochemical Exploration with Stream Sediments

(1) Results of data processing

In Appendix Table 10 are shown 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 maximum value of each element is divided by its crustal abundance and the result is considered to represent the element's degree of concentration. Sn is found to have the highest concentration, followed by Zr, U and Th, while low degrees of concentration are noticed for Ti, Li, Y and Ag.

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 for 13 elements, excluding Ag.

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

The first principal component:

The highest values of positive correlation are shown by Nb and Y; ranked next are W, Zr, Ti, Th, Ce and Li. Au, Sn and Ta have no correlation with the first principal component. Elements having positive values in the factor leading, are often associated with granitic rocks, particularly pegmatite. Hence this principal component is interpreted to indirectly point to granitic rocks. Samples having factor scores of 2.0 or over are numerous in the vicinities of porphyritic biotite granite, such as around Bt.Lapat and Bt.Kayumambang and along S.Nibul.

The second principal component:

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

The third principal component:

Au shows a negative value. This composition is probably the information on Au that was not obtained from the first and second compositions.

The forth principal component:

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

(2) Geochemical anomalies and anomalous zones

The thresholds of the respective element are given in Appendix Table 12.

Thirty geochemical anomalous zones are extracted from the survey area (Table 2-1 and Fig. 2-10). These zones are divided into two ranks, A and B, according to the value of the anomaly. The zones with values larger than twice the threshold are assigned A rank, and those with less values B rank. When thus ranked, there are six A-rank anomalous zones for Sn, two for Sn, W, and Au and one for other elements.

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

S.A.Antan (No.6)

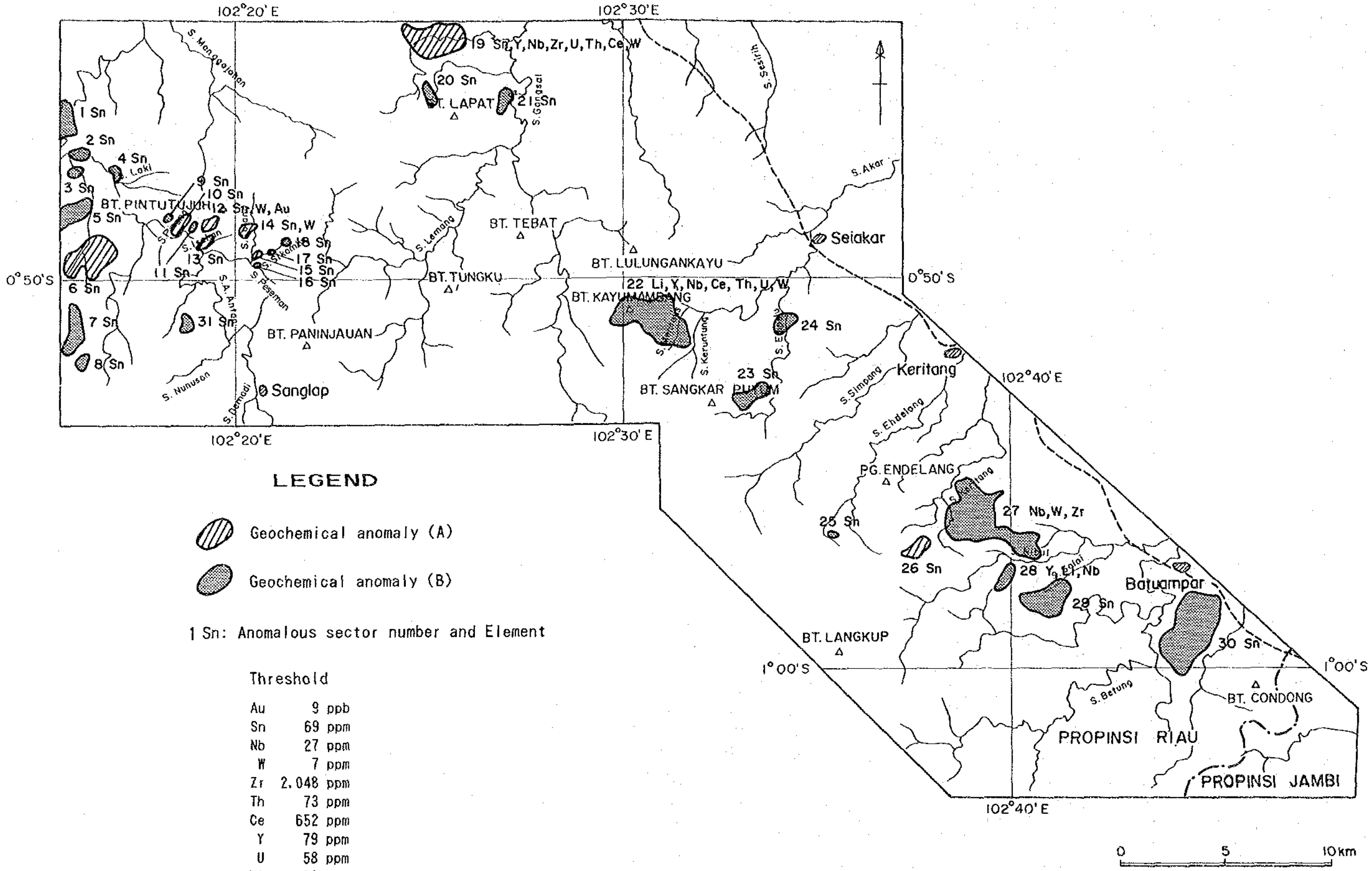
Anomalous values of Sn (100～170 ppm) were detected in four localities. The anomalous zone is composed of the Neogene S.Demadi Formation.

S.Pinang (No.10)

Anomalous values of Sn (80～180 ppm) are distributed in three localities. The zone is composed of the Paleozoic Bt.Pintutujuh Formation.

Table 2-1 Anomalous Zones delineated from Stream Sediment Geochemistry in Pegunungan Tigapuluh Area

No.	Location	Number of anomalous samples	Anomalous elements and the range	Rank
1	S.Cenakobesar	1	Sn:88ppm	B
2	S.Antan	1	Sn:95ppm	B
3	Tributary of S.Antan	1	Sn:120ppm	B
4	S.Antan	1	Sn:83ppm	B
5	Tributary of S.Antan	1	Sn:110ppm	B
6	Tributary of S.Antan	4	Sn:100-170ppm	A
7	Tributary of S.Antan	1	Sn:100ppm	B
8	Tributary of S.Antan	2	Sn:74-82ppm	B
9	Tributary of S.Antan	1	Sn:77ppm	B
10	S.Pinang	3	Sn:80-180	A
11	Tributary of S.Antan	1	Sn:70ppm	B
12	S.Isahan	7	Sn:70-400ppm,W:7-32ppm,Au:10-15ppb	A
13	S.Isahan	5	Sn:71-330ppm	A
14	S.Tulang	4	Sn:230-290ppm,W:7-28ppm	A
15	S.Sikambu	1	Sn:710ppm	A
16	S.Peseman	1	Sn:80ppm	B
17	S.Sikambu	1	Sn:290ppm	A
18	S.Sikambu	1	Sn:94ppm	B
19	S.Muara	5	Nb:27-44ppm Th:91-125ppm U :83-165ppm W :11-17ppm (Ce:680ppm) (Sn:220ppm) Zr:2,450-10,300ppm Y :210-360ppm	A
20	S.Muara	1	Sn:80ppm	B
21	Tributary of S.Gangsal	1	Sn:95ppm	B
22	Bt.Kayumambang	9	Nb:31-33ppm Y :79-130ppm (U:64ppm) W :11-22ppm Li:37-47ppm (Th:85ppm)	B
23	Tributary of S.Empelu	1	Sn:75ppm	B
24	S.Empelu	2	Sn:87-130ppm	B
25	Tributary of S.Endelang	1	Sn:78ppm	B
26	S.Keritang	1	Sn:140ppm	A
27	S.Keritang -- S.Nibul	18	Nb:27-45ppm (Zr:2,200-4,300ppm) (W :9ppm)	B
28	Tributary of S.Nibul	5	Nb:36-45ppm (Y :85ppm) Li:32-36ppm	B
29	S.Salai	5	Nb:28-33ppm Y :85-90ppm Li:32-39ppm	B
30	South of Batuampar	1	Sn:96ppm	B
31	S.Tanau	1	Sn:69ppm	B



LEGEND

Geochemical anomaly (A)

Geochemical anomaly (B)

1 Sn: Anomalous sector number and Element

Threshold

Au	9	ppb
Sn	69	ppm
Nb	27	ppm
W	7	ppm
Zr	2,048	ppm
Th	73	ppm
Ce	652	ppm
Y	79	ppm
U	58	ppm
Li	31	ppm

Fig.2-10 Distribution Map of Anomalous Zones Delineated by Stream Sediment Geochemical Exploration in the Pegunungan Tigapuluh Area

Upper reaches of S.Isahan (No.12)

Anomalous values of Sn (70~400 ppm), W (7~32 ppm) and Au(10~15 ppb) were found in seven localities. In the zone, the Paleozoic Bt.Pintutujuh Formation and intruding leucocratic granite are distributed. Tin mineralization occurs in this zone.

Lower reaches of S.Isahan (No.13)

Anomalous values of Sn (71~330 ppm) were found in five localities. The zone is composed of the Paleozoic Bt.Pintutujuh Formation.

S.Tulang (No.14)

Anomalous values of Sn (230~290 ppm) and W (7~28 ppm) were found in four localities. In the zone, the Paleozoic Bt.Pintutujuh Formation and intruding leucocratic granite are distributed.

Lower reaches of S.Sikambu (No.15)

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

Tributary of S.Sikambu (No.17)

A Sn anomalous value (290 ppm) was found at one localities. The Paleozoic Bt.Pintutujuh Formation and leucocratic granite intruding it are distributed in the zone.

North of Bt.Lapat (No.19)

Anomalous values of Nb (27~44 ppm), W (11~17 ppm), Zr (2,450~10,300 ppm), Th (91~125 ppm), Y (21~360 ppm) and U (83~145 ppm) were found in five localities. Anomalies of Sn (220 ppm) and Ce (680 ppm) are recognized in parts of the zone. The zone is composed of porphyritic biotite granite.

S.Kuritang (No.26)

A Sn anomalous value (140 ppm) was detected in one locality. The zone is composed of the Paleozoic Bt.Pintutujuh Formation.

1-3-2 Geochemical Exploration with Panned Concentrates

(1) Statistical processing

Appendix Table 13 shows the geometric mean, the maximum and minimum values of all the samples. A total of stream sediment and panned 192 samples were collected from the same sites. The average values of the samples of the two groups and their ratio between the two groups are given in Appendix Table 14. When the geochemical data (average values) of the panned samples were divided by those of the stream sediment samples and the resultant value was taken as the degree of concentration by panning, it showed that the degree of concentration was highest for Sn, being 6.7 times, followed by 1.5～2 times for W and Ce. Other elements ranged from 0.8 to 1.5 times, which indicates little concentration as far as the average values are concerned.

(2) Geochemical anomalies and anomalous zones

The thresholds of the respective elements are given in Appen.Table 15.

Twenty-five anomalous zones were extracted in the survey area (Table 2-2 and Fig. 2-11). These zones are divided into two ranks, A and B, according to the value of the anomaly. The zones with values larger than twice the threshold are assigned A rank, and those with less values B rank.

There are 11 areas of A-rank anomaly, which are summarized as follows.

S.A.Antan (No.2)

Au anomaly (72 ppm) and Sn anomaly (>1,000 ppm) were detected in one locality. This zone is composed of the Paleozoic Bt.Pintutujuh Formation. The zone overlaps with part of the B-rank anomaly zone by the stream sediments.

S.Pinang (No.5)

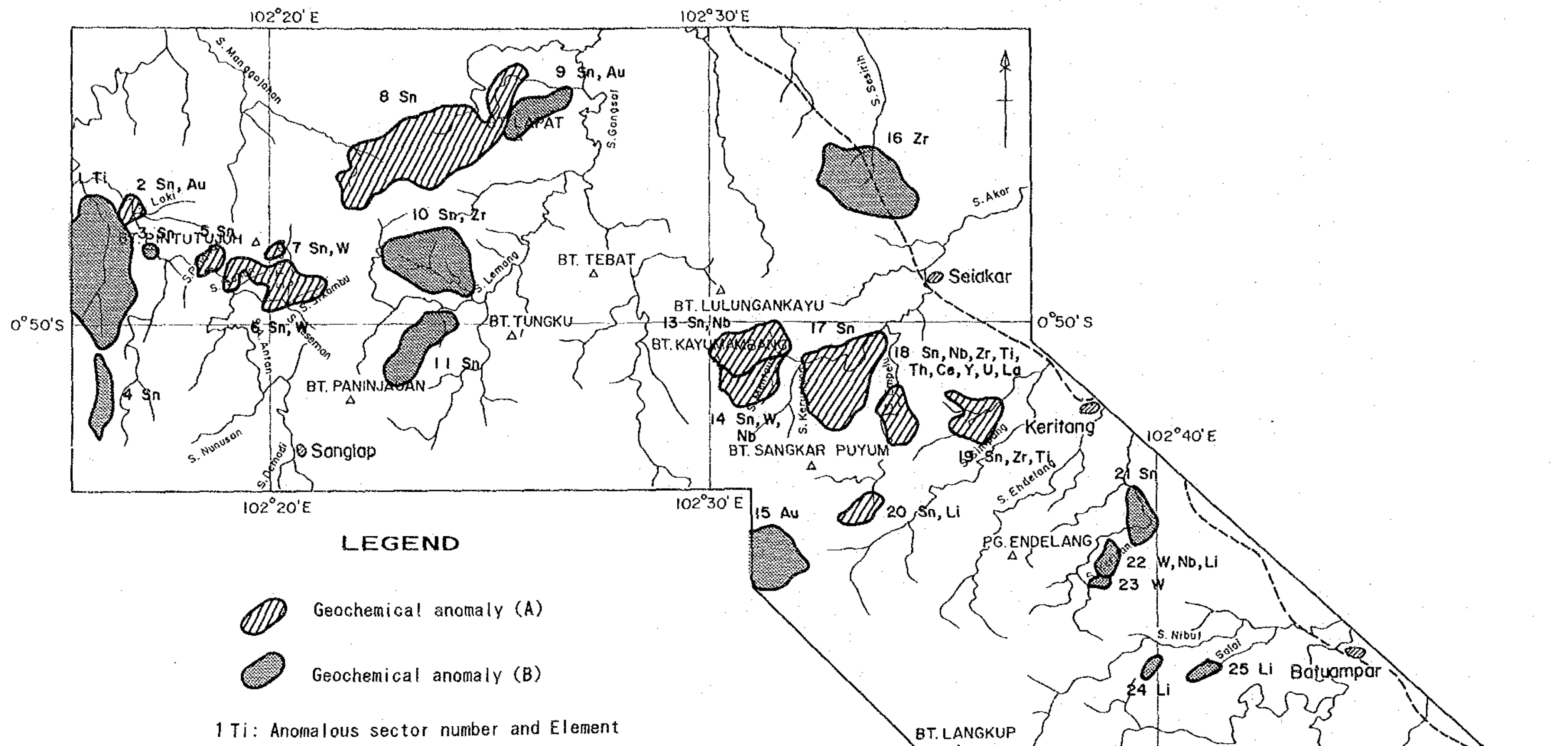
Sn anomaly (>1,000 ppm) was detected in three localities. The zone is composed of the Paleozoic Bt.Pintutujuh Formation. This zone overlaps with part of the A-rank anomaly zone by the stream sediments.

S.Isahan and S.Sikambu (No.6)

Sn anomaly (600～>1,000 ppm) and W anomaly (16～55 ppm) occur in nine localities. Tin mineralizations are found in Upper reaches of S.Isahan and Lower reaches of S.Sikambu. The zone overlaps partly with the A-rank anomaly zones by the stream sediments.

S.Tulang (No.7)

Sn anomaly (>1,000 ppm) and W anomaly (27 ppm) are found in one locality. The zone is composed of the Paleozoic Bt.Pintutujuh Formation and leucocratic granite, and it overlaps with the A-rank anomaly zone by the



Threshold

Au	10 ppb
Sn	504 ppm
Nb	74 ppm
W	16 ppm
Zr	6,974 ppm
Ti	20,719 ppm
Th	289 ppm
Ce	1,240 ppm
Y	216 ppm
U	72 ppm
Li	52 ppm
La	1,290 ppm

Fig.2-11 Distribution Map of Anomalous Zones Delineated by Panned Concentrate Geochemical Exploration in the Pegunungan Tigapuluh Area

Table 2-2 Anomalous Zones delineated from Panned Concentrate Geochemistry in Pegunungan Tigapuluh Area

No.	Location	Number of anomalous samples	Anomalous elements and the range	Rank
1	Tributary of S.Antan	1	Ti:40,640ppm	B
2	S.Antan	1	Sn:>1,000ppm Au:72ppb	A
3	S.Antan	1	Sn:560ppm	B
4	Tributary of S.Antan	1	Sn:608ppm	B
5	S.Pinang	3	Sn:>1,000ppm	A
6	S.Isahan -- S.Sikambu	9	Sn:600->1,000ppm W:16-55ppm	A
7	S.Tulang	1	Sn:>1,000ppm W :27ppm	A
8	S.Manggajahan -- Bt.Lapat	3	Sn:>1,000ppm	A
9	Bt.Lapat	1	Au:13ppb Sn:931ppm	B
10	Tributary of S.Lemang	1	Sn:510ppm	B
11	Tributary of S.Lemang	1	Sn:537ppm	B
12	Southwest of Batuampar	1	Zr:7,854ppm	B
13	Bt.Kayumambang	1	Sn:>1,000ppm Nb:77ppm	A
14	S.Mentaus	1	Sn:>1,000ppm W :75ppm Nb:100ppm	A
15	Tributary of S.Gangsal	1	Au:96ppb	B
16	S.Talang Lakat	1	Zr:9,200ppm	B
17	S.Akar	1	Sn:>1,000ppm	A
18	S.Empelu	1	Sn:714ppm Nb:176ppm Zr:43,260ppm Ti:48,720ppm Th:395ppm Ce:2,814ppm Y :441ppm U :126ppm La:1,386ppm	A
19	S.Selanama	1	Sn:>1,000ppm Zr:15,708ppm Ti:26,355ppm	A
20	S.Empelu	1	Sn:>1,000ppm Li:61ppm	A
21	S.Keritang	1	Sn:594ppm	B
22	S.Keritang	1	Nb:78ppm W :23ppm Li:68ppm	B
23	S.Keritang	2	W :18-42ppm	B
24	Tributary of S.Nibul	1	Li:57ppm	B
25	S.Salai	1	Li:74ppm	B

stream sediments.

West of Bt.Lapat (No.8)

Sn anomaly (>1,000 ppm) was detected in three localities. The Paleozoic Bt.Pintutujuh Formation and porphyritic biotite granite and biotite granite intruding the former are distributed in the zone. The geochemical exploration with stream sediments in this area failed to detect any anomalies of Sn or other elements.

East of Bt.Kayumambang (No.13)

Sn anomaly (>1,000 ppm) and Nb anomaly (77 ppm) were detected from one locality. Porphyritic biotite granite, Bt.Pintutujuh Formation and hornfels are distributed in the zone. The anomalous zone partly overlaps with the B-rank anomaly (Nb) by the stream sediments.

S.Mentaus (No.14)

Sn anomaly (>1,000 ppm), W anomaly (75 ppm) and Nb anomaly (100 ppm) were obtained from one locality. The geology of the zone is similar to that of the No.13 anomalous zone. Part of the anomalous zone in this area overlaps with the B-rank anomalous zone (Nb, W) by the stream sediments.

S.Akar (No.17)

Sn anomaly (>1,000 ppm) was detected in one locality. The zone is composed of the Paleozoic Bt.Pintutujuh Formation, the Neogene S.Empelu and S.Demadi Formation. The anomalous zones overlaps partly with the B-rank anomalous zones by the stream sediments.

S.Empelu (No.18)

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

North of S. Simpang (No.19)

Anomalous values of Sn (>1,000 ppm), Zr (15,708 ppm) and Ti (26,355 ppm) were obtained from one locality. The zone is composed of the Quaternary system and the Neogene Empelu Formation. The anomalous zone does not overlap with that of the stream sediments.

S.Empelu (No.20)

Sn anomaly (>1,000 ppm) and Li anomaly (61 ppm) are found in one locality. The zone is composed of the Paleozoic Bt.Pintutujuh Formation and the Neogene S.Empelu Formation. The anomalous zones does not overlap with that by the stream sediments.

1-3-3 Correlation Between Geochemical Anomalies and Mineralization-Alteration

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

All other anomalous zones have no mineralization in their zones.

It is seen that geochemical anomalies were obtained for both stream sediments and panned concentrates at the known mineralized zones. Localities other the above known mineralized zones where both type of samples show A-rank anomalous geochemical values are, shown in Fig.1-2, four localities around the known mineralized zones for Sn or Sn-W.

Chapter 2 Bt.Pintutujuh Area

2-1 Geological Survey

Geological survey was conducted in the Bt.Pintutujuh area as a promising area and its objectives were to elucidate the relationship among mineralization, geologic structure and igneous activity, and to extract promising mineralized zones.

2-1-1 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 around biotite granite bodies.

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 1-9 shows the geology and geologic sections.

2-1-2 Intrusive Bodies

The intrusive bodies distributed in this 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 (128 to 110 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 (Appendices Tables 2 and 3). As analytical results of major elements of intrusive rocks are stated in

Chapter 1 Pegunungan Tigapuluh Area, in this section, we show analytical results of trace elements.

Results of principal component analysis of assay values of trace elements contained in intrusive rocks are shown in Appendices Table 4.

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 score is obtained from one sample of the leucocratic granites 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.

2-1-3 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.

2-1-4 Mineralization and Associated Alteration

The mineral showings in the survey area (Fig.2-9) 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.

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.
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.

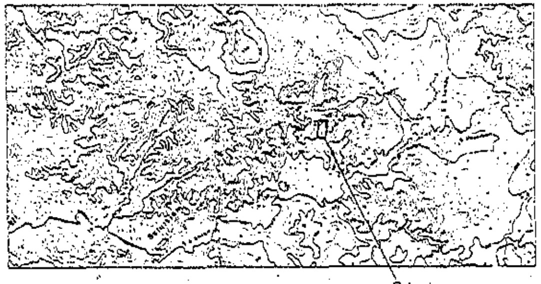
Quartz-muscovite veins with 10 cm width occur in the slate which is in direct contact with the leucocratic granite.

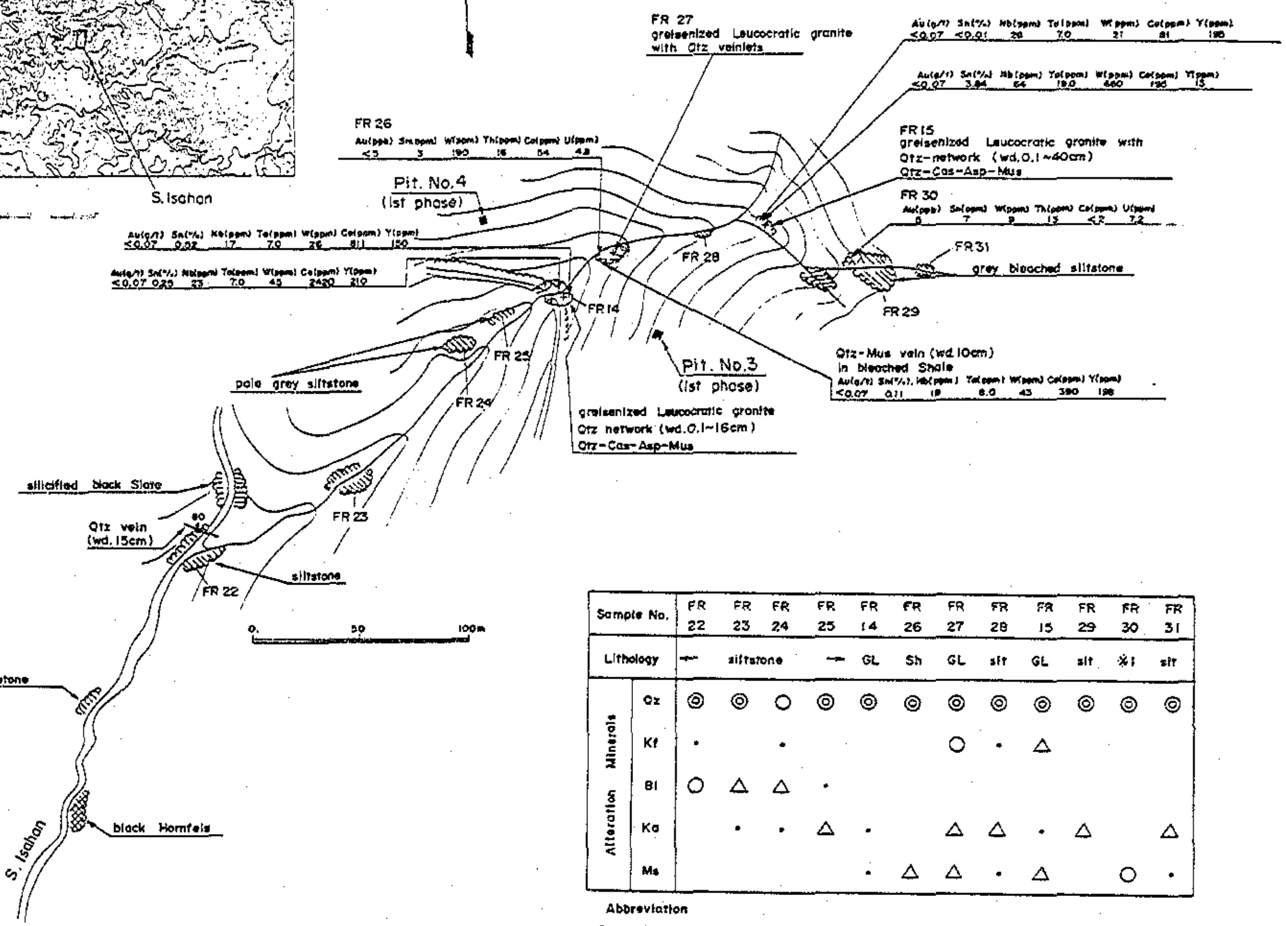
Most of the potassium feldspar and plagioclase are altered to muscovite in the leucocratic granite. Kaolinite, beryl and limonite are observed in some cases. The rock forms dykes of 1 to 5 m in width.

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 is considered to be the product of greisenization. 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-

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	•		•				○	•	△			
	Bl	○	△	△	•								
	Ka		•	•	△	•		△	△	•	△		△
	Ms					•	△	△	•	△		○	•

Abbreviation

Qz : Quartz
Kf : K-feldspar
Bl : Biotite
Ka : Kaoline
Ms : Muscovite
GL : Leucocratic granite
Sh : Shale
slt : Siltstone
※1 : Silicified rock

Fig.2-12 Sketch of S.Isahan Mineralized Zone 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. 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. 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.

The host rock underwent muscovitization and kaolinitization.

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 muscovitized and kaolinitized.

⑤ Branch of S.Sikambu and southward

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

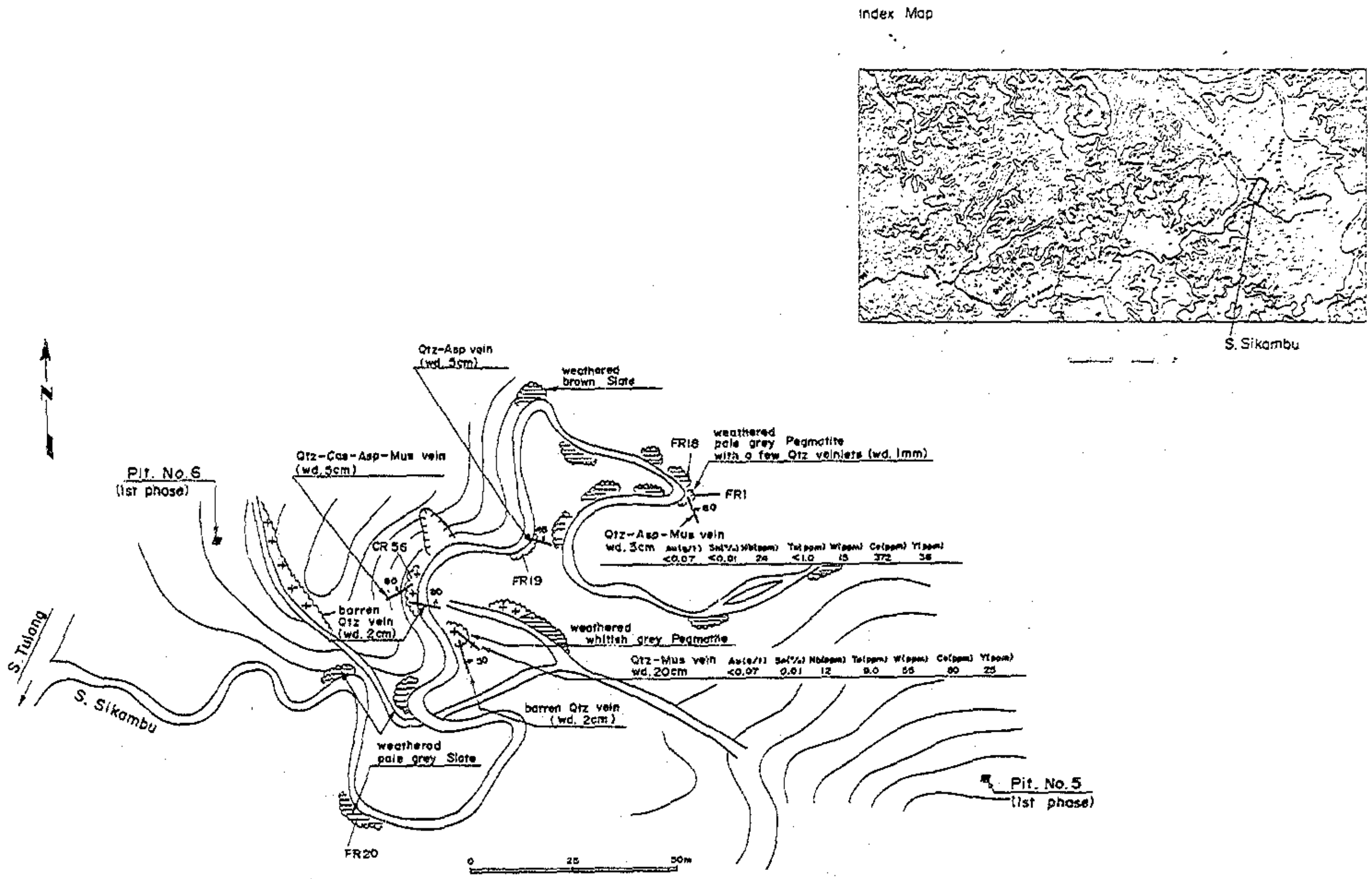
(2) Quartz veins in the biotite granite

This type of mineralization is stated in Chapter 1 Pegunungan Tigapuluh Area.

(3) Quartz veins in Paleozoic strata

Quartz veins 10 to 20 cm wide occur at; a branch of S.Manggajohan in the northern part, 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.



	As(g/t)	Sn(%)	Nb(ppm)	Ta(ppm)	W(ppm)	Ce(ppm)	Y(ppm)
Qtz-Asp-Mus vein wd. 3cm	<0.07	<0.01	24	<1.0	15	372	36
Qtz-Mus vein wd. 20cm	<0.07	0.01	12	9.0	56	80	25

Fig.2-13 Sketch of S.Sikambu Mineralized Zone

(4) Discussions

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. The other elements were low grade.

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.

2-1-5 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 survey area. Therefore, concealed bodies of porphyritic biotite granite which is directly related to mineralization can be expected below the leucocratic 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 NNW-SSE direction. These structures coincide with the direction of assumed faults at S.Laki and S.Tulang.