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REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE KRA BURI AREA, THE KINGDOM OF THAILAND

CONSOLIDATED REPORT

MARCH 1994

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a Mineral Exploration in the Kra Buri Area Project and entrusted the survey to the Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Kingdom of Thailand a survey team headed by Mr.Iwao Uchimura for 1991 and Dr. Hiroyuki Takahata for two years from 1992 to 1993.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Kra Buri area, and made the report of each fiscal year. This report submitted hereby summarized the results of the various survey performed during three years.

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

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

November, 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Takashi Ishikawa

Takashi Ishikawa
President
Metal Mining Agency of Japan

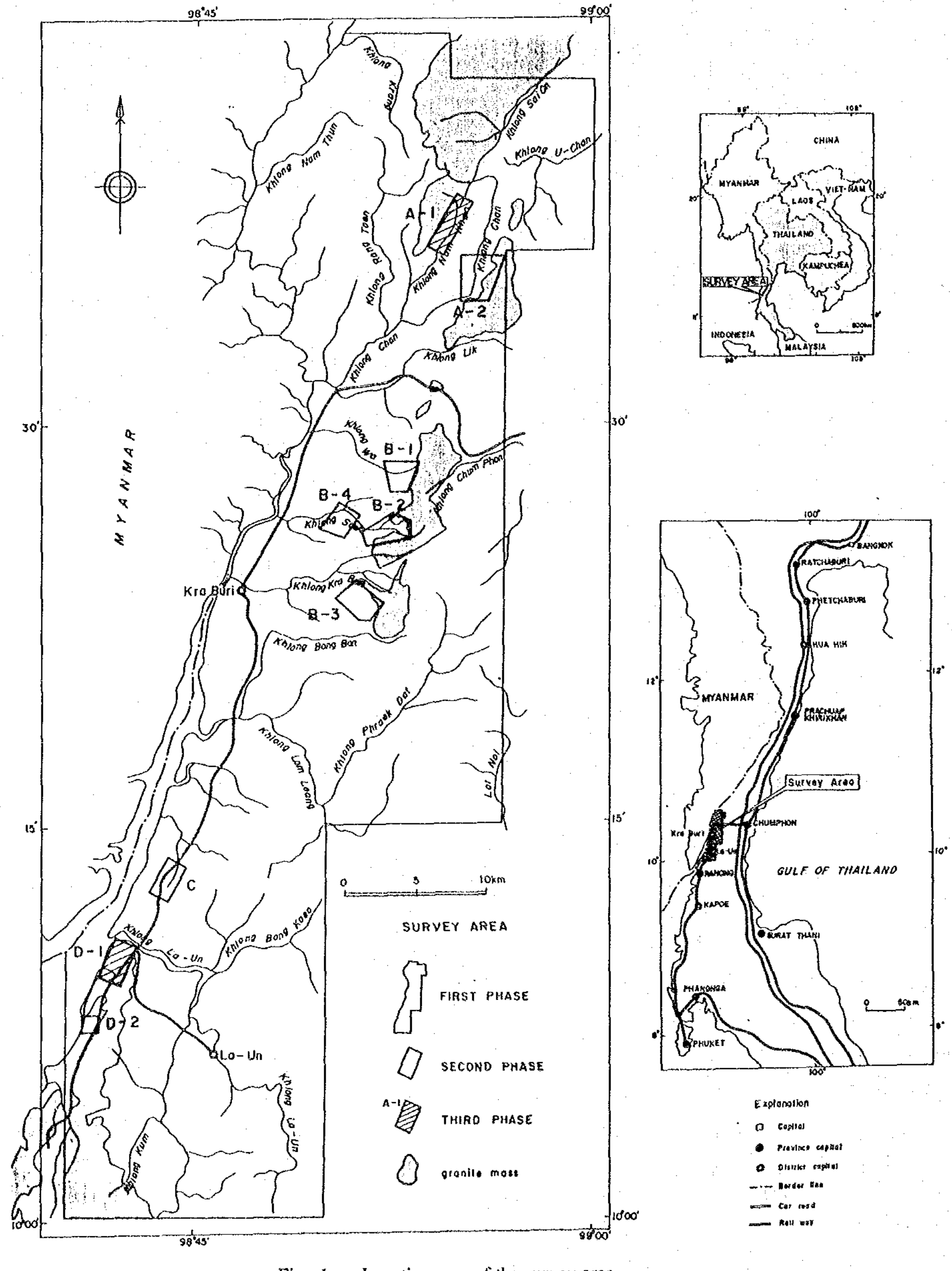

Fig. 1 Location map of the survey area

SUMMARY

The Cooperative Mineral Exploration Project in the Kra Buri Area, the Kingdom of Thailand was made to evaluate the potential for rare elements such as tin, tungsten, and niobium, and that for rare earth elements.

The Kra Buri Area is situated in the Ranong Province, and in the northern extension of the Ranong-Phuket tin area, which is the largest tin produced area in Thailand. The survey area covers 1,500 square kilometers, 80 kilometers from north to south and 20 kilometers from east to west.

This area is underlain by sedimentary rocks of the Silurian-Devonian to the Jurassic, Cretaceous granites, and alluvium. The sedimentary rocks are cut by NNE-SSW faults. The granite bodies intruded into the northern, central and southern part of the area, and have a close association with the faults' direction.

The first year's program revealed the distribution of four granite masses, the existence of placer deposits, the geochemical charactereristic of two pathfinder groups, namely, tin group (Sn, W, Ta, Nb) and rare earth group, (REE, Th, U), and the distribution of geochemical anomalies.

Based on the results of the studies of geochemical characteristics, mineral occurreces, alteration zones in the area, four sites had been selected as the promising areas for the minerals. These are in the southern part of the Northern west mass as area A, western and southeastern parts of the Central mass as area B, western flank of the Southern mass as area D, and Khao Fachi silicified area as area C.

For the detailed soil geochemical prospecting of second survey's program, nine sub-areas were selected from anomaly zones of stream sediments to delineated mainly the extension of alluvial basins containing placer deposits. Several sub-areas were also expected to be the existence of primary ore deposits or adsorption-type rare earth deposits.

As a result of second survey, two promising areas were selected for Area A-1 and D-1, whose reserves are relatively large.

The third phase survey was planned based on the second phase survey results. Pit and drill surveys in the area A-1 and a drill survey in the area D-1 have been performed.

In area A-1, relatively high grade tin deposits have been found in the river bed sediments which are distributed along Khlong Nam Khao and its tributaries at the southern part. The ore deposits are composed of five separated parts, and the total ore reserve is estimated to 780,000 m^3, 360 to 1,500 g/m^3 in tin. The secondary ore contains not only tin but also tantalum, niobium, rare earths, and titanium. It seems that the ore deposits are of economical, if the

all elements are technically recoverable. The area is presently used for agriculture, therefore it is necessary to compare their economical preferability.

Some parts concentrated by rare earth elements have been found in the area D-1, however their reserves and grades are not enough for economical mining, in addition to that the ores are situated in an environmental conservation area.

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PART I GENERAL REMARKS

Chaper 1 INTRODUCTION

1-1 Background

Thailand is one of the major tin producing countries in the world. Besides of tin, she produces rare metals such as niobium and tantalum, which are associated with tin, and rare earth elements such as samarium and cerium as byproducts.

Demand for rare earth elements increases recent years, and in reflect such background, the Government of Thailand requested the Japanese Government to conduct a cooperative mineral exploration project for rare earth elements in the tin producing area in southern Thailand. In response to the request, the Japanese Government dispatched a preliminary survey mission to Thailand, and finally the Japan International Cooperation Agency and the Metal Mining Agency of Japan entered into an agreement with the Department of Mineral Resources, Ministry of Industry, Thailand on 27th, February 1991. Based on this agreement, a three years' program of cooperative mineral resources exploration in the Kra Buri area, the Peninsula of Thailand, was supposed to conduct from 1991.

The objective of the project is to assess the potential for tin, tungsten, niobium, tantalum and rare earth elements, and to select potential areas, by means of integrated interpretation of geology, geological structure, mineral occurrences, and geochemical characteristics.

1-2 Contents of the Survey

The procedure of this survey was as follows:

The survey was started with a interpretation of Landsat TM images, a regional geological survey and reconnaissance geochemical prospecting over the whole survey area, then by marking a detailed gelogical survey and a detailed geochemical prospecting of promising areas that had been picked out as the result of the first survey. These areas were further narrowed down. Finally examinations were made for the potential of secondary deposits by making pit and drilling survey. The flow chart of the suvey process and evalution process are shown in Figures 2 and 3.

The contents of the surveys and the quantities of these works in each year are set forth in the following:

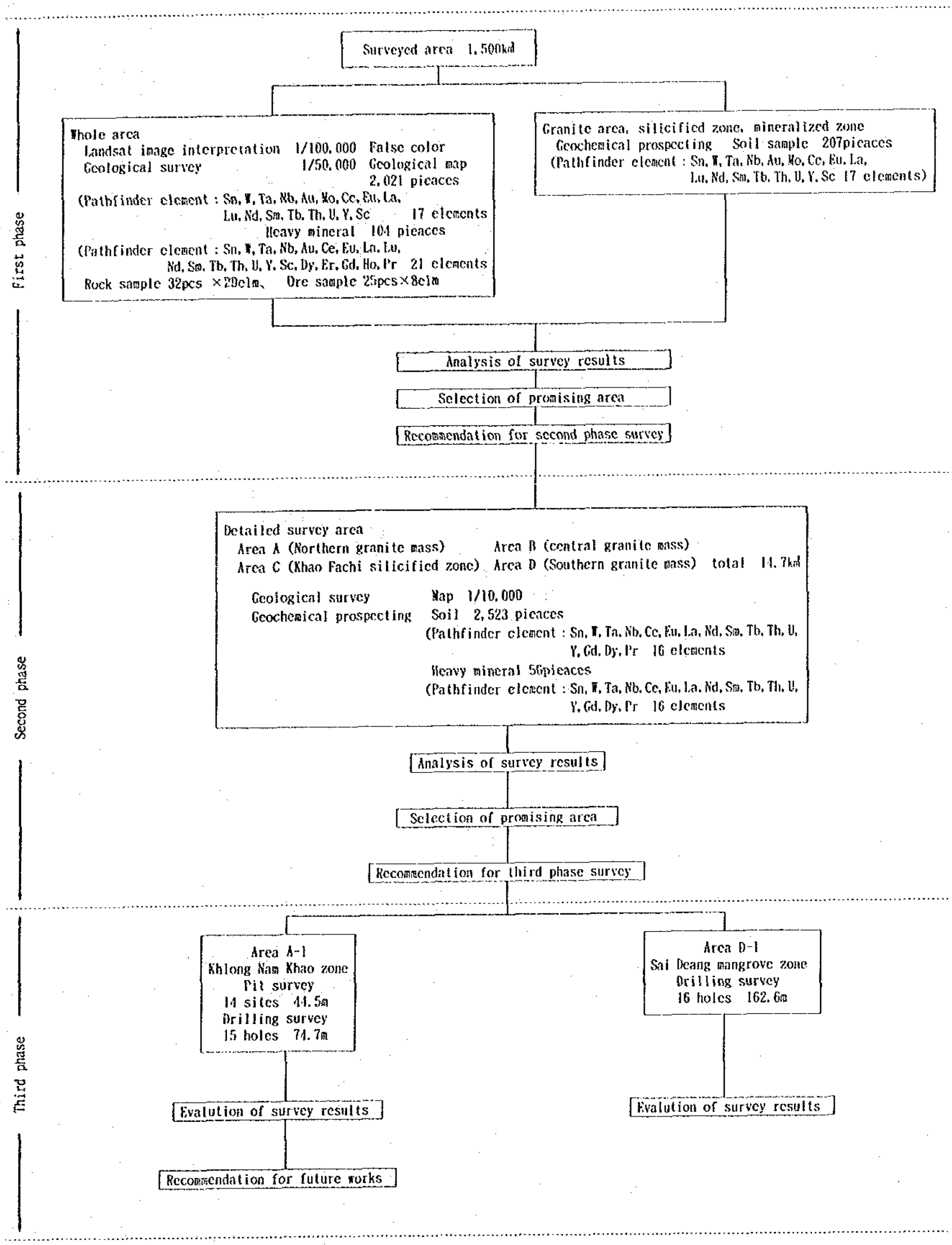

Fig. 2 Flow Chart of the Exploration Program

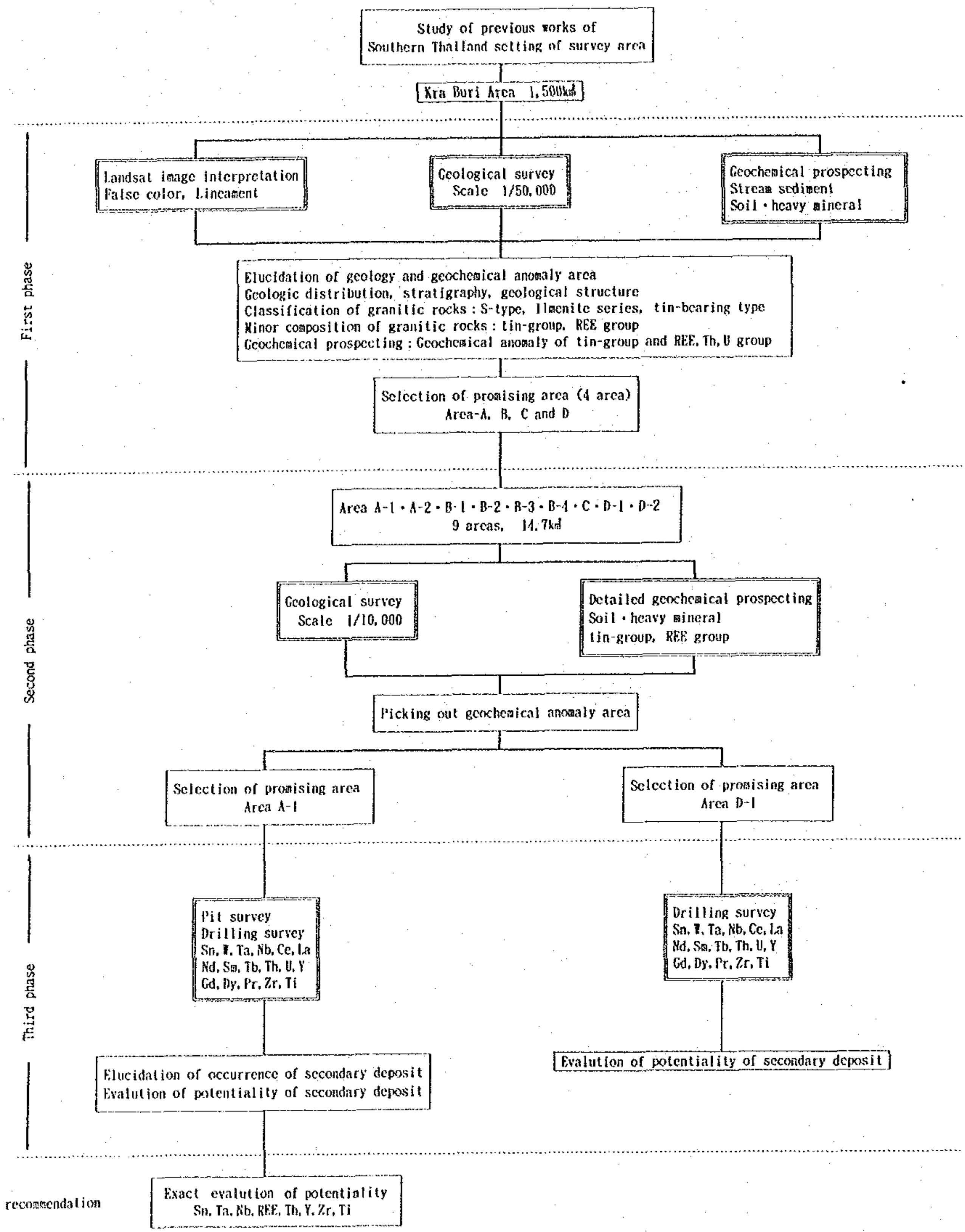

Fig. 3 Flow Chart of the Selecting promising area

1-2-1 The First Phase Survey in 1991

A satellite TM image interpretation and a regional geological survey over the whole Survey area covering an area of 1,500 km^2 and reconnaissance geochemical prospectings by stream sediments, heavy minaral and soil samples were conducted.

(1)Satellite Image Interpretation

An adequate false color image was made from CCT using TM data of Landsat 5 to interpretate the geology and geography in the Kra Buri area.

(2)Geological Survey

A regional geological survey was made in parallel with the collection of geochemical samples. A geologic map on a scale of 1:50,000 was prepared.

Microscepic observation, X-ray diffracted analysis, chemical analysis for main and trace composition of representative samples was made. In particular, the relation between petrological character of Cretaceous granite and the minaralization of tin and rare earth elements were studied. These granite rocks belong to the S-type, ilmenite series of tin granite.

(3)Geochemical prospecting

Selecting dranaige systems from the whole Survey Area so that they are of nearly uniform density, a total of 2,021 stream sediment samples, which are -80 mesh products, were collected from the systems and subjected to chemical analysis. The chemical analysis of the stream sediments was for the 17 pathfinder elements.

Five hundred sixty panned sammples had been collected every four stream sediment samples at the same time. After observation by a stereo-microscpe and a ultra-violet light, 129 samples have been chemically analyzed by 25 pathfinder elements.

In addition, 207 soil samples have been collected in granite distribution areas to obtain data for rare earth elements.

These geochemical data were statistically processed, some geochemical anomaly map on ascale of 1:100,000 was prepared for each method. Finally the correlations among tin and rare earth elements and the promising area for these elements were studied.

1-2-2 The Second Phase Survey in 1992

From the results of the first phase survey, four promising areas were selected Area A, Area B and Area D around four granite mass and Area C situated at the Khao Fachi silicified zone. The most promising sub-areas, totalling 14.7 km^2 were selected through four areas. The detailed geological survey and soil geochemical prospecting were conducted to select anomaly zones indicated the extension of alluvial basins containing placer deposits and the existance of primary ore deposits and/or adsorption-type rare earth deposits.

Sampling sites were set with rectangular system; 100x50m grid systems in the Area A, B and C, and 100x100m grid systems in the Area D in view of topographical and geological conditions. Actual sampling points of each site were simply measured by compass and measuring tape.

Each sample was usually to be collected at the point nearby 1m under surface, because it seems that heavy minerals in the secondary ore deposit are partial to deeper zone. The soil samples passed through 80 mesh screen were kept for chemical analysis.

Additionally some different kinds and facies of rocks were collected. These were analyzed to check the geochemical background and studied by microscopic observation, and X-ray diffraction in case of necessity. Mineralized samples (rocks or panned samples) were examined by chemical analysis and observation on polished sections in case of necessity.

These geochemical data were statistically processed, a geochemical anomaly map on ascale of 1:10,000 was prepared for each element. The potential of each sub-area were revealed by these results.

1-2-3 The Third Phase Survey in 1993

The third phase survey was planned based on the second phase survey results. Pit and drill surveys in the A-1 area and a drill survey in the D-1 area have been performed.

(1)Area A-1

The pits were principally planned to dig 1.5 x 1.5 meters in size and 4 meters in depth to reach basement rocks, but some pits were unable to reach basement rocks because of underground water or boulders exceeding 1 meter in size. Some pits are 3 meters in depth. The number of pits dug in the area is 14, and total depth is 44.5 meters.

The Banka drilling was planned to confirm ores at 15 sites around promising pits. All holes have reached to basement rocks. The total depth of the holes is 74.7 meters.

Sketching of all walls, 1:25 in scale, has been done after completion of the pits. Then, 50 centimeters long channel sampling has been performed due to their geological conditions, and collected 89 samples have been panned to separate heavy minerals, which have been chemically assayed and made polished sections for microscopic observation.

Columnar sections, 1:50 in scale, have been made for all length of the drill holes by geological observation for each core tube section. Samples for every 1.5 meters section have been collected, and measured their volume and weight. 57 samples have been panned to separate heavy minerals, which have been chemically assayed.

(2)Area D-1

The Banka drilling was planned to confirm ores at 16 sites covered the whole area. All holes have reached to basement rocks. The total depth of the holes is 162.6 meters.

Columnar sections, 1:50 in scale, have been made for all length of the drill holes by geological observation for each core tube section. Samples for every 1.5 meters section have been collected, and measured their volume and weight. 79 samples have been panned to separate heavy minerals, which have been chemically assayed.

Based on these results of this survey, the potentiality of secondary deposits in both areas were studied.

The quantities of surveys in each phase are shown in Table 1.

1-3 Schedule and Personnel

1-3-1 The First Phase in 1991

(1)Negotiation and Planning

Period: from February 18, 1991 to February 28, 1991

Members:

Japan

Shozo SAWAYA	Metal mining Agency of Japan
Hiroshi OIKAWA	Ministry of International Trade and Industry
Hideo SATO	Ministry of Foreign Affairs
Kenzo MASUTA	Metal Mining Agency of Japan
Minoru FUJITA	Metal Mining Agency of Japan, Bangkok

Thailand

Visith Noiphan	Director General, Dept. of Mineral Resources
Prakong Polahan	Deputy Director General, ditto

Table 1 Contents of survey

Item \ Years			Phase I (1991)	Phase II (1992)					Phase III (1993)		
Kind of Survey			Interpretation Landsat Image Geological Survey Geochemical prospecting	Detailed Geological Survey Detailed Geochemical Prospecting					Pitting, Drilling Survey		
Areas (km^2) and Quantities			1500km^2	A:northern mass area(A-1,2) 6.0 B:central mass area(B-1,2,3,4) 2.5 C:Khao Fachi silicified zone 1.8 D:southern mass area(D-1) 4.4 Total 14.7					Area A-1 Pitting 14 holes 44.5m Drilling 15 holes 74.7m	Area D-1 Drilling 16 holes 162.6m	tatal
				A	B	C	D	total			
Indoor work	Thin sections		53	5	2	-	4	11	-	-	-
Indoor work	Polish		13	8	5	1	8	22	27	14	41
Indoor work	X-ray diffract		22	7	1	2	1	11	2	3	5
Indoor work	EPMA		17	-	-	1	4	5	-	-	-
Indoor work	Chemical analysis	Stream sed	2021	-	-	-	-	-	-	-	-
Indoor work	Chemical analysis	Components for analysis	Sn,W,Ta,Nb,Au,Mo,Ce,Eu La,Lu,Nd,Sm,Tb,Th,U,Y Sc								
Indoor work	Chemical analysis	Heavy min.	104	19	17	6	14	56	146	70	216
Indoor work	Chemical analysis	Components for analysis	Sn,W,Ta,Nb,Au,Mo,Ce,Eu La,Lu,Nd,Sm,Tb,Th,U,Y Sc,Dy,Er,Gd,Ho,Pr,Tm	Sn,W,Ta,Nb,Ce,Eu,La,Nd Sm,Tb,Th,U,Y,Gd,Dy,Pr							
Indoor work	Chemical analysis	Soilsample	207	1204	507	362	450	2528	-	-	-
Indoor work	Chemical analysis	Components for analysis	Sn,W,Ta,Nb,Au,Mo,Ce,Eu La,Lu,Nd,Sm,Tb,Th,U,Y Sc	Sn,W,Ta,Nb,Ce,Eu,La,Nd Sm,Tb,Th,U,Y,Gd,Dy,Pr							
Indoor work	Chemical analysis	Rocks	32	6	1	1	5	13	-	-	-
Indoor work	Chemical analysis	Components for analysis	SiO_2,TiO_2,Al_2O_3,Fe_2O_3 FeO,MnO,MgO,CaO,Na_2O K_2O,P_2O_5,LOI Sn,W,Ta,Nb,Au,Mo,Ce,Eu La,Lu,Nd,Sm,Tb,Th,U,Y Sc	SiO_2,TiO_2,Al_2O_3,Fe_2O_3 FeO,MnO,MgO,CaO,Na_2O K_2O,P_2O_5,LOI Sn,W,Ta,Nb,Ce,Eu,La,Nd Sm,Tb,Th,U,Y,Gd,Dy,Pr							
Indoor work	Chemical analysis	Ore sample	25	-	-	-	-	-	-	-	-
Indoor work	Chemical analysis	Components for analysis	Sn,W,Ta,Nb,Au,Mo,Ce,Eu La,Lu,Nd,Sm,Tb,Th,U,Y Sc								

Thawat Japakasetr	Project Manager,	ditto
Gawee Permpool		ditto
Paichit Pathnopas		ditto
Prayong Angsuwattana		ditto
Praphis Sampattavanija		ditto
Phairat Suthakorn	Project Vice Manager,	ditto
Peerapong Khuenkong		ditto
Patchara Jariyawat		ditto

(2) Survey Mission

Period: from June 10, 1991 to Febrary 22, 1992

(Field suvey: from July 7, 1991 to September 19, 1991)

Members:

Japan

Coordination and Planning

Masayoshi SHIMODE	Metal Mining Agency of Japan, Bangkok
Haruhisa MOROZUMI	Metal mining Agency of Japan

Geological and Geochemical Survey Team

Iwao UCHIMURA	Geologist
Hiroyuki TAKAHATA	ditto
Keizo WATANABE	ditto
Hiroyuki TAKAHARA	ditto
Hirohisa HORIUCHI	ditto

Thailand

Coordination and Planning

Thawat Japakasetr	Dept. of Mineral Resources
Phairat Suthakorn	ditto

Geological and Geochemical Survey Team

Peerapong Khuenkong	Geologist, Dept. of Mineral Resources
Patchara Jariyawat	ditto
Karoon Tonthongchai	ditto
Manoon Tanasung	ditto
Kittiphong Udomtanateera	ditto
Boonchu Panglinput	Field assistant, ditto
Taval Japakasetr	ditto

1-3-2 The Second Phase

Period: from June 10, 1992 to October 31, 1992

(Field survey: from June, 17 1992 to August, 14 1992)

Members:

Japan

Coordination and Planning

Toshio SAKASEGAWA	Metal Mining Agency of Japan
Kousuke TAKAMOTO	Metal Mining Agency of Japan
Masayoshi SHIMODE	Metal Mining Agency of Japan, Bangkok

Geochemical Survey Team

Hiroyuki TAKAHATA	Geologist
Yasunori ITO	ditto
Makoto MIYOSHI	ditto

Thailand

Coordination and Planning

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Phairat Suthakorn	ditto

Geochemical Survey Team

Peerapong Khuenkong	Geologist, Dept. of Mineral Resources
Patchara Jariyawat	ditto
Karoon Tonthongchai	ditto
Manoon Tanasung	ditto
Boonchu Panglinput	Field assistant, ditto

1-3-3 The Third Phase in 1993

Period: from June 28, 1993 to November 30, 1993
(Field survey: from July 5,1993 to August 9, 1993)

Japan

Planning and coordination

Toshio SAKASEGAWA	Metal Mining Agency of Japan
Jiro OHSAKO	ditto
Yasuhisa YAMAMOTO	ditto
Takafumi TUJIMOTO	ditto
Satoshi SHIOKAWA	ditto
Kousuke TAKAMOTO	ditto
Masayashi SHIMODE	ditto, Bangkok Office

Pit and drilling survey

Hiroyuki TAKAHATA	Geologist
Yasunori ITO	ditto

Thailand

Planning and coordination

Boonmai Inthuputi	Department of Mineral Resources
Phairat Suthakorn	ditto

Pit and drilling survey

Peerapong Khuenkong	Geologist, Department of Mineral Resources
Karoon Tonthongchai	ditto
Boonruam Songkran	Field assistant, ditto
Taval Japakasetr	ditto

Chapter 2 Geography

2-1 Topography and Drainage

In the Peninsula of Thailand, the Tenasserim Mountains extend from the western mountains of the Indonesian Peninsula to Ranong Provinces, and the Phuket Mountains extend from the Tenasserim Mountains to Chumphon, Phangnga, and Krabi Province, forming the backbone mountains of the peninsula.

The survey area is situated in the boundary between above mentioned two mountains, and 90 percent of the land is mountainous area showing altitude of 100 to 700 meters, but no high mountain exists.

The principal mountain ridges show a clear trend of NNE to SSW, characterized by narrow ridge lines and steep mountainside slopes. This trend coincides with the geological structure of the sedimentary formations in the area. Also the lens-shapes of granites distributed in the northern and southwestern areas show same trend, having relatively flat tops and steep flanks, where many water falls and steep cliffs exist.

Drainages in the area also show the trend of NNE to SSW, and alluvial extends into the narrow up-stream areas of the drainage systems. Crossing this main drainage trend, many minor streams cut the steep mountain flanks.

The River Kra Buri runs NNE to SSW along the border with Myanmar, the western edge of the survey area. Alluvial plains are distributed along its river sheds. Large alluvial plains are distributed in the water sheds of the Khlong Chan in the northern area and the Khlong La-Un in the southern area. A lowland swamp area extends in between the mouths of the River Chan and Khlong La-Un.

2-2 Climate and Vegetation

The Peninsula of Thailand is situated in the tropical monsoon area. The rainy season by the southwest monsoon ranges from May to November, and the dry season by the northeast monsoon ranges from December to April. Between February and April, it is the warmest time in a year due to weaken northeast winds.

The monthly temperature data in the recent six years in Ranong City, to the south of the survey area show that the average monthly temperatures are almost in a flat line, between 26 and 30°C. However daily changes in the dry season are rather larger, from 19 to 38°C, than those in the rainy season, from 22 to 33°C.

The monthly precipitation data in the recent five to six years in Kra Buri Town and La-Un Town show that the annual precipitation in the towns ranges between 1,800 and 3,000 mm. Ninety percent of the precipitation is concentrated in the rainy season.

The vegetation in the area is mainly of tropical monsoon forest in mountainous areas, artificial forest in hilly plantation areas, and agricultural land in flat areas. The mountain forest is of virgin heavy deciduous rees mainly consisting of teak wood, oak, bamboo, etc. In the hilly areas, artificial plantation forests consisting of tropical fruits, gum tree, oil palm, and coffee are mixed with natural virgin forest. In the plains, large areas are cultivated as rice fields and vegetable gardens. Mangroves are seen in the lowland swamp area in the mouths of the Khlong Kra Buri and Khlong La-Un.

Chapter 3 Geological Information

3-1 Existing Geological Information of the Kra Buri Area

Southeast Asia including the Malay Peninsula has undergone four major orogenic movements in late Precambrian, Variscan (Hercynian) in the late Paleozoic, Indonesian in the Triassic to Jurassic, and Alps in the Cretaceous to Tertiary times. The area among the Khorat Plateau, eastern Myanmar, Malay Peninsula and Borneo Island has been deformed by a tectonic holding movement accompanied by igneous activity in the Indonesian age.

The granites distributed in the zone are commonly called tin-granite or tin-tungsten granite according to their associated minerals. Hatchison and Taylor (1978) subdivided the tin-granite into three belts, the Eastern, Main Range, and Western Belts. Furthermore, Hatchison (1983) divided the Western Sub-belt into two belts. One is the Northern Area dominated by Triassic granites redefined as the "Northern Thailand Granite Area". Another id the Southern Area dominated by Cretaceous granites redefined as the "Southern Thailand Granite Area".

The survey area is situated in the southern Western Belt. The area is located in the area along the Ranong Fault, between the Ranong Fault which extends along the Khlong Kra Buri from Ranong to Prachuap Khirikhan situated in the Thailand Bay side and the Khlong Marui Fault which extends from Phangnga to Surat Thani. The area is called Western Phuket Belt, and the geological structure tends to NNE to SSW, in contrast with NNW to SSE in the northern Western Belt.

The Western Phuket Belt is underlain by clastic rocks and limestones of Cambrian to Jurassic time and intruded Cretaceous granites. No Cambrian and Ordovician rock is distributed in the survey area. The main constituting rocks are mudstones and sandstones of the Silurian to Devonian, mudstones and sandstones of the Carboniferous, limestones of the Permian, sandstones and conglomerates of the Jurassic, and intruded Cretaceous granites.

The survey area, based on the geological map 1:250,000 in scale published by DMR, 1985, is underlain by the Kra Buri Formation of the Tanaosi Group of the Silurian to Devonian, the Matri Formation of the Carboniferous, the Chumphon Formation of the Ratburi Group of the Permian, and intruded Jurassic granites and Cretaceous andesites to rhyolites.

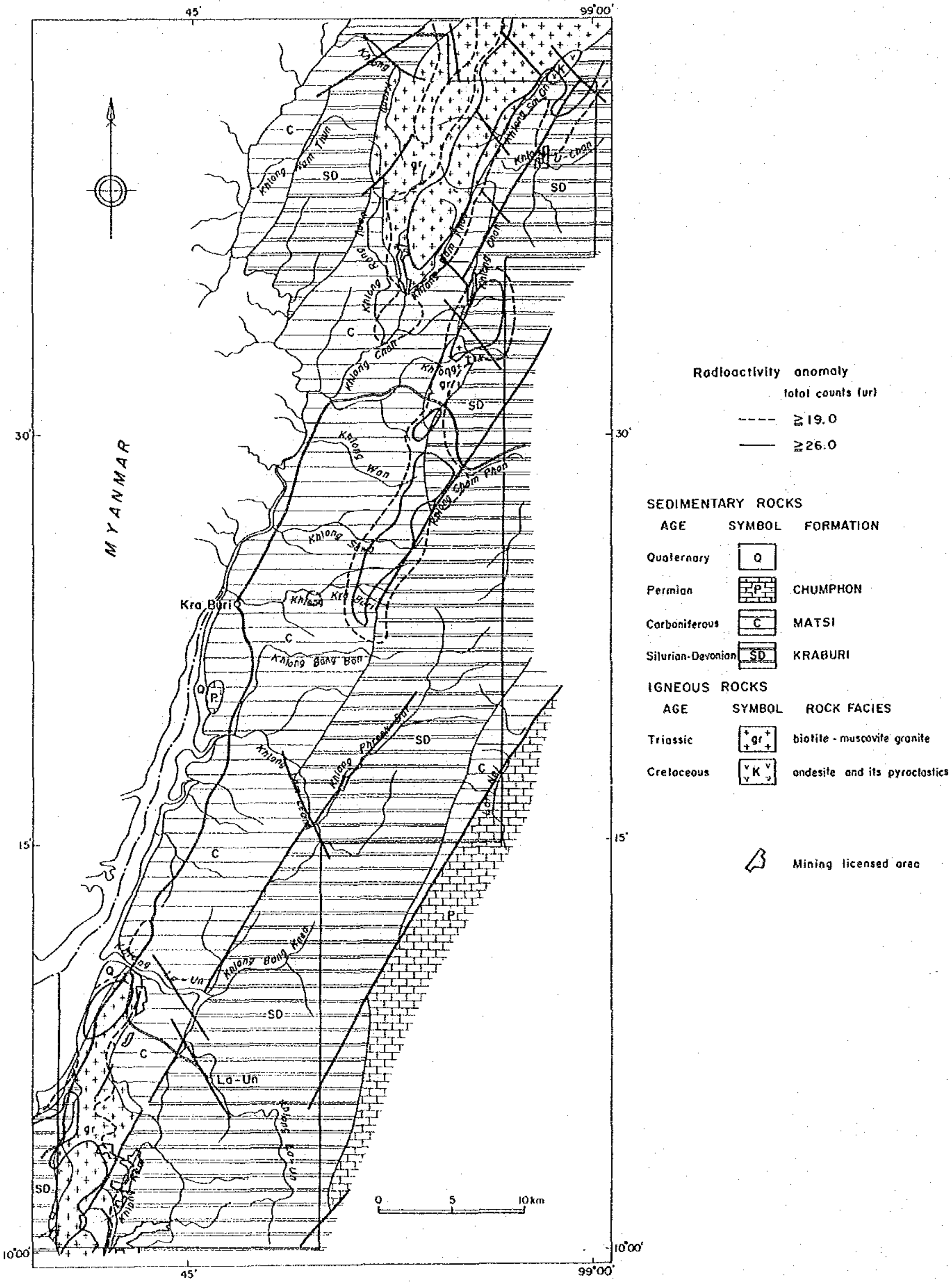

Fig. 4 Summarized Map of Previous Works

The geological structure of the area shows a general trend of NNE to SSW controlled by the Ranong Fault and Khlong Marui Fault. The granite intrusions were also controlled by those directions.

Many tin mines have been known in the Malay Peninsula for many years, and one of the largest tin producing area in the world. The peninsula of Thailand is in the northern tin producing area, and the Ranong to Phuket area to the south of the survey area is one of the major tin producing areas in Thailand. The tin deposits are classified into to categories, the secondary ore deposits containing in river flood plains and beach sands, and the primary ore deposits containing in granites as argillaceous-disseminated type and in pegmatites.

Many secondary ores in flood plains around granite bodies have been mined in the survey area in one time, and old pits are scattered in the area.

3-2 Mining Activity in the Survey Area

The tin mining activity in southern Thailand has been performed for 400 years at least. When Portuguese set up their trading station in Phuket in the 16 century, already several tin mines were in operation. Dredge mining for tin was first started in the Port Thung Kha 1906, then Australian, British, and Chinese people came to begin dredge mining operation. Five hundred eighty tin mines were registered in southern Thailand in 1965. Almost of all were small-scale private operations applying dredging or gravel pumping methods.

Since then, tin mining in Thailand expanded their activities mainly in the peninsula areas, and reached its peak in 1979. However, after that year, many small to medium scale mining operations have been forced to close their operations due to low market price caused by the development of competitive new materials such as plastics, and the development of new mining operations in Brazil and China. A few mines only for tin are active in Thailand at present, and only one dredging boat is in operation in the survey area, although many old workings are scattered in the area.

Table 2 shows the tin mining activities during the period from 1988 to June 1992. The registered mining claims and operating mines in Ranong County are decreasing in the recent years. The operating mines except one dredging boat for tin are for kaolin, and heavy minerals such as tin, ilmenite, monazite is recovered as byproducts. Annual production of kaolin per one mine is 4,000 tons, in contrast with 1 ton for heavy minerals. Market prices applied for minerals are of those settled by DMR Ranong Branch.

Minerals including rare earth elements such as monazite and xenotime were treated as waist in the active tin producing age. However, those are going to being recovered from the waist and "aman" reflecting the increase of the demand for rare earth elements in the recent years. The reserves and grades of those waists have not been definitely estimated yet, and no economical evaluation has been done.

Many of the tin mines recovering the secondary ores in land areas by the local people in the Ranong area are small in scale, and no precise production records and information for the ores are available. Major mining methods used by those people are gravel pumping and open pit, and the later is preferable for selective mining of high grade ores. The lowest grade for the economical operation is estimated to 0.3 katty/yd^3 (237.31 g/m^3) for both types of mining methods. The cost for opening new mine is estimated to 4 million bahts for the gravel pumping method, and 10 million bahts for the open pit method, based on the experience of DMR Ranong Branch. Also, tax for claims of 0.6 to 0.7 million bahts per 300 rai (1 rai = 16 ares) is required.

Table 2 Mining Situation in Ranong Province

	1988	1989	1990	1991	1992/6
Leisenced area	106	88	72	68	68
Working mines	20	13	11	12	13
Registered kind of Mining	cassiterite,wolframite,kaolinite associated minerals as tantalite-columbite,monazite,xenotime,zircon				
Minerals	Productin by year (Unit: tonne)				
cassiterite	1,059.74	950.58	985.51	940.28	432.38
wolframite	20.22	3.90	9.60	9.42	-
kaolinite	26,090.00	29,568.00	38,297.00	52,708.00	23,398.02
xenotime	3.00	-	-	8.00	-
monazite	9.00	-	66.00	116.00	-
zircon	266.00	-	20.24	118.70	-
columbite-tantalite	8.00	-	97.25	-	-
Minerals	Market price (Baht/tonne)				
cassiterite	184,387	218,440	155,674	139,667	165,218
wolframite	98,902	80,151	64,007	117,636	94,009
kaolinite	700	700	700	700	700
xenotime	69,604	68,604	69,604	69,604	69,604
monazite	12,559	12,559	13,737	13,737	13,737
zircon	7,901	13,207	13,203	13,207	13,207
columbite-tantalite	61,645	52,983	52,983	52,983	52,983
Minerals	Market price (Yen/tonne)				
cassiterite	923,780	1,094,384	779,925	699,732	827,741
wolframite	495,501	401,555	320,675	589,358	470,987
kaolinite	3,507	3,507	3,507	3,507	3,507
xenotime	348,716	343,706	348,716	348,716	348,716
monazite	62,921	62,921	68,822	68,822	68,822
zircon	39,584	66,167	66,167	66,167	66,167
columbite-tantalite	308,841	265,445	265,445	265,445	265,445

Capter 4 Conclusion and Recommendation

4-1 Conclusion

In this Survey, regional geological survey and geochemical prospecting stream sediment, panned sample (heavy mineral) and soil samples were mede in the first phase, detailed geological survey and geochemical prospecting by soil sample, and geological survey by pit and drilling survey in the third phase. In this course, the scopes of the surveys were narrowed down to more promising area, and the following conclusion was formed.

(1) Through the lithostratigraphic classification of various rocks in the whole Survey Area, the stratigraphy has been established. Four Cretaceous granite masses was intruded into sedimentary rocks regulated by geological stracture.

The granites belong to the S-type, ilmenite series granite, and classified into the tin-granite based on their principal chemical components and tin contents.

(2) There are old secondary ore deposits of tin around four granite masses. Geochemical anomalies by all methods are distributed in Quaternary deposits around granite masses. Placer deposits of tin in alluvial basins and the possibility of primary deposits and adsorption-type rare earth deposits were expected.

(3) As the results of the surveys of the first phase and second phase, the two areas of A-1 and D-1 were picked out, and pit and drilling survey were carried out in these areas.

These survey have lead to the following conclusion.

Area A-1

(i) Potential for secondary ores in talus weathering residual deposits and stream sediments has been expected in the area A-1. The survey results have revealed that potential for secondary ores in stream sediments was high in this area.

(ii) The areas evaluated as of high potential for secondary ores in talus weathering residual deposits based on the second phase survey results have been surveyed, and the assay results show that the grades of ores are one fifties to one thousands less than those in the second phase results. The differences between those are due to the different sample treatment methods. Actual mining grades would be close to third phase results.

(iii) Tin concentrated zones in secondary ores are in the lower parts, and rare earths concentrated zones tend to situate above the tin zones. It possibly shows that timing of supply for tin and rare earths in the sedimentary basin are different.

(iv) Content of rare earths is correlate to that of tritium, zirconium, titanium, niobium, and tantalum. The sedimentary basins along the Khlong Nam Khao contain much tantalum and niobium.

(v) Five potential zones for secondary ores are located in the area A-1. The total probable ore reserves of the three zones along Khlong Nam Khao are 639,000 m^3, and the grades are as follows.

SnO_2	; 500 g/m^3
Ta_2O_5	; 10 g/m^3
Nb_2O_5	; 36 g/m^3
TR_2O_3	; 135 g/m^3
ThO_2	; 18 g/m^3
Zr_2O_3	; 23 g/m^3
TiO_2	;1025 g/m^3

The total probable ore reserves of the two zones in the western side are 146,000 m^3, and the grades are as follows.

SnO_2	;1000 g/m^3
Ta_2O_5	; 15 g/m^3
Nb_2O_5	; 24 g/m^3
TR_2O_3	; 50 g/m^3
ThO_2	; 6 g/m^3
Zr_2O_3	; 16 g/m^3
TiO_2	; 290 g/m^3

Area D-1

(i) The area D-1 is dominantly underlain by mangrove soil, however preferable sedimentary basins for secondary ores were expected underneath the mangrove soil in the area. The survey results reveal that no significant sand and gravel layer exists in the area, and fewer amounts of useful minerals are contained in the sediments.

(ii) Major parts of the sediments, except some areas around ancient river systems, in the area have deposited under the quiet reductional environment, and contain little amounts of coarse heavy minerals.

(5) As the horizontal and vertical distribution of geochemical anomalies in sedimentary basin, it is revealed that the source of tin and rare earth minerals may be diffirent in granitic rocks..pa

4-2 Recommendation for the Future Works

The secondary ores confirmed in the area A-1 show significantly high contents of tin, accompanied by tantalum, niobium, rare earths, titanium, and zirconium. Even though the scale of the ore deposits is small, however, it is evaluated that the ores are of economical. The separation of drill holes was too large precisely to evaluate the ores. Therefore it is recommended that further detailed surveys are performed before the final decision for development. Furthermore, it should be reminded that the area is utilizing for agriculture, and economical compensation will be required for development of mining. Total economical tradeoff consideration is necessary.

Through the all programs, secondary ores containing not only tin but also rare earths have been the main target because of low tin market price. Speaking of tin, the old mining site in the watershed of the Khlong Kum, southern Kra Buri area, has the highest potential, and the upper stream area of the Khlong Lam Leang has high potential for primary ores. It is recommended further exploration activities to evaluate ore deposits in this area.

PART II DETAILED DESCRIPTION

Chapter 1 Satellite Image Interpretation

Two kinds of information, spectral and topographic, are generally used for photogeological reading of satellite images. The spectral information is expressed in different color tone in false color images, mainly caused by different reflection characters of surface materials of the earth. The topographic information is expressed in tone and shade, mainly reflecting topography and sun position at each position of the image.

1-1 Satellite Image

1-1-1 Data Used

An adequate false color image has been made from CCT using Landsat TM data to interpret the geology in the Kra Buri area. The interpretation has been done by photogeological reading.

The Landsat-5 TM data CCT (BSQ formatted, 6250BPI) is a full scene including the whole survey area, an area of 185 km x 170 km, and its data when the image taken.

Orbit Frame	Path 130, Raw 53
Center of image	Latitude 10°10' North
	Longitude 98°26' East
Date taken	February 10, 1991
ID No.	5253703551
Sun Position	Angle of Elevation 44.3°
	Azimuth 121.9°
Processing Level	Bulk Process

1-1-2 Image Production

1. Image Processing

The survey area is in the tropical rain forest or tropical monsoon area, and mainly covered by heavy vegetation. The spectral information of the area therefore could principally reflect the information of the surface vegetation's status. Accordingly, the topographic information should be taken as the most important factor for photogeological interpretation. The image processing for making the image has been done to extract that topographic information as much as possible. The image for reading should present as many density levels as possible, maximum 256 tones, accordingly it is desirable that an accumulation histogram for digital values of each band show liner shape. The histogram equation process for density is a tool for the process, and it produces images showing strong contrast compared with original images.

In this study, the process for each band has been applied for the digital values of the land area, because about a half of the TM scene occupies marine area. Then the image obtained has been processed by the Unsharp Masking Method to make easy reading of lineaments by means of sharpen image and enhanced edge effect.

2. Band Selection for making False Color Image

Landsat TM data have digital values of seven bands for each pixel. Among them, Bands 1 to 5 and 7 are in the visual to inter-infrared wavelength range and have the spatial resolution of 30 m x 30 m. On the other hand, Band 6 is in the thermal infrared range, and has the resolution of 120 m x 120 m. Band 5 is rarely used for false color images because of its resolution capacity. In general, Bands in the visual to inter-infrared waves are used. In this survey, Bands 1 to 5 and 7 have been used.

Judging from experiences, combinations of Bands 1-4-5, 1-5-7, and 2-3-4 in false color images are commonly applied for photogeological reading of heavily vegetated areas. In this survey, various combinations have been tested, and the result indicates that above mentioned three combinations are excellent for the purpose compared with others. The results of evaluation for those three combinations are as follows.

	Comb.1-4-5	Comb.1-5-7	Comb.2-3-4
Clearness of boundary between clouds and surface	VG	G	G
Clearness of mountain topography	VG	G	VG
Clearness of ring structure in low land	VG	G	M

Note: VG very good, G good, M moderate

As the results shown, the combination of Bands 1-4-5 is best for photogeological reading. A full scene false color original image in the scale of 1:1,000,000 has been produced by means of assign blue, green, and red for Band 1, 4, and 5. An enlarged image, scale of 1:100,000, from the original one has been used for practical study. Figure 5 shows the area interpreted.

Fig. 5 Interpretation Map of Landsat Image

1-2 Lineament

Figure 5 shows the lineament extracted, which are classified into two categories based on their clearness. Most of the lineaments are linear, and classified into five trends, NNE-SSW, NE-SW, N-S, E-W, and NW-SE to NNW-SSE.

The most frequently appearing trend among them is that of NNE-SSW, which is evenly distributed in the area. This trend reflects the global geological structure in the area, especially that of the area between the Ranong Fault and the Khlong Marui Fault. These two faults are strike faults and strongly control global geological arrangement of the area. The lineament also shows the faults bordering between the Silurian-Devonian formations and Carboniferous- Permian formations, and boundary between the granite bodies and surrounding formations. Many minor lineaments parallel to the above mentioned large two faults presumably represent accessory faults.

The lineaments showing the trend of NE-SW are concentrated in the central area, from the east of Ban Pak Chan to the Khlong La-Un. There are two kinds of lineaments in this trend, high clearness long extension and low clearness short extension. A fault expressed by this lineament cut the granite body with right lateral in the mountain area east of Kra Buri Town. The lineaments normally cut the NNE-SSW lineaments.

The lineaments showing the trend NW-SE appears less frequently in the area, and show a short extension and poor clearness. The lineaments usually do not cut other lineaments or show a little displacement. It is unsure whether the lineaments representing faults or not from the field survey.

The lineaments showing the trend E-W are distributed over the whole survey area. Lineaments showing low clearness and short extension are distributed in the northern area, and those showing high clearness and long extension, although low frequency, appear in the southern half of the area. The lineament partly branch from the NE-SW lineaments, however normally cut the NE-SW and NNE-SSW lineaments.

The lineaments showing the trend N-S are to the south of the Khlong Lam Leang. Those of high clearness are especially in the surrounding area of the granite bodies in the southern area.

In the area, curved and ring-shape lineaments and wavy lineaments showing low clearness other than linear shape exist in the sedimentary rock distribution areas. These lineaments probably reflect cuesta topography of sedimentary formations. However no evidence for it has been obtained in the fields. Those curved and ring-shape lineaments tend to appear corresponding to the places underlain by gentle dipping formations.

The frequency is high in the sedimentary rock areas, especially in the Silurian- Devonian. Some lineaments exist in the granite bodies, and in some cases less lineaments in the rims of the bodies. In such rim areas, gentle hills lower than those in the surrounding sedimentary rock areas are distributed surrounding steep mountains of the granite. This characteristic feature is dominant in the granite bodies in the northern and southern areas, on the contrary no such feature in the stock shape granites in the central area.

1-3 Geology

The study area is classified into five categories, A, B, C, D, E, based on reading factors such as tone, smoothness, drainage pattern and density, resistivity for weathering and erosion, and state of lineament. Figure 5 shows the results of the interpretation.

The photographic and topographic characteristics of each category are as follows.

Category A appears in the northwestern and eastern areas, where are high mountain regions stretching NNE-SSW. It shows dark green in the image. The southern part is steeper than the northern part, and shows deep gouges cut by rivers. The lineaments trend NNE-SSW in the whole survey area. The drainage pattern is of dense dendritic, and tends to stretch NNE-SSW in the main stream areas. The smoothness is rough, and status of the undulated surface is well observed. The resistivity for erosion is presumably high, judging from the characteristics of the topography and the drainage pattern. Accordingly, It is judged that this category represents mudstone or sandstone formations, which show strong resistivity for erosion.

Category B appears in the northeastern to westcentral area, where is hilly area stretching NNE-SSW. It shows pale green to yellow in the image. The area is a mountain range showing same level mountain tops, and shows less clear lineaments than those in Category A. The drainage pattern is of small scale dendritic, having wide streams and shallow gouges. The resistivity for erosion is presumably medium to high. The smoothness is coarse to medium, and status of the undulated surface is observed. This category possibly represents some type of sedimentary rocks.

Category C appears limitedly in the western plain and mountain areas, being controlled by the topog raphy. No lineament exists in this category's areas. It shows reddish brown to brown in the image, and high resistivity for erosion. A river runs in the center of this category's area. The smoothness is fine, showing gentle smooth surface condition. This category presumably represents unconsolidated gravel, sand, and clay areas.

Category D appears only in the lowland plains along the river mouths. It shows dark green in the image, and significantly low resistivity for erosion. Many meandered rivers run in this category's areas. The smoothness is fine, and no undulation is observed in the areas. This category could represent unconsolidated gravel, sand, and clay areas.

Category E appears in the northcentral and southwestern areas, where are highland areas stretching N-S. It shows green in the image. The tone and smoothness are similar to those of Category A, however its lineaments and drainage pattern are much different. The lineaments show the trends of N-S and NE-SW, and the drainage pattern is of distorted rectangular. It possibly means that the resistivity is higher than that of Category A, and more faults and joints exist in the area. Accordingly, it is presumed that Category E represents some kinds of intrusive bodies, possibly large-scale plutonic bodies judging from their scale.

The tones of the image used for the interpretation well reflect the state of vegetation corresponding to the topographic characters rather than geological conditions. The dark green parts seen in Categories A and E correspond to dense virgin forests due to rugged topography. The pale green to yellow parts seen in Category B correspond to the artificial forests consisting of tall trees like rubber tree and some fruits trees spreading over relatively low hilly areas. The reddish to brown parts seen in Category C correspond to agricultural garden, rice field, upland rice field, tall coffee, and residential areas. The dark green parts seen in Category D correspond to undeveloped swamp areas with mangrove.

Chapter 2 Geological Survey

2-1 General Geology

Southeastern Asia containing the Malay Peninsula has undergone four big tectonic movements occurred in late Precambrian, Variscan (Hercynian to late Palaeozoic), Indochinaian (Triassic to Jurassic), and Alpine (Cretaceous to Cenozoic) times. The area between the Khorat Plateau and eastern Myanmar, Malay Peninsula, and Borneo Island (Kalimantan) are the area where has undergone tectonic folding accompanied with igneous activity in Indochinian age. The granites distributed in the area are called "Tin Granite or Tin- Tungsten Granite" based on their accompanied economic minerals, although precise definition exists for the name. Hutchison and Taylor (1978) divided the granite belt into three sub-belts, the Eastern Belt, Main Range Belt, and Western Belt. Furthermore, Hutchison (1983) divided the Western Belt into the Northern Area dominantly underlain by Triassic granites and the southern Area dominantly underlain by Cretaceous granites, and defined them again as "Northern Thailand Granite Area" and "Western Belt". The survey area is situated in the Western Belt, and placed between the Ranong Fault and Khlong Marui Fault. The Ranong Fault stretches from Ranong to Prachuap Khirikhan faced on the Gulf of Thailand, along the Khlong Kra Buri. The Khlong Marui Fault stretches between Phangnga and Surat Thani. The area is particularly named as Western Phuket Belt, and dominantly shows NNE-SSW geological trend. On the contrary the Western Belt to the north area shows NNW-SSE trend.

The Western Phuket Belt is underlain by sedimentary rocks and limestones of Cambrian to Jurassic age and Cretaceous granite. However no Cambrian and Ordovician formation exists in the survey area. In the survey area, Silurian to Devonian mudstone and sandstone, Permian limestone, Jurassic sandstone and conglomerate, and Cretaceous granites are distributed.

The geological structure in the survey area is controlled by the Ranong and Khlong Marui Faults, showing general trend of NNE-SSW, and the granite intrusions also elongate in the same direction.

The belt from the survey area to Ranong-Phuket areas is one of the principal tin producing areas in Thailand. Many secondary tin deposits were mined out in the past. However only one mine was in operation in 1991.

2-2 Detailed Geology

Reading from the 1:250,000 geological map (DMR 1985), the survey area is underlain by the Kra Buri Formation of the Silurian to Devonian Tanaosi Group, Matri Formation of the Carboniferous, Chumphon Formation of Permian Ratburi Group, and various igneous rocks, Jurassic granites, Cretaceous andesites and rhyolites.

In the survey this time, a new granite body has been identified corresponding to the airborne radioactive anomaly detected 1989, and a formation correlated with the Fang Dang Formation of the Jurassic Korat Group has been found. However, no clear stratigraphic relation over the area has been established due to poor outcropping and strong weathering. The regional geology and stratigraphy will therefore be referred to DMR information 1985. Regarding the time of the granite intrusion, however, data will be taken from Hutchison (1983) and Suensilpong et al. (1983) as Cretaceous age.

The granites situated in the area is geographically divided into four groups; West mass around the Khlong Nam Khao in the northern area, East mass to the east of the Khlong Chan in the northern area, Central mass to the east of the highway number 4 connecting Kra Buri and Chumphon, and Southern mass along the highway in the south. The Southern mass is the northern extension of the Ranong Granite, one of so-called tin granites described by Sirinawin et al. (1986).

Figures 6 and 7 show the geologic map and schematic geologic column of the area.

2-2-1 Sedimentary and Pyroclastic Rocks

1. Kra Buri Formation, Tanaosi Group (SD)

The formation is stratigraphically the lowest one in the area, and largely distributed in the area, especially in the river basins of the Khlong Krang and Khlong Nam Thun in the northern area, the northeastern to southwestern areas occupying about the eastern half of the area. In the southwestern area, it is distributed small areas between the granite bodies.

The rocks of the formation are slate, sandstone, pebble bearing mudstone and sandstone. In the eastern area, where the lowest part of the formation is possibly crops out judging from the geologic structure, the formation comprises alternation beds of hard slate and sandstone. The overlying beds decrease its sandy parts, and change to massive mudstone. The upper part of the formation is dominated by round-pebble, 2 to 5 cm in diameter, bearing mudstone and sandstone. In the river basin of the Khlong U-Chan, conglom-

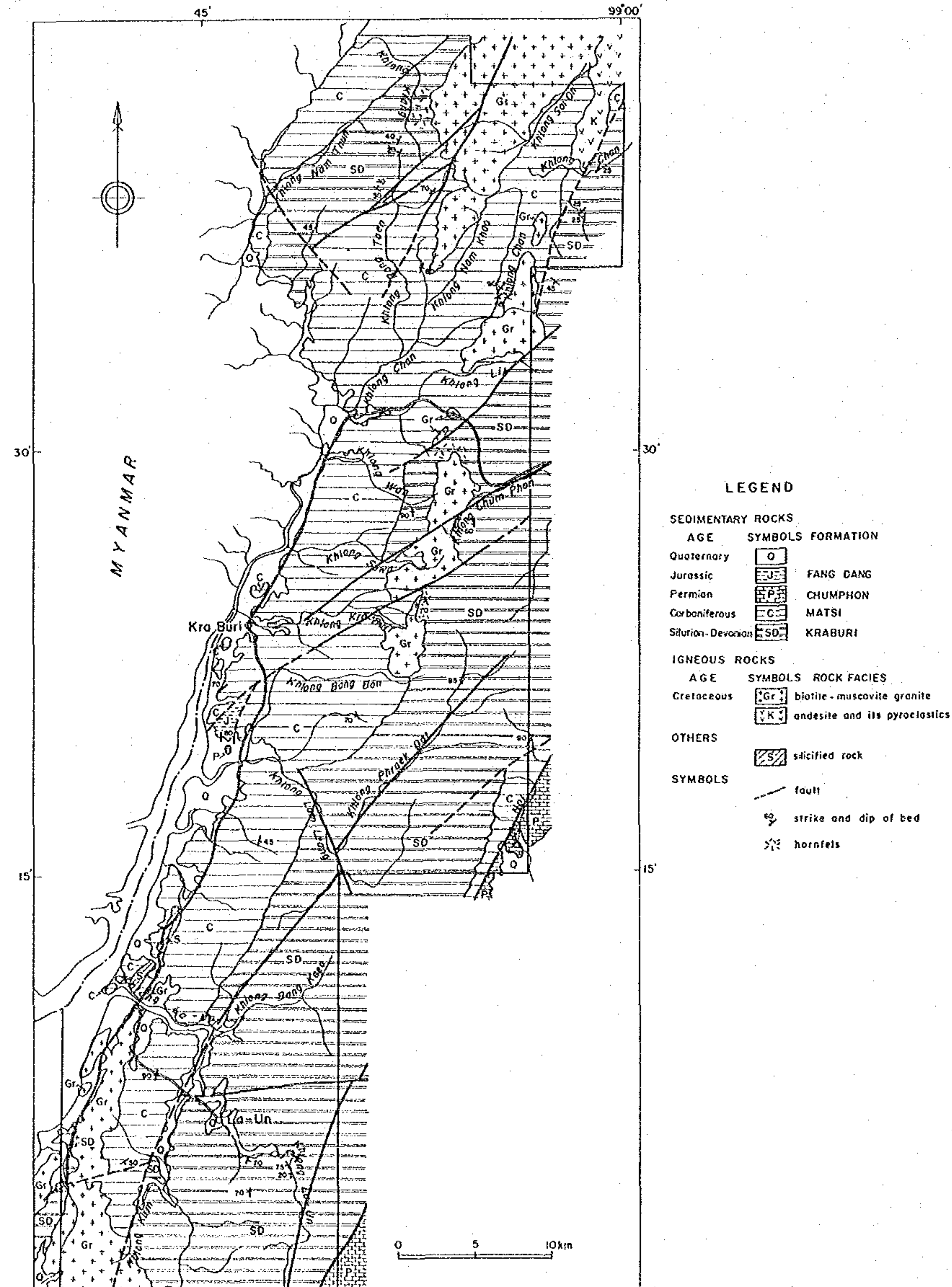

Fig. 6 Geologic Map of the Kra Buri Area

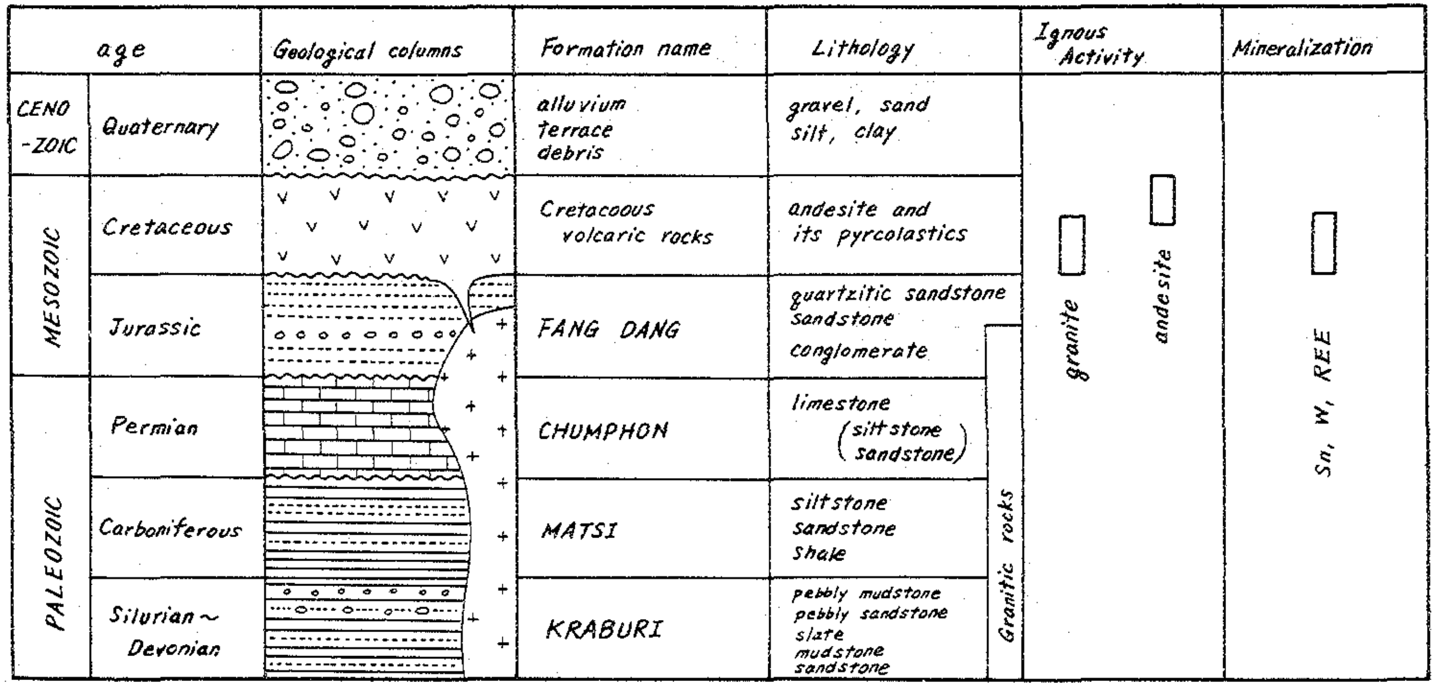

Fig. 7 Schematic Geologic Column of the Kra Buri Area

erates comprising cobbles, 10 cm in diameter, are intercalated with the pebble bearing mudstone and sandstone beds, and a chert dominated bed is overlain by those.

The mudstone and sandstone of the formation have undergone recrystallization in the matrix, forming Muscovite in the sandstone and biotite along the foliation of the mudstone. The formation has been intruded by the granites, however undergone only little hornfels metamorphism, which is seen along the Krang on the western rim of the northern granites and the northern rim area of the central stock-like granites. The thermally altered sandstone containing fragments of basic rocks and carbonate rocks has skarn-like appearances comprising tremolite, epidote, and chlorite.

The general trend of the formation is NNE-SSW. Measured strikes present the trend of N-S to NE-SW, and dip to the east, and the structure is of folded having the axis plunging to the west.

2. Matri Formation (C)

The formation is largely distributed in the northwestern corner of the area and the area from the northeastern area through Pak Chang and along the east bank of the Khlong Kra Buri. According to DMR (1985), the formation is defined as of Carboniferous because it yields fossils of bryozoan and brachiopods. No fossil in the formation has been found during the survey this time.

Hard slate is dominant to the south of the La-Un Khlong, and siltstone and fine sandstone are dominant to the north, where the rocks have undergone strong weathering altering to reddish soil. A thin bed of ortho-quartzite and many floats of quartz-like pebbles are seen in the middle stream area of the Wan Khlong, to the northeast of Kra Buri Town. Same types of floats also have been found in the Khlong Lam Leang basin.

Recrystallization of the matrix in the sandstone and mudstone is weaker than that of the Kra Buri Formation. Hornfels metamorphism by the contact with the granite bodies is significant on the eastern side of the Southern mass, and the grade of the thermal metamorphism is same as that of the Kra Buri Formation.

The geological structure of the formation is of steep dip with NNE-SSW strike in the south, on the contrary gentle dip, 20° to 50°, with random strike in the north.

3. Chumphon Formation, Ratburi Group (P)

The formation is distributed in a large area from the upper stream area of the Khlong Sawi on the southeast of the survey area toward the east. The distribution area of the formation is small. A small area in the mouth of the Khlong Lam Leang is also underlain by this formation.

The rock facies are mainly of non-crystallized limestone, interbedded with thin beds of siltstone and sandstone. Pinnacles of limestone stand in the upper stream area of the Khlong Sawi, and large floodplain is distributed between those pinnacles.

The formation has fault contact with the underlying Kra Buri and Matri Formations. The limestone distributed on the mouth of the Khlong Lam Leang stands alone in the alluvial lowland with dense mangrove forests. No relation between the limestone and other formations can be found because of its isolated situation.

4. Fang Dang Formation, Korat Group (J)

The formation occupies a corner of the hilly area spreading to the north of the mouth of the Khlong Lam Leang, an area of the Chumphon Formation. The rock facies are of quartz-rich coarse sandstone to pebbly conglomerate, accompanied with a little siltstone. The sandstone and conglomerate comprise over 70 percent of quartz and feldspar derived from the granites, and filling altered clayey materials and fine silica minerals.

The formation generally strikes N20°-50°E and dips 70°-90° to the west. It is in fault contact with the surrounding formations, showing no stratigraphical relation with them.

5. Cretaceous Andesite and its pyroclastics (K)

The andesites overlie the Matri Formation in the northeastern corner of the area. It was previously judged as intrusive dikes, however dark reddish grey autobrecciated lavas and its rim facies, tuff breccias, have been found in this survey.

6. Alluvial Deposit (Q)

The deposit is distributed in the basins of the main rivers, and consists of unconsolidated gravel, sand, and clay.

2-2-2 Granitic rocks

The granites in the area are separated into four bodies, the West mass and East mass in the northern area, Central mass, and Southern mass (Fig. 8).

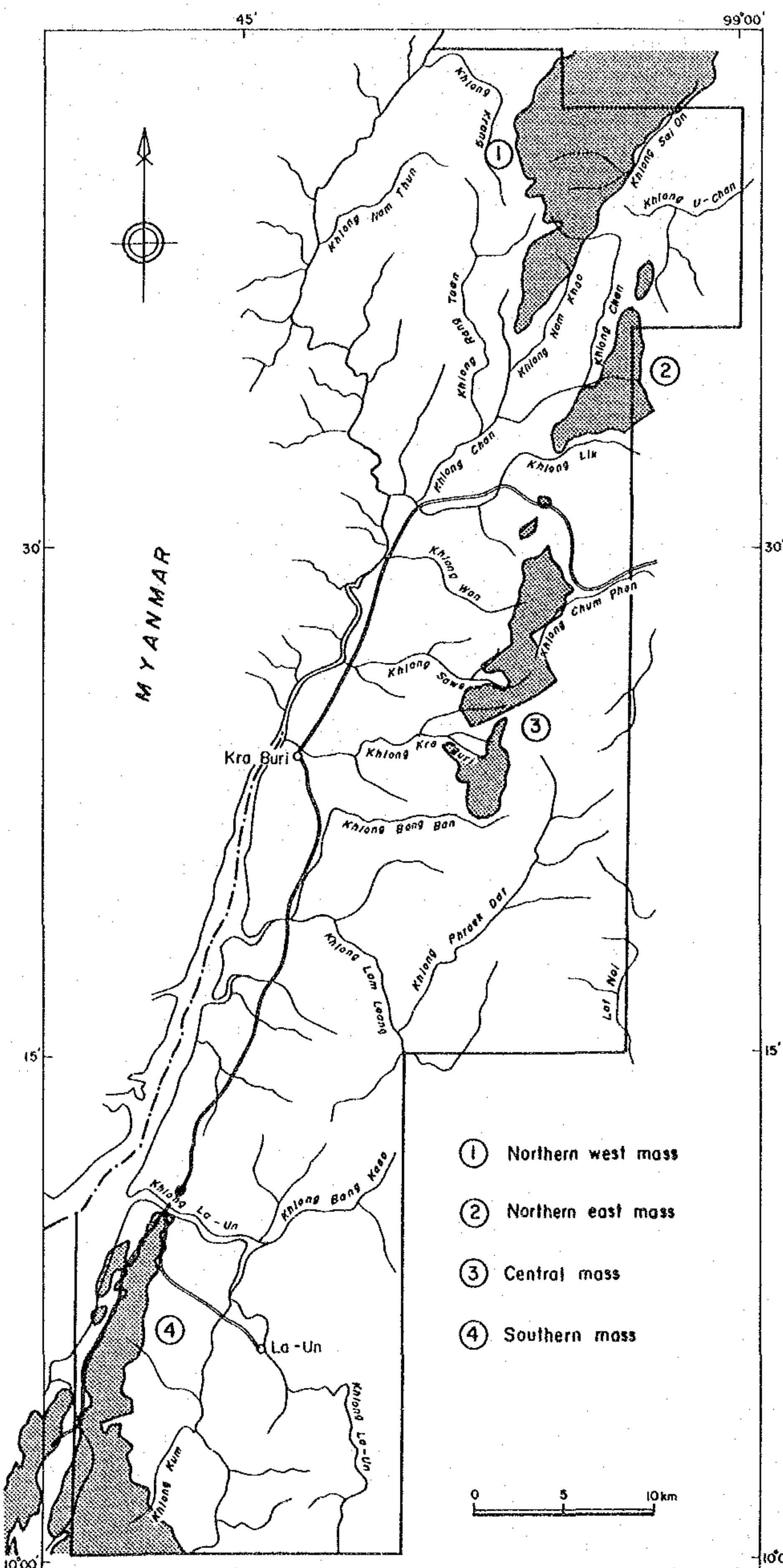

Fig. 8 Distribution Map of Granite Rocks

The granitic masses except the East mass form steep mountain bodies, exposing granite outcrops on the flanks. Many water falls also can be seen on the flanks.

On the contrary, the East mass forms a gentle hilly mountain in a well eroded stage. All granite bodies are oval in the shape of the distribution, elongating NNE-SSW in the northern three bodies and N-S in the Southern mass. These trends correspond with that of the Ranong Fault, which controls general geological structure of the area. It is therefore possible to conclude that the trend of the intrusion has been controlled by the trend of the fault. The granite bodies except the Central mass are presumably in fault contact with the surrounding sedimentary formations, because the boundaries of the granite bodies are linear.

Hutchison (1983) and Suensilpong et al. (1983) described that the Western Belt including the survey area has been strongly undergone the Alpine Tectonic Movement of Cretaceous to Cenozoic age, and the age of the intrusion of the granites should be the same. Suensilpong et al. (1983) also indicated that the Rb-Sr radioactive age of the granites was 107 to 120 Ma, on the other hand the K-Ar radioactive age in the micas was 54 to 85 Ma. Garson et al. (1975) also indicated the same point, and explained that the discrepancy between them was presumably caused by two stages of intrusion, the preceding I-type granite intrusion (porphyritic biotite granite) and the later stage S-type granite intrusion (two-mica granite) brought by the remelt of the crust. It is quite possible that the intrusion stage of the granites is Cretaceous.

1. Northern west mass

The mass is situated to the west of the Khlong Nam Khao and Khlong Sai On, and between the Khlong Krang and Khlong Rang Taen in the northern area. The eastern border line is linear, suggesting that the border is in fault contact. On the contrary, the sedimentary rocks of the Kra Buri and Matri Formations on the west of the granite body have been metamorphosed to hornfels, in where quartz veins exist someplace.

The eastern and western flanks of the granite mountain are steep, appearing many water falls. Poor weathered soil, about 10 m thick, exposes on the top of the mountain, on the contrary thick soil, more than 30 m some places, exist in the flat plain in the northern area. The granite body is dominated by coarse grained two-mica granite, partly containing mega-phenocrysts of K-feldspar.

The main constituent minerals are quartz, microcline, orthoclase, and plagioclase, and the accessory minerals consist of zircon, apatite, sphene, and opaque minerals. The colored minerals such as biotite, muscovite, and tourmaline are common, beside allanite is rarely seen.

Rock samples taken except one have undergone mylonitization, and contain recrystallized quartz. Muscovite is seen in the altered plagioclase and recrystallized quartz veinlets. It is therefore not sure that whole part of the granite is two-mica granite.

2. Northern east mass

The mass is situated to the north of the Khlong Lik in the northern area and to the east of the Khlong Chan, forming narrowly extended body from north to south. It forms gentle hill area different from other three masses. The body has undergone kaolinization and montmorillonitization, and changed to white in color over the whole body. It is presumably of two-mica granite, but it is unclear due to very limited exposures of fresh parts and deep weathering. Muscovite is concentrated in some significantly altered parts, where are presumably of muscovite granite origin.

The main constituent minerals are quartz, microcline, orthoclase, and plagioclase, being accompanied by zircon, apatite, sphene, and opaque minerals. The colored minerals such as biotite and muscovite are common. Kaolinization, montmorillonitization, and muscovite alteration of the plagioclase are significant, and the biotite has been chloritized.

3. Central mass

The body is situated to the south of the highway connecting Kra Buri and Chumphon, and to the upper stream area of the Khlong Bang Bon to the east of Kra Buri Town. This granite is separated into three small-scale bodies by a fault stretching NE-SW. Steep cliffs having water falls surround the granite bodies. Weathered soil is poor in the bodies.

The bodies gave intense heat affection to the surrounding rocks, forming hornfels. Hornfels metamorphism is significant in the northern body, where some disseminated sulphides are seen. Numerous quartz veins, ranging several tens centimeters to several meters wide stretching NE-SW, are scattered in the sedimentary rocks to the southeast of the small-scale southern granite body, in the upper stream area of the Khlong Phraek Dat, a branch of the Khlong Lam Leang.

Most parts of the granites are of biotite granite and two-mica granite containing phenocrysts of K-feldspar, maximum 2 cm x 5 cm in size. A little fine grained two-mica granite as an outer rim-face appears in the upper stream area of the Khlong Wan. No intense cataclasis occurred in the body except along some faults.

The main constituent minerals comprise of microcline, quartz, and plagioclase, being accompanied by zircon, apatite, sphene, and opaque minerals. The colored minerals of biotite and muscovite are common, besides rutile is rarely seen. Kaolinization and muscovite alteration of the plagioclase are significant, and the biotite has been altered to chlorite.

4. Southern mass

The body is situated along the highway to the south of the Khlong La-Un in the southern area. A small body of the granite is situated to the north of the Khlong La-Un, where is on the extended part of the granite. Steep cliffs surrounded the granite bodies, cropping out the rocks. Weathered soil at the top of the mountain is poor, less than 8 m thick at the road to the TV transmitter station in the southern area.

On the eastern side of the granite, the surrounding rocks have been intensely metamorphosed by the heat. The rocks of the Kra Buri Formation on the west of the granite body have undergone weak thermal metamorphism. Thin layers of granite bodies injected into the sedimentary layers on the west side of the granite, indicating strong tectonic control for the injection. The rocks have been affected by intense *mylonitization, especially on the west side of the granite.*

The granite mainly consists of two-mica granite containing k-feldspar phenocrysts. It is hard to determine whether the muscovite is of recrystallized one by the cataclasis or not. The main constituent minerals are quartz, microcline, orthoclase, and plagioclase, being accompanied by zircon, apatite, sphene, opaque minerals, and allanite.

Fine grained two-mica granite and muscovite tourmaline granite are seen at the contact zone with the surrounding sedimentary rocks on the east side of the body. These rocks intruded into the porphyritic two-mica granite there. The constituent minerals of the rocks are almost same as those of the porphyritic granite. No cataclastic texture is seen in the rocks.

2-3 Geochemical Characteristics of Granites

2-3-1 Principal Chemical Component

Many authors have proposed various classifications for granites based on the conditions and environment relating to their felsic magma's formation and differentiation. Chappell and White (1974), and White and Chappell (1977) proposed the classification of S-type (sedimentary source type) and I-type (igneous source type), Ishihara (1977) proposed the classification of the Magnetite-series and Ilmenite-series. Also White (1979) proposed the M-type (Mantle source type). Those classifications are based on their principal chemical components and mineral assembly of the granites.

According to Aranyakanon (1962), Ishihara et al. (1980), Ishihara (1981), Hutchison (1983), and Suensilpong et al.(1983), the tin-granite accompanied with tin mineralization in Thailand belongs to the S-type or Ilmenite-series. Otherwise the granite accompanied with molybdenum, tungsten, and gold belongs to the I-type or Magnetite-series.

The differential index (D.I.) shown by the sum of weight percentages of the normative quartz, orthoclase, albite, nepheline, and kalsilite indicates slightly different figures for each body, 86.83 to 91.86 for the West mass, 89.88 to 91.88 for the East mass, 85.44 to 91.24 for the Central mass, and 83.76 to 94.39 for the Southern mass. The differences are little enough to be able to judge that the differential grades for the all masses are almost same. The fine-grained two-mica granite and muscovite tourmaline granite in the Southern mass show the highest D.I.

The normative corundum has been figured out in each sample. It suggests that the granite has been originated from peraluminous magma. Values of the normative corundum are higher in the East and Southern Bodies, and slightly lower in the Central mass. Among the sub-bodies of the Central mass, the southern body shows higher values than the northern body.

White and Chappell (1974) classified granites into the S-type indicating more than 1.0 percent of normative corundum and the I-type indicating less than 1.0 percent of norm-corundum and some of normative diopside. Based on these criteria, one sample from the West mass and two samples from the Central mass are of the I-type.

In the classification diagram of granites based on the ratio of normative quartz, albite, and orthoclase (Fig.10), all samples are in the granite in a broad sense. However, the major portions of the samples are distributed an area of adamellite close to the granite area in a narrow sense. The granites in the area there-

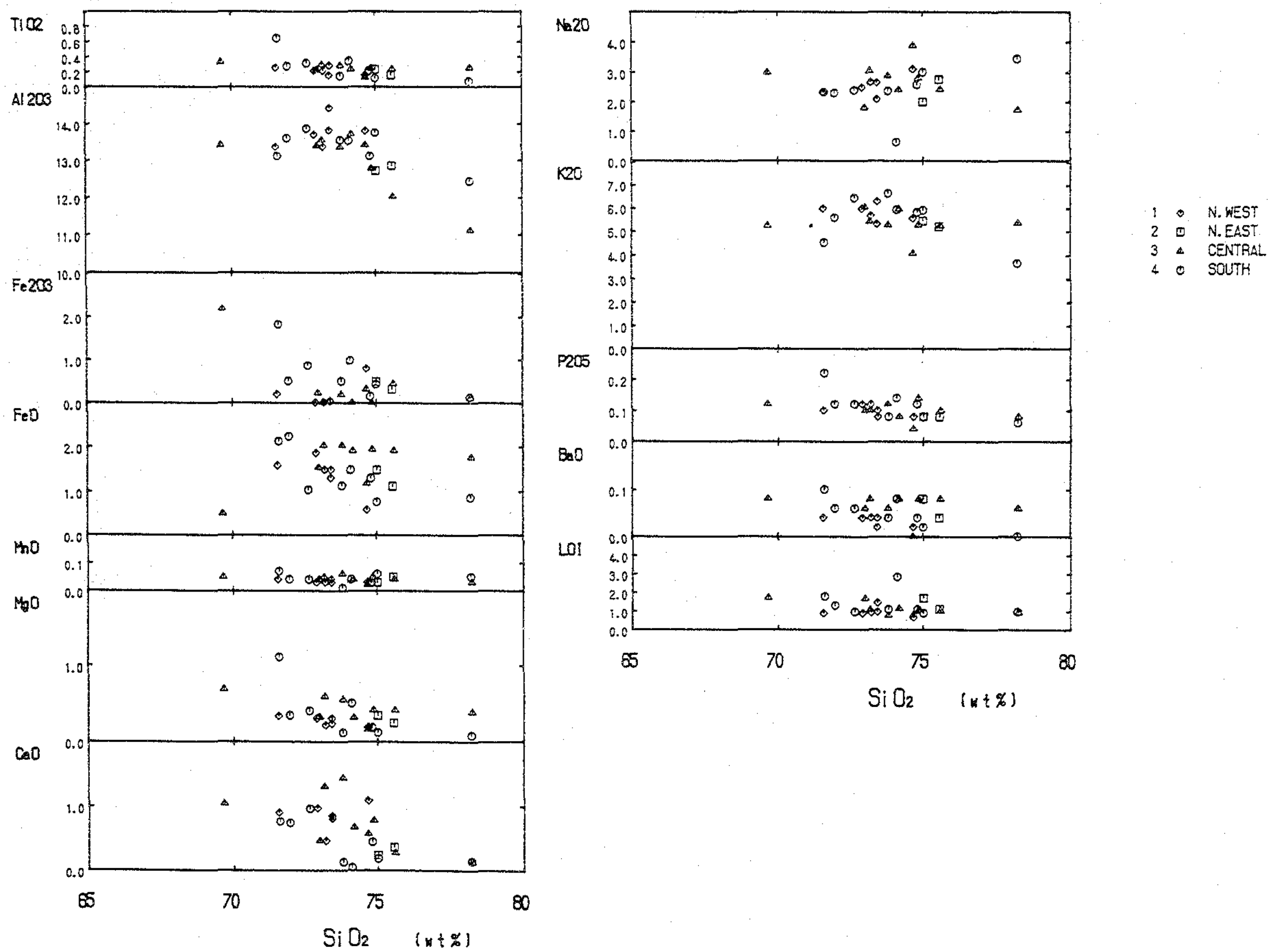

Fig. 9 Variation Diagrams of Granitic Rocks

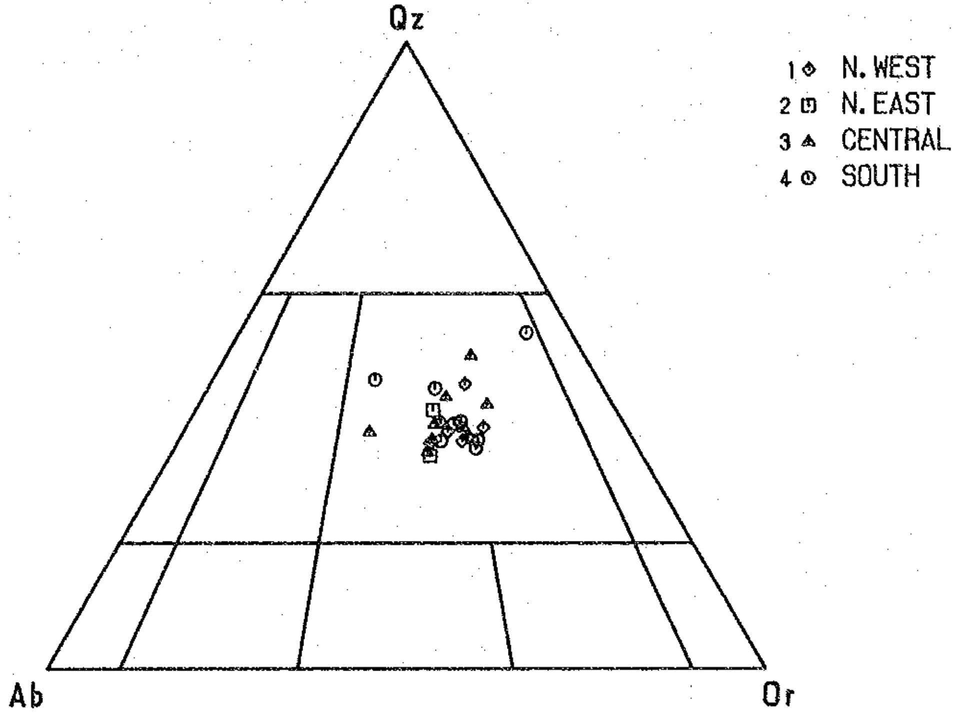

Fig. 10 Normative Qz-Ab-Or Diagram

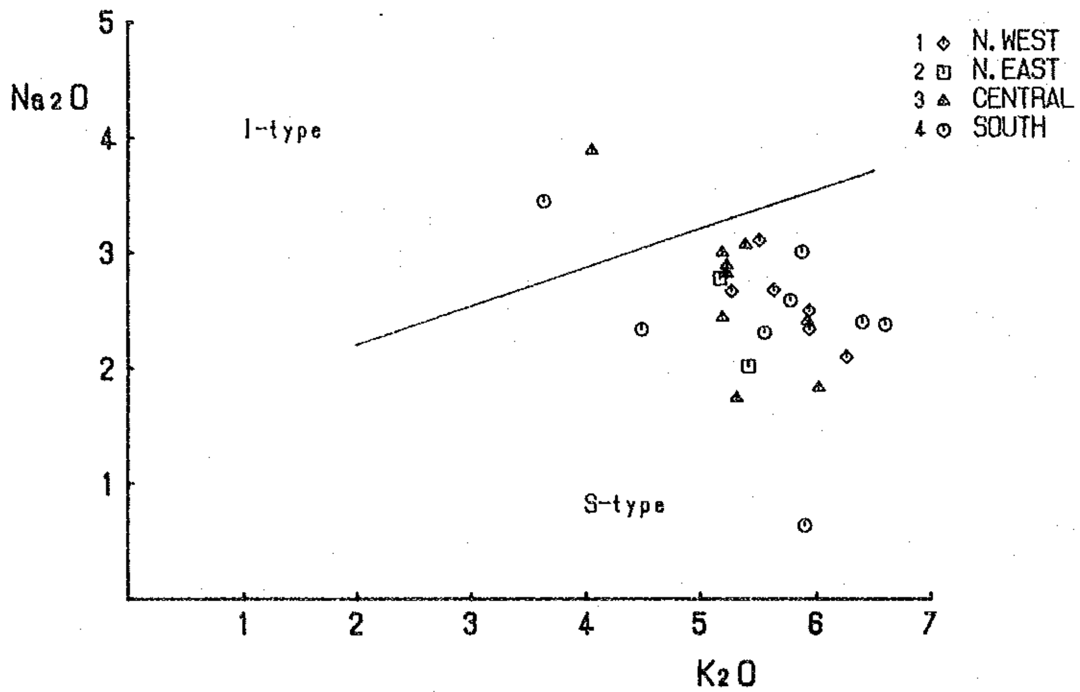

Fig. 11 Na_2O-K_2O Diagram

fore should be classified into adamellite.

Figure 9 shows the relationship between SiO_2 and oxides. Generally no significant correlation is seen there, however weak negative correlations exist between SiO_2 and TiO, Al_2O_3, Fe_2O_3, FeO. In the correlation between SiO_2 and Al_2O_3, the Central mass shows a strong positive correlation, the Southern mass shows a weak negative correlation, and the northern two bodies show very weak positive correlations. In the correlation between SiO_2 and FeO, the West mass and Southern mass show negative correlations, the Central mass shows no correlation. In the correlation between SiO_2 and Na_2O, the northern bodies show no correlation, the Southern mass shows a weak positive correlation, and the Central mass shows a weak negative correlation. Each granite in the area has similar chemical composition, however a little differences in the behaviour of the elements presumably indicate effects of different magma formation and differentiation, and later cataclasis or other tectonic movements.

Chappell and White (1974), and White and Chappell (1977) proposed three methods to classify granites into the S-type and I-type. The three methods use ratios of chemical components as follows,

Na_2O/K_2O

$Al_2O_3/(Na_2O+K_2O+CaO)$

ACF diagram; $Al_2O_3+Fe_2O_3$-(N_2O+K_2O)/CaO/FeO+MnO+MgO

In the correlation diagram between Na_2O and K_2O (Fig.11), the S-type granites contain less Na_2O, and are situated in the area below the line connecting the points of (K_2O=5%, Na_2O=3.2%) and (K_2O=2%, Na_2O=2.2%). The granites in the survey area are situated in the area of the S-type granite, except two samples. The granite samples situated in the S-type granite area are from the coarse-grained two-mica granite in the Central mass and the fine-grained muscovite tourmaline granite in the rim of the Southern mass.

Both granites are of primary in their chemical components, because no recrystallization by mylonitization and alteration of feldspar have occurred. The SiO_2-K_2O diagram shows no correlation or slightly negative correlation in spite of commonly positive correlation in this case. It is inferred that the granites in the area are added by K_2O during the pneumatolysis and later tectonic movements.

In the classification method using the ratio of $Al_2O_3/(Na_2O+K_2O+CaO)$, the S-type is in the area more than 1.1, and the I-type is in the area less than 1.1. The granites in the survey area are situated in the S-type area, 1.35 even in the case of the lowest one. It is reasonable because the granites have been originated by peraluminous magma figured out from the normative corundum.

In the case of ACF diagram (Fig.12), the S-type granites are situated in the field poor in CaO, and the I-type granites are situated in the field rich in CaO. The boundary between those appears in a line in the diagram. The granites in the survey area are classified into the S-type except one sample from the West mass.

The relationship among CaO, Na_2O, and K_2O is basically important matter to interpret the chemical components of granites. Ishihara et al. (1976) classified the Japanese Miocene granites into three trends based on the CNK diagram (CaO-Na_2O-K_2O), the Outer Belt in Southwestern Japan, Tanzawa-Niijima, and Intermediate. The Outer Belt in Southwestern Japan is characteristic in the high K2O/Na2O ratio, and classified into the typical S-type. The Tanzawa-Niijima Trend is of tonalite and trondhjemite granite, showing increase of SiO_2, decrease of CaO, and less concentration of K_2O. This is correspond to the M-type (Mantle source type) defined by White (1979). The granites in the survey area are classified into the S-type except two samples that are classified into the I-type based on Na_2O-K_2O correlation diagram (Fig.11).

In general, the granites in the area are classified into the S-type, except a few cases.

Investigation of the panning samples has revealed that all black minerals in the samples are ilmenite. The granites in the area, accordingly, are classified into the Ilmenite-series.

One of the characteristic features of the granites in the area is poor in CaO as seen in the CNK diagram. Comparing with the chemical components of the granites in the Ranong-Phuket area reported by Garson et al. (1975) and Suensilpong et al. (1983), the CaO contents of the granites in the survey area are about one third of those of the above mentioned area, despite the granites in the area are of coarse-grained adamellite. The CaO contents are correspondent to those of fine-grained two-mica granites (less than 1.0 %). It is needed further investigation to explain this problem, whether it is primarily characteristic in this area or due to later addition.

2-3-2 Minor Elements

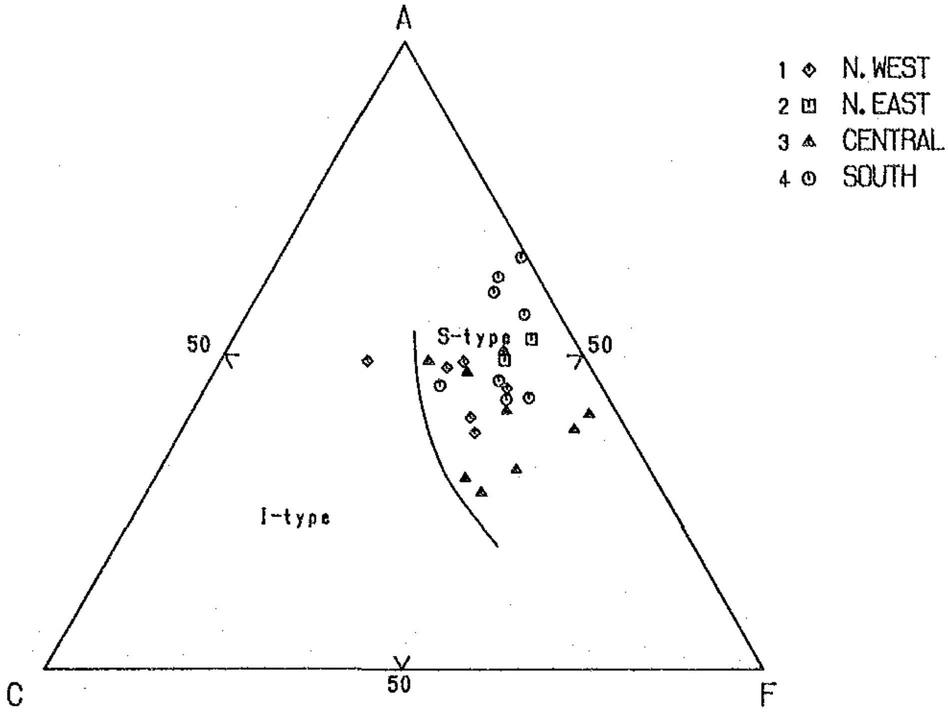

Fig. 12 ACF(Al_2O_3+Fe_2O_3-Na_2O-K_2O/CaO/FeO+MgO) Diagram

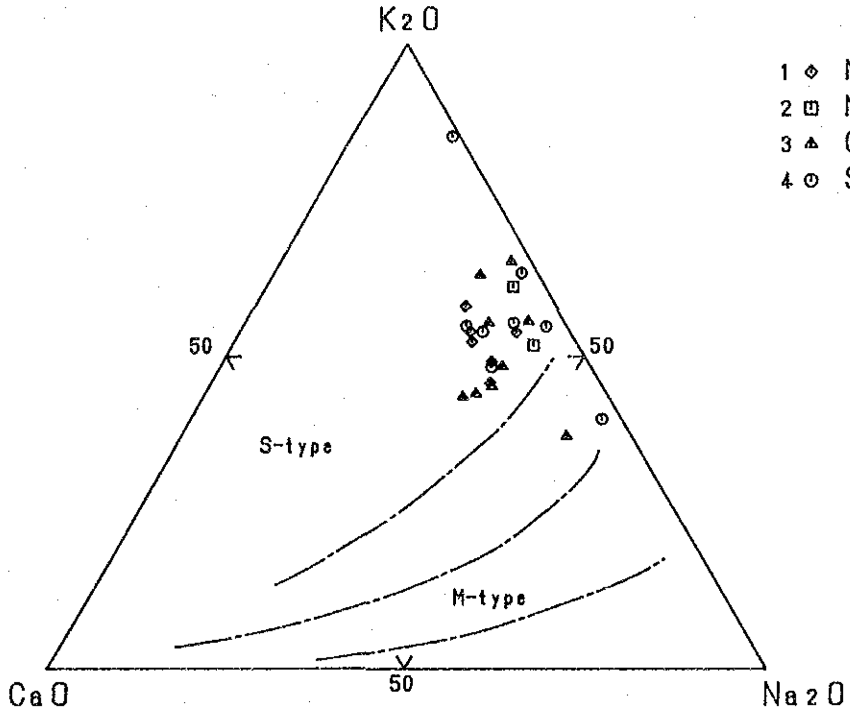

Fig. 13 CNK(CaO-Na2O-K2O) Diagram

The Sn contents range from 8 ppm to 199 ppm, which are higher than the average Sn contents, 3 ppm, of the granites in the world shown by Taylor (1964). Tischendorf (1977) reported that the tin grade of the "normal granites" is 4.3 ppm and that of the "metallogenetically specialized granite" is 30 plus minus 15 ppm. He called "tin-granite" for those containing more than 15 ppm Sn. Yeap, cited in Hosking 1973, reported that the average Sn grade of the tin-granites in the Peninsular Thailand is 6.5 ppm and that of the barren granites is 5.1 ppm. The Sn contents of the granites in the area are much higher than those figures, indicating high potential for tin.

The tin contents for each granite are; 16 to 76 ppm for the Northern west mass, 14 to 26 ppm for the Northen east mass, 8 to 29 ppm for the Central mass, 10 to 23 ppm and 46 to 199 ppm for the Southern mass. In general, the Northern west mass and Southern mass show high contents of tin, and this is corre-sponded to the distribution of the secondary tin ores in the same areas.

The samples showing especially high contents are from the fine-grained two-mica granite and the muscovite-tourmaline granite in the Southern mass, 95 ppm and 199 ppm respectively. Tin has a tenden-cy to concentrate in the highly differentiated granites.

Figure 14 shows the standardized pattern of the rare earth elements with the chondrite. It generally shows the characteristic REE patterns for well differentiated granite, which show clear right-declining linear line presenting high contents of the light rare earths such as La and Ce, low heavy rare earths contents, clear Eu anomaly. This characteristics are particularly significant in the tin-granites of the Western Belt (private letter, Dr. M.Kamitani, GSJ). The granites especially rich in La and Ce are the Northern west mass and Southern mass, corresponding to their tin contents. The two samples from the Southern mass showing highest tin contents contain less amounts of La and Ce. It is inferred that the two elements are fixed into the granites in the early stage rather than in the last stage granite magma.

The granite in the East mass shows the REE pattern similar to that of the highest differentiated gran-ites, however its facies are of medium to fine-grained two-mica granite. This mass is therefore inferred to be of essentially less light rare earths.

The correlation between the tin contents and light rare earths contents in the granite is good, because no high tin contents in the stream sediments taken around the granite bodies which contain lower lightrare earth contents are obtained. Therefore, it is possible to evaluate the tin potential by means of investigation

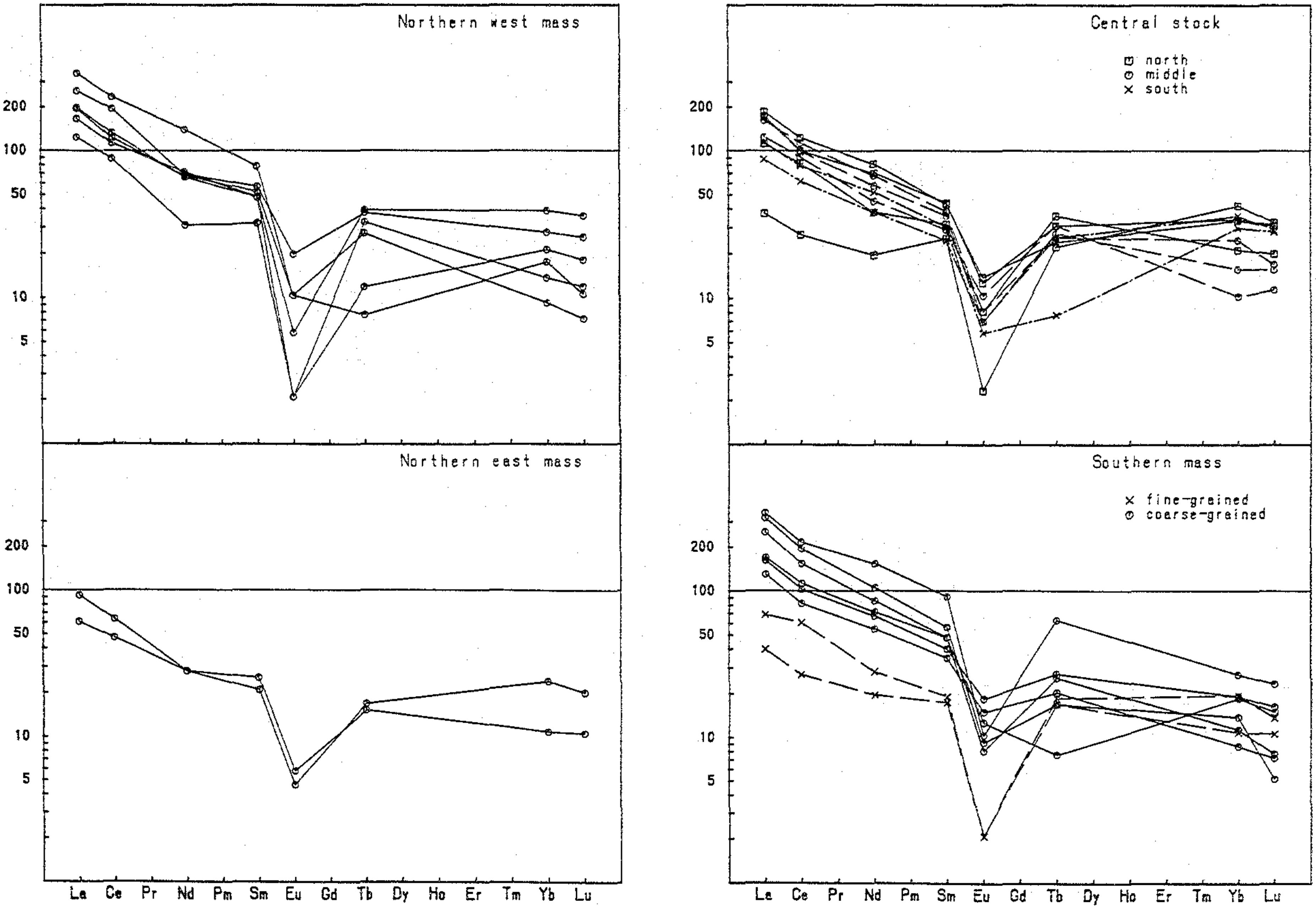

Fig. 14 Rare Earth Element Abundance Pattern of Granitic Rocks

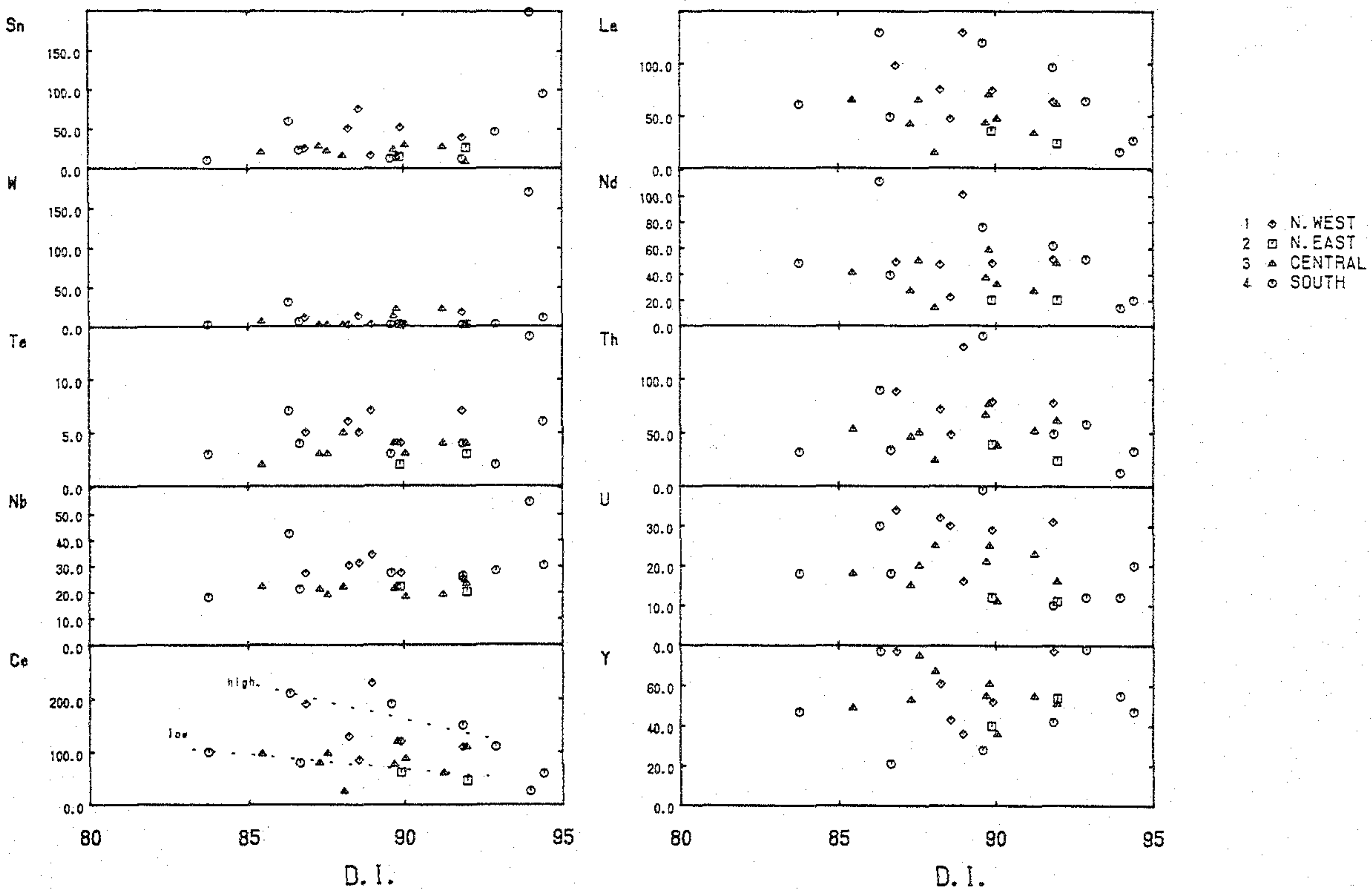

Fig. 15 Variation Diagrams of Minor Element of Granite

of the light rare earths contents in the typical and common granites in the Western Belt.

Ishihara and Mochizuki (1980) mentioned that the granites in Thailand contained 5 to 57 ppm (average 16.2 ppm) of U and 3 to 85 ppm (average 33.0 ppm) of Th, and the Th/U ratio was 0.2 to 11 ppm. Nevertheless, the granites in the area contain 10 to 39 ppm (average 21.1 ppm) of U and 13 to 140 ppm (average 58.8 ppm) of Th, and the Th/U ratio is 0.96 to 8.15. It is characteristic in rich Th contents.

The Au contents in 21 samples out of 25 are less than detection limit, however one sample taken from the Northern west mass contains 770 ppb of Au.

Figure 18 shows the relation between the differential index and principal minor elements contents of the granite samples. Sn, W, Ta, and Nb show no correlation with D.I., however, the elements tend to be rapidly concentrated in the rocks, in case D.I. is maximum high, i.e., rocks are highly differentiated.

The Southern mass consists of geochemically two kinds of granites, high contents and low contents of rare earths, Th, U, and Y. The granites containing high contents of these elements also show high contents of Sn, W, Ta, and Nb, and the granites containing low contents of these elements show low contents of Sn, W, Ta, and Nb. Other than the Southern mass, the Northern west mass shows the medium character on those elements contents, and the Central and Northern east mass are of low Sn and rare earths contents. Such geochemical characteristics are corresponded with the results of the geochemical survey and distribution of ore deposits, and possibly control the tin and rare earths mineralization.

Generally, the rare earths, Th, U, and Y contents tend to decrease at later differential stages, and rapidly drop down at the last stage. In other words, these elements are concentrated in common facies granites. This tendency is reverse in case of Sn, W, Ta, and Nb, which are concentrated into the highly differentiated facies, such as muscovite granite, tourmaline granite, pegmatite, and greisen. Highly differentiated facies are generally underlain by lowly differentiated facies, and easily eroded when the ground is upheaved. This erosion probably brings tin and tungsten minerals to the surrounding sedimentary basins at the primary stage, then rare earths and thorium minerals at the later stage. This interpretation is supported by the stream sediment geochemical survey results, showing overall rare earths anomaly on the whole area of the granite, on the contrary no Sn anomaly on the granite.

The highly differentiated granites have only been confirmed in the contact zone of the Southern mass in the survey this time. This limited exposure probably means that the most parts of the highly differentiated rocks have been eroded out. However, there is a potential for tin-rich primary ores on the top of subsurface granites, if such cupola-like granites exist.

2-4 Geological Structure

The Ranong-Phuket area, the largest tin producing area in the Peninsular Thailand, is bordered by two parallel major faults, the Ranong Fault and Khlong Marui Fault. The survey area is situated in the northern end of the area. The tectonic movements formed the principal structure of the area are of late Palaeozoic and Jurassic folding, and the granite intrusion occurred at the same stages.

The geological structure of the area is characterized by the Ranong Fault and several parallel relating faults, and the folding of the sedimentary formations. The sedimentary formations generally strike NE-SW, dip toward east, and are overfolded forming an anticline structure. The formations are cut by some strike faults, running NE-SW.

The Ranong Fault extends NE-SW, bordering the west boundary of the area along the Mae Nam Kra Buri to Hau Hin. Several parallel associated faults and cross cutting faults striking NW-SE controlled the granite intrusions, and formed the block structure in the area.

2-5 Ore Deposits and Mineral Occurrences

2-5-1 Tin deposits

The survey area is situated in the northern extension area of the Ranong-Phuket area, the largest tin producing area in the Peninsular Thailand. Several tin ore deposits and occurrences exist in the survey area.

The tin mineralization is closely associated with the granite activity. Primary ores generated in the granites bring secondary placer or eluvial ores around the granite bodies. The tin bearing granite belts are in the Cretaceous to Tertiary Western Tin Belt stretching from Myanmar to the Peninsular Thailand, the Triassic Central Tin Belt from western Thailand through the west coast of the Malay Peninsula to Sumatra, and early Cretaceous to Permian Eastern Tin Belt from the east of Bangkok to the east coast of the Malay Peninsula. Around 90 percent of the total tin production of Thailand comes from the Peninsular

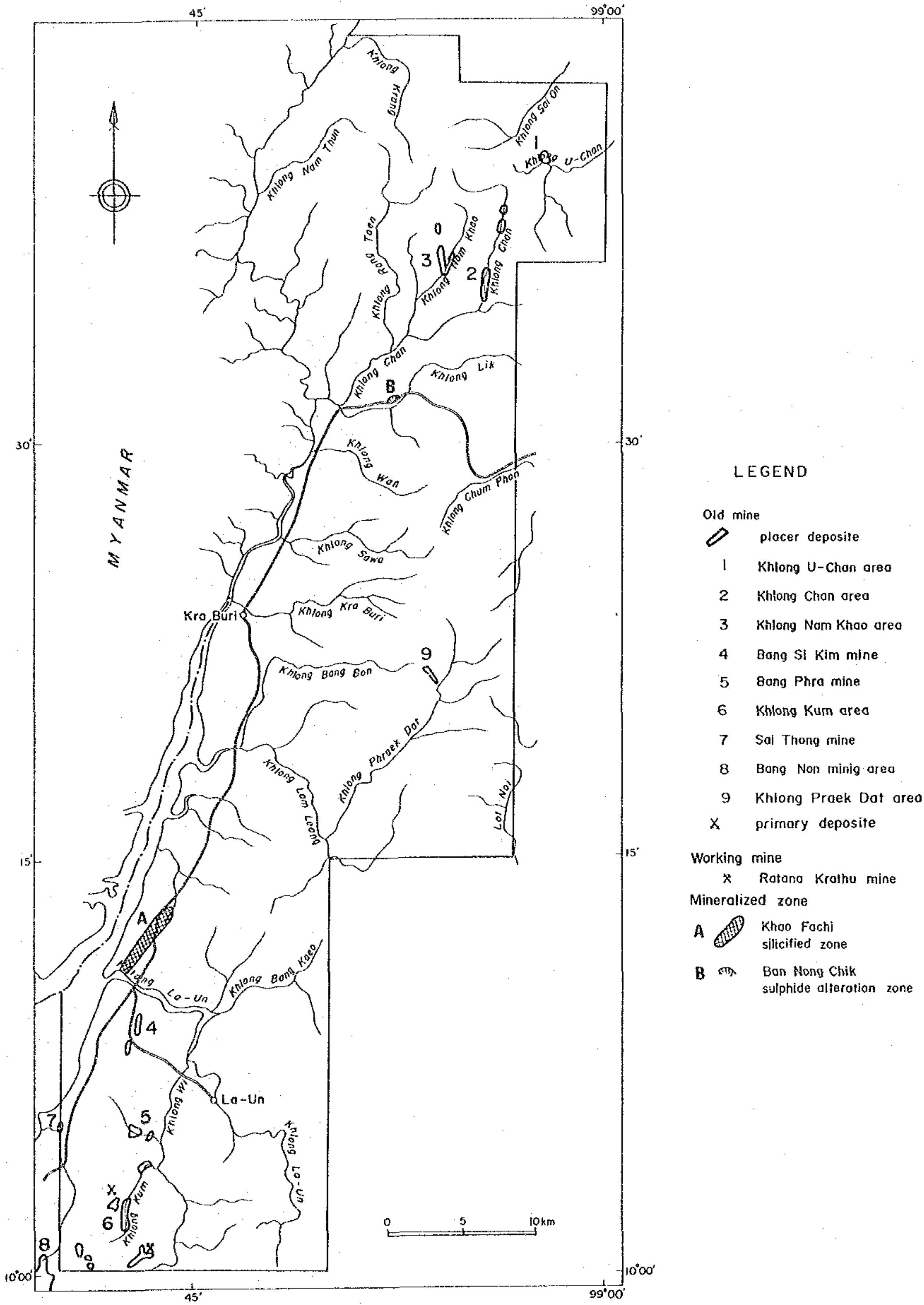

Fig. 16 Distribution Map of Mineralized Zones

Thailand.

Genetically, there are two kinds of ores, primary ores such as hydrothermal, impregnated, altered, vein, pegmatite, and greisen, and secondary ores such as alluvial, placer, and colluvial deposits, originated from primary ores. Principal tin ores are of placer and vein.

In the survey area, many secondary ore deposits are distributed, small-scale to large-scale. The tin area is divided into three areas, the Southern Granite, Northern Granite, and Central Granite.

Figure 16 shows the distribution of tin mineral occurrences.

1. Southern Granite Area

The area is in the northern extension of the Ranong Granite, and contains tin occurrences along the eastern and western edges of the granite body. Only one operating mine owned by the Ratana Krathu Co., Ltd. is in the east side of the granite. The deposits are distributed in the alluvial basin of a branch of the Khlong Wi. The old workings spread over an area of about 3 km long, and the mining is in operation at the place 1 km upstream from the branch point.

The mining is performed by gravel pumping method. Tin bearing sediments consisting of sand, gravel, and clay, 4 to 5 m thick on the river bottom, are loosen by high pressure water jet from a nozzle, 1.5 inches in diameter. The loosen sand and gravel are lifted up into a Palong with some 6 inches gravel pumps.

The present owner started operation one year ago after acquisition of the mining right from the Ngan Thawee Co., Ltd. At present, the mine is operated by 10 employees, producing 36 kg of tin concentrates per month. The production comes mainly from the waste of the old workings, which still contains some minerals. The main product of the mine is rather sand and gravel as construction material than tin. In other words, tin is a by-product. Previous production history of the mine is not clear.

A large alluvial secondary placer deposit is situated in the area along the Ban Bang Non in the southwestern corner of the area, occupying an area of 3 km north to south and 2 km east to west, and scattering many old workings in there. The placer extends to the Ranong area, and miners from the Phuket operated mining works in the area. Today, some rehabilitation programs such as foresting in the old working areas are performed there.

Some old workings are scattered in the basin area of the Khlong Kum. The Bang Si Kim mine near by the Khlong La-un, the west Ban Yai area along the Khlong Kum and its branches, and the Bang Phra mine in a branch of the Khlong Wi are the main ones, all of them situated in basins surrounded by mountains.

In the old workings for the secondary ores on the west of the Khlong kum, talus deposits containing some tin minerals in the contact zone of the granites were mined out by trenching, and the mined materials are led to hydraulic classifiers.

Only one old primary working by the hydraulic mining method is situated in the site about 2 km west of the Ban Yai. It is small-scale, 150 meters x 40 meters and 30 meters deep, and mined only weathered and altered soften parts, then probably given up the operation due to the difficulty of hard rock operation. It is on the border of the granite, and extends east to west and steeply dips to the north. The host rock is of two-mica granite containing gigantic K-feldspar phenocrysts, being accompanied by tourmaline pegmatite veins, 10 to 40 cm wide. The pegmatite veins transitionally change to porphyritic granites through fine-grained tourmaline aplite, and form banded rocks extending N70°E and dipping 60° to the south. The fluidal texture formed by K-feldspar and tourmaline crystals is parallel to the trend of the pegmatite, therefore it is inferred that the granitic rocks containing pegmatite veins were formed through the differentiation in situ. The boundary with the foot wall of the granitic body is also concordant to the texture. At the eastern end of the working, the boundary with the sedimentary rocks is almost vertical, and kaolinized vein-like fine-grained tourmaline granites exist between them. The soil sample taken there contains just normal amount of minor elements.

2. Northern Granite Area

An alluvial placer ore deposit area is situated in the basin of the Khlong Nam Khao and its branches, the southern edge of the West mass. The area is smaller than that of the Southern areas. The old workings are flooded at present, although the scale of the operation looks like very large. Other than this area, small-scale old workings are in the upper stream areas of the Khlong Nam Khao, Khlong Chan, and Khlong U-Chan.

3. Central Granite Area

A small-scale ore deposit is in the upper stream area of the Khlong Phraek Dat, about 3 km southeast of a stock-like granite body. The deposit is of small-scale along a stream in sedimentary rocks, and probably originated from quartz veins, extending NE-SW, in the sedimentary rocks. Cassiterite and scheelite are common in the ores. No granite float is seen in the stream, nor rare earths geochemical anomaly in stream sediments. No clear evidence exists there, though a concealed granite body might be underneath there.

According to the local people, they perform mining operation by panning during the dry season in the Khlong Phraek Dat and its downstream, Khlong Lam Leang, recovering cassiterite ores from the stream sediments. It is said that one average community group recovers 1.5 to 3.0 kg of minerals a day. The local word "Leang" means a panning pan, in this connection.

No clear old working remains in the down stream area to the west of the Central mass, but several small mounds of sand and gravel are along the stream, indicating some small-scale operations were performed there.

2-5-2 Other Mineral Occurrences

Other than above mentioned tin occurrences, there are a silicified zone extending to NNE from the Khao Fachi, to the north of the mouth of the Khlong La-Un, and a sulphide disseminated altered zone along the highway No. 4 to the east of Ban Pak Chan.

1. Khao Fachi Silicified Zone

The zone is situated on the ridge, extending NNE-SSW, of the Khao Fachi, to the north of the mouth of the Khlong La-Un. The northern end of the zone extends to the highway to the north of Khao Hin Lak. The scale of the zone is of about 5 km long and 700 meters wide. The zone is situated in the northern extension of the Southern mass, and a small-scale granite body parallels to the extension of the zone crop out to the east of the zone, around the crematory in Ban Khao Fachi. The host rock of the zone is probably alternation beds of mudstone and sandstone, judging from its remaining sedimentary textures. The zone has also undergone weak clay alteration, probably kaolinization.

The data of the chemical analysis of the silicified rock show 21 ppm W, 68 ppm Ce, 38 ppm La, 28 ppm Nd, and 29 ppm Y, and that of the soil samples taken from the same place show 10 and 24 ppm Sn, 200 and 550 ppm Ce, 100 and 300 ppm La, 83 and 220 ppm Nd, 90 and 270 ppm Th, 11 and 23 ppm U, and 38 and 59 ppm Y. The rare earth elements are rich in the samples.

The geochemical anomalies of tin and rare earth elements are distributed at upper stream of Khlong Bang Yai Lang, the northern end of Khao Fachi Silicified Zone.

Probably a concealed granite body abundantly containing such elements is situated beneath there.

2. Ban Nong Chik Sulphide Alteration Zone

The zone is situated in the sedimentary rocks along the highway, about 4 km to the east of Ban Pak Chan. The host rock is the shale and sandstone of the Matri Formation. A block, extending about 300 meters, of sedimentary rocks crops out on the north side of the highway, and 10 black alteration zones, 3 to 40 meters wide, are scattered in the exposure. The largest one is at the eastern end of the exposure, being intercalated with hard shale. The alteration zone contains small amount of pyrite and marcasite grains in finely crashed shale. Two porous quartz veins penetrate into the black alteration zone, one strikes N80°E and dips 80° to the south, and the other strikes N50°E and dips vertical. The former is of quartz vein disseminated by black minerals, 40 centimeters to 3 meters wide, and the latter is of kaolinite quartz vein, 10 to 50 cm wide.

This occurrence is not significant, and probably caused by small-scale hydrothermal activity along a sheared zone associated with the ENE-WSW fault, which dislocated the Central mass.

The results of the chemical analysis of the samples from the kaolinite quartz vein and black alteration zone are as follows.

	Sn	W	Ta	Nb	Au	Ce	La	Nd	Th	U	Y
	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm
AR-004	<5	<4	<1	9	<5	20	11	7	4.3	<0.5	9
AR-027	<5	<4	2	17	6	65	35	32	14	5.9	17

Chapter 3 Geochemical Prospecting

3-1 *Stream Sediment*

3-1-1 Sampling

A geochemical sampling program has been performed for selected principal rivers and its branches at the same time the geological survey performed. Sampling space ranges from 300 meters to 400 meters. Stream sediments in the middle of streams were sampled and sieved with 80 mesh screen. About 150 grams final products of under 80 mesh were obtained from each sampling point. Total number of the samples taken is 2,021.

The object of the survey is to evaluate potential for tin, tungsten, niobium, and tantalum, together with rare earths, uranium, thorium, and yttrium. Thus, following 17 elements have been selected as the path-finders, Sn, W, Ta, Nb, Au, Mo, Ce, Eu, La, Lu, Nd, Sm, Tb, Th, U, Y, Sc.

The X-ray fluorescence analysis has been applied for Sn, Nb, and Y, and neutron activation analysis for the rest of 14 elements.

3-1-1 Analysis of Geochemical Data

It is well known that frequency distribution of grades of elements in geochemical samples, especially in minor elements, generally shows normal distribution. Therefore, common logarithm of the grade figures has been used for the interpretation.

The group consisting of Sn, W, Ta, and Nb shows strong positive correlations each other. The group consisting of rare earths, Th, U, Y, and Sc shows significantly strong positive correlations each other except to Eu, which shows strong negative correlation. In addition to that, the correlation between the former group and the latter group is significantly strong.

This means that geochemically anomalous values of all detected elements are in well accordance each other, and anomalies for each element are in fact duplicated in the field. The correlation between the two groups tends to be a little weaker than those in the same group elements, due to some rare earth elements in some cases show low anomalous values although the former group elements show high anomalies. There are some reverse examples in the area around the Northern west mass. The strong correlations between the two groups probably indicates that the eroded materials containing both group's elements from the granites deposited in the same sedimentary basins.

The correlations between gold and both group's elements are weak, indicating gold has been concentrated by a different mechanism from the cases of the other elements.

Molybdenum shows negative correlations with the other 16 elements.

In this survey, average and standard deviation values together with frequency distribution and accumulated frequency distribution curves have been used to set thresholds. Table 3 shows the thresholds for each element.

Table 3 Division into Geochemical Anomaly of Stream Sediments

Element	Unit	Threshold	M+xσ
Sn	ppm	118.10	1.5
W	ppm	36.61	2.0
Ta	ppm	21.73	2.0
Nb	ppm	73.57	2.0
Au	ppb	8.67	4.0
Mo	ppm	9.21	1.5
Ce	ppm	363.75	2.0
Eu	ppm	1.88	2.0
La	ppm	125.98	1.5
Lu	ppm	3.67	2.0
Nd	ppm	94.27	1.5
Sm	ppm	26.09	2.0
Tb	ppm	5.06	2.0
Th	ppm	87.18	1.5
U	ppm	32.67	2.0
Y	ppm	199.47	2.0
Sc	ppm	8.67	2.0

3-1-3 Distribution of Geochemical Anomalies

Figure 17 shows the distribution of the anomaly zones in the area for each element.

Anomaly zones for Sn are distributed in the old working areas in the Khlong Nam Khao and Khlong Chan. In addition to that, small-scale anomaly zones are in a branch of the upper part of the Khlong Chan and in the Khlong Phrae Ka Muang, which is one of the upper branches of the Khlong U-Chan. The anomaly zone in the old working areas in the Khlong Chan extends to the west, but not to the east of the river. The anomaly in the Khlong Phrae Ka Muang tends to increase its intensity to the north, suggesting us possibility of sitting some subsurface granite bodies in the upper stream area. The Sn anomaly zones are distributed on the western and southeastern sides of the Central mass. On the western side, the anomaly zones are in the flat plain extending to the west of the mountain. On the southeastern side, the anomaly zones spread over an area of 5 km by 3 km on the west of the upper part of the Khlong Phraek Dat. An anomaly zone situated in the joint of the Khlong Phraek Dat and Khlong Lam Leang is probably brought from the above mentioned large anomaly in the Khlong Phraek Dat.

Around the Southern mass, the Sn anomaly tends to increase its intensity to the south, overlapping the area of the old workings. A small-scale Sn anomaly zone is situated the upper stream area of the Khlong Bang Yai Rang to the north of the Khao Fachi Silicified Zone.

Anomaly zones for W are distributed in the following areas; the branches of the Khlong Krang on the west of the Northern west mass in the northern area, the branch of the Khlong Chan in the Northern east mass in the northern area, the upper stream of the Khlong Phlu Yai of the upper Khlong Sawa and Khlong Wan on the west of Central mass, the old working area on the left bank of the Khlong Phraek Dat on the south of the Central mass, the Bang Non old working area to the southwest of the Southern mass, the Ratana Krathu Mine, and the Khlong Kum basin. The anomaly zones in the south are corresponding to the area where scheelite grains have been found in the stream sediment and panning samples. The anomaly zone on the southeast of the Southern mass is overlain by a wolframite anomaly zone.

Anomaly zones for Nb and Ta show basically similar patterns as those of Sn, although the zones spread over in a larger area than that of the Sn anomaly zones. No Nb and Ta anomaly zone are overlapped on the Sn and W anomaly zones in the Khlong Phraek Dat. A small anomaly zone is situated to the north of the Southern mass along the coast line as well as in the Khlong Bang Yai.

Anomaly zones for Ce, La, Sm, Nd, Th, U, Y, Tb, and Lu are commonly overlapped each other. Anomaly zones overlie the whole areas of the northern granite bodies. In the Central mass, anomaly zones are in the Khlong Wan, Khlong Phlu Yai, and upper stream of the Khlong Kra Buri on the west, and middle streams of the rivers. In the Southern mass, An anomaly area is spread in the west, but only small-scale anomaly zones of U, Tb, Y are situated in the east in spite of anomalies of Sn and W are distributed there. A small-scale high intensity anomaly zone is in the upper stream of the Khlong Bang Yai Lang, at the northern end of the Khao Fachi Silicified Zone.

Small-scale anomaly zones for Eu are situated in the Northern east mass in the northern area, Central mass, and the northern part of the Southern mass. Other than those, some samples in the background oareas show high contents of the element, over the average figure. These are probably brought from the plagioclase in the sedimentary rocks.

Contents of Mo are clearly higher in the sedimentary areas than in the granite areas, indicating the element is primary rich in the sedimentary rocks. No granite activity associated with molybdenum mineralization has presumably occurred in the area.

Anomaly zones for Au spread over the area as spots. It appears that samples of high Au contents are arrayed in the direction of NNE-SSW, suggesting us that the mineralization has been brought into sheared zones parallel to the Ranong Fault.

3-2 Soil Samples

3-2-1 Sampling

A geochemical sampling program has been performed for the soil in the granite areas to estimate contents of following elements, Sn, W, Ta, Nb, rare earths, U, Th, Y, and Sc, after the geological survey was completed. The sampling areas have been selected mainly in the granite distribution areas, together with surrounding sedimentary rock areas to obtain background values. In addition to those, an alteration zone and a sulphide dissemination zone have been selected. Soil sections on road cutting have been observed prior to take samples, and incases no cutting exists the surface has been dug to take samples from the B or C-horizons.

About 2 to 3 kg of soil has been sampled at each point. After dried up, they have been sieved by 80 mesh screens, and the final products have been divided in two portions, one for the Thailand team and the other for the Japanese team. The samples for the Japanese team have been chemically assayed. The total number of the samples is 207.

3-2-2 Pathfinder Elements

The same 17 elements as those in the case of the stream sediments have been selected, i.e., Sn, W, Ta, Nb, Ag, Mo, Ce, Eu, La, Lu, Nd, Sm, Tb, Th, U, Y, Sc. The assay method and detection limits for each element are also same as those for the stream sediment geochemistry.

3-2-3 Analysis of Geochemical Data

The correlation coefficients between each element show same tendency as those in the stream sediment geochemistry, although slightly weaker. Sc generally shows negative correlations with other elements, on the other hand W shows no correlations with Nb, Rare earths, Th, U, and Y. It probably indicates that the geochemical characters of the soil samples are strongly controlled by the rocks of the ground, and the concentration of the minor elements in the rocks varies place by place. On the contrary, minor elements are much concentrated in stream sediments, and possibly show strong correlations each other.

Columnar soil sampling was conducted in the cuttings facing the road lead to the TV transmission station on the north of Ban Bang Non in the southwestern end of the area. Table 4 shows the contents of the minor elements in the four sampling points. No significant difference showing leaching or concentration of elements in the A, B, and C soil horizons is recognized in the results. It indicates that rare earth elements are not much concentrated in the soil.

Table 4 Geochemical data of soil profile in Ban Bang Non

		Sampling Point			
Element	unit	1	2	3	4
Sn	ppm	89	87	108	104
W	ppm	6	7	<4	<4
Ta	ppm	8	10	9	10
Nb	ppm	53	55	50	62
Au	ppm	7	<5	<5	<5
Ce	ppm	340	250	280	270
Eu	ppm	0.2	<0.2	<0.2	<0.4
La	ppm	27	30	22	32
Lu	ppm	0.6	0.5	0.6	1.08
Sm	ppm	16	16	12	19
Tb	ppm	<0.5	<0.5	<0.5	1.2
Th	ppm	160	130	120	200
U	ppm	11	12	10	15
Y	ppm	33	26	24	48
Sc	ppm	11	8.6	8.8	12

Figure 17 shows the grade distribution of the minor elements in the soil. The grade distributions of Sn, W, Nb, and Ta are significantly concordant each other, as shown in the correlation coefficients. Highly concentrated parts are in the southern end of the Northern west mass in the northern area and the southern end of the Southern mass. Anomalies for Nb appear, in addition to there, in the northern end of the Northern west mass in the northern area and in the old working area for primary ores in the east side of the Southern mass. These elements are of relatively low grade in the Northern east mass in the northern area and Central mass.

The elements, Ce, Tb, La, Nd, Sm, Th, and U, show similar distribution patterns, showing high concentration along the western rim of the Southern mass, and partly overlapped with Sn group's elements. This group's elements are of low concentration in the Northern east mass in the northern area and Central mass.

The elements, Y and Lu, show duplicated high values together with the Sn group elements. A highly concentrated anomaly exists in the Northern east mass in the northern area. This is shown by a soil sample in the metamorphosed muscovite granite zone, and its accompanied Sn value is as high as 109 ppm. A high contents sample also appears in the Central mass.

The elements, Mo, Eu, and Sc, show high values in the granite, and some high content samples are scattered in the sedimentary rock areas.

Among the minor elements in the soil samples, Sn, W, Ta, Nb, Ce, Tb, La, Nd, Sm, Th, U, Y, and Lu are derived from the heavy minerals in the granites, accordingly show high contents in the granite areas. Ce, Tb, La, Nd, Sm, Th, and U are also highly concentrated into the Khao Fachi Silicified Zone, indicating some potential for the existing of subsurface granite bodies.

The soil in the area is about 20 m in thickness, except that of the deeply weathered Northern east mass, which contains low Sn and rare earth elements. Some well differentiated muscovite granite rich in Y and Sn appears in the granite mass. This mass is situated in a low hilly area, thus the rocks are poorly exposed. Further geological survey is needed to know the detailed geology of the rocks.

Two samples taken from the basal clay in the old working in a branch of the Khlong Nam Khao show lower contents in all elements than those of the samples from the granite areas.

3-3 Panned Samples

3-3-1 Sampling and Analyzed Elements

Panned samples have been taken every four stream sediment samples at the same time. About 20 liters of sand has been reduced to 50 grams by panning using large panning pans at the sampling sites, then concentrated again at the base camp. The final products are 4 to 30 grams in weight, and many of them are less than 10 grams. Additional sampling has been performed when it is necessary. The total number of the samples taken is 560. After observation by a stereo-microscope and a ultra-violet light, 129 samples have been chemically analyzed. Samples of ore concentrate from the Ratana Krathu Mine are included in.

The elements analyzed are; Sn, W, Ta, Nb, Au, Mo, Ce, Eu, La, Lu, Nd, Sm, Tb, Th, U, Y, and Sc, same 17 elements as those for the stream sediment samples, and additional 6 rare earth elements, Di, Er, Gd, Ho, Pr, and T. The assay method for the rare earth elements is of the neutron radioactivation analysis, and the detection limits for each element are; 10 ppm for Di, Gd, and Ho, 100 ppm for Er, and 500 ppm for Pr and Tm.

3-3-2 Megascopical Observation

The panned samples have been megascopically observed at first. The identified minerals are of cassiterite, wolframite, scheelite, zircon, garnet, tourmaline, ilmenite, monazite, xenotime, rutile, and anatase. Areas rich in heavy minerals are surrounding areas of the Northern west mass and the Southern mass, the old working areas for secondary deposits. Little heavy minerals are contained in the stream sediments in the eastern branches of the Khlong Chan, on the other hand much of them are in the western branches. Small-scale old workings are scattered along the Khlong Chan. The minerals have probably been brought from the western branches as well as the main stream. Much amount of cassiterite sands is distributed around the Northern west mass and Southern mass, especially in the old working areas on the eastern side of the mass. The upper streams of the Ratana Krathu Mine area contain much amount of heavy minerals. A little amount of heavy minerals is found in the streams flowing out from the Central mass, on the other hand much amount of cassiterite is distributed in the conjunction of the Khlong Lam Leang and Khlong Phraek Dat, and along the Khlong Lik.

Some amounts of wolframite minerals are observed in the surrounding area of the Southern mass, especially around the Ratana Krathu Mine. On the other hand, scheelite minerals are largely distributed around all granite bodies, among them especially around the Central mass. The samples from the old working area in the upper stream of the Khlong Phraek Dat contain much amount of cassiterite, showing

2 to 3 mm in grain size.

A small amount of monazite and xenotime are contained in the surrounding areas of the granite bodies. In the Southern mass, they are more concentrated on the western side than eastern side. In the Central mass, they are concentrated in the streams flowing out from the center body.

The distribution of ilmenite shows the same pattern as that of monazite and xenotime, also appeared in the old working area in the upper stream of the Khlong Phraek Dat.

Little amount of rutile and anatase is contained in the surrounding areas of the granites, showing less frequency.

Zircon, tourmaline, and garnet spread over the area, especially in the sedimentary rock areas. Most of them are of well-rounded grains supposedly originated from sedimentary Origin. Near the granite bodies, euhedral crystals and rounded grains are mixed in some places.

Cassiterite, monazite, and xenotime are concentrated in the foot areas of the mountains, such as the old working areas of secondary tin deposits. These heavy minerals are commonly transported far way, thus topographic features are of important factor for mineral prospecting.

3-3-3 Results of Chemical Analysis

Among the elements assayed, Mo shows out of detection, and Tm shows out of detection limit.

The group consisting of Sn, W, Ta, and Nb, and the group consisting of rare earth elements, Th, Y, and U show strong positive correlations in the group elements, but no correlation exists between the two group's elements.

The principal constituent elements are concentrated in the south end of the Northern west mass and the south end of the Southern mass, the old working area and around the Ratana Krathu Mine. On the other hand, rare earth elements are concentrated around the northern masses, however some slightly high anomalous samples are scattered in the northern coast, north of the Southern mass, showing different pattern from that of the tin group elements. The rare earth elements show different distribution from that of Th, U, and Y, which show low concentration in the Southern mass (Fig. 17).

3-3-4 EPMA analysis

Some rare earth elements contained in heavy mineral were analyzed with EPMA. Four polished thin sections were selected for analysis.

The measured minerals were cassiterite, monazite, xenotime, polycrase, rutile and zircon. Ilumenite could not be measurable because spectral peak of Ti is very close to peaks of La and Ce. Additionally tourmalines were attempted to measure qualitatively, but rare earth elements were not detected.

(1) cassiterite (SnO_2)

Cassiterites in the survey area are divided into two groups under microscope. One shows high birefrigence and colourless to light amber colour under opened nicol. Another shows light amber to light yellowish green colour under opened nicol and shows anomalous interference colour like chlorite under crossed nicol. The former occurs around Northern and Central mass and contains low amount of minor elements. The later occurs around Southern mass and contains 0.n to n% in Ti,Ta and Ni.

(2) rutile (TiO_2) and anatase (TiO_2)

It is known that rutile and anatase contain rare earth elements in large quantities. Nevertheless the spectral peak of Ti is close to ones of La and Ce, then their quantitative values are low confidence.

These minerals are commonly observed in RATANA-3 of Ratana Krathu mine. These are principal carrier of rare earth elements.

(3) zircon ($ZrSiO_4$)

Zircon contains small amount of Hf and Ta.

(4) monazite ($(Th,Ln)PO_4$)

Monazite is a phosphate mineral composing of thorium and rare earth elements. Monazites in GH-001 contain about 12% of ThO2 and in SAITHONG-1 about 8 to 12%.

Analytical values of yttrium in monazite are lacking in trust. Because characteristic peaks of Y and P are extremely close to each other and automatically calculated into two oxides, in spite of Y contents in monazite is very lower than one of P.

Geochemical anomalies of light rare earth elements in the survey area seem to be caused by monazite.

(5) xenotime ($LnPO_4$)

Xenotime is a phosphate mineral composed mainly Y and heavy rare earth elements. This mineral abundantly exists in SAITHONG-1 on the West of Southern mass. Main component of xenotime is Y, and next abundance is Yb, Er and Dy in the survey area.

Geochemical anomalies of heavy rare earth elements seem to be attribute to this mineral.

(6) polycrase ($(Ln,U,Th)(Nb,Ta,Ti)_2O_6$)

Polycrase and euxenite are each end member of solid solution, the former has high contains in niobium and tantalum and the latter is highly titanium. This mineral commonly occurs in GH-001. It shows tabular habit and dark reddish brown under opened nicol with maximally 1mm length in size. Also it has high reflection under reflected microscope.

Analyzed mineral in the survey area is polycrase because of high Ti contents and have Nb=17-22% and Ta=8-10%.

Geological anomaly of Nb and Ta overlapping with anomaly of rare earth elements is caused by this mineral.

3-4 Discussion

The results of the three kinds of geochemical surveys show that the anomaly zones of those three methods are well coincident each other, although the soil geochemical anomalies are limited in the location of the granite bodies. The contents of the elements analyzed reflect the heavy minerals' distribution derived from the granite bodies, and the large geochemical halos are concentrated around the old working areas for secondary accumulated ore deposits (Fig. 17).

In the survey, the 17 elements for the soil and stream sediment survey, and the 23 elements for the panning survey have been selected as the pathfinder elements. The elements showing geochemically high anomalies are grouped into two, the tin group consisting of Sn, W, Ta, and Nb, and the rare earths group consisting of Ce, La, Lu, Nd, Sm, Tb, Th, U, and Y. In the panning survey, Dy, Er, Gd, Ho, and Pr are added in the rare earths group.

In the northern area, the tin group anomaly zones are extensively distributed in the old working area along the Khlong Nam Khao in the southern end of the Northern west mass, and in the old working area along the Khlong Chan between the Northern west and Northern east masses. In addition, some small-scale anomaly zones are in the upper streams of the Khlong Chan and Khlong Phrae Ka Muang. The only one anomaly zone of W is situated along the Khlong Krang on the west side of the Northern west mass, where scheelite minerals are distributed. On the other hand, the anomaly zones of the rare earths group show more extensive than those of the tin group, over the Northern west and Northern east masses includ-

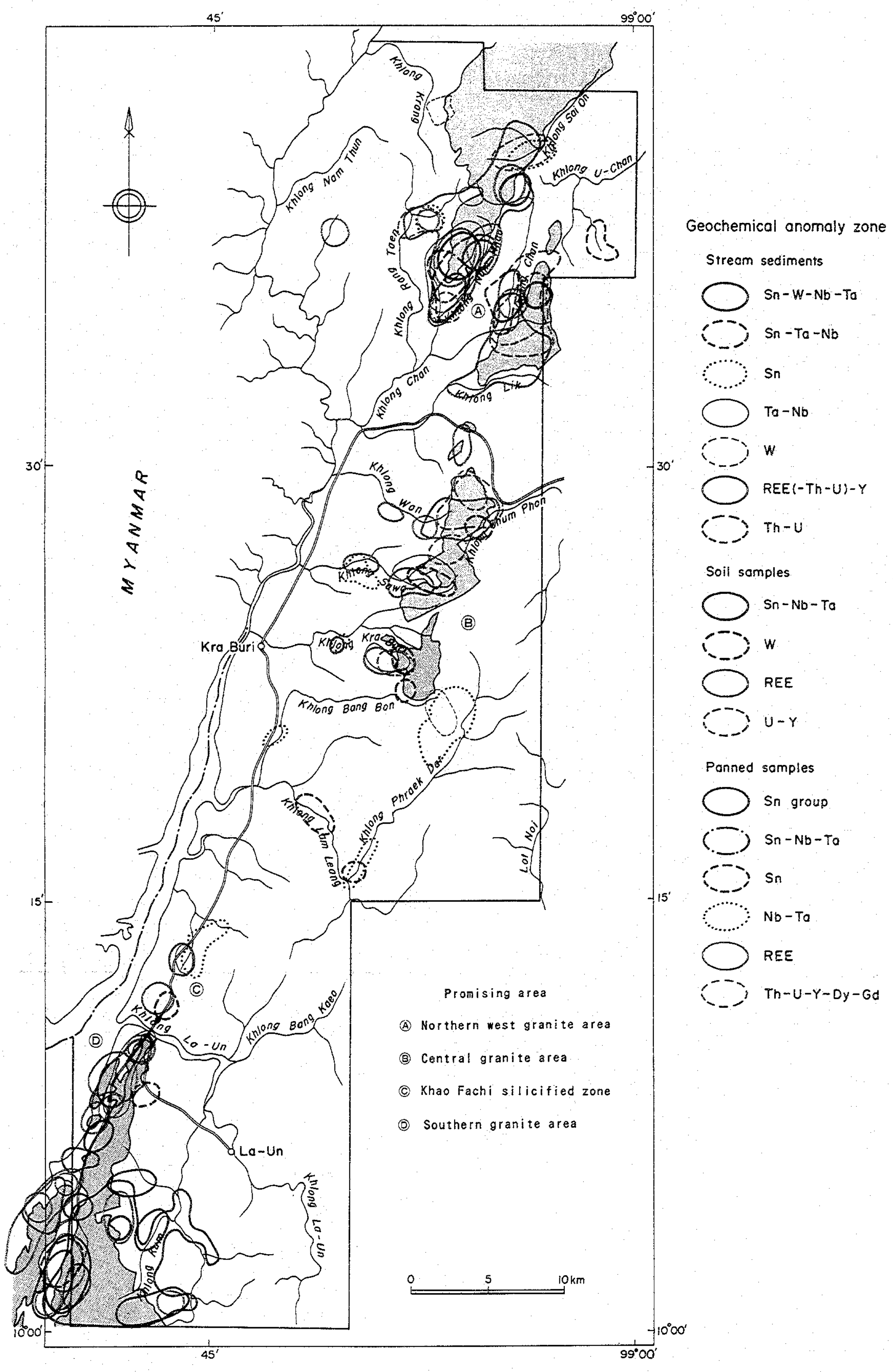

Fig. 17 Results of Geochemical Survey in First Phase

ing the old working areas, although each element shows slightly different behaviour. This phenomenon indicates that the rare earth elements tend to be concentrated into the early stage granites rather than the later stage well differentiated facies. The rare earths group elements are presumably still being supplied.

In the Central mass, the anomaly zones by both groups are situated in the westward flowing streams from the mass, one is on the boundary between the granite and sedimentary rocks, and the other is in the area changing from the hilly area to the alluvial plain. Some other stream sediment anomaly zones are on the north and northeastern sides of the granite mass. The Central mass is characterized by the Sn and W anomaly zone, not being accompanied by Ta, Nb, and rare earths anomaly, in the upper stream of the Khlong Phraek Dat, far way to the southeast of the mass. The Sn anomaly zone especially widely spreads in the area 5 km x 3 km. This anomaly probably has been brought by the quartz veins in the sedimentary rocks, and suggests that subsurface granite bodies possibly exist underneath there.

In the Southern mass, The tin group's anomaly zones are largely distributed on the southern areas of the granite, from the Ban Bang Non district in the southeastern corner of the area to the Ratana Krathu Mine and old working area in the Khlong Kum basin. On the other hand, the rare earths group's anomaly zones are distributed on the western side of the granite, and only some high contents samples are scattered along the streams on the eastern side of the granite. This is probably caused by the different geological environment on both sides, although both sides show topographically similar steep slopes. On the eastern side, sedimentary rocks still remain on the flank, indicating the depth of the erosion of the granite is still shallower than that of the eastern side, and such difference probably caused the different eroded mineral supply to the surrounding sedimentary basins. The large plain area is distributed on the eastern side, however on the western side, the flat plain is narrow except in the Bang Non district, and the tin group's minerals could be rapidly transported to the sea.

In the Khao Fachi Silicified Zone in the northern extension area of the Southern mass, the both group's anomaly zone overlies the zone. It also suggests that some subsurface granite bodies probably exist underneath there.

The Au anomaly zones sporadically scatter over the area, however, the samples showing over the average value tend to align to the trend of NNE-SSW, parallel to the dominant fault line.

Eu and Sc are of low contents in the geochemical samples, and only small-scale anomaly zones are mainly situated in the granite bodies, but the slightly high contents samples are sporadically distributed in the sedimentary rock areas.

Almost all samples show the Mo contents of less than detection limit, however all samples showing values over the detection limit are in the sedimentary rock areas. It is inferred that molybdenum mineralization is probably not associated with the granites in the area.

Judging from the above mentioned factors, following areas are selected as high potential areas.

For Sn, W, Nb, and Ta

Best potential area;

the old working area to the south of the Southern mass.

Other potential area;

the surrounding areas of the Northern west and Northern east masses in the northern area.

the surrounding areas of the Southern mass.

the offshore to the west of the Southern mass.

For Rare earth elements, Th, U, and Y

Best potential area;

the surrounding areas of the Northern west and Northern east masses in the northern area.

the western side of the Southern mass, coastal area.

Other potential area;

the western side of the Central mass.

For the concealed tin and rare earths primary ores

High potential area;

the western side of the upper stream of the Khlong Phraek Dat.

the Khao Fachi Silicified Zone.

Chapter 4 Detailed Geochemical Prospecting

Surveyed areas in Second Phase survey are nine sub-areas as follows; Area A-1 and A-2 around northern granitic mass; Area B-1, B-2, B-3 and B-4 beneath of Central granite mass; Area C closed to Khao Fachi silicified zone and Area D-1, D-2 on the West of Southern granite mass. There were mainly selected from the four promising areas of the Phase I survey to examine secondary deposits.

Total area of nine sub-areas is 14.7km^2. Every sub-areas overlaps geochemical anomaly zone in the Phase I survey which were corresponded to granite mass or silicified zone, hoping to find secondary and primary ore deposits as cassiterite and rare earth minerals.

Sampling sites were set with rectangular system; 100x50m grid systems in the Area A, B and C, and 100x100m grid systems in the Area D in view of topographical and geological conditions. Actual sampling points of each site were simply measured by compass and measuring tape.

Each sample was usually to be collected at the point nearby 1m under surface, because it seems that heavy minerals in the secondary ore deposit are partial to deeper zone. The soil samples passed through 80 mesh screen were kept for chemical analysis.

Additionally some different kinds and facies of rocks were collected. These were analyzed to check the geochemical background and studied by microscopic observation, and X-ray diffraction in case of necessity. Mineralized samples (rocks or panned samples) were examined by chemical analysis and observation on polished sections in case of necessity.

4-1 Area A-1

4-1-1 Location

Area A-1 is about 25 kilometers north-northwest of Kra Buri Town. The center of the area is at latitude about 10°37'N and longitude about 98°54'E. The area was settled to be in parallel with Nam Khao River running south-southwestward at the eastern foot of the Northern west granite mass, because an alluvial basin stretches along this river.

The main river in Area A-1 is the above-mentioned Nam Khao River running on the eastern edge of the area. Its main tributaries run southeastward, forming alluvial fans from the granite mass on the northwest of the area. The survey area consists of gentle slope and ranges in altitude from 50 to 120 meters.

The area northwest of Area A-1 is a steep mountainous district consisting of the granite mass. The borderline between this district and Area A-1 consists of steep cliffs. The southwestern part of the survey area is a relatively gentle hills consisting of sedimentary rocks.

An unpaved road branching from the Route 4 leads northward to Sai On River by way of the survey area longitudinally along Nam Khao River. The distance of the roads from Kra Buri town to the survey area is about 30 kilometers, and it takes about one hour to get there by car.

In the first year's survey, the geochemical anomaly of Nb, Ta, REE, Y, U and Th was detected by the stream sediments prospecting in Area A-1, and the anomaly of Sn, W, Nb, Ta, REE, U, Y and Th was detected from panned heavy mineral samples.

4-1-2 Geology

The Area A-1 is underlain by Carboniferous Matri Formation, Cretaceous granite and the Quaternary (Fig. 18).

The Matri Formation, which consists of mudstone and conglomerate, forms mountains in the western side of the survey area and forms small hills with a relative height ranging from 10 to 40 meters in the northeastern part and southwestern part.

Cretaceous granite forms the mountains on the northwestern side of the survey area. The eastern slope of the mountains consists of steep cliffs in a row; therefore it is inferred that the Matri Formation is faults contact with the granite in this area. This granite is mainly a coarse-grained two-mica granite, partly containing megacrystals of potassium feldspar. This rock is composed mainly of quartz, microcline, orthoclase, plagioclase, biotite, muscovite and tourmaline, with accessories zircon, apatite, sphene and ilmenite. Allanite occurs in less abundant. This granite has been extensively subjected to mylonitization; thereby cataclastic texture and mylonitic texture are common in the granite.

The Quaternary is composed of talus and fluvial sediments. Alluvial fans are present from the north-western foot of the mountains to Nam Khao River between the AA08 and AA25 survey lines, and consist of granite clastics including boulders with a maximum diameter of several meters. Fluvial sediments consisting of coarse sand derived from granite mass are distributed along Nam Khao River.

Small hills ranging in relative height from 10 to 30 meters are scattered in the area south of the AA25 line, which consist of Matri Formations. The valleys between these small hills are underlain by fluvial

A – 1

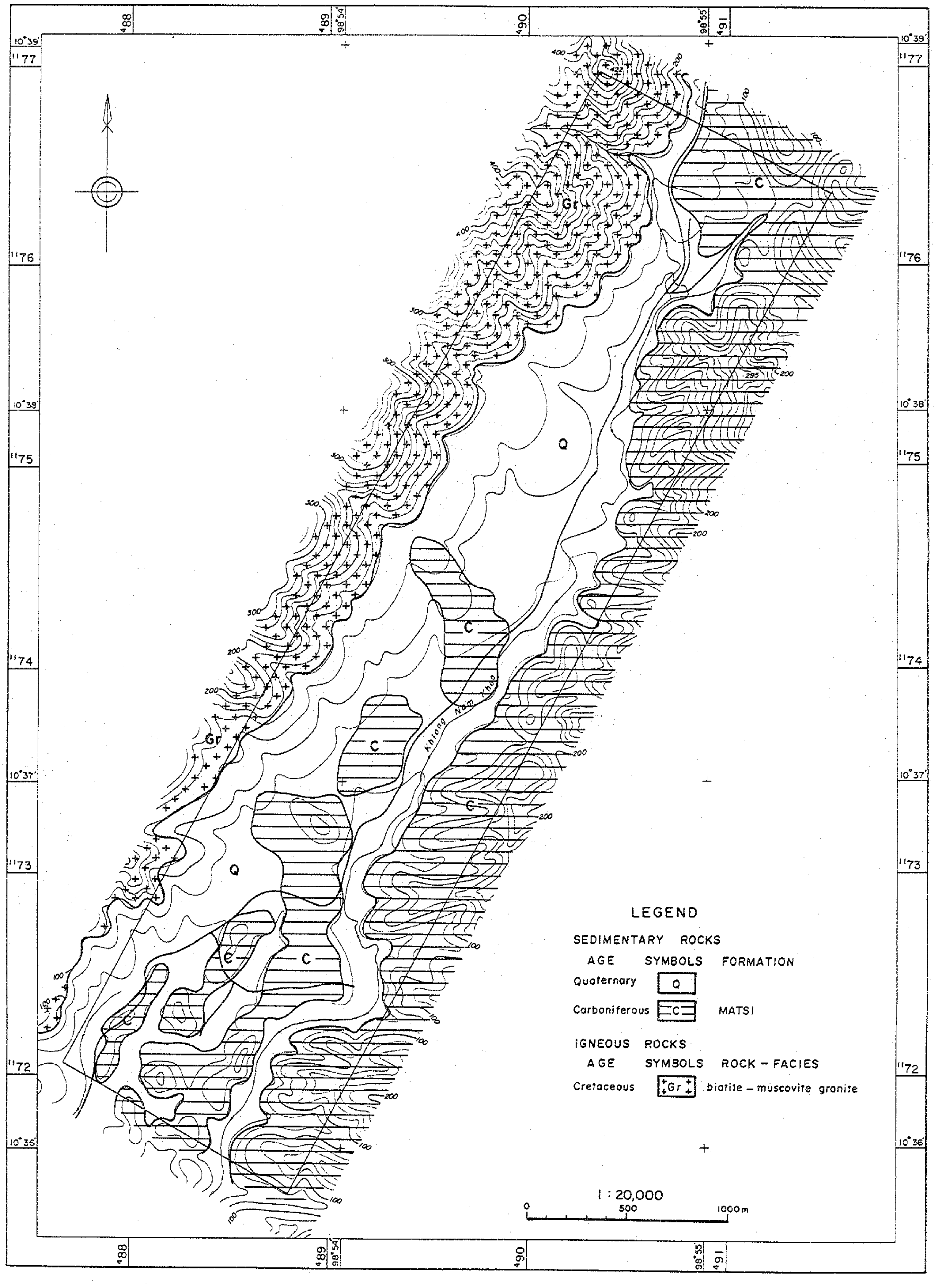

Fig. 18 Geologic Map of Area A-1

sediments mainly consisting of white clay.

4-1-3 Results of Geochemical Prospecting

(1) Soil Samples

The frequency distribution of trace elements in geochemical samples is known to have nearly a log-normal distribution as long as the precision of analysis is reliable enough. The logarithmic transformation of raw data is therefore done before the data processing.

The strong positive correlation is recognized in the Sn group elements except W (Sn, Ta and Nb), and in the rare earth elements (lantanoid, Y, Th and U). The positive correlation is also recognized between these two groups. Tungsten has a weaker positive correlation with the other Sn group's elements than the results of the first year's study, and has very small negative correlation values with the rare earth group's elements.

Ta and Nb have a positive correlation with the rare earth group. The analysis of panning samples revealed that the minerals containing these elements are cassiterite (SnO_2), monazite ($(Ce,La,Th)PO_4$), xenotime (YPO_4) and polycrase, and Ta and Nb coexist also in polycrase besides cassiterite, columbite and tantalite.

As mentioned above, analytical elements are divided into five groups, namely, Sn, W, Ta-Nb, Total REE, Th-U.

Threshold area as follows;

Sn; 30 ppm W; 9.5 ppm Ta-Nb; 36 ppm

Total REE; 320 ppm Th-U; 78 ppm

The element content maps are shown in Fig. 19 (1) to (3).

The clusters of Sn anomalous values are recognized in the AA09, AA15-AA19, AA26-AA31, AA36-AA41 and AA50-AA54 survey lines. The areas of anomalous values in the AA09 and AA15-AA19 are underlain by talus sediments consisting of granite's sand and gravel distributed in the north of Area A-1. Anomalous values in the AA26-AA31 line area overlaps with an alluvial basin consisting of course granite's sand accumulated in the valleys between several Matri Formation hills. Anomalous values in the south of the area coincides with the distribution of white clay layers consisting of kaolinite and muscovite, which have accumulated in the narrow valleys between Matri Formation hills. Therefore, the extension of of Sn anomaly almost indicates the extension of a cassiterite-bearing alluvial basin.

The anomalous values of W are distributed in the AA16-AA19, AA24-AA28, AA36-AA41 and AA50-AA52 lines. Some of them overlap with the anomalous areas of Sn, but the anomalous values in the AA24-AA28 and AA40-AA41 overlap with the Matri Formation distributed area. According to the results of the first year's panning study, the occurrences of scheelite were reported in Area A-1; thereby it may be inferred that these anomalous values and scheelite indicate the skarnization of the calcareous parts in the Matri Formation.

The anomalous values of Ta-Nb are found on the AA08-AA10, AA15-AA21, AA26-AA31 and AA35-AA40 lines. The areas of these anomalous values well overlap with that of Total REE and Th-U. Polycrase is common heavy mineral in Area A-1 based on the first year's panning study; thereby it appears that the distribution of anomalous values shows the occurrences of polycrase.

The anomalous zones of Total REE and that of Th-U are very similar to each other. Anomalous values concentrate on the AA06-AA22, AA26-AA31 lines, but are also distributed in the AA21-AA30, AA31-AA44 lines along the Nam Khao river. In the alluvial basin in the south of Area A-1, where high Sn anomaly zone is found, the anomalous values of the Total REE and Th-U are only distributed near the granite mass. The anomaly zones of Total REE and Th-U overlap with the talus and fluvial sediments' areas consisting of coarse-sand and gravel derived from a granite mass, and these areas show the distribution of the placer deposits of rare earth minerals such as monazite and xenotime.

(2) Samples of Heavy Minerals

Ten heavy mineral samples were collected in this survey. Two samples were panned from the soil of an irrigation pond near the AA5110 point in the southwest of the survey area, where the anomalous value of Sn was recognized. Eight samples were collected from the places along Nam Khao River.

The chemical analyses of heavy mineral samples show that the content of Sn, Ta, Nb and W tends to be higher in the south of the survey area. The highest Sn content is obtained from the soil of an irrigation pond which is the basal material of the alluvial basin.

On the contrary, the contents of REE, Th and U tend to be higher in the northern part of the survey area. This tendency is harmonious with the results of soil geochemical exploration.

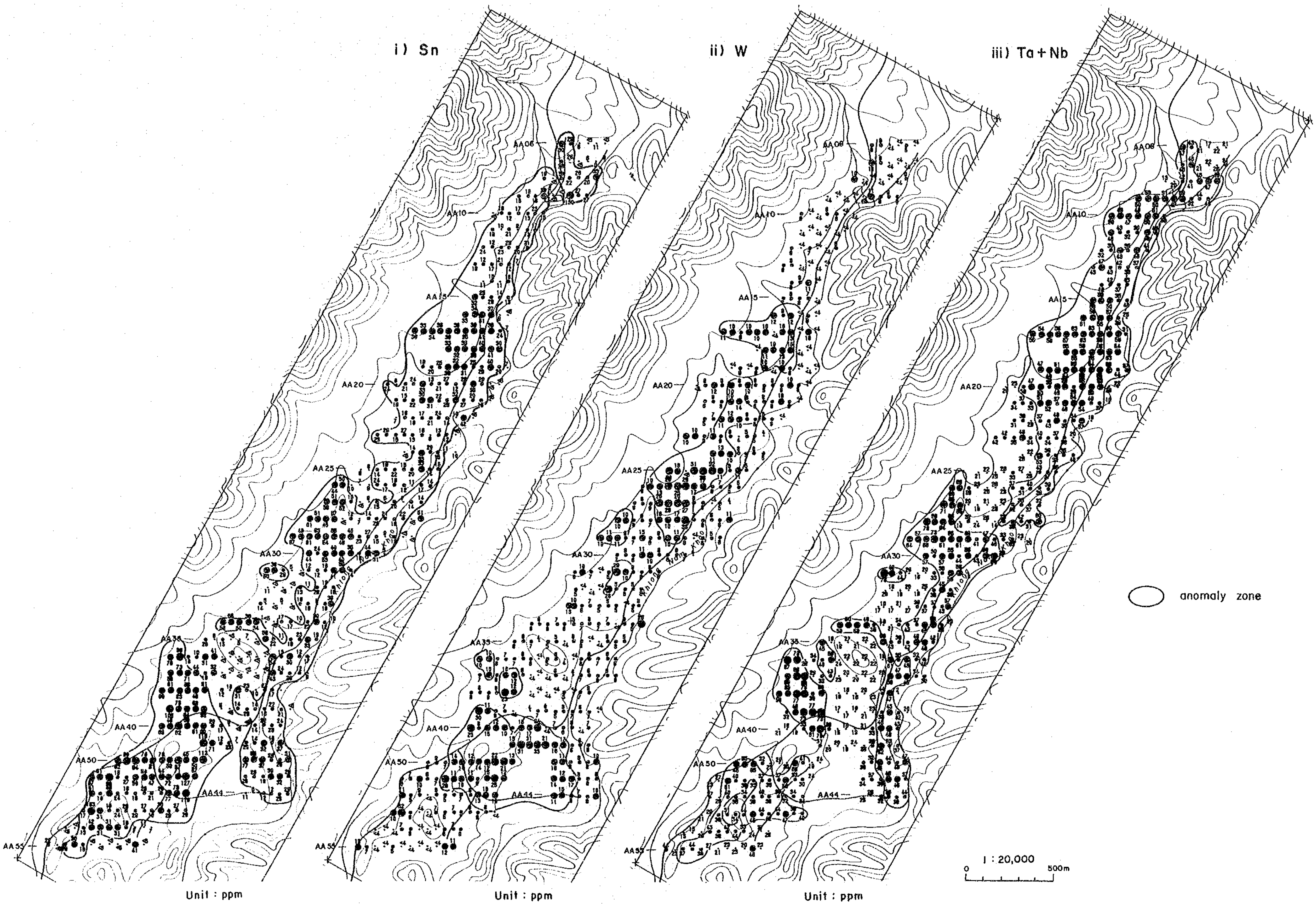

Fig. 19 Results of the geochemical survey of Area A-1 (1)