No. 33

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

PHASE I

MARCH 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

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

The JICA and the MMAJ sent to the Kingdom of Thailand a survey team headed by Mr. Iwao Uchimura from July 7 to September 19,1991.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Kura Buri Area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

March, 1992

Kensuke Yanagiya

President

Japan International Cooperation Agency

Gen-ichi Fukuhara

President

Metal Mining Agency of Japan

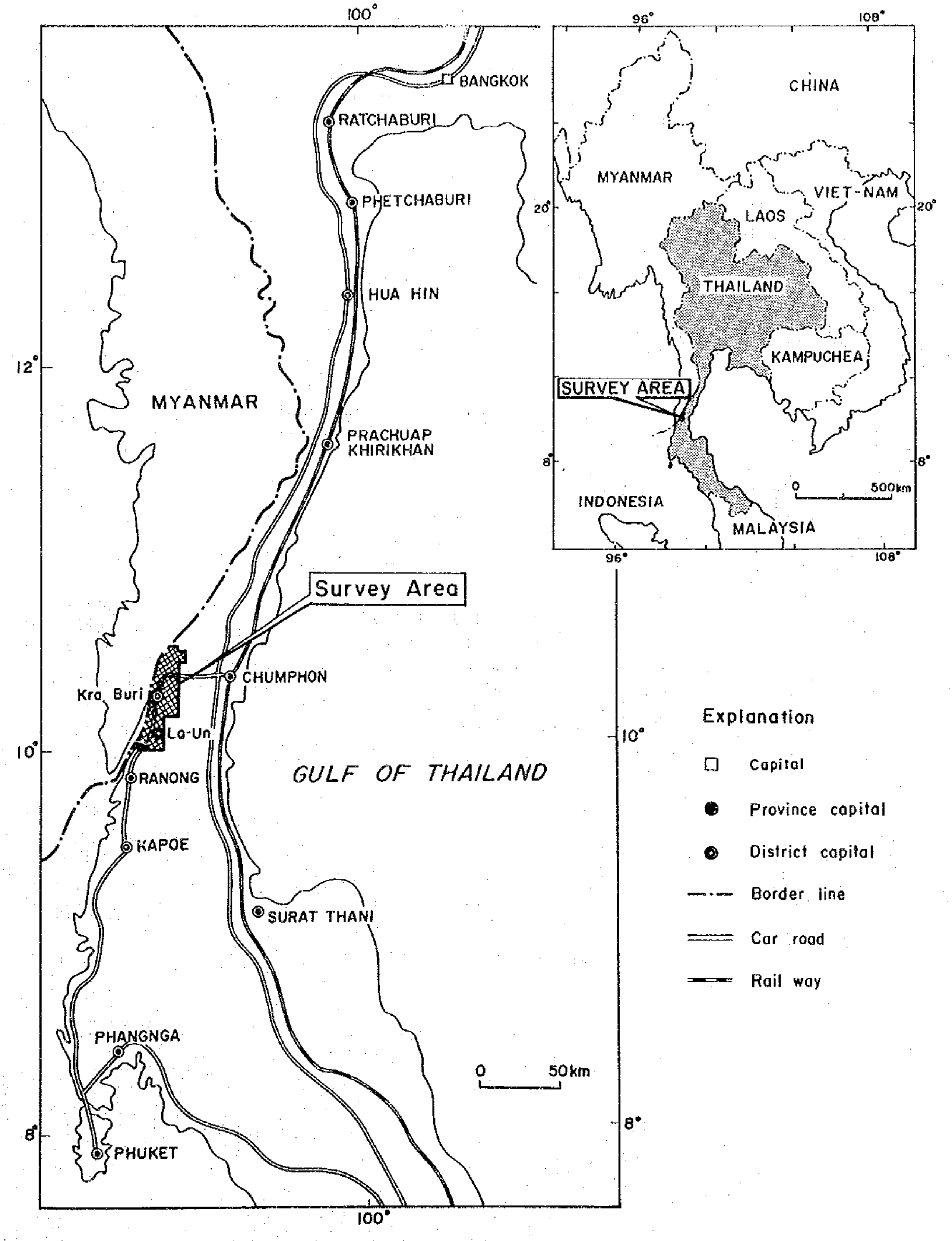

Fig. 1 Location map of the survey area

SUMMARY

This survey is the first year's programme of the Cooperative Mineral Exploration Project in the Kra Buri Area, the Kingdom of Thailand. The objective of the project is to examine the potential for tin, tungsten, and niobium resources, as well as rare earth elements.

The survey area is an area of 1,500 square kilometers, 80 kilometers north to south and 20 kilometers east to west, in the Kra Buri Area, Ranong Province, in the Peninsular Thailand, where is the northern extension area of the Ranong-Phuket area, the largest tin producing area in Thailand.

Satellite image interpretation objectified the whole survey area clarified the identification of geological structure and the distinction of geological unit. This result remarkably accorded with the field observations.

The survey area consists of sedimentary rocks of Silurian- Devonian to Jurassic ages and Quaternary alluvial sediments. Granites intruded in the above mentioned sedimentary rocks. Several major faults showing the trend of NNE-SSW are characteristic in the area, and the granites of Cretaceous age intruded accordance with this trend in the northern, central, and southern areas. The granite intrusions are separated into four bodies, the West mass and East mass in the northern area, Central mass, and Southern mass. These belong to the S-type, ilmenite series of tin-granite.

The investigation of the minor elements in the granites has revealed that the minor elements are grouped into two categories, the tin group consisting of Sn, W, Ta, and Nb, and the rare earths group consisting of rare earth elements and radioactive elements such as Th, U, and Y, based on their behaviour. The contents of the group elements differ in each body. It is judged that intrusive bodies showing high chemical contents of both group's elements are of high potential for economic ores. The Southern mass and West mass in the northern area show high contents in both groups.

All tin deposits in the area are secondary in their genesis. Several old mining sites exist in the southern part of the Northern west mass and the surrounding area of the Southern mass, of which only one mining site is in operation. Other than above mentioned sites, two mineralized zones are situated in the area; a sulphide disseminated alteration zone near Ban Pak Chan in the northern area and a silicified zone in the Khao Fachi area in the mouth of the Khlong La-Un.

The result of the geochemical study has indicated that the behaviour of the pathfinder elements of the two groups was clearly different. Anomaly zones of the tin group are in the southern part of the Northern west mass, western and southeastern parts of the Central mass, southern part of the Southern mass, and Khao Fachi area. Anomaly zones of the rare earth group are in the whole part of the Northern west mass, western part of the Central mass, western flank of the Southern mass, and Khao Fachi area.

Based on the results of the studies of geochemical characteristics, mineral occurrences, and alteration zones in the area, following four sites have been selected as promising areas for the minerals.

① Northern west mass

The mass geochemically indicates high potentiality for tin and REE mineralization, because of characterized by the high contents of the two group's elements. There exists a high anomaly of the tin group in the southern part of the body, whereas a rare earth group's anomaly covers over the whole mass. There is a potential for tin deposits containing rare earth elements in the southern part of the mass.

② Southern mass

The mass shows the highest potentiality in the area. There exists a high anomaly of the tin group in the southern part of the body, whereas a rare earth group's anomaly is widespread along the western flank of the mass. There exists a potential for tin deposits containing Nb and Ta in the southern part of the mass, and rare earths deposits in the western part of the mass.

③ Central mass

The potentiality of this mass is lower than ones of above-mentioned two masses. However, both group's anomalies are duplicated along the rivers in the western flank of the body, where a potential for tin deposits containing rare earth elements exists. On the other hand, a large-scale Sn-W anomaly is distributed to the southeast of the mass, where several quartz veins crop out. The quartz veins probably brought the Sn-W anomaly of the area. This suggests that a subsurface granitic body might be underneath there. If it is true, there is a potential for primary ores of tin and rare earths on the top of a supposed subsurface granitic body.

④ Khao Fachi Silicified zone

The zone is a silicified zone accompanied with a white clay argillized area, being hosted in the sedimentary rocks to the north of the mouth of the Khlong La-Un. A soil geochemical anomaly of the rare earths group and a stream sediment geochemical anomaly of the rare earth group overlies there. There might be subsurface granitic bodies, because the zone is situated in the southern extension of the Southern mass. A weak air-bone γ-ray spectrometric anomaly covers this zone. If it is proved, there is a potential for primary ores as well as the area to the southeast of the Central mass.

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PART I GENERAL REMARKS

Chapter 1 Introduction

1-1 Background and Objective

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

Demand for rare earth elements increases recent years. 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 discussed about this matter with the Department of Mineral Resources, Ministry of Industry. Finally both sides reached an agreement, and the Japanese representative, the Japan International Cooperation Agency and the Metal Mining Agency of Japan, and the Thailand representative, the Department of Mineral Resources, Ministry of Industry, entered into an agreement. Based on this agreement, a three-year program of cooperative mineral resources exploration in the Kra Buri area, the Peninsular Thailand was supposed to conduct from 1991.

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

1-2 Contents of the Survey

1-2-1 Area and Objective of the Survey

The survey area is situated in the northern part of the Malay Peninsula of Thailand, occupies an area of 1,500 square kilometers, 80 kilometers north to south, and 20 kilometers east to west, along the Mae Nam Kra Buri in Amphoe Kra Buri, Ranong Province. The area administratively belongs to Amphoe Kra Buri, Amphoe La-Un, and Amphoe Muang Ranong, Ranong Province, whereas a small part of the northeastern area belongs to Amphoe Tha Sae and Amphoe Muang Chumphon, Chumphon Province.

The objective of the survey is to examine situation of mineral resources for niobium, tantalum, tin, tungsten, gold, molybdenum, Uranium, and rare earth elements, by means of geological and geochemical surveys, and to select potential areas for primary and secondary ore deposits, including subsurface deposits associated with subsurface granite bodies.

1-2-2 Contents of the Survey

This year's programs consist of preliminary geological and geochemical surveys for the whole target area, and some associated laboratory tests.

The geological survey has been performed along evenly selected stream lines in the area, along with geochemical sampling of panning stream sediments. In addition to that, some soil samples for geochemical survey have been collected in granite distribution areas to obtain data for rare earth elements.

Topographic maps on a scale of 1:10,000 enlarged from original 1:50,000 scale maps have been used for the survey, and the final results of the survey have been compiled in the original 1:50,000 scale maps.

Following table summarizes the contents and quantities of the survey works.

Table 1 Contents of Survey

Contents	Item		Quantity
Satellite Image Interpretation	Area		1,500 km^2
Geological and Geochemical Surveys	Area Route length		1,500 km^2 600 km
Laboratory Works	Rock Thin Section Ore Polished Section X-ray Diffraction EPMA		53 pieces 13 pieces 22 pieces 17 points
Chemical Analysis	Stream Sediments	Sn,W,Ta,Nb,Au,Mo,Ce,Eu, La,Lu,Nd,Sm,Tb,Th,U,Y,Sc	2,021 pieces
	Panned Samples	Sn,W,Ta,Nb,Au,Mo,Ce,Eu, La,Lu,Nd,Sm,Tb,Th,U,Y,Sc, Dy,Er,Gd,Ho,Pr,Tm	560 pieces (104 analyzed)
	Soil Samples	Sn,W,Ta,Nb,Au,Mo,Ce,Eu, La,Lu,Nd,Sm,Tb,Th,U,Y,Sc	207 pieces
	Rock Samples	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	32 pieces
	Ore Samples	Sn,W,Nb,Ta,Y,La,Ce,Nd	25 pieces

1-3 Schedule and Personnel

1-3-1 Negotiation and Planning

The mission for the negotiation and planning of the project scheme was dispatched to Thailand as stated below.

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
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

1-3-2 Survey Mission

Period: 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

Chapter 2 Geography

2-1 Location and Access

The survey area is situated in the area 98°40' to 99°00' east in latitude, and 10°00' to 10°45' north in longitude, about 20 km east to west and 80 km north to south, 1,500 square km. Surat Thani City, one of the largest cities in southern Thailand, is about 150 km to the southeast. The area mainly belongs, administratively, to Amphoe Kra Buri and Amphoe La-Un, Ranong Province, and partly to Amphoe Tha Sae and Amphoe Muang Chumphon, Chumphon Province, in the northeastern corner, and Amphoe Muang Ranong, Ranong Province, in the southwestern corner.

Kra Buri Town, where survey team's base camp was set up, is situated in between Chumphon City in Chumphon Province on the east coast and Ranong City in Ranong Province on the west coast, 62 km from the former city and 60 km from the latter city. Highway No.4, a completely paved trunk road, starts from Bangkok through Chumphon, Ranong, Phuket, and Hat Yai, and reaches to the Malaysian border. Routes Ranong - Kra Buri - Chumphon and Ranong - Surat Thani are well served by routine buses, express buses, taxies. Express bus service from Bangkok to Phuket through Chumphon, Kra Buri, and Ranong is available every morning and night. Distance from Bangkok to Kra Buri is 554 km, and time by the express bus is 10 hours.

The nearest airport from the survey area is in Surat Thani, and direct three or four jet flight services take about 65 minutes from Bangkok.

Railway service is available between Bangkok and Chumphon, about 500 km for nine hours.

Road system in the survey area is well developed. Above mentioned highway No.4 crosses from the northeastern corner to southwestern corner, and highway 4091 branches from highway No.4 and connects to La-Un Town, Amphoe La-Un. Other local roads are unpaved but well connect among villages along principal rivers. Those unpaved roads are very muddy in the rainy season, even some roads are under construction works for improvement, and four wheel drive cars are required for transportation. Damages of roads and bridges by heavy rains are frequently happened in such roads, and accessibility is shut down in parts having no bridges for crossing rivers.

Common transportation means for the local people are cars and motorbikes, besides boats in water front area.

2-2 Topography

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

The survey area is situated in the boundary between above mentioned both 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 NNS to SSW, characterized by narrow ridge lines and steep mountain 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 are distribute in the narrow upstream areas of the drainage systems. Crossing this main drainage trend, many minor streams cut the steep mountain flanks.

The Mae Nam 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 Mae Nam Kra Buri and Khlong La-Un.

2-3 Climate and Vegetation

The Peninsular 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 hottest time in a year due to weaken northeast winds.

Table 2 and Figure 2 show monthly temperature data in the recent six years in Ranong City, to the south of the survey area. 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.

Table 3 and Figure 3 show monthly precipitation data in the recent five to six years in Kra Buri Town and La-Un Town. The annual precipitation in the towns is ranges between 1,800 and 3,000 mm, in which 90 percent of the precipitation is concentrated in the rainy season. Table 4 and Figure 4 show daily precipitation data during the survey period in both towns.

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 trees mainly consisting of teakwood, oak, bamboo, etc. In the hilly areas, artificial plantation forests consisting of tropical fruits, rubber tree, oil palm, and coffee are mixed with natural virgin forest. In the plains, large areas are cultivated as rice fields and vegetable gardens, and mangroves are seen in the lowland swamp area in the mouths of the Mae Nam Kra Buri and Khlong La-Un.

2-4 General Information

The survey area is, as mentioned in 2-1 of this chapter, mainly in Amphoe Kra Buri of Ranong Province, and partly in Amphoe La-Un and Amphoe Muang Ranong of Ranong Province in the southern area, and in Amphoe Tha Sae and Amphoe Muang Chumphon of Chumphon Province in the northeastern corner.

Table 2 Temperature at Ranong city

Year / Month	1986			1987			1988			1989			1990			1991			Average of Six Years		
	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE
1	34.9	17.7	26.45	33.9	18.3	26.54	35.4	20.0	26.87	35.0	20.0	27.61	35.2	20.1	27.87	35.2	20.8	27.95	34.9	19.5	27.2
2	37.0	18.0	26.84	37.0	18.9	27.43	38.0	20.7	28.86	36.5	16.5	26.84	38.3	21.0	29.33	35.6	20.5	28.41	37.1	19.3	28.0
3	36.6	19.0	28.51	38.6	19.9	28.81	38.5	21.1	28.98	36.3	21.5	27.59	38.7	20.4	30.01	37.5	19.8	29.27	37.7	20.3	28.9
4	38.1	22.0	29.29	35.7	22.0	30.08	38.1	23.6	30.19	35.0	22.6	29.98	38.3	22.9	30.57	37.8	23.2	30.00	37.2	22.7	29.9
5	37.2	22.3	27.05	34.6	22.6	27.79	34.8	23.6	27.20	34.1	23.2	27.77	36.6	23.3	28.69	35.7	23.8	29.08	35.5	23.1	27.9
6	32.7	21.8	26.87	34.6	23.5	28.24	33.4	22.0	27.69	33.2	22.8	27.08	33.2	23.5	28.25	35.2	23.5	29.10	33.7	22.9	27.9
7	32.6	21.4	26.73	33.2	23.5	28.29	33.0	22.8	25.50	33.6	23.2	27.92	32.6	21.6	27.55	33.9	22.9	27.15	33.2	22.6	27.2
8	31.7	21.8	26.13	33.1	22.3	27.04	33.0	22.6	27.55	32.6	26.6	26.02	32.2	23.1	27.71	32.6	23.0	27.30	32.5	23.2	27.0
9	31.9	22.1	26.32	34.0	22.5	26.85	32.4	22.9	26.79	33.5	24.4	27.38	32.9	21.8	27.25				32.9	22.7	26.9
10	32.3	22.0	26.82	34.6	23.0	28.14	32.5	22.3	26.67	33.5	22.5	27.12	33.7	22.5	27.54				33.3	22.5	27.3
11	33.3	20.5	26.90	33.0	22.6	26.39	33.7	20.7	26.51	34.5	22.0	27.84	33.7	20.4	27.04				33.6	21.2	26.9
12	33.1	17.8	26.49	33.7	19.4	25.91	34.4	19.9	26.01	35.0	18.5	27.21	33.7	19.7	27.30				34.0	19.1	26.6

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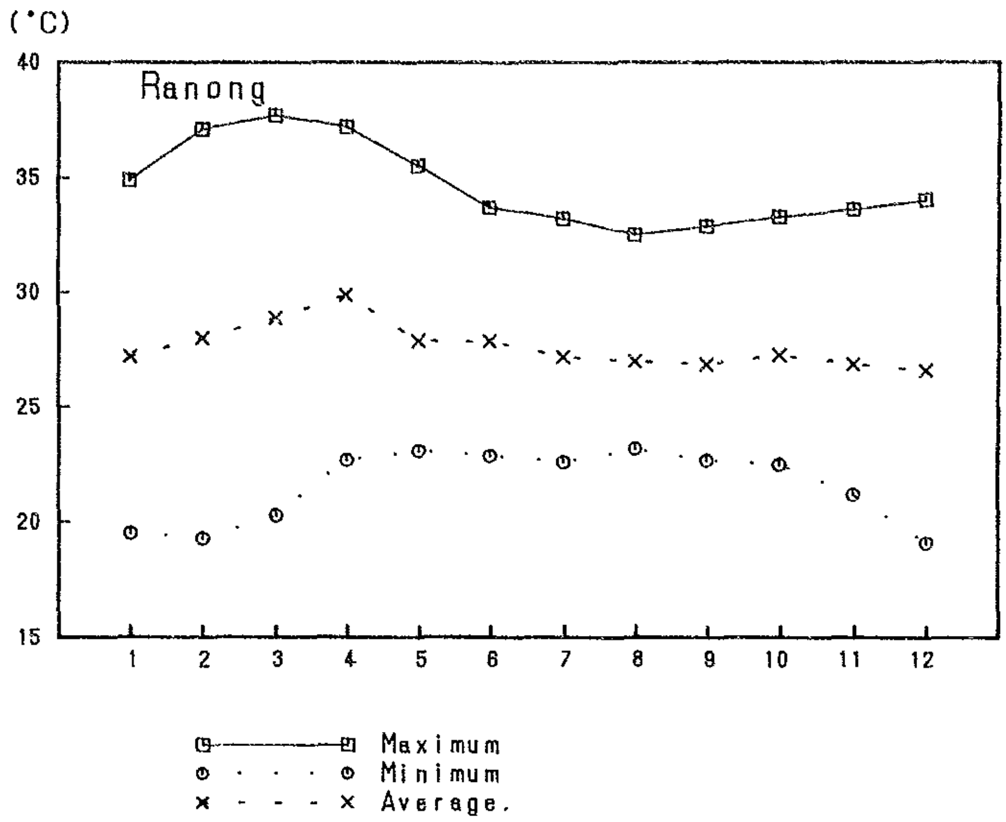


Fig. 2 Temperature diagram at Ranong city

Table 3 Manthly rainfall at Kra Buri and La-Un town

Month \ Year	1986	1987	1988	1989	1990	1991
1	0.0	0.0	0.1	29.8	0.2	26.3
2	0.0	0.0	7.0	5.3	0.0	6.2
3	27.9	27.9	25.7	45.8	15.4	10.8
4	47.7	70.7	85.0	92.5	118.8	21.9
5	333.7	226.3	149.7	499.8	243.0	119.0
6	316.4	242.3	235.4	383.2	782.8	121.1
7	383.7	77.8	221.1	149.1	409.1	475.0
8	578.6	422.6	148.9	411.3	612.3	638.3
9	394.3	347.8	363.8	193.1	458.4	
10	34.5	115.2	316.9	74.9	432.1	
11	33.5	218.3	259.3	90.6	72.1	
12	0.0	19.1	0.0	0.0	1.9	
TOTAL	2150.3	1768.0	1812.9	1975.4	3146.1	1418.6

Unit: mm

La-Un

Month \ Year	1987	1988	1989	1990	1991
1	0.0	0.0	0.0	0.0	0.0
2	0.0	12.7	5.3	0.0	57.4
3	0.0	41.1	42.5	0.0	38.9
4	22.0	9.0	189.3	85.7	80.6
5	67.0	258.2	448.4	216.6	40.9
6	206.8	549.1	353.3	413.7	174.6
7	57.0	604.2	241.6	398.6	347.4
8	750.0	26.9	651.2	516.4	431.4
9	348.8	464.9	280.1	534.1	
10	176.7	611.2	408.8	403.8	
11	230.5	402.8	153.9	124.0	
12	0.0	0.0	0.0	20.6	
TOTAL	1858.8	2980.1	2774.4	2713.5	1171.2

Unit: mm

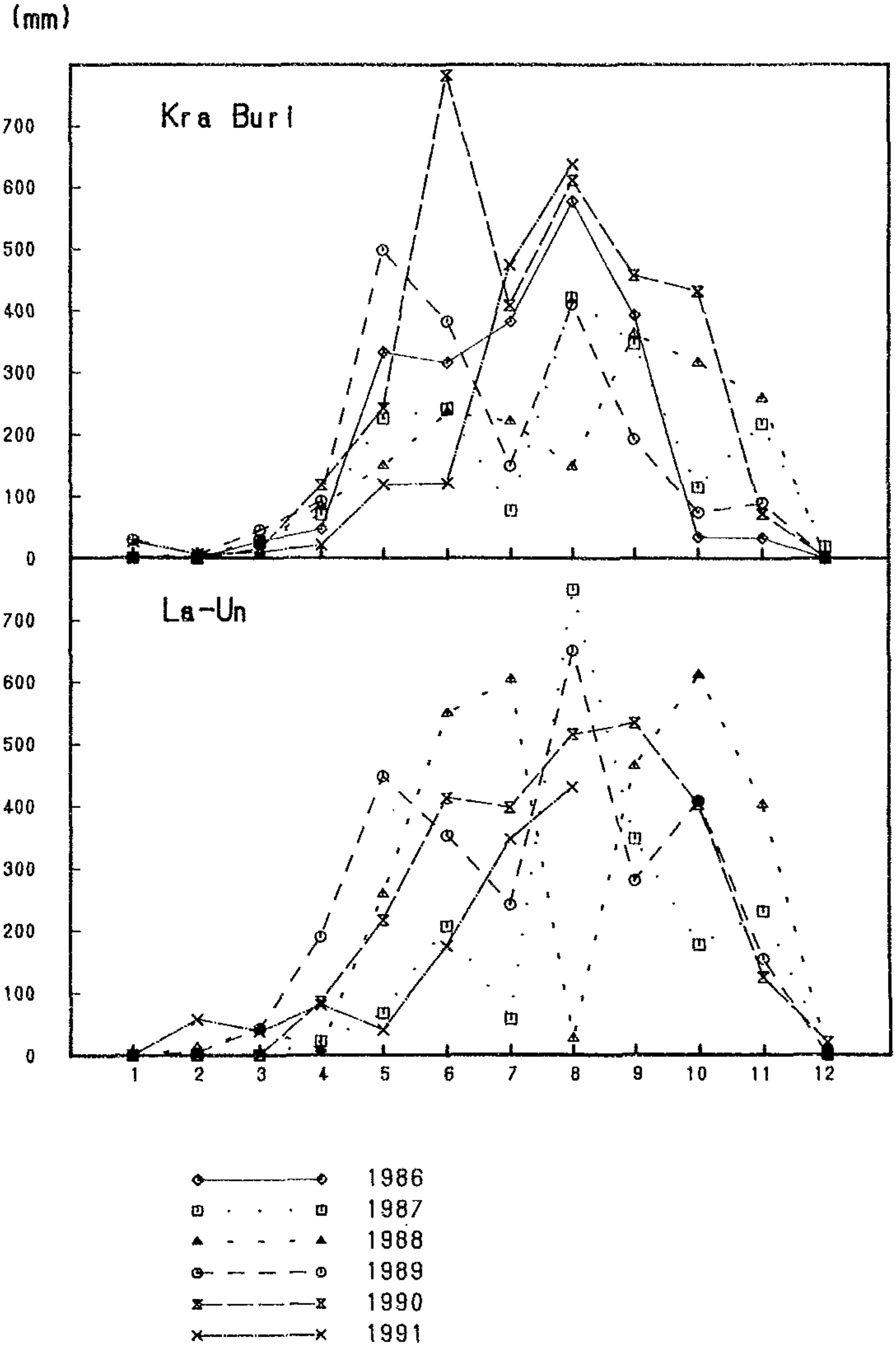


Fig. 3 Monthly rainfall diagram at Kra Buri and La-Un town

Table 4 Daily rainfall at Kra Buri and La-Un town

Date	Kra Buri	La-Un	Date	Kra Buri	La-Un	Date	Kra Buri	La-Un
1991 7 1	1.4	0.0	8 1	8.4	0.0	9 1	11.6	0.0
2	10.8	3.6	2	0.0	0.0	2	5.2	0.0
3	9.3	24.8	3	-	0.0	3	0.0	0.0
4	-	0.0	4	0.0	1.7	4	8.1	23.7
5	-	0.0	5	5.7	8.3	5	3.7	3.8
6	7.4	0.0	6	10.3	12.6	6	41.5	26.4
7	19.2	18.4	7	44.9	9.4	7	59.7	57.3
8	21.5	5.3	8	1.0	-	8	66.3	48.6
9	11.7	1.7	9	-	-	9	38.4	3.7
10	4.8	0.0	10	12.6	-	10	19.6	-
11	32.4	75.3	11	9.3	0.0	11	30.9	-
12	14.0	13.5	12	7.1	0.0			
13	19.6	3.8	13	-	0.0			
14	37.5	27.6	14	10.7	14.8			
15	18.2	0.0	15	23.5	9.3			
16	-	-	16	9.5	6.8			
17	-	-	17	23.7	27.4			
18	-	-	18	36.1	53.6			
19	-	0.0	19	37.6	86.4			
20	42.9	0.0	20	40.9	0.0			
21	28.6	13.4	21	5.2	0.0			
22	17.4	2.8	22	13.7	0.0			
23	55.3	0.0	23	11.4	18.3			
24	49.1	38.4	24	52.8	22.5			
25	46.7	86.3	25	59.3	46.8			
26	3.5	7.9	26	12.6	23.8			
27	11.8	1.5	27	54.5	38.6			
28	6.4	1.7	28	68.9	19.3			
29	-	18.4	29	32.4	0.0			
30	0.0	0.0	30	38.7	13.5			
31	-	0.0	31	7.5	18.3			
TOTAL	469.5	344.4	TOTAL	638.3	431.4			

Note) 0.0: not measured due to very small amount, -: nil. unit: mm

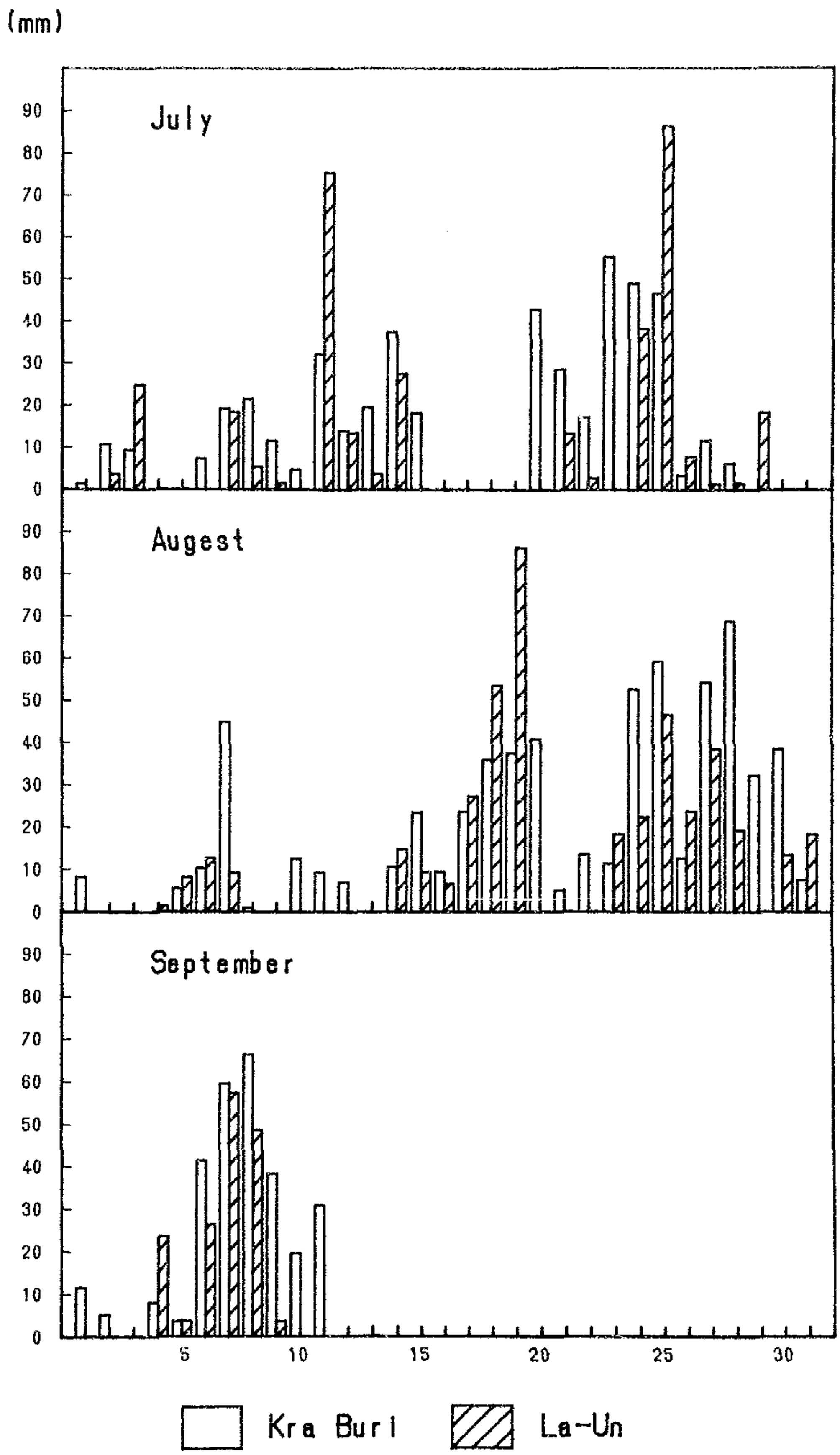


Fig. 4 Daily rainfall diagram at Kra Buri and La-Un town

Amphoe Kra Buri is divided into six sub-administrative districts, and has the population of 30,932 according to the January 31, 1991 census, 16,108 male and 14,824 female. Kra Buri Town, Principal town of the county, is in the center of the survey area, providing a regional administrative office of the county, a hospital, a post office,a police station, some primary and secondary high schools, a bank, some markets, restaurants and general shops, etc. Amphoe Kra Buri has 52 villages, of which larger ones are situated along Highway No.4, and other small ones scattered along principal rivers.

Amphoe La-Un is divided into five sub-administrative districts, having the population of 8,826 at the end of 1990.

Industries in the area are principally agriculture for rice, rubber, and fruits, besides some fishery and livestock farming for cattie, buffaloes, hogs, and paultry are seen in the Mae Nam Kra Buri basin.

Main mining activity in the survey area is for tin, but only one mine is in operation at present. It was very active till 10 years ago, and 22 mining claims were applied for 15 years.

Chapter 3 Existing Geological Information

3-1 Previous Works

Many tin mines have been active in the Malaya Peninsula for many years, and one of the largest tin producing areas in the world. The peninsular Thailand is the northern extension of the main tin producing zone of Malaya, and the Ranong-Phuket area on the south of the survey area is the largest tin producing area in Thailand. Almost all deposits are however placer deposits, and few published data for the mining are available because no technical difficulty exists. The geological map covering the survey area is "Geological Map of Thailand, Changwat Chumphon and Amphoe Kra Buri"(DMR,1985), which describes stratigraphic classification, rock facies, distribution of formations, and geological structure.

The Department of Mineral Resources has conducted air-borne geophysical survey programs covering whole area of Thailand since 1984 as a part of the mineral resources development project. The programs consist of magnetic, electromagnetic, and radioactive survey programs, most of which have been completed by now. The survey results have been publishing time by time, and magnetic and radioactive survey results covering this survey area are available now, of which the radioactive survey results clearly

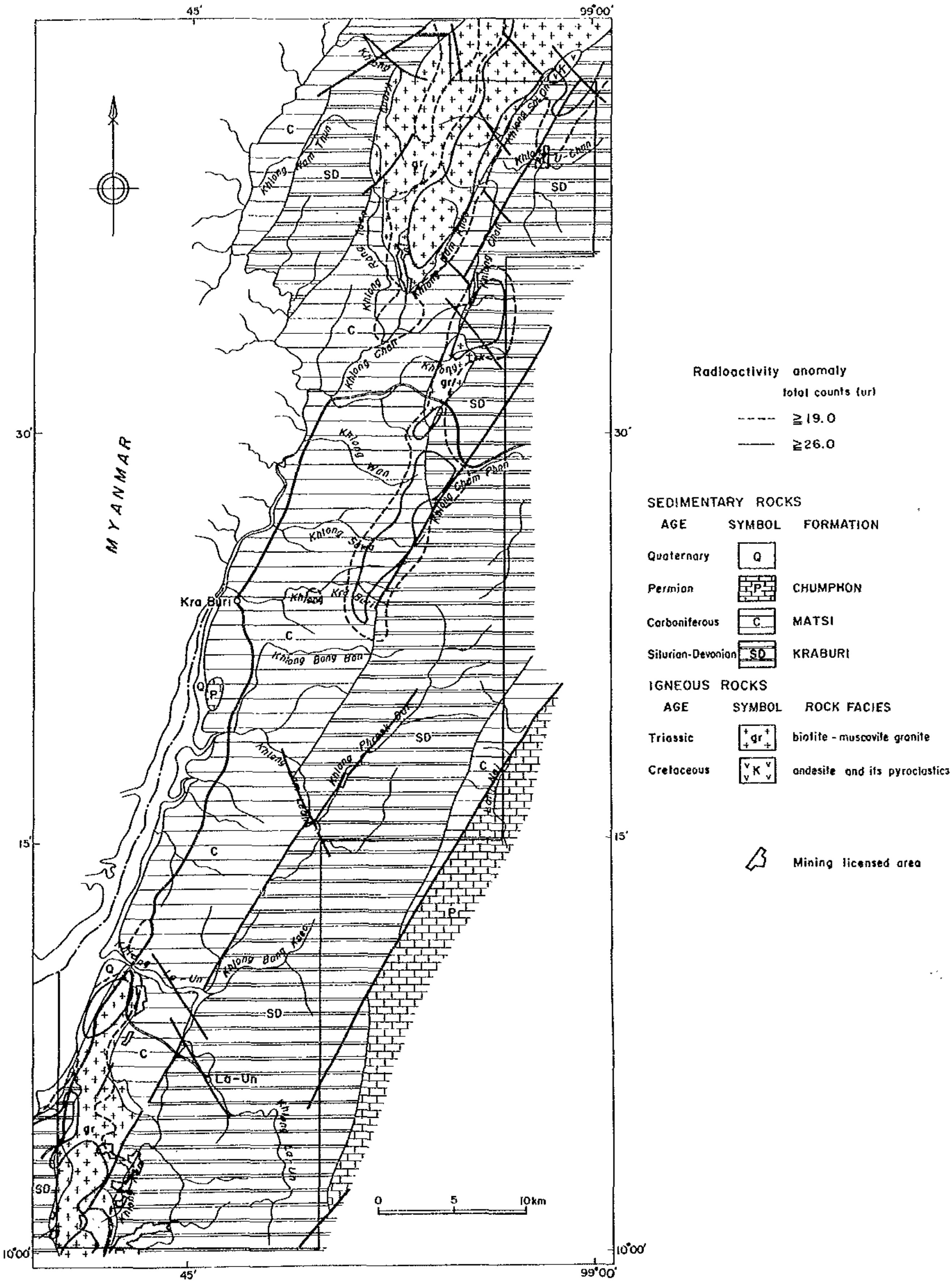


Fig. 5 Summarized map of previous works

show anomalies over the granite bodies.

Some tin mineral occurrences and old workings are scattered in the area, although few literatures describing those exist.

Aranyakanon (1961) performed detailed petrological and mineralogical studies on many samples from the Haad Som Pan Deposit, which is a primary tin tungsten deposit situated to the east of the Nivet area, Ranong Provinces. He described on the relationship between the alteration of the host rocks and mineralization, contents of magnetite in tin-bearing granites and barren granites, and temperature of the genesis.

Garson et al.(1975) describes the detailed geology of the peninsular Thailand, and evaluated the potential for metallic minerals and diamond considering with geochemical survey results as well as for non-metallic mineral resources.

Sirinawin et al. (1986) studied on the primary tin ore deposits in the Ranong- Phuket area, and described that the granites in the area were of particular kind bearing boron, and there are two types of ore deposits, argillized disseminated type and pegmatite type. He also showed the grades, ore reserves, and types of ore deposit for all known ore deposits in the area. In addition to that, he suggested that there is a possibility to discover primary ores by means of studies of secondary ores, because many secondary ores were not clear on their genesis.

3-2 Geology and Ore Deposits in the Kra Buri Area

Around the survey area there is underlain by Cambrian to Jurassic sedimentary rocks, which were intruded by Cretaceous granites, and Quaternary formations. The old sedimentary formations have undergone Triassic to Jurassic tectonic movements, and been folded. The formations finally have been blocked by faults trending N-S and NNE-SSW, allowing granitic intrusion into the block boundaries.

The Malay Peninsula is one of the largest tin producing areas in the world. The tin minerals are mined from placers in the Quaternary formations. The cassiterite as a tin mineral has been brought from the Mesozoic granites largely distributed in the area and some primary ores. The tin-bearing granites in the Malay Peninsula are classified into three sub-belts, Eastern, Main Range, and Western Sub-belts, based on the data of the geological structure and ore genesis (Hutchison and Taylor, 1978).

The survey area is in the Western Sub-belt, and in the northern extension of the Ranong-Phuket area, where is the largest tin producing area in Thailand. Secondary mineral occurrences are distributed around the granite bodies in the area.

3-3 Mining

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. In 1965, 580 tin mines were registered in southern Thailand, of which almost all were of small-scale private operation applying dredging or gravel pumping methods (Sawata, 1971).

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 are active at present, and only one mine is in operation in the survey area, although many old workings are scattered in the area. Table 5 shows tin production from the registered mining claims in the survey area in the recent 15 years. Figure 6 shows tin production from Ranong and Chumphon Provinces from 1973 to 1988.

Chapter 4 Comprehensive Discussion

4-1 Characteristics of Granite

The area is underlain by sedimentary rocks from Silurian to Jurassic time, and Cretaceous granites intruded into those sedimentary rocks. Tin mineralization is closely associated with the granitic activity.

The granites occur as stocks in the northern, central, and southern areas, and divided into four bodies; the West and East masses in the northern area, Central mass, and Southern mass. These granite bodies belong to the Western Belt, which is defined by Hutchison (1983), and are of the S-type and ilmenite

Table 5 Registred mining area in the Kra Buri area

Name	License No.	Locality		Area Km²	Mineral	Production (Metric tonnes)															Total tonnes
		Tambol	Amphoe			1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Rattanakaset Part. LTD.	10024/8673	Pakchan	Kra Buri	0.36	Tin	404	1243	1015	-	-	-	-	-	-	-	-	-	-	-	-	2662
Rattanakaset Part. LTD.	10023/8723	Pakchan	Kra Buri	0.47	Tin	-	-	-	1016	616	-	-	-	-	-	-	-	-	-	-	1632
Mr. Un Na-Ranong	10022/8724	Pakchan	Kra Buri	0.47	Tin	-	-	-	-	-	-	125	164	361	344	277	-	-	-	-	1271
Ngantawei Phe-nong Co., LTD.	13317/11859	Bang Phra Nua	La-Un	0.46	Tin	-	-	-	241	569	-	-	-	-	-	-	-	-	-	-	810
Mr. Thei Nu-Noi	13266/11813	Bang Phra Nua	La-Un	0.15	Tin	-	43	133	12	172	270	373	57	-	-	-	-	-	-	-	1060
Mr. Toem-Sak Fongsrisin	13455/11990	Bang Phra Nua	La-Un	0.30	Tin	-	-	-	-	-	-	-	194	282	30	-	-	-	-	-	506
Mr. Netiwut Chantad	18411/11989	Bang Phra Nua	La-Un	0.32	Tin	-	-	517	-	74	-	-	-	-	-	-	-	-	-	-	591
Mr. Wisit Amarattanukul	18330/12627	Bang Non	Muang	0.11	Tin, W	-	-	-	-	-	48	33	32	19	-	-	-	-	-	-	132
Muang Rae Kratoo ROP.	19379/12472	Sai Deeng	Muang	0.19	Tin	-	-	-	156	215	108	4	-	-	-	-	-	-	-	-	483
Mr. Toem-Sak Fongsrisin	19316/12194	Bang Phra Nua	La-Un	0.41	Tin	-	-	-	812	686	1172	260	-	-	-	-	-	-	-	-	2930
Rattanakaset Part. LTD.	19328/12127	Bang Non	Muang	0.10	Tin	-	-	410	899	424	-	-	-	-	-	-	-	-	-	-	1733
Mr. Toem-Kiat Tantiwiwat	19338/11991	Bang Phra Nua	La-Un	0.16	Tin	-	-	621	157	-	-	-	-	718	-	520	-	-	-	-	2016
Mr. Tiwa Tiwaratanakul	19406/12806	Bang Non	Muang	0.02	Tin	-	-	-	-	-	389	4	-	-	-	-	-	-	-	-	393
Ngantawei Phe-nong Co., LTD.	19446/13203	Bang Non	Muang	0.06	Tin	-	-	-	-	-	-	452	509	-	-	-	-	-	-	-	961
Mr. Buntam Isarakan	19462/13604	Bang Phra Nua	La-Un	0.01	Tin	-	-	-	-	-	-	-	-	52	178	-	-	-	-	-	230
Mitprasan ROP.	8166/9030	Bang Phra Nua	La-Un	0.10	Tin, W	173	-	-	-	-	-	-	-	-	-	-	-	-	-	-	173
Mr. Kamol Nopphaket	19270/12714	Rabro	Tha Sae	0.43	Tin	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	8
					Total	577	1286	2696	3293	2764	1987	1251	956	1432	552	797	0	0	0	0	17591

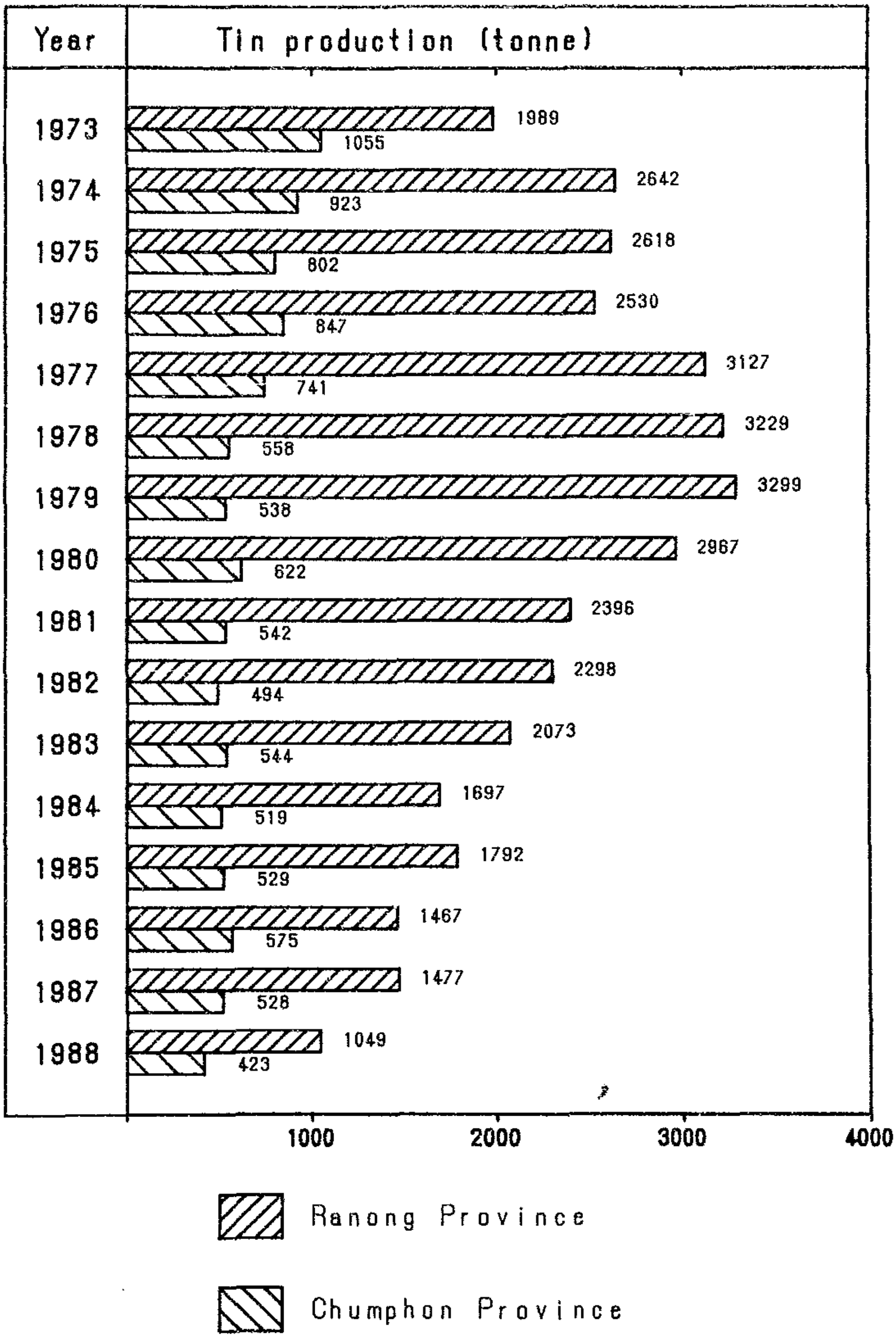


Fig. 6 Quantity of tin production by year in Ranong and Chumphon province

series granites.

The results of the minor element study indicate that all granite bodies show high Sn contents, meaning they belong to the tin-granite. Among them, the Northern west mass and the Southern mass contain remarkably high grade of Sn, on the contrary the East mass in the northern area contains relatively low grade of Sn, compared with other three masses.

All masses show high concentration of light rare earth elements, such as La and Ce, in the chondrite standardized pattern, and low concentration of heavy rare earth elements. This kind pattern lowering to the right is typical in the standardized pattern of the typical granites showing clear Eu anomalies. Especially, the Northern west mass and the Southern mass show high contents of La and Ce. On the contrary the Northen east mass shows low contents in the elements. This trend is concordant to that of the tin contents, indicating high potential for tin ores in masses containing high contents of light rare earth elements.

Considering the relationship between the differentiation index of rocks and minor element contents, it tends to that Sn, W, Ta, and Nb are remarkably concentrated into the most differentiated specific rock facies like muscovite granite, tourmaline granite, pegmatite, and greisen, on the contrary rare earth elements decrease their contents in such rock facies. Most of the typical granites in the area show the geochemical characteristics of two kinds, high contents in both Sn-W-Ta-Nb group and REE-Th-U-Y group, and low contents in both groups. The Southern mass contains both kinds, the Northern west mass area contains the intermediate characteristics kind, and the Northern east mass and Central mass contain the low concentrated granite.

The tin ore deposits in the area are concentrated in the Northern west mass and around the Southern mass, which are dominated by the high concentrated granites. Good correlation between the distribution of the ore deposits and their geochemical characteristics is recognized. It is judged that the potential for tin and rare earth minerals are dominated by the geochemical characteristics of the granites.

Few highly differentiated granites, which might contain primary ores crop out in the granitic areas, however it is possible to exist some subsurface primary ores on the top of cupola type subsurface granite bodies, if exist.

4-2 Geochemical Anomaly

Soil geochemical anomalies exist in the granite distribution areas, and those anomalies well correspond with those of stream sediments and panned samples.

The elements showing geochemical anomalies are grouped into two, the tin group consisting of Sn, W, Ta, and Nb, and the rare earth element group consisting of Th, U, and Y.

In the northern area, anomalies of the tin group are distributed in the south end of the Northern west mass and in the area between the West mass and East mass, where many old workings exist. Anomalies of the rare earth group are distributed over the West and East masses, and old working area, although it shows different behavior in each element. The anomalies of the latter group expand larger than those of the former group.

In the Central mass, anomaly zones of the tin group and rare earth group are duplicated along the river system flowing to the west. On the southeastern side of the mass, an anomaly consisting of Sn and W without Ta, Nb, and the rare earth group elements exists in the sedimentary rock area in the upper stream of the Khlong Phraek Dat, apart from the granite mass. The Sn anomaly, especially, extends an area of 5 km x 3 km.

In the Southern mass, tin group anomalies occupy a large area in the southern part of the mass. Rare earth group anomalies are distributed along the west side of the mass and only slightly high anomalies are scattered on the east side. A small-scale anomaly of both groups exists in the northern extension of the mass, Khao Fachi Silicified Zone.

4-3 Promising Area

Only secondary tin ore deposits exist in the area, and all of those are in the surrounding areas of the granite bodies. Other than those, the Khao Fachi Silicified Zone accompanied with a weak argillized zone altered from sedimentary rocks in the mouth of the Khlong La-Un and a black altered zone accompanied with a little of disseminated sulphide minerals along the highway between Chumphon and Kra Buri.

Judging from above mentioned geochemical characteristics, geochemical anomaly zones, and relationship among those anomalies, mineral occurrences and alteration, following zones are listed as

PART II DETAIL DESCRIPTION

potential areas for economic ores(Fig.28).

① West mass in the northern area

The geochemical characteristics of the Granite indicate high potential for the minerals. A strong tin group anomaly exists in the southern part, where some known ore deposits are distributed. Anomalies of rare earth group spread over the granite mass.

② Southern mass

This granite mass shows the highest potential judging from the geochemical characteristics of the granite. A high tin group anomaly is in the southern part of the mass, where some known ores exist. Anomalies of the rare earth group widely spread along the western side of the mass.

③ Central mass

The potential for this mass is low judging from the geochemical characteristics. Anomalies for the both groups are duplicated along the western side of the granite. This area is entirely undeveloped. The sedimentary basin in the river area is of small-scale. On the other hand, an anomaly zone consisting of both groups spreads over along the southeastern side of the mass, and quartz veins, which are presumably sources of those anomalies, are situated in the same area. It is supposed that a subsurface granite body exist around there.

④ Khao Fachi Silicified Zone

The soil samples taken from the zone show high rare earth group anomalies. Anomalies of both group elements in the stream sediments are recognized in small areas. This area is on the extension of the Southern mass, therefore it is possible that a subsurface granite body exist around there. Also air-bone γ-ray spectrometric anomaly indicates the existanse of a concealed granitic body.

Chapter 5 Conclusion and Recommendation

5-1 Conclusion

In this survey, the geological survey and geochemical prospecting have been performed to select potential areas for minerals from the area of 1,500 square kilometers around the Kra Buri Town, the

Peninsular Thailand. The conclusions of the survey are as follows.

1. The tin mineralization in the Malay Peninsula is associated with the granitic activities since Mesozoic age. The granites intruded into the sedimentary formations from Silurian-Devonian to Jurassic time in the area are of Cretaceous age.

2. These granites are stock-like, and divided into four bodies, the West mass and East mass in the northern area, Central mass, and Southern mass.

3. 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.

4. The minor element components of granitic rocks are divided into two groups, the tin group comprising Sn, W, Ta, and Nb, and the rare earths group comprising rare earth elements, Th, U, and Y, based on their chemical behavior. Each granite mass has different ratio of the two groups' contents.

5. In the geochemical investigation, the behavior of the path-finder elements is summarized into the two groups.

6. Following four promising areas have been selected, being based on the results of the integrated interpretation of the geochemical characteristics, mineral occurrences, and alteration zones.

① Northern west mass

The mass shows geochemically high contents of both tin and rare earths groups. This fact shows that this mass has high potentiality germinating tin and rare earth ores. Particularly high geochemical anomaly of the tin group in the southern part. The rare earths group's anomaly overlies whole area of the granite. There is potential for tin ores containing rare earth elements.

② Southern mass

The mass geochemically shows high potentiality for both tin and rare earths groups as same as the Northern west mass. Wide spread of the high geochemical anomaly of the tin group in the southern part. Anomalies of the rare earths group are largely distributed along the west rim of the mass. There is high potential for tin ores containing Nb and Ta in the southern part, and for rare earths ores in the western part.

③ Central mass

The potentiality of the both geochemical groups is low in the mass. However the two group's duplicated anomaly are in the western side of the mass, along a river. There is potential for rare earths ores containing tin there. A large geochemical anomaly of Sn and W as well is distributed in the southeastern side of the mass, where many quartz veins exist. There is some potential for subsurface primary ores on the top of a concealed granite body.

④. Khao Fachi Silicified Zone

This is a silicified zone accompanied with white clay derived from sedimentary rocks in the mouth of the River La-Un. A soil geochemical anomaly of the rare earth group and a stream sediment geochemical anomaly of the both tin and rare earth groups are duplicated in the area. The zone is in the northern extension of the Southern mass. There is potential for subsurface primary ores on the top of a expected concealed granite body.

5-2 Recommendations for the Second Phase survey

Four promising areas for Sn, Nb, Ta, rare earths, Th, U, and Y have been selected based on the results of this year's surveys. It is recommended that detailed geological and geochemical survey programs to be conducted in the selected four areas to narrower the targets, and at the same time geophysical survey programs to be conducted to ensure the existence and scale of concealed granite cupolas.

Chapter 1 Satellite Image Interpretation

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 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

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.

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 7 shows the area interpreted.

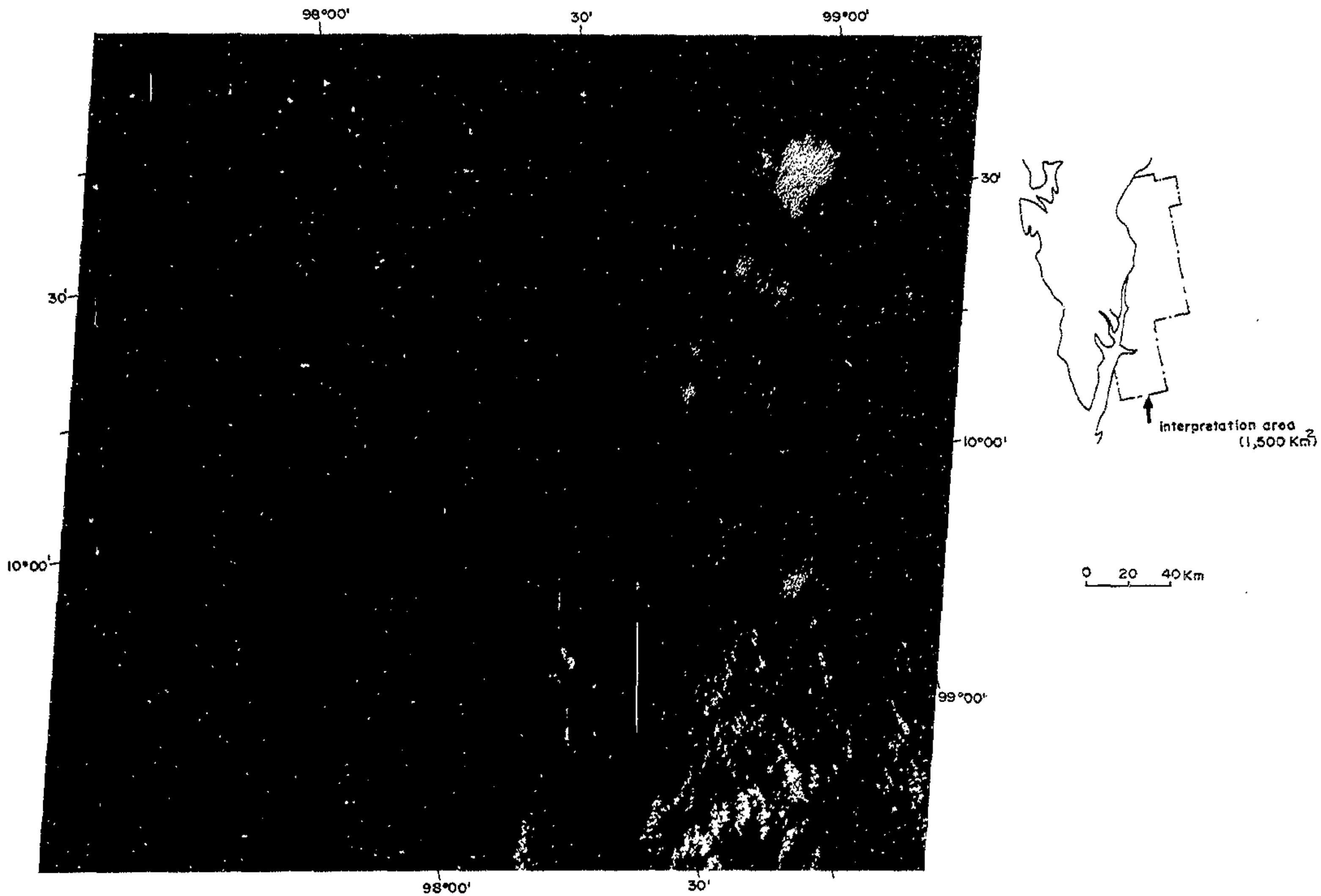


Fig. 7 Area of Landsat image interpretation

1-2 Lineament

Figure 8 and PL-3 show 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

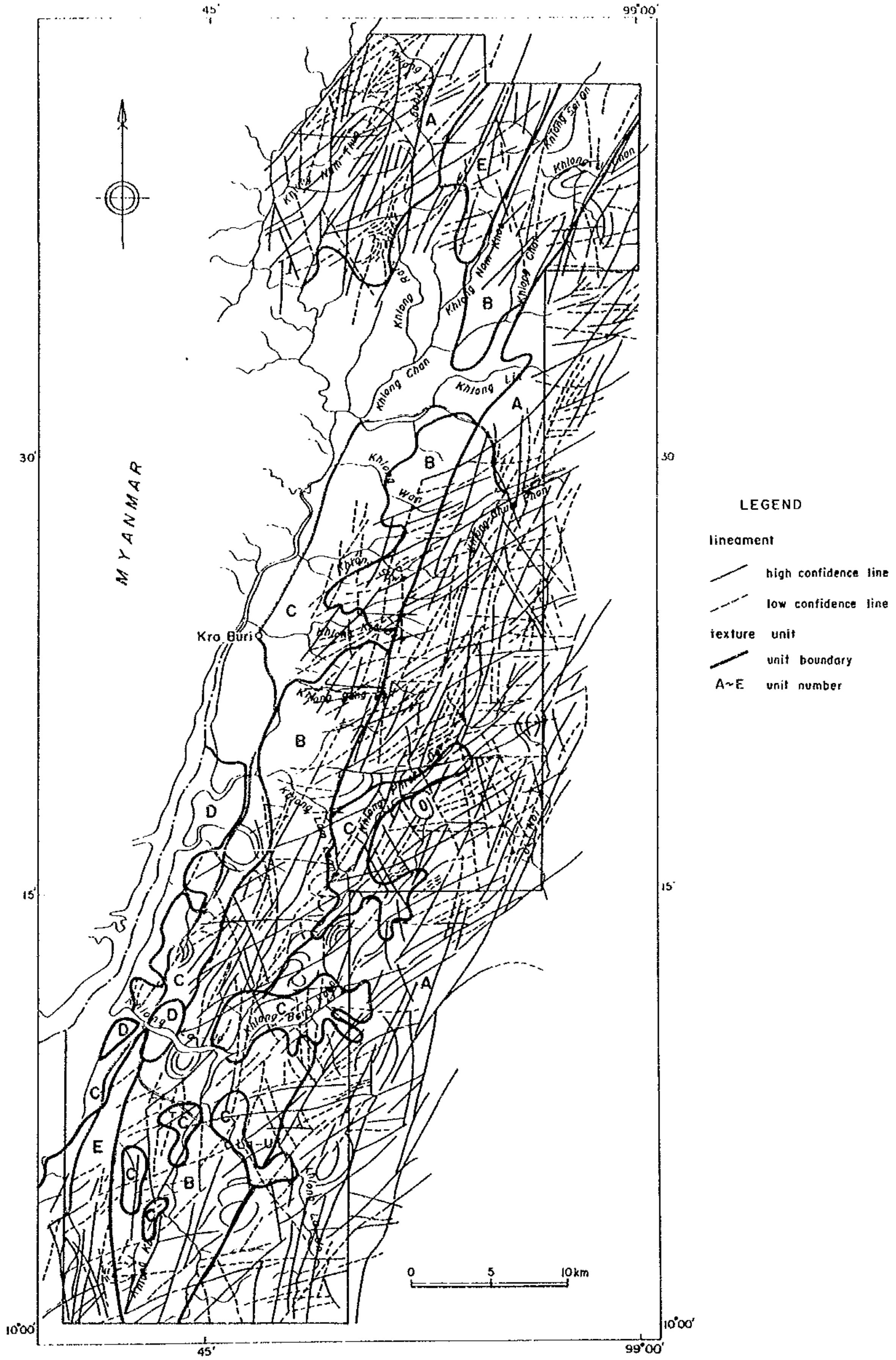


Fig. 8 Interpretation map of Landsat image

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.

Figure 9 shows the frequency distribution diagram of lineaments for each unit of one square kilometer. 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 8 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

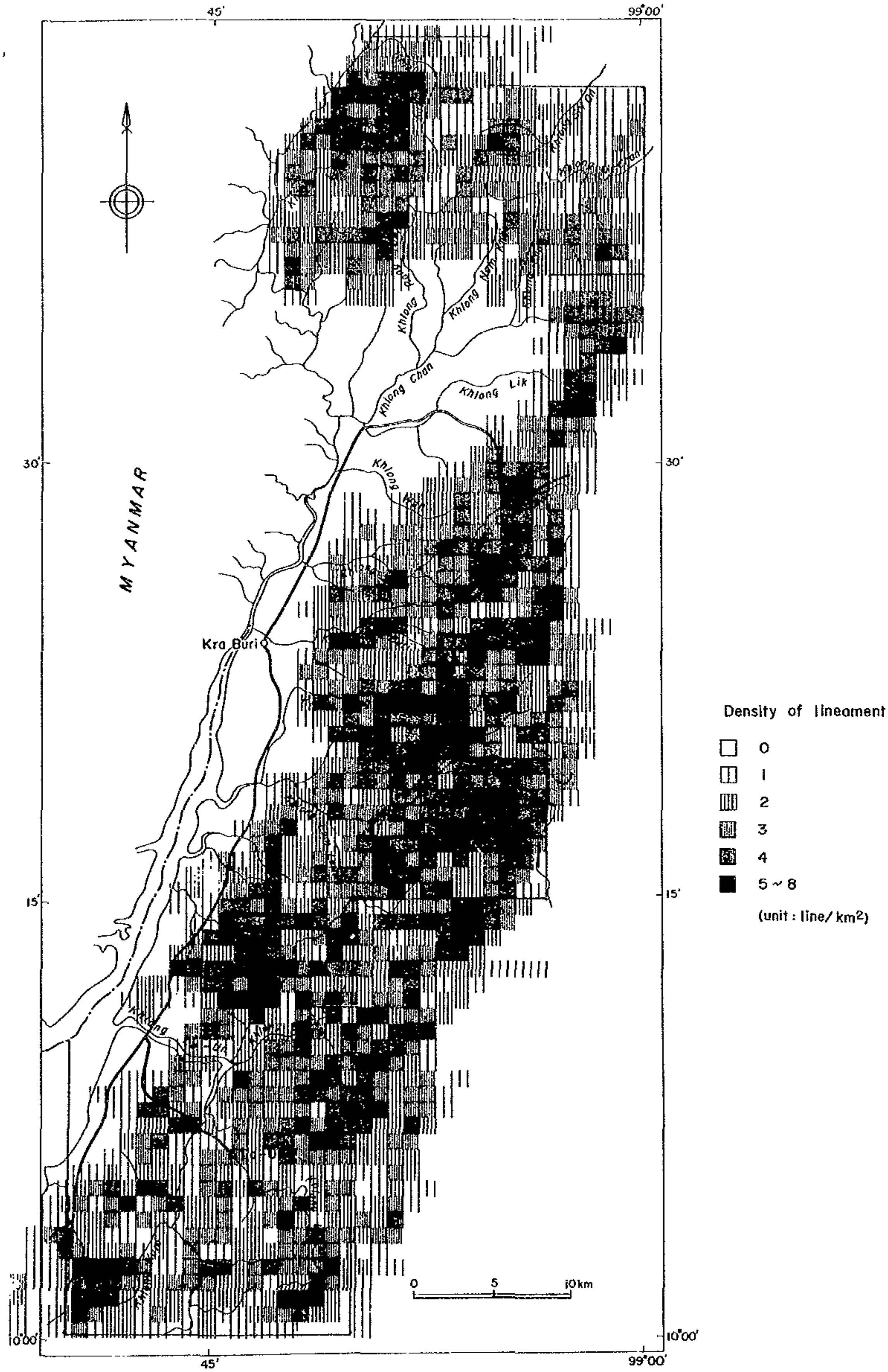


Fig. 9 Density of Lineament

smoothness is coarse to medium, and status of the undulated surface is observed. This category possibly represents some kind of sedimentary rocks.

Category C appears limitedly in the western plain and mountain areas, being controlled by the topography. 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 is in operation at present.

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, Matsi 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 10 and 11 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

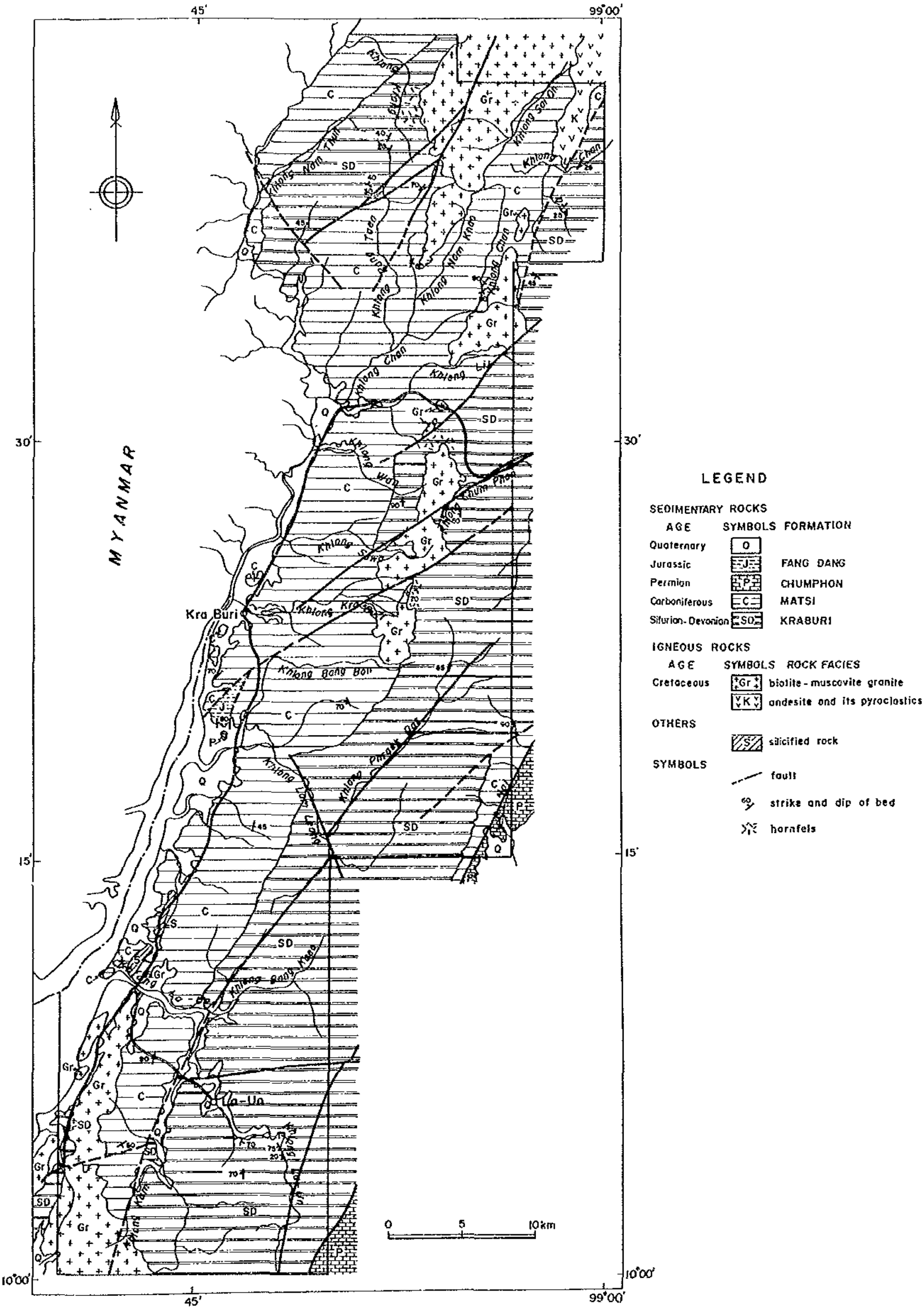


Fig. 10 geologic map

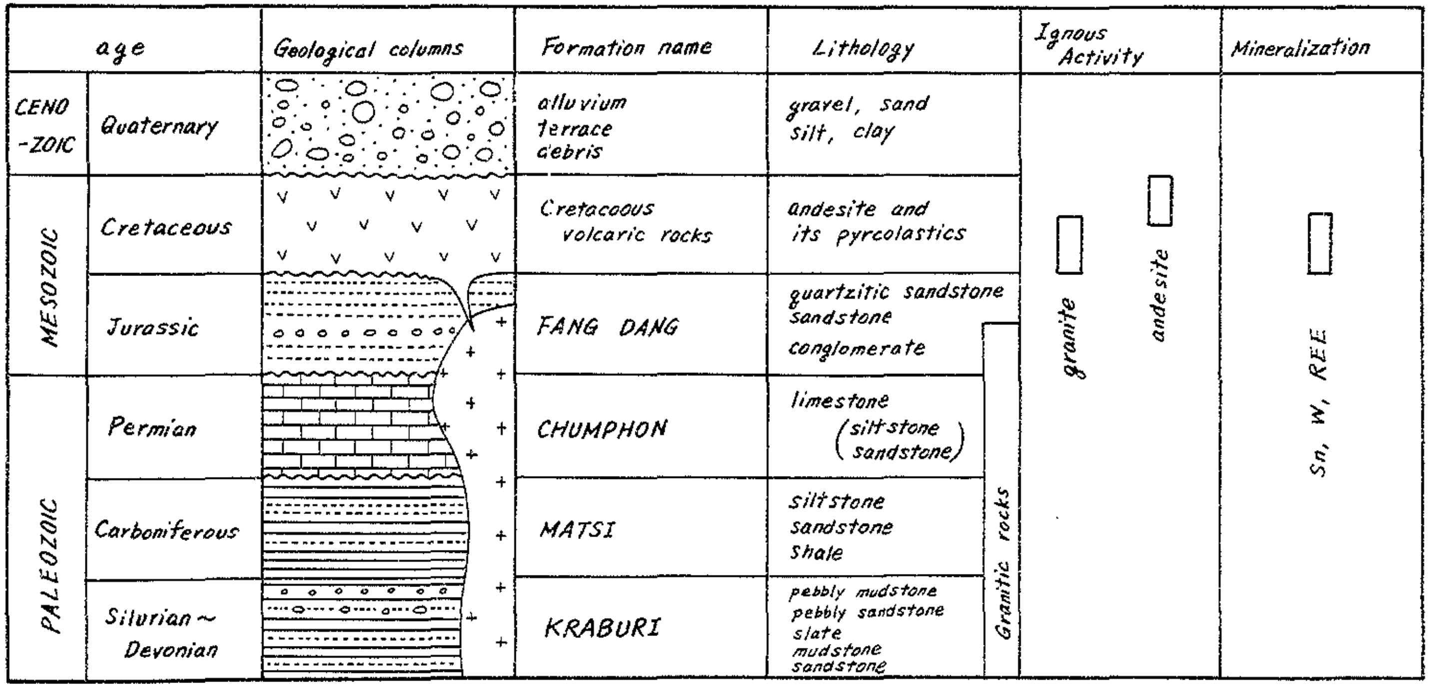


Fig. 11 Schematic geologic column

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, conglomerates 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. Matsi 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 Matsi 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 Matsi 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.

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 Matsi 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.

In this survey, 25 rock samples taken from the four granite masses, 6 from the West mass, 2 from the East mass, 9 from the Central mass, and 8 from the Southern mass, have been chemically analyzed. The results are shown in the table of principal chemical components of rock samples in Appendix 2.

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.13), 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 therefore should be classified into adamellite.

Figure 12 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.14), 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.

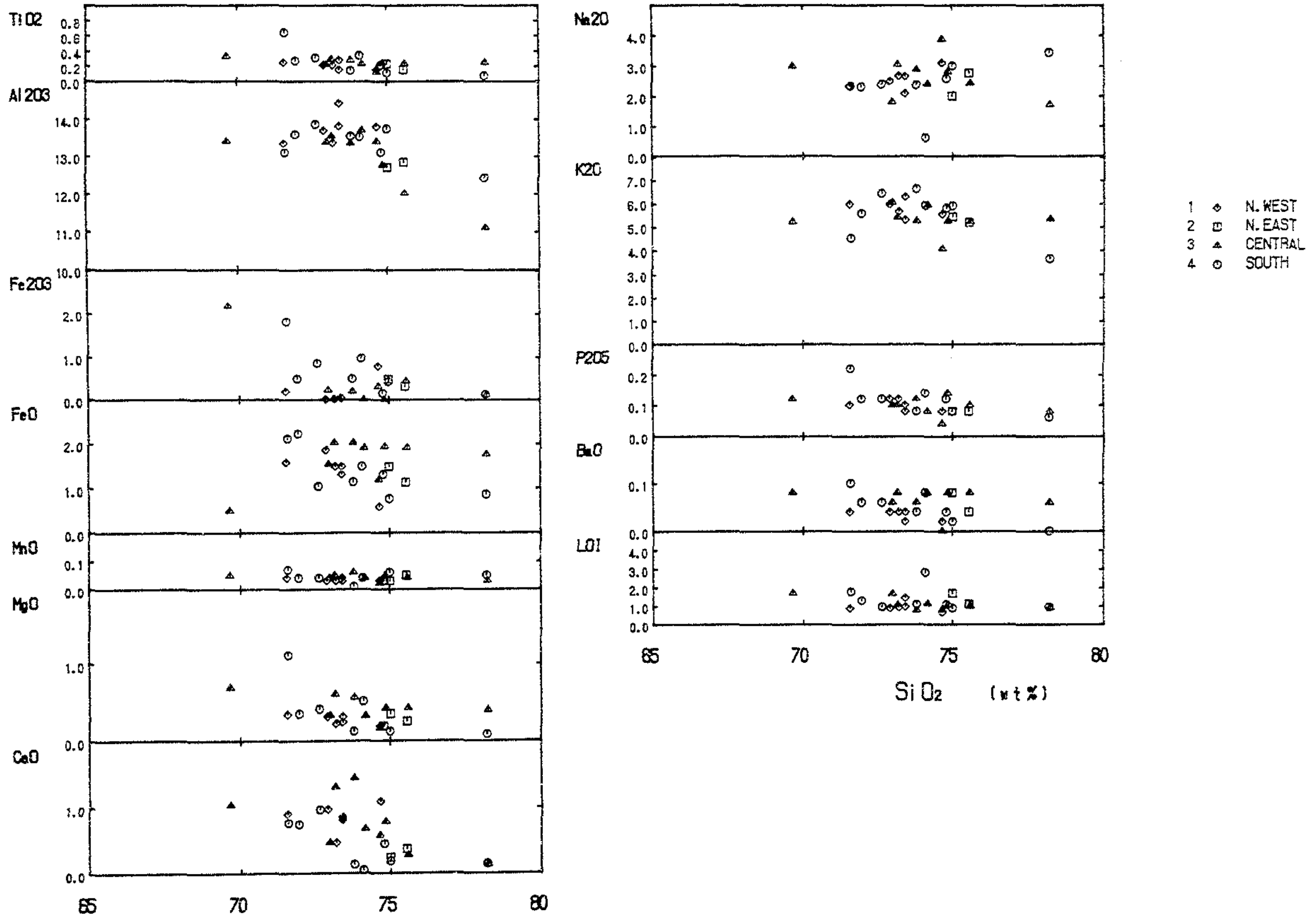


Fig. 12 Variation diagrams of granitic rocks

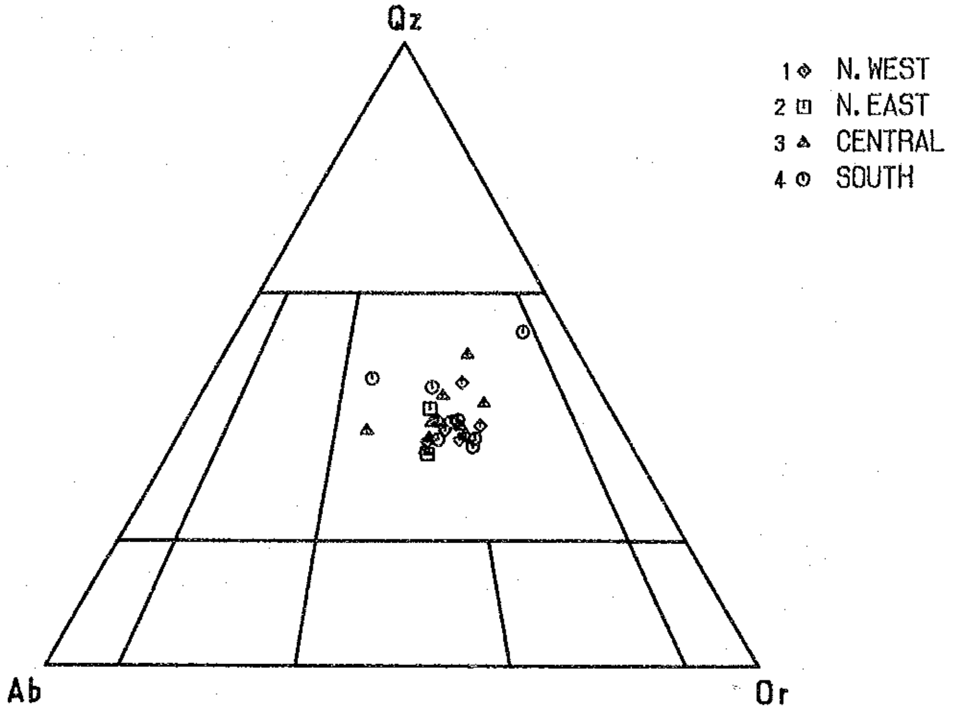


Fig. 13 Normative Qz-Ab-Or diagram

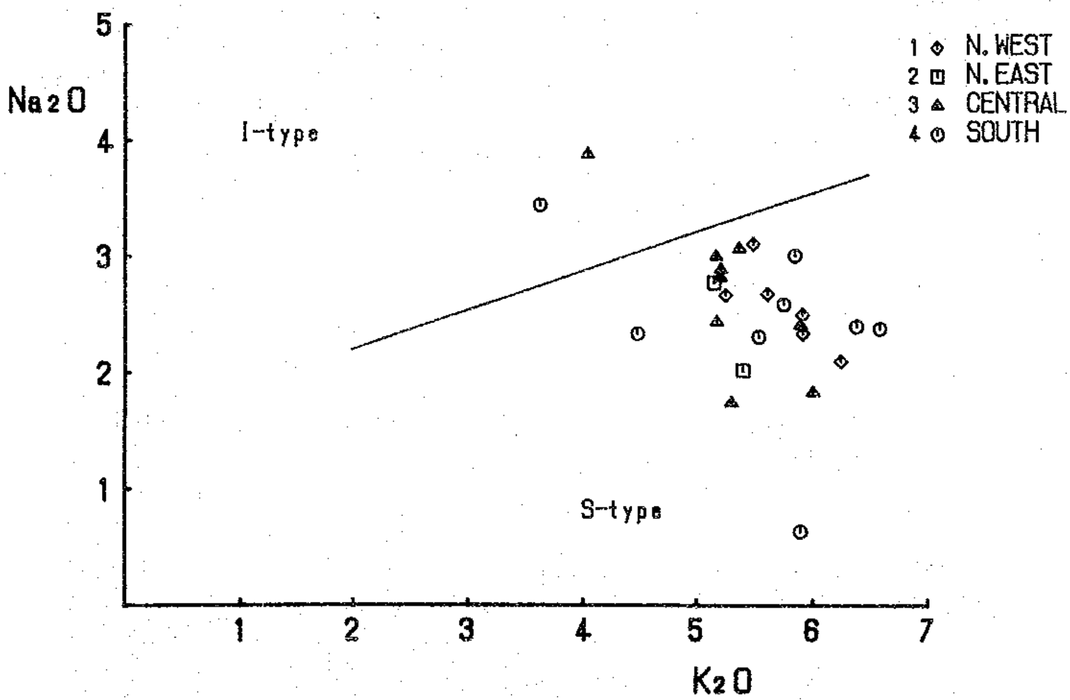


Fig. 14 Na_2O-K_2O diagram

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.15), 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.14).

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

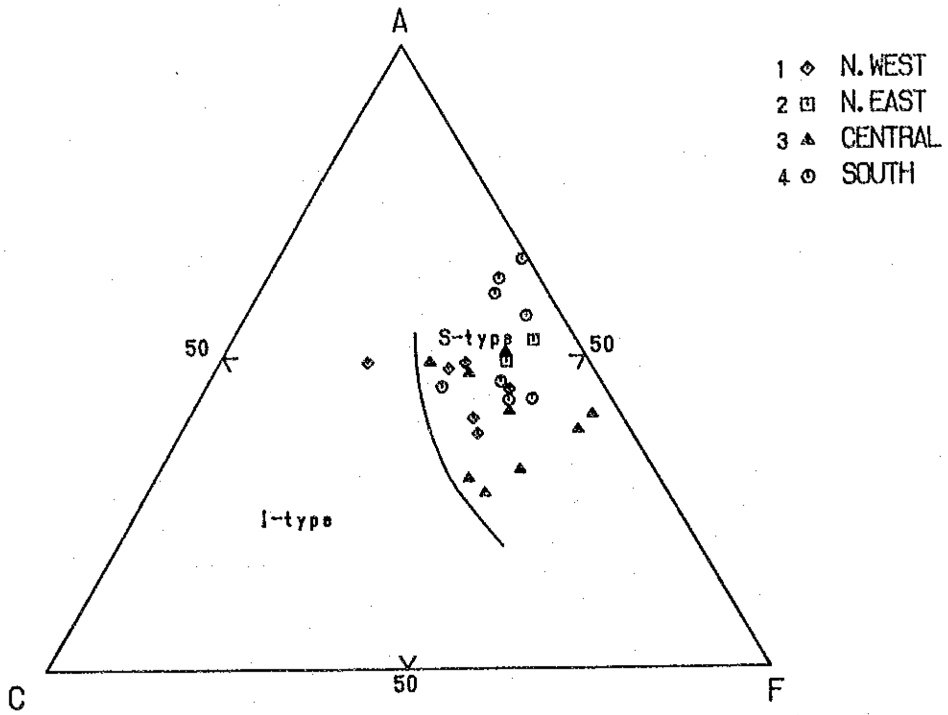


Fig. 15 ACF($Al_2O_3+Fe_2O_3-Na_2O-K_2O/CaO/FeO+MgO$) diagram

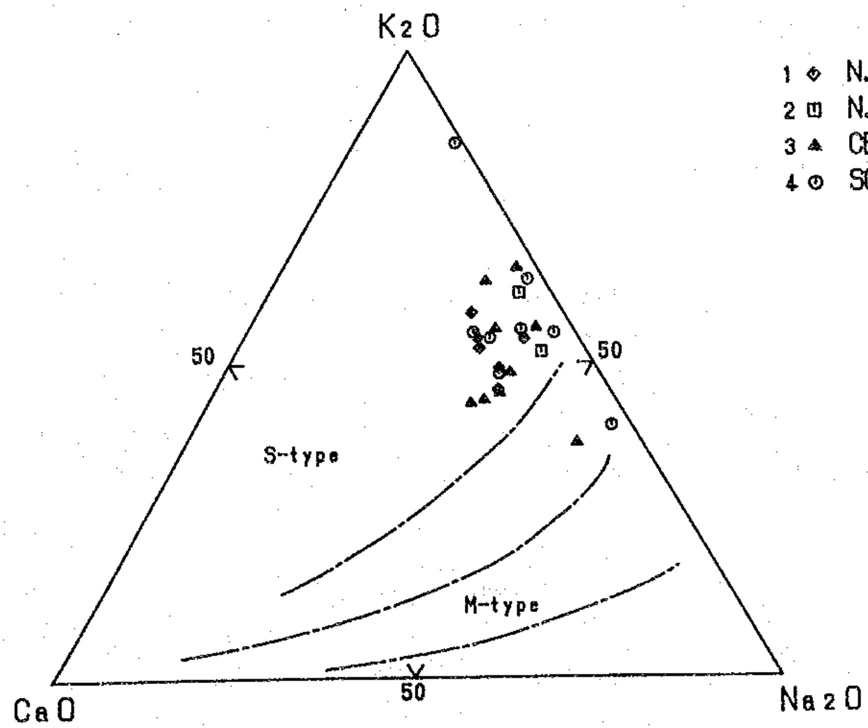


Fig. 16 CNK($CaO-Na_2O-K_2O$) diagram

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

Appendix-3 shows the results of the chemical analysis for 18 minor elements, Sn,W, Ta, Nb, Au, Mo, Th, U, Y, Sc, Ce, Eu, La, Lu, Nd, Sm, Tb, Yb. Table 6 shows the principal statistics of the minor elements.

Table 6 Basic statistics quantities of the minor elements of granitic rocks

Element	Unit	Highest	Lowest	Average	std. Dev.
Sn	ppm	199	8	37.72	39.15
W	ppm	170	<4	14.04	32.82
Ta	ppm	14	2	4.56	2.43
Nb	ppm	54	18	25.95	7.95
Au	ppb	770	<5	34.16	150.20
Mo	ppm	<5	0	0	0
Ce	ppm	230	26	106.2	52.54
Eu	ppm	1.7	<0.2	0.73	0.44
La	ppm	130	14	61.84	32.09
Lu	ppm	1.38	0.2	0.70	0.34
Nd	ppm	110	14	44.36	23.64
Sm	ppm	21	4	9.33	3.97
Tb	ppm	3.7	0.5	1.42	0.72
Th	ppm	140	13	58.76	30.00
U	ppm	39	10	21.12	8.14
Y	ppm	78	21	53.48	15.33
Sc	ppm	9.8	2.3	4.89	1.64
Yb	ppm	10.4	2.17	5.34	2.38

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 corresponded 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 tendency to concentrate in the highly differentiated granites.

Figure 17 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 granites, 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 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

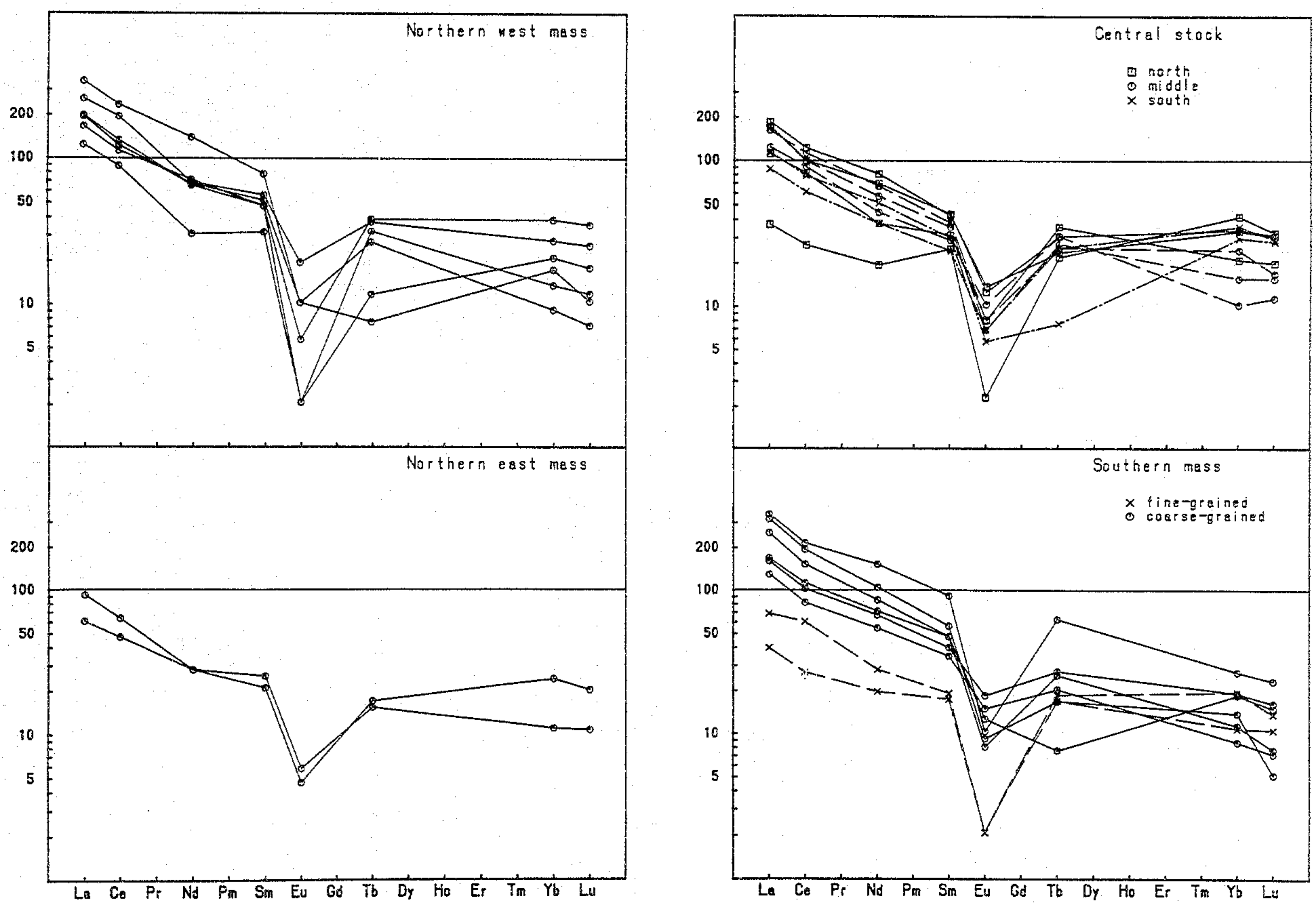


Fig. 17 Rare earth element abundance pattern of granitic rocks

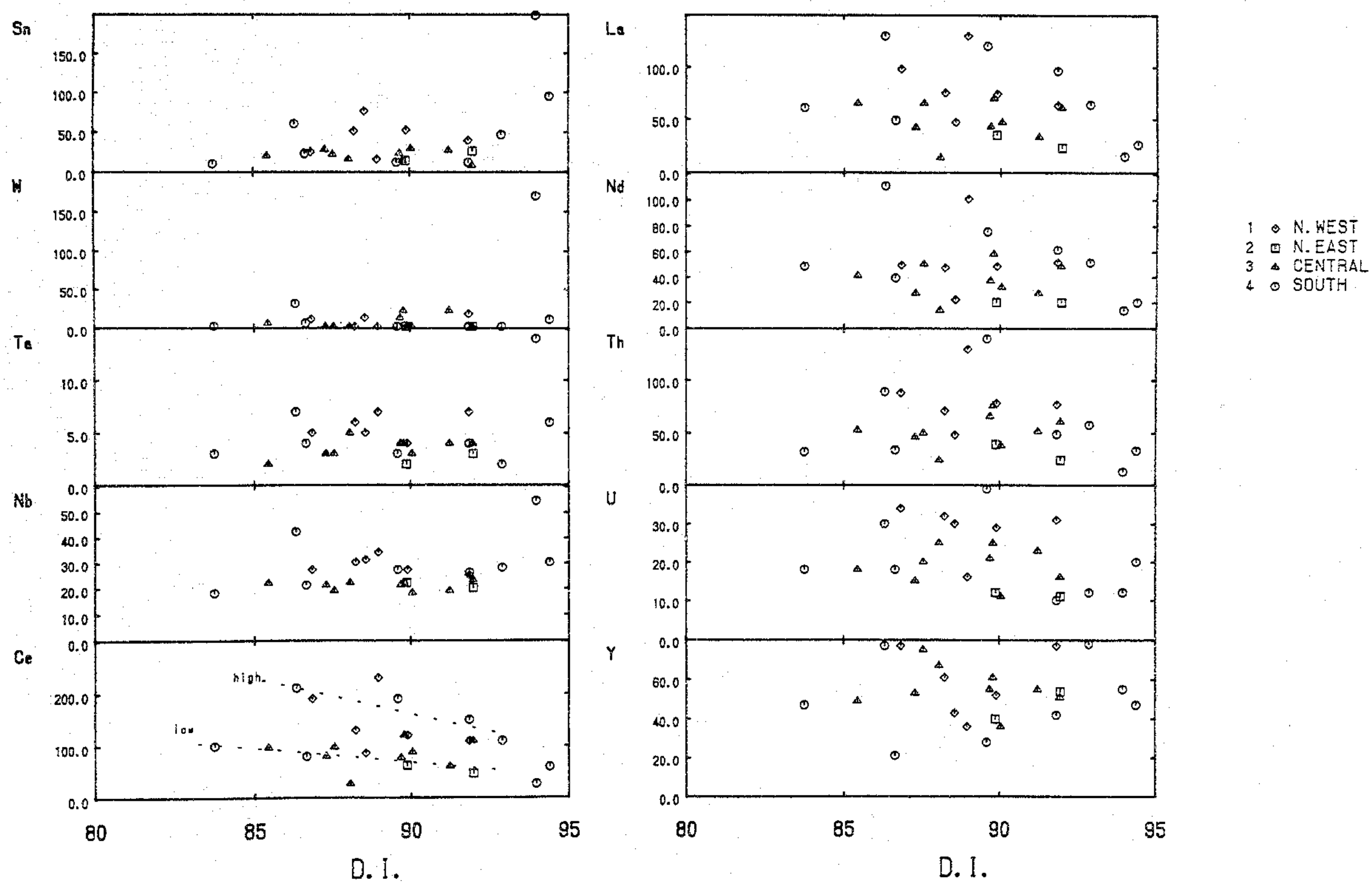


Fig. 18 Variation diagram of minor elements

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 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 19 shows the distribution of tin mineral occurrences.

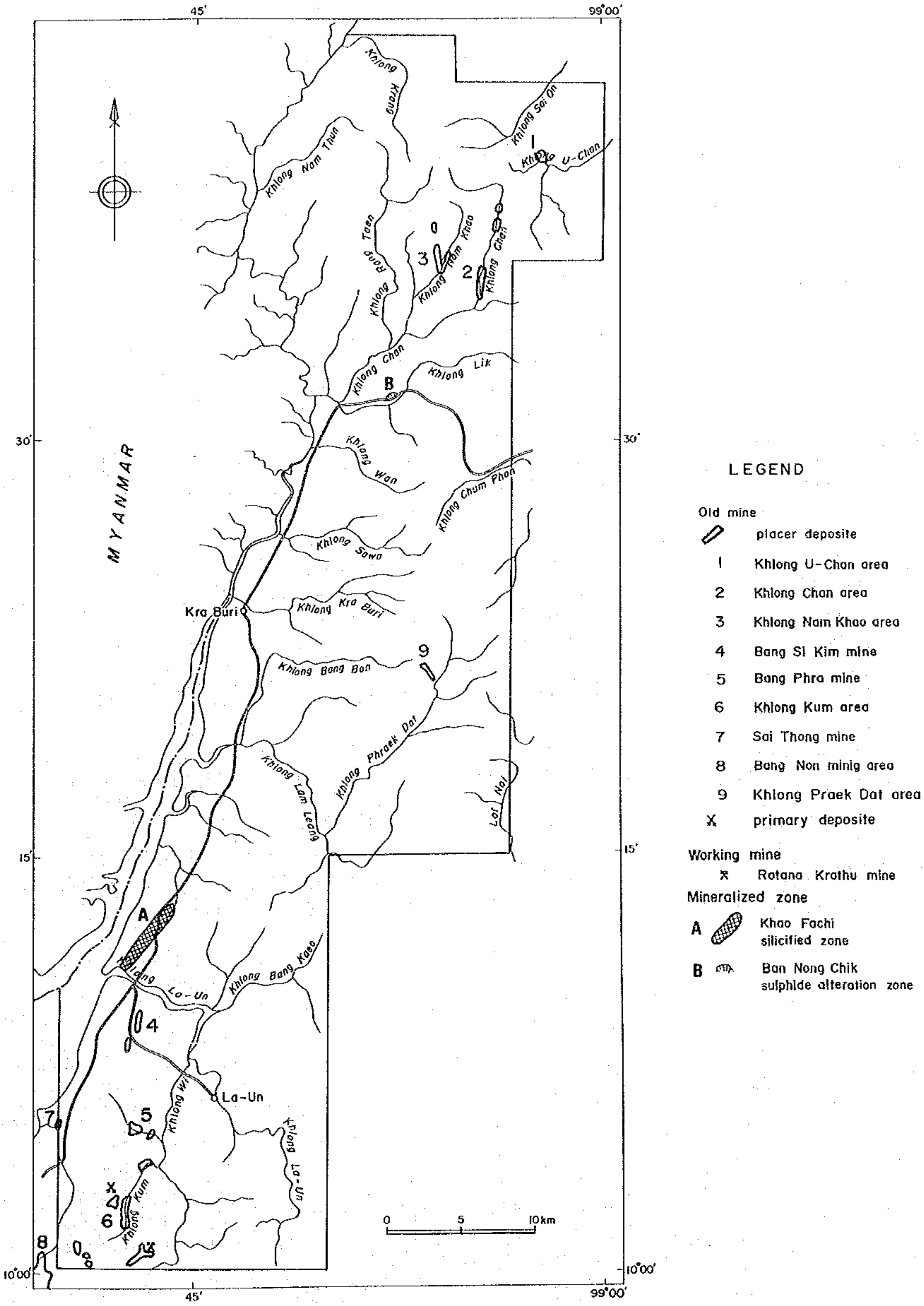


Fig. 19 Distribution of mineralized zones

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.

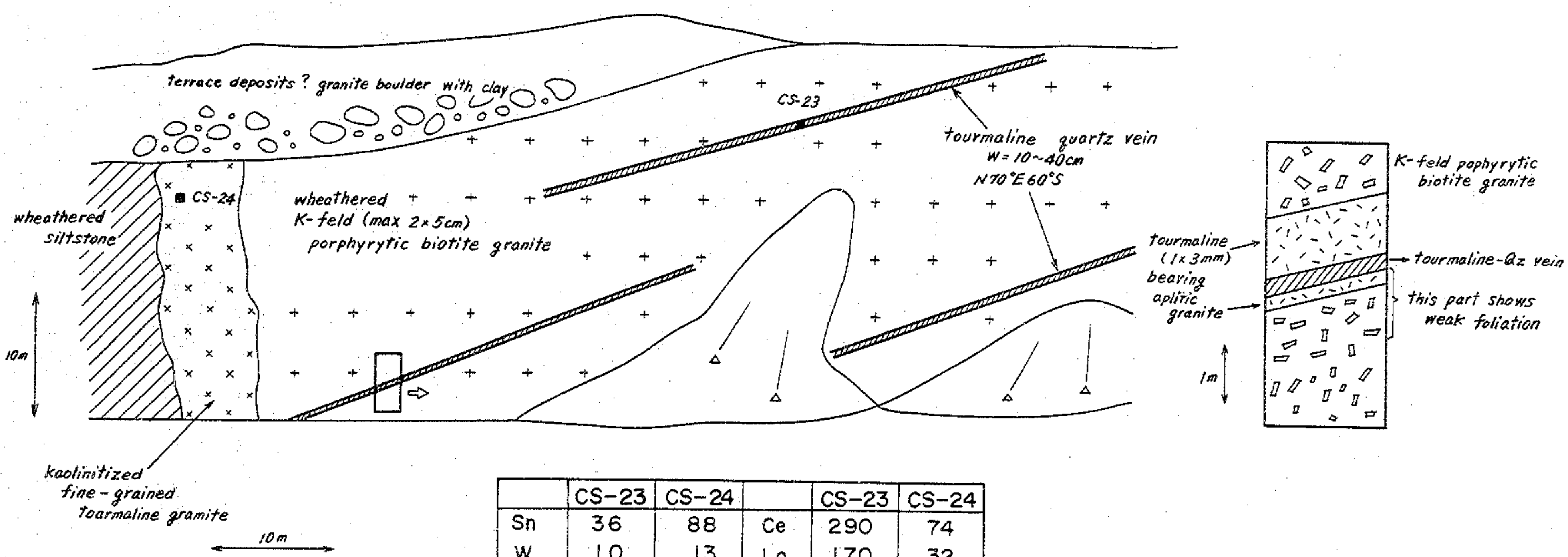
The present owner started operation one year ago after acquisition of the mining right from the Ngan Thawee Co., Ltd. At present, the mine is operated by 10 employees, producing 36 kg of tin concentrates per month. The production comes mainly from the waste of the old workings, which still contains some 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



	CS-23	CS-24		CS-23	CS-24
Sn	36	88	Ce	290	74
W	10	13	La	170	32
Nb	35	111	Na	150	28
Ta	8	31	Th	150	
U	30	9			unit:ppm
Y	75	71			

Fig. 20 Sketch of primary tin deposit to the west of Ban Yai

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. Figure 20 shows the working. 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.

Appendix-5 shows the results of the chemical analysis of the panning samples from the old working area and the concentrate from the Ratana Krathu Mine.

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 Matsi 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 (Fig.21), 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

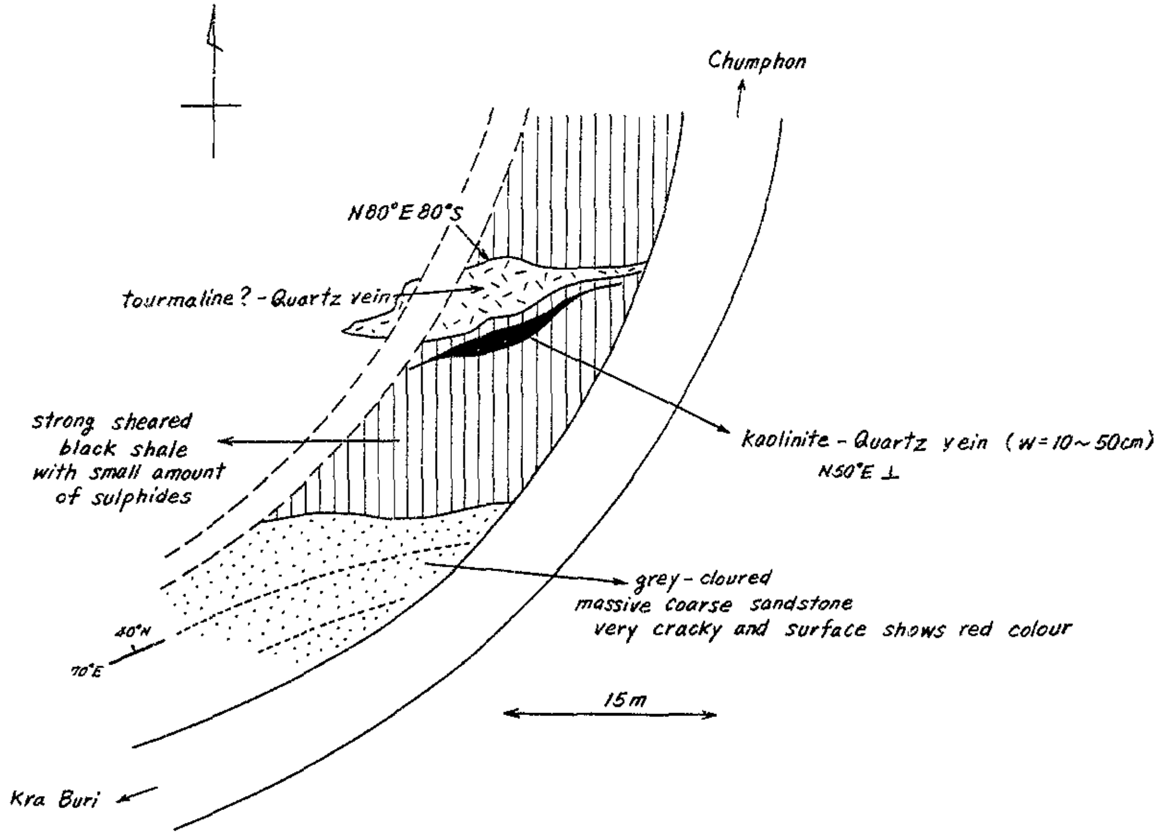


Fig. 21 Sketch of Ban Nong Chik sulphide alteration zone

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. PL- 4 shows the sample locations together with those for the panned samples.

The samples taken were dried, then divided in two portions for the Japanese team and Thailand team. The samples for Japanese were used for chemical analysis.

3-1-2 Pathfinder Elements

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 pathfinders, 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. The detection limit for each element is as follows.

5 ppm for Sn, Mo, and Nd; 4 ppm for W, 3 ppm for Ce;

1 ppm for Ta, Nb, La, and Y; 0.5 ppm for Th, U, Tb;

0.2 ppm for Eu; 0.1 ppm for Sm, and Sc; 0.05 ppm for Lu; 5 ppb for Au.

GSJ rock reference samples have been interposed in every 100 sample to check the accuracy of the analysis.

3-1-3 Analysis of Geochemical data

1. Statistic Processing

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. For the convenience of statistical processing, the half figures of the values lower than the detection limits have been used. Table 7 shows the maximum, minimum, and average values, and the standard deviation for each element. Figure 22 shows the cumulative frequency distribution for each element. The classification of the frequency distribution is based on the figures of 1/2σ.

Table 7 Geochemical basic statistic quantities of Stream Sediments

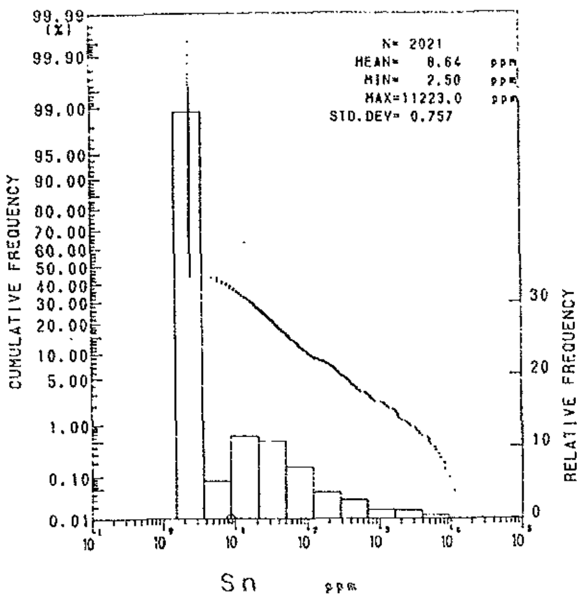
Element	Unit	Max.	Min.	Average	av.ant-log.	Std.Dev.
Sn	ppm	11,223	<5	0.9366	8.64	0.7571
W	ppm	2,600	<4	0.5815	3.86	0.4910
Ta	ppm	440	<1	0.1478	1.41	0.5946
Nb	ppm	480	<2	1.1985	15.79	0.3341
Au	ppb	200	<5	0.4283	2.68	0.1277
Mo	ppm	140	INT	-0.0527	0.89	0.6779
Ce	ppm	2,800	9	1.8090	64.42	0.3759
Eu	ppm	4.4	<0.2	-0.2658	0.54	0.2696
La	ppm	1,700	4	1.5309	33.95	0.3796
Lu	ppm	15.08	<0.05	-0.2156	0.61	0.3899
Nd	ppm	970	<5	1.3843	24.23	0.3892
Sm	ppm	170	0.5	0.6296	4.26	0.3934
Tb	ppm	33	<0.5	-0.2460	0.57	0.4749
Th	ppm	1,500	2.7	1.2579	18.11	0.4550
U	ppm	150	<0.5	0.5581	3.61	0.4780
Y	ppm	1,150	<1	1.4446	27.84	0.4276
Sc	ppm	19	0.7	0.5038	3.19	0.2172

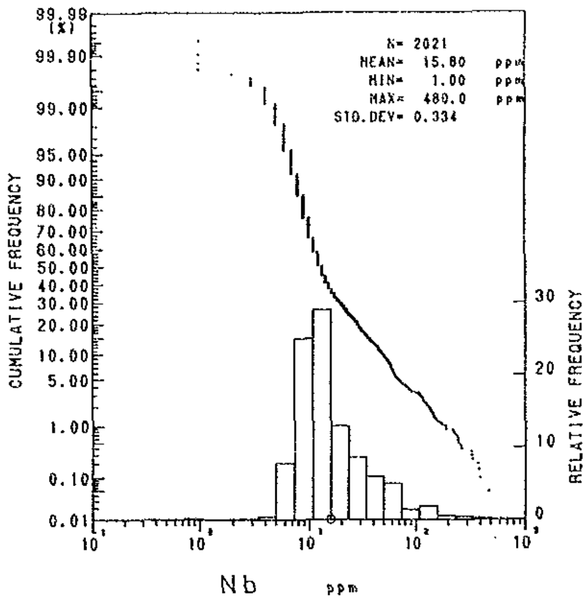
Table 8 shows the correlation coefficients between each element. The group consisting of Sn, W, Ta, and Nb shows strong positive correlations each other. The group consisting of rare earths, Th, U, Y, and Sc shows significantly strong positive correlations each other except to Eu, which shows strong negative correlation. In addition to that, the correlation between the former group and the latter group is significantly strong.

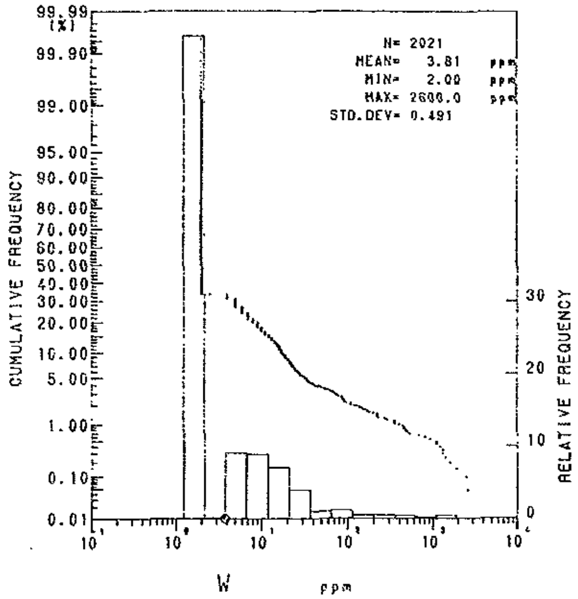
This means that geochemically anomalous values of all detected elements are in well accordance each other, and anomalies for each element are in fact duplicated in the field. The correlation between the two groups tends to be a little weaker than those in the same group elements, due to some rare earth 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

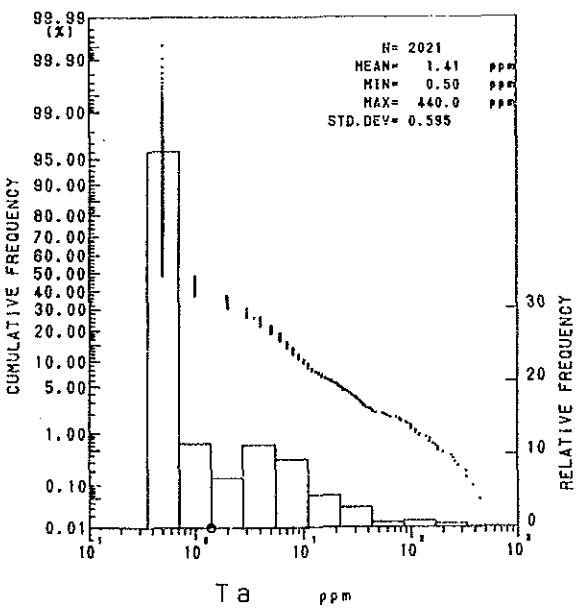
Table 8 Geochemical correlation coefficients of stream sedimennts

	Sn	W	Ta	Nb	Au	Mo	Ce	Eu	La	Lu	Nd	Sm	Tb	Th	U	Y	Sc
Sn	1.000	0.757	0.809	0.720	0.058	-0.455	0.461	-0.101	0.443	0.520	0.424	0.500	0.507	0.502	0.568	0.574	0.321
W	0.757	1.000	0.808	0.761	0.067	-0.470	0.464	-0.067	0.447	0.543	0.432	0.497	0.495	0.523	0.593	0.578	0.409
Ta	0.809	0.808	1.000	0.885	0.089	-0.656	0.646	-0.044	0.621	0.738	0.599	0.686	0.688	0.722	0.791	0.775	0.471
Nb	0.720	0.761	0.885	1.000	0.117	-0.603	0.678	0.035	0.654	0.732	0.631	0.711	0.693	0.737	0.774	0.780	0.552
Au	0.058	0.067	0.089	0.117	1.000	-0.103	0.207	0.070	0.211	0.165	0.199	0.199	0.174	0.196	0.170	0.160	0.100
Mo	-0.455	-0.470	-0.656	-0.603	-0.103	1.000	-0.615	-0.099	-0.600	-0.735	-0.584	-0.635	-0.656	-0.695	-0.776	-0.721	-0.327
Ce	0.461	0.464	0.646	0.678	0.207	-0.615	1.000	0.315	0.994	0.843	0.969	0.991	0.841	0.963	0.832	0.880	0.505
Eu	-0.101	-0.067	-0.044	0.035	0.070	-0.099	0.315	1.000	0.319	0.233	0.341	0.298	0.211	0.242	0.162	0.213	0.288
La	0.443	0.447	0.621	0.654	0.211	-0.600	0.994	0.319	1.000	0.823	0.971	0.988	0.832	0.955	0.815	0.864	0.483
Lu	0.520	0.543	0.738	0.732	0.165	-0.735	0.843	0.233	0.823	1.000	0.810	0.864	0.873	0.884	0.917	0.944	0.496
Nd	0.424	0.432	0.599	0.631	0.199	-0.584	0.969	0.341	0.971	0.810	1.000	0.963	0.812	0.926	0.790	0.843	0.475
Sm	0.500	0.497	0.686	0.711	0.199	-0.635	0.991	0.298	0.988	0.864	0.963	1.000	0.863	0.964	0.847	0.906	0.513
Tb	0.507	0.495	0.688	0.693	0.174	-0.656	0.841	0.211	0.832	0.873	0.812	0.863	1.000	0.862	0.825	0.880	0.409
Th	0.502	0.523	0.722	0.737	0.196	-0.695	0.963	0.242	0.955	0.884	0.926	0.964	0.862	1.000	0.910	0.906	0.497
U	0.568	0.593	0.791	0.774	0.170	-0.776	0.832	0.162	0.815	0.917	0.790	0.847	0.825	0.910	1.000	0.899	0.499
Y	0.574	0.578	0.775	0.780	0.160	-0.721	0.880	0.213	0.864	0.944	0.843	0.906	0.880	0.906	0.899	1.000	0.515
Sc	0.321	0.409	0.471	0.552	0.100	-0.327	0.505	0.288	0.483	0.496	0.475	0.513	0.409	0.497	0.499	0.515	1.000









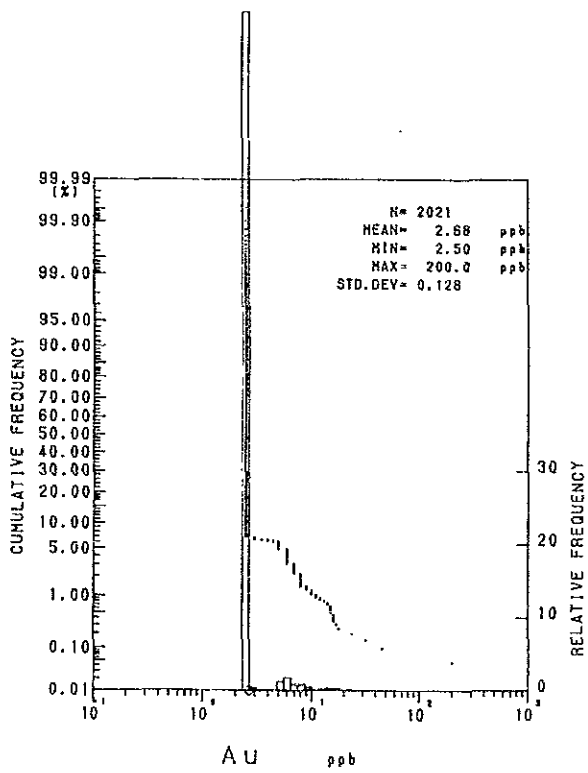


Fig. 22 Relative frequency and cumulative frequency histgram of stream sediments (1)

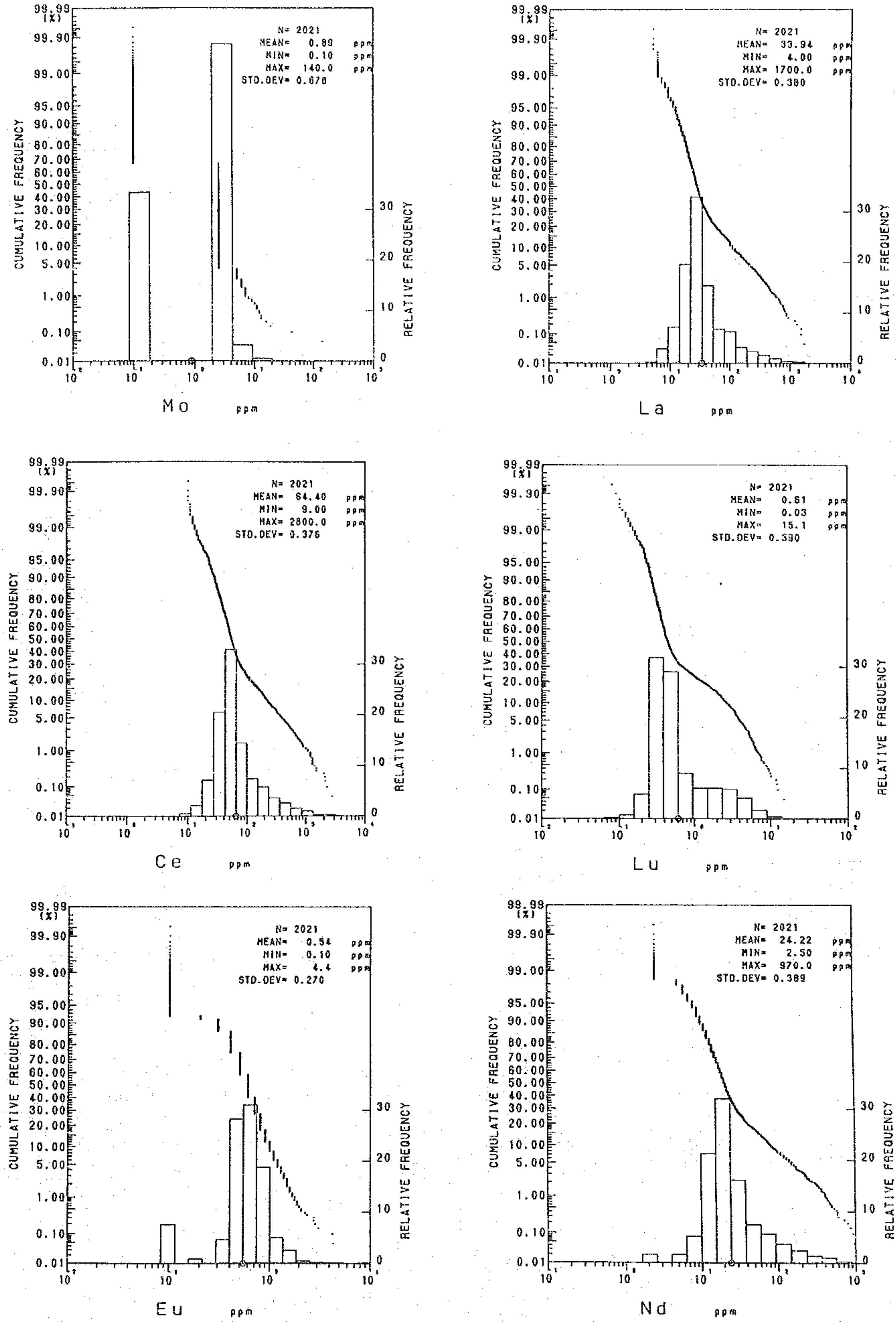


Fig. 22 Relative frequency and cumulative frequency histgram of stream sediments (2)

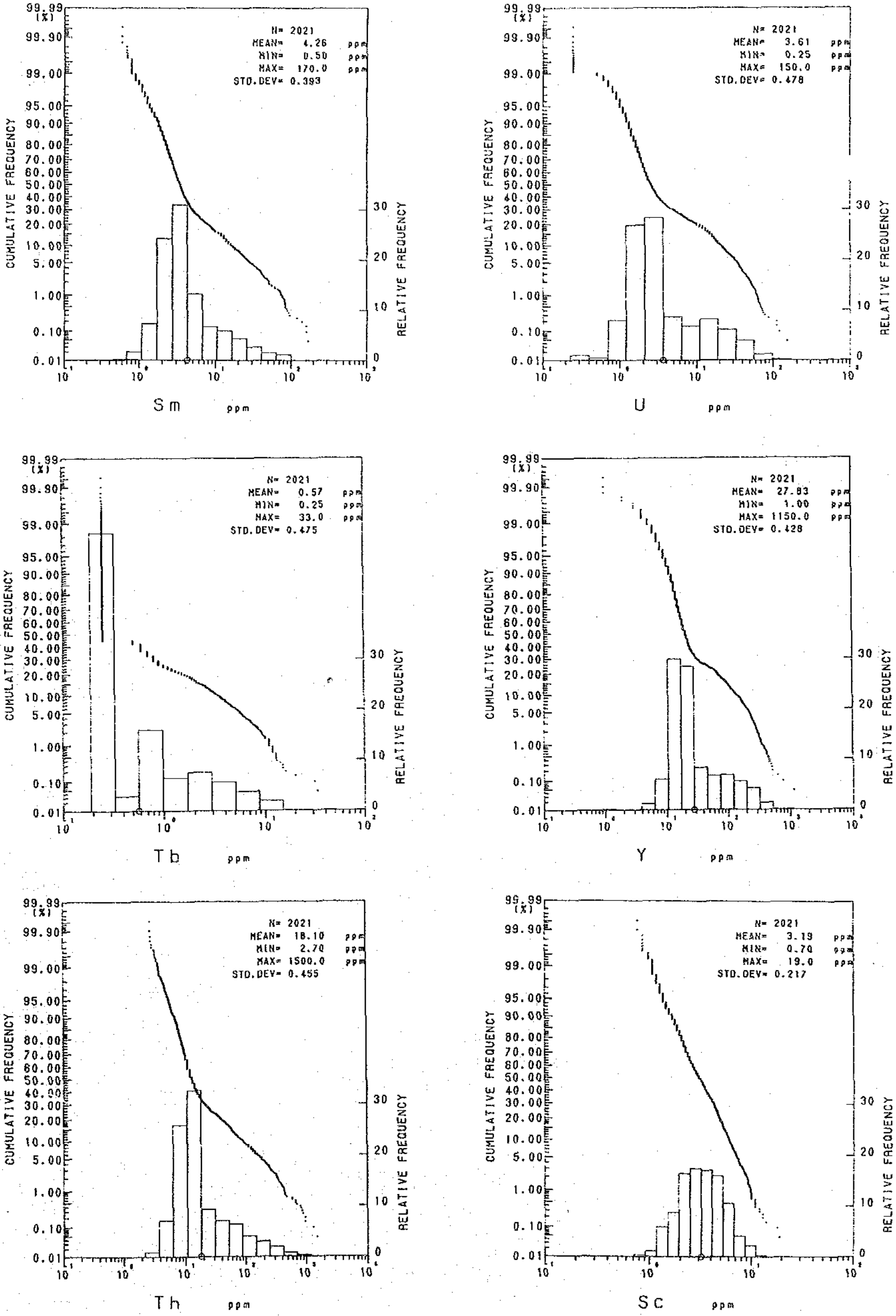


Fig. 22 Relative frequency and cumulative frequency histgram of stream sediments (3)

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.

2. Classification of Anomaly Values

Lepeltier (1969), Sinclair (1976), and Govett et al. (1983) proposed some methods to set thresholds, a way using natural turning points in frequency distribution curves, a way using turning points in accumulated frequency distribution curves, a way using average and standard deviation values, a way based on percentiles, etc.

In this survey, average and standard deviation values together with frequency distribution and accumulated frequency distribution curves have been used to set thresholds. Table 9 shows the thresholds for each element.

Table 9 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. Distribution of Geochemical Anomalies

Figure 23 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.

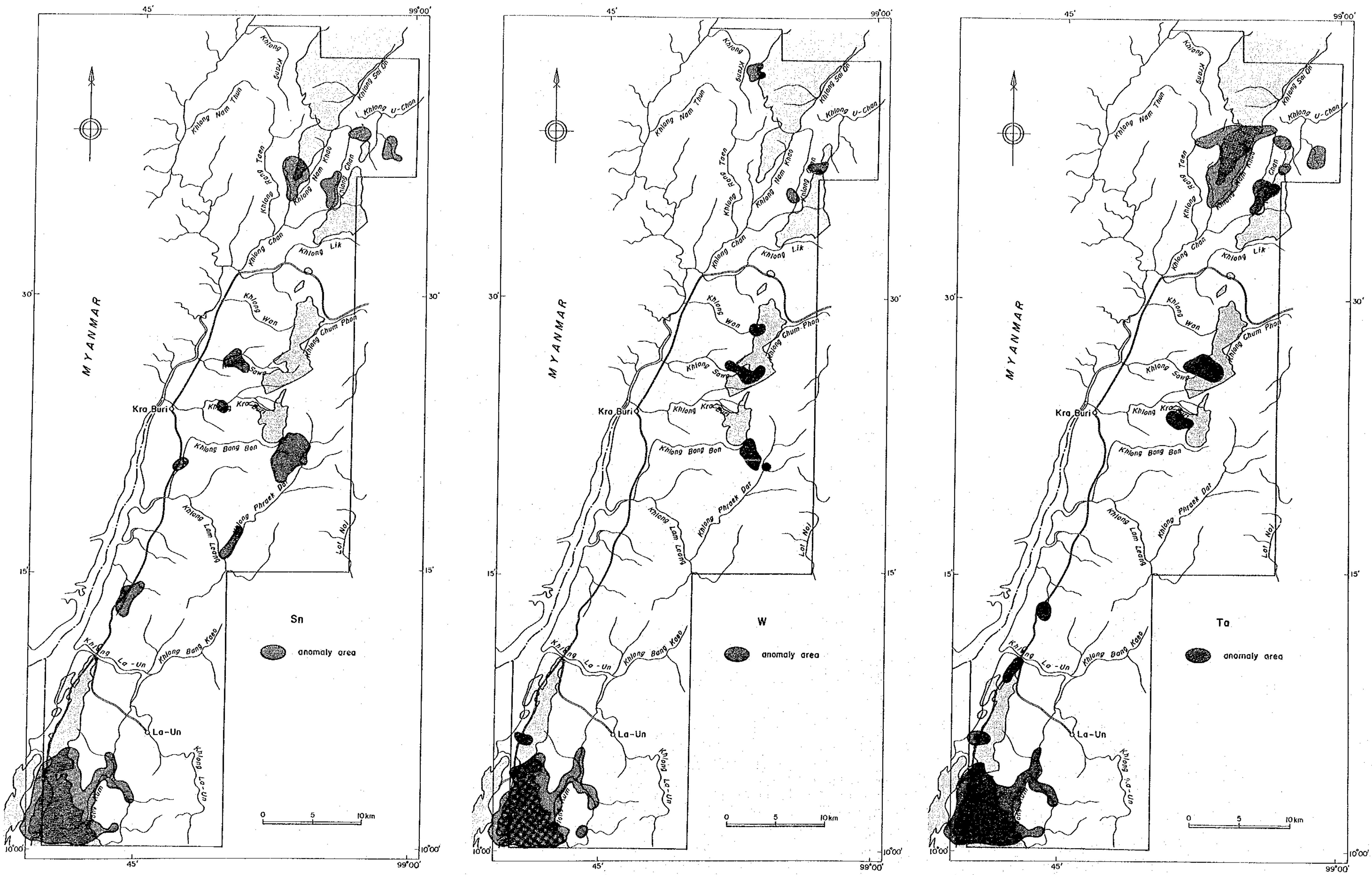


Fig. 23 Geochemical anomaly map of stream sediments (1)

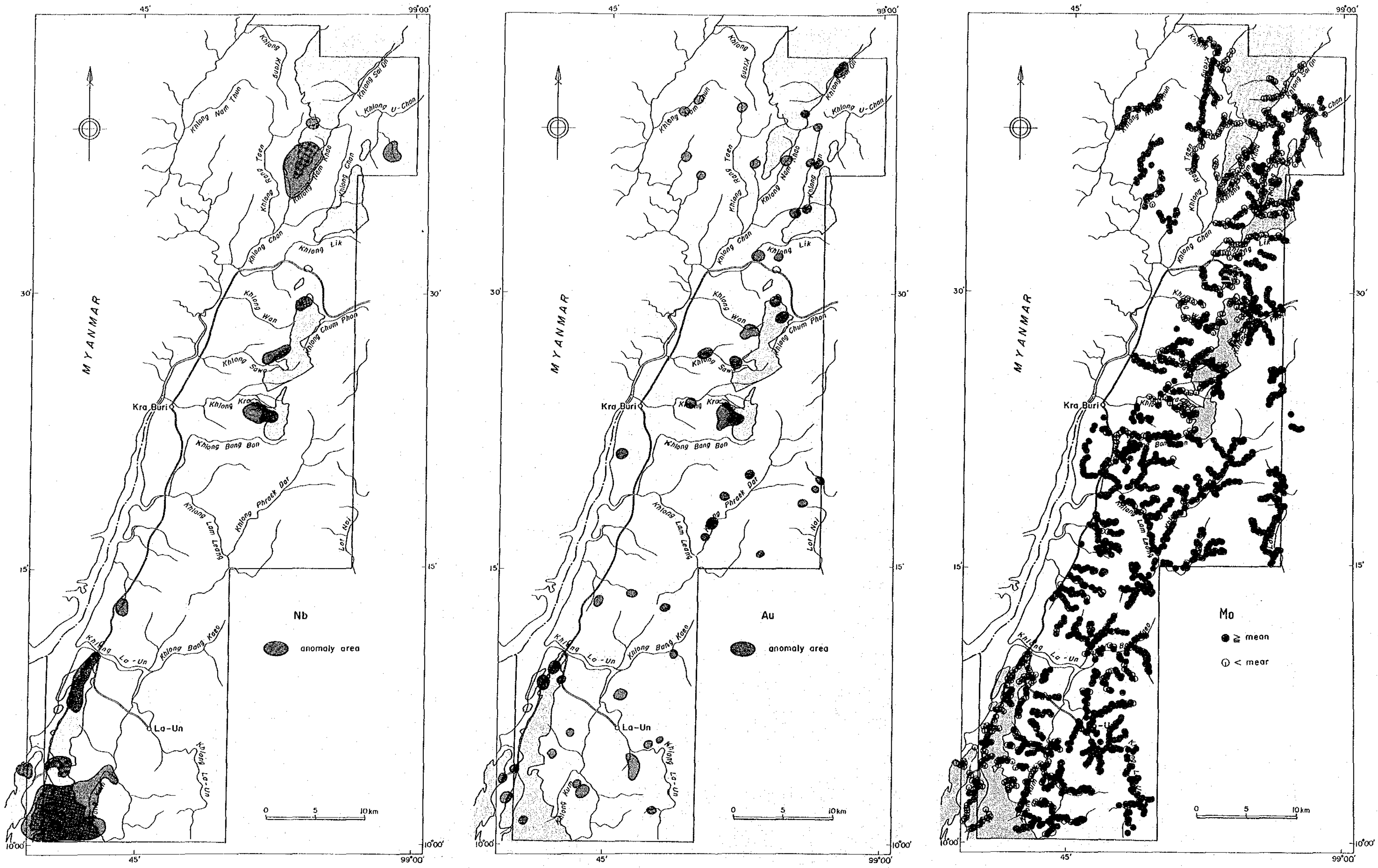


Fig. 23 Geochemical anomaly map of stream sediments (2)

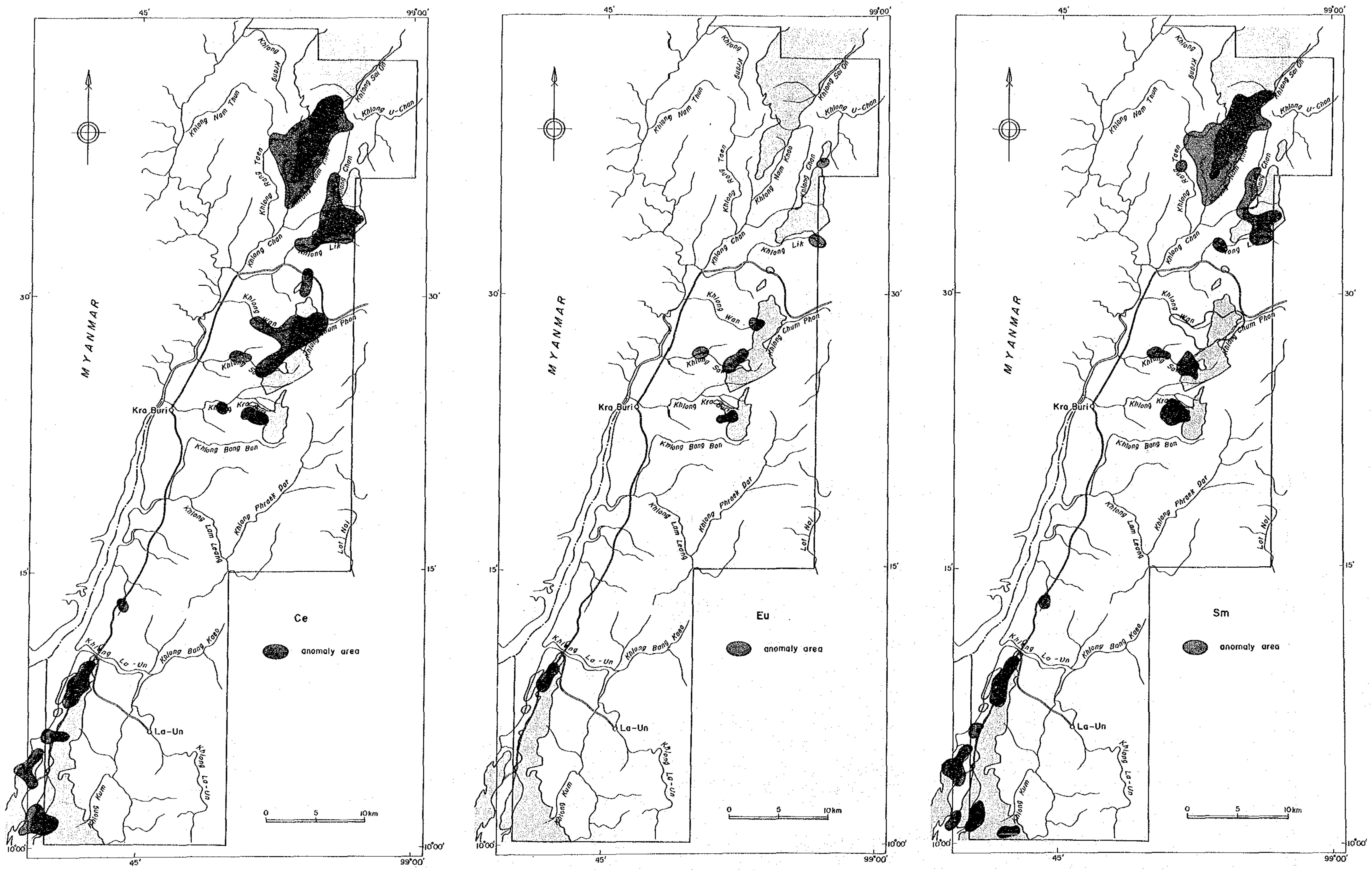


Fig. 23 Geochemical anomaly map of stream sediments (3)