No. 34

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

PHASE II

MARCH 1993

JAPAN INTERNATIONAL COOPERATION AGANCY

METAL MINING AGENCY OF JAPAN

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93-019

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PREFACE

In response to a request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a Mineral Exploration in the Kra 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 a survey team headed by Mr. Hiroyuki Takahata to the Kingdom of Thailand from June 17 to August 14, 1992.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Kra Buri Area. 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.

October, 1992

Kensuke Yanagiya

President

Japan International Cooperation Agency

Takashi Ishikawa

President

Metal Mining Agency of Japan

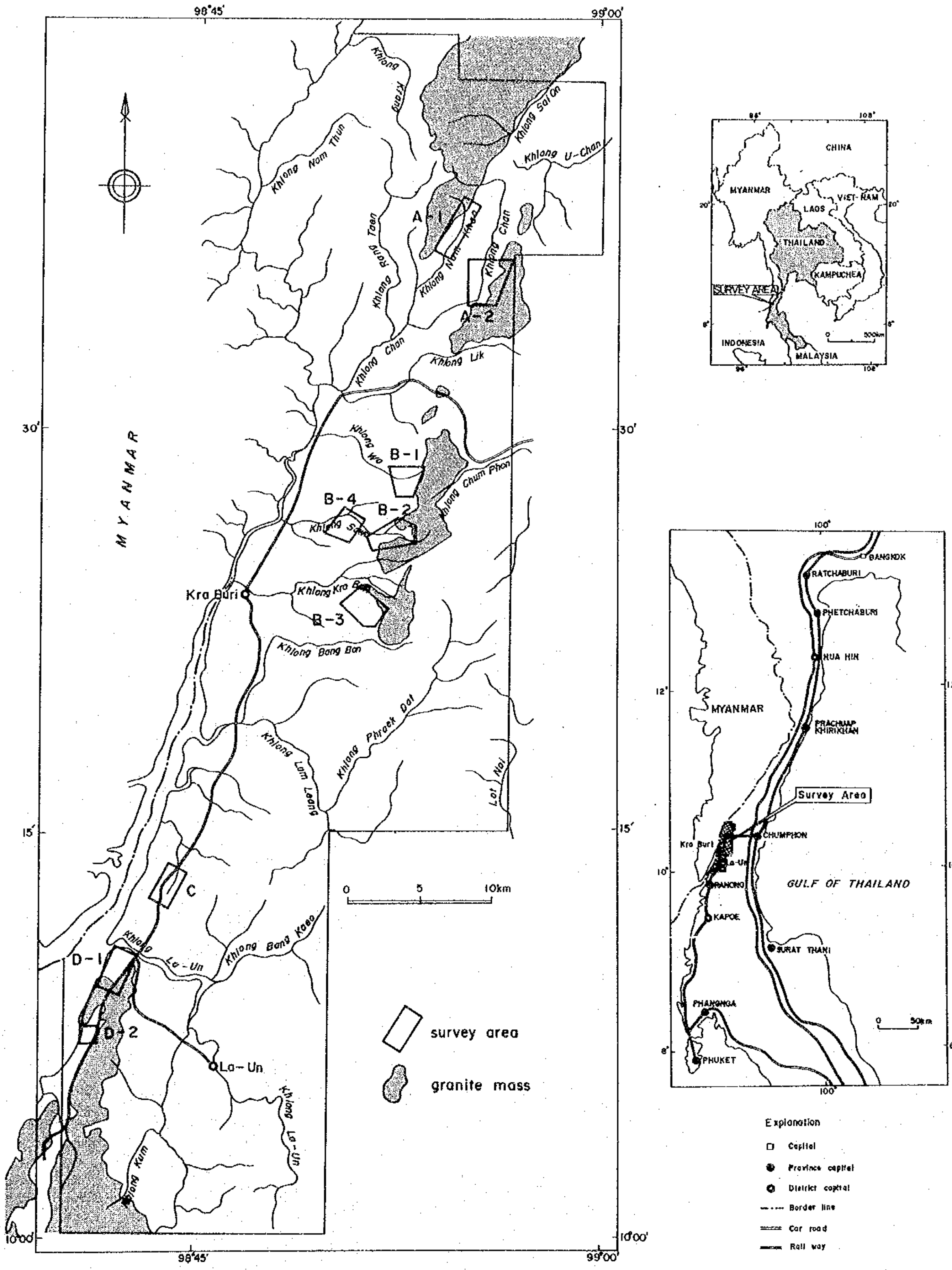

Fig. 1 Location map of the survey area

SUMMARY

In the Kra Buri Area, the detailed soil geochemical prospecting was conducted as the second phase program of the Cooperative Mineral Exploration Project. Nine areas were selected from the anomaly zones detected by the first year program. The purpose is mainly to delineate the extension of alluvial basins containing placer deposits, also to evaluate the possibility of primary deposits and adsorption-type rare earth deposits.

From the detailed geochemical exploration, it has been made clear that the geochemistry of two pathfinder groups, namely tin group (Sn, W, Ta, Nb) and rare earth group (REE, Th, U), shows the different geochemical characteristics in the granite masses. The anomaly areas of the tin group elements are found in the extremely high differentiated part that sits in the uppermost part of the granite masses, whereas those of the rare earth group are found in the low differentiated part under the uppermost part. It is inferred that the crystallization of rare earth minerals occurred at the earlier differentiation stage than that of tin and tungsten minerals.

The potentiality of placer tin deposits and rare earth deposits are evaluated as follows:

(1) In Area A-1, anomaly zones are distributed in four places such as the northern, central, southeastern and southwestern parts of this area. They overlap with the distribution of talus deposits and alluvial sediments. The reserves of cassiterite and rare earth minerals are estimated to be 1.31 million m^3 (at a tin content of 0.126kg/m^3) and 2.20 million m^3 (at a monazite content of 1.315kg/m^3 and a xenotime content of 0.236kg/m^3) respectively.

(2) In Area A-2, rare earth contents of non-argillized granite are higher than those of argillized facies; thereby this area has a very low potential of adsorption-type deposits. The geochemical anomalies indicate a small placer deposit reserving less than 300 thousand m^3.

(3) In Area B-1 to B-4, alluvial basins lie narrowly along rivers surrounded by mountains and hills. The reserves in area B-1 to B-4 are 60 to 300 thousand m^3 respectively. Ore grade is also low.

(4) In Area C, the geochemical anomaly of tin is caused by silicified rocks in the north. The anomaly of rare earth elements is found in the southeast. The reserves of cassiterite and rare earth minerals are estimated to be more than 100 thousand m^3 and about 600 thousand m^3 respectively, but they are low grade.

(5) In Area D-1, mangrove mud covers widely in the west. Though markedly anomaly values are not found in a mangrove mud, some anomalies are detected from the samples in the edge of eastern mountains and the bottom of creeks in a mangrove area. It is inferred that the potential for placer deposits exists under a mangrove mud. The reserve of rare earth ore is estimated at 7.5 million m^3 (at a monazite content of 1.480kg/m^3 and a xenotime content of 0.167kg/m^3) and that of tin ore at 14.55 million m^3 (at a cassiterite content of 0.222kg/m^3). These reserves are the largest in this program.

(6) In Area D-2, mangrove mud covers widely. It is also inferred that a placer deposit exists under a mangrove mud in this area. The reserve is estimated to be 1.6 million m^3, but it is low grade.

It can be stated that further investigation is recommended at Area A-1 and D-1, because their reserves are relatively large. The normal drilling or 'Banka' drilling is proposed to confirm directly the reserves and grades in both areas.

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PART I GENERAL REMARKS

Chapter 1 Introduction

1-1 Background

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

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 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. On the basis of 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 Conclusion and recommendation of the first phase survey

1-2-1 Conclusion

In the first phase, 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 at Cretaceous time.
2. These granites are stock-like forms 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 and ilmenite series granite. They are also 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. One is the tin group comprising Sn, W, Ta, and Nb, and the other is the rare earth elements 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 on the basis of the integrated interpretation of the geochemical characteristics, mineral occurrences, and alteration zones.

   i. Northern west mass

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

ii. Southern mass

This mass geochemically shows high potentiality for both tin and rare earth elements groups as same as the Northern west mass. The high geochemical anomaly of the tin group spreads widely in the southern part. Anomalies of the rare earth elements 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, whereas for rare earth element ores in the western part.

iii. Central mass

The potentiality of the both geochemical groups is low in this mass. However anomalies of both elements groups were detected in the western side of the mass along a river, there is potential for rare earth elements ores containing tin. A large geochemical anomaly of Sn and W is distributed in the southeastern side of this mass, where many quartz veins exist; thereby some potential for subsurface primary ores exists on the top of a concealed granite body.

iv. Khao Fachi Silicified Zone

This silicified zone is accompanied with white clay derived from sedimentary rocks in the mouth of the Khlong (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 an expected concealed granite body.

1-2-2 Recommendation

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

1-3 Contents of the second phase survey

1-3-1 Surveyed area

The survey area is situated in the northern part of the Malay Peninsula of Thailand. This area 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.

Nine sub-areas are prospected in the second phase survey; Area A-1 and A-2 around northern granitic mass; Area B-1, B-2, B-3 and B-4 beneath of Central granite mass; Area C closed to Khao Fachi silicified zone and Area D-1, D-2 on the West of Southern granite mass. These were mainly selected from the four promising areas of the first phase survey to examine placer deposits.

Total area of nine sub-areas is 14.7km^2. Each sub-area overlaps with geochemical anomaly zone in the first phase survey which correspond to granite mass or silicified zone, and has high potential for placer and primary ore deposits as cassiterite and rare earth minerals.

1-3-2 Objective of survey

The objective of the survey is to examine situation of mineral resources for niobium, tantalum, tin, tungsten, uranium and rare earth elements by means of geological and geochemical surveys, and to select promising areas for primary and placer deposits.

This survey is conducted as second phase of the cooperative mineral exploration in the Kra Buri Area, the Kingdom of Thailand which is high potential area for rare earth deposits. The main objective of the survey is to delineate the promising areas for placer deposits through considering the relationship between geological situation and detailed geochemical prospecting.

1-3-3 Method of survey

The soil geochemical sampling program is designed on the topographic maps on the scale of 1:5,000 that is enlarged from original maps on the scale of 1:50,000.

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

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

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

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

Table 1 Contents of survey

1. Geochemical survey:	
- area surveyed	
Area A	6.0 km^2
Area B	2.5 km^2
Area C	1.8 km^2
Area D	4.4 km^2
total	14.7 km^2
2. Sampling:	
(1) Soil samples for geochemical analysis	
Area A	1,204 samples
Area B	507 samples
Area C	362 samples
Area D	450 samples
total	2,523 samples

(2) Rock samples for:

	- thin section	11 samples
	- X-ray diffraction	12 samples
	- geochemical analysis	13 samples

(3) Ore samples for:

	- polish section	22 samples
	- EPMA	5 samples
	- geochemical analysis	56 samples

3. Chemical analysis:

Soil samples	Sn, W, Ta, Nb, Ce, Eu, La, Nd, Sm, Tb, Th, U, Y, Gd, Dy, Pr	2,523 pieces
Ore samples (Panned samples)	Sn, W, Ta, Nb, Ce, Eu, La, Nd, Sm, Tb, Th, U, Y, Gd, Dy, Pr	56 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, Ce, Eu, La, Nd, Sm, Tb, Th, U, Y, Gd, Dy, Pr	13 pieces

1-3-4 Personnel of survey mission

Japan

Coordination and Planning

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

Geochemical Survey Team

Hiroyuki TAKAHATA	Geologist
Yasunori ITO	ditto
Makoto MIYOSHI	ditto

Thailand

Coordination and Planning

Thawat Japakasetr	Dept. of Mineral Resources
Phairat Suthakorn	ditto

Geochemical Survey Team

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

1-3-5 Period of survey

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

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

Chapter 2 Geography

2-1 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 both mountains, 90 percent of the land is mountainous area showing altitude of 100 to 700 meters, but no high mountain exists.

The principal mountain ridges trend clearly NNE to SSW characterized by narrow straight ridge 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 trend this same direction, 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 distributed 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 this river. 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.

2-2 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. From February to April, it is the hottest season in a year due to weaken northeast winds.

The average monthly temperatures in the recent six years in Ranong City to the south of the survey area are almost in a flat line among 26 and 30°C. However temperature varies notely in the dry season ranging from 19 to 38°C in a day, and those in the rainy season ranging from 22 to 33°C.

As shown in monthly precipitation data in the recent five to six years in Kra Buri Town and La-Un Town, the annual precipitation in the towns ranges between 1,800 and 3,000 mm, in which 90 percent of the precipitation is concentrated in the rainy season.

The vegetation in the area is mainly of tropical monsoon forest in mountainous areas, artificial forest in hilly plantation areas and agricultural land in flat areas. The mountain forest is of virgin heavy deciduous 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. Mangroves are seen in the lowland swamp area in the mouths of the Mae Nam Kra Buri and Khlong La-Un.

Chapter 3 Geological Information

3-1 Geology and ore deposits in the Kra Buri area

Southeastern Asia containing the Malay Peninsula has undergone four big tectonic movements occurred in late Precambrian, Variscan (Hercynian to late Palaeozoic), Indochinian (Triassic to Jurassic), and Alpine (Cretaceous to Cenozoic) times. The area among the Khorat Plateau, eastern Myanmar, Malay Peninsula and Borneo Island (Kalimantan) 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 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.

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.

The geological structure in the survey area is controlled by the Ranong Fault and the Khlong Marui Fault, trending generally NNE-SSW, and the granite intrusions also elongate in the same direction.

Many tin mines have been active in the Malaya Peninsula for many years, 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. The Ranong-Phuket area on the south of the survey area is the largest tin producing area in Thailand. There are placer deposits in alluvial deposit and beach deposit and two kinds of primary ore deposits, argillized disseminated type and pegmatite type in places. In Kra Buri area, some old workings are scattered along main drainage around granite masses.

3-2 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

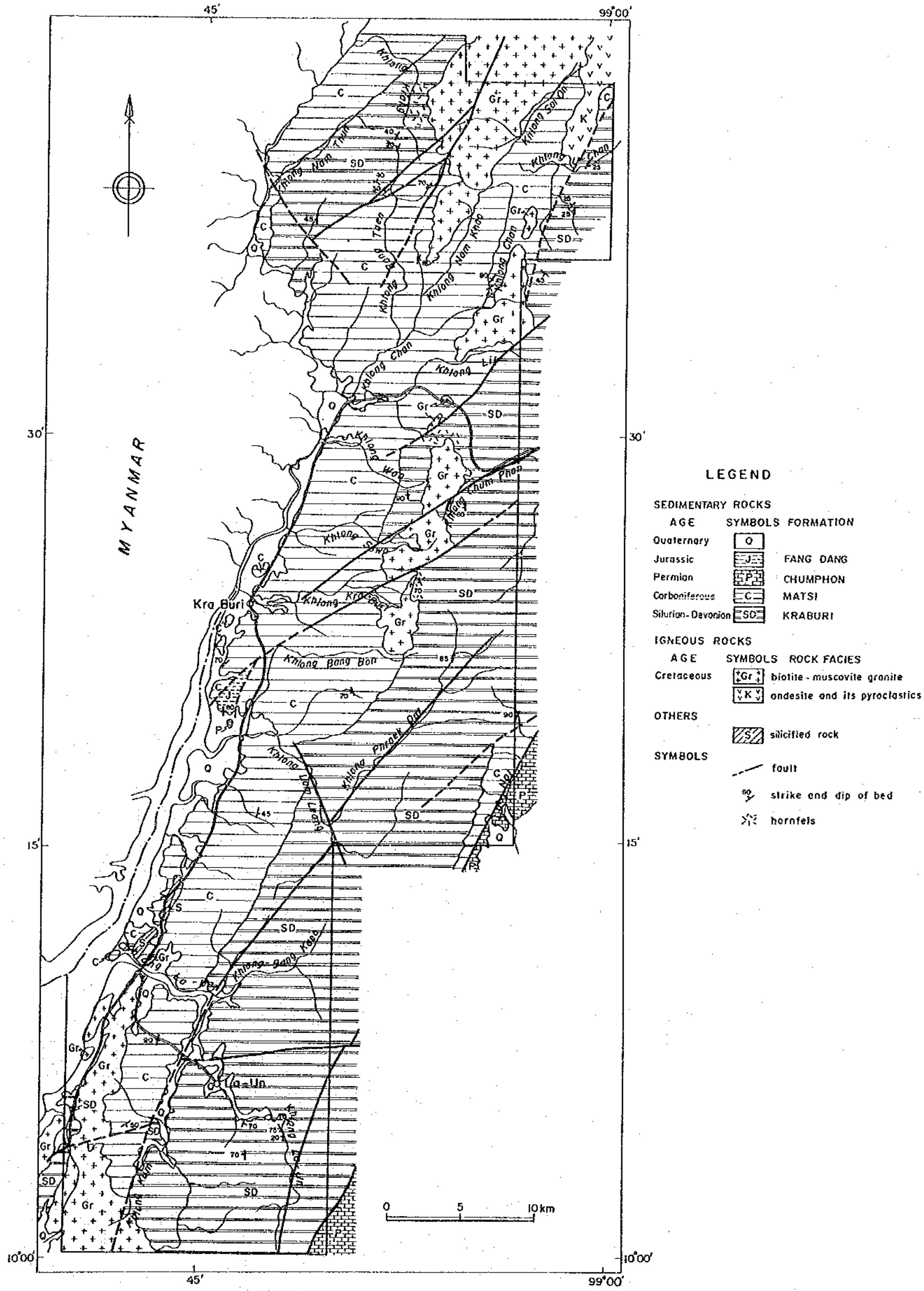

Fig. 2 Geologic map of the Kra Buri Area

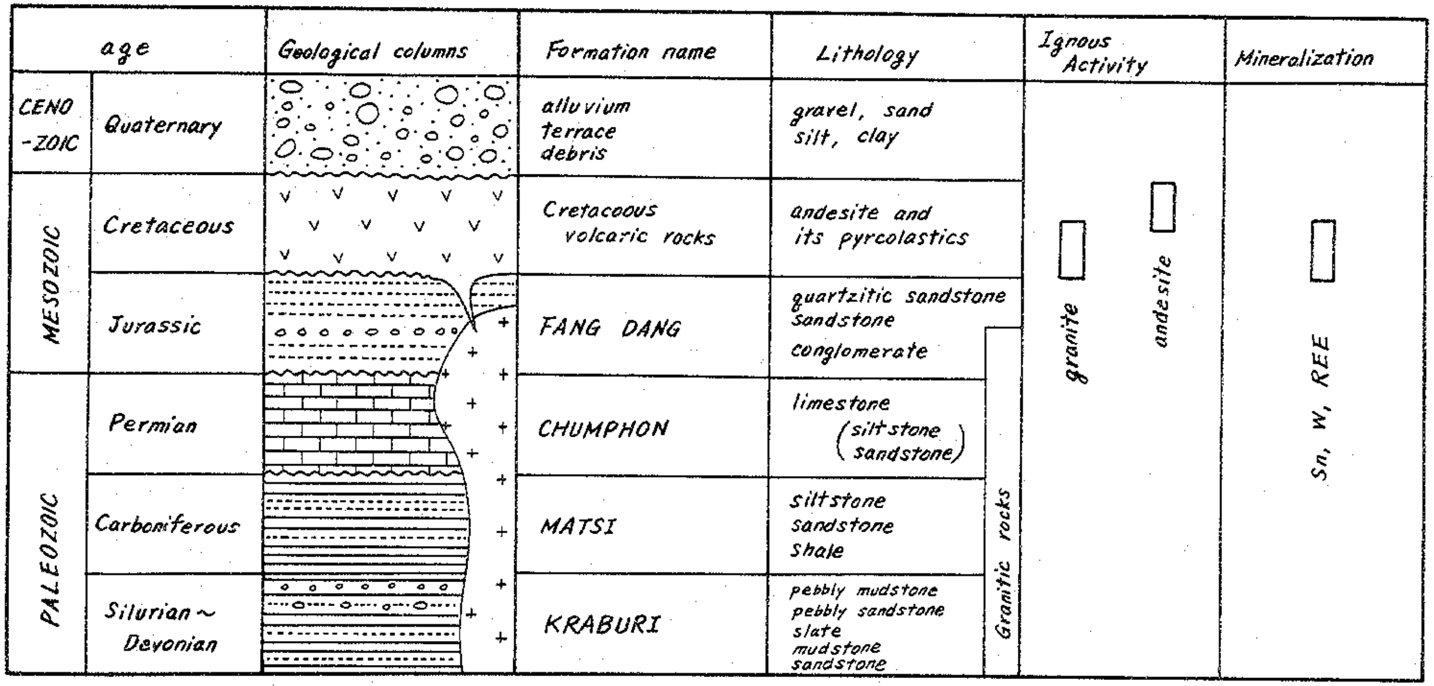

Fig. 3 Schematic geologic column of the Kra Buri Area

southern Thailand, of which almost all were of small-scale private operation applying dredging or gravel pumping method (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, although many old workings are scattered in the area.

Table 2 shows mining situation in the Ranong Province in the recent five years from 1988 to 1992 June. Registered mining claims and working mines are still decreasing in this province. Almost mines are digging kaolinite with a small amount of cassiterite, ilmenite, monazite and other heavy minerals without only a working dredge boat. The ratio of production between kaolinite and heavy minerals is one metric ton to 4,000 metric tons in reality at some working mines.

Rare earth minerals such as monazite and xenotime had been disposed for waste, when cassiterite was vigorously working at one time. In recent years rare earth minerals are begun to collect from waste and "amang" because of their increasing demands. But ore-grade and reserves of each mine is not so clear, because they do not always mine on a plan.

Tin mines except off-shore mines in Ranong district are almost on a small scale. The gravel pumping method or open pit method are commonly used in these mines. The later method is profitably better than the former, because it is easy to control mining sites against over prime cost. No statistics of productions and scales of each mine exist. According to the information of Ranong branch of DMR, the lowest cut-off grade of both methods is 0.3 katty/yd^3 (237.31g/m^3) and it costs four million baht for gravel pumping method or ten million baht for open pit method to exploit a new mine.

Table 2 Mining situation in Ranong Province

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

Chapter 4 Comprehensive Discussion

The potential for mineral deposits and the relationship between granite and mineral deposits in the Kra Buri Area are discussed here.

The first year program revealed that the geochemical anomalies of rare earth elements were detected in and around the granite masses, and old workings of placer tin deposits were close to the granite masses; thereby it suggests that these anomalies have a close association with a granite mass and heavy minerals, such as cassiterite, monazite and xenotime, have been transported from the granite masses to alluvium such as talus and fluvial sediments resulting of the weathering and erosion of the granite masses.

The purpose of the second year program is mainly to delineate the extension of alluvial basins containing placer deposits, also to evaluate the possibility of primary deposits and adsorption-type rare earth deposits; thereby in this program the detailed soil geochemical prospecting was conducted in this program in nine areas which were selected from the anomaly zones detected by the first year geochemical prospecting of stream sediments.

In Area A-2 and D-1, soil samples from the granite areas show high trace element content, which reflects high trace elements content of the granite masses. Trace element contents also vary with the granite facies.

In Area A-2, the argillized granite in the north and the south margin of the granite masses is rich in tin and tungsten and poor in rare earth elements, whereas a massive two-mica granite containing megacrystals of potassium feldspar is poor in tin and tungsten and rich in rare earth elements. Though the elements content of soil samples corresponds nearly with that of granites, soil samples from slopes and lowland along valleys show higher content; thereby the heavy minerals have been transported from the granite mass to lower places and concentrated there.

In Area D-2, the granite mass contains silicified part and argillized part as its marginal facies. Silicified granite is more tin and tungsten and less rare earth element. An argillized granite is less tin and less rare earth element than the massive two-mica granite.

The relationship between tin content and rare earth elements' content in each granite mass shows a negative correlation in Fig.39.

The relationship between the differentiation index (D.I.) and trace elements content, as shown in Fig.40, indicates that high differentiated facies are rich in tin while low differentiated facies rich in rare earth element. This suggests that the crystallization of cassiterite and rare earth minerals occurs in the different stages of differentiation; rare earth minerals such as monazite and xenotime crystallize in the early stages of differentiation, whereas cassiterite crystallizes at more differentiated granite such as muscovite granite, tourmaline granite, greisen, pegmatite vein and quartz vein. The reasons are as follows;

1) In Area A-2, soil samples in the argillized granite after muscovite granite are rich in Sn and W, whereas soil samples in the non-altered massive two-mica granite are rich in rare earth elements.

2) As shown in Area A-1, much tin is typically contained in fluvial and talus sediments consisting mainly of clay with gravel derived from quartz veins, whereas rare earth elements are contained in fluvial and talus sediments consisting of sand and gravel derived from the granite masses.

3) On the basis of the geochemical prospecting of stream sediment in the first year program, only tin and tungsten anomalies were detected in the hornfels area in the east of the central granite mass where quartz veins are observed in hornfels, whereas strong rare earth elements anomalies and weak tin anomalies were detected along valleys in the west of the central granite mass where granite crops out.

The schematic model of crystallization of cassiterite and rare earth minerals and the generation of placer deposits is shown in Fig.41. Each stage is explained as follows;

1) After granite melt intruded into sedimentary rocks, rare earth minerals crystallize at the main granite facies in the early stage of crystallization differentiation. Residual liquid moves to the upper margin of the granite mass, and it forms the differentiated granite facies such as muscovite granite, tourmaline granite and greisen. Also pegmatites and quartz veins are formed in wall rock. Tin and tungsten concentrate in residual liquid, then cassiterite and walframite and/or scheelite are crystallized when the differentiated facies are produced.

2) When the area starts to be uplifted, marginal facies such as pegmatites and greisen are eroded to produce sediments. Heavy minerals such as cassiterite are transported to an alluvial basin.

3) Further erosion causes the exposure of the main granite facies. Finally monazite and xenotime are transported to an alluvial basin.

The stage between second and third is applicable to the alluvial basin in the south of Area A-1. The third stage is applicable to the alluvial basin in the north of Area A-1. In the east of the central granite mass, tin and tungsten geochemical anomalies are inferred to be derived from quartz veins related with a concealed granite.

The reserves and grades of placer deposits are decided by heavy minerals content of sources, i.e., the tin and rare earth content of each granite mass though the scale and form of alluvial basins are also important.

Fig.30 shows that the southern mass and the northern west mass contain more tin and rare earth elements; thereby they are the sources of large placer deposits in Area A-1 and D-1. The northern east mass and the central mass tend to contain relatively less tin and rare earth elements.

The southern granite mass varies in composition. On the basis of the first year geochemical prospecting of stream sediments, strong tin anomalies and no rare earth elements anomalies were detected in the east, whereas weak tin anomalies and strong rare earth elements anomalies were detected in the northwest. Also strong tin and rare earth elements anomalies are found in the southwest. In harmony with these facts, the composition of granite has much tin and less rare earth element in the east, less tin and much rare earth element in the northwest. The intermediate composition between both of them shows in the southwest.

In the central mass, which is divided into three rock bodies, the southern rock body has a high tin content in comparison with the northern and middle rock bodies. A placer deposit and heavy mineral samples in Area B-3, adjoining the southern mass, show a high tin content in comparison with those of Area B-1 and B-2.

Fig.40 suggests that a granite containing tin at 25 ppm or above has a potential for placer tin deposits, and a granite containing rare earth elements at 300 ppm and above has a potential for placer rare earth deposit.

Chapter 5 Conclusion and Recommendation

5-1 Conclusion

The purpose of this program is mainly to delineate the extension of alluvial basins containing placer deposits, also to evaluate the possibility of primary deposits and adsorption-type rare earth deposits; thereby the detailed soil geochemical prospecting was conducted in this program for nine areas which were selected from the anomaly zones detected by the first year geochemical prospecting of stream sediments.

On the basis of the interpretation of geochemical data and geological evidence, it has been made clear that the pathfinder elements are separated into two groups, namely tin group (Sn, W, Ta, Nb) and rare earth group (REE, Th, U). The geochemistry of these two groups shows the different geochemical characteristics in the granite masses. The anomaly areas of the tin group elements are found in the extremely high differentiated part that sits in the uppermost part of the granite masses, whereas those of the rare earth group in the low differentiated part under the uppermost part. It is inferred that the crystallization of rare earth minerals occurred at the earlier differentiation stage than that of tin and tungsten minerals.

The potential of tin deposits and rare earth deposits are evaluated as follows;

(1) In Area A-1, anomaly zones are distributed in four places such as the northern, central, southeastern and southwestern parts of this area. They overlap with the distribution of talus deposits and alluvial sediments. The reserves of cassiterite and rare earth minerals are estimated at 1.31 million m^3 (at a cassiterite content of $0.116kg/m^3$) and 2.20 million m^3 (at a monazite content of $1.315kg/m^3$ and a xenotime content of $0.236kg/m^3$) respectively.

(2) In Area A-2, an adsorption-type rare earth deposit was expected to exist because of the distribution of argillized granite. Rare earth contents of non-argillized granite are higher than those of argillized facies; thereby this area has a very low potential of adsorption-type deposits. The geochemical anomalies indicate a small placer deposit reserving less than 300 thousand m^3.

(3) In Area B-1 to B-4, alluvial basins lie narrowly along rivers surrounded by mountains and hills. The reserves in area B-1 to B-4 are estimated at 60 to 300 thousand m^3 respectively. Ore grade is also low.

(4) In Area C, the geochemical anomaly of tin is caused by silicified rocks in the northwest. The anomaly of rare earth elements is found in the southeast. The reserves of cassiterite and rare earth minerals are estimated at more than 100 thousand m^3 and about 600 thousand m^3 respectively, but they are low grade.

(5) In Area D-1, mangrove mud covers widely in the west. Though markedly anomaly values are not found in a mangrove mud, some anomalies are detected from the samples of the edge of eastern mountains and the bottom of creeks in a mangrove area. It is inferred that the potential for placer deposits exists below a mangrove mud. The reserve of rare earth ore is estimated at 7.5 million m^3 (a monazite content of $1.480kg/m^3$ and a xenotime content of $0.167kg/m^3$) and that of tin ore at 14.55 million m^3 (at a cassiterite content of $0.222kg/m^3$). These reserves are the largest in this program.

(6) In Area D-2, mangrove mud covers widely. It is also inferred that a placer deposit exists under mangrove mud in this area. The reserve is estimated to be 1.6 million m^3, but it is low grade.

5-2 Recommendation for the future survey

Two areas, Area A-1 and D-1, can be recommended to further exploration because of their existence of relatively large alluvial basins containing placer deposits. To evaluate three-dimensional ore grade and precise ore reserve, it is necessary to obtain the vertical information of ore grade.

In Area A-1, the test pitting survey is preferable to the drilling. Because alluvial sediments contain many boulders in this area. It is desirable to investigate two points, where the anomaly of tin and rare earth overlap each other.

In Area D-1, the vertical drilling survey is suited. Because the sediments in a mangrove area reach 20 meters in thickness. The survey area is affected by a tide and is mostly submerged at high tide; thereby the 'Banka' drilling is preferable to the normal drilling at three or four sites to confirm ore deposits.

PART II DETAILED DESCRIPTION

Chapter 1 Area A-1

1-1 Location

Area A-1 is about 25 kilometers north-northwest of Kra Buri Town. The center of the area is at latitude about 10°37'N and longitude about 98°54'E. The area was settled to be in parallel with Khlong (River) Khao running south-southwestward at the eastern foot of the Northern west granite mass. An alluvial basin stretches along this river (Fig.4).

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

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

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

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

1-2 Survey method

Soil samples were collected from each point designed by a rectangular grid method. The spacing between survey lines is 100 meters, and the interval between sampling points 50 meters. Placer deposits were main targets in this area; thereby heavy minerals might concentrate at the deeper part in the alluvial basin. Though it is desirable to collect samples from as deep portions as possible, it becomes more difficult to take samples as holes become deeper. Taking these factors into consideration, samples were collected at a depth of 1 meter inside the alluvial basin in principle.

Each sampling point was determined by a simplified location survey through pocket compasses and measuring tapes. The total number of samples was 459. The collected soil samples were dried and passed through 80 mesh screen. Their fractions under 80 mesh were taken for chemical analyses of 16 pathfinder elements: tin, tungsten, niobium, tantalum, cerium, europium, lanthanum, neodymium, samarium, terbium, thorium, uranium, yttrium, gadolinium, dysprosium and praseodymium. These elements were decided by the geochemical study of the first year program.

Panned heavy minerals were also collected from some soil sampling points to estimate the reserves of ores in alluvial basins. The pathfinder elements of the panned samples were the same as those of soil samples.

This method of determining sampling traverse lines and points, and pathfinder elements in Area A-1 are the same as those in other survey areas.

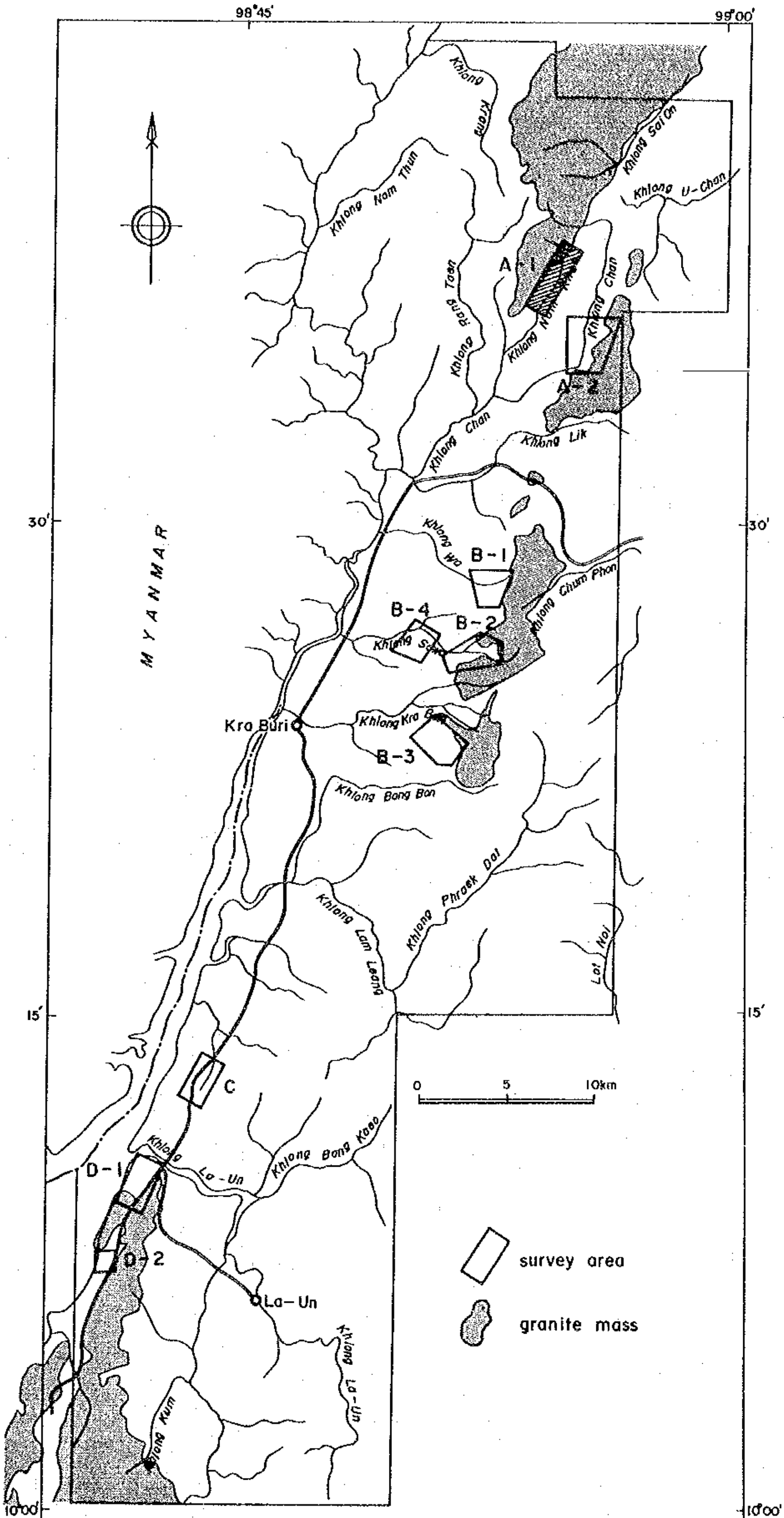

Fig. 4 Location map of Area A-1

A - 1

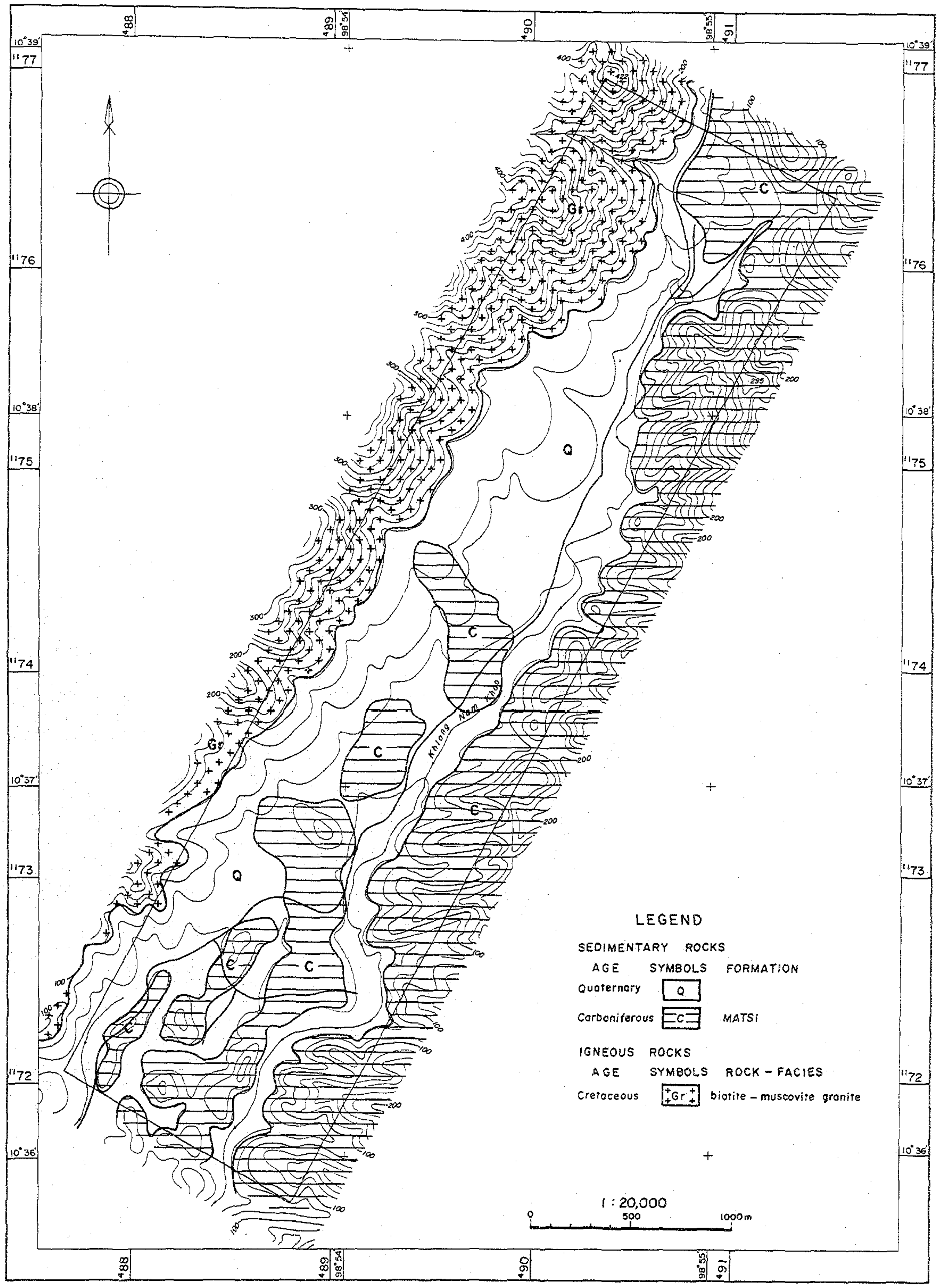

Fig. 5 Geologic Map of Area A-1

1-3 Geology

The Area A-1 is underlain by Carboniferous Matsi Formation, Cretaceous granite and the Quaternary (Fig. 5).

Matsi Formation forms mountains in the west of the survey area and small hills with a relative height ranging from 10 to 40 meters in the northeast and southwest. The formation consists of mudstone and conglomerate.

Cretaceous granite forms the mountains on the northwestern side of Area A-1. The eastern slope of the mountains consists of steep cliffs in a row; therefore it is inferred that Matsi Formation is faults contact with the granite mass in this area. This granite is mainly a coarse-grained two-mica granite, partly containing megacrystals of potassium feldspar. This rock is composed mainly of quartz, microcline, orthoclase, plagioclase, biotite, muscovite and tourmaline, with accessories zircon, apatite, sphene and ilmenite. Allanite occurs in less abundant. This granite has been extensively subjected to mylonitization; thereby cataclastic texture and mylonitic texture are common.

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

Small hills ranging in relative height from 10 to 30 meters consisting of Matsi Formations are scattered in the south of the AA25 line. The valleys among these small hills are underlain by fluvial sediments mainly consisting of white clay.

1-4 Result of geochemical prospecting

1-4-1 Soil samples

The frequency distribution of trace elements in geochemical samples is known to have nearly a log-normal distribution as long as the precision of analysis is reliable enough. The logarithmic transformation of raw data is therefore done before the data processing. In view of statistical analysis, when the value of raw data is below-detection-limit, half of the detection limit value is used for processing.

The range, the mean value (M) and the standard deviation (σ) for each element are shown in Table 3. Their correlation coefficients between these elements are shown in Table 4.

The strong positive correlation is recognized in the Sn group elements except W and in the rare earth elements. The positive correlation is also recognized between these two groups. Tungsten has a weaker positive correlation with the other Sn group elements than the results of the first year study, and has very small negative correlation values with the rare earth group elements.

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

As mentioned above, analytical elements are divided into five groups, namely, Sn, W, Ta-Nb, Total REE, Th-U. Fig.6 shows the histograms and cumulative probability graphs of the five groups.

Table 3 Geochemical basic statistic quantities of Area A-1

Element	Unit	Max.	Min.	Average	av.ant-log.	Std.Dev.
Sn	ppm	163.0	<5.0	1.259	18.17	0.422
W	ppm	52.0	<2.0	0.748	5.60	0.430
Ta	ppm	15.0	<1.0	0.435	2.72	0.365
Nb	ppm	75.0	<2.0	1.520	33.10	0.181
Ce	ppm	460.0	13.0	2.144	139.32	0.287
Eu	ppm	2.7	<0.5	-0.240	0.57	0.250
La	ppm	240.0	4.0	1.781	60.41	0.346
Nd	ppm	140.0	<5.0	1.521	33.15	0.412
Sm	ppm	28.0	0.4	0.888	7.73	0.386
Tb	ppm	5.6	<0.5	0.061	1.15	0.363
Th	ppm	200.0	9.7	1.762	57.76	0.273
U	ppm	32.0	1.6	0.902	7.98	0.300
Y	ppm	258.0	6.0	1.673	47.08	0.299
Gd	ppm	27.8	1.0	0.878	7.55	0.330
Dy	ppm	40.0	1.2	0.898	7.90	0.283
Pr	ppm	35.0	<20.0	1.048	11.16	0.128
Yb	ppm	21.4	1.4	0.712	5.15	0.226
Lu	ppm	3.1	0.2	-0.153	0.70	0.216
Ta+Nb	ppm	90.0	2.0	1.559	36.20	0.184
T.REE	ppm	1056.3	29.2	2.504	319.33	0.302
Th+U	ppm	222.0	11.4	1.819	85.90	0.274

Table 4 Geochemical correlation coefficients in Area A-1

	Sn	W	Ta	Nb	Ce	LA	Nd	Sm	Tb	Th	U	Y	Gd	Dy	Yb	Lu
Sn	1.000	0.393	0.587	0.581	0.260	0.357	0.304	0.345	0.343	0.443	0.469	0.344	0.355	0.379	0.339	0.313
W	0.393	1.000	0.035	0.051	-0.186	-0.148	-0.158	-0.163	-0.135	-0.108	-0.070	-0.095	-0.179	-0.142	-0.100	-0.073
Ta	0.587	0.035	1.000	0.640	0.532	0.579	0.511	0.550	0.550	0.644	0.627	0.514	0.543	0.575	0.548	0.514
Nb	0.581	0.051	0.640	1.000	0.684	0.717	0.649	0.704	0.686	0.790	0.748	0.718	0.696	0.719	0.703	0.665
Ce	0.260	-0.186	0.532	0.684	1.000	0.953	0.901	0.927	0.849	0.909	0.865	0.845	0.873	0.850	0.877	0.847
LA	0.357	-0.148	0.579	0.717	0.953	1.000	0.920	0.958	0.870	0.936	0.898	0.868	0.911	0.884	0.897	0.858
Nd	0.304	-0.158	0.511	0.649	0.901	0.920	1.000	0.931	0.791	0.863	0.826	0.803	0.844	0.814	0.811	0.786
Sm	0.345	-0.163	0.550	0.704	0.927	0.958	0.931	1.000	0.835	0.897	0.861	0.859	0.890	0.868	0.877	0.844
Tb	0.343	-0.135	0.550	0.686	0.849	0.870	0.791	0.835	1.000	0.864	0.850	0.817	0.833	0.826	0.893	0.853
Th	0.443	-0.108	0.644	0.790	0.909	0.936	0.863	0.897	0.864	1.000	0.944	0.822	0.860	0.847	0.893	0.858
U	0.469	-0.070	0.627	0.748	0.865	0.898	0.826	0.861	0.850	0.944	1.000	0.821	0.836	0.843	0.879	0.848
Y	0.344	-0.095	0.514	0.718	0.845	0.868	0.803	0.859	0.817	0.822	0.821	1.000	0.864	0.882	0.879	0.843
Gd	0.355	-0.179	0.543	0.696	0.873	0.911	0.844	0.890	0.833	0.860	0.836	0.864	1.000	0.901	0.869	0.834
Dy	0.379	-0.142	0.575	0.719	0.850	0.884	0.814	0.868	0.826	0.847	0.843	0.882	0.901	1.000	0.883	0.847
Yb	0.339	-0.100	0.548	0.703	0.877	0.897	0.811	0.877	0.893	0.893	0.879	0.879	0.869	0.883	1.000	0.973
Lu	0.313	-0.073	0.514	0.665	0.847	0.858	0.786	0.844	0.853	0.858	0.848	0.843	0.834	0.847	0.973	1.000

The distributions of Sn and W data sets show nearly log-normal distributions except their below-detection-limit values. The distributions of Ta-Nb, Total REE, and Th-U show bimodal distributions.

The thresholds of Sn, W, Ta-Nb, Total REE, and Th-U, which bounds the background values and anomalous values, were determined to be M+0.5σ based on the skew points of the probability graphs and the boundaries of two populations. Threshold are as follows;

Sn; 30 ppm W; 9.5 ppm Ta-Nb; 36 ppm Total REE; 320 ppm Th-U; 78 ppm

The element content maps are shown in Fig.7 (1) to (3).

The clusters of Sn anomalous values are recognized in the AA09, AA15-AA19, AA26-AA31, AA36-AA41 and AA50-AA54 survey lines. The areas of anomalous values in the AA09 and AA15-AA19 are

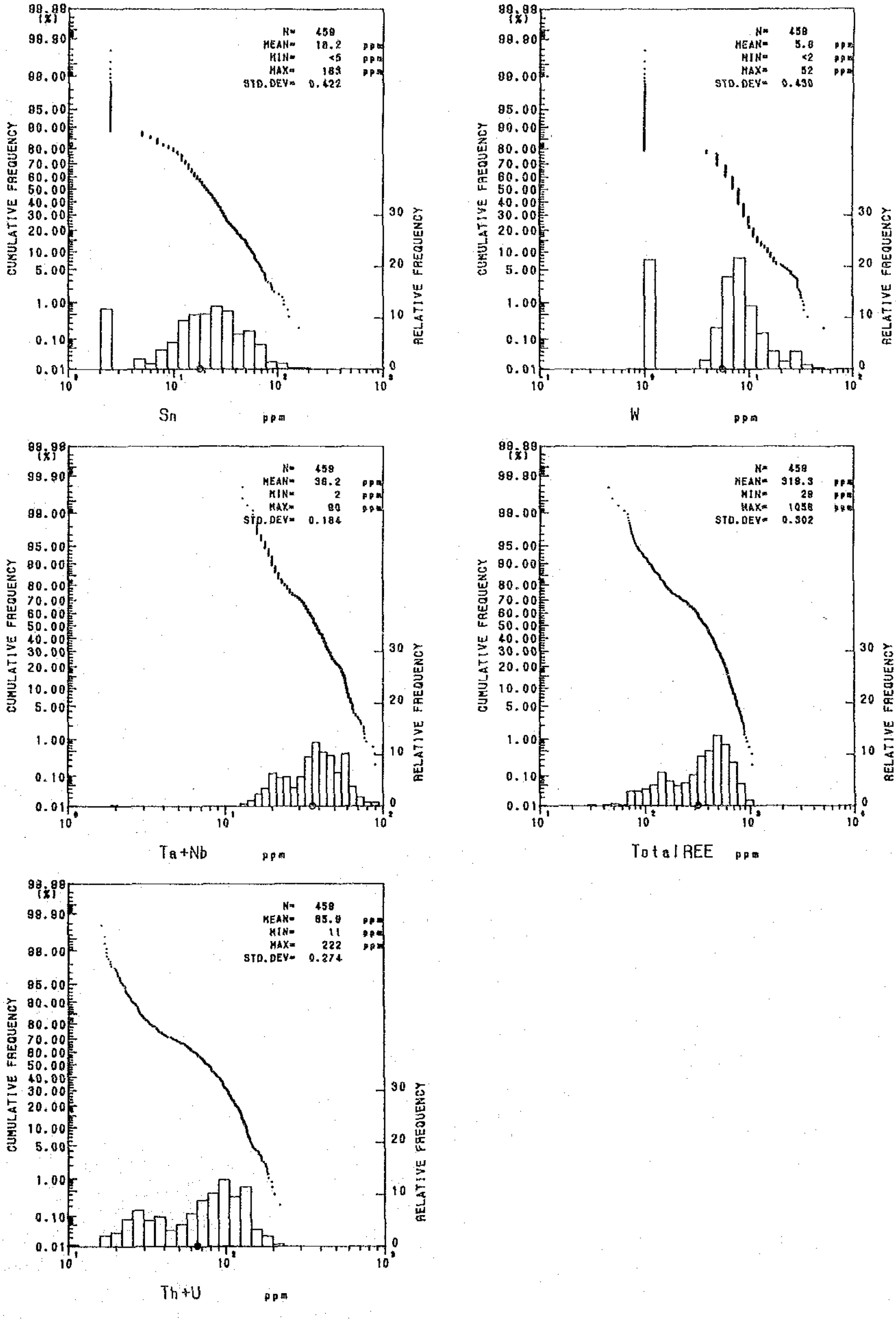

Fig. 6 Histograms and cumulative probability graphs of Area A-1

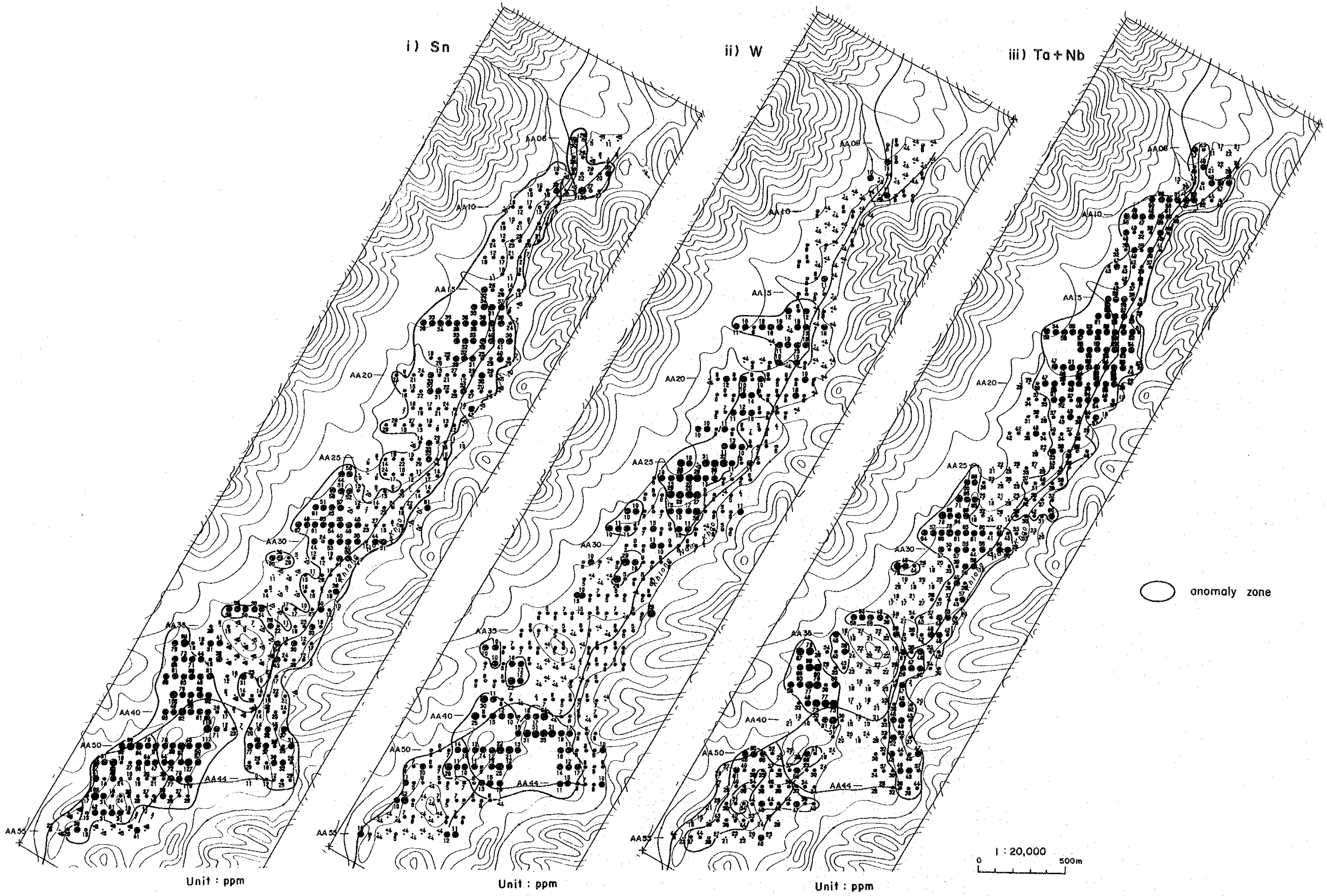

Fig. 7 Results of the geochemical survey of Area A-1 (1)

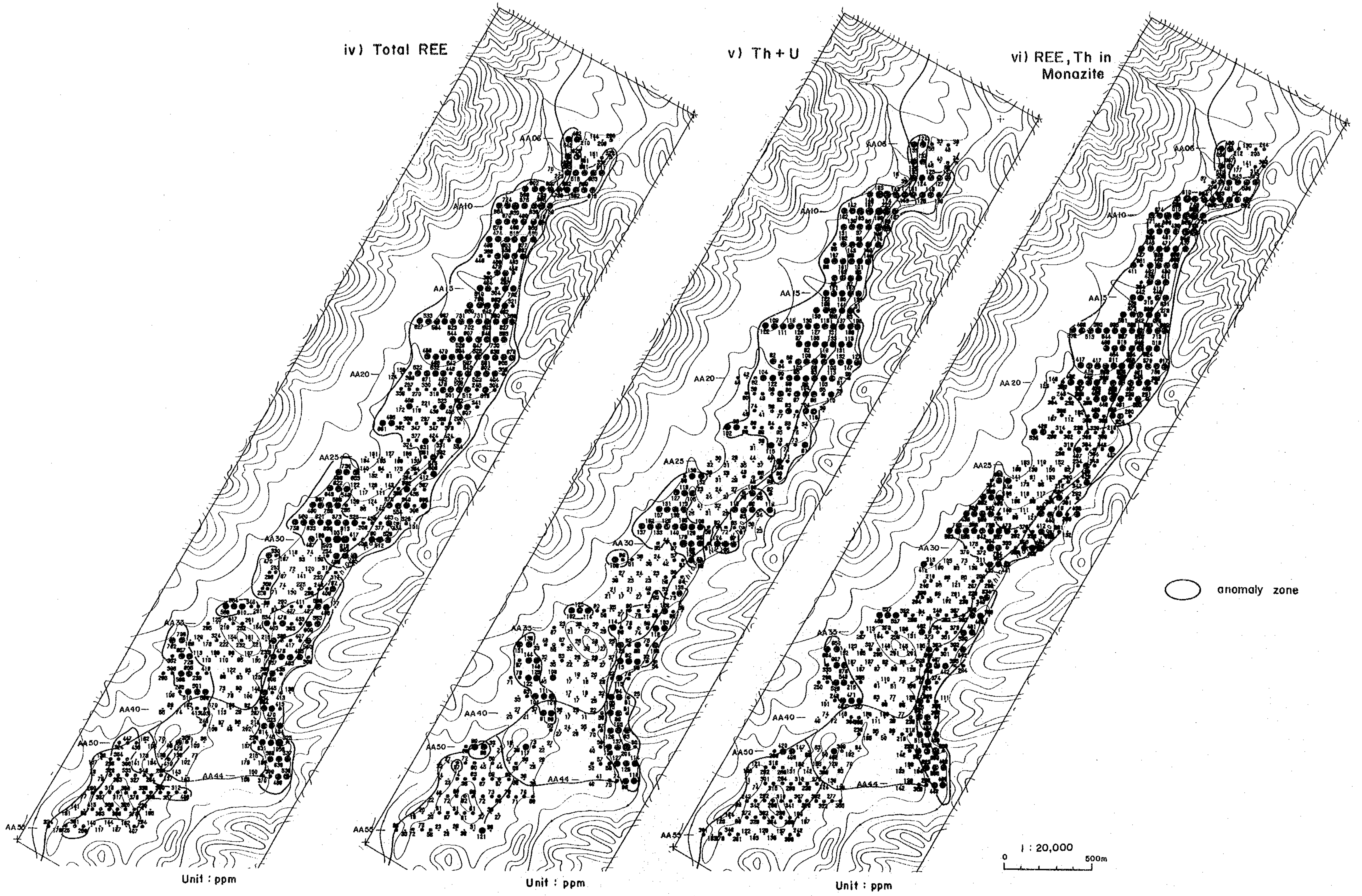

Fig. 7 Results of the geochemical survey of Area A-1 (2)

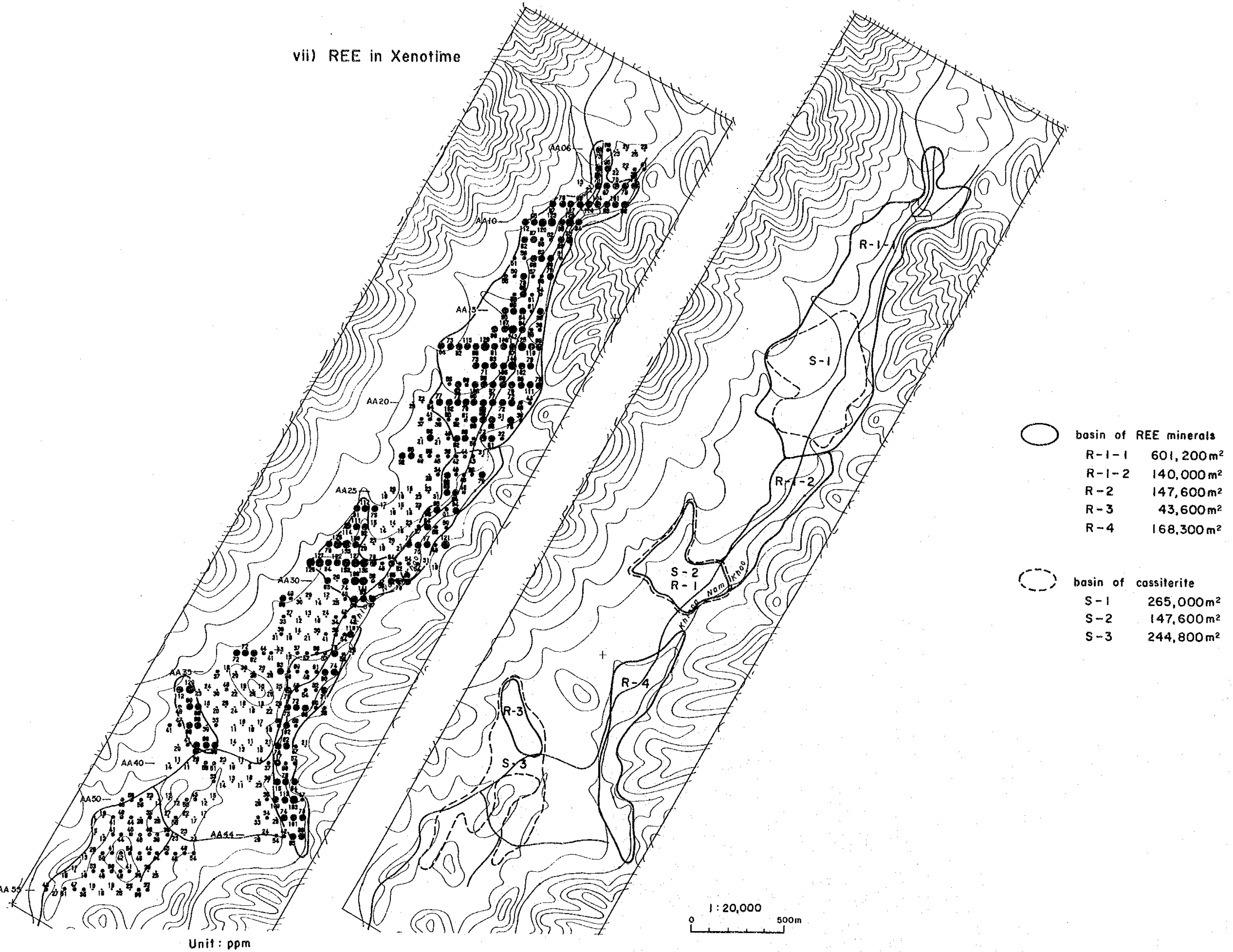

Fig. 7 Results of the geochemical survey of Area A-1 (3)

underlain by talus sediments consisting of granite sand and gravel distributed in the north of Area A-1. Anomalous values in the AA26-AA31 line area overlaps with an alluvial basin consisting of course granite's sand accumulated in the valleys between several Matsi Formation hills. Anomalous values in the south of the area coincides with the distribution of white clay layers consisting of kaolinite and muscovite, which have accumulated in the narrow valleys between Matsi Formation hills. Therefore, the extension of of Sn anomaly almost indicates the extension of a cassiterite-bearing alluvial basin.

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

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

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

1-4-2 Heavy mineral samples

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

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

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

1-5 Discussion

The reserves of ore deposits are estimated on the basis of the assumption that the geochemical anomaly zones would indicate the distribution of placer tin and rare earth deposits.

As shown in Fig.7, the anomalous zones of Sn are distributed in three places: from S-1 to S-3, and that of Total REE in four places: from R-1 to R-4. The boundaries of each anomaly zone were determined based on the element content distribution maps and the geographical characteristics.

The sand and gravel bed was presumed to be average 2 meters thick, because the thickness observed at gullies was more than 2.5 meters.

The average grades of cassiterite, monazite and xenotime are estimated by using their content in soil and their formulas. Cassiterite is assumed to have ideal formula, and the average formulas of monazite and xenotime are based on the data of microprobe analysis. The element contents in soil are allocated for these minerals based on their formulas. Monazite, xenotime and polycrase are the only assumed minerals in this calculation.

The constants, which are used to calculate the above mentioned minerals, are as follows:

1) Ratio of Sn to SnO_2: 78.6%
2) Ratio of R to monazite ($TRPO_4$): 61.1% (Average atomic weight of TR: 149)
3) Ratio of R to xenotime ($TRPO_4$) : 53.4% (Average atomic weight of TR: 109)
4) Weight of wet soil with a volume of $1m^3$: 1.570 metric tons

The identical calculation methods are also used in other survey areas.

Table 5 shows the results of calculation in the area A-1. It is expected that the reserves of monazite and xenotime are 2,200 thousand metric tons and the average grades $1.315kg/m^3$ and $0.236kg/m^3$ respectively. The reserve of cassiterite is 1,315 thousand metric tons and the average grade of cassiterite is $0.116kg/m^3$; thereby Area A-1 has a relatively high potential for placer deposit.

Table 5 Reserves in Area A-1

Area name		Mineral name	Areas (m^2)	Ave. Thick (m)	Reserves (m^3)	Ave. Contents (ppm)	Ave. Oregrade (kg/m^3)	Reserves of Minerals (t)
1	R-1-1	monazite	601,200	2	1,202,400	546	1.403	1,686
		xenotime				81	0.238	286
	R-1-2	monazite	140,000	2	280,000	381	0.979	274
		xenotime				64	0.188	52
	S-1	cassiterite	265,000	2	530,000	30	0.060	31
2	R-2 S-2	monazite	147,600	2	295,200	527	1.354	399
		xenotime				98	0.288	85
		cassiterite				46	0.092	27
3	R-3	monazite	43,600	2	87,200	572	1.470	128
		xenotime				95	0.279	24
	S-3	cassiterite	244,800	2	489,600	73	0.146	71
4	R-4	monazite	168,300	2	336,600	470	1.208	406
		xenotime				74	0.217	73
Total		monazite	1,100,700	2	2,201,400	–	1.315	2895
		xenotime				–	0.236	521
		cassiterite	657,400	2	1,314,800	–	0.116	153

Chapter 2 Area A-2

2-1 Location

Area A-2 is 23 kilometers northeast of Kra Buri Town, and located southeast of Area A-1. The center of this area is at latitude 10°35'N and longitude 98°55'E. The area covers the east granite mass in the northern Kra Buri area (Fig. 8).

The main rivers are Khlong (River) Chan running southward in the western part of the area and Khlong Noi running westward in the southern part of the area. Their large tributaries run to the NNE-SSW direction, and their small branchs are found to the E-W or N-S direction. This area ranges in altitude from 50 to 230 meters. The southern part of this area consists of dissected and gentle hills whereas the northern part consists of steep mountains, generally ranging in altitude from 50 to 230 meters.

An unpaved road branching from the Route 4 leads northward to Khlong U-Chan by way of the survey area. The distance of the roads from Kra Buri Town to the survey area is about 30 kilometers, and it takes about one hour by car.

The first year geochemical prospecting of stream sediments revealed the anomaly of Sn and W on the west of Khlong Chan, the anomaly of Ce, Sm, La, Nd and Th along Khlong Chan, and the anomaly of Ta, U, Y, Tb from Chan River to the northern east granite mass where the strong anomaly of REE, U, Y and Th were also detected by the geochemical prospecting of soil samples. Primary deposits or adsorption-type rare earth deposits were expected in the granite mass, because the granite in this area has a deeply argillized and weathered crust.

2-2 Survey method

Soil samples were collected from each point designed by a rectangular grid method. The spacing between survey lines is 100 meters, and the intervals between each sampling point 50 meters.

The area on the west of Khlong Chan was excluded from the target area, because the anomaly of only Sn and W was recognized here and its alluvial basin is rather small in scale.

The number of collected samples is 747.

2-3 Geology

Area A-2 is underlain by Carboniferous Matsi Formation in its western half, Cretaceous granite in the eastern half, and Quarternary fluvial sediments found along the rivers (Fig.9).

Matsi Formation consists of mudstone, siltstone and black slate, and is distributed in the mountains on the west of Khlong Chan. The formation is composed generally of argillized and weathered soft rocks, except a hard phyllitic slate between the base points of the AB19-AB22 survey lines and Khlong Chan.

Cretaceous granite forms rather steep mountains on the north of the AB17 line, and forms gentle hills on the south of this line. This granite is medium to coarse-grained two-mica granite (adamellite), composed mainly of quartz, microcline, orthoclase, plagioclase, biotite, muscovite and tourmaline, with accessories zircon, apatite, sphene and ilmenite.

The granite has been altered by superficial weathering. The weathering crust partially remains on the ridges, but a fresh granite exposes in the valleys.

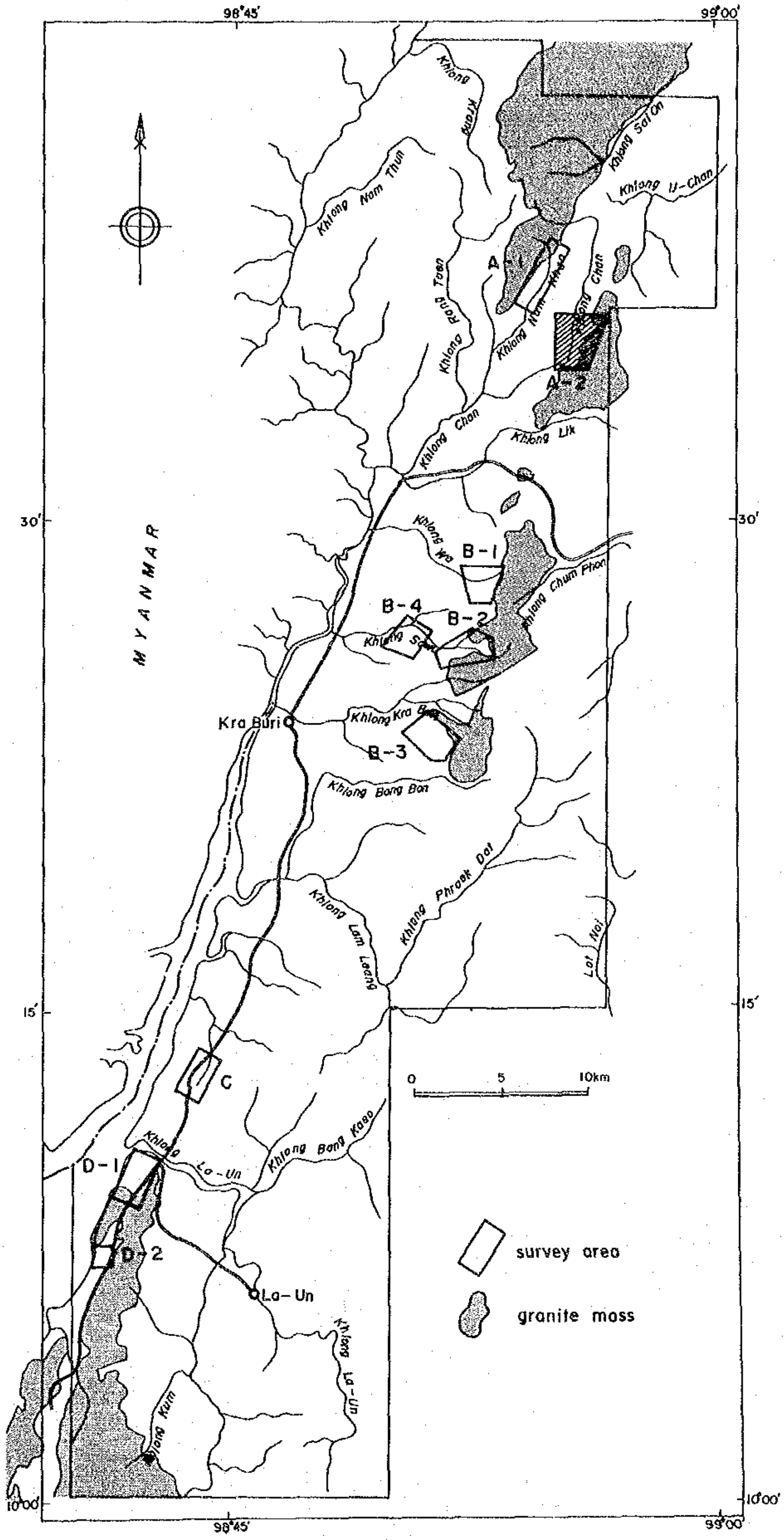

Fig. 8 Location map of Area A-2

A - 2

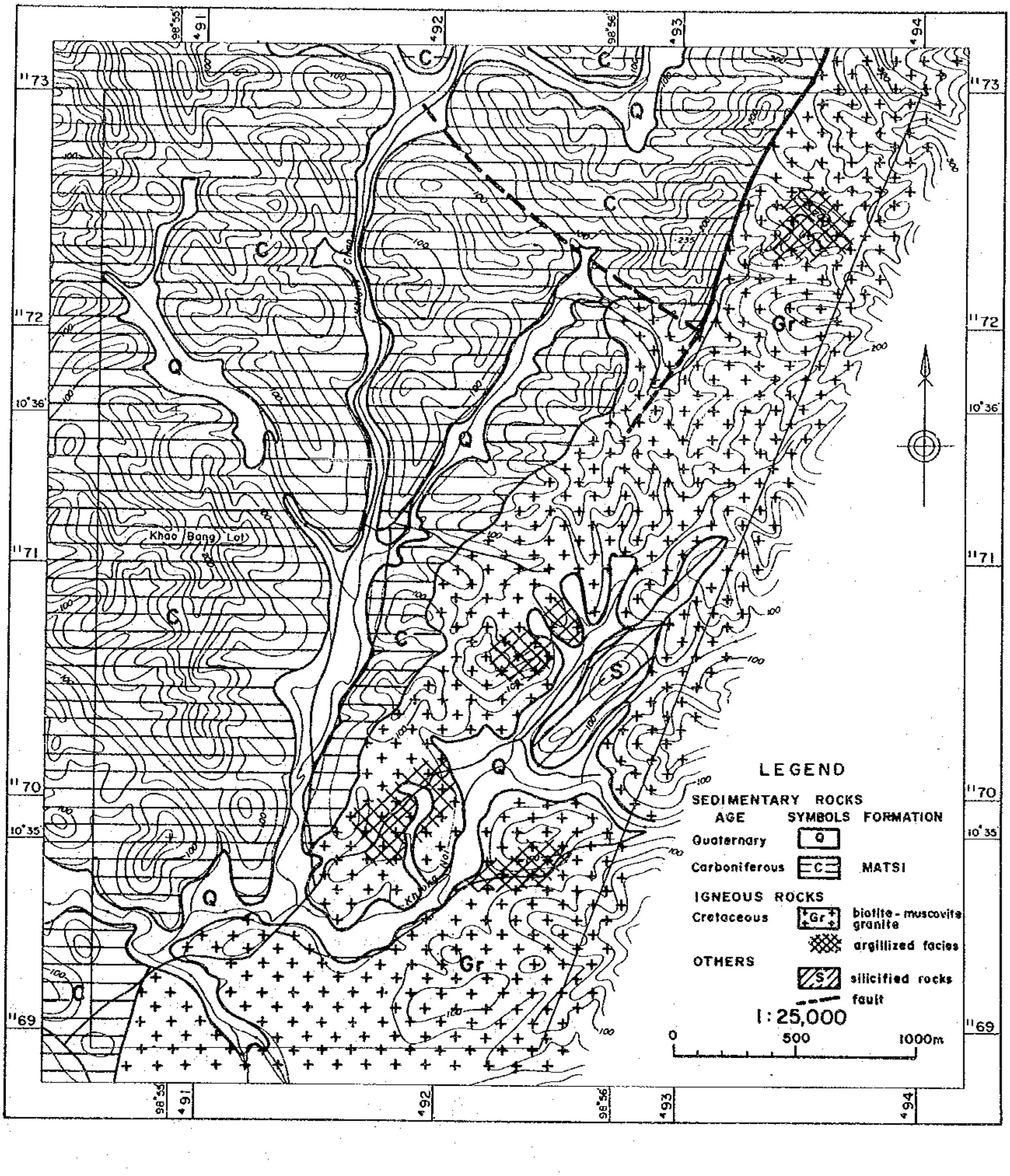

Fig. 9 Geologic map of Area A-2

The greisen-like altered granite occurs on the ridges north of the AB06 survey line, where the granite has been widely subjected to sericitization and partly kaolinization. It is inferred that this altered granite reachs until deeper part. Many quartz boulders, ranging from 1 to 3 meter in diameter, are found around the east end of the AB01 and AB02 survey lines on the north of the argillized granite. It can be stated that the granite in this part underwent regional hydrothermal alteration.

Argillized granite is widely distributed on hills near from AB2810 to AB3110 point and in the area from point No.10 to No.12 on the AB20-AB22 lines. A lot of clay derived from argillized granite have accumulated in valleys among hills.

In the granite mass, roof-pendent of silicified rocks occures in the NNE-SSW direction near the AB20-AB26 lines in the eastern edge of the survey area.

Fluvial sediments consisting mainly of sand and silt are distributed in the basins of Khlong Chan, its tributaries, and Khlong Noi. White clay consisting mainly of sericite and kaolinite are distributed on gentle hills on the south of the AB20 line.

2-4 Result of geochemical prospecting

2-4-1 Soil samples

The range, the mean value (M) and the standard deviation (σ) for each element are shown in Table 6.

Fig.10 shows the histograms and the cumulative probability graphs of five elements groups, i.e., Sn, W, Ta-Nb, Total REE and Th-U.

The distribution of Sn is nearly log-normal distribution except their below-detection-limit values. One of the skew points is found near the mean value (24.7 ppm) in its cumulative probability graph, and the threshold was taken at this point. The 35 percent of W data is a below-detection-limit value; thereby the values higher than 4 ppm can be useful. The groups of Ta-Nb, Total REE and Th-U show bimodal distribution. Their thresholds are taken at the boundary of two populations, and the boundary is near from the M-0.5σ on the histograms, i.e., 30 ppm, 252 ppm and 48 ppm respectively. The content distribution maps are shown in Fig.11 (1) to (8).

Specially high Sn values are found around AB18 and AB19 lines. High anomaly values on the eastern side of both lines are on the ridge and slope, it may mean that the cassiterite bearing quartz veins or pegmatites exist around these points. High anomaly values on the western side of both lines are in a valley, it may indicate a alluvial basin containing cassiterite. The high concentration zone of Sn almost overlaps with granite area, and the values from 40 to 80 ppm are found in the AB01-AB10, AB20-AB33, AB36-AB37 line areas. Its distribution almost overlap with that of argillized granite. The Sn content in lowlands stretching along Khlong Noi and its tributaries is lower than that in the neighbor areas. It indicates that alluvial basins containing cassiterite have not been developed. The content of the other elements' groups in this lowlands also tends to be lower than that in the neighbor areas. Anomaly values in Khlong Chan basin are found to be distributed in a very narrow and long area along the river.

The high W anomaly zones overlap with the distribution of granite. The distribution of W concentration is also in harmony with that of Sn.

There are three Ta-Nb anomaly zone of 50 ppm and over. One of zone overlaps with the argillized granite of the AB01-AB08 and AB26-AB33 lines. The second overlaps with the high Sn anomaly near

Table 6 Geochemical basic statistic quantities of Area A-2

Element	Unit	Max.	Min.	Average	av.ant-log.	Std.Dev.
Sn	ppm	501.0	<5.0	1.393	24.7	0.376
W	ppm	26.0	<2.0	0.591	3.9	0.443
Ta	ppm	13.0	<1.0	0.604	4.0	0.254
Nb	ppm	125.0	<2.0	1.501	31.7	0.167
Ce	ppm	530.0	38.0	2.074	118.7	0.156
Eu	ppm	5.3	<0.3	-0.095	0.8	0.209
La	ppm	360.0	3.0	1.641	43.8	0.232
Nd	ppm	240.0	5.0	1.465	29.2	0.234
Sm	ppm	49.0	0.9	0.809	6.4	0.221
Tb	ppm	8.0	<0.5	0.088	1.2	0.303
Th	ppm	210.0	16.0	1.712	51.6	0.194
U	ppm	32.0	1.8	0.862	7.3	0.182
Y	ppm	655.0	<2.0	1.811	64.7	0.237
Gd	ppm	36.2	0.5	0.836	6.8	0.231
Dy	ppm	36.0	0.5	0.958	9.1	0.214
Pr	ppm	50.0	<20.0	1.019	10.5	0.089
Yb	ppm	45.2	2.5	0.933	8.6	0.242
Lu	ppm	5.8	0.1	0.079	1.2	0.237
Ta+Nb	ppm	130.0	3.0	1.557	36.0	0.163
T.REE	ppm	1297.1	78.5	2.482	303.4	0.160
Th+U	ppm	240.0	18.9	1.773	59.3	0.185

the AB18-AB19 lines. Other high anomaly zone is distributed on the western side of the AB21-AB lines.

The anomaly values of Total REE, Th-U almost overlaps with the granite body, except the argillized granite in the northern part and the lowlands along Khlong Noi where the contents are low. The high anomaly is distributed in the area of AB10-AB19 lines, where bed rocks crop out along a valley and weathering crust is thin. Though the specially high content samples are distributed along a valley, there are little fluvial sediments and this valley is narrow; therby the only small reserve can be expected. Another high anomaly is recognized nallowly along the tributary of Khlong Chan on the western edge of the BA12-BA19 lines, and a alluvial basin containing rare earth minerals is expected here.

2-4-2 Heavy mineral samples

Heavy mineral samples were panned from fluvial sediments of Khlong Chan and Khlong Noi. The quantity of heavy minerals are very small in Area A-2. Heavy minerals are fine-grained and well-rounded. The highest Sn content is obtained from ABM-04 collected from near the confluence of Khlong Chan and Khlong Noi. The Sn content of Khlong Chan samples tend to be higher than that of Khlong Noi samples. Two samples have high Total REE, Th-U content. One sample is collected from a tributary of Khlong Chan (ABM-01) and the other sample from the gentle stream on the granite (ABT-03).

2-5 Discussion

Area A-2 is composed of gentle hills. The granite is thought to be deeply argillized and to have a weathering crust. Therefore primary ore deposits and adsorption-type rare earth deposits were expected in the argillized and weathered portion of the granite. However, it has been made clear by this survey that the argillized part of granite is poor in REE, whereas the fresh granite area is rich in REE, and weathering crust is rather thin. It means that there is little possibility of primary ore deposits and clay adsorption-type rare earth deposits in this area.

The calculated reserve of placer deposits are rather small and low grade (Table 7), because the alluvial basin located along Khlong Chan is on a small scale. These lead to the conclusion that Area A-2 has a low potential for placer deposit.

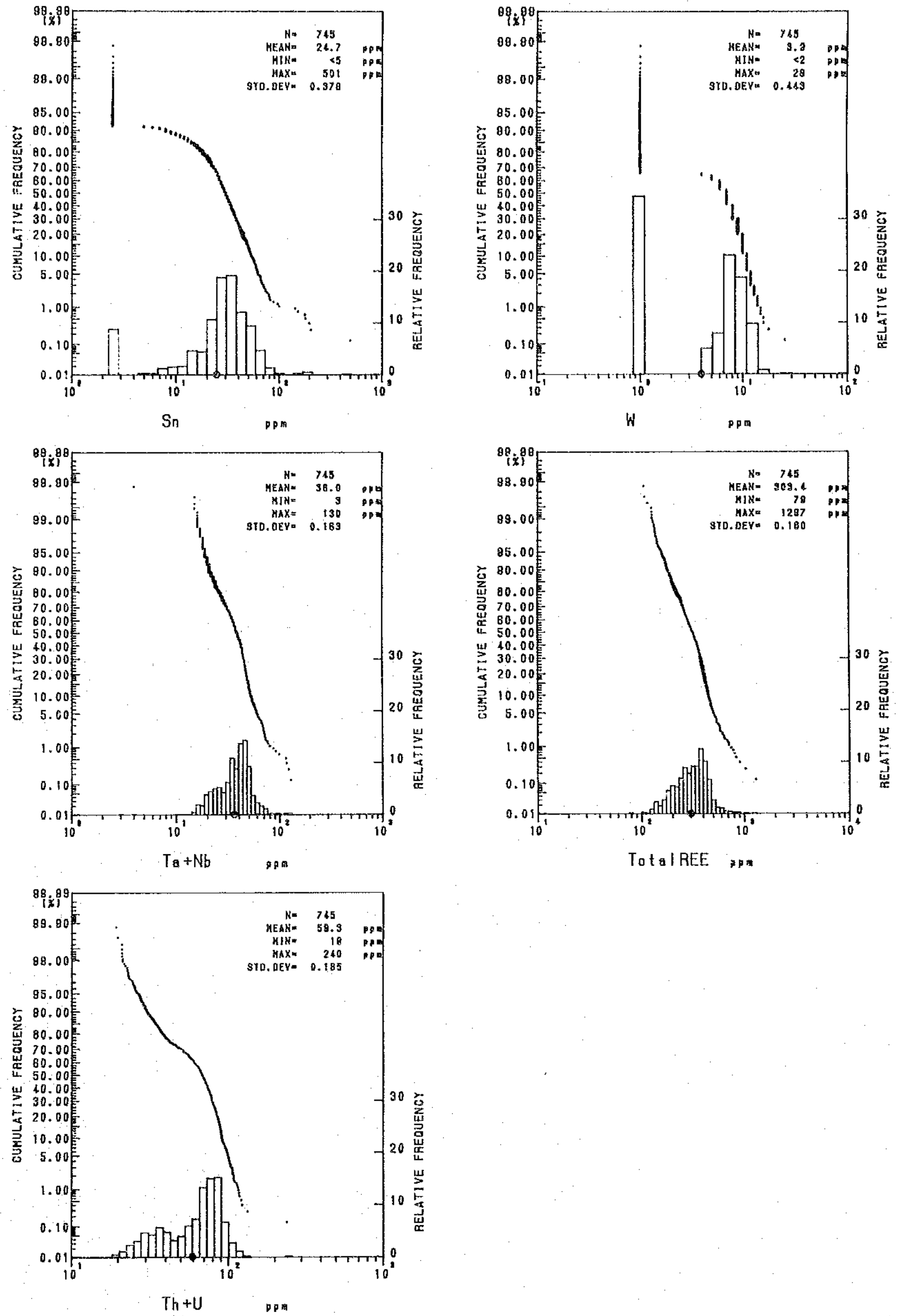

Fig. 10 Histograms and cumulative probability graphs of Area A-2

Sn

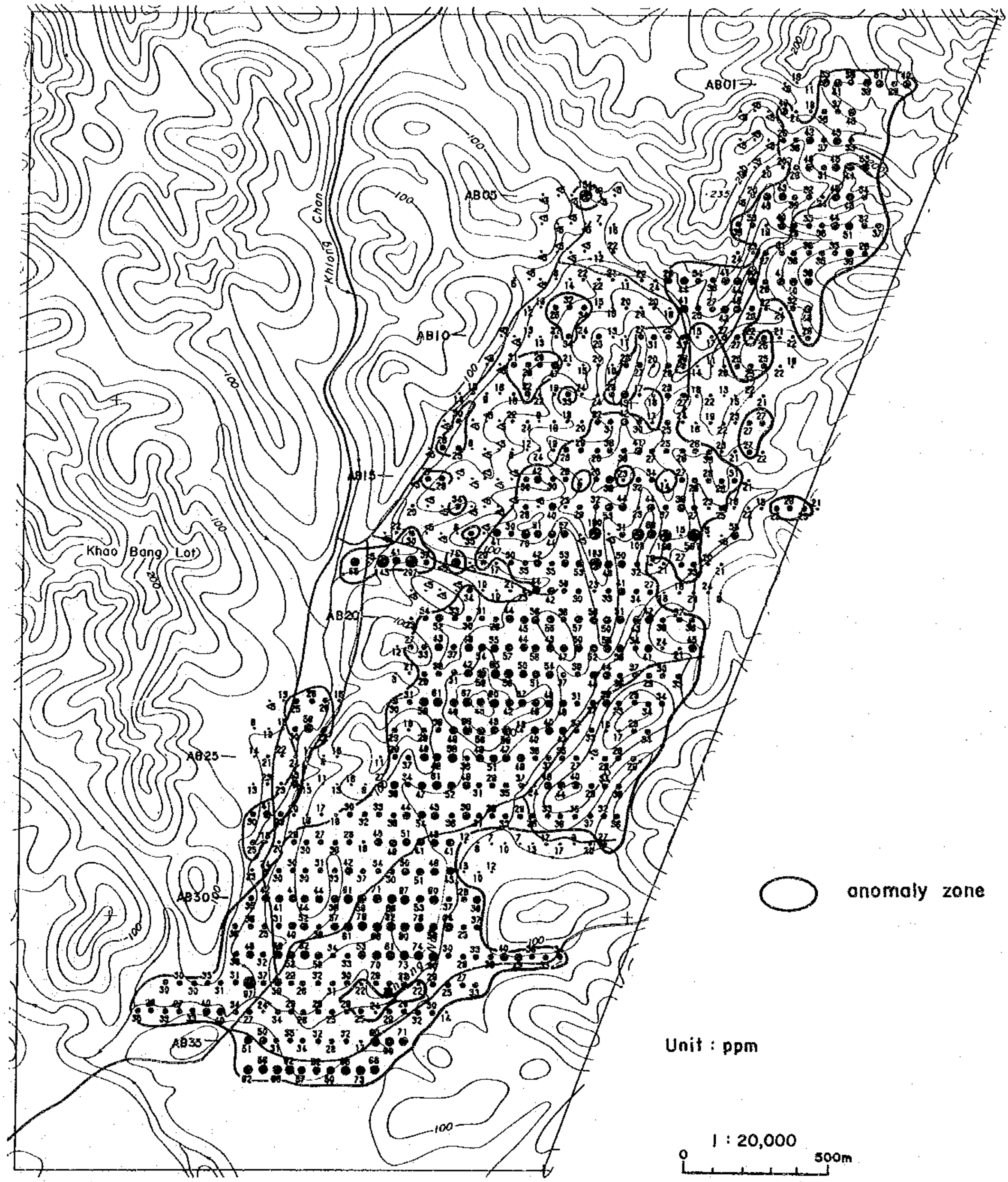

Fig. 11 Results of the geochemical survey of Area A-2 (1)

W

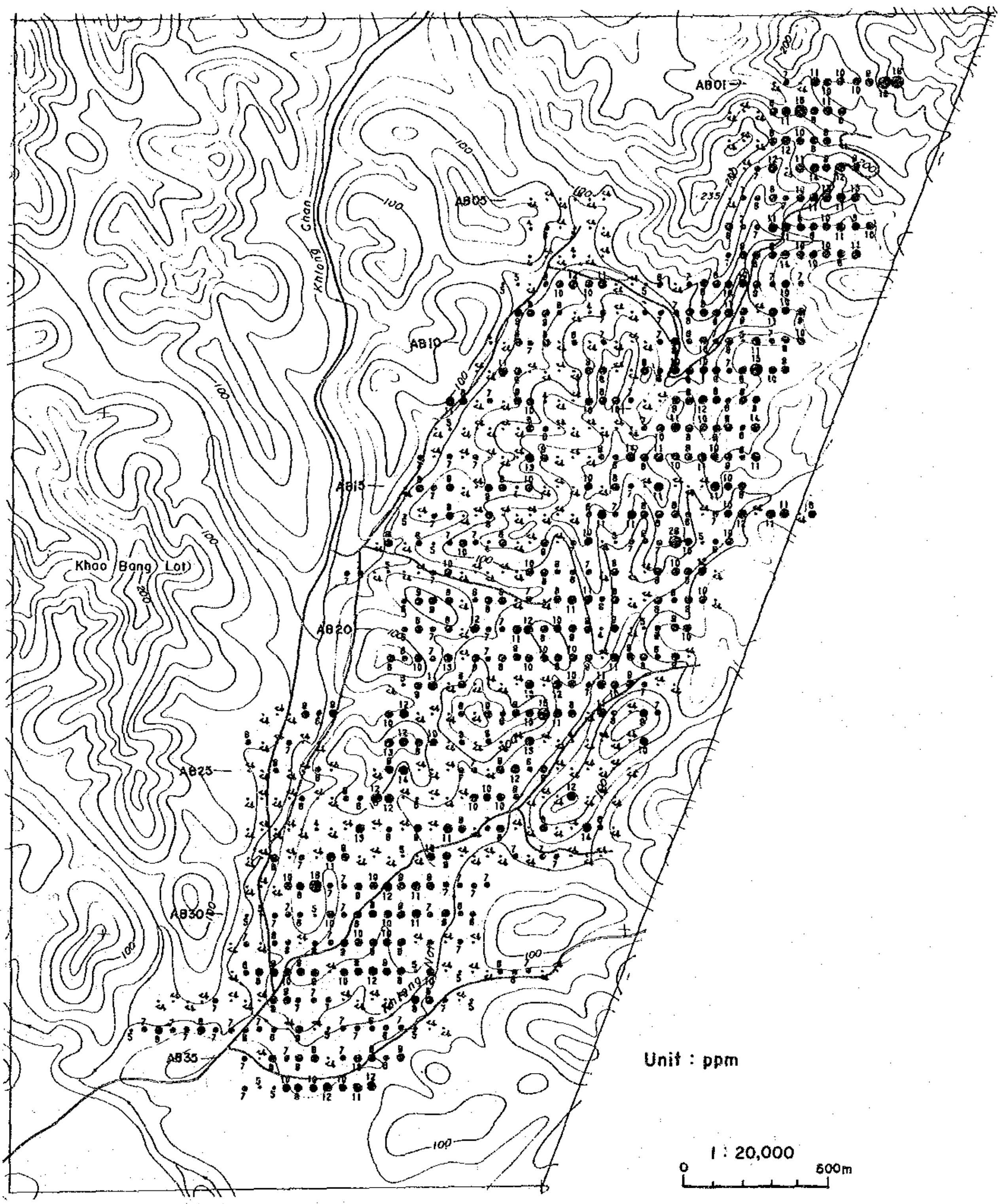

Fig. 11 Results of the geochemical survey of Area A-2 (2)

Ta + Nb

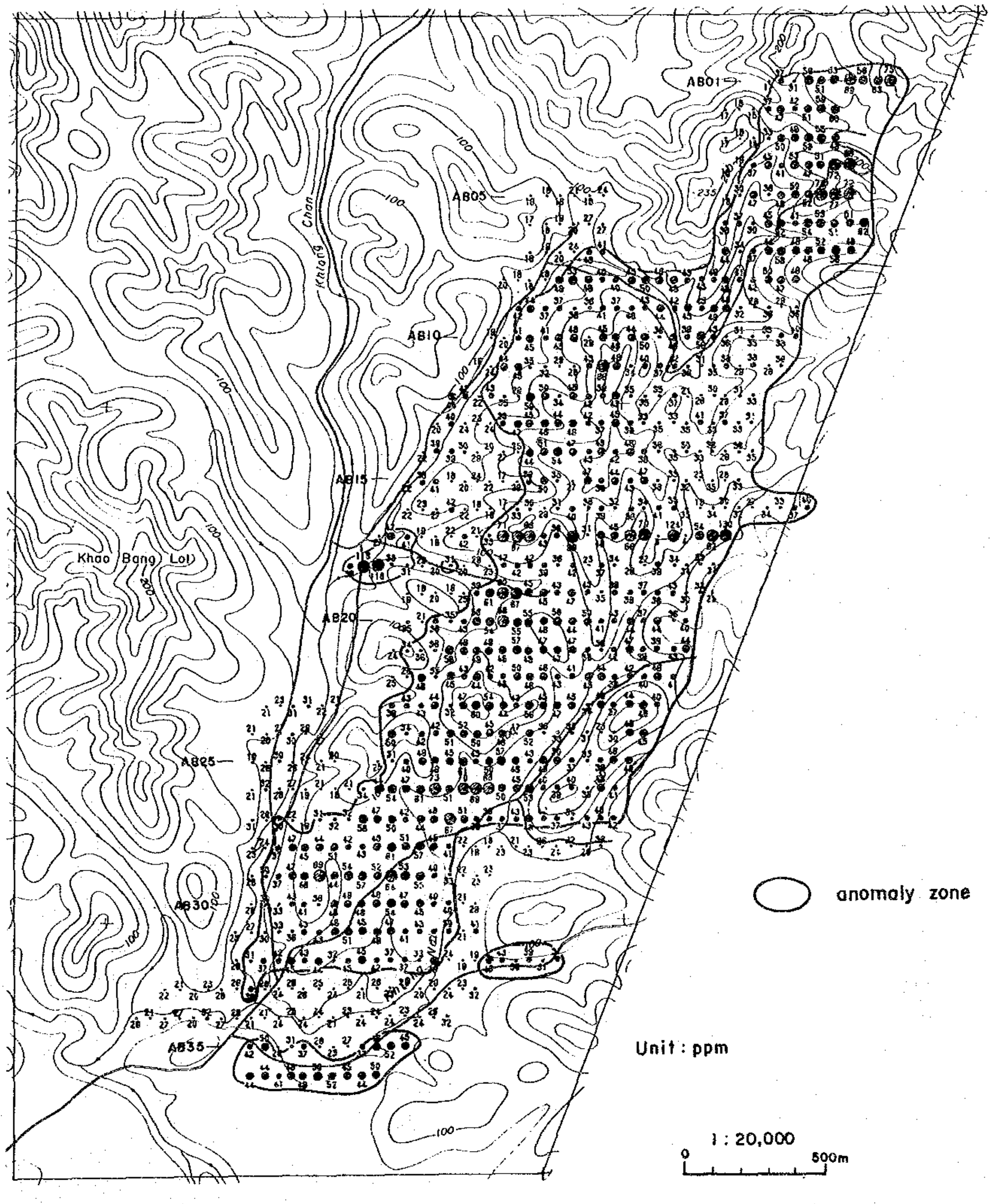

Fig. 11 Results of the geochemical survey of Area A-2 (3)

Total REE

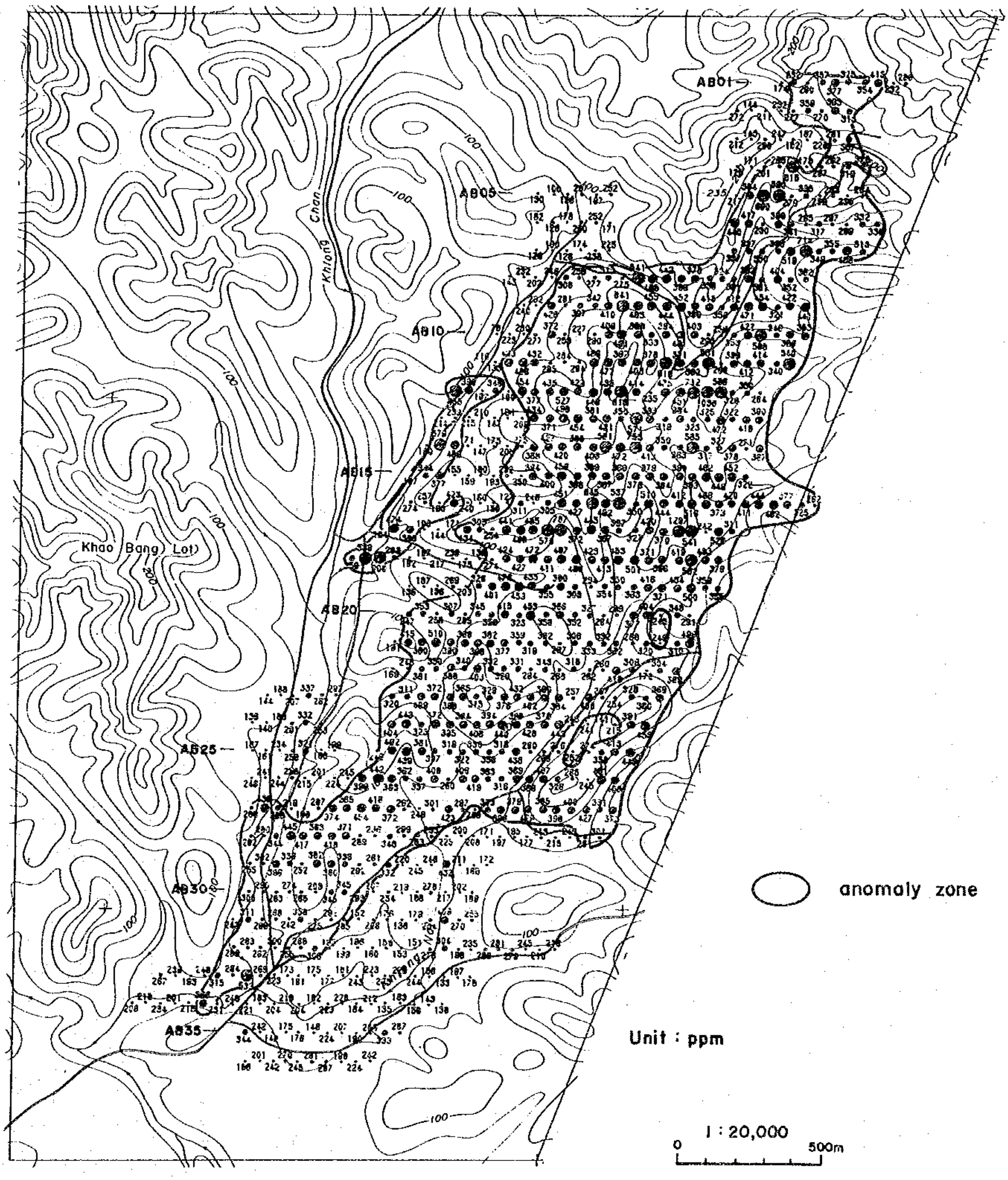

Fig. 11 Results of the geochemical survey of Area A-2 (4)

Th + U

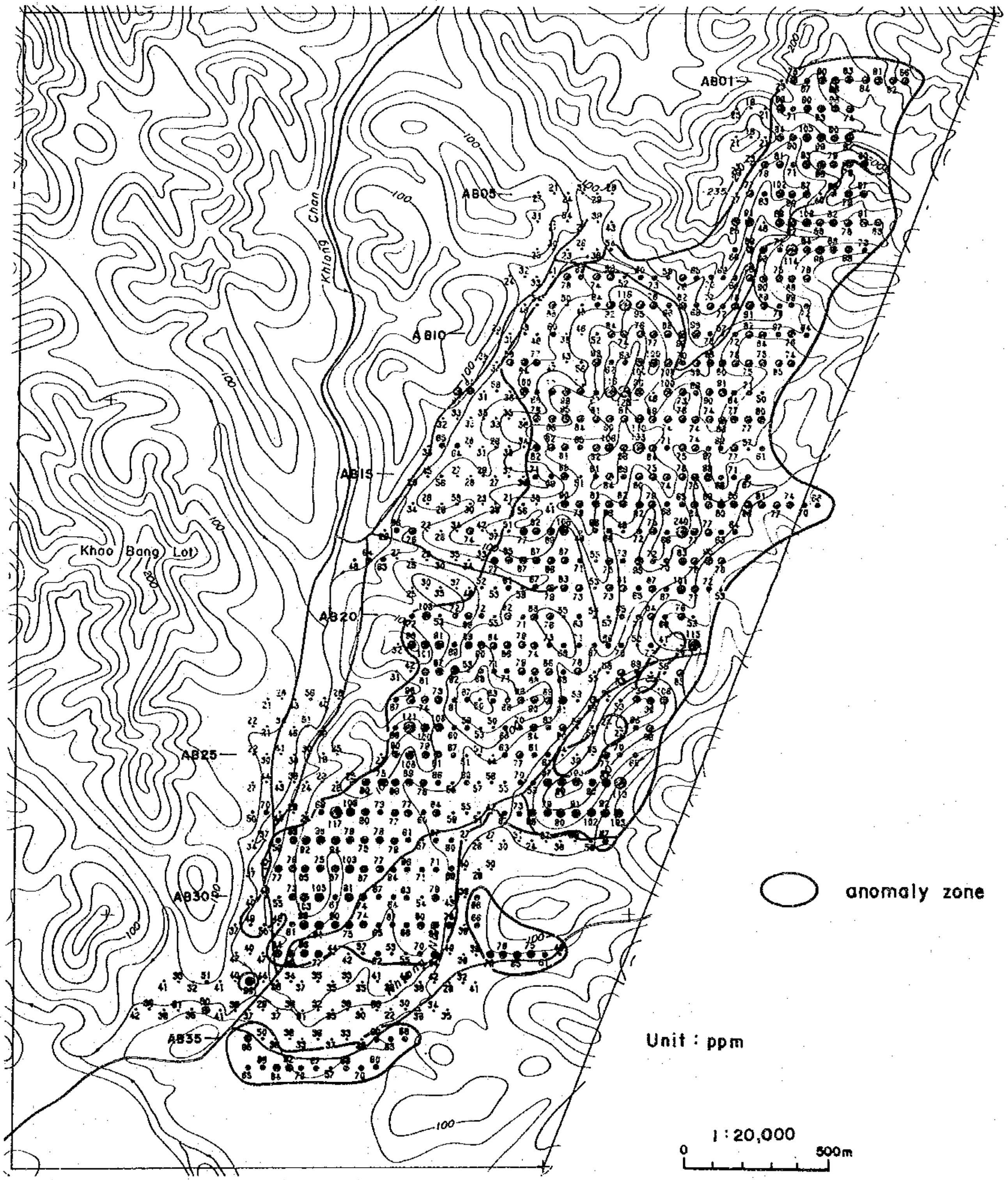

Fig. 11 Results of the geochemical survey of Area A-2 (5)

REE, Th in Monazite

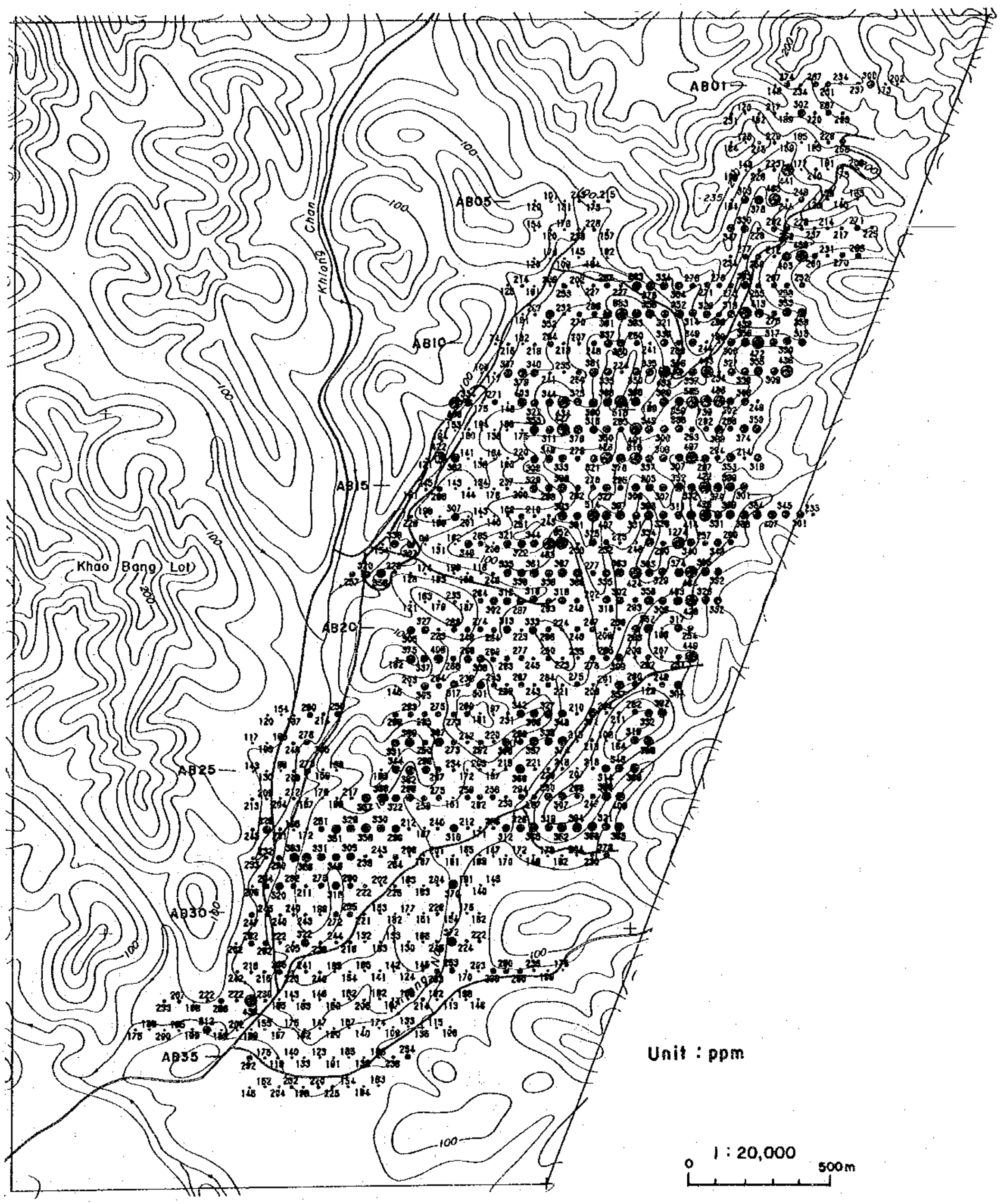

Fig. 11 Results of the geochemical survey of Area A-2 (6)

REE in Xenotime

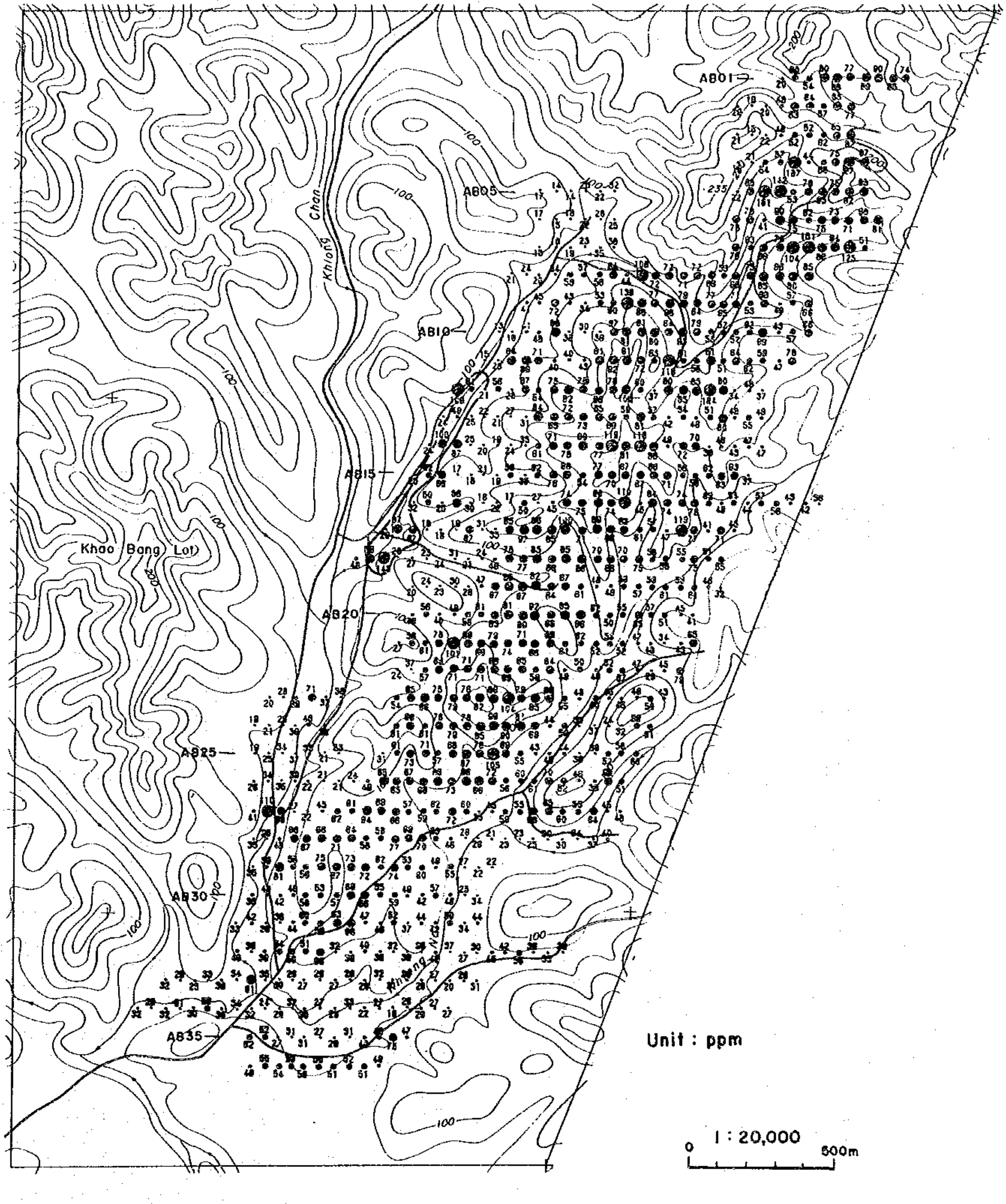

Fig. 11 Results of the geochemical survey of Area A-2 (7)

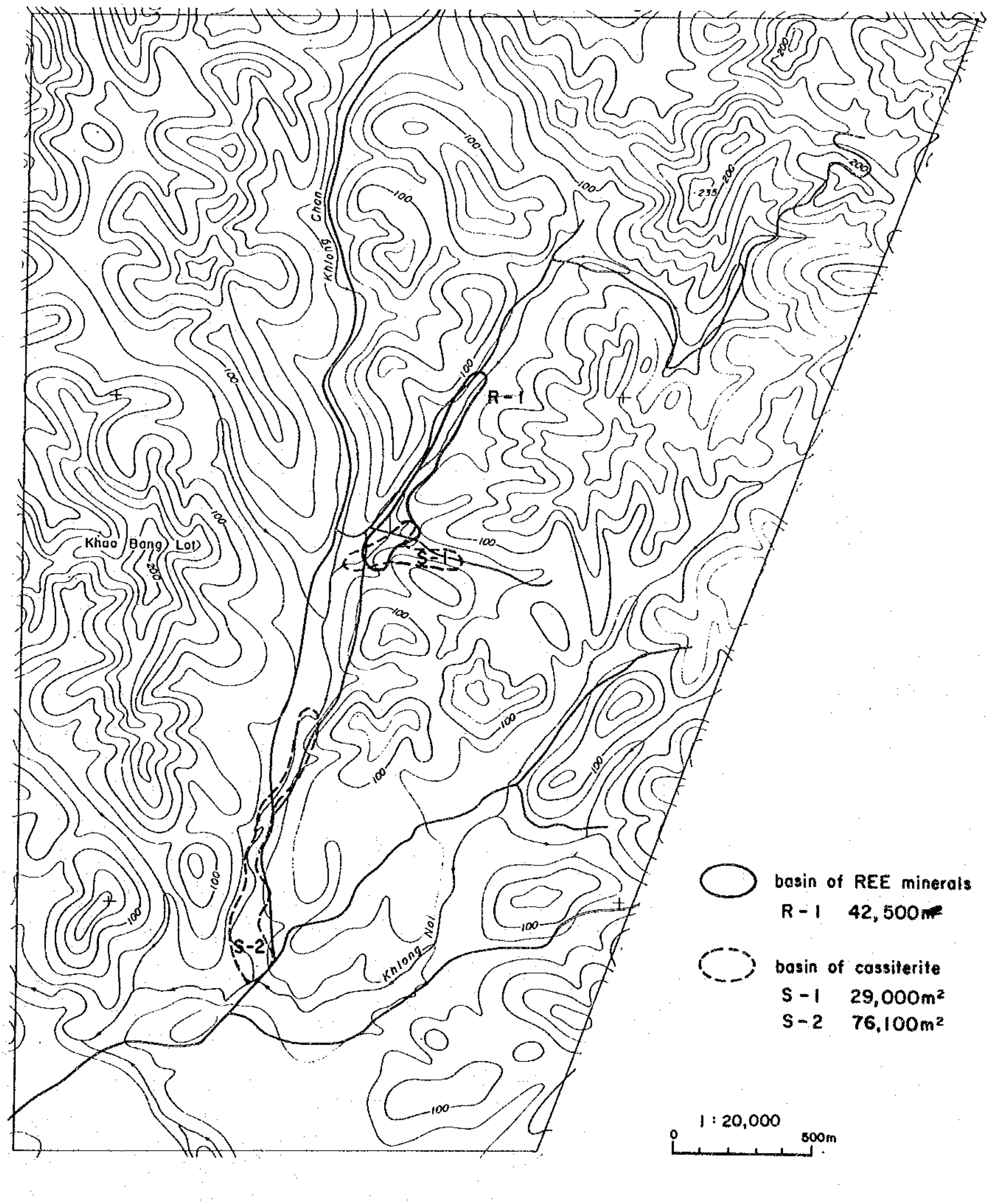

Fig. 11 Results of the geochemical survey of Area A-2 (8)

Table 7 Reserves in Area A-2

Area name	Mineral name	Areas (m^2)	Ave. Thick (m)	Reserves (m^3)	Ave. Contents (ppm)	Ave. Oregrade (kg/m^3)	Reserves of Minerals (t)
R-1	monazite	42,500	2	85,000	329	0.845	71
	xenotime				80	0.235	19
S-1	cassiterite	29,000	2	58,000	89	0.178	10
S-2	cassiterite	76,100	2	152,200	40	0.080	12
Total	monazite	42,500	2	85,000	—	0.845	71
	xenotime				—	0.235	19
	cassiterite	105,100	2	210,200	—	0.104	22

Chapter 3 Area B-1

3-1 Location

Area B-1 is about 7 kilometers northeast of Kra Buri Town. The center of the area is at latitude 10°28'N and longitude 98°35'E. The area was settled along the upper stream of Khlong (River) Wan in the north of the central granite mass, because of the extension of an alluvial basin (Fig.12).

The river system is a dendriform, and rivers run westward from the central granite mass. The area ranges in altitude from 50 to 300 meters. The western part of the survey area consists of rather steep mountains with narrow valleys, whereas the east part consists of a flat basin.

An unpaved road branches from the Route 4 at Khalong Village, and leads to the survey area. The distance of the roads from Kra Buri Town to Area B-1 is about 17 kilometers. It takes about 40 minutes by car, but it is difficult to get there after raining.

The anomaly of W, REE, Th, Y and U was detected by the first year geochemical prospecting of stream sediments, and the anomaly of Sn, REE, Th and U was detected by that of heavy mineral samples.

3-2 Survey method

Soil samples were collected from each points designed by the rectangular grid method. The spacing between survey line is 100 meters, and the interval between sampling points 50 meters. The number of collected samples are 106.

3-3 Geology

Area B-1 is underlain by Silurian-Devonian Kra Buri Formation of the Tanaosi Group, Cretaceous granite and Quaternary sediments (Fig.13).

Kra Buri Formation is dominant in the survey area. The formation is distributed in mountains and hills, and consists of slate, pebble-bearing mudstone and siltstone.

Cretaceous granite is distributed in the mountains in the east of Area B-1, and consists of biotite granite containing megacrystals of potassium feldspar, reaching a maximum size of about 2 by 5 centimeters. The rock is mainly composed of microcline, orthoclase, quartz, plagioclase and biotite, with accessories zircon, apatite, sphene and ilmenite.

The Quaternary is fluvial sediments. A relatively-wide alluvial basin is found near the BA10-BA15 lines, where the accumulations of a white clay about 1.5 meters thick and a sandy-silt about 1 meter thick overlies Kra Buri Formation. Much quartz gravel is found in the base of this alluvial basin. A small amount of sand and gravel is found along gullies near the BA01-BA03 lines in the northern part of the area. The sediments containing white clay are distributed near the BA05-BA07 lines on a small scale.

3-4 Result of geochemical exploration

3-4-1 Soil samples

The range, mean values (M) and standard deviation (σ) for each element are listed in Table 8. Fig.14 shows the histograms and the cumulative probability graphs of the five elements groups, i.e., Sn, W, Ta-Nb, Total REE and Th-U.

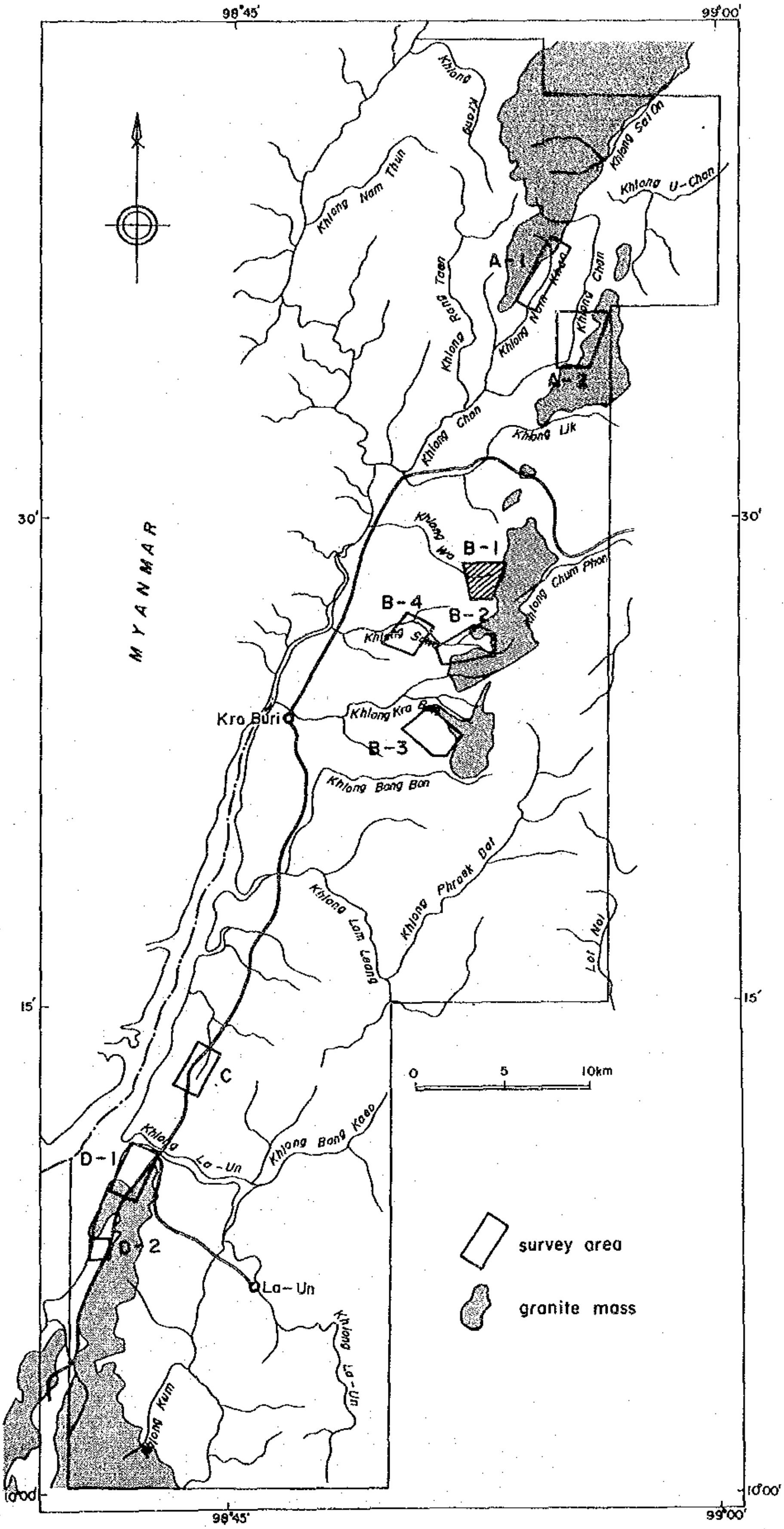

Fig. 12 Location map of Area B-1

B - 1

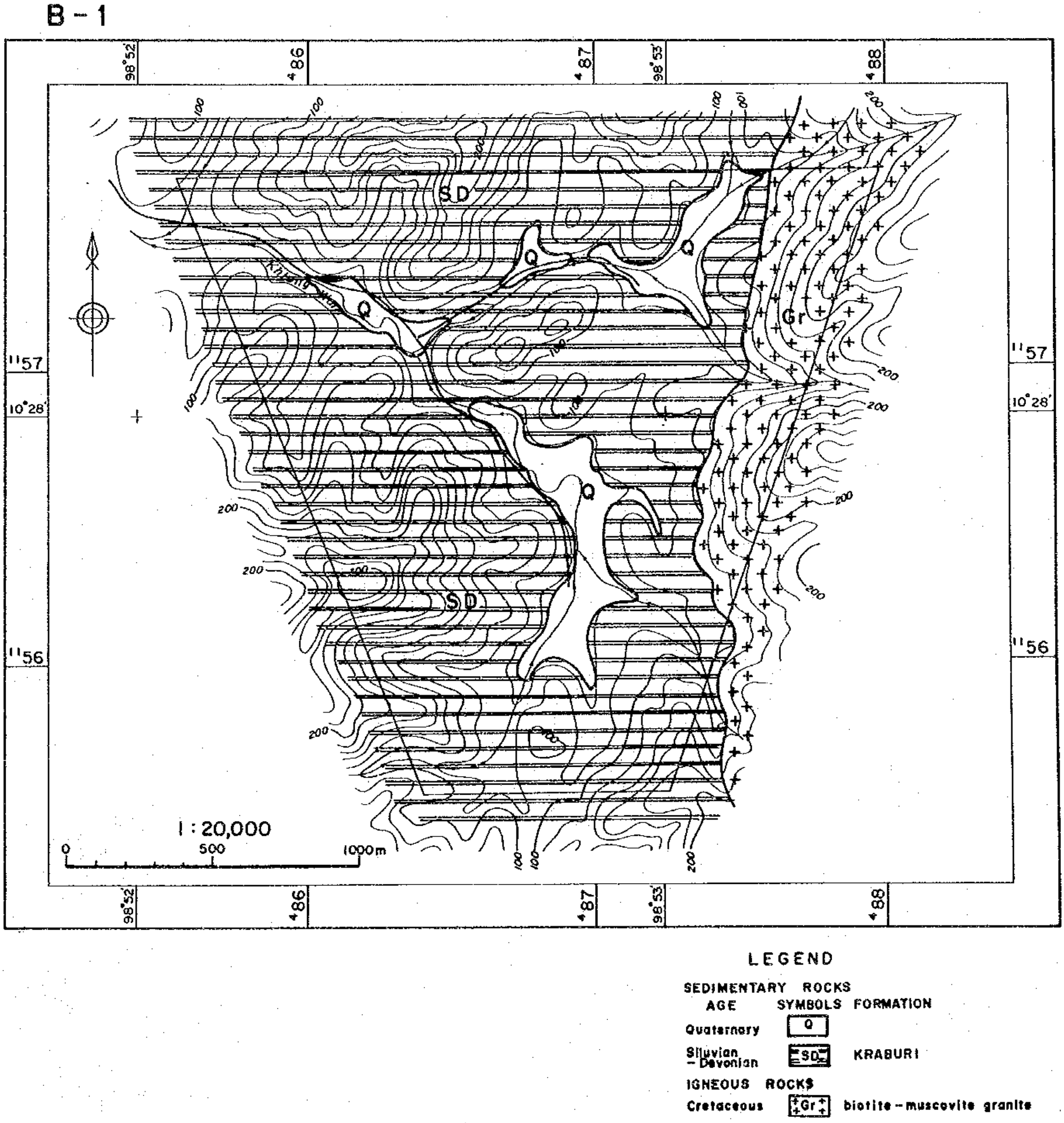

Fig. 13 Geologic map of Area B-1

The below-detection-limit values of both Sn and W account for about 40 percent of all the values. The above-detection-limit values of Sn show in a wide range. There is a natural gap in the cumulative probability graph of Sn at M+σ (20 ppm); thereby the threshold is taken at this value.

The maximum value of W is 10 ppm, and it means that there are no anomaly values. But the distribution of above-detection-limit values overlaps with that of anomaly values of the other elements groups on the content distribution maps.

The Ta-Nb group shows a bimodal distribution, and the threshold is determined to be the mean value (33 ppm) based on the boundary of two populations and the natural gap in the cumulative probability graph. The values of Total REE and Th-U groups are also composed of three or four populations, and the thresholds are determined to be M+0.5σ (304ppm and 61ppm, respectively) based on the natural gaps their cumulative probability graphs.

Table 8 Geochemical basic statistic quantities of Area B-1

Element	Unit	Max.	Min.	Average	av.ant-log.	Std.Dev.
Sn	ppm	59.0	<5.0	0.852	7.1	0.445
W	ppm	10.0	<2.0	0.477	3.0	0.393
Ta	ppm	8.0	<1.0	0.353	2.3	0.432
Nb	ppm	154.0	<2.0	1.473	29.7	0.232
Ce	ppm	370.0	20.0	1.965	92.2	0.264
Eu	ppm	3.0	<0.2	-0.264	0.5	0.388
La	ppm	220.0	5.0	1.563	36.6	0.345
Nd	ppm	130.0	<5.0	1.298	19.9	0.406
Sm	ppm	28.0	0.6	0.664	4.6	0.369
Tb	ppm	5.0	<0.5	-0.138	0.7	0.361
Th	ppm	130.0	15.0	1.605	40.3	0.213
U	ppm	28.0	1.4	0.828	6.7	0.297
Y	ppm	498.0	<2.0	1.561	36.4	0.409
Gd	ppm	20.5	<0.5	0.662	4.6	0.377
Dy	ppm	26.4	1.3	0.783	6.1	0.318
Pr	ppm	28.0	<20.0	1.016	10.4	0.074
Yb	ppm	16.4	1.9	0.726	5.3	0.258
Lu	ppm	2.3	0.3	-0.104	0.8	0.239
Ta+Nb	ppm	157.0	4.0	1.514	32.6	0.214
T.REE	ppm	919.9	40.9	2.339	218.1	0.289
Th+U	ppm	152.0	17.1	1.675	47.4	0.222

The content maps of the groups are shown in Fig.15 (1) to (4). The cluster of Sn anomaly values is found in the eastern edge of the BA02-BA03 lines and in the area of BA11-BA15 line. Other anomaly values are scattered at the points of BA0707, BA0902 and BA1002. The Sn anomaly zone in the BA02-BA03 lines coincides with the talus, alluvial fan and terrace sediments, mainly consisting of sand and gravel, derived from the granite mass. The BA11-BA15 anomaly zone is distributed in a southernmost part of the wide alluvial basin. The extension of this anomaly is larger than the BA02-BA03 anomaly. The basin consists mainly of clay and silt, and much quartz gravel accumulates at a base of the basin. The Sn grade is also high in this zone.

The distribution of Ta-Nb is almost same as that of Total REE, except some high values on the east of the BA11 line.

The largest anomaly zone of Total REE is found in the BA02-BA03 lines, which coincides with talus sediments in the north of the survey area. Other anomaly zones of Total REE overlap with terrace sediments consisting mainly of sand and pebble in the BA05-BA07 lines and fluvial sediments along a