THE KINGDOM OF THAILAND
REPORT ON THE COOPERATIVE MINERAL EXPLORATION
OF
YANG KIANG AREA
(THE COLUMBITE-TANTALITE EXPLORATION PROJECT)

CONSOLIDATED REPORT

OCTOBER 1989

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

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

The JICA and MMAJ sent to the Kingdom of Thailand a survey team headed by Mr. Iwao Uchimura for three years from fiscal 1986 to 1988.

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

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

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

June, 1989

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato
President
Metal Mining Agency of Japan

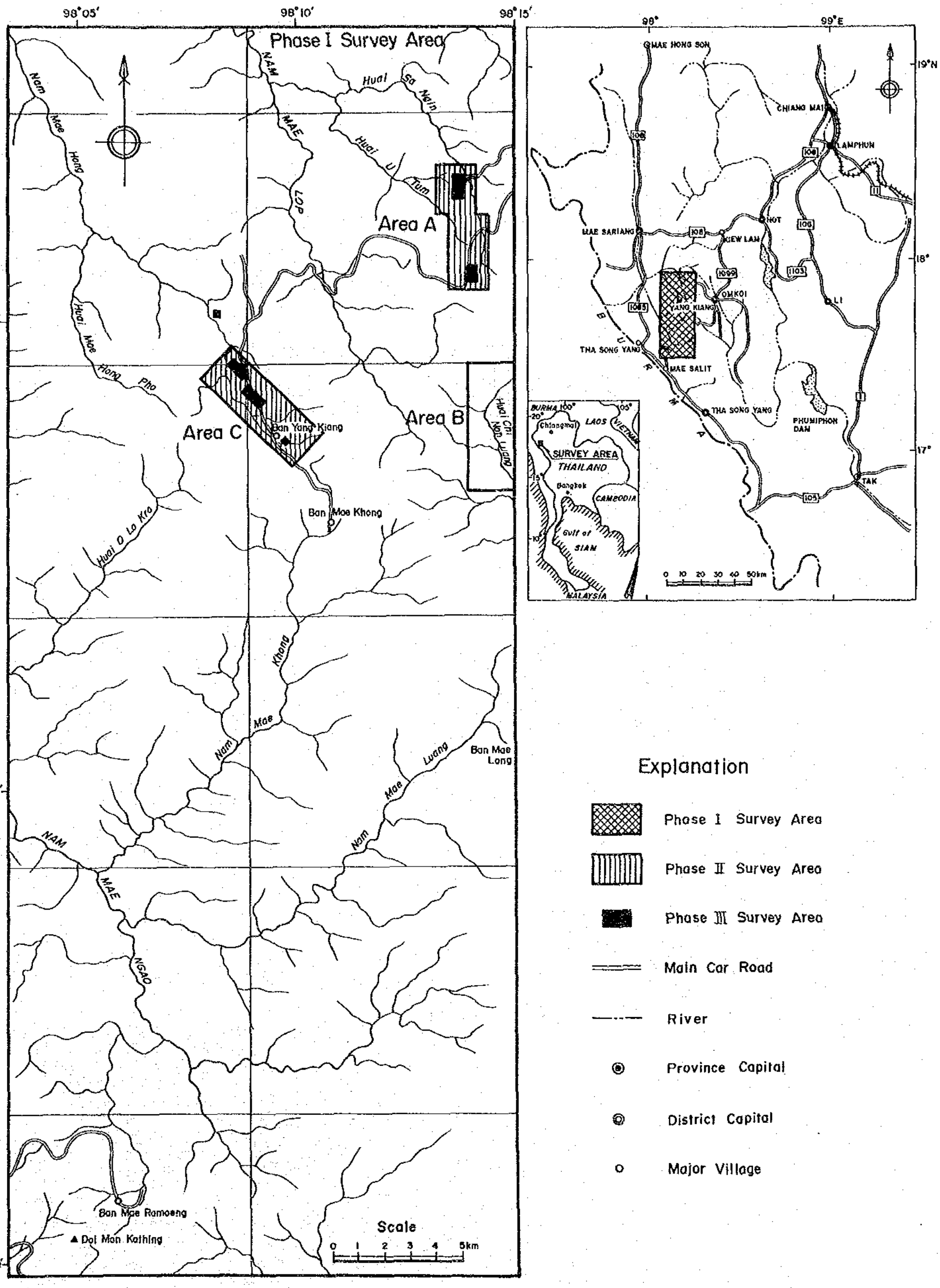

Fig.1 Location map of the survey area

SUMMARY

The survey was conducted in order to ascertain the presence of mineral resources such as niobium, tantalum, tin, tungsten, copper, lead, zinc, gold and silver in Yang Kiang northern Thailand.

The survey area is composed of Cambrian to Triassic sedimentary rocks, granitic intrusions and alluvium. Its eastern area is occupied by a batholithic granite, while its western part is characterized by distribution of sedimentary rocks.

Granitic stocks intruded in accordance with structural direction trending northwest of sedimentary rock at the middle and southwest end of the area. One of stocks at the southwestern edge of the area is of two mica granite, the others are biotite granite in which small scale two mica granites intrude in places.

The results of K-Ar isotopic dating of these granites suggest 189 Ma as the to,e of biotite granite intrusion, 73 to 80 Ma as the time of two mica granite intrusion and its associated tin and tungsten mineralization, and 40 Ma as the time of sulfide mineralization.

Small-scale placer deposits of tin and tungsten are scattered along the stream in the eastern granite distribution. Tin and tungsten vein-type deposits and their accompanying placer deposits are observed in the granite stock at the southwestern edge of the area.

Niobium, thantalum, tin and tungsten geochemical anomalous zones by stream sediment were detected in the eastern, central and southwestern areas.

The area of Huai Sa Ngin - Huai U Tum (Area A) in the eastern and the area around Yang Kiang village (Area C) in the center were selected for geochemical soil prospecting as the areas with high possibility of mineral deposits of niobium, tantalum, tin and tungsten; subsequently trench survey in Area A and drilling survey in Area C were carried out respectively.

Area A is composed of biotite granite of Triassic, two mica granites of Cretaceous, and dike rocks composed of pegmatite, aplite and quartz-veins intruding into these granites.

Especially pegmatite dikes which contain niobium, tantalum, tin and tungsten were found in most of the trenches. Analytical values of them are relatively high, and closely coincident with high geochemical anomalous values.

This finding indicates that the geochemical anomalies are ascribed to pegmatites. However, mineral contents of them are not sufficient to warrant their exploitation as primary ore deposits.

Tin and tungsten minerals were found in panning samples collected from the stream sediments. Old workings of placer deposits are scattered along the stream, and they have already been mined by local people.

These suggest that minerals of placer deposits originate from pegmatite. Most of promising areas for placer deposits have already been mined by local people, and the probability of discovering new placer deposits in the area seems to be low.

Area C is composed of Cambrian to Ordovician sedimentary rocks, granitic intrusives of the Triassic and the Cretaceous, and alluvium.

Geochemical anomalous zones, of in tin and tungsten are distributed in a NNW-SSE trending strip where many small-scale gossans are also scattered.

Drilling survey indicated that sedimentary rocks as roof pendant are sporadically distributed on a small scale in granite distribution.

Contact metasomatic deposits replacing limestone or calcareous rock are found along the boundary between granite and sedimentary rock or in sedimentary rock itself.

Orebodies are embedded in skarn. Ore minerals are sphalerite, chalcopyrite and pyrrhotite as major minerals, galena, scheelite and argentite as minor minerals.

Each orebody is lens-shaped ranging from $20x20m^2$ to $70x100m^2$ wide and from 5 to 10m thick, and not widely traceable. They are distributed over a zone 200 to 300m wide and more than 3km long.

Moreover, a considerable skarn zone and massive sulfide are found in a limestone area 1km NNW of Area C. This suggests that the mineralization is of a higher grade in this direction.

The total amount of ore reserves was estimated at 899,000t, Cu:0.49%, Pb:0.08%, Zn:1.17%, Ag:27g/t. While this suggests that mineralization is too low grade to warrant exploitation, there would be a rather high possibility of the presence of rich ore deposits in a NNW direction from Area C.

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PART I GENERAL REMARKS

PART I GENERAL REMARKS

CHAPTER 1 OUTLINE OF THE SURVEY

1–1 Background and Objective of the Survey

Starting in 1983, the Japanese Government conducted a cooperative mineral exploration in the Omkoi area of northern Thailand. The survey provided numerous data on the geology, geologic structure, related igneous rocks and characteristics of mineral deposits in the Omkoi area, and identified mineral indications of tungsten. On the basis of these findings, the Thai Government requested additional cooperative mineral exploration in the Yang Kiang area adjacent to Omkoi (Fig. 1).

In response to this request, a three phase study over three years was commenced in 1986 under cooperation between the governments of Thailand and Japan. The purpose of the survey was to clarify geology and geologic structure and their relation to mineralization and geochemical characteristics in the survey area, as a basis for identifying any ore deposits of niobium, tantalium tin, tungsten, gold, copper, lead, tungsten and other useful minerals with development potential.

1–2 Survey Method and Components

The survey began with geological reconnaissance of the area and geochemical pospecting of stream sediments to preliminarily identify candidate areas of mineral deposit. Detailed geologic survey and geochemical soil prospecting was then performed to further narrow down potential areas. Finally, drilling and trench survey was carried out to confirm presence of mineral indications. Work flows are shown in Fig. 2 and Fig. 3.

Survey components for each phase are described below.

1–2–1 First Phase (1986)

Geologic reconnaissance and preliminary geochemical prospecting of stream sediments was performed in the survey area (1,000km^2).

1. Geologic Reconnaissance

Geologic survey was carried out simultaneous to collection of geochemical prospecting samples. A 1:50,000 scale geologic map was prepared. Microscopic observation and chemical analysis of major and minor components of representative rock samples were performed. Relationship mineral and chemical components and geochemical characteristics, and tin and tungsten mineralization was studied, particularly with regards to the granite distributed over

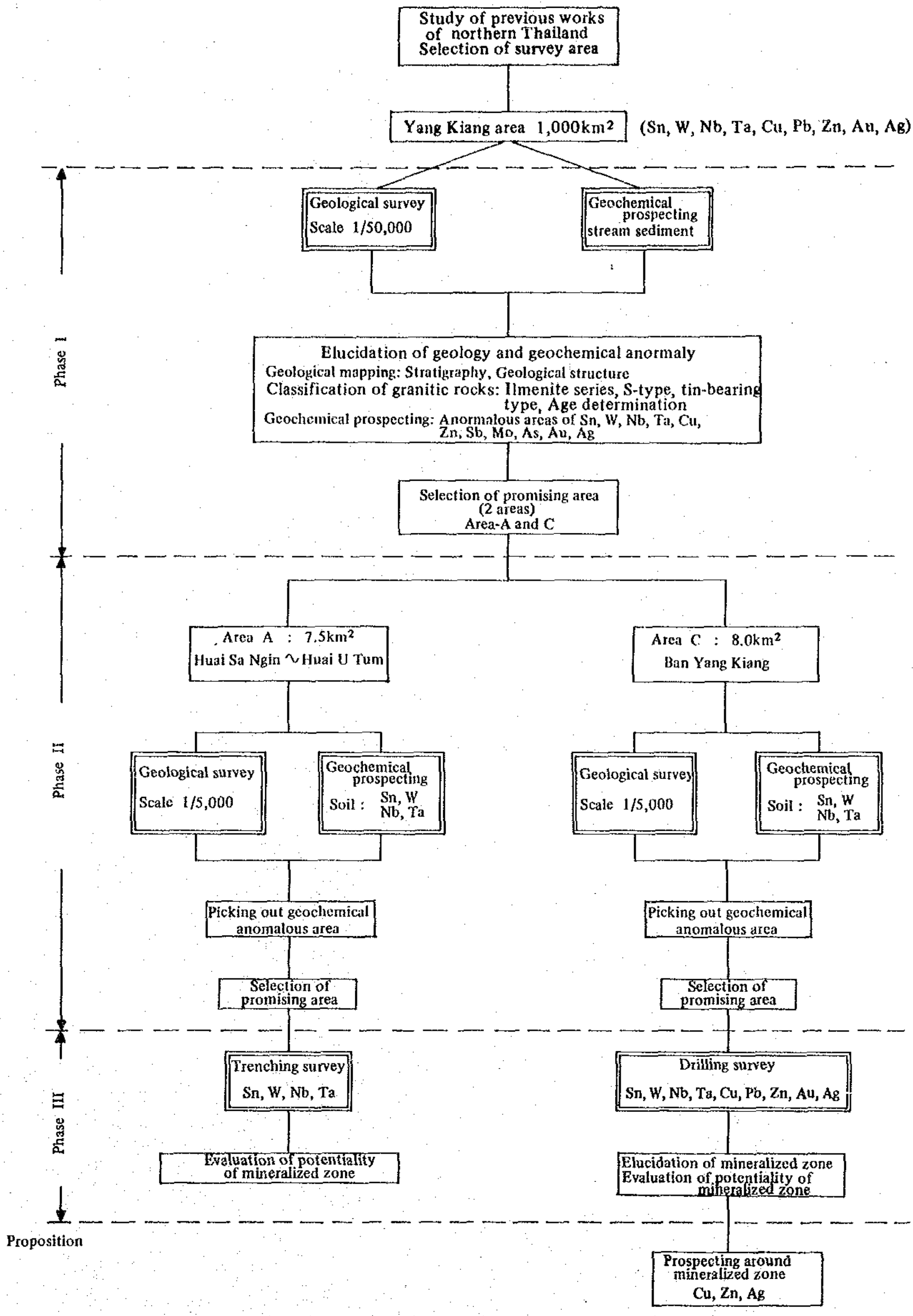

Fig.2 Flow Chart of the Exploration Program

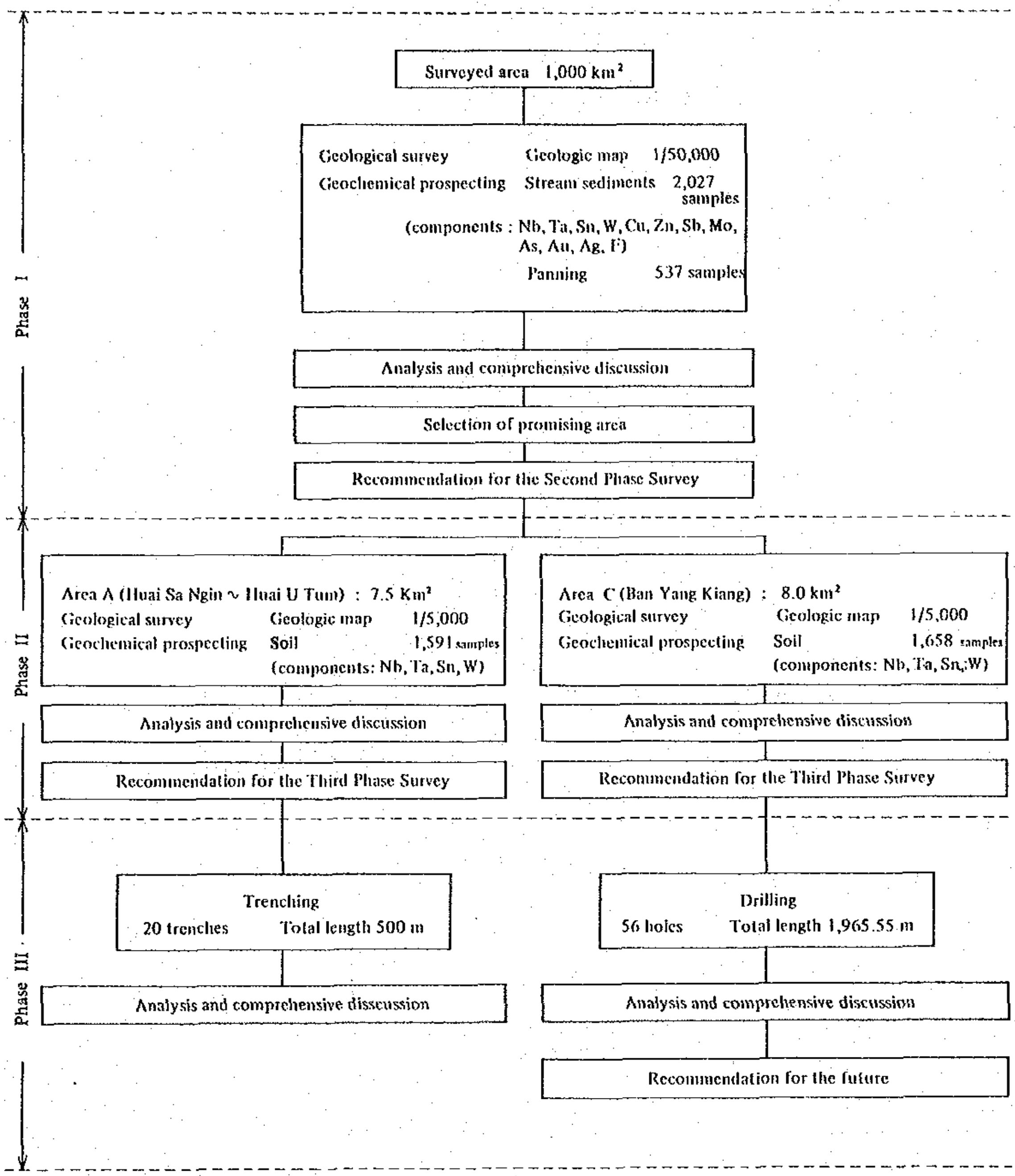

Fig.3 Flow Chart of the Survey

the large portion of the area.

Dating was performed for the 4 main granite masses. Survey of existing mines was carried out, including microscopic observation, x-ray diffraction, and chemical analysis of crude ores and concentrates.

2. Geochemical Prospecting

River systems were selected so as to evenly cover the survey area. A total of 1,259 samples of stream sediments (−80 mesh fraction) were then taken from these rivers and geochemically analyzed. Geochemical analysis was carried out for 12 indicator elements: Nb, Ta, Sn, W, Cu, Zn, Sb, Mo, As, F, Au, and Ag. On the basis of statistical processing, a 1/50,000 scale geochemical anomaly map was prepared for each element, and the relationship between elements was studied.

1–2–2 Second Phase (1987)

On the basis of first phase survey, 2 candidate areas were selected: i) Area A: Huai Sa Ngin ~ Huai U Tum, 7.5km², and ii) Area C: vicinity of Yang Kiang village, 8.0km². Total area for the two areas is 15.5km². Detailed geologic survey and geochemical soil prospecting was then performed for each area.

1. Geologic Survey

Geologic survey was carried out simultaneously with collection of geochemical samples. 1/5,000 scale geologic map was prepared for each area. Microscopic observation and chemical analysis of major and minor components of representative rock samples were carried out. Data was correlated with that of the first phase survey, and relationship with mineralizaion was particularly studied again in detail. Supplementary survey was carried out at points of mineral indication in each area.

2. Geochemical Survey

A 100m x 50m grid was drawn, and 1,591 soil samples collected from Area A and 1,658 soil samples from Area C for a total of 3,249 samples (−80 mesh products). Samples were geochemically analyzed for 4 indicator elements: Sn, W, Nb, Ta. On the basis of statical processing, a 1/5,000 scale geochemical anomaly map was prepared for each element, and the relationship between elements was studied.

1–2–3 Third Phase (1988)

1. Trench Survey

Trench dimensions were a standard 1m width, 2m depth and 25m length. Total trench

Table 1 Contents of survey and their quantities

Item \ Year			Phase I 1986	Phase II 1987	Phase III 1988	
Kind of survey			· Geological survey · Geochemical prospecting by stream sediment	· Geological survey · Geochemical prospecting by soil	· Trench	· Drilling
Area and quantities			1,000 km^2	Area A : 7.5 km^2 Area C : 8.0 km^2 Total : 15.5km^2	Area A 20 trenches Total 500m	Area C 56 holes Total 1,965.55m
Indoor tests	Thin sections		15 pieces	15 pieces	5 pieces	20 pieces
	Polished sections		15 pieces	21 pieces	6 pieces	13 pieces
	X-ray diffraction		14 samples	24 samples	6 samples	8 samples
	EPMA analysis		–	–	6 samples	10 samples
	Age determination (K-Ar method)		5 samples	–	–	–
	Chemical analysis	Rock	12 samples	11 samples	–	–
		Components for analysis	SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, BaO, Sn, Ig. loss	SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, BaO, Ig. loss	–	–
		Ore	12 samples	17 samples	50 samples	209 samples
		Components for analysis	Nb, Ta, Sn, W	Nb, Ta, Sn, W	Sn, W, Nb, Ta	Sn, W, Nb, Ta, Cu, Pb, Zn, Cd, Au, Ag
		Geochemical samples	2,027 samples	3,249 samples	–	–
		Compornents for analysis	Nb, Ta, Sn, W, Cu, Zn, Sb, Mo, As, Au, Ag, F	Sn, W, Nb, Ta	–	–

number was 20 and total length was 500m. A 1:100 scale sketch was prepared on the basis of findings. Also, samples were collected from each trench (total of 50 samples) for confirmation of mineral indications.

2. Drilling Survey

Drill hole depth was 30~50m with the exception of one portion where depth was 75m. Total drilled depth was 1,965.55m. On the basis of results, 1:200 scale drilling logs were prepared. Also, samples were collected from each hole (total of 209 samples) for confirmation of mineral indications.

On the basis of the above, presence of mineral indications, their scale, interrelationship and ore potential were comprehensively studied. Survey components are shown phasewise in Table 1.

1–3 Survey Period and Survey Team

Individuals participating in the planning, negotiation and execution of the survey are as follows.

1–3–1 First Phase (1986)

1. Period: 23 October 1986 ~ 11 May 1987
2. Team Members

	JAPAN	THAILAND
Planning and Negotiation	Norikazu Matsuda	Sivavong Changkasiri
	Naoki Kamijo	Chanin Rasrikriengkrai
	Takeshi Izumi	Phairat Suthakorn
	Seiichi Ishida	Prachon Charoensri
	Natsumi Kamiya	Kasem Chancharoonpong
	Yasuo Endo	Samai Chiemchindratana
	Toshihiko Hayashi	Sunoj Uenguoom
Field Survey	Iwao Uchimura	Peerapong Khuenkong
	Hiroshi Yoshida	Patchara Jariyawat
	Kenichi Takizawa	Arun Tritrangarn
	Yoshikatu Ichige	Wason Chanseang
	Hiroyuki Takahata	Boonchu Panglinput
	Makoto Miyoshi	Sawang Wanlaid

1–3–2 The second phase (1987)

1. Period: 5 Nobember 1987∿29 February 1988
2. Tearm Members

	JAPAN	THAILAND
Planning and Negotiation	Takeshi Izumi	Sivavong Changkasiri
	Seiichi Ishida	Thawat Japakasetr
	Yoshitaka Hosoi	Phairat Suthakorn
		Prachon Charoensri
		Kasem Chancharoonpong
		Samai Chiemchindratana
		Sunoj Uenguoom
Field Survey	Iwao Uchimura	Peerapong Khuenkong
	Jun Matsunaga	Patchara Jariyawat
	Yasunori Ito	Wason Chanseang
	Takamasa Horikoshi	Sawang Wanlaid
	Junichi Maeno	
	Makoto Miyoshi	

1–3–3 The third phase (1988)

1. Period: 4 December 1988∿30 June 1989
2. Team Members

	JAPAN	THAILAND
Planning and Negotiation	Minoru Fujita	Thawat Japakasetr
	Seiichi Ishida	Phairat Suthakorn
	Hiroshi Shimotori	Prachon Charoensri
Field Survey	Iwao Uchimura	Peerapong Khuenkong
	Takamasa Horikoshi	Patchara Jariyawat
		Wason Chanseang
Drilling	Shouhei Kusano	Veerachart Jittamasey
	Hisao Ataku	Sontaya Pungsuk
	Etsuo Hatakeyama	Kwanchai Saingtong
	Kazuto Tatsuyanagi	Sukhum Tawachana
	Hidenori Fujinuki	Winai Trumong
	Yuuji Shinkubo	Sangwarn Kattapong
		Suwicha Puthanon

CHAPTER 2 PREVIOUS WORKS

The survey area is in northwestern Thailand, located in a tin belt which extends from the Thai-Malaya peninsula to the Thai-Burma border.

A German Geological Mission (GGM, 1972) conducted a regional survey in northern Thailand in cooperation with the Department of Mineral Resources from 1965 to 1971, and evaluated its mineral potential based on the stratigraphy and geological structure established by the survey. The report describes tin, tungsten, fluorite, and antimony deposits in the Omkoi area. Based on the results of the survey, the Geological Map of Northern Thailand (1:250,000 scale), compiled by E. v. Braun, L. Hahn, and H. D. Maronde, 1981, was prepared.

Hahn and Siebenhüner described fossils from the above mapped area in 1982.

Vichit and Khunkong described tin and tungsten occurrences and characteristics in the Omkoi area in 1983. At the same time, they discussed the relationship between tin deposits and niobium-tantalum minerals found in stream sediment from the area.

JICA & MMAJ (1986) carried out a series of geological survey and geochemical prospecting over the area of 1,000km^2 around Omkoi town from 1983 to 1985, and selected some favorable zones for Sn-W mineralization.

CHAPTER 3 SUMMARY OF GEOLOGY AND ORE DEPOSITS

Northern Thailand, including the survey area, is located roughly in the center of the Indochina peninsula.

The Indochina peninsula has been repeatedly subjected to orogenic movement taking place during four ages: at the end of the Precambrian age, during the Variscan orogeny (the Hercynian orogeny at the end of the Paleozoic), the Indochina orogeny (the Triassic to the Jurassic of the Mesozoic) and the Alpine~Himalayan orogeny (the Cretaceous of the Mesozoic to the Cenozoic). The geological structure of northern Thailand is a product of these orogenic movements, having been particularly affected by the fractural movement resulting from this orogeny.

Northern Thailand is divided from the west into four tectonic provinces on the basis of the results of the above orogenic movements (JICA, 1984): the West Tectonic Province (along the Thai-Burma boarder), the Main Western Range Tectonic Province (between Mae Sariang and Chiang Mai), the Central North Tectonic Province, and the East Tectonic Province (Khorat Plateau).

The greater part of the survey area falls within the Main Western Range Tectonic Province. The southwest part of the area is included in the West Tectonic Province. The Main Western Range Tectonic Province. The southwest part of the area is included in the West Tectonic Province. The Main Western Range Tectonic Province consists of metamorphic rocks of the end of the Precambrian, and Precarboniferous sedimentary rocks of the Paleozoic to the Mesozoic which unconformably overlay these metamorphics, and granitic rock of the Carboniferous and Traiassic intruded into the above mentioned rocks. The West Tectonic Province consists of carbonate rocks and clastic rocks of the Paleozoic to Mesozoic, and Mesozoic granite intruded into them (Fig. 4).

The east part of the area is occupied by batholith granite extending north~south, and the west part is distributed with sedimentary rocks of the Paleozoic and Mesozoic. The sedimentary rocks strike NW~SE. Granite stocks intrude in conformity with this structural direction at the middle and southwest end of the area.

It is reported that ore deposits bear close relationship with granite activity after the Mesozoic (GGM, 1972). Ore deposits and mineral indications of tin, tungsten, lead, zinc, antimony, etc. are seen throughout the area.

All ore deposits of tin and tungsten occur in granite or quartz veins originating therefrom, and are found in the cupolas and margins of granite bodies, or in sedimentary rocks overlying the same.

Secondary ore deposits of tin and tungsten are found in batholith granite at the eastern portion of the area. Primary and secondary ore deposits are found in granite stock centered on the Mon Kathing mountains at the southwestern extreme of the area.

Tin and tungsten mines located in Omkoi district to the east are Yong Ku, Pha Pun, Pha Pun Dong, Pi Tu Khi, Huai Yap and Huai Sue. In the west in the Mae Sariang district, mines are Mae Rama, Pha Mark, etc.

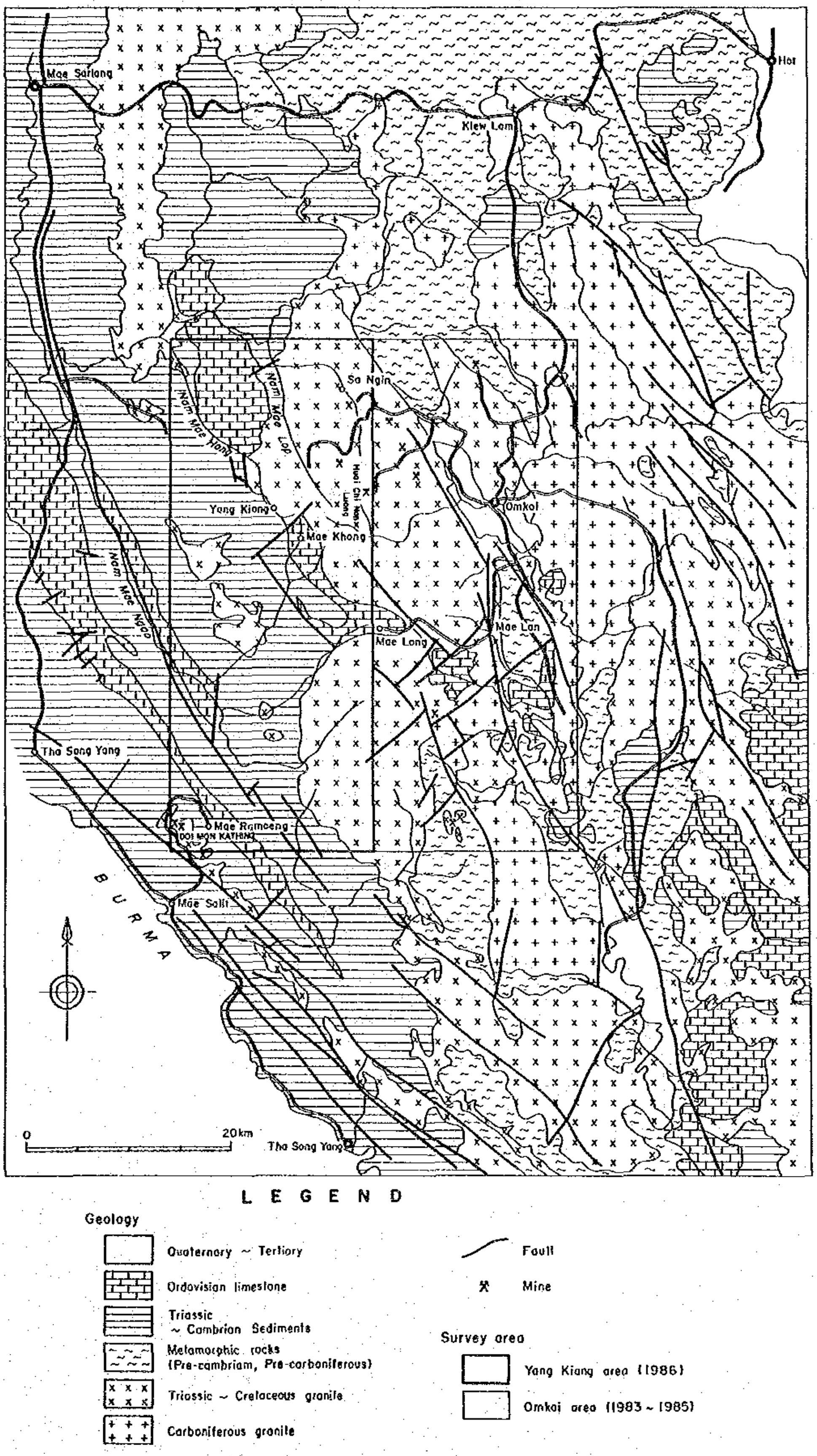

Fig.4 Regional geologic map

CHAPTER 4 GEOGRAPHICAL INFORMATION OF THE SURVEY AREA

4–1 Location and Accessibility

As shown in Fig. 1, the survey area is located in northern Thailand, about 200km southwest of Chiang Mai at east longitude 98°03′30″～98°15′00″, and north latitude 17°29′00″～17°56′30″. The area is 50km north to south and 20km east to west. Total land area is 1,000km^2.

Administratively, the eastern half of the area falls within Omkoi district of Chiang Mai province. The western portion of the area is in Mae Sariang district of Mai Hong Son, and the southwest～southern portion in Tha Song Yang district of Tak province.

The Yang Kiang area adjoins the Omkoi area on its east side where a Cooperative Mineral Exploration was conducted from 1983 to 1985.

The town of Omkoi, Omkoi district, where the base camp was set for the survey, is accessible from Chiang Mai by National Highway No.1099 southward from the village of Kiew Lam which is at distance of about 120km from Chiang Mai on National Highway No.108 connection Chiang Mai with Mae Sariang and Mae Hong Son. There is bus service making one round trip a day between Chiang Mai and Omkoi. Both national highways No.108 and 1099 are fully paved roads. The distance from Chiang Mai to Omkoi is about 170km, which is covered by car in about three hours.

National Highway No.1085 runs southward from Mae Sariang to the west of the survey area and leads to Tak via Tha Song Yang. This highway is not yet paved between Mae Sariang and Mae Salit, and is being improved at its southern portion.

The distance between Omkoi and Mae Sariang is 114km which can be covered by car in 2 hours. Mae Sariang and Mae Salit are separated by 116km, which can be covered by car in about 3.5 hours. Chiang Mai and Bangkok are separated by about 570km as the crow flies, and this distance is covered by 4 to 5 flights a day of regular air service, taking about 60 minutes. The rail route between the two cities is 751km, requiring about 13.4 hours. The highway between the cities is covered by express bus in about 10 hours.

Several motorable roads lead to the survey area, namely, from Omkoi to U Tum Tai and Ko Pro Lu in the northeast of the area (unpaved), and National Highway No.1267 from Mae Salit to Mae Ramoeng (fully paved).

In the case of unpaved road, four wheeled drive is necessary for safe negotiation due to rugged terrain and sharp curves. About 3～4 hours is necessary to make the trip from Omkoi to the area. During the rainy season, the road is largely impassable due to muddy conditions.

In addition, the area is criss-crossed by paths connecting the scattered hill tribe settlements and cultivated fields.

4–2 Topography

To the east of Nam Mae Lop, which flows from southeast to northwest through the northeastern part of the area, terrain is comparatively well dissected highland 700~1,100m in elevation. Rugged terrain with sharp relief ranging from 200m to 1,600m elevation is found between Nam Mae Lop and Nam Mae Ngao, flowing southeast to northwest in the southwestern part of the area. The region west of Nam Mae Ngao is gentle landform gradually increasing in elevation to a range of mountains running northwest to southeast, and including Doi Mon Kathing at the southwest extremity of the survey area and which is the site of scattered mines. The southwest side of these mountains is sharp cliff.

4–3 Climate and Vegetation

Climate of the survey area belongs to the tropical savanna type. The rainy season is the result of the southwest monsoon from May to October, and the dry season is the result of the northeast monsoon from November to February. The nouthwest wind weakens in March and April, producing the hottest season in the year.

Generally, monthly average temperature is in the range of 16~28°C. Daily variation of temperature in the dry season is extreme at 3~35°C. In high mountain areas, temperatures fall as low as 0°, resulting in frost.

Annual precipitation is 800~900mm. Almost no rainfall falls from December to March.

In the northern to eastern portion of the area, vegetation is mainly sparse virgin forest of broadleaf trees mingled with some coniferous trees such as pine. Thick jungle mixed with stands of palm tree is dominant in the southwest portion of the area.

4–4 General Information

Population of the survey area is almost entirely Karen hill tribes. Their remote, small villages consisting of several to 20 or 30 dwellings, are scattered in flat places along rivers and between hills.

Primary schools are located at the major villages of Yang Kiang, Mae Khong and Mae Ramoeng. Traveling medical service is also available at the villages. These are evidence of the gradual development occurring in the area. However, the population continues to engage in primarily subsistence living due to the lack of access in and out of the area.

Principal industry of the area is paddy cultivation and rice cultivation in upland fields by the slash and burn method. Animal husbandry is also practiced (beef cattle, water buffalo, hogs), as well as weaving, mining (tin and tungsten) and logging (teak).

Transport of goods is by manpower, and in some cases by elephant.

Omkoi town is the administrative and commerical center of Omkoi district, and is the site of the Omkoi district office, as well as a primary school, middle school, hospital, post office and police station. There are also shops, restaurants, a gas station and other establishments. The greater part of the population of Omkoi town is Thai.

CHAPTER 5 SUMMARY OF SURVEY RESULT

5–1 Whole Survey Area

5–1–1 Geologic Setting

The geology of the survey area consists of Pre-Carboniferous metamorphic rocks and the Cambro-Ordovician, Ordovician, Siluro-Devonian, Devono-Carboniferous, Carbono-Permian and Permo-Triassic sedimentary rocks. Granitic rocks intruded into these sedimentary rocks. Quaternary sand and gravel beds also develop in small scale along streams.

The sedimentary rocks are mainly composed of alteration of sandstone and shale with limestone, and limestone dominates only in the Ordovician.

The granitic rocks are developed as five masses in this area: two batholith distribute in the northeast and southeast of the survey area, and three stock masses at the center, northwest and the southwestern corner of the survey area. The granitic stock at the southwestern corner is called the Mon Kathing mass. Four granitic masses excluding the Mon Kathing mass are mainly composed of biotite granite with porphyrytic K-feldspar. Muscovite-biotite granite is also observed in the part of the batholithic mass and the Mon Kathing stock.

All the granitic masses in this area are classified into tin granite, because of its high concentration of tin, more than 15ppm Sn.

Isotopic ages of the granitic masses were measured by K-Ar method. The center stock was determined to be 189 Ma which is the oldest age in this measurement. 73 to 80 Ma were from the northeast and southeast batholiths and 40 Ma from the Mon Kathing stock. The Rb-Sr ages and K-Ar ages of Triassic granites in the surrounding area previously obtained are 190 to 236 Ma. So the oldest age, 189 Ma can be considered to the age of intrusions. The ages of 73 to 80 Ma may correspond to tin and tungsten mineralization, the age of 40 Ma to sulfide mineralization.

The geological structure is approximately NW-SE, N-S, and NE-SW in the direction. Sedimentary rocks strike NW-SE direction, and they present a monoclinal structure in the southwest of the survey area. A synclinal structure with NW-SE direction is seen in the northern half. The faults are mainly developed in NW-SE direction. The NE-SW and N-S faults are secondary.

5–1–2 Ore Deposits

As for the ore deposits, there are secondary Sn-W ore deposits developing on the granitic batholiths of the northeast mass and primary and secondary ore deposits around the Mon Kathing stock.

The former ones are eluvial ore deposits. Several old workings of such deposits are also found in this area. The ore minerals are cassiterite with subordinate scheelite.

The ore deposits in the Mon Kathing area are tin and tungsten-bearing quartz veins developing in the granitic stock and eluvial ore deposits occurring in gravels accumulated near such kinds of quartz veins.

The several quartz veins, striking NW-SE, occur in the granitic stock with the width from 10 to 80cm for each veins. The quartz veins are exposed for a distance of about 4km and five workings can be seen along the veins. The principal ore mineral is wolframite with accessory cassiterite. Pyrrhotite, arsenopyrite, chalcopyrite and pyrite are observed as disseminated sulfide minerals near the quartz veins.

5–1–3 Result of Geochemical Prospecting

The geochemical prospectings using stream sediments were attempted to extract geochemical anomaly areas of the 12 elements, such as niobium, tantalum, tin, tungsten, copper, zinc, antimony, molybdenum, arsenic, gold, silver and fluorine. As the result high anomaly areas of tin, tungsten, niobium and tantalum were found; especially Huai Sa Ngin-Huai U Tum (Area A), Huai Chi Non Luang (Area B) and around Yang Kiang village (Area C) the northeast mass and the Mon Kathing stock are remarkable. The Mon Kathing stock area has already been prospected. It was difficult to conduct survey work in Area B because the Department of Forestry has the forest plantation area. Therefore detailed survey was conducted in Area A, and Area C.

5–2 Area A

5–2–1 Geology

Area A is covered by granites being regarded as Triassic. The granites consist of medium to coarse grained K-feldspar bearing porphyritic biotite granite, fine to medium-grained two mica granite, pegmatite, and aplite. The relation of the first two is not clear because of mal-exposure, but they are thought to be different rock bodies because of difference in their distribution, form, lithology and texture. It is inferred that after the biotite granite batholith was formed, the two mica granite intruded, pegmatite and aplite subsequently intruded into both granite bodies.

5–2–2 Ore Deposits

Old workings of placer deposits of tin and tungsten are in the upper and the lower stream of Huai Sa Ngin and tributaries of Huai U Tum.

Cassiterite and scheelite were found in panning concentrates of stream sediment. Moreover, cassiterite, scheelite, columbite, tantalite, and others are found in panning concentrates of several weathered pegmatites.

This fact indicates that placer deposits originated from pegmatite dikes.

5–2–3 Result of Geochemical Prospecting

Geochemically anomalous zones rich in tin, tungsten, niobium, and tantalum are generally coincident with each other and distributed geographically in elevated area around old workings of placer deposits, and mineral indications.

Trench survey were conducted on the high anomalous zones.

5–2–4 Trench Survey

Trench survey was carried out in the zones where geochemical high anomalies of niobium, tantalum, tin and tungsten overlap.

Dike rocks composed mainly of pegmatite were found in most of the trenches, and the analytical values of these rocks coincide nearly with geochemical anomalous values.

This suggests that geochemical anomalies originate from pegmatites.

While dike rocks in a few of the trenches contain high values of niobium, tantalum and tin, these are of too low a grade to warrant exploitation as primary ore deposits.

Tin and tungsten minerals were found in panning samples collected from the streams around the geochemical anomalous zones and many old workings of placer deposits are scattered along the streams.

These reveal that dike rocks such as pegmatites are the source of placer deposits.

However, most of promising areas for placer deposits have already been mined by local people, and the probability of discovering new placer deposits in the area seems low.

5–3 Area C

5–3–1 Geology

Area C is covered by Cambrian to Carboniferous sedimentary rocks, Triassic granites, and alluvium.

The sedimentary rocks consist of Ordovician limestone, Devonian to Carboniferous sandstone and shale distributed long and narrowly in the south western part of the area, and small masses of Cambrian to Ordovician sandstone and shale in places as roof pendants.

The sedimentary rocks have undergone skarnization at boundaries with the granites.

The granites are medium to coarse grained K-feldspar bearing porphyritic biotite granite and fine to medium-granied two mica granite.

Relation between the biotite granite and the two mica granite is not clear, but these two types of granites are inferred to be independent bodies because of their distribution, form, lithology and texture. It is inferred that after the biotite granite batholith was formed, the two mica granite stock intruded along the structure lines of NW-SE to NNW-SSE direction.

5–3–2 Mineralization

A number of gossans exist in the area of two mica granite distribution. These form a gossan zone approximately 200m wide and approximately 3km long in the NNW-SSE direction.

Because the gossans are underlain by a skarn zone, they are inferred to be formed by oxidization of the skarn and occur with dissemination of iron, copper, zinc, tin, and tungsten minerals.

Original rock of the skarn is inferred to be Cambrian to Ordovician sedimentary sequence because less skarnized rocks show relic texture of sandstone and shale.

Mineralization of copper, zinc, tin, tungsten and less amount of lead and silver are observed in the skarn.

A silicified zone rich in iron and copper is in the two mica granite under the skarn.

Mineralization and alteration in the skarn and the silicified zone are inferred to be formed by intrusion of the two mica granite and the silicified zone are inferred to be formed by intrusion of the two mica granite and the following pneumatolysis and hydrothermal process.

Kaolinization is observed in the two mica granite in the area and is to form a kaolin zone in the southern part of the area. This indicates that the area has undergone pneumatolytic to hydrothermal alteration.

5–3–3 Result of Geochemical Prospecting

Geochemical anomalies rich in tin and tungsten are aligned along NNW-SSE strip and mostly overlap in the gossan zone. Geochemical anomalies rich in niobium and tantalum are in the south-west extension of the tin and tungsten anomalies and overlap on the kaolin zone.

Generally, geochemical anomalies rich in tin, tungsten, niobium and tantalum extend in NNW-SSE direction and reflect existence of mineralization and alteration controlled in the same direction.

It anticipated that promising mineralized zones are present in the amonalous zones .

5–3–4 Drilling Survey

Drilling survey confirmed that sedimentary rocks as roof pendant, 50x50m to 500x500m wide and 5 to 50m thick, are sporadically scattered on a small scale.

Mineralization were found along the boundary between granite and sedimentary rocks as well as in sedimentary rocks. In this area, it was confirmed that contact metasomatic deposits occur replacing limestone or calcareous rock.

Skarn is composed of epidote, hedenbergite, amphibole, garnet and quartz.

Orebodies are present in skarn. There are two kinds of orebodies; one is dissemination of sphalerite and chalcopyrite, another is massive sulfide composed of abundant pyrrhotite with minor amount of chalcopyrite. Ore minerals are sphalerite, chalcopyrite, pyrrhotite and pyrite as major minerals, galena, scheelite, magnetite and covelline as minor minerals.

Each orebody is lens-shaped ranging from 20x20m to 70x100m wide and from 5 to 10m thick, and not widely traceable. They are distributed over a zone 200 to 300m wide and more than 3km long. Moreover drilling in a limestone area 1km NNW of Area C confirmed the presence of a considerable skarn zone and massive sulfide beneath the limestone.

This suggests that mineralization is predominant in this direction.

Ore reserve is estimated at 899,000 tons, Cu:0.49%, Zn:1.17%, Ag:27g/t; these grade are too low to warrant mining in the area.

Promising area exists between the above-mentioned limestone area and Area C, where the distribution of roof pendant limestone and a scattering of gossans suggest the presence of ore deposits. Further study of the area extending NNW of Area C would be expected.

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6–1 Conclusion

As the results of reconnaissance geological and geochemical survey in the first phase, detailed geological and geochemical survey in second phase, and trench and drilling survey in the third phase, the following conclusions were obtained.

(1) Stratigraphy in the area was established by the classification of rock facies comparing with geochronologic data.

Granitic rocks were divided into five masses, and geochemical characteristics indicated that all of them belong to S-type granite and tin bearing granite.

(2) Tin and tungsten vein-type deposits and their placer deposits occur in the granite stock of southwest end of the area. Both of them have already been developed.

Old workings of placer deposits of tin and tungsten are scattered along the streams in the east granite mass distribution.

(3) From the first phase and the second phase survey, Area A (Huai Sa Ngin to Huai U Tum) and Area C (around Yang Kiang village) were extracted as the areas with high possibility of mineral deposit of niobium, tantalum, tin and tungsten.

Trench survey in Area A and drilling survey in Area C led to the following conclusions.

Area A

(i) Dike rocks composed mainly of pegmatite were seen in most of the trenches and analytical values of the niobium, tantalum, tin and tungsten of dike rocks nearly coincide with geochemical anomalies values. This indicates that geochemical anomalies originate from pegmatite.

(ii) Although pegmatites in trench T–16 to 20 showed relatively high values of tin, niobium and tantalum, these minerals are not present in ore grade sufficient to warrant the exploitation for a primary ore deposit.

(iii) Tin and tungsten minerals were found in panning samples collected in the streams around geochemical anomalous zones where the above mentioned trenches are located, and old workings of placer deposits are scattered along the streams. These suggest that pegmatites are the source of placer deposits.

(iv) Most promising areas of placer deposits have already been mined by local inhabitants, and the probability of discovering new placer deposits would seem to be low.

Area C

(i) Sedimentary rocks as roof pendant are scattered on a small scale in the distribution of granites.

(ii) Contact metasomatic ore deposits were found along the boundary between granites and sedimentary rocks, replacing limestone or calcareous rock. Mineralizations were also confirmed in the limestone area 1km NNW of Area C.

This suggests that mineralization is predominant in this direction.

(iii) Ore minerals are composed of sphalerite, chalcopyrite, pyrrhotite, scheelite, magnetite, pyrite and galena, and a small amount of bismuth, silver and tin minerals. The major ore minerals are sphalerite and chalcopyrite.

(iv) Ore reserve is estimated at 899,000 tons, Cu:0.49%, Pb:0.08%, Zn:1.17%, Ag:27g/t. This is too low a grade to warrant exploitation.

6–2 Recommendation for the Future

Extension of mineralization is expected from Area C towards the northwest where limestone is widely distributed.

We recommend that geophysical survey such method as IP would be carried out in order to detect distribution and depth of mineralization. This could be followed by drilling in order to ascertain the presence of orebodies.

PART II SURVEY DESCRIPTION

PART II SURVEY DESCRIPTION

CHAPTER 1 GEOLOGY OF THE SURVEY AREA

1–1 Stratigraphy

According to the German Geological Mission (GGM, 1972), sedimentary rocks and metamorphic rocks in the survey area are classified as follows: metamorphic rocks of Pre-carboniferous, sedimentary rocks from the Cambrian to the Triassic, and Quaternary sand and gravel. Granitic rocks are concluded to be the result of activity during the Triassic.

Survey findings indicated some differences with the GGM report regarding the distribution of each formation. Nevertheless, the report was largely referred to it due to the general lack of outcroppings in the area.

Geologic map and schematic geological column of this area are shown in Fig. 5 and Fig. 6.

Sedimentary rocks in this area can be divided into northeast and southwest zones with differing rock facies by a NW-SE fault running parallel to the Nam Mae Ngao in the southwest of the area. In the northeast zone, Ordovician limestone formation is mainly limestone intercalated with chert and shale. In limestone in the southwest zone, calcareous shale and shale alternate in about the same quantities. The succession that overlies this limestone formation is also different in the two zones. In the northeast region, Silurian to Carboniferous rocks rest on the limestone in generally conformable manner, and are overlain unconformably by Permian and Triassic sediments. On the other hand, there is no Siluro-Devonian rock formation, and Carbono-Permian rocks lie unconformably on the limestone formation.

However the lowest sequence of Cambro-Ordovician rocks are essentially the same facies.

These difference between the sedimentary rocks of the two zones indicate the difference in original sedimentary environment. According to the classification by JICA (1984) of tectonic provinces in northern Thailand, these belong to separate tectonic provinces. The northeast zone belongs to the Main Western Range Tectonic Province, and the southwest zone to the West Tectonic Province.

Details of each formation are as follows:

1–1–1 Pre-Carboniferous Metamorphic Rock

Paragneiss distributes as xenolith several hundreds of meters in scale in granite body around Nong Ung at the northeastern extremity of the area. It is composed mainly of quartz, K-feldspar, plagiclase and biotite, with clear gneissic texture due to the preferred orientation of biotite.

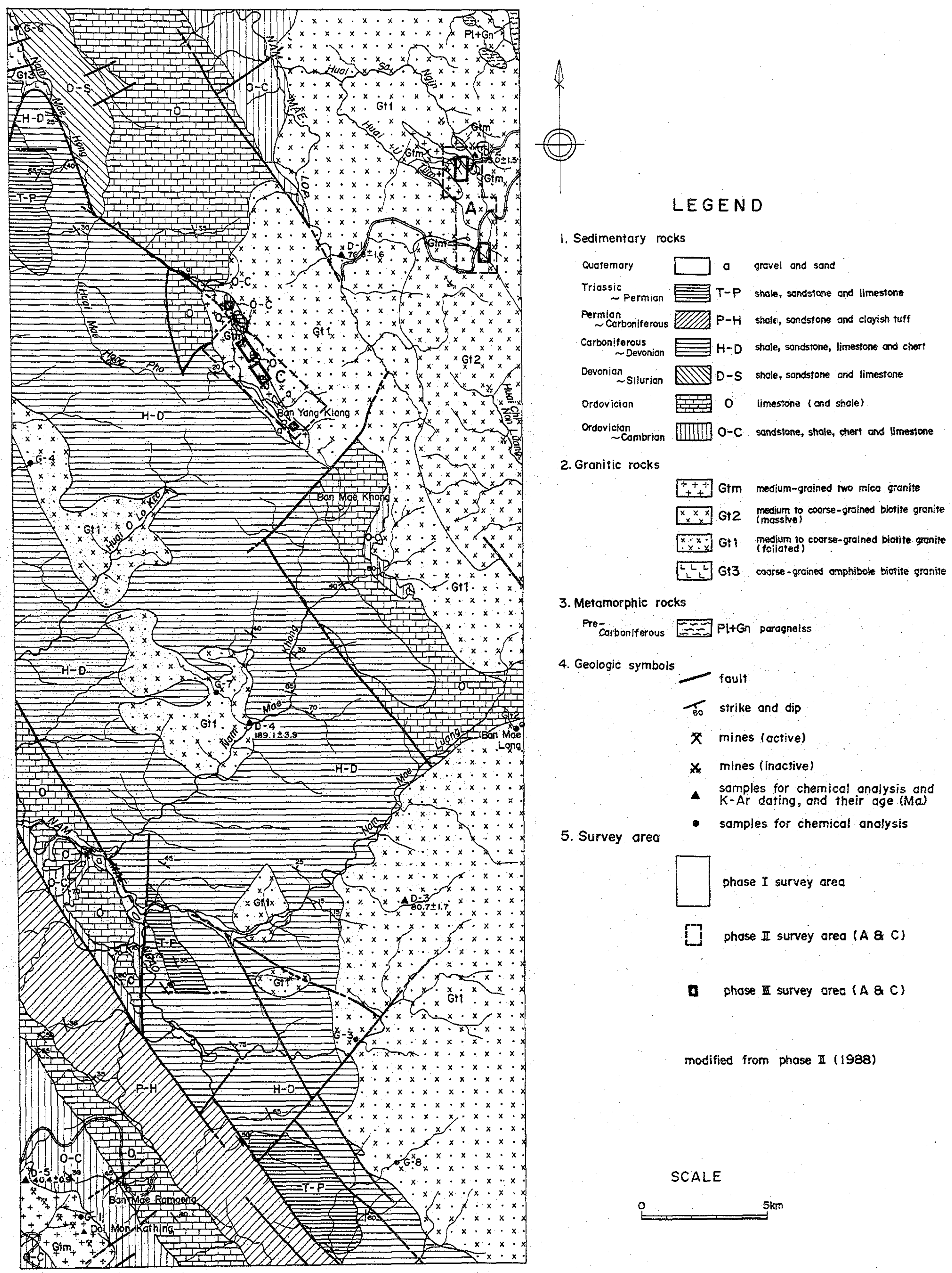

Fig.5 Geologic map of the Yang Kiang area

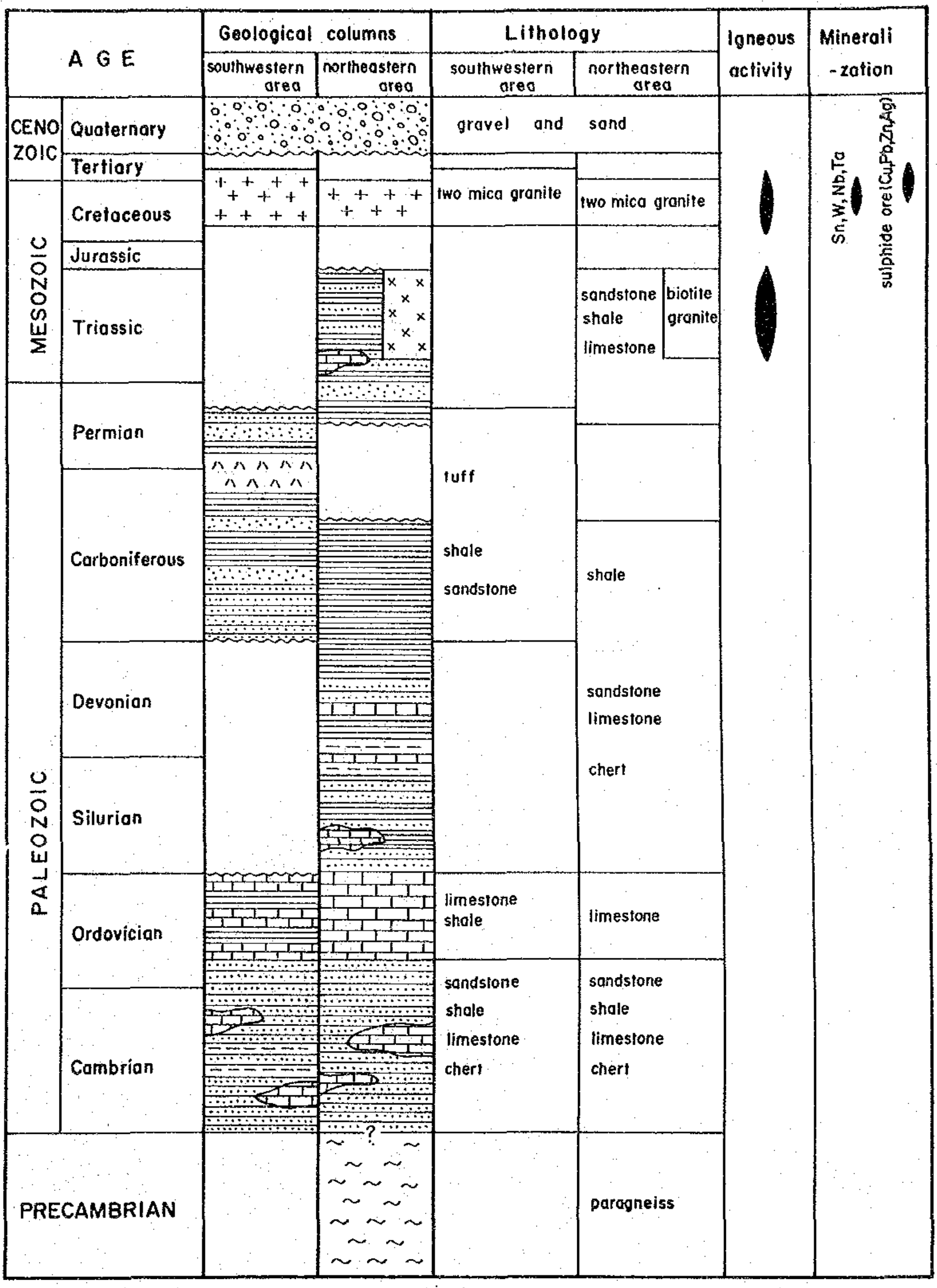

Fig.6 Schematic geological column

Comparatively distinct gneissic texture is recognized as well in the granitic rocks around the former. Both formations have identical N60°W/50°N orientation. Their boundary, however, remains unclear as the coarse grained portion of gneiss exhibits the same facies as the granite body.

The relationship with the Paleozoic sedimentary rock remains unknown, as this rock occurs as xenolith in granite body.

1–1–2 Cambro-Ordovician Formation

This formation is distributed along the Nam Mae Lop in the north of the area, and the west bank of the Nam Mae Ngao and around Doi Mon Kathing in the southwest.

This formation is composed mainly of alternation of fine to medium grained sandstone and shale and alternation of fine grained sandstone and chert, partially intercalated with thin layers of calcareous shale and limestone. No fossil has been recognized.

Near the Nam Mae Lop and Mae Khong, these rocks are intruded by granite on the east side and have undergone contact metamorphism over a width of several meters. At this location, the formation strikes N-S to NW-SE, and dips 30∼65°W. Ordovician limestone formation overlies this Cambro-Ordovician formation on the west side in parallel fashion, and the two formations are therefor considered to be conformable.

On the west bank of the Nam Mae Ngao, the Cambro-Ordovician formation strikes N-S to N40°W, and dips 15°∼70°E, or even vertically at some points. In contrast, the overlying Ordovician limestone dips gently east. As a result, the relationship between the two is inferred to be unconformable.

Around Doi Mon Kathing, the two formations exhibit conformity, both striking N35° to 40°W and dipping 38° to 55°E. Granite intrudes the structure concordantly at the center of this area. The Cambro-Ordovician rock around the granite intrusion have undergone strong contact metamorphism. In particular, the rock has metamorphosed to schistose hornfels at the point of contact with the granite.

1–1–3 Ordovician Limestone Formation

This formation is extensively distributed in the area between Nam Mae Lop and Nam Mae Hong, forming karsts at the peaks of mountains. In addition, the formation is distributed between Mae Khong and Mae Long in the east, and near the middle reaches of the Nam Mae Ngao and the vicinities of Mae Ramoeng in the southwest. Except for around Mae Ramoeng, where it consists of an alternation of limestone, calcareous shale and shale, the formation is white to gray, fine grained limestone, and intercalated with thin layers shale and chert.

Upper and lower portion Ordovician conodonts have been reported (Hahn, et al 1982), except for the east.

The formation distributed in the north and east has undergone thermal metamorphism by granite, being recrystallized into coarse texture. Some portions have been partially silicified, but no skarnized portion is seen except for small quantities of calcsilicate boulders, a few meters in size and yellowish green, to the north of Yang Kiang.

The formation strikes NW-SE throughout the entire area. However, the northern portion dips west, while that in the southwest dips east. The eastern portion is a syncline, sinking slightly towards the north.

Most of the formation is considered to be conformable with the underlying Cambro-Ordovician formation; however, there is a possibility of unconformity in some parts.

1–1–4 Siluro-Devonian Formation

These rocks are distributed over Ordovician limestone formation on the east bank of the Nam Mae Hong in the north. The formation is mainly shale and sandstone, accompanied by lenticular limestone. It is considered to be conformable with the Ordovician limestone; however, the relationship with other formations is unclear due to intervening faults.

1–1–5 Devon-Carboniferous Formation

This formation is widely distributed in the middle of the area. It is dominated by black shale, with lenticular chert, lenticular, limestone, alternation of chert and limestone, red shale and sandstone, and others. The structure and stratigraphy of the formation is unclear as it consists mainly of bedding, massive shale, preventing location of a key bed. As a result, the zone exhibiting the above described rock facies has been lumped as one.

Shale, calcareous shale and lenticular limestone are distributed in the vicinity of Nam Mae Ngao, where Silurian and upper Devonian to lower Carboniferous conodonts occur. Along Nam Mae Luang near Nam Mae Ngao, thin alternate layers of chert and limestone have developed under the massive shale. Red shale is distributed in places at the northwest of Yang Kiang and at the confluence of Nam Mae Ngao and Huai Mae Khong. In general, alternation of limestone, chert, sandstone and shale is predominant at the lower portion of the formation, with shale dominant at the upper.

Although the formation shows some alternating anticlinic and synclinic structure, it generally forms a large syncline striking NW-SE.

An intrusion of batholith granite occurs in the east, and intrusion of four granitic stocks in the middle. Siluro-Carboniferous rock is metamorphosed to biotite hornfels or biotite-muscovite hornfels at the point of contact with granite for a range of several to several tens of meters. However, skarnization is not seen.

It was expected that skarnization or other mineralization was anticipated as the caps of granite stocks, however, only small quantities of quartz veins, several millimeters in width were found in the granite.

1–1–6 Carbono–Permian Formation

This formation is distributed in a belt shape in the direction NW-SE in the southwest. It is composed mainly of shale and sandstone, accompanied by clayey tuff. Strike is NW-SE and dip is 35° to 40°E.

The formation unconformably covers the Ordovician formation and is in fault contact on the east side with Cambro-Silurian rocks.

Upper portion, middle Carboniferous conodonts have been reportedly produced from this rock around Kre Kro.

1–1–7 Permo-Triassic Formation

This formation is distributed on a small scale in the northwest and southwest. It is composed of sandstone, shale and small quantities of lenticular limestone.

Fusulinas from the middle Permian and bivalves from the middle to upper Triassic have been reported in a small mass on the east bank of the Nam Mae Ngao.

1–1–8 Quaternary Sand and Gravel

Quaternary sand and gravel consist of alluvium filling in the topographically low areas. These are uncompacted sand and gravel along major rivers.

1–2 Igneous Activity

Granitic rock activity in northern Thailand is assumed to have occurred at three different times, namely, the Carboniferous, the Triassic and the Cretaceous to Tertiary (GGM, 1972).

There are two granitic batholiths in the east and six granitic stocks in the middle of the area to the southwest. All of these are attributed to igneous activity during the Triassic. The above are divided into 5 classifications depending on distribution and facies: northeast mass, southeast mass, southeast mass, northwest mass, central mass and Mon Kathing mass.

(1) Northeast Mass

Both the northeast mass and southwest mass are extensions of the Triassic granite in the Omkoi area as reported by JICA and MMAJ (1986); however, their respective facies are different. The northeast mass is separated from the southeast mass by Ordovician limestone near Mae Long.

The mass is mainly composed of medium to coarse grained K-feldspar bearing porphyritic biotite granite (gneissose∼massive), and medium grained muscovite-biotite granite. These are accompanied by pegmatite and aplite.

The medium to coarse-grained K-feldspar bearing porphyritic biotite granite dominates the northeast mass. It contains characteristicaly megaphenocrysts of K-feldspar with mean size of 2 to 4cm (max. 2X6cm). It may be classified in the strict sense as granite.

It is distributed in massive form from U Tum Nua to Yong Lae, corresponding to the center of the area. Gneissose facies are distributed around the massive facies.

The gneissose structure is recognized as relatively weak, preferred orientation from biotite throughout. However, from the vicinities of U Tum Tai and Sa Ngin to Nong Ung in the north-east, flow texture due to K-fledspar phenocrysts and preferred orientation from biotite are evident and strongly expressed around xenoliths of Pre-Carboniferous metamorphic rock.

As the massive portion and gneissose portion share a transitional boundary, both portions indicate core and marginal facies of a batholith.

This granite is composed of quartz, K-feldspar, plagioclase, and biotite, with accessory zircon, apatite, and opaque minerals. Plagioclase crystals have been almost completely replaced with minute muscovite particles, and secondary muscovite has been found between quartz and K-feldspar grains. The biotite has been replaced with chlorite, epidote and muscovite along edges and cleavage face. The opaque minerals, which are contained in extremely small quantities, are magnetite and ilmenite; the former has altered to hematite, and the latter to leucoxene. As this granite contains magnetite, it belongs to the magnetite series proposed by Ishihara (1977).

The medium grained muscovite-biotite granite is distributed over an area of 2 by 4 km to the north of Yang Kiang village which lies at the western extremity of the northeast mass. It also sporadically occurs in biotite granite. It is mainly composed of quartz, K-feldspar, plagioclase, muscovite and biotite. Large primary muscovite is contained in amounts either the same as or greater than amounts than biotite. The alteration of plagioclase due to fine grained muscovite is also recognized, but this alteration is less strong than that of the biotite granite.

Pegmatite and aplite veins are several centimeters to several meters in width. They trend NW-SE, WNW-ESE, N-S and NE-SW. Although they are found throughout the northeast mass, they are particularly concentrated at 10 to 20% of area at the east side of the Nam Mae Lop.

Many pegmatite quartz boulders are found at the ridge near Sa Ngin. These are mainly composed of quartz, K-feldspar, plagioclase and muscovite. The pegmatites around the secondary tin ore deposits at Sa Ngin are also composed mainly of quartz, K-feldspar, plagioclase and muscovite. However, they also contain large amounts of tourmaline, garnet and zircon.

1–2–2 Southeast Mass

The southeast mass is a batholith, composed of medium to coarse grained, K-feldspar bearing porphyritic biotite granite. A small mass of medium grained muscovite-biotite granite is also present, however, distribution is too small to be represented on the map.

As with the northeastern mass, the granite contains megaphenocrysts of K-feldspar. Gneissose texture through weak preferred orientation due to biotite is recognized throughout the area. Constituent minerals are quartz, K-feldspar, plagioclase and biotite, with accessory apatite, zircon and opaque minerals. This is the same as the northeast mass.

This mass has essentially the same alternation as the northeast mass, but contains actinolite and other minerals indicating the possibility of weak contact metamophism. The rock contains very small quantities of magnetite, hematite and ilmenite, and therefore belongs to the magnetite seires as identified by Ishihara (1981).

Medium grained, muscovite-biotite granite is distributed in a very small scale, and its relationship to biotite granite is unknown. Constituent minerals are quartz, potassium feldspar, plagioclase, biotite and muscovite, with accessories of apatite, zircon, tourmaline and hematite. A small amount of large primary muscovite is found. Some of the central portion of the plagioclase has been replaced. The characteristics of the mineral composition suggest that this granite belongs to the ilmenite series proposed by Ishihara (1981).

Veins of pegmatite and aplite, several centimeters in width, are sporadically seen in the southeast mass. These are not accompanied by mineralization and alteration.

1–2–3 Northwest Mass

The northwest mass is distributed along the lower Nam Mae Hong. According to GGM (1972), the mass is a part of a larger mass widely distributed north of the survey area.

This mass is mainly composed of K-feldspar bearing porphyritic granite, and therefor resembles the biotite granite of the other masses. However, this granite characteristically contains amphibole. It is mainly composed of quartz, K-feldspar, plagioclase, biotite and amphibole, with accessory apatite, zircon, sphene, magnetite, pyrite and hematite. The plagioclase has altered into muscovite, and the biotite into chlorite and epidote. Most of the amphibole has been entirely replaced with calcite, chlorite and others. The granite belongs to the magnetite seires proposed by Ishihara (1981).

1–2–4 Central Mass

This mass distributes as four stocks located respectively in the middle of the area at Huai O Lo Kro, the north bank of Huai Mae Khong, near Mae Luang and Sae Khi.

All of these are composed of medium to coarse grained, K-feldspar bearing porphyritic, biotite granite. Facies have undergone almost no metamorphism, even at points of contact with shale. Constituent minerals are quartz, K-feldspar, plagioclase and biotite, with accessory pyrite. Alteration is only very slight throughout, including minor alteration of plagioclase and slight chloritization of biotite at its edges. The mass belongs to the magnetite series.

1–2–5 Mon Kathing Mass

The Mon Kathing mass is the host rock of the Doi Mon Kathing ore deposits in the southwest. The mass is composed mainly of medium grained muscovite-biotite granite. In contrast to the other masses, porphyritic texture of K-feldspar is not conspicuous. Facies range from equal quantities of muscovite and biotite, to muscovite only. Constituent minerals are quartz, K-feldspar, plagioclase, muscovite and biotite, with accessory apatite and zircon. Opaque mineral content is ilmenite, and the granite is accordingly classifed as ilmenite series.

1–3 Geologic Structure

1–3–1 Folds

Northern Thailand, including the survey area, has a complex structural history comprising four tectonic movements: at the end of the Pre-cambrian, the Carboniferous, the Triassic to the Jurassic, and the Cretaceous to the Neogene. Outcrops along rivers are rare, and massive shale is the predominant sedimentary rock, preventing the location of key beds for identification of geologic structure. Nevertheless, it is seen that the structure of the area generally trends NW-SE.

The distribution of sedimentary rock may be divided into a northeast zone and a southwest zone on the basis of sedimentary environment.

The Cambrian to Triassic rocks are distributed in the northeast. Specifically, Cambro-Ordovician formation is distributed at the northeast and southwest extremities of the northeast and trend NW-SE. Dip is SE at the northeast extremity and NW at the southwest extremity. Overall, structure of the northeast zone is thought to comprise a single syncline. The eastern portion of

Ordovician limestone and overlying Siluro-Carboniferous shale form a syncline gently dipping to the north. The lower part of the middle mass of Siluro-Carboniferous rocks is composed of much limestone and chert, suggesting that the formation is a series of small synclines and anticlines, overall forming a single large syncline.

The southwest region is distributed with the Cambrian to the Permian sedimentary rocks. These strike NW-SE and form a monocline to the northeast.

1–3–2 Faults

In the survey area, NW-SE and NE-SW faults are dominant, with N-S faults also present. Sedimentary rocks in the area trend NW-SE, although the principal structural direction of northern Thailand is N-S. Accordingly, the principal structural direction is considered to be NW-SE, with NE-SW and N-S as secondary.

The largest fault trends NW-SE through the west bank of the Nam Mae Ngao. It divides the West Tectonic Province and the Main Western Range Tectonic Province (JICA, 1984).

1–4 Ore Deposits

Tin and tungsten ore deposits in northern Thailand are considered to be closely related to Mesozoic granite (GGM, 1972). Primary deposits are massive ore deposits resulting form greisenization and skarnization at the cupolas and margins of granite bodies and vein ore deposits accompanying quartz veins and pegmatite veins. Secondary ore deposits derive from these primary deposits.

Both primary and secondary tin and tungsten ore deposits and skarn ore deposits are distributed in the area. The former are found in the area of distribution of granite batholith in the northeast and granitic stocks in the southwest extremity. Deposits in the northeast are secondary deposits in gravel and sand beds along the Huai Chi Non Luang and Huai Sa Ngin. Deposits in the southwest are vein ores occurring in granitic stock around Doi Mon Kathing, and secondary ore deposits derived from these (Fig. 5). Skarn deposits are found at the north of Yang Kiang village.

1–4–1 Northeast Ore Deposits

K-feldspar bearing porphyritic biotite granite is broadly distributed in the area. Pegmatite, aplite and quartz veins are well developed particularly in the area of distribution of secondary ore between the Huai Chi Non Luang and Huai Sa Ngin. Small masses of medium grained, muscovite-biotite granite are also sporadically present.

The remains of small mine workings are also seen. Ore is composed mainly of cassiterite, with some scheelite.

(1) Huai Chi Non Luang Zone

This zone is located at the eastern extremity of the survey area, and is surrounded by gently sloping hills 1,100 to 1,200 m in elevation. A motorable road leads from Omkoi to the area. Tin and tungsten bearing gravel bed, 1 to 2 m in thickness, exist along the Huai Chin Non Luang and its tributaries. This bed was worked by the local people for about 2 years around 1980. Peak production was 2t/mo of concentrates with 40 workers. Content of ore was almost completely cassiterite. It has been reported that scheelite bearing quartz veins were also seen, however, such was not confirmed under this survey.

In addition to cassiterite, scheelite is detected under ultraviolet rays in panning samples. Results of analysis indicate Sn at 9.79∿27.5%, W at 0.02∿0.19%, Ta at 0.30∿0.39% and Nb at 0.17~0.21%.

(2) Huai Sa Ngin ~ Huai U Tum

This zone is located in the northeast, and deposits are found in gravel and sand bed which has developed along the upper reaches of the Huai Sa Ngin and Huai U Tum tributaries of the Nam Mae Lop.

These two tributaries flow on the east and west sides, respectively, of a NW-SE directed ridge (El: 1,300~1,400m). A motorable road extends from Omkoi to this ridge.

The old workings in this zone have records for approximately one year around 1980, at which time they produced about 2t/mo of concentrates with 10 to 20 workers. Ore consists mainly of cassiterite, with a small quantity of scheelite. Tin and tungsten bearing quartz veins were also reported.

In addition to cassiterite, large quantities of scheelite is detected under ultraviolet rays in panning samples. Results of analysis indicate Sn at 1.92~17.2%, W at 0.08~5.31%, Ta at 0.17~0.57% and Nb at 0.02~0.35% (Table 2).

1–4–2 North of Yang Kiang Village

Old mines are located at 2 locations 1 km north-northwest of Yang Kiang village, and again another 1 km north thereof.

The former is a prospecting gallery, and is collapsed a short distance from the entrance. Ores are contact metasomatic deposits consisting of small amounts of sphalerite, chalcopyrite and scheelite disseminated in skarnized Cambro-Ordovician sedimentary rocks and underlying silicified muscovite-biotite granite.

The latter is 50m x 7m in scale, and excavated to a maximum depth of 10m. Details of mine

Table 2 Assay of Ore Samples

No.	Sample No.	Location	Description	Sn(%)	W(%)	Nb(%)	Ta(%)
1	0–1	Huai Sa Ngin	Panning concentrate	6.49	0.08	0.28	0.36
2	0–2	Huai Sa Ngin (50m South of 0-1)	Panning concentrate	11.3	0.32	0.35	0.57
3	0–3	Huai U Tum Tai	Panning concentrate	17.2	0.35	0.33	0.56
4	0–4	Huai U Tum Tai (50m West of 0-3)	Panning concentrate	1.92	0.27	0.22	0.35
5	0–5	Huai Chi Non Luang	Panning concentrate	9.79	0.19	0.17	0.39
6	0–6	Piliko mine	Sn-W concentrate	16.7	43.6	0.01	0.00
7	0–7	Mae Moei mine	Sn-W concentrate	55.6	14.3	0.00	0.00
8	0–8	Mae Salit Luang mine	Wolframite quartz vein	0.011	29.6	0.00	0.00
9	0–9	Mae Moei mine	Sn-W concentrate (fine fraction)	37.2	21.0	0.00	0.00
10	0–10	Piliko mine	Sn ore	73.4	0.03	0.00	0.00
11	GT–14H	Huai Chinon (2Km North of 0-5)	Panning concentrate	27.5	0.02	0.21	0.30
12	BP–16H	Huai Sa Ngin	Panning concentrate	15.2	5.31	0.02	0.17

performance are not clear. A mineralized zone 80m X 40m X 50m is observed at the surface, and is further classified into a surface oxidized zone, a skarn zone, a silicified zone and muscovite-biotite granite. Excavation is into the silicified zone, and magnetite and chalcopyrite are seen in disseminated form.

1–4–3 Doi Mon Kathing in the Southwest

(1) Location and Accessibility

The five tin and tungsten mines of Mae Salit Luang, Mae Moei, Surin, Moru and Piliko are concentrated in a 4 X 1.5km area around Doi Mon Kathing at the southwest extremity of the survey area.

As shown in Fig. 7, the mines are sited in a line running NW-SE. Mae Moei is the largest, and Mae Salit Luang is next. All mines are located near the tops of mountains at 900~1,000m elevation. Although mountain summits are gentle topography, mountain sides are steep.

National Highway No.1267 runs from Mae Salit Luang at 500m elevation to the south foot of Doi Mon Kathing, and passes via the west foot of the mountain to Mae Ramoeng at 600m elevation on the northeast side of Doi Mon Kathing. The road then continues to its junction with National Highway No.1085. Total distance south from Mae Salit Luang to the junction with National Highway No.1085 is about 15km.

Foot paths leave the above road for the mines at Mae Salit Luang, Mae Moei and Moru along the Huai Mae Salit Noi Ke Kro and Huai Kho Phu Do. The mines can be reached in 1.5 to 2 hours on foot. Piliko mine can be reached in 30 min. on foot along a path from the motorable road at the northwest foot of the mountain.

(2) Geology and Ore Deposits

This zone consists of sedimentary rocks of the Cambrian, intruded by granitic stock. The Cambrian rocks are formed of shale, sandstone and chert, which have metamorphosed into schistose hornfels in the vicinity of the ore deposits. Granite is muscovite-biotite granite, in which some tourmaline is present near the mines.

There are three types of ore deposits, namely tin and tungsten bearing quartz vein, tin and tungsten disseminated granite and eluvial ore deposit. The object of ore recovery is mainly the quartz veins and eluvial ore deposit.

(i) Tin and Tungsten Bearing Quartz Vein

Although quartz veins are seen at various places, mineralized veins are only distributed to an elevation of about 1,000m on the ridge extending NNW from Doi Mon Kathing. Veins strike NW-SE and dip 75° to 90°W; vein width ranges from several to 80cm. These veins are observed spo-

radically over a 4 km towards the mines from the southeast side. Seven to eight parallel veins occur in each mine at intervals of 5 to 20 meters. Vein length is assumed to be 30 to 100m.

Wolframite is the main ore mineral, accompanied by cassiterite. Pyrite, chalcopyrite and arsenopyrite are also observed. Chemical analysis of the cassiterite-quartz veins at Piliko mine and the cassiterite and wolframite-quartz veins at Mae Salit Luang mine show Sn at 73.4%, W at % and Sn at 0.011%, W at 29.6%, respectively. Ta and Nb are not present (Table 2).

(ii) Tin and Tungsten Disseminated Granite

Sulfide minerals such as arsenopyrite, pyrrhotite, pyrite and chalcopyrite are disseminated in granite around the above described veins, being heavily concentrated at certain points. Although tin and tungsten are not perceivable by the naked eye, they are obtained through panning of weathered granite.

(iii) Eluvial Ore Deposit

Comparatively gentle, basinlike lowlands extend near the east foot and north foot of Doi Mon Kathing, and are the site of 1~5m thick beds of gravel and sand. These beds contain such heavy minerals as cassiterite and wolframite.

(iv) Mine Description

Mining of ore in the area began in earnest after World War II. Centered on the Mae Moei and Mae Salit Luang mines, a number of mines were developed, of which 5 are currently in operation.

Vein ore deposits are worked by a combination of manual and machine excavation along the vein from the outcrop. Concentrate ore is recovered by a process of crushing and panning. Weathered sections and eluvial ore deposits are broken by with pressurized water. Raw ore is then passed through a sluicing trough to obtain concentrate.

All the mines at present continue very scaled down operatons, at times suspending work, due to a suppressed market for minerals.

(a) Mae Moei Mine

The mine exploits vein ore deposits distributed over a ridge on the north side of Doi Mon Kathing and secondary ore deposits to their north. In the case of the vein deposits, almost the entire shallow section has been exhausted, and at present the lower section is being mined by sinking shaft, about 2m in diameter, to a depth of 5 to 10m. Shoring is erected at the shaft openings, and excavated ore and waste rock are lifted to the surface by bucket and rope. A numbers of these shafts have been excavated at 10 m intervals along mineral veins.

At the mine's most active period, more than 1,000 workers were employed. At present, however, number of workers is around 20 to 30, producing 4t/mo of concentrates.

At the mine site, there are a mine office, ore dressing plant, 20~30 lodgings, stores, a temple, a meeting hall, cultivated fields, a fish pond, etc. forming a self sufficient community.

(b) Mae Salt Luan Mine (Wijin Mine)

The mine exploits vein ore deposits distributed over a ridge extending on the southeast side of Doi Mon Kathing, and eluvial ore deposits in a basinlike lowland spreading on the east side of the vein deposits. The mine employs about 15 workers, producing 1t/mo of mainly eluvial ore concentrates.

(c) Surin Mine

The mine is located west of Mae Moei mine, exploiting eluvial ore deposits along the upper reaches of the Huai Mae Kho Phu Do. At present, operations have been suspended, although several families used to work the mine in the past.

(d) Moru Mine

The mine corresponds to the northwest extension of the vein at Mae Moei mine. Veins exposed at the ridge have been nearly exhausted, and a tunnel has been excavated for about 50m into the underlying section. Tunneling, however, was later suspended due to failure to strike mineral ore.

Mining operations were commenced about 5 years ago. The mine presently employs 20 workers, producing 700~800kg/mo of concentrates.

(e) Piliko Mine

Veins exploited by the mine are distributed on a ridge which lies about 800m northwest of the veins at the Moru mine. Excavation is currently in progress along these veins which consist of quartz veins with 30 to 80cm width, strike of N-S and 20m length, and several other quartz veins which cross the former obliquely with 10 to 40cm width and strike of NW-SE.

Ore mineral is mainly wolframite occurring sporadically in massive form several cm to 12~13 cm in width in quartz veins. In addition, aresenopyrie, chalcopyrite and pyrite are disseminated in the quartz veins and host granite.

Mining operations began in earnest about 1 year ago. The mine currently employs about 20 workers, producing 1.5t/mo of concentrates.

(v) Results of Ore Analysis

Values for chemical analysis of concentrates of tin and tungsten from Mae Moei and Piliko mines, cassiterite from Piliko mine and the wolframite and cassiterite from Mae Salit Luang mine are shown in Table 2.

In contrast to the secondary deposits in the northeast, the above deposits are characterized by dominant wolframite content, high sulfide content, and absence of niobium and tantalum.

1–5 Geochemical Characteristics of Granitic Rocks

Granitic rocks had been collectively discussed till the middle of the 1970's. From that time the classification of granitic rocks due to definition of the properties of felsic magmas which have come to create the granitic rocks has been attemped by using main chemical components.

The instances of this classification are as follows: S-types (sedimentary source types) and I-types (igneous source types) by Chappell & White (1974) and White & Chappel (1977), the magnetite-series and ilmenite-series by Ishihara (1977), and M-types (mantle source types) by White (1979). The classification into S-types, I-types and M-types is to throw light on the origin of a magma, while the one into the magnetite-series and ilmenite-series is to find whether the processes of magma generation and magmatic differentiation were under an oxidation condition or a reduction condition. Accordingly, the classification systems of these two view-points do not always concur with each other, while S-type granitic rocks usually correspond to the ilmenite-series, both the magnetite-series and the ilmenite series are included in I-type and M-type granitic rocks.

On the other hand, Ishihara et al. (1980) deals with the relation between the properties of granitic rocks and tin mineralization of the peninsular part of Thailand, and Ishihara (1981) discussed mineralization related with granitic rocks belonging to the magnetite-series and ilmenite-series.

In this survey 12 samples collected from the above-stated granitic mass distributed in the survey area were put to chemical analysis for main components in order to study their geochemical properties. Results of analysis are show in Table 3. Sample localities are shown in Fig. 5.

1–5–1 Chemical compositon and Classification of Granite-type

The differentiation indexes of granitic rocks in the survey area which are expressed by the total of the weight percentage of normative quartz, orthoclase, albite, nepheline and kalsilite have the following values: 80.7 to 87.7 with the northeast mass, 79.3 to 84.8 with the southeast mass, 79.5 with the northwest mass, 80.5 to 84.5 with the center mass, and 89.1 to 89.6 with Mon Kathing mass. The last one composed of muscovite-biotite granite presents the highest value, meaning that this mass mostly differentiated. Almost same values are presented with the other four granite masses.

In the variation diagrams correlation between the differentiation indexes and main components (Fig. 8), when all the 12 samples are viewed, components that are positively correlated with the differentiation indexes are as follows: SiO_2 displays a strong correlation; besides it a weak correlation is found in Na_2O and K_2O. The components having a negative correlation are TiO_2, FeO, MnO, MgO, CaO and BaO. The components lacking in correlation are Al_2O_3, P_2O_5 and Sn.

Regarding to each masses, in the northeast mass and the center mass, a trend showing positive correlation is distincter than all samples, but the differentiation trends of these two mass are different. In the southwest mass a positive correlation is found with K_2O, and a negative correlation with TiO_2 and CaO. Other components don't have variation against the differentiation index

Table 3 Chemical Analyses of Granitic Rocks

Sample No.	D − 1	D − 2	D − 3	D − 4	D − 5	G − 1	G − 2	G − 3	G − 4	G − 6	G − 7	G − 8
Rock type	biotite granite	biotite granite	biotite granite	biotite granite	two mica granite	two mica granite	Altered granite	biotite granite	biotite granite	biotite granite	biotite granite	biotite granite
mass	northeast	northeast	southeast	center	Mon Kathing	Mon Kathing	southeast	southeast	center	northwest	center	southeast
SiO_2	68.80	71.80	70.00	69.80	71.60	71.90	70.00	70.00	70.90	68.00	68.80	69.50
TiO_2	0.50	0.34	0.47	0.53	0.40	0.40	0.44	0.35	0.44	0.57	0.54	0.38
Al_2O_3	14.40	13.20	13.60	12.90	14.00	14.00	13.90	13.70	12.80	12.90	13.30	14.60
Fe_2O_3	0.80	0.61	0.57	0.76	1.00	0.34	0.71	0.64	0.63	1.39	0.77	0.49
FeO	2.16	1.51	2.30	2.01	1.00	1.44	2.08	1.72	1.87	1.80	2.08	1.94
MnO	0.05	0.03	0.05	0.04	0.09	0.03	0.05	0.04	0.05	0.05	0.05	0.05
MgO	1.50	0.84	1.58	2.14	0.15	0.15	1.27	1.37	1.73	2.65	2.23	1.35
CaO	1.99	1.28	2.10	1.07	0.92	0.91	1.54	1.44	1.25	1.49	1.61	1.21
Na_2O	3.00	3.25	2.81	2.66	2.65	2.84	3.04	2.96	2.66	2.08	2.19	2.85
K_2O	5.23	5.55	4.63	6.06	6.10	5.88	4.84	5.36	5.88	6.28	6.25	6.21
P_2O_5	0.27	0.18	0.18	0.23	0.26	0.25	0.17	0.24	0.22	0.25	0.26	0.23
BaO	0.127	0.103	0.098	0.151	0.035	0.038	0.122	0.127	0.119	0.169	0.167	0.195
LOI	0.69	0.41	0.84	1.06	1.08	0.93	0.87	0.88	0.87	1.60	1.43	1.02
Total	99.517	99.103	99.228	99.411	99.285	99.108	99.032	98.827	99.419	99.229	99.677	100.025
Sn (ppm)	15	14	13	14	64	9	15	17	14	16	13	16
Q	24.42	27.39	28.19	25.27	31.14	30.61	27.90	26.85	27.25	24.83	25.01	24.00
C	0.83	0.00	0.58	0.57	1.99	1.91	1.27	0.99	0.31	0.57	0.63	1.54
or	30.91	32.80	27.36	35.81	36.05	34.75	28.60	31.68	34.75	37.11	36.94	36.70
ab	25.39	27.50	23.78	22.51	22.42	24.03	25.72	25.05	22.51	17.60	18.53	24.12
an	8.11	5.04	9.24	3.81	2.87	2.88	6.53	5.58	4.76	5.76	6.29	4.50
di	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0.00	0.00	0.00
hd	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
en	3.74	2.06	3.94	5.33	0.37	0.37	3.16	3.41	4.31	6.60	5.55	3.36
fs	2.57	1.74	3.07	2.26	0.52	1.76	2.60	2.13	2.28	1.31	2.38	2.62
mt	1.16	0.88	0.83	1.10	1.45	0.49	1.03	0.93	0.91	2.02	1.12	0.71
il	0.95	0.65	0.89	1.01	0.76	0.76	0.84	0.66	0.84	1.08	1.03	0.72
ap	0.63	0.42	0.42	0.53	0.60	0.58	0,39	0.56	0.51	0.58	0.60	0.53

Sample locations are shown in Fig. 5.

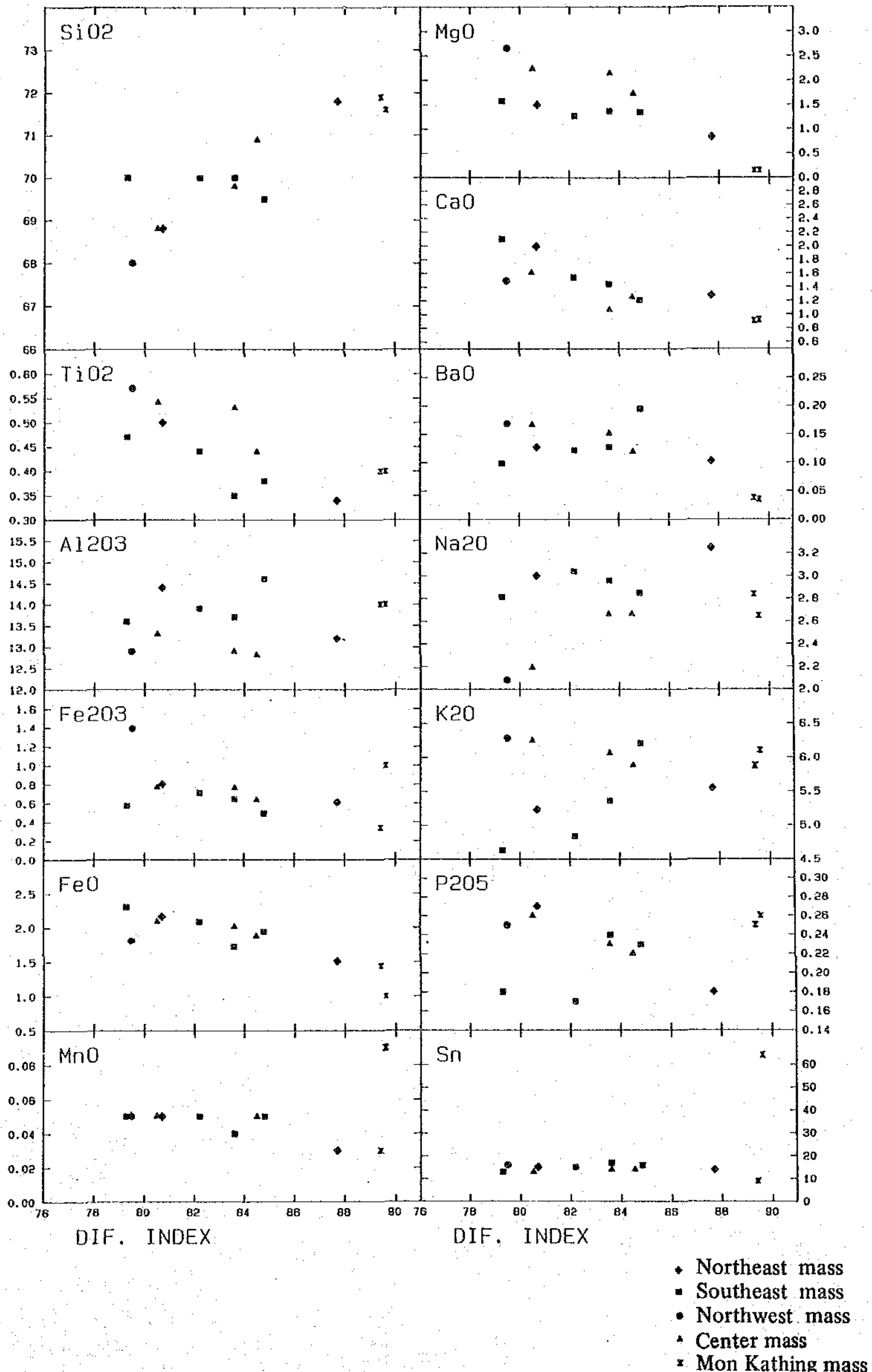

Fig.8 Variation diagrams of Granitic Rocks

and no correlation is found.

The differentiation indexes of the two samples from Mon Kathing mass are nearly the same, but a large difference is found in Fe_2O_3, FeO, MnO, and Sn. Other components don't have variation.

As for the northwest mass, though the sample was only one, it has high content in K_2O and low in CaO, Na_2O and Al_2O_3 in spite of low differentiation indexes.

In this survey the granite distributed over the survey area was divided into five masses. As described in the above, each mass has its own petrochemical properties, which is considered to be the reflection of the affects of the magma generation, magmatic differentiation and subsequent mineralization of each mass.

Regarding to the normative minerals, in the classification of the granitic rocks according to the ratio of normative quartz, plagioclase and orthoclase (Fig. 9) all samples are plotted in the region of granite in a narrow sense, in accord with the field and microscopic observations.

Normative corundum is calculated except for Sample D-2; these granitic rocks excluding Sample D-2 are granite derived from peralumina magma. According to Chappell & White (1974) granite with 1.0% or more of normative corundum is classified into the S-types, while granite classified into the I-type granite, the biotite granite of the southwest mass into the I-type the muscovite and biotite granite into the S-type and the muscovite and biotite granite of Mon Kathing mass into the S-type.

In effecting the classification into the S-types and I-types by main components of granite, the following index help discrimination considerably. That is, Na_2O/K_2O ratio, $Al_2O_3-K_2O-Na_2O/CaO/FeO + MgO$ (ACF) ratio, and $Al_2O_3/(Na_2O + K_2O + CaO)$ ratio. In Na_2O/K_2O ratio (Fig. 10) the S-type has comparatively little of Na_2O; when K_2O is about 5% Na_2O is not more than 3.2%, and when K_2O is about 2% Na_2O occupies the region of not more than 2.2%. In this figure all samples are classified into the S-type.

In $Al_2O_3/(Na_2O + K_2O + CaO)$ ratio the values of 1.1 and over are regarded as the S-types and those of less than 1.1 the I-types. In the samples from this survey the two samples of Mon Kathing mass D-5 and G-1, present the values of 1.10 and 1.11 respectively, so that these are classified into the S-type. However, other granite masses have the values of 0.96 to 1.07 and is classified into the I-type.

In the ACF diagram (Fig. 11) the S-type granite is plotted in a region with less Ca, while the I-type one in a region with more Ca. This corresponds to the fact that, in the result of studying the metamorphic rocks on the ACF diagram, the pelitic rock is plotted in a region with little Ca and much Al and that the basic volcanic rock in a region with much Ca and little Al, indicating

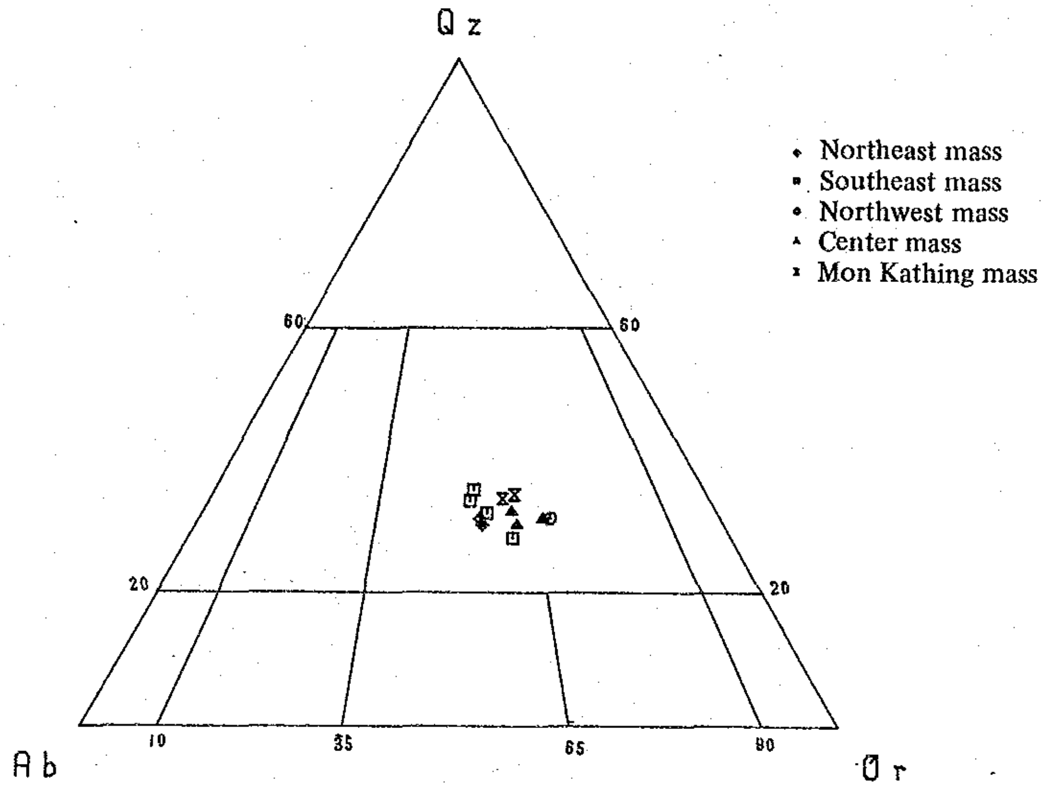

Fig.9 Normative Q–Ab–Or Diagram

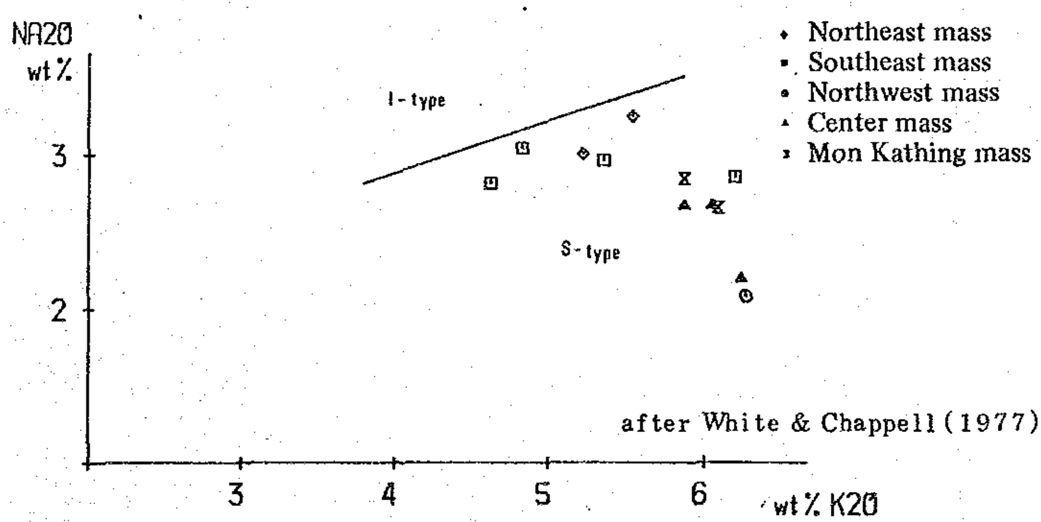

Fig.10 Na_2O-K_2O diagram

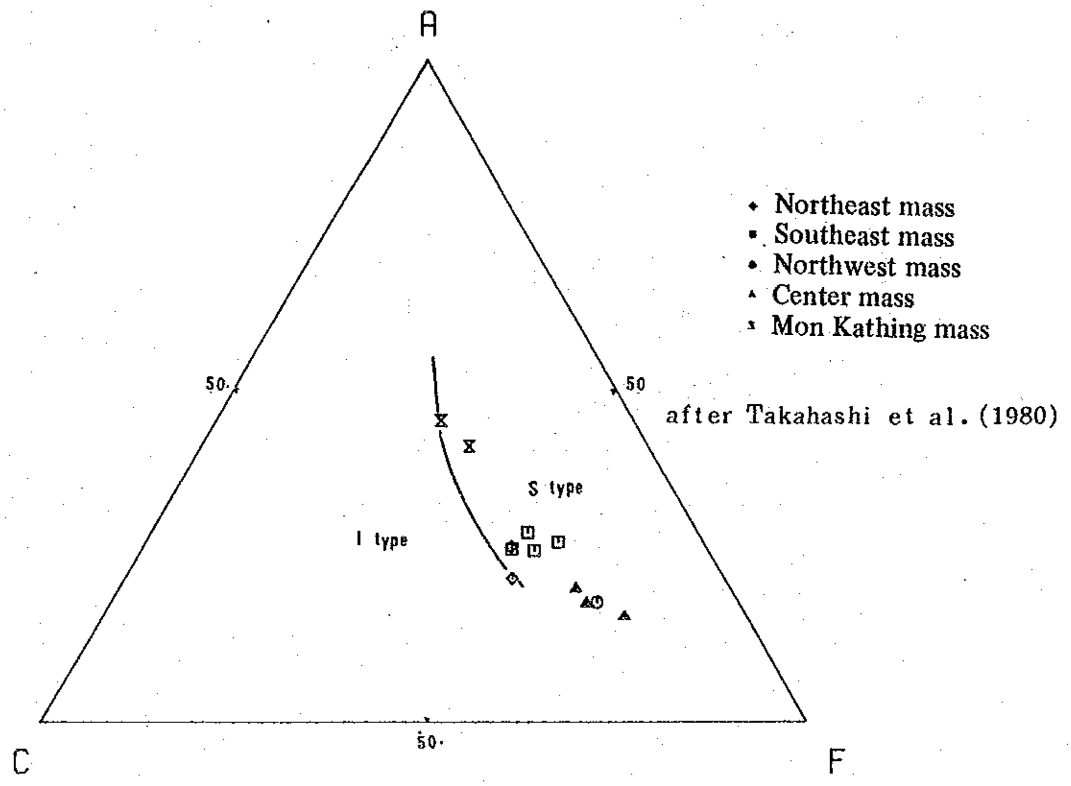

Fig.11 ACF (Al_2O_3-Na_2O-K_2O/CaO/FeO+MgO) diagram

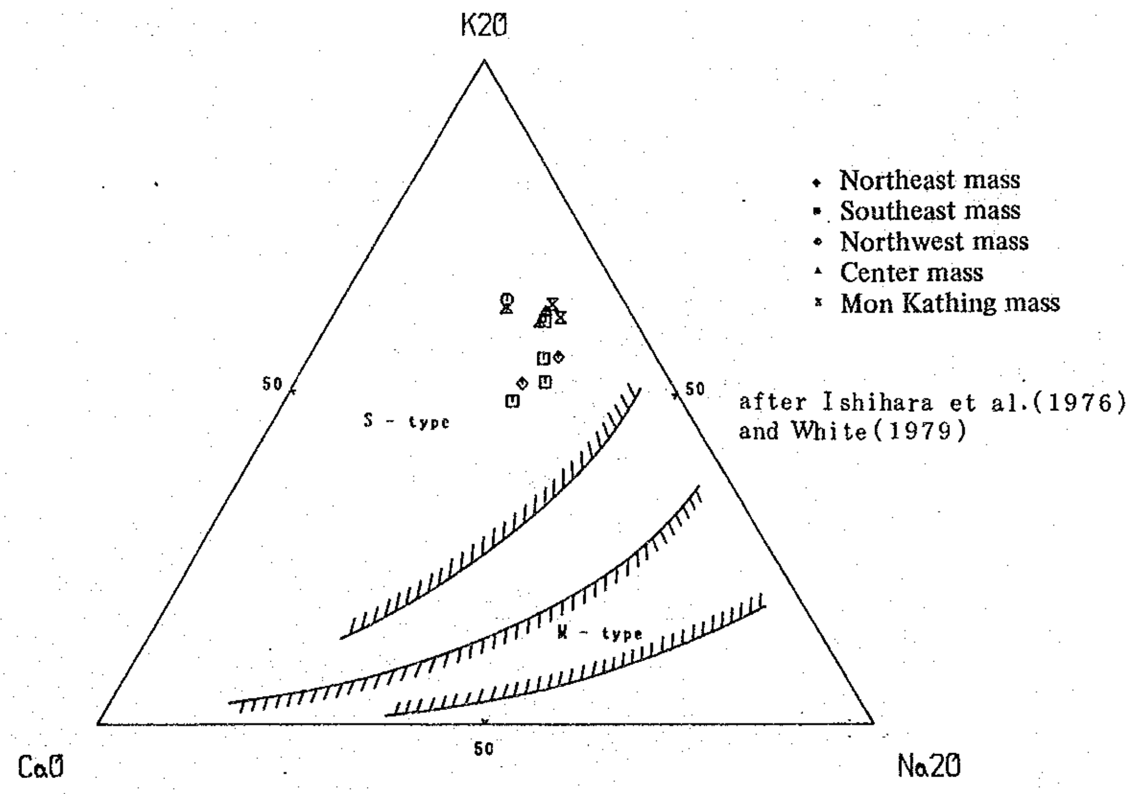

Fig.12 CNK (CaO-Na_2O-K_2O) diagram

that the S-type granite is affinitive in origin with pelitic rocks and the I-type one with basic igneous rocks. All samples are classified into the S-type granite in this survey, so it is presumed that these primary magmas originated in the crust. In the result of this survey, it is noticed that as compared with the past results they has been plotted, nearly at F-end member (FeO+MgO).

The relations between CaO, Na_2O and K_2O are fundamentally important in considering the main components of granite, and the CaO–Na_2O–K_2O(CNK) diagram proves effect in observing the quantity of CaO and that of alkali. Ishihara et al. (1976) divided Miocene granitic rocks of Japan on such a CNK diagram, classifying them into three trends: the southwest Japan outer zone trend with a large K_2O/Na_2O ratio, the Tanzawa – Niijima trend with an extremely small K_2O/Na_2O ratio, and the middle trend between these. The southwest Japan outer zone trend is a typical S-type trend. The Tanzawa – Niijima trend corresponds to so called tonalite-trondhjemite granite in which CaO decreases and SiO_2 increases but K_2O does not increase as differentiation advances. This is equal to the M-type (mantle source type) granitic rocks after White (1979). When the granite distributed in this area is classified by these indexes, all samples come under the S-type (Fig. 12).

Ishihara (1977), remarking the kinds of opaque minerals contained in granite, classified granitic rock into the magnetite-series and the ilmenite-series. The difference between the two series is represented by Fe_2O_3/FeO ratio in the main components of the whole rock. The magnetite series granite has a value of not less than about 0.5, while ilmenite series granite a value of less than 0.5. However, the boundary value is not always distinct, and there is a considerable overlapping area as shown in Fig. 13. When the granite of the survey area is classified by using this standard value, it is classified into the ilmenite series with the exception of Sample D-5 of Mon Kathing mass with the value of 1.00 and Sample G-6 of the northwest mass with the value of 0.76, both of which are classified into the magnetite series.

The result of the above-mentioned classification is set forth in Table 4. Accordingly, typical S-type granite is only Mon Kathing mass. The other masses are classified into the I-type by the index with the use of alumina but into the S-type by the index with the use of alkali. Since all of the granite has been subjected to sericitization, it is highly possible that the granite masses except for Mon Kathing masr may be classified into the I-type in some measure.

Regarding the classification into the magnetite series and the ilmenite series, a sample that is divided into the magnetite series as the result of microscopic observation is classified into the ilmenite series according to Fe_2O_3/FeO ratio. This would be accounted for by the fact that the judgment with microscope depended only on the mineral assemblage and that the extremely small quantity ratio of opaque minerals was not reflected in Fe_2O_3/FeO ratio.

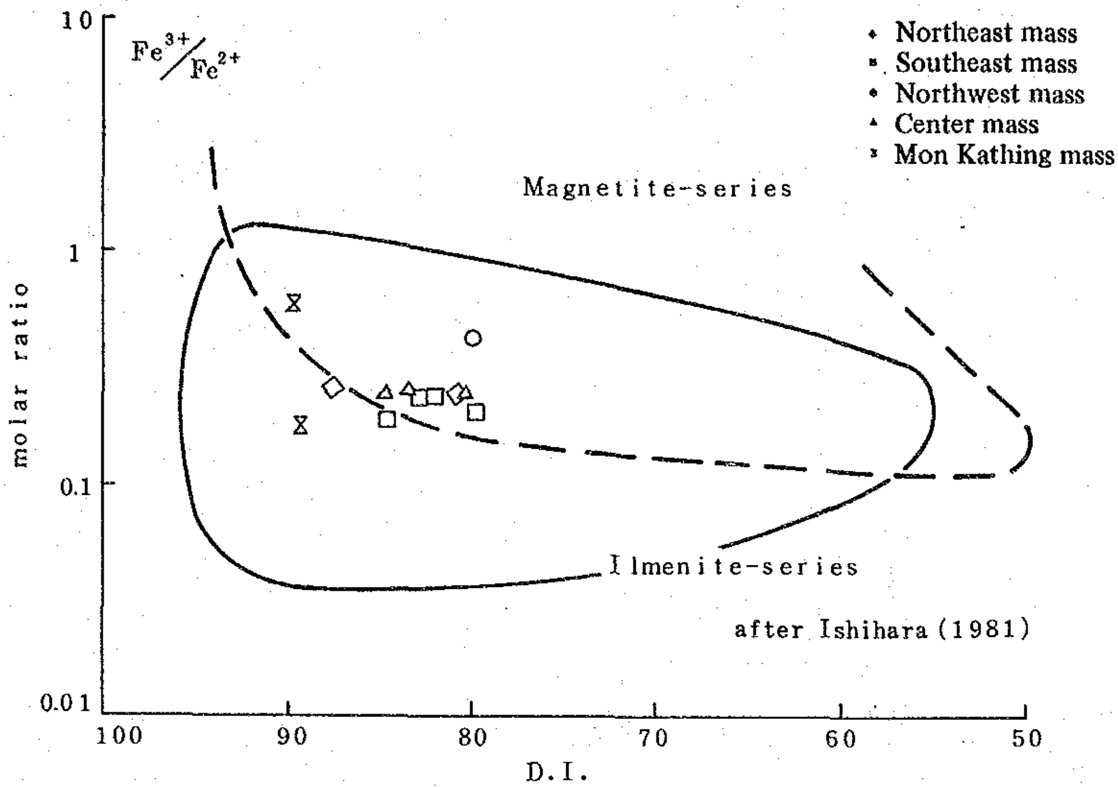

Fig.13 Fe^{3+}/Fe^{2+}-Differentiation index diagram

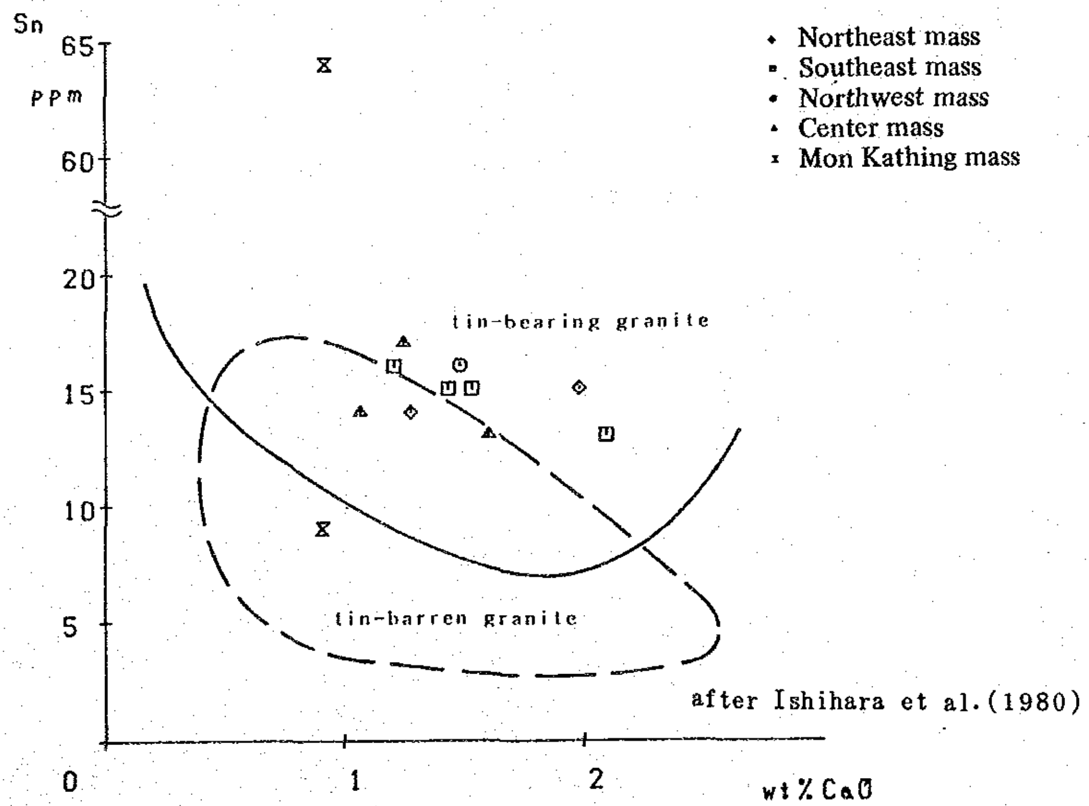

Fig.14 Ca-Sn diagram

Table 4 Classification of Granite Series

Item / Sample No.	Locality	Rock name	Classification of granite series on each criterion: Norm corundum	Na_2O/K_2O	$\frac{Al_2O_3}{Na_2O+K_2O+CaO}$	ACF	CNK	Fe_2O_3/FeO	Microscopic observation (Mineral assemblage Mode of opaque minerals)
D–1	Ban Ko Phlai Lu	Biotite granite	I (0.83)	S (3.00-5.23)	I (1.01)	S	S	il (0.37)	mg
D–2	Huai Sa Ngin	Biotite granite	I (0.00)	S (3.25-5.55)	I (0.96)	S	S	il (0.40)	mg
D–3	West of Ban Yang ORO De Nue	Biotite granite	I (0.58)	S (2.81-4.63)	I (1.01)	S	S	il (0.25)	mg
D–4	Junction of Huai Mae Khong and Huai Sate Kro	Biotite granite	I (0.57)	S (2.66-6.06)	I (1.00)	S	S	il (0.38)	mg
D–5	2km North-east of Doi Mon Kathing	Two mica granite	S (1.99)	S (2.65-6.10)	S (1.11)	S	S	mg (1.00)	il
G–1	Doi Mon Kathing	Two mica granite	S (1.91)	S (2.84-5.88)	S (1.10)	S	S	il (0.24)	il
G–2	East of Ban Mae Long Luang	Altered granite	S (1.27)	S (3.04-4.84)	I (1.06)	S	S	il (0.34)	mg
G–3	South-west of Ban Pli Kro	Biotite granite	I (0.99)	S (2.96-5.36)	I (1.03)	S	S	il (0.37)	mg
G–4	Huai Mae Bang	Biotite granite	I (0.31)	S (2.66-5.88)	I (0.98)	S	S	il (0.34)	mg
G–6	Junction of Nam Mae Hong and Huai Klong Ta	Biotite granite	I (0.57)	S (2.08-6.28)	I (1.00)	S	S	mg (0.77)	mg
G–7	East of Ban Mae Ha Khi	Biotite granite	I (0.63)	S (2.19-6.25)	I (1.00)	S	S	il (0.37)	mg
G–8	West of Ban Se Kra	Biotite granite	S (1.54)	S (2.85-6.21)	I (1.07)	S	S	il (0.25	il
Remark			Chapell & White (1974) (S 〉1.0, I 〈 1.0)	Chapell & White (1974) White & Chapell (1977)	Chapell & White (1974) White & Chapell (1977)	Fig. 18	Fig. 19	Fig. 20	

S; S-type, I; I-type, mg; Magnetite series, il; Ilmenite series

1–5–2 Tin Content of Granitic Rocks

The tin content of granitic rocks in the survey area ranges from 9 to 64 ppm and is almost fixed between 13 and 17 ppm, except for the two samples of Mon Kathing mass. Sample D-5 of this mass has the content of 64 ppm, the highest value. This granitic mass is the one that is considered to have the closest relation with tin–wolframite deposits, and has the characteristic of the granite related with cassiterite–wolframite mineralization as pointed out by Ishihara (1981).

Sample G-1 presents the lowest value of 9 ppm, which might have reduced tin content, because this granite has been subjected to intense mylonitization.

Tayler (1964) reported that the average tin content of granite is 3 ppm. Tischendorf (1977), regarding tin mineralization, mentioned the tin content of "normal granites" to be 4.3 ppm and that of "metallogenetically specialized granites to be 30 ± 14 ppm, and referred to granite containing more than 15 ppm of tin as high-tin granite. Yeap (cited in Hosking, 1973) said that the average tin content of tin-bearing granite in the Malay Peninsula was 6.5 ppm and that of tin-barren granite 5.1 ppm. Ishihara et al. (1980) showed the tin content of tin-bearing granite and tin-barren granite in the peninsular part of Thailand as in Fig. 14, and pointed out that comparatively high content of tin was the characteristic of tin-bearing granite though there were many overlapping areas. In Fig. 13 there are doubtlessly large areas where tin content of tin-bearing granite and that of tin-barren granite overlap with each other; the neighborhood of about 15 ppm is generally the boundary value between the two, and this value agrees with that of the high-tin granite brought forward by Tischendorf (1977). From the above-mentioned if tin content is higher than about 15 ppm, the granite has a high possibility of bearing a tin deposit.

Since granitic rocks in this survey area are considered to have tin content of more than 13 ppm, it is classified into tin-bearing granite, presenting the possibility of occurrence of tin deposits.

1–5–3 Geochemical Characteristics of Granites in Mineralized Zone

Whole rock assay was performed for 12 samples, and the relationship between geochemical characteristics of the granites and tin-tungsten mineralization was studied in the former section. The results of the survey reveal that almost all granites in the area are granite proper, corresponding to S-type granite proper, corresponding to S-type granite defined by Chappell and White (1974), and White and Chappell (1977), and high tin bearing granite.

A whole rock assay has been performed for 11 granite samples obtained from biotite granites and two mica granite in Area A and Area C where mineralized zones were found, and geochemical characteristics of the granites have been studied.

1 Differentiation Index (D.I.) and Normative Mineral

Table 5 shows principal chemical components and norm minerals of the granites. The differentiation indices of the granites, shown by the sum of the weight per cent of norm quartz, orthoclase, albite, nepheline, kalsilite, are 85.9 to 90.1 in the biotite granite in Area A, 87.2 to 95.7 in the two-mica granite in Area A, and 93.2 to 94.7 in the two-mica granite in Area C. The indices are higher than those of the Phase I survey, in which the samples were obtained from various locations of the whole area. The results suggest that the granites of the second phase survey area are of more differentiated stages.

Of these the biotite granite in Area A and the two-mica granite in Area C are the most differentiated, and the biotite granite in Area C is the least differentiated. The biotite granite in Area A is of medium differentiation.

Figure 15 shows the relationship between the differentiation indices and principal compo-ments, combined with the results of the first year's survey. The differentiation indices and SiO_2 contents show strong positive correlation. However, TiO_2, Fe_2O_3, FeO, MnO, MgO, CaO, BaO show negative correlation with the differentiation indices, especially in the case of CaO. Other components, Al_2O_3, Na_2O, K_2O, and P_2O_5 show no correlations.

According to the ratio of the norm quartz, plagioclase, and orthoclase, the granites in the area are classified as granite proper except for granodiorite and quartz monzonite in Area A (samples AR-1 and AR-4). This result is well coincident to the results of the Phase I survey (Fig. 16).

Norm corundum is calculated to be present in all samples for the second phase as was the case with almost all of the Phase I samples. It suggests that the granites have been derived from per-aluminum magma.

2 Classification of the Granitic Rocks

In the correlation diagram of $Na_2O - K_2O$ (Fig. 17), all the samples of the first year's survey are plotted in the S-type area. However, the samples of the second phase survey are mainly plotted in the I-type area and the border area of I-type and S-type, except for a few samples, i.e. AR-5, AR-6, and CR-3.

According to the criteria of $Al_2O_3/(Na_2O + K_2O + CaO)$, the biotite granite in Area A is classified as I-type and the rest as S-type.

On the other hand, according to the criteria of norm corundum, all the granite samples in the area are classified into S-type except for one sample collected in Area A, AR-4.

As the ACF diagram (Fig. 18) shows, a sample of the biotite granite in Area A, AR-1, is plotted in the S-type area, two samples of the two mica granite in Area C, CR-4 and CR-5, are

Table 5 Chemical Analyses of Granitic Rocks in Area A and C

	Area A						Area C				
Sample No.	AR-1	AR-2	AR-3	AR-4	AR-5	AR-6	CR-1	CR-2	CR-3	CR-4	CR-5
Rock type	Biotite granite	Biotite granite	Biotite granite	Biotite granite	Two mica granite	Two mica granite	Biotite granite	Biotite granite	Two mica granite	Two mica granite	Two mica granite
SiO_2	72.21	71.60	70.44	66.64	72.84	75.81	72.24	70.53	74.62	75.31	75.72
TiO_2	0.20	0.40	0.27	0.41	0.39	0.10	0.37	0.41	0.15	0.08	0.10
Al_2O_3	15.53	14.10	15.37	16.93	14.12	13.02	14.09	14.37	13.68	14.02	13.73
Fe_2O_3	0.39	0.65	0.52	0.53	0.44	0.27	0.38	0.56	0.55	0.43	0.39
FeO	0.65	1.30	1.01	1.08	1.30	0.22	1.59	1.61	0.50	0.29	0.10
MnO	0.04	0.03	0.03	0.01	0.02	0.00	0.05	0.05	0.05	0.03	0.01
MgO	0.36	1.10	0.95	0.94	0.99	0.26	0.86	1.38	0.21	0.05	0.07
CaO	1.89	1.16	0.79	0.59	0.84	0.20	1.34	1.22	0.42	0.36	0.28
Na_2O	5.44	3.34	4.40	4.36	2.55	2.21	3.18	2.81	3.25	4.01	3.26
K_2O	1.93	5.20	5.12	7.89	5.28	7.06	4.30	5.12	5.18	3.96	5.03
P_2O_5	0.07	0.23	0.34	0.12	0.21	0.06	0.25	0.24	0.19	0.32	0.27
BaO	0.05	0.08	0.06	0.12	0.07	0.05	0.07	0.11	0.01	0.00	0.01
LOI	0.52	0.58	0.58	0.40	0.96	0.52	1.05	1.27	0.89	0.93	1.12
total	99.28	99.77	99.88	100.02	100.01	99.78	99.77	99.68	99.70	99.79	100.09
Q	28.47	28.16	22.58	8.26	34.42	35.24	32.83	29.64	35.07	36.71	37.40
C	1.19	1.37	1.93	0.35	3.14	1.49	2.32	2.49	2.41	3.14	2.92
or	11.41	30.73	30.26	46.63	31.20	41.72	25.41	30.26	30.61	23.40	29.73
ab	46.03	28.26	37.23	36.89	21.58	18.70	26.91	23.78	27.50	33.93	27.59
an	9.01	4.40	1.81	2.36	2.92	0.69	5.14	4.68	0.86	0.00	0.00
di	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
hd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
en	0.90	2.74	2.37	2.34	2.47	0.65	2.14	3.44	0.52	0.12	0.17
fs	0.62	1.25	1.04	0.89	1.42	0.02	2.09	1.91	0.31	0.10	0.00
mt	0.57	0.94	0.75	0.77	0.64	0.39	0.55	0.81	0.80	0.62	0.07
il	0.38	0.76	0.51	0.78	0.74	0.19	0.70	0.78	0.28	0.15	0.19
ap	0.16	0.53	0.79	0.28	0.49	0.14	0.58	0.56	0.44	0.74	0.63
D.I	85.91	87.15	90.07	91.78	87.20	95.66	85.15	83.68	93.18	94.04	94.72

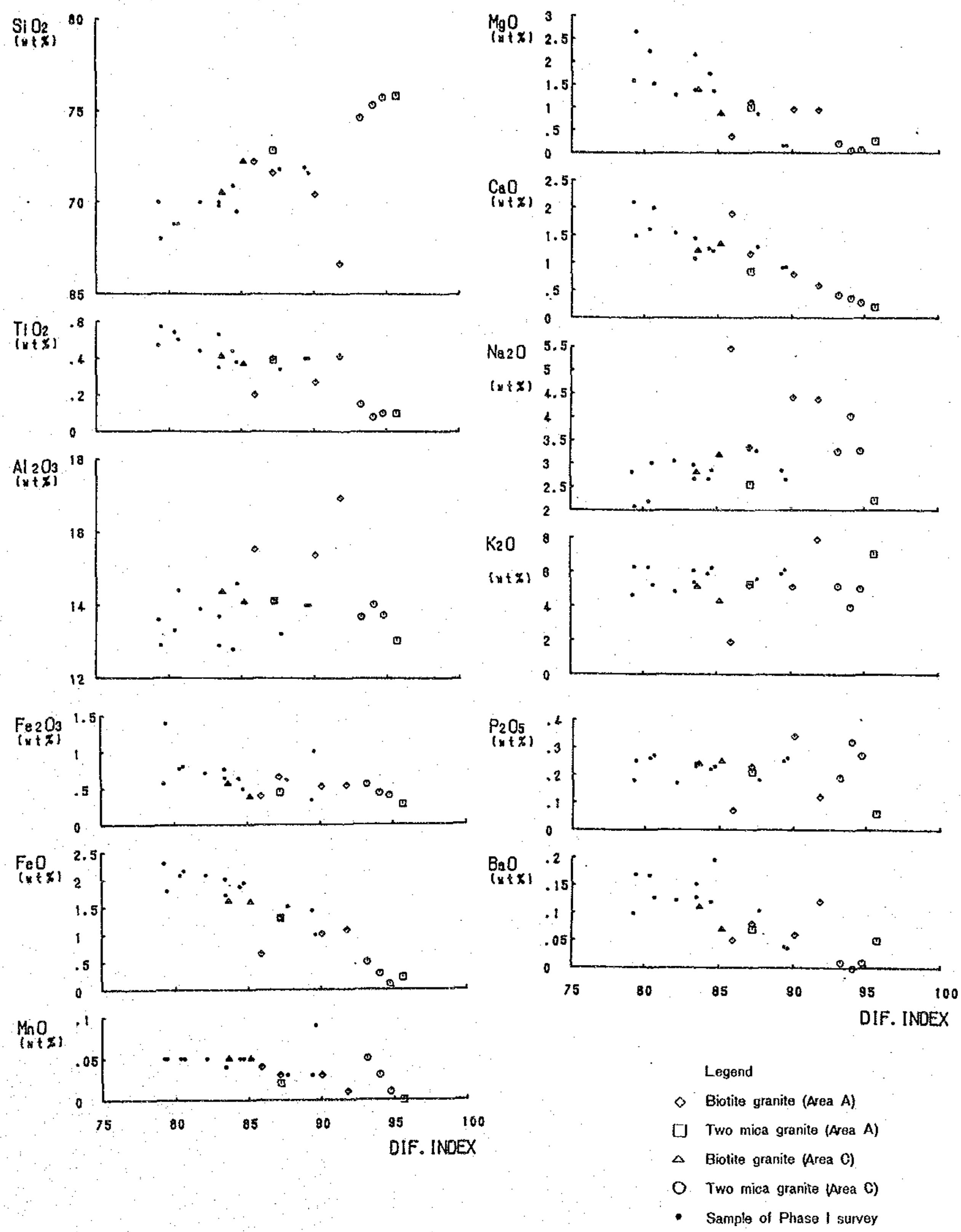

Fig.15 Variation diagrams of granitic Rocks (Area A and C)

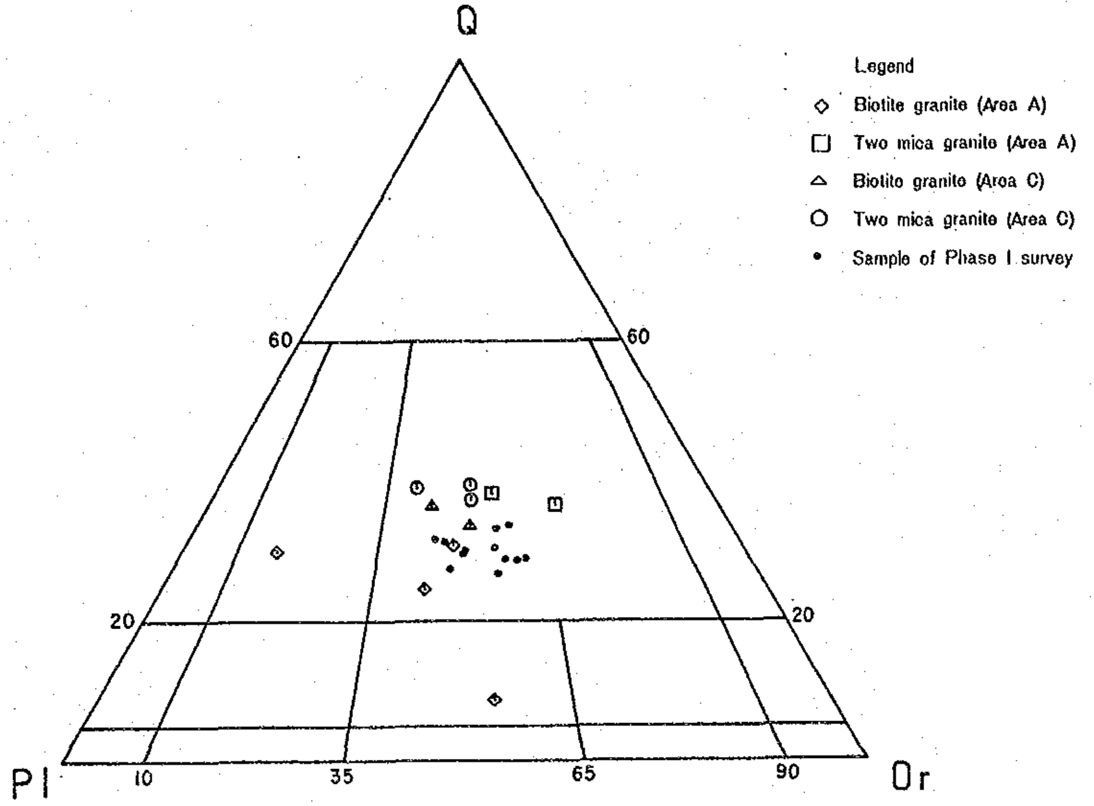

Fig.16 Normative Q-Ab-Or Diagram (Area A and C)

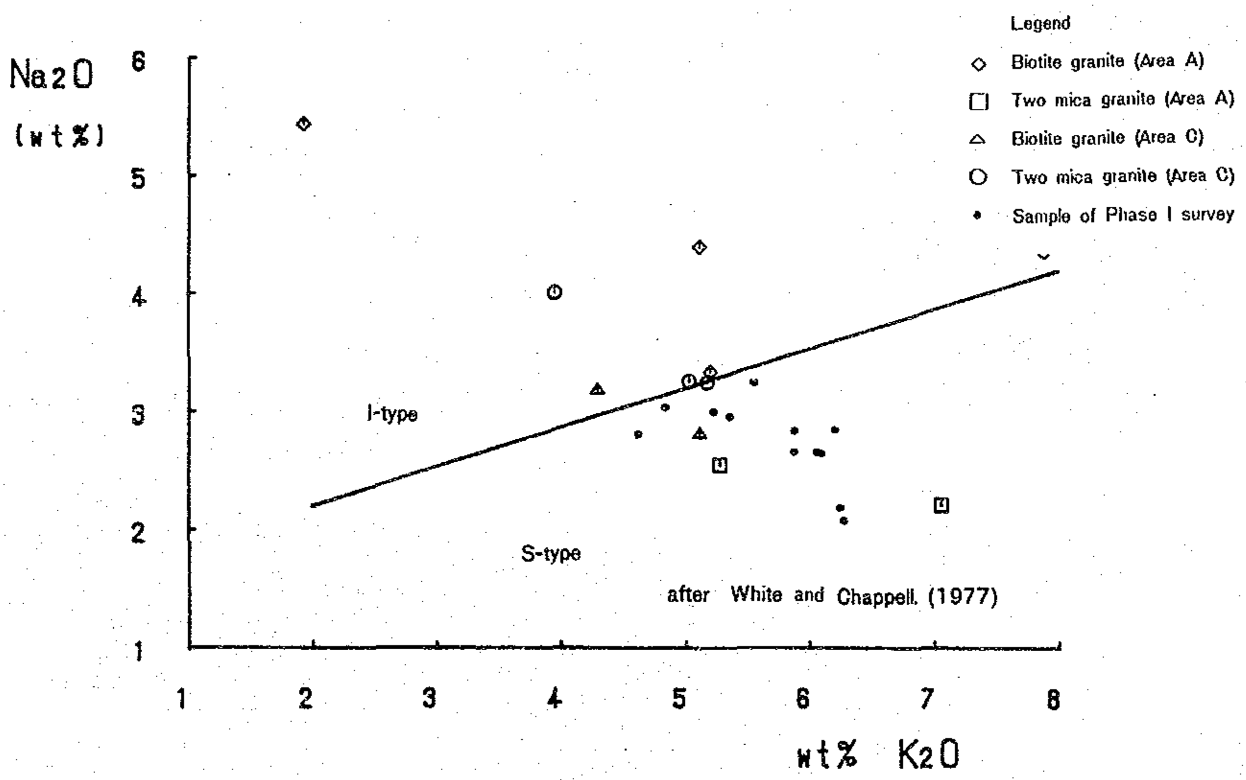

Fig.17 Na_2O-K_2O diagram (Area A and C)

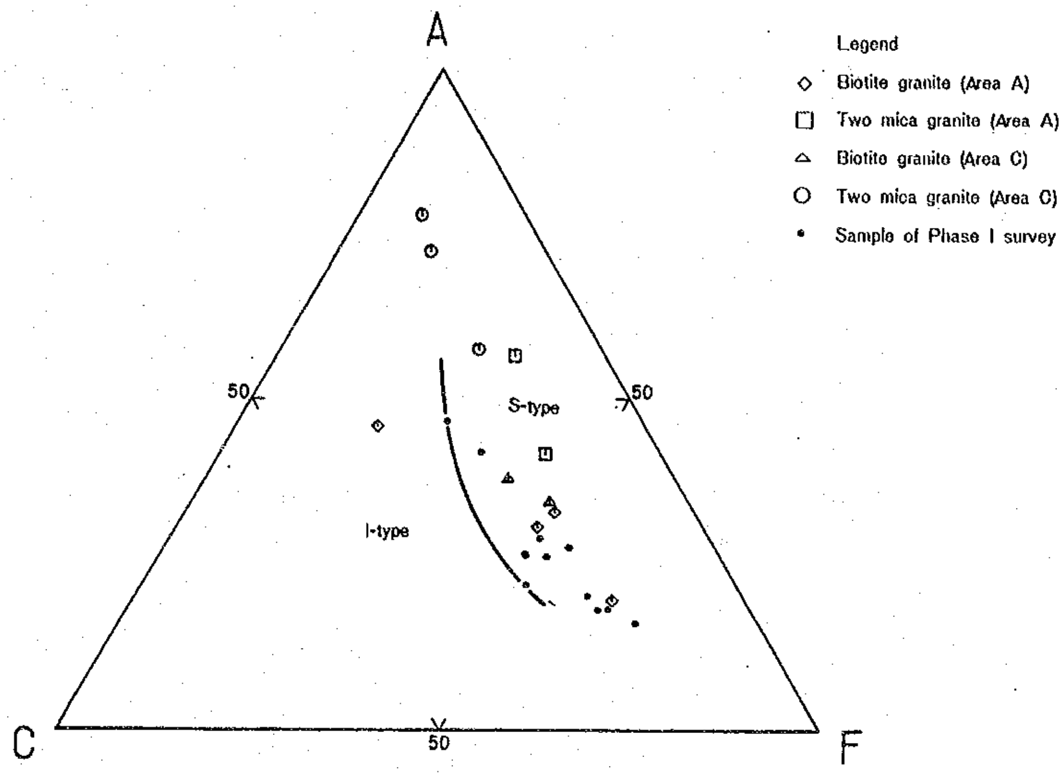

Fig.18 ACF (Al_2O_3-Na_2O-K_2O/CaO/FeO+MgO) diagram (Area A and C)

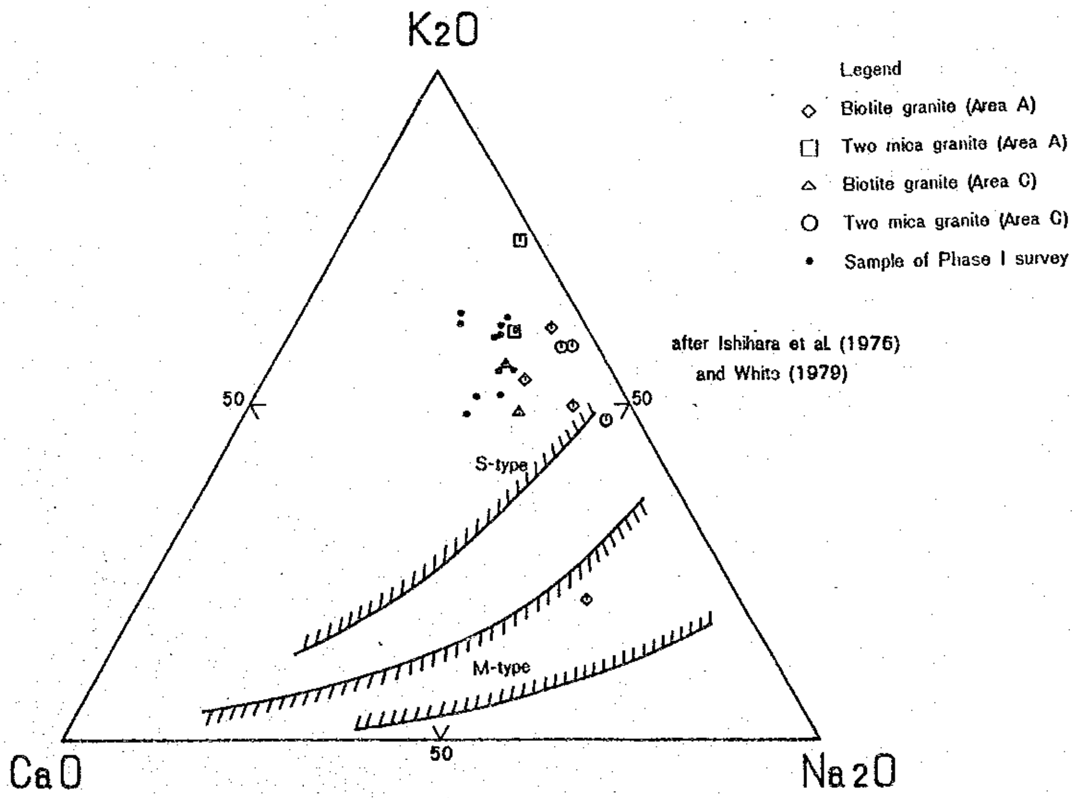

Fig.19 CNK (CaO-Na_2O-K_2O) diagram (Area A and C)

plotted in a border area of the two types, and all the rest of the samples are plotted in the S-type area.

As Figure 19 shows, the granites in the Yang Kiang area show nearly the same trend in CNK (CaO-Na_2O-K_2O) diagram as that of the outer zone of southwest Japan, namely of S-type (Fig. 20).

Applying Ishihara's criteria (1981), the granites in the survey area are generally classified into the Ilmenite-series except for a few samples, AR-6, CR-3, CR-5, which show enormously high differentiation indices. Therefore, the granites are adequate for associating the above mentioned mineralization, judging from their characteristics.

Table 6 summarizes the results of the classification.

Classifications of the Magnetite-series and Ilmenite-series, and the I-type and S-type are principally based on different criteria. However, most of S-type granites are in the Ilmenite-series, and I-type granites are in both series. In summary, the granites in the area are mainly of the S-type and the Ilmenite-series.

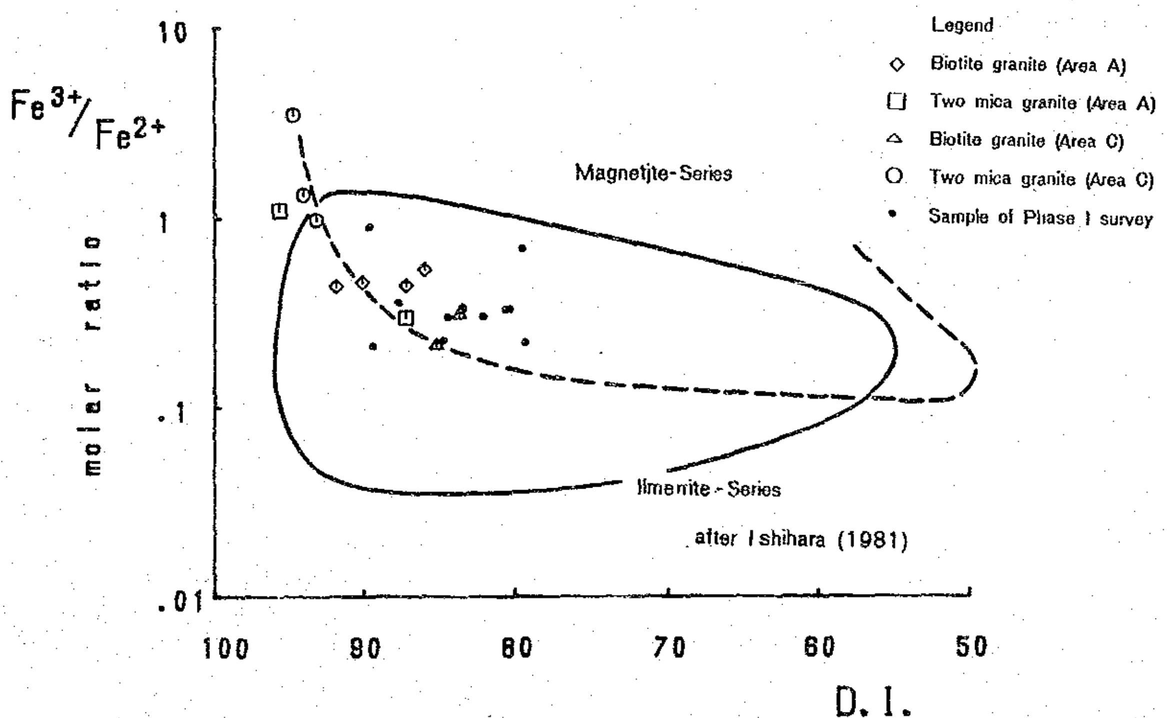

Fig.20 Fe^{3+}/Fe^{2+}-Differentiation index diagram in Area A and C

Table 6 Classification of Granite Series in Area A and C

Item / Sample No.	Locality	Rock name	Classification of granite series on each criterion						
			Norm corundum	Na_2O/K_2O	$\frac{Al_2O_3}{Na_2O+K_2O+CaO}$	ACF	CNK	Fe_2O_3/FeO	Microscopic observation Mineral assemblage Mode of opaque minerals
AR–1	Huai Sa Ngin (X0, Y7.5)	Biotite granite	S (1.19)	I (5.44/1.93)	I (1.07)	I	S ?	il or mg (0.60)	il
AR–2	Huai U Tum (X18, Y05)	Biotite granite	S (1.37)	I (3.34/5.20)	I (1.07)	S	S	il or mg (0.50)	mg
AR–3	Huai Sa Ngin (X32, Y19)	Biotite Granite	S (1.93)	I (4.40/5.12)	I (1.08)	S	S	il or mg (0.51)	il
AR–4	Branch of Huai U Tum (X36, Y10)	Biotite granite	I (0.35)	I (4.36/7.89)	I (1.01)	S	S	il (0.49)	il
AR–5	Huai U Tum (X22, Y4)	Two mica granite	S (3.14)	S (2.55/5.28)	S (1.23)	S	S	il or mg (0.34)	il
AR–6	Branch of Huai Sa Ngin (X43, Y14)	Two mica granite	S (1.49)	S (2.21/7.06)	S (1.12)	S	S	– (1.23)	il
CR–1	Branch of Nam Mae Hong (C6–37)	Biotite granite	S (2.32)	I (3.18/4.30)	S (1.14)	S	S	il or mg (0.24)	il
CR–2	Nam Mae Hong (C5–32)	biotite granite	S (2.49)	S (2.81/5.12)	S (1.16)	S	S	il or mg (0.35)	il
CR–3	Branch of Nam Mae Hong (C31–35)	Two mica granite	S (2.41)	S (3.25/5.18)	S (1.17)	S	S	il (1.10)	mg
CR–4	Branch of Nam Mae Hong (C24–24)	Two mica granite	S (3.14)	I (4.01/3.96)	S (1.22)	S–I	S	– (1.48)	il
CR–5	Nam Mae Hong (C9–28)	Two mica granite	S (2.91)	I (3.26/5.03)	S (1.21)	S–I)	S	mg (3.90)	il
Remark			Chapell & White (1974) (S ＞ 1.0, I ＜ 1.0)	Chapell & White(1974) White & Chapell(1977)	Chapell & White (1974) White & Chapell (1977)	Fig. 18	Fig. 19	Fig. 20	

S ; S-type, I ; I-type, mg ; Magnetite series, il ; ilmenite series

3 Discussions

The mineralization in the area is principally associated with pegmatites in Area A, and associated with two mica granites in Area C. This suggests that two mica granites and pegmatites showing significantly high differentiation indices are presumably the final differentiation products of the magma which formed the Northeast mass, and are closely associated with mineralization.

1–6 Dating of Granitic Rocks

The granitic rocks distributed in the survey area have been considered to be Triassic.

The granitic rocks in the Omkoi area to the east of the survey area had been previously attributed to the Carboniferous and Triassic. However, JICA and MMAJ (1986), on the basis of Rb-Sr and K-Ar dating, surmise that these rocks derive from activity during 3 periods, namely, the Carboniferous, Triassic and Cretaceous.

Occurrence of tin and tungsten deposits in Thailand is closely related to Mesozoic to Cenozoic granite and quartz and pegmatite veins originating from these. Mineralization is thought to have occurred at two periods, namely the Triassic and Cretaceous. However, that for the Mae Lama mass 20km west of the survey area and peninsular Thailand is widely considered to be at the end of the Cretaceous. Consequently, dating of granitic rocks is important in picking out promising areas of mineral occurrence.

Radioactive dating of granitic rocks of northern Thailand is discussed in reports by Baum, et al (1970), Braun (1970), Teggin (1975), Braun, et al (1976), and Beckinsale, et al (1979). By Rb-Sr dating, age is broadly divided into early Triassic to early Jurassic (236~190Ma) and early Cretaceous (130Ma). Although K-Ar dating indicates ages younger by about 10~20Ma in comparison to Rb-Sr dating, the two generally coincide overall. Nevertheless, a portion of the results of the K-Ar dating suggest age significantly younger than that by Rb-Sr dating. This is considered attributable to (1) rejuvenation of K-Ar age due to hydrothermal action occurring along faulting after granite intrusion, or (2) the upheaval and cooling by tectonic movement of formerly opened, K-Ar system granite under high temperature in deep ground even after intrusion, and its transition into closed K-Ar system granite (Huntchinson, 1983). Ishihara, et al (1980), illustrated a similar tendency by pointing out that there was discordance between the result of Rb-Sr dating and K-Ar dating of granitic rocks in a tin mine zone in peninsular Thailand. This is attributed: (1) discordance resulting from the initial stage of the intrusion and solidification of granite to the last pegmatite stage being one cycle, (2) rejuvenation due to the hydrothermal process accompanying mineralization, or (3) rejuvenation due to faulting and shearing movement.

Table 7 Results of the K-Ar method age determination

Sample No.	Coordination		Locality	Rock description	Mineral	K (wt%)	^{40}Ar rad (10^{-8} cc STP/g)	Atm. ^{40}Ar (%)	Age (Ma)
	E	N							
D–1	413.6	1973.4	northeastern mass Ban Ko Pro Lui	coarse-grained biotite granite	biotite	7.87 ±0.16	2392±17 2398±17	6.8 4.9	76.8±1.6
D–2	418.7	1977.7	Northeastern mass Huai Sa Ngin	medium-grained biotite granite	biotite	7.97 ±0.16	2306±16 2302±19	5.3 4.9	73.0±1.5
D–3	415.7	1947.7	Southeastern mass Ban Yang O Ro De Nua	coarse-grained biotite granite	biotite	6.36 ±0.13	2015±15 2056±16	6.1 4.2	80.7±1.7
D–4	409.7	1954.9	Center mass Huai Mae Khong	coarse-grained biotite granite	biotite	7.58 ±0.16	5810±46 5921±48	2.0 1.4	189.1±3.9
D–5	401.0	1936.8	Mon Kathing mass Doi Mon Kathing	medium-grained muscovite-biotite granite	biotite	7.12 ±0.14	1152±10 1103±8	12.1 12.0	40.4±0.9
					muscovite	7.03 ±0.14	1173±10	20.0	42.5±0.9

The constants for the age calculation are: $\lambda\beta = 4.96 \times 10^{-10}$ year^{-1}, $\lambda\epsilon = 0.581 \times 10^{-10}$ year^{-1}, $^{40}K/K = 1.167 \times 10^{-4}$
Whole rock analysis data are shown in Table 3.

1–6–1 Result of Measurement

Two granite samples from the northeast mass and one each from the southeast mass, central mass and Mon Kathing mass were taken. Biotite was separated from the granite and dated. Muscovite from the granite sample from Mon Kathing was also separated and dated. Locations of sampling are shown in Fig.5, and results of dating are given in Table 7.

The 4 samples from the three masses excluding Mon Kathing are K-feldspar porphyrite bearing biotite granite, and the sample from the Mon Kathing mass is medium grained, muscovite-biotite granite.

In K-feldspar bearing porphyritic biotite granite, alteration of feldspar into muscovite is heavy, as well as alteration of biotite into chlorite, epidote and muscovite. Batholith granite of the northeast and southeast is considered to have very likely undergone thermal metamorphism judging from recrystallization seen in sample D-2 and actinolite in sample D-3.

Result of dating is as follows: 73.0 ± 1.5Ma, 76.8 ± 1.6Ma and 80.6 ± 1.7Ma for the 3 samples from the northeast and southeast mass, 189.1 ± 3.9Ma for the central mass; 40.4 ± 0.9Ma for biotite of the Mon Kathing mass and 42.5 ± 0.9Ma for muscovite of the same mass.

1–6–2 Observation

Widely differing ages of 73~80Ma and 189Ma were obtained. The values of 73~80Ma from samples D1~3 from the northeast mass and the southeast mass are roughly the same as the 70Ma obtained from the same rock bodies in the Omkoi area by JICA and MMAJ (1986). Also, the value of 189Ma for sample D-4 from the central mass is in general agreement with the value of 190~236Ma obtained by the Rb-Sr and K-Ar methods from Triassic granite distributed around the survey area. The Triassic granite around the survey area and the K-feldspar bearing biotite granite in the survey area have the same lithofacies and mineral composition. It is thought that these granites intruded at the early Triassic to the early Jurassic. The younger ages of the northeast mass and southeast mass in comparison to the central mass may be ascribable to the samples having been subjected to heavy alteraion and thermal metamorphism. From a regional viewpoint, the development of fault systems in the direction N-S to NW-SE in the batholith granite bodies for the Omkoi area to the east of the survey area suggests the possibility that rejuvenation was caused by igneous activity and hydrothermal process resulting from faulting movement.

It is known that the age of formation of tin and tungsten mineralized veins and greisens developed at the margin of Mae Lama granite mass (Rb-Sr dating of 130 ± 4Ma by Beckinsale, et al, 1979) and surrounding sedimentary rock about 20km west of the survey area, is 78Ma by the Rb-Sr method and 72Ma for muscovite and 53Ma for biotite by the K-Ar method (Braun, et al, 1976). This suggests that the tin and tungsten bearing quartz veins were probably formed during the age 73 to 80Ma (Braun, et al, 1976).

The Mon Kathing mass is an extension of the above mentioned Mae Lama mass, and has been subjected to similar tin and tungsten mineralization. In addition, the Mon Kathing mass shows dissemination of sulfide minerals and replacement of muscovite-biotite granite in disseminated manner by arsenopyrite. This suggests that after the intrusion of muscovite-biotite granite in this mass, tin and tungsten mineralization occurred at the age of 70Ma, followed by the mineralization of sulfide minerals which continued until 40Ma (the Paleogene).

CHAPTER 2 GEOCHEMICAL PROSPECTING BY STREAM SEDIMENTS

2–1 Sampling

Sampling was carried out simultaneously with geological survey along selected main rivers and their tributaries. Sampling interval was 300 to 400m as a rule. Stream sediment samples were taken from the middle of the stream bed and screened with a 80 mesh sieve. About 100g of the -80 mesh fraction was then taken. At the same time, panning samples were collected at the rate of one sample per four points.

The total number of collected river sediment samples is 2,027. Total number of panning samples is 539.

Collected samples were air dried and divided into halves for use by both the Thai and Japanese sides.

2–2 Chemical Analysis Method

As occurrence of useful elements such as niobium, tantalum, tin and tungsten as well as copper, zinc and molybdenum were anticipated in the area, the 12 elements of niobium, thantalum, tin, tungsten, copper, zinc, molybdenum, antimony, gold, silver, arsenic and fluorine were selected as path finder elements.

For chemical analysis, inductively coupled, plasma emission spectrography was applied to tin, molybdenum, tungsten, zinc, tantalum, niobium and copper, the atomic absorption analysis method was applied to silver, arsenic, and antimony, the activity method was applied to fluorine, and neutron activation analysis was applied to gold.

Critical detection values for these elements are 1ppb for gold, 0.1ppm for silver and antimony, and 1ppm for other elements.

2–3 Classification of anomalous values

Mean values and standard deviation were used to decide the threshold values, anomalous values and background values.

Table 8. Division into Anomaly Value Levels

Element \ Class	Background zone	Low anomaly zone	High anomaly zone 1	High anomaly zone 2
Nb	34	54	88	
Ta	11	32	90	
Sn	27	64	–	
W	60	171	487	
Cu	82	249	–	
Zn	182	468	–	
Sb	10	–	–	
Mo	5	9	–	
As	133	252	900	
Au	9	–	–	
Ag	0.3	–	–	
F	780	1,002	–	

Unit: ppm, Au in ppb

2–4 Distribution of Anomalous Zones

An anomalous zone for each element was picked out on the basis of the above division into anomalous levels. Anomalous zones for niobium, tantalum, tin and tungsten are shown in Fig. 21.

Selected anomalous zones for each element are discussed below:

Niobium

Anomalous zones are distributed in the northeast mass at the upper reaches of the Huai Sa Ngin and Huai U Tum, in the catchment of the Huai Chi Non Luang, and around the villages of Yang Kiang and Mae Khong, as well as around Mon Kathing in the southwest. These zones are all small scale. Relatively speaking, however, those at the Huai Sa Ngin, around Yang Kiang village and the Huai Chi Non Luang can be described as more sizable distributions.

Tantalum

Almost all anomalous zones overlap with those of niobium. However, the tantalum zones show greater anomaly. Zones of high anomaly are particularly concentrated on the Huai Chi Non Luang, and the upper reaches of the Huai Sa Ngin and the Huai U Tum. An anomalous zone extends from the villages of Mae Khong and Yang Kiang to Nam Mae Hong.

Tin

Small scale anomalous zones are distributed along the Huai Chi Non Luang, around Yang Kiang village and Mae Khong village and in the Mon Kathing area. On the whole, anomalies are low and indistinct. However, relatively larger and more distinct anomalous zones are seen along the Huai Chi Non Luang and around Yang Kiang village.

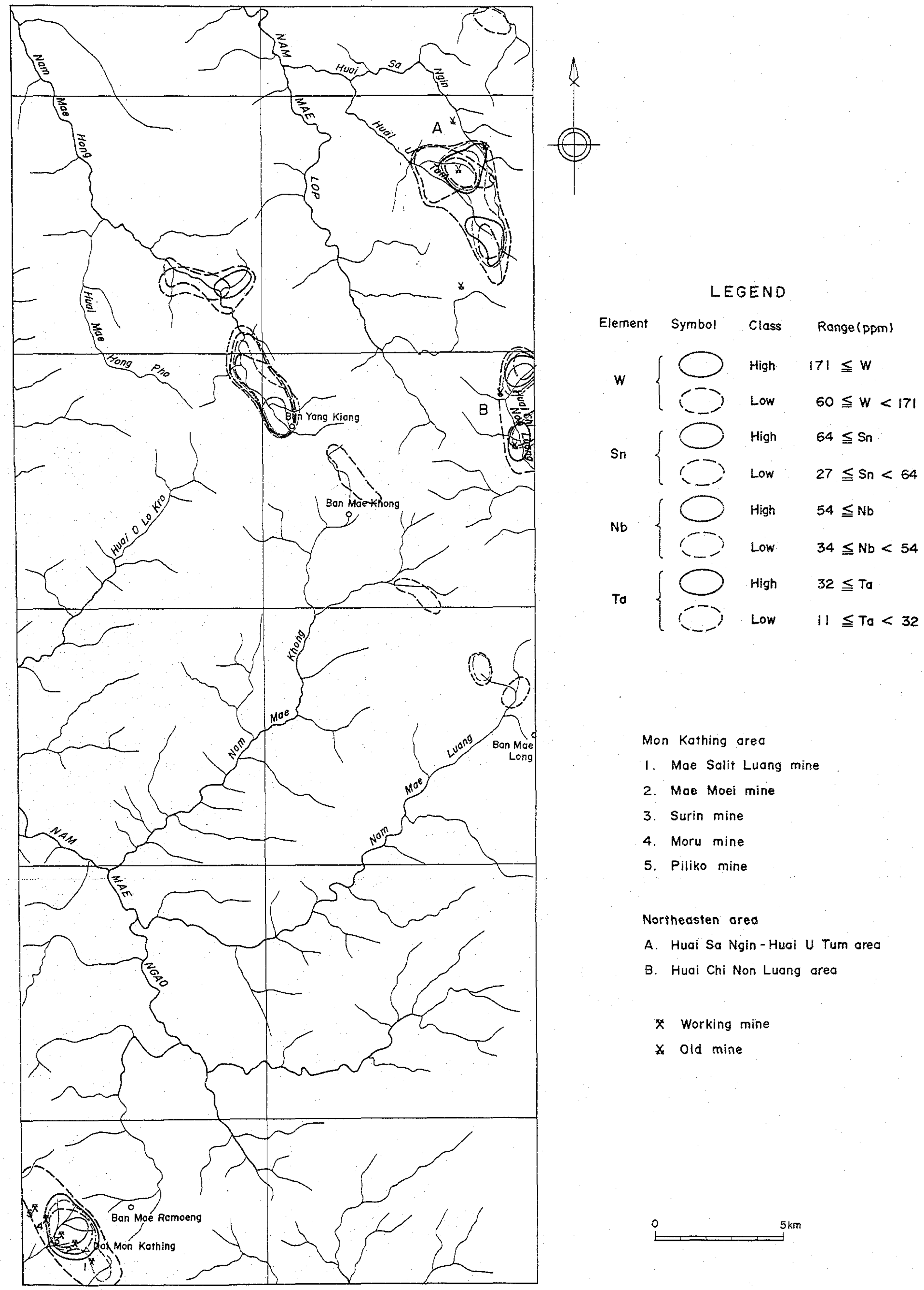

Fig.21 Mines and geochemical anomalies of Nb, Ta, Sn, W

A zone of low anomaly is found along the upper reaches of the Nam Mae Ngao, however, it is indistinct.

Tungsten

Although anomalous zones overlap with those of niobium and tantalum, distribution is limited almost entirely to the northeast and around Mon Kathing. A distinct highly anomalous zone is found around Yang Kiang village, along the Huai U Tum and around Mon Kathing.

Copper

Most are zones of low anomaly broadly distributed from the northwest to the south in seeming correspondence to the distribution of sedimentary rock.

Zinc

Distribution of anomalous zones shows same trend as for copper.

Arsenic

Distribution of anomalous zones shows same trend as for copper and zinc. However, a highly anomalous zone is seen in the Mon Kathing area.

Molybdenum

Anomaly is almost completely unobserved due to low content. However, slightly anomalous values are found in the south.

Antimony

Anomaly is almost completely unobserved due to low content. However, some anomalous values are found in places.

Gold

Anomalous values are scattered throughout the survey area. However, they are almost completely under 10ppb.

Silver

Values at several ppm are scattered throughout the area.

Fluorine

Anomalous zones are widely distributed in batholith granites, however, they are not distinct.

2–5 Study of Heavy Mineral Samples

Heavy mineral samples were collected at the rate of 1 sample per 4 geochemical prospecting samples from stream sediments.

In collecting a smaple, first about 30ℓ of stream sediment was panned to about 100∼150g at the site. This was further concentrated by panning again at the base camp, and the sample was examined by naked eye. An ultraviolet lamp was used to identify scheelite, zircon, etc.

Identified minerals were cassiterite, wolframite, scheelite, zircon, garnet, tourmaline, etc. Opaque minerals such as magnetite and ilmenite were either observed only in very small quantities, or not at all throughout the survey area.

Survey results are discussed in further detail below (see Fig. 22∿24).

Cassiterite, the distribution of which is comparatively limited, was seen in the upper reaches of the Nam Mae Lop, Huai Sa Ngin, Huai U Tum, Huai Chi Non Luang and the southwest foot of Doi Mon Kathing. With the exception of the vicinity of Mon Kathing, cassiterite occurs with garnet.

Wolframite was only found in the Mon Kathing mass in the southwest.

Scheelite of pinhole size granularity is uniformly distributed over the survey area. Large distributions of large grained scheelite, 0.5 to 1mm dia, are limited to Huai U Tum, Huai Sa Ngin and the upper reaches of the Nam Mae Lop. Other areas where large grained scheelite is found include the Huai Chi Non Luang, the Mon Kathing, and the Huai Lui.

Garnet is found in abundance the northeast of the line connecting the Nam Mae Lop and Huai Chi Non Luang.

Zircon is distributed evenly throughout the survey area.

Samples containing none of the above minerals were particularly numerous for areas distributed with Silurio-Carboniferous sedimentary rocks, accounting for 40% of the samples in those areas.

2–6 Discussion

Promising areas for mineral deposits were considered on the basis of correlation of the above anomalous zone distribution, and the relationship between geology and ore deposits (Fig. 21).

The anomalous zones for niobium, tantalum, tin and tungsten correspond, and are limited to the northeast granite batholith and the Mon Kathing granite mass. The anomalous zone extending from Yang Kiang along the Mae Hong in northwest direction is assumed to be the result of transport of elements from upstream.

Anomalous zones are concentrated the upper reaches of the Huai U Tum and Huai Sa Ngin (Area A), Huai Chi Non Luang (Area B), around Yang Kiang village at the upper reaches of the Nam Mae Hong (Area C), and the Mon Kathing area.

A zone of high anomaly for tantalum is found at the upper reaches of Huai U Tum and Huai Sa Ngin, further upstream from U Tum Tai, where old workings are scattered, and the Huai Sa Ngin. Pegmatites bearing muscovite, garnet and tourmaline are found in large quantity

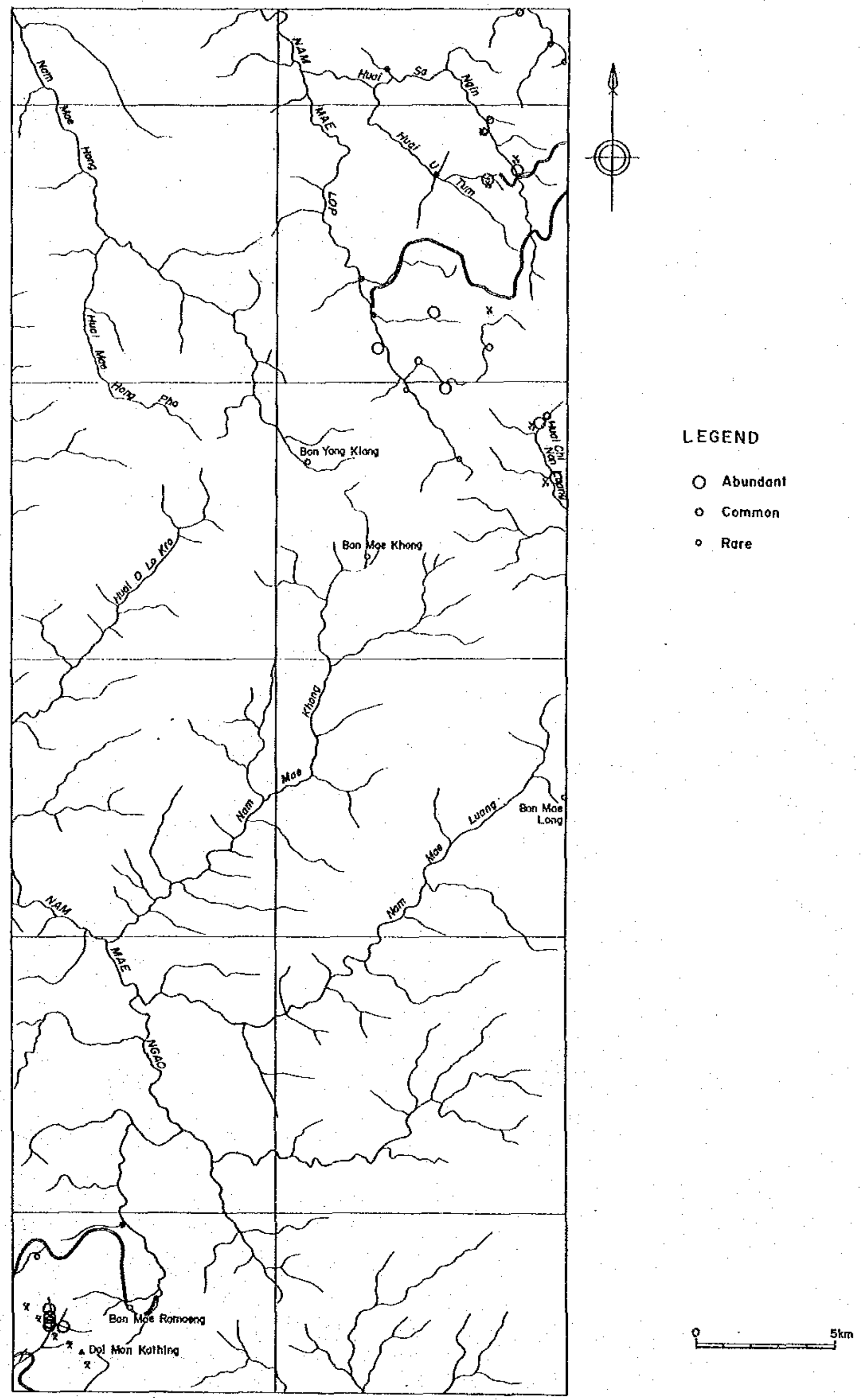

Fig.22 Location of cassiterite under megascopic observation of heavy minerals in stream sediment

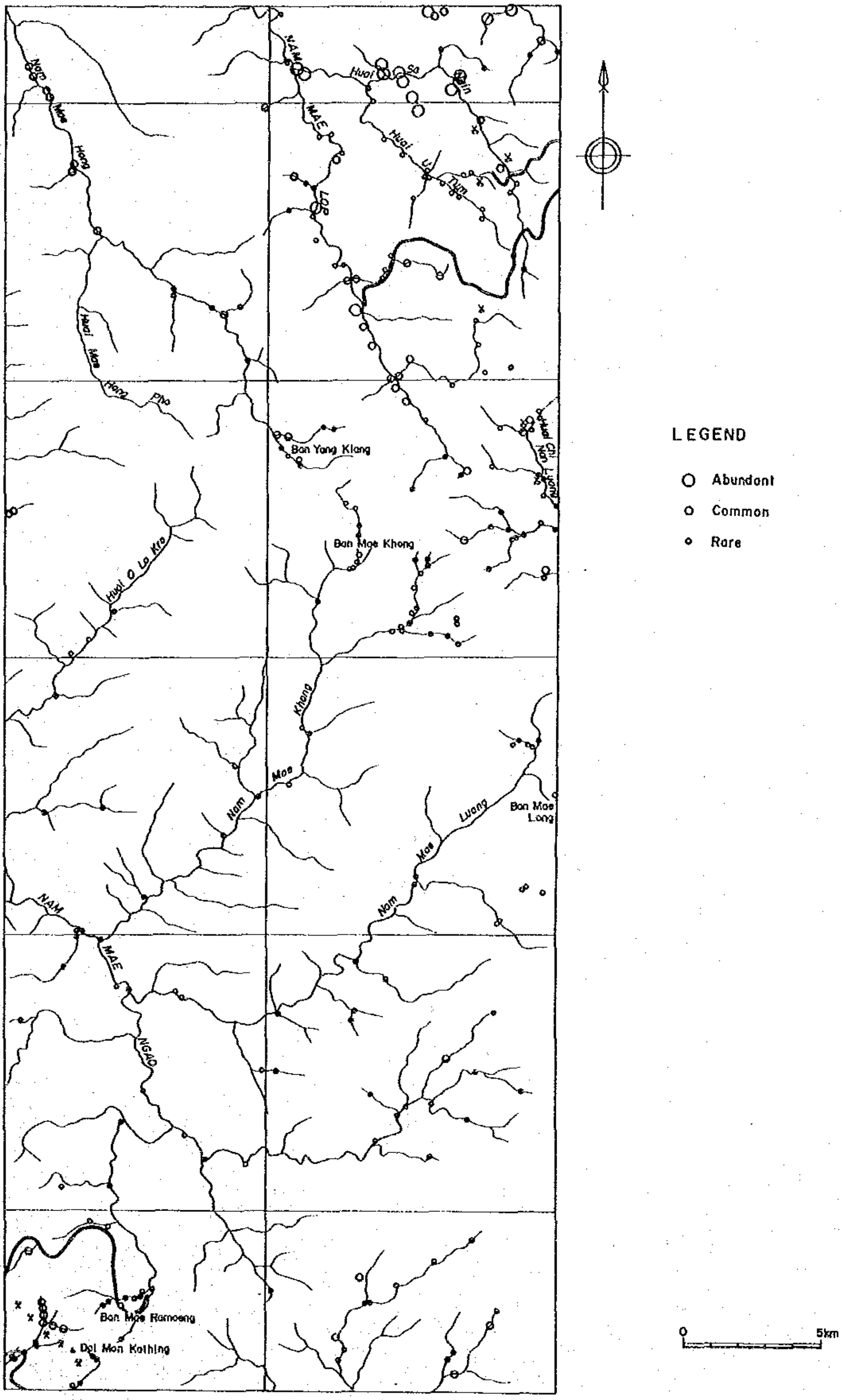

Fig.23 Location of scheelite under megascopic observation of heavy minerals in stream sediment

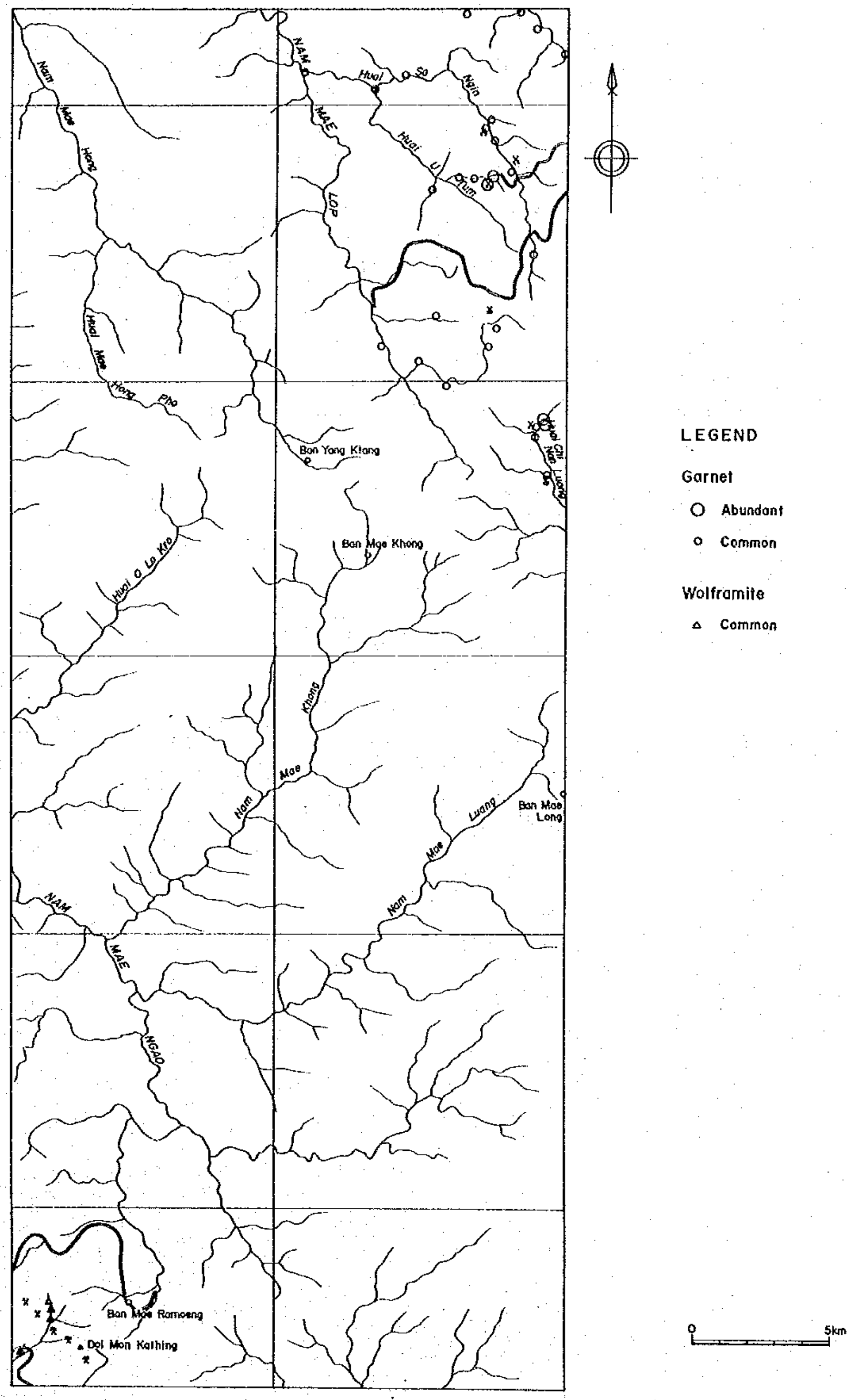

Fig.24 Location of garnet and wolframite under megascopic observation of heavy minerals in stream sediment

throughout the zone. Granite host rock shows heavy alteration.

A highly anomalous zone is seen on the Huai Chi Non Luang near the largest old workings and at its uppermost reaches. Although the back area for the sand and gravel bed is unclear, the source is considered to be small tributaries flowing into the Huai Chi Non Luang from the northwest at its uppermost reaches due to the presence along these tributaries of large amounts of cassiterite and garnet.

On the basis of distribution of element bearing material and the distribution of scheelite in heavy mineral samples, it is thought that the source of the anomalous zone around Yang Kiang and Mae Khong is northeast of a line connecting Nam Mae Hong and Nam Mae Khong.

Chemical analysis of panning concentrate taken from the Huai Chi Non Luang and Huai Sa Ngin show relatively high content of niobium and tantalum. Due to the fact that pegmatite intrusion is seen at both areas and large quartz floats are numerous around the old workings, it is possible that the highly anomaly zone for niobium and tantalum is related to them.

A highly anomalous zone as a result of cassiterite and wolframite deposits is found in the Mon Kathing area. Niobium and tantalum were not detected in chemical analysis of concentrates from this area.

An anomaly of tin is found in the uppermost reaches of the Nam Mae Ngao. It is conceivable that the muscovite-biotite granite distributed in the area played a role in the tin mineralization.

With the exception of the anomalous zone related to copper and fluorine deposits at Mon Kathing, anomalous zones for copper, zinc and fluorine show similar distribution. Zones of low anomaly for these elements are widely distributed from north to south in the central part of the area. This distribution corresponds to that for Siluro-Carboniferous sedimentary rocks.

Contents of molybdenum, antimony, gold and silver are overall low in the survey area, in many cases below critical levels for detection. As a consequence, no anomalous zones were found. Samples with relatively high content of molybdenum and antimony were distributed in Siluro-Carboniferous sedimentary rocks, as was seen for copper, zinc and fluorine. Gold and silver are scattered throughout the survey area.

Samples high in fluorine content are distributed in the batholith granite in the east of the survey area. Within this, deposits are relatively concentrated around Mae Khong village and to the south of Mae Long village.

From the above results, it was seen that the elements for which geochemically anomalous zones exist in the area are niobium, tantalum, tin and tungsten, and that these are limited to the northeast and the Mon Kathing area. Results of study of heavy mineral samples indicate the same as well.

The Mon Kathing area is the site of known tin and tungsten deposits (mines), and zones of high anomaly have been identified.

Zones of high anomaly for the 4 elements are found concentrated in several locations in the northeast. Although there are old workings of secondary deposits in one portion, it is considered highly probable that the deposits are primary on the basis of scale of anomalous zone and the characteristics of host rock.

The above results indicated that Huai Sa Ngin and Huai U Tum (Area A), Huai Chi Non Luang (Area B), around Yang Kiang (Area C), and Mon Kathing mass were selected to the possible area of Sn-W-Nb-Ta ore deposit.

Area B seemed unsuitable for our work becouse the Department of Forestry has declared it a part of the forest plantation area and Mon Kathing area has already been prospected.

Therefore Area A and C were selected for the next phase survey.