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

PHASE I

JUNE 1987

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, northwestern Thailand and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

For the work in 1986, the first phase, the Metal Mining Agency of Japan dispatched the survey team to the Kingdom of Thailand between October 23, 1986 and March 18, 1987.

The field survey was brought to completion with the cooperation of the Government of the Kingdom of Thailand, in particular, Department of Mineral Resources, Ministry of Industry.

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.

May, 1987

Keisuke Arita

Keisuke ARITA
President
Japan International Cooperation Agency

Junichiro Sato

Junichiro SATO
President
Metal Mining Agency of Japan

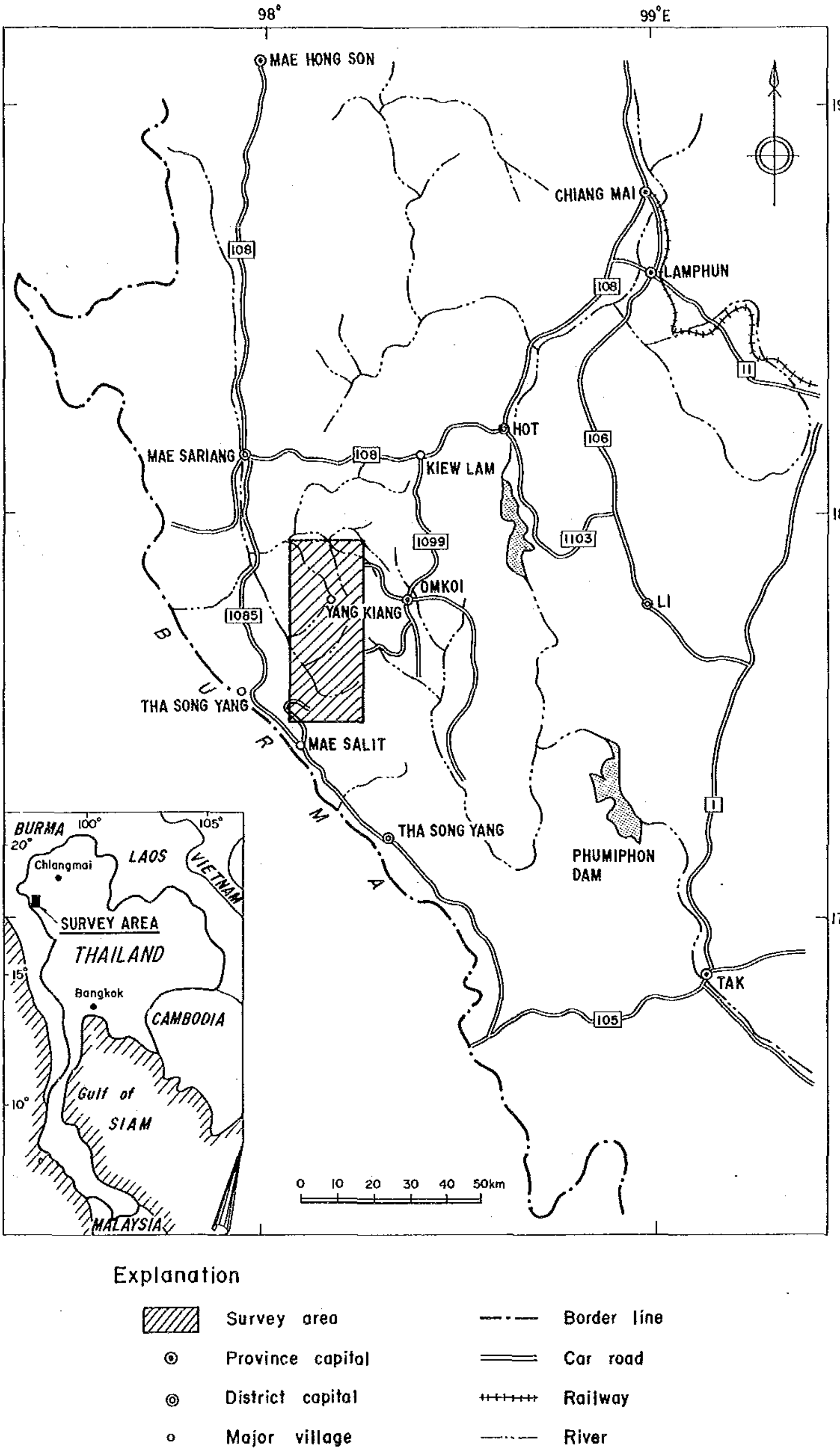

Fig. 1 Location map of the survey area

SUMMARY

This is the first phase survey of the cooperative mineral exploration in the Yang Kiang area, northwestern Thailand.

The survey area is a rectangular bounded by 50 km in the north and south, 20 km in the east and west (area of 1,000 km^2) around Yang Kiang village which lies about 25 km west of Omkoi, Omkoi district, Chiang Mai province. This area borders on the west of the Omkoi area, where the cooperative mineral exploration was conducted from 1983 to 1985.

In this survey geological and geochemical prospectings were carried out to select some high possibility areas of mineral deposits and also to understand geological structure, igneous activity and the mineralization in this area. The distribution of heavy metals such as tin, tungsten, niobium and tantalum in stream sediment was studied geochemically and correlated to other geological data.

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 intrude 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 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 obtained 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 sulphide 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 secondarily.

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 found in sand and gravel beds along the upper streams running in the mountainous region. Several old workings of such deposits are also found in this area. The ore minerals are cassiterite with subordinate scheelite. Niobium and tantalum are detectable by geochemical examination of panning concentrates from this area.

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 80 cm for each veins. The quartz veins are exposed for a distance of about 4 km 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 sulphide minerals near the quartz veins. Niobium and tantalum are hardly detected by chemical analyses of panning concentrates from the Mon Kathing area.

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 the northeast mass and the Mon Kathing stock are remarkable. The contents of zinc, copper and arsenic are mostly lower than the background values for the whole survey area except for the Mon Kathing area, while their relatively high contents of these elements are distributed in the area of sedimentary rocks. Therefore these may be sedimentary rock origin. The distribution of high fluorine contents corresponds to the areas of batholithic granite; especially those in the Huai Chi Non Luang and the Mae Long district. Gold, silver, molybdenum and antimony indicate no considerable anomaly in this area.

The above-mentioned result indicates that the two anomaly areas of the northeast mass and the Mon Kathing mass are selected to the possible area of the Sn-W-Nb-Ta ore deposits.

As for the northeast mass, this mass is the extension of tin and tungsten-bearing granite in Omkoi area, and some old workings of eluvial ore deposits of tin and tungsten exist at places.

In addition niobium and tantalum are detected in panning concentrates.

On the other hand the extent of mineralization of the Mon Kathing mass is limited and this area has already been prospected. Niobium and tantalum are hardly detected in panning concentrates.

Therefore it is concluded that Huai Chi Non Luang, Huai Sa Ngin to Huai U Tum area and Yang Kiang area in the northeast mass are considered to be high in possibility of the occurrence of undiscovered ore deposits.

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INTRODUCTION

CHAPTER 1 OUTLINE OF THE SURVEY

1–1 Introduction

The first series of cooperative exploration was lasted from 1983 to 1985 at the Omkoi area in northern Thailand.

This series of the survey revealed the geology, geological structure, related igneous rocks and the characteristics of mineral deposit, and found some new mineral indication zones of niobium, tantalum, tin and tungsten.

On the basis of the above results, the Government of Thailand requested to the Japanese Government to conduct the second series of cooperative mineral exploration at the Yang Kiang area where it adjoins the Omkoi area and is expected to be present similar mineral indication zones.

In response to this request the Japanese Government has sent a mission in July 1986 and has negotiated with the Department of Mineral Resources, the Ministry of Industry. As the result of this negotiation the two government reached an agreement of setting about the above mentioned second series of survey. And this survey started at 1986 as the Phase I of the three years, cooperative activity.

1–2 Schedule and Personnel of the Survey

(1) Negotiation and Planning of the Survey

The mission for negotiating a scheme and planning the first phase survey was dispatched to Thailand as follows.

(a) Period: July 14 to July 19, 1986

(b) Members of the mission

Japan

Takeshi Izumi	Metal Mining Agency of Japan	
Yasuo Endo	ditto	
Toshihiko Hayashi	Japan International Cooperation Agency	

Thailand

Sivavong Changkasiri	Department of Mineral Resources	(Director General)
Chanin Rasrikriengkrai	ditto	(Project Director)
Phairat Suthakorn	ditto	(Project Manager)
Prachon Charoensri	ditto	
Kasem Chancharoonpong	ditto	
Samai Chiemchindaratana	ditto	

Sunoj Uenguoom	Department of Mineral Resources

(2) The Phase I Survey

(a) Period: October 23, 1986 to March 18, 1987

(b) Members of survey team

Japan

Coordination and planning

Norikazu Matsuda	Ministry of International Trade and Industry
Naoki Kamijo	Japan International Cooperation Agency
Takeshi Izumi	Metal Mining Agency of Japan
Seiichi Ishida	ditto
Natsumi Kamiya	ditto
Yasuo Endo	ditto

Geological and geochemical survey

Iwao Uchimura	Geologist
Hiroshi Yoshida	ditto
Kenichi Takizawa	ditto
Yoshikatsu Ichige	ditto
Hiroyuki Takahata	ditto
Makoto Miyoshi	ditto

Thailand

Coordination and planning

Chanin Rasrikriengkrai	Department of Mineral Resources
Phairat Suthakorn	ditto

Geological and geochemical survey

Peerapong Khuenkong	Geologist
Patchara Jariyawat	ditto
Arun Tritrangarn	ditto
Wason Chanseang	ditto
Boonchu Panglinput	Field assistant
Sawang Wanlaid	ditto

1–3 Contents of the Survey

(1) Survey area and Objective

The survey area is located around Yang Kiang village about 25 km west of Omkoi, Omkoi district, bounded by 50 km in the side of north and south by 20 km in the side of east and west.

The objective of the survey is to find and evaluate mineral deposits of niobium, tantalum, tin and tungsten, and in addition, gold, silver, copper, lead, zinc, molybdenum, antimony and other metals with geological and geochemical survey.

(2) Previous Works

A German geological mission conducted systematic survey of the northern part of Thailand in cooperation with the Department of Mineral Resources from 1965 to 1971. They described the general geology, stratigraphy and geologic structure and stated various kinds of mineral deposits in this region and also evaluated their potential. Their final report (1972) briefly described the mineral deposits of tin, tungsten, fluorine and antimony in the Omkoi area.

On the basis of the results of this regional survey, Geological Maps of Northern Thailand (Braun, E. von, Hahn, L. and Maronde, H.D., 1981) on the scale of 1:250,000 were compiled. The Yang Kiang area is included in sheet (Amphoe Li) 6. Hahn & Siebenhuner (1982) made a description of fossils obtained in the map.

Vichit & Khuenkong (1983) investigated the mineral deposits and mineral indication zones of tin and tungsten, which occur scatteringly in the Omkoi area; they described the characteristics of the tin and tungsten mineralization and considered the relation between the tin-tungsten mineralization and niobium-tantalum minerals in stream sediments.

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

(3) Contents of the Survey

In this phase, regional geological survey and geochemical prospecting were conducted over the whole survey area. Sampling points were distributed with nearly uniform density over the whole area.

Geological mapping was performed using topographical maps of the scale of 1:25,000, which was enlarged from original maps on a scale of 1:50,000. The geologic map and geochemical anomaly maps were compiled on sheets of 1:50,000 scale.

Laboratory examinations and analytical research were performed in Japan.

The quantities of the items of the survey and the details of the laboratory examinations are shown in Table 1.

Table 1 Contents of Survey and Their Quantities

		Item	Quantity
Field survey		Reconnaissance survey Geological survey Geochemical prospecting	Area of survey: 1,000 km^2 Total route : 600 km
Laboratory examinations		Microscopic observation of thin sections Microscopic observation of polished sections X-ray diffraction tests K-Ar dating	15 pieces 15 pieces 14 samples 5 samples
	Chemical analysis	Rock: SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, Fe_2O_3, FeO, MnO, TiO_2, P_2O_5, BaO, LOI, Sn	12 samples (168 components)
		Ore: Nb, Ta, Sn, W	12 samples (48 components)
		Stream Sediments: Nb, Ta, Sn, W, Cu, Zn, Sb, Mo, As, Au, Ag, F	2,027 samples (24,324 components)
		Heavy minerals: megascopic observation	537 samples

CHAPTER 2 GEOGRAPHIC INFORMATION OF THE SURVEY AREA

2–1 Location and Accessibility

As shown in Fig 1, the survey area is located in the range of Long. 98°03'30"E to Long. 98°15'00"E and Lat. 17°29'00" to Lat. 17°56'30", west on the Omkoi area where a cooperative mineral exploration project was made from 1983 to 1985. This area is about 200 km to the southwest of Chiang Mai city in northern Thailand, and covers a 1,000 km^2 area, 50 km in the north-south direction and 20 km in the east-west direction. Administratively its eastern half falls under Omkoi district, Chiang Mai province, its west under Mae Sariang district, Mae Hong Son province, and its southwest to south portion under Tha Song Yang district, Tak province.

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

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

The distance between Omkoi and Mae Sariang is 114 km which is covered by car in 2 hours. The one between Mae Sariang and Mae Salit is 116 km which is covered by car in about 3.5 hours.

The straight distance between Chiang Mai and Bangkok is about 570 km; there is a regular air service with four to five flights a day, and it takes about 60 minutes. A Railway service takes about 13.5 hours on 751 km between these cities. There also is a highway connecting them, which is covered by a express bus in about 10 hours.

Some car roads lead to the survey area: the one from Omkoi to U Tum Tai and Ko Pro Lu in the northeast of the survey area, the one from Omkoi to Haui Chi Non Luang in the middle of the east of the same area, and the one from Omkoi to Mae Long in the southeast of the area, all of which are unpaved; in addition, National Highway No. 1,267 leading from Mae Salit to Mae Ramoeng, which is fully paved. Since the first three have many steep slopes and curves, four wheel-drive car must be needed for safety drive. It takes three to four hours from Omkoi to these destination villages. They become muddy and hardly passable in rainy season. A car road has been laid up from Ko Pro Lu to Yang Kiang which is located in the middle of the survey area, but it has been made impassable by fallen trees and gullys.

Many small paths develop and connect scattering villages and cultivated fields of the hill tribes in the survey area.

2–2 Topography

The east part of Nam Mae Lop, which runs northward from southeast to northwest in the northeastern part of the area, presents a plateau like landform, ranging from 700 to 1,100 m in altitude, with a comparatively high degree of dissection. On the other hand, the part between Nam Mae Lop and Nam Mae Ngao, which run northward in the southwestern part from southeast to northwest, displays the features of steep mountains having a relative height difference of about 1,600 m from 200 m to 1,800 m in altitude. The west region of Nam Mae Ngao presents a gentle mountainous landform growing gradually higher toward a range of mountains and hills running northwest and southeast, including Doi Mon Kathing, where mines lie scatteringly in the southwest extremity of the survey area. The southwest side of these mountains and hills presents a sharp cliff landform.

2–3 Climate and Vegitation

The survey area is under a climate of the tropical savanna type. Rainy season is influenced by the southwest monsoon from May to October, and dry season under the influence of the northeast monsoon from November to February. Between March and April it is the hottest season in a year as the northeast wind is weak.

Generally, the monthly average temperature is in the range of 16 to 28°C, but daily variation of temperature in dry season is extremely, it ranges from 3 to 35°C. In high mountain areas sometimes the lowest temperature is about 0°C and then it frosts.

Annual precipation is between 800 and 900 mm, there is only little rainfall from December to March.

In the north to east of the survey area, most of the vegetation consists of primeval thin forests of broadleaf trees mingled with such coniferous trees as pine, but in the southwest area thick forests with palm trees as the jungle is dominated.

2–4 General Information

Hill tribes of the Karen live over the whole survey area. Their remote small villages, which consist of several to tens houses, scatter at the flat place of valleys and hills.

There are primary school and traveling clinic at major villages as Yang Kiang, Mae Khong and Mae Ramoeng. Therefore peoples are gradually civillized. However most of them have made still self-sufficing living because car roads are still underdeveloped.

The Principal part of the industry is farming, mainly rice is cultivate on the paddy field and on dryland by the slash-and-burn method, and the other kinds of industry are stock farming (beef cattle, water buffalos, and hogs), textile manufacture, mining (tin and tungsten) and timber (mainly teakwood) production.

The transportation of various materials, cereals and the likes, often depends on elephants, in addition to human power.

Omkoi town where the survey team placed its base camp has the office of Omkoi district. In addition to it there are a primary school, junior high school, hospital, post office and police station, and also there are a general shop, restaurant, gas station and others. So this village forms an administrative and commercial center. The Thai race accounts for the greater part of the population of Omkoi town.

DETAILED DESCRIPTION

CHAPTER 3 GEOLOGICAL SURVEY

3–1 Summary of Geology

The Indochina peninsula has been repeatedly subjected to orogenic movements taking place four times: at the end of the Precambrian age, in the Variscan orogeny (the Hercynian orogeny at the end of the Paleozoic), the Indosinian 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 constructed by these repeated orogenic movements, being strongly affected by fractural movements resulting from the orogenic movements.

According to the fractural movements, northern Thailand is divided, from the west, into the four tectonic provinces (JICA, 1984): the West Tectonic Province (along the Thai-Burmese border), Main Western Range Tectonic Province (between Mae Sariang and Chiang Mai), Central North Tectonic Province, and East Tectonic Province (Khorat Plateau).

The most part of the survey area comes under the Main Western Range Tectonic Province, while its southwest part 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 Triassic intruded into the abovementioned rocks. The West Tectonic Province consists of carbonate rocks and clastic rocks of the Paleozoic to Mesozoic and Mesozoic granite intruded into these (Fig. 2).

To summarize the general geology of this area, its east part is occupied by a batholith granite lying in the north-south direction, and its west part is mainly distributed with sedimentary rocks of the Paleozoic and Mesozoic. The sedimentary rocks strike NW-SE direction, and granite stocks are intruded in concordant with this structural direction at the middle and southwest end of the area.

3–2 Stratigraphy

According to the German Geological Mission (GGM, 1972), sedimentary rocks, metamorphic rocks and granitic rocks in the survey area are classified as follows: metamorphic rocks of Precarboniferous, sedimentary rocks from the Cambrian to the Triassic, Triassic granitic rocks, and Quaternary allvium.

As the results of this survey there are some differences in the GGM report about the distribution of each formation. But mainly this report follows the GGM report for the geological distribution and stratigraphical relations. Because these formations crop out so small in this

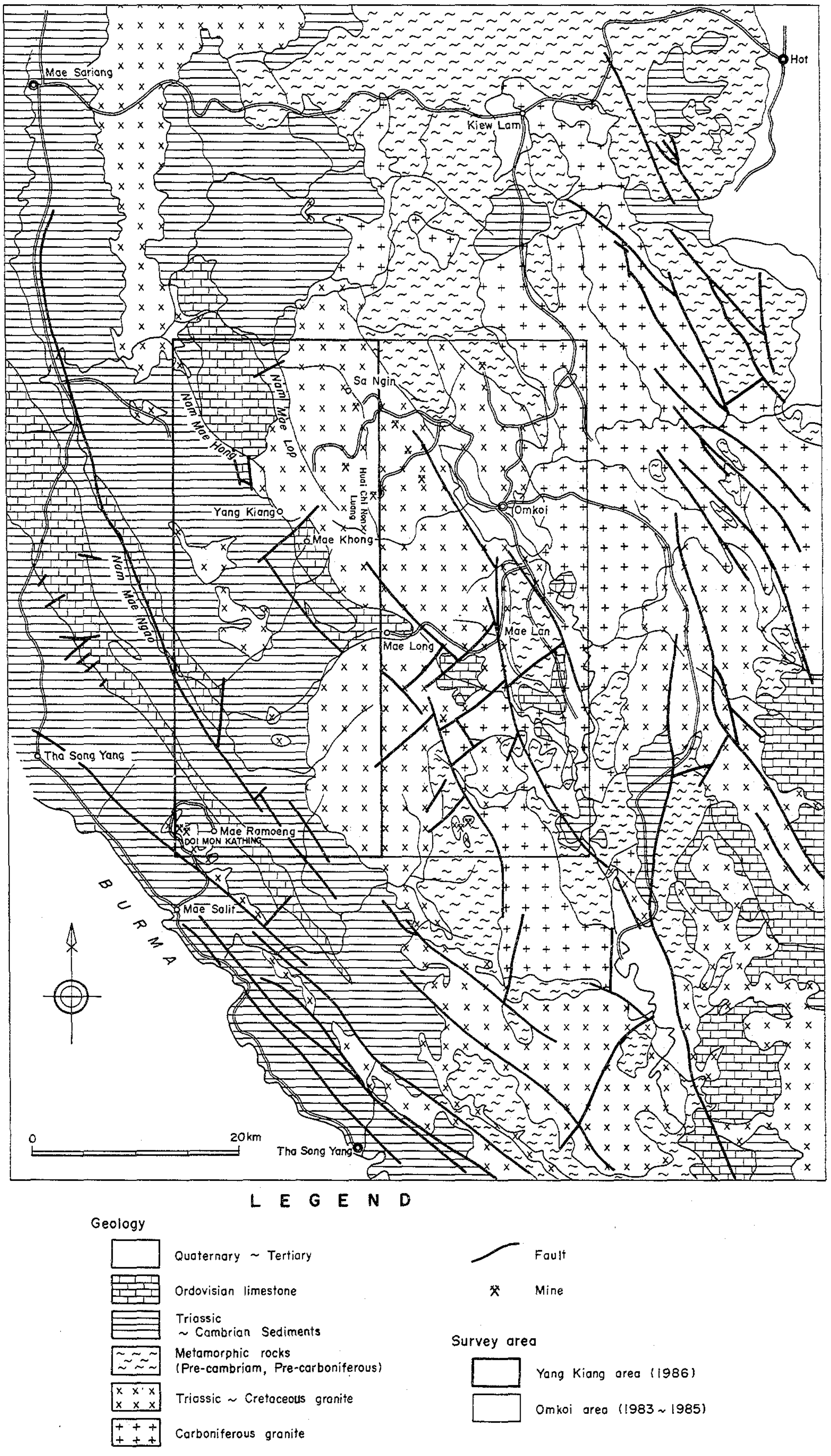

Fig. 2 Regional geological map

survey area that it is difficult to classify these formations strictly.

The geologic map and schematic geological column of this area are shown as Fig. 3 and Fig. 4 respectively.

Sedimentary rocks in this area can be classified as shown in Fig. 3 and 4. They divide into the northeast region and southwest region by a NW-SE fault through Nam Mae Ngao in southwestern area. Each two region have different facies of sedimentary rocks. In the northeast region Ordovician limestone formation are mainly formed of limestone and interlaid with chert and shale, in the southwest region limestone, calcareous shale, and shale alternate in about same quantities. Besides the succession that overlies this limestone formation is also different in two region. In the northeast region Silurian to Carboniferous rocks rest on almost conformable, and the Permian and Triassic sediments unconformably sit on them. On the other hand, in the southwest region Siluro-Devonian rocks are lacking, and the Carbono-Permian rocks unconformably lie on this limestone formation.

Only the lowest formation, the Cambro – Ordvician rocks, have almost same facies.

These differences between the sedimentary rocks of two regions indicate originally the difference of sedimentary environment. Actually according to the division of tectonic provinces of northern Thailand by JICA (1984), they belong to different tectonic provinces. The northeast region belongs to the Main Western Range Tectonic Province, and the southwest region to the West Tectonic Province.

The detail of each formation is as follows;

(1) Pre-Carboniferous Metamorphic Rock

Paragneiss distributes as handreds meters of xenolith in a granite body around Nong Ung at the northeastern most of this area.

It is composed mainly of quartz, potassium feldspar, plagioclase and biotite, and it has gneissic texture owing to the preferred orientation of biotite.

Also in granitic rocks around this rock comparative distinct gneissic textute is recognized. The structure of the paragneiss and the granitic rocks is concordant in the direction of N 60° W/ 50° N. So owing to the close resemblance between the coarse-grained parts of the paragneiss and the granitic rocks, some part of these boundaries are indistinct.

The relation with the Paleozoic sedimentary rocks remains unknown, because this rock occurs as xenolith in a granite body.

(2) The Cambro – Ordovician Formation

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

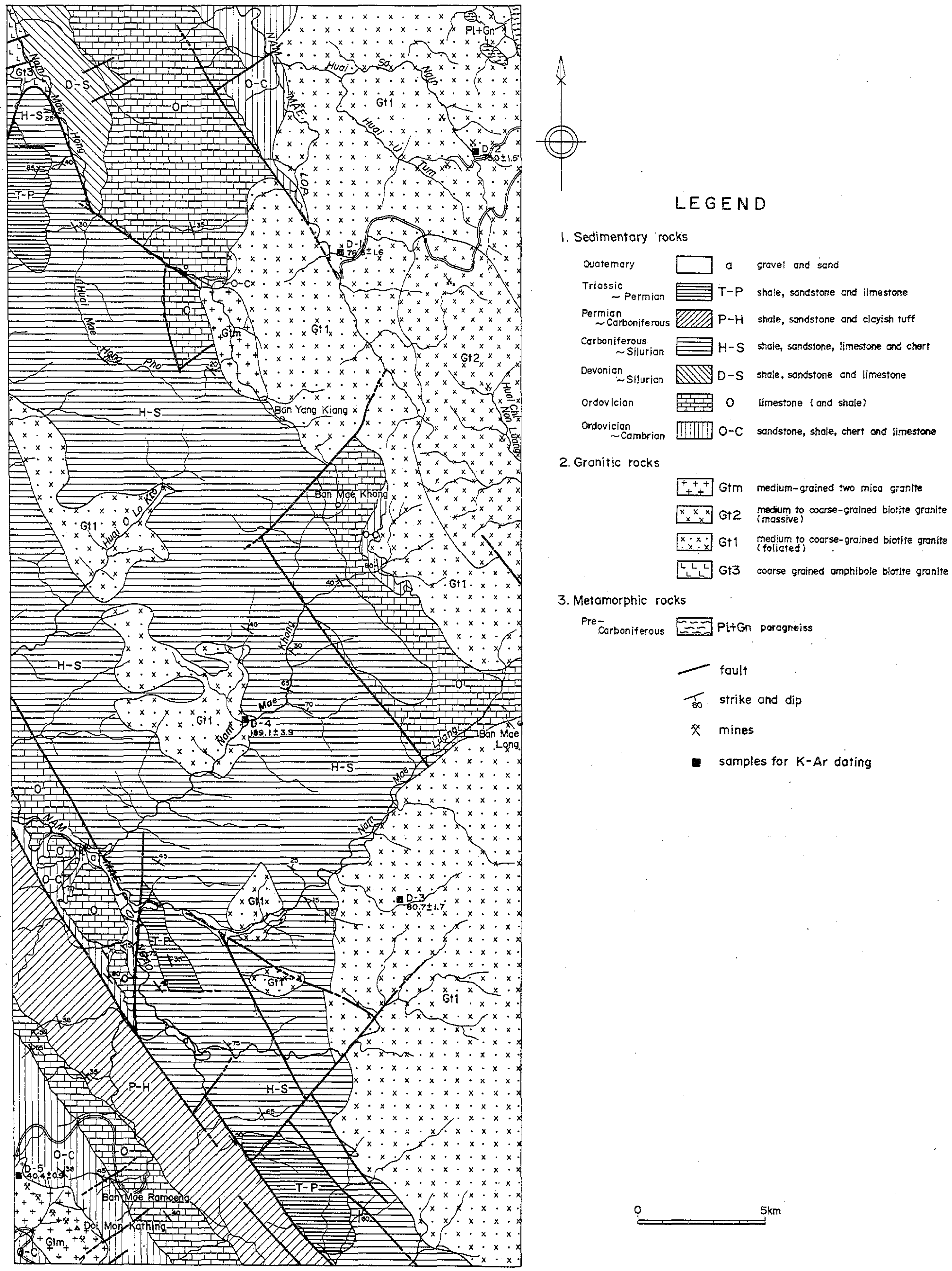

Fig. 3 Geologic map of the Yang Kiang area

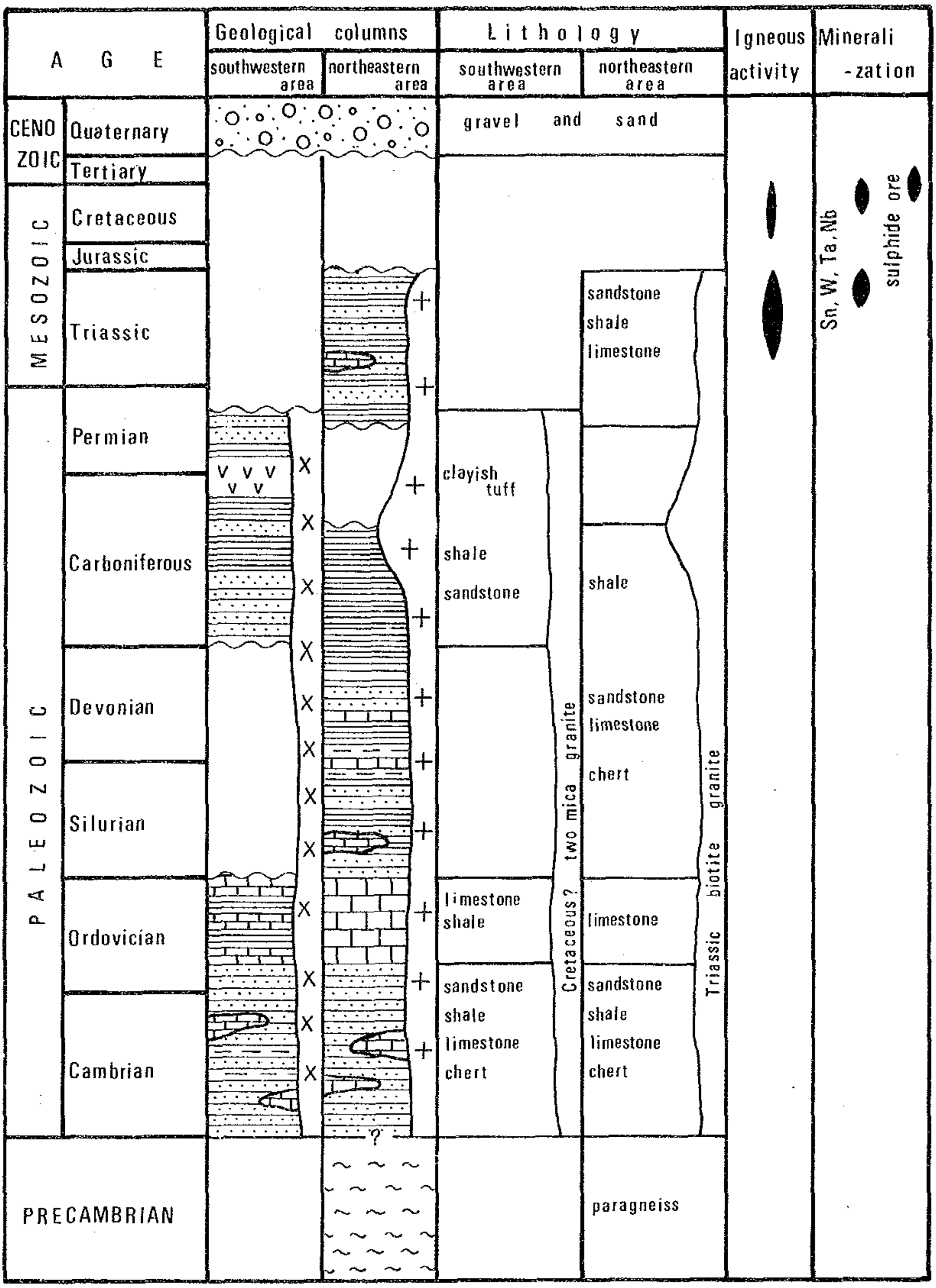

Fig. 4 Schematic geological column

This formation is composed mainly of the alternation of fine to medium-grained sandstone and shale and the alternation of fine-grained sandstone and chert. They are partly interlayered with thin layers of calcareous shale and limestone. No fossil has been recognized.

Near the Nam Mae Lop and Mae Khong, these rocks were intruded by granite in east side. These rocks underwent contact metamorphism at the part of contact with granite in the width of several to 20 meters, and here they strike NS to NW-SE and dip 30 to 65°W.

The Ordvician limestone formation overlies in parallel with this Cambro – Ordvician formation on the west side, therefore the relationship of these formation is considered to be conformable.

On the west bank of the Nam Mae Ngao this formation strike NS to N40°W and dip 70°E or partly vertical. In contrast with this, the Ordvician limestone formation dips gently east. Therefore the relationship between the two is infered to be unconformable.

Around the Doi Mon Kathing both of formation strike N35 to 40°W and dip 38 to 55°E. Therefore the relationship is conformable. A granite was intruded in concordant with this structure in the center of this region. The Cambro – Ordvician rocks around this granite underwent strongly a contact metamorphism. Especially they metamorphosed to schistose hornfels at the part of contact with granite.

(3) Ordovician Limestone Formation

This formation is extensively distributed in an area between the Nam Mae Lop and the Nam Mae Hong, and there is the development of Karsts at mountains. In addition this formation is distributed in an east area between Mae Khong and Mae Long, near the middle reaches of the Nam Mae Ngao, and in the vicinities of Mae Ramoeng in the southwest part. This formation, except for near Mae Ramoeng, is white to gray, fine-grained and interlaid with thin layers of shale and chert. On the other hand, near Mae Ramoeng this is composed of the alternation of limestone, calcareous shale and shale.

Conodonts of the lower to upper Ordovician has been reported (Hahn et al. 1982), except for the east area.

These formation distributed in the north and east area have undergone thermal metamorphism by granite and have been recrystallized into coarse grains, and there are some parts which have been partially silicified, but no skarnized parts are recognized except for small quantities of boulders of calcsilicate rock, which are a few meters in size and yellowish green, in an area to the north of Yang Kiang.

They strike NW-SE in the whole area. The north area dips west. The southwest area dips east. The east area shows a syncline, which plunges southwest at a low angle.

Most of this formation is considered to be conformable with the Cambro-Ordvician formation, but there is a possibility of unconformity in some part.

(4) Siluro-Devonian Formation

These rocks, distributed over the Ordorician limestone formation, are distributed on the east bank of Nam Mae Hong in the north area. These rocks are mainly shale and sandstone, accompanied by lenticular limestone. They are considered to be conformable with the Ordvician limestone, but the relationship with other formation is unknown because their relations are cut by faults.

(5) The Siluro-Carboniferous Formation

This formation are widely distributed in the middle of this area. This is dominated by black shale, with lenticular chert, lenticular limestone, chert, interlayered with small limestone, red shale and sandstone, and others.

Because this black shale is massive in the most part and a key bed could not be found, the structure and stratigraphy of this formation has not been made so clear.

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, chert and thin alternate layers of limestone has developed under the massive shale. Red shale is distributed in places at the northwest of Yang Kiang and in the junction of Nam Mae Ngao and Huai Mae Khong. On the whole, in the lower part of this formation, the alternation of limestone, chert, sandstone and shale develop, and shale becomes dominant toward the upper.

Though those rocks are folded in some anticlines and synclines, as a whole they are broadly folded in one syncline that trends NW-SE.

These rocks were intruded by a batholith of granite in the east of this area, and intruded by four stock of granite in its middle. This Siluro-Carboniferous rocks metamorphosed to biotite hornfels or biotite – muscovite hornfels at the boundary of granite in the range of several to tens meters, but no skarnization is recognized in these rocks.

Skarnization was expected to be found in the cupola of granite and their vicinities, but no skarnization and mineralization was recognized. Only small quantities of quartz veins, several millimeters in width, are found in granite.

(6) The Carbono-Permian Formation

This formation is distributed in a belt shape in the direction of NW-SE in the southwest of this area. They are mainly composed of shale and sandstone, accompanied by clayish tuff.

They strike NW-SE and dip 35 to 40°E. This formation unconformably covers the Ordvician formation. This formation on the east side is in fault contact with the Combro-Silurian rocks.

Middle of the upper Carboniferous conodonts have been reported in the neighborhood of Kre Kro.

(7) The Permo-Triassic Formation

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

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

(8) Alluvium

Alluvial is composed of sand and gravel bed which filled up the valleys of main rivers.

3–3 Igneous Activity

The activities of granitic rocks in northern Thailand took place in three times in the Carboniferous, the Triassic, and the Cretaceous to the Tertiary (GGM, 1972).

In this area there are two batholith of granitic mass in its east and six granitic stock mass from the middle to the southwest. All of them have been attributed to igneous activity in the Triassic in the past.

They are classified into 5 masses from their distribution and facies; the northeast mass, southeast mass, northwest mass, center mass, and Mon Kathing mass.

Their details are described as follows:

(1) Northeast Mass

The northeast mass is separated from the southeast mass by Ordvician limestone near Mae Long. Both the northeast mass and southwest mass are an extension of the Triassic granite in the Omkoi area which have been reported by JICA & MMAJ (1986).

This mass is mainly composed of medium to coarse-grained potassium feldspar porphyritic biotite granite with granitic and gneissose texture and medium-grained muscovite-biotite granite. They are accompanied by pegmatite and aplite.

The medium to coarse-grained potassium feldspar porphyritic biotite granite dominates in the northeast mass. It contains characteristically megaphenocrysts of potassium feldspar with the means size of 2 to 4 cm (max. 2x6 cm). It is classified into granite in a narrow classification. Its massive parts are distributed in the middle of the northeast mass from U Tum Nua to Yong Lae, while its gneissose parts develop near the mantle of the mass, surrounding the massive parts.

massive parts.

The gneissose texture is recognized as comparatively weak preferred orientation of biotite, as a whole of the mass. However, from the vicinities of U Tum Tai and Sa Ngin to Nong Ung at the northeast end of the area, flow texture due to potassium feldspar phenocrysts and preferred orientated biotite are evident and strongly expressed around xenoliths of Pre-carboniferous metamorphic rock. Because the massive parts and gneissose parts are in a transitional relation with each other, the gneissose parts indicate marginal facies of a batholith.

This granite is composed of quartz, potassium feldspar, plagioclase, and biotite, with accessory zircon, apatite, and opaque minerals. Plagioclase crystals have been almost replaced with minute muscovite particles, and secondary muscovite has been found between quartz and potassium feldspar grains. The biotite has been replaced with chlorite, epidote and muscovite along the edge and cleavage. The opaque minerals, which are contained in extremely small quantities, are magnetite and ilmenite; the former has altered into hematite, and the latter into leucoxene. Since 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 end of the northeast mass. Additionally this granite is also scattered in biotite granite. It is mainly composed of quartz, potassium feldspar, plagioclase, muscovite and biotite. Primary large-size muscovite is contained in the same quantity as biotite or more. The alteration of plagioclase due to fine-grained muscovite is also recognized, but this alteration is not stronger than the alteration of the biotite granite.

The pegmatite and aplite veins are several centimeters to several meters in width. They trend NW-SE, WNW-ESE, N-S, and NE-SW. They are found at places in the northeast mass. Especially the northeast mass contains 10 to 20% of them on the east side of Nam Mae Lop. Many boulders of pegmatite quartz are found at the ridge near Sa Ngin. They are mainly composed of quartz, potassium feldspar, plagioclase and muscovite. Though the pegmatites near a eluvial cassiterite deposite in Sa Ngin are also mainly composed of quartz, potassium feldspar, plagioclase and muscovite, characteristically they contain a large amount of tourmaline, garnet and zircon.

(2) Southeast Mass

The southeast mass is a batholith and mainly composed of medium to coarse-grained potassium feldspar porphyritic biotite granite. There is a small mass of medium-grained muscovite - biotite granite, whose distribution is too small to be represented on the map.

This biotite granite contains megaphenocrysts of potassium feldspar. Over the whole area gneissose texture through weak preferred orientation due to biotite is recognized. The constituents are quartz, potassium feldspar, plagioclase and biotite, with accessory apatite, zircon and opaque minerals. This is the same as the northeast mass. This mass have the almost same alteration as northeast mass, but contains actinolite and other minerals. These minerals indicate the possibility that this mass underwent a contact metamorphism.

This rock contains very small quantities of magnetite, hematite and ilmenite, therefore it belongs to the magnetite-series.

The medium-grained muscovite-biotite granite are composed of quartz, potassium feldspar, plagioclase, biotite and muscovite, as accessories apatite, zircon, tourmaline and hematite. The relationship between this mass and the biotite granite is unknown. A small amount of primary large muscovite are found. Some plagioclase have been replaced with the secondary muscovite. The characteristics of the mineral composition suggest that this granite belongs to the ilmenite-series proposed by Ishihara (1981).

Veins of pegmatite and aplite are sporadically in the southeast mass. And most veins are several centimeters in width. They are not accompanied by mineralization and alteration.

(3) Northwest Mass

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

This mass are mainly composed of patassium feldspar porphyritic granite, therefore it resembles the granite of the other mass. But this granite characteristically contains amphibole.

This is mainly composed of quartz, potassium feldspar, plagioclase, biotite and amphibole, with accessory apatite, zircon, sphene, magnetite, pyrite and hematite. The plagioclase has altered into muscovite, the biotite into chlorite and epidote, and most of amphibole have been entirely replaced with calcite, chlorite or others. It belongs to the magnetite-series proposed by Ishihara (1981).

(4) Center Mass

This mass distributes as four stocks. They are Huai O Lo Kro, the north bank of Huai Mae Khong, near Mae Luang and Sae Khi in the middle of the this survey area.

All of them are composed of medium to coarse-grained potassium feldspar porphyritic biotite granite, and their facies hardly change even at its contacts with shale.

They are composed of quartz, potassium feldspar, plagioclase and biotite, as accessories pyrite.

They alter only little on the whole. Plagioclase is hardly altered and the biotite chloritized its marginal parts slightly.

These mass also belongs to the magnetite-series.

(5) Mon Kathing Mass

Mon Kathing mass is the country rock of the Doi Mon Kathing ore deposits in the southwest of this survey area. This mass is mainly composed of fine to medium-grained muscovite and biotite granite, which does not have porphyritic texture of potassium feldspar.

The quantity of muscovite varies from about the same quantity as biotite to muscovite only. The constituents are quartz, potassium feldspar, plagioclase, muscovite and biotite, with accessory apatite and zircon and ilmenite. Therefore this granite belongs to ilmenite-series.

In the surroundings of Doi Mon Kathing ore deposits group, there are innumerable quartz and pegmatite veins. They are accompanied by the mineralization of cassiterite, wolframite, sulphide ore and others. The details of ore deposits are described in Chapter 3-5.

3–4 Geological Structure

(1) Folds

Northern Thailand including the survey area has the complex structural history of four tectonic movements: at the end of the Pre-cambrian, the Carboniferous, the Triassic to the Jurassic, and the Cretaceous to the Neogene.

Generally outcrops are rare in this survey area. In addition, massive shale is dominant. It is difficult to find the structure of massive shale. Therefore the geological structure has not been altogether clarified, but generally the structure of this area trends NW-SE.

The distribution of the sedimentary rocks is divided into the northeast region and the southwest region by the difference of sedimentary environment.

The Cambrian to Triassic rocks distribute in the northeast region. This region as a whole shows one syncline.

The Cambro-Ordvician formation trends NW-SE, dips SE at northeast end and dips NW at southwest end. The east mass of Ordvician limestone formation and the Siluro-Carboniferous shale are also folded into northwest-trending syncline, which plunges north at a low angle. The middle mass of the Siluro-Carboniferous rocks are seemed to be fold into a syncline, with repeating small cyclic folds. This structure is indicated by the lower part of this formation which contains much of limestone and chert.

The southwest region is distributed with the Cambrian to the Permian sedimentary rocks. They strike NW-SE and dip NE and shows monocline.

(2) Faults

In the survey area NW-SE and NE-SW faults are prevalent, in addition there are ones in the direction of N-S. Though generally the principal structural direction of northern Thailand including this survey area is N-S, in this area sedimentary rocks trend NW-SE. Therefore the principal structural direction is considered to be NW-SE, and secondary ones are NE-SW and N-S.

The largest fault is a NW-SE one through the west bank of Nam Mae Ngao. This fault makes the division into the West Tectonic Province and the Main Western Range Tectonic Province in Northern Thailand (JICA, 1984).

3–5 Ore Deposits

Tin and tungsten ore deposits in northern Thailand are reported to be closely related to the Mesozoic granite (GGM, 1972). Primary deposits are massive ore deposits resulting from greizenization and skarnization of the cupolas and margins of granite bodies and vein-type ones accompaying quartz veins and pegmatite veins, and secondary ore deposits derive from these primary deposits.

Both primary and secondary tin and tungsten ore deposits are distributed in the survey area at places. They are found in the regions where the northeast batholith mass and the granitic stock mass at the southwestern most. The deposits in the northeast are eluvial ore deposits in gravel and sand bed which develop along Huai Chi Non Luang and Huai Sa Ngin. The deposits in the southwest are vein-type ones occurring in a granitic stock mass around Doi Mon Kothing and eluvial ore deposits derive from them (Fig. 5).

(1) Ore deposits in the northeast area

Potassium feldspar porphyritic biotite granite is broadly distributed around this ore deposits. Pegmatite, aplite and quartz veins develop, and small mass of medium-grained muscovite-biotite granite scatters in this granite.

Secondary ore deposits are distributed from Huai Chi Non Luang to Huai Sa Ngin, and small old workings are at places. The ore is composed of cassiterite and some scheelite.

(i) Huai Chi Non Luang Area

This area is east extremity of the survey area. Here is surrounded by gently-sloping hills, 1,100 to 1,200 m above sea level. A car road leads from Omkoi to this area. 1 to 2 meters in thickness of tin and tungsten-bearing gravel and sand bed develops along Huai Chin Non Luang and arborescent tributary valley. This bed was exploited by local people for two years about 1980. That the maximum monthly production of concentrates amounted to

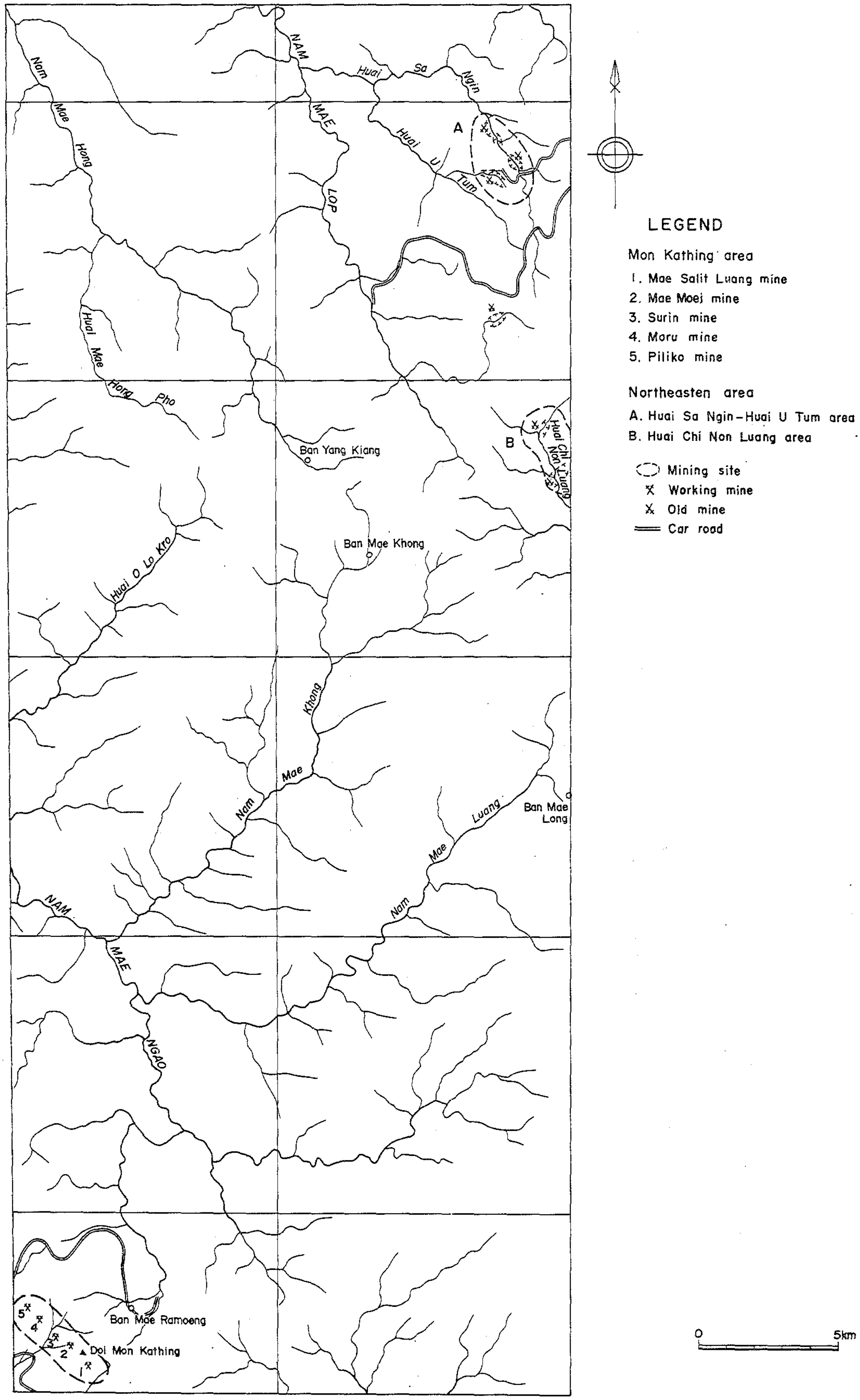

Fig. 5 Distribution of mines

two tons with about 40 workers. This ore was mainly composed of cassiterite. Scheelite-bearing quartz veins were found in some parts, but such veins have not been discovered in this survey.

In panning concentration, in addition to cassiterite, scheelite is detected under ultra-violet rays. As a result of chemical analysis the following contents were found; Sn 9.79 to 27.5%, W 0.02 to 0.19%, Ta 0.30 to 0.39%, and Nb 0.17 to 0.21% (Table 2).

(ii) Huai Sa Ngin to Huai U Tum Area

This area, located in the northeast of the survey area, has gravel and sand bed which develops along the upper reaches of Huai Sa Ngin and Huai U Tum where are the tributaries of Nam Mae Lop.

These two valleys run on the east and west sides of a NW-SE directed ridge, 1,300 to 1,400 m above sea level. Up to this ridge the car road was lead from Omkoi.

The old workings in this area have the records for approximately one year about 1980, producing about two tons of concentrates a month with 10 to 20 workers. The ore consists mainly of cassiterite and contained a small quantity of scheelite. It is said that tin and tungsten-bearing quartz veins were seen.

In panning concentration, in addition to cassiterite a large quantity of scheelite is recognized under ultraviolet rays. As a result of chemical analysis the following contents were found; Sn 1.92 to 17.2%, W 0.08 to 5.31%, Ta 0.17 to 0.57%, and Nb 0.02 to 0.35% (Table 2).

(2) Ore deposits in Doi Mon Kathing area in the southwest

(i) Location and Accessibility

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

These mines are disposed on a line in NW-SE as shown in Fig. 6. Among them Mae Moei Mine is the largest and Mae Salit Luang Mine follows. All the mines are distributed only in the vicinities of mountain tops with an elevation of 900 to 1,000 m. The mountain tops are gentle, but the mountain-sides are steep.

On the skirts of the mountains, Route No. 1267 runs from Mae Salit Luang, 500 m above sea level, to the south foot of Doi Mon Kathing and reaches around its west foot and to Mae Ramoeng, 600 m above sea level, on its northeast side of Doi Mon Kathing. This road goes south from Mae Salit Luang and joins Route No. 1085 at the 15km south of Mae

Salit Luang.

There are mountain paths branching from the above-mentioned car road and reaches the mines of Mae Salit Luang, Mae Moei and Moru along Huai Mae Salit Noi Ke Kro and Huai Kho Phu Do. It takes 1.5 to 2 hours on foot to reach these mines.

Half an hour walk is needed to arrive at the working of Piliko Mine from the motorable road at the northwest foot.

(ii) Geology and ore deposits

This area consists of sedimentary rocks of the Cambrian and of granite stock intruded into them. The Cambrian rocks are formed of shale, sandstone and chert, which have metamorphosed into schistose hornfels in the vicinities of the ore deposits. The granite is muscovite-biotite granite, in which some tourmaline is recognized near the mines.

There are three type of the ore deposits; the tin and tungsten-bearing quartz vein, tin and tungsten-disseminated granite, and eluvial ore deposit.

Workings are mainly the types of quartz veins and eluvial ore deposit.

(a) Tin and tungsten-bearing quartz veins

Although quartz veins are seen at places, the distribution of mineralization veins is limited to the elevation of about 1,000 m on a ridge extending from Doi Mon Kathing in the direction of NW. The veins strike NW-SE and dip 75 to 90°W. Their width ranges from several to 80 cm. These veins scatter within a length of 4 km on the mines of Mae Salit Luang, Mae Moei, Moru and Piliko. In each mine seven or eight parallel veins occur at intervals of five to twenty meters. Their length is presumed to be 30 to 100 m.

The ore minerals are mainly wolframite, accompanied by cassiterite, and additionally pyrite, chalcopyrite and arsenopyrite are recognized. The chemical analysis values of the cassiterite-quartz veins of Piliko Mine and of the cassiterite and wolframite-quartz veins of Mae Salit Luang Mine are Sn 73.4%, W 0.03% and Sn 0.011%, W 29.6% respectively. Ta or Nb isn't contained.

(b) Tin and tungsten-disseminated granite

Some granite around mineralization veins is disseminated with such sulphide minerals as arsenopyrite, pyrrhotite, pyrite and chalcopyrite, which are notably concentrated partially. Tin and tungsten minerals are hardly recognized, but they are recovered through the panning of weathered granite.

(c) Eluvial Ore Deposit

Comparatively gentle basin-like low lands extend near of the east foot and north

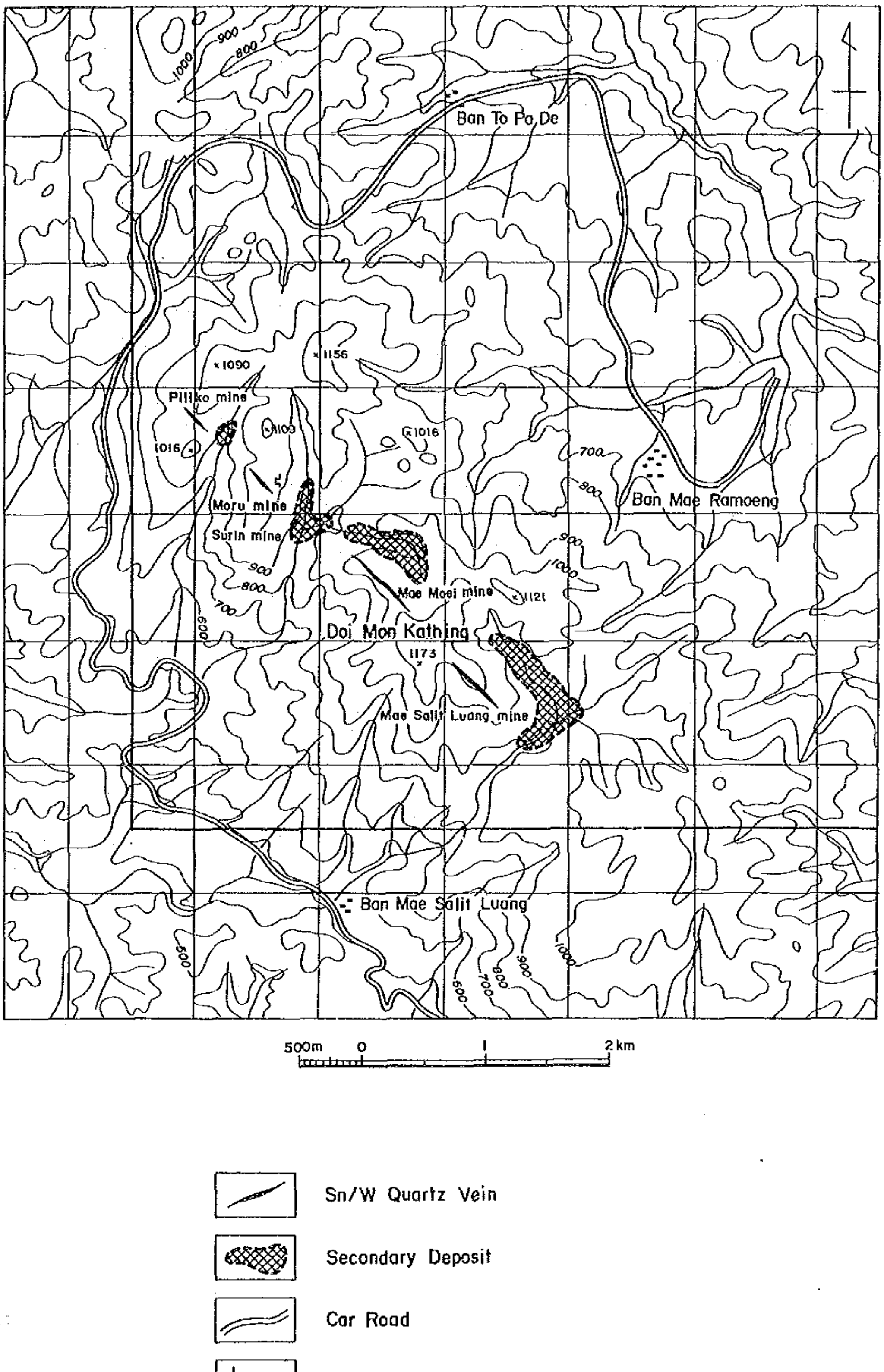

Fig. 6 Map of ore deposits in Mon Kathing area

foot of Doi Mon Kathing there develop gravel and sand bed with thickness of 1 to 5 m. These bed contain such heavy minerals as cassiterite and wolframite.

(iii) Brief description of mines

The workings of this area was mainly started after World War II. Many mines were developed around Mae Moei Mine and Mae Salit Luang Mine, at present five mines are in operation.

The working method of vein-type deposits are manually dug and partly machine excavation along the vein from the outcrop. The concentrate ore is produced by the process of crushing and panning.

Weathered parts and eluvial ore deposits are broken by washing with pressured water. By running the raw ore through a sluicing trough the concentrate is recovered.

All the mines manage to continue meager operation, some of them suspending work, because of the low hovering prices of the minerals. The mines are briefly described as follows.

(a) Mae Moei Mine

This mine exploits vein-type deposits distributed over a ridge on the north side of Doi Mon Kathing and eluvial deposit distributed to their north. In the vein-type deposits almost all their shallow parts have been exhausted, and now the portions *under such parts are being mined by sinking shafts, about 2 m in diameter, to a depth* of 5 to 10 m. By setting up props at the heads of shafts, excavated ore and waste rock are put in a bucket and lifted to the surface with a rope. There are such shafts in an innumerable number along mineral veins at the intervals of more than 10 meters.

More than 1,000 employees worked here at the best time, but only a few workers are at present, producing four tons of concentrate ore a month.

At this situated about 1,000 m above sea level, there are the mine office, ore dressing plant, dozens of lodgings, stores, a temple, meeting place, farms, and a fish pond, forming quite one community.

(b) Mae Salit Luang Mine (Wijin Mine)

This mine exploits vein-type ore deposits and eluvial ore deposits. Vein-type ore deposits are distributed over a ridge extending on the southeast side of Doi Mon Kathing, and eluvial ore deposits are on a basin-like lowland spreading on the east side side of vein-type ore deposits. About 15 employees are working there. The mine operation is mainly the eluvial ore deposit, and one ton of concentrate ore is produced a month.

(c) Surin Mine

This mine is located west of Mae Moei Mine, exploiting a eluvial ore deposit lying along the upper reaches of Huai Mae Kho Phu Do.

Several families used to operate it, but the operation is now suspended.

(d) Moru Mine

This mine is the northwest extension of the vein of Mae Moei Mine. Since veins exposed on the ridge have been nearly exhausted, a tunnel was driven for about 50 m to aim at the lower part. But this tunnel has not reached a deposit yet, and the tunneling is now suspended.

The mining operation was started about five years ago. There are 20 workers and the mine produces 700 to 800 kg of concentrate ore a month.

(e) Piliko Mine

The veins of this mine are distributed on a ridge which lies about 800 m northwest of the veins of Moru Mine. Mining is going on along this quartz veins with 30 to 80 cm in width, and a strike of N-S and a length of 20 m. Several other quartz veins cross this vein obliquely, 10 to 40 cm in width and a strike of NW-SE.

The ore mineral is wolframite which scatter in the quartz veins as aggregation. The size of these ores ranges from several centimeters to more than ten centimeters. In addition to this, aresenopyrite, chalcopyrite and pyrite are disseminated in the quartz veins and granite.

The mining operation was mainly started from about one year ago. Now it produces 1.5 tons of concentrate ore a month, employing about 20 workers.

(iv) Result of analysis of ore

The values of the result of chemical analysis of the concentrated ore of Mae Moei Mine and Piliko Mine, the cassiterite of Piliko Mine, and the wolframite and cassiterite of Mae Salit Luang Mine are set forth in Table 2.

Characteristically the ore deposits of this area are mainly composed of wolframite, contains much sulphide, and Niobium and Tantalum do not accompany. These characteristics are not same as the eluvial deposits in the northeast area.

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

3–6 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 Chapell & White (1974) and White & Chapell (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 ozidation condition or a reduction condtition. Accodingly, 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-tupe 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 are were put to chemical analysis for main components in order to study their geochemical properties. Results of analysis are show in Table 3.

(1) Chemical composition 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 granitc masses.

In the variation diagrams correlation between the differentiation indexes and main components (Fig. 7), 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.

Table 3 Chemical Analysis of Granitec Rocks

Sample No. / Ingredient	D − 1	D − 2	D − 3	D − 4	D − 5	G − 1	G − 2	G − 3	G − 4	G − 6	G − 7	G − 8
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
mass	northeast	northeast	southeast	center	Mon Kathing	Mon Kathing	southeast	southeast	center	northwest	center	southeast

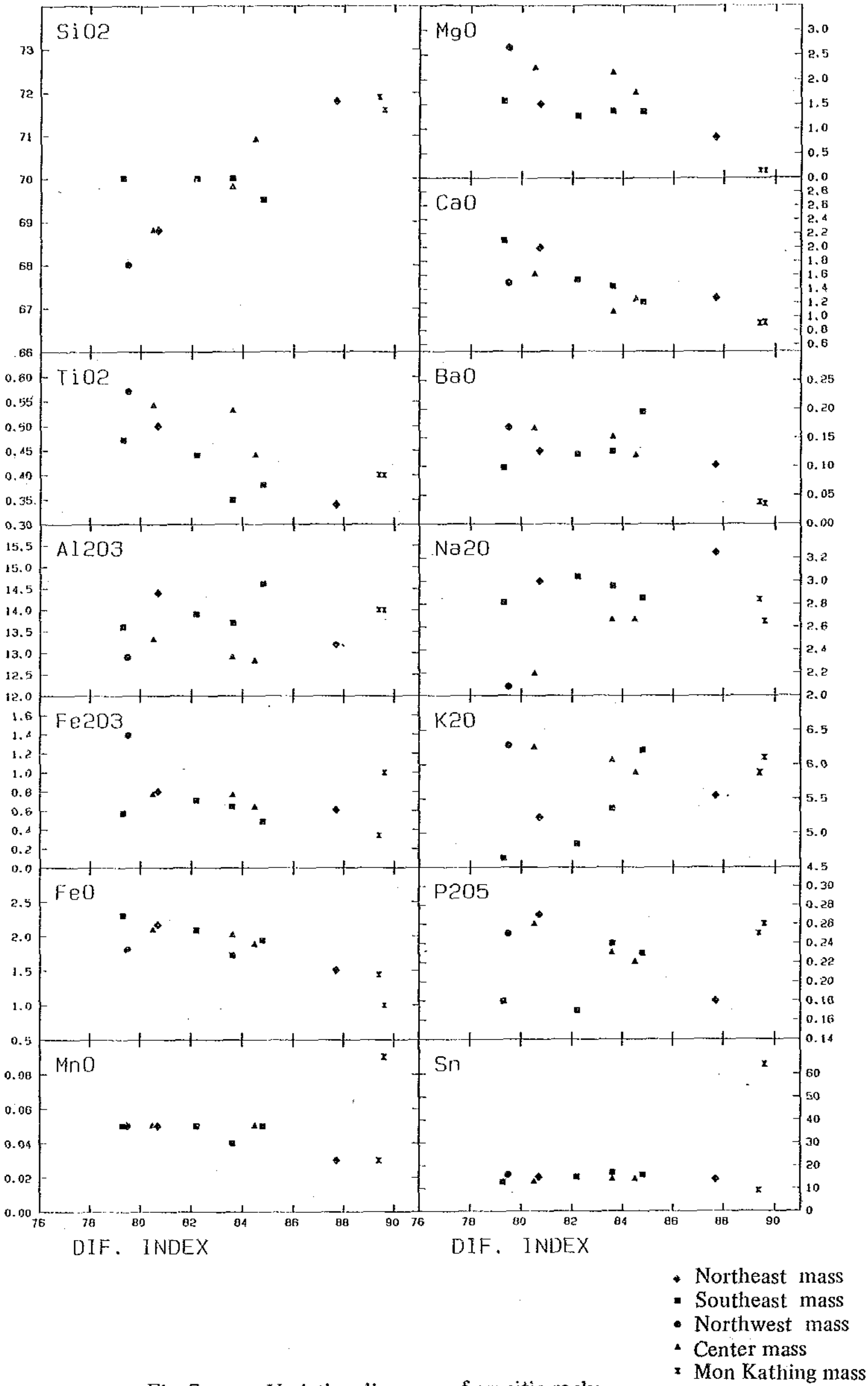

Fig. 7 Variation diagrams of granitic rocks

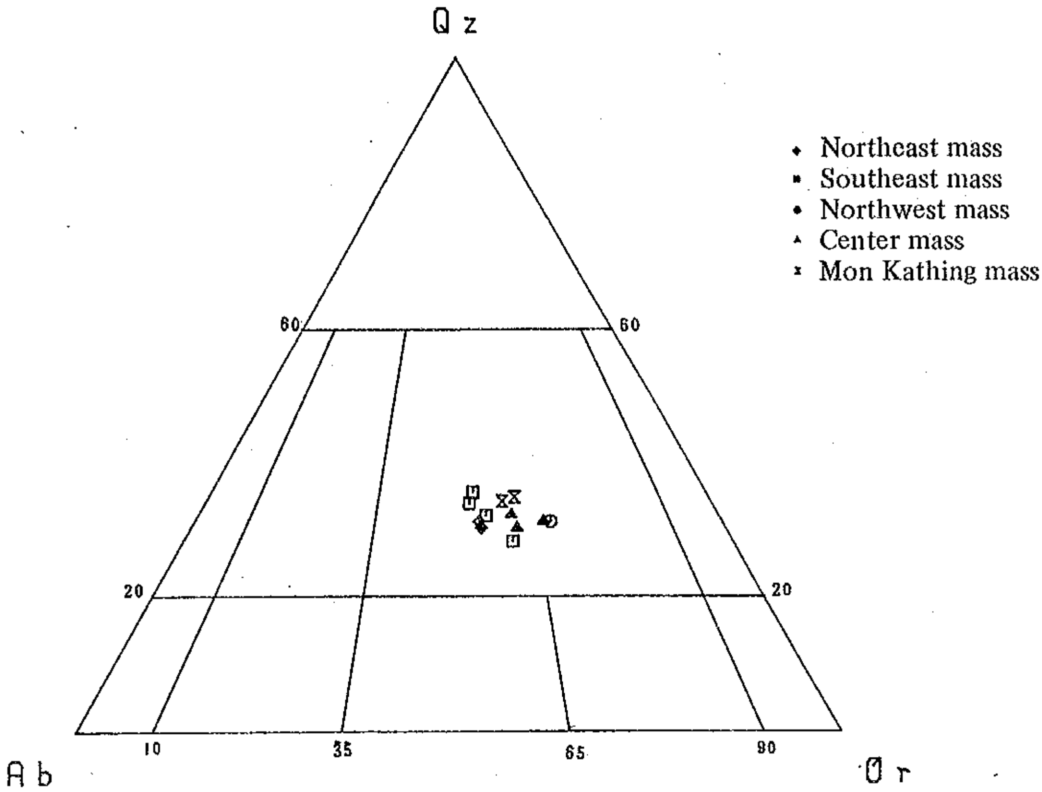

Fig. 8 Normative Q-Ab-Or diagram

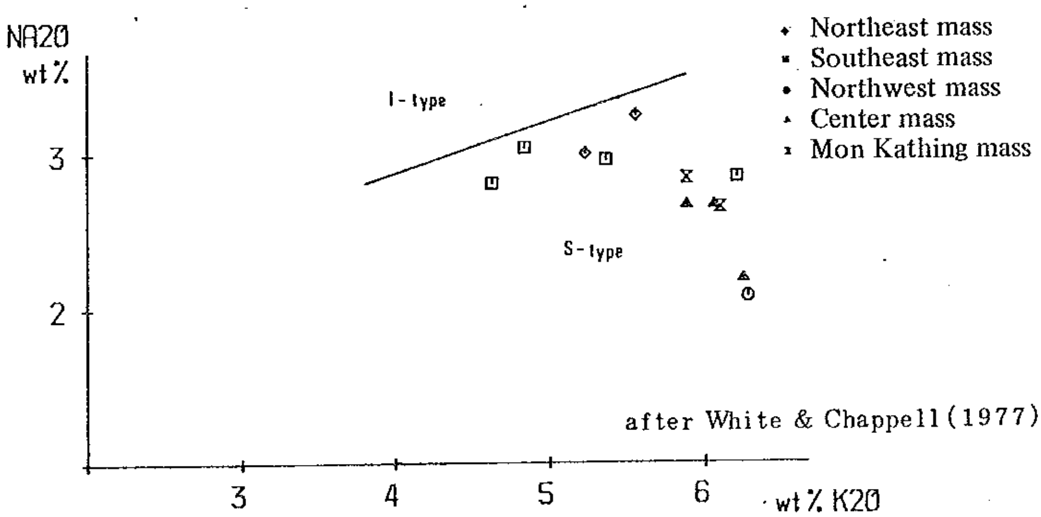

Fig. 9 Na_2O-K_2O diagram

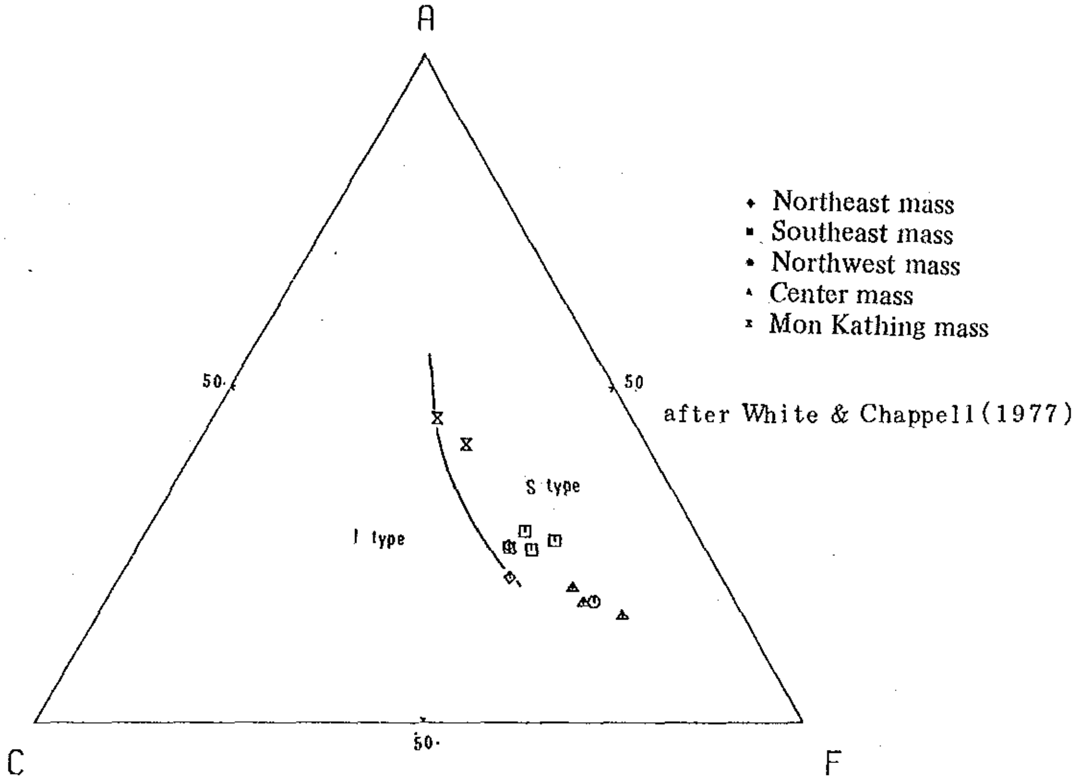

Fig. 10 ACF (Al_2O_3-Na_2O-K_2O/CaO/FeO+MgO) diagram

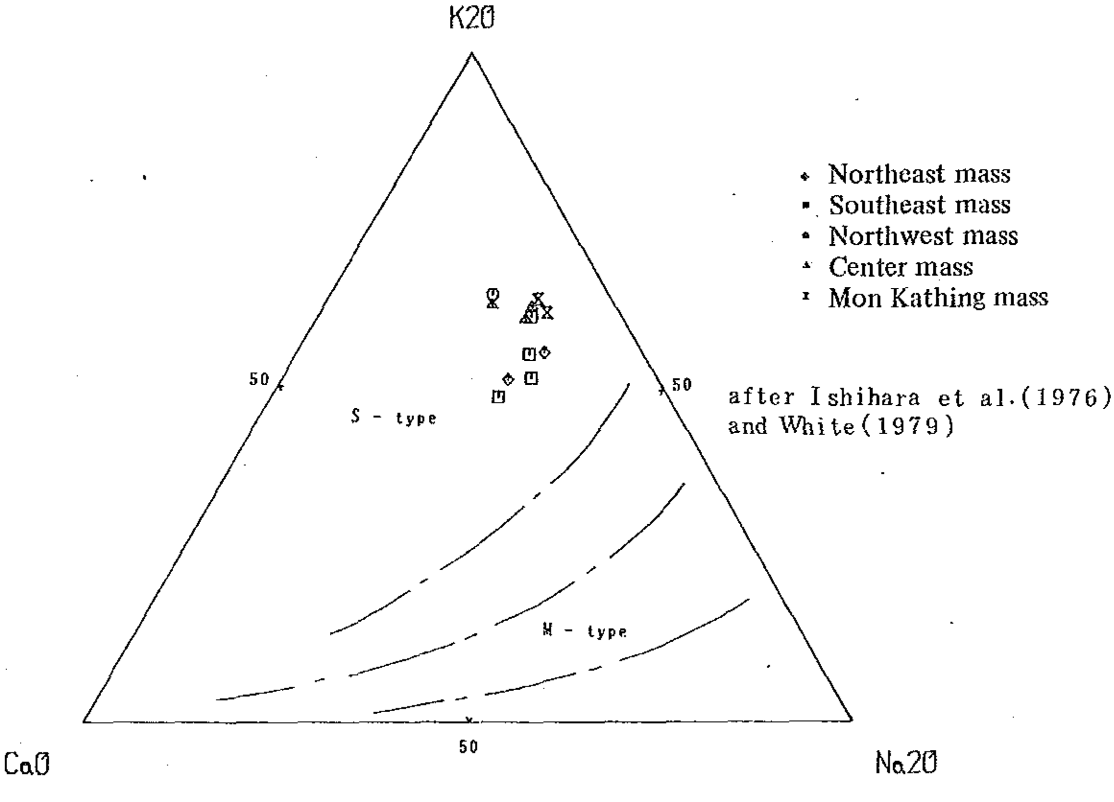

Fig. 11 CNK (CaO-Na_2O-K_2O) diagram

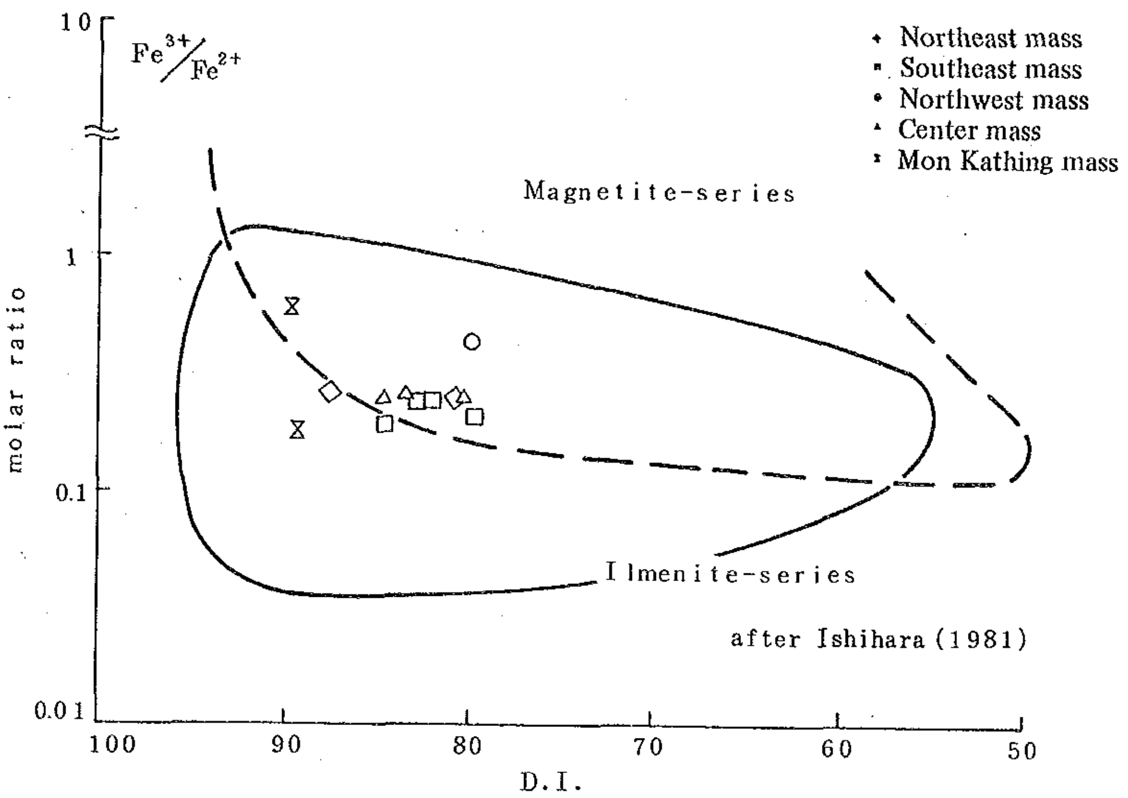

Fig. 12 Fe^{3+}/Fe^{2+}-Differentiation index diagram

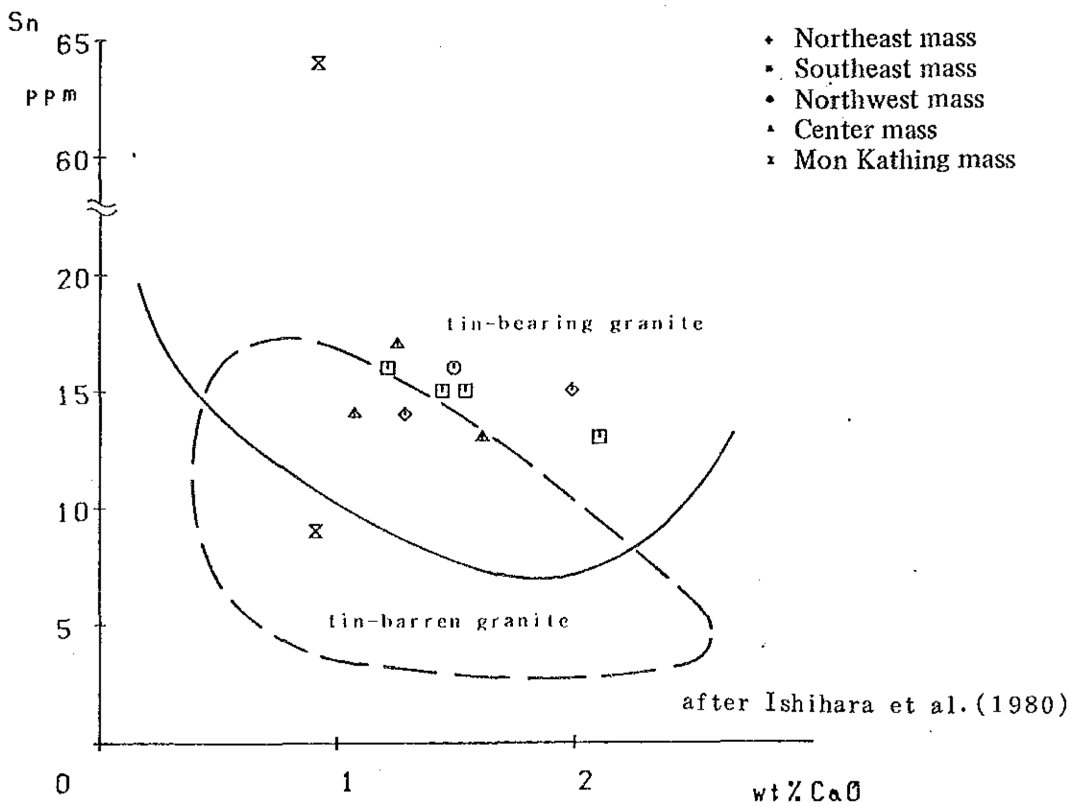

Fig. 13 CaO-Sn diagram

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 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. 8) 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 Chapell & 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 Non 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, $Al_2O_3-K_2O-$

In effecting the classification into the S-types and I-types by the main components of granite, the following indices 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. 9) 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. 10) 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 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.11).

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. 12. 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

Table 4 Classification of Granite Series

Item / Sample No.	Norm corundum	Na_2O/K_2O	$\frac{Al_2O_3}{(Na_2O+K_2O+CaO)}$	ACF	CNK	Fe_2O_3/FeO	Microscopic observation
D–1	I (0.83)	S (3.00-5.23)	I (1.01)	S	S	il (0.37)	mg
D–2	I (0.00)	S (3.25-5.55)	I (0.96)	S	S	il (0.40)	mg
D–3	I (0.58)	S (2.81-4.63)	I (1.01)	S	S	il (0.25)	mg
D–4	I (0.57)	S (2.66-6.06)	I (1.00)	S	S	il (0.38)	mg
D–5	S (1.99)	S (2.65-6.10)	S (1.11)	S	S	mg (1.00)	il
G–1	S (1.91)	S (2.84-5.88)	S (1.10)	S	S	il (0.24)	il
G–2	S (1.27)	S (3.04-4.84)	I (1.06)	S	S	il (0.34)	mg
G–3	I (0.99)	S (2.96-5.36)	I (1.03)	S	S	il (0.37)	mg
G–4	I (0.31)	S (2.66-5.88)	I (0.98)	S	S	il (0.34)	mg
G–6	I (0.57)	S (2.08-6.28)	I (1.00)	S	S	mg (0.77)	mg
G–7	I (0.63)	S (2.19-6.25)	I (1.00)	S	S	il (0.37)	mg
G–8	S (1.54)	S (2.85-6.21)	I (1.07)	S	S	il (0.25)	il

S–type; S, I–type; I, Magnetite series; mg, Ilmenite series; il 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 mass 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.

(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. 13, 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.

3–7 Dating of Granitic Rocks by K-Ar Method

The granitic rocks distributed in this survey are said to be Tirassic granite. The granitic rocks in the Omkoi area on the east of this area had been attributed to the Carboniferous and Triassic granite MMAJ & JICA (1986) stated that the derive from activites in the three times of the Carboniferous, Triassic and Cretaceous from the Rb-Sr method and K-Ar method.

The formation of tin and tungsten deposits in Thailand is closely related with Mesozoic to Cenozoic granite and those quartz veins or pegmatite veins. For the time of their mineralization, two periods, the Triassic and Cretaceous are considered, but with Mae Lama mass 20 km west of this survey area and the peninsular part of Thailand this mineralization occurred at the end of the Cretaceous. Accordingly, the dating of the granitic rocks is important in picking out promising areas.

On the radioactivity dating of granitic rocks of northern Thailand including the survey area there are the reports of Baum et al. (1970), Braun (1970), Teggin (1975), Braun et al. (1976), and Beckinsale et al. (1979). According to the Rb-Sr dating, the ages are broadly divided into the early Triassic to the early Jurassic (236 to 190 Ma) and the early Cretaceous (130 Ma). The results of the K-Ar dating are younger by about 10 to 20 Ma than those of the Rb-Sr dating, but the two coincide with each other in a broad way. However, a part of the results of the K-Ar dating presents a remarkably younger age than those of the Rb-Sr dating. This is accounted for the K-Ar age rejuvenation by a hydrothermal process taking place along a fault subsequent to granite intrusion or by activity; the opened K-Ar system granite with high temperature was upheaved and cooling by tectonic movement changes it into the closed K-Ar system granite. (Hutchison, 1983). Ishihara et al. (1980), as an instance of a similar tendency, pointed out that there was discordance between the results of the Rb-Sr dating and K-Ar dating of granitic rocks in a tin mine zone in the peninsular part of Thailand. He considers the following three causes: this disconcordance indicates one cycle from the initial stage of the intrusion and solidification of granite to the last pegmatite stage, the rejuvenation due to a hydrothermal process accompanying mineralization, or the rejuvenation due to faulting and shearing movement.

(1) Result of Measurement

In the present survey two granite samples from the northeast mass and one from each of the southeast mass, center mass, and Mon Kathing mass were taken. Biotite was separated and was put to measurement. About Mon Kathing mass muscovite was also subjected to measurement. The result is set forth in Table 5.

Mentioning the kinds of the measured granitic rocks, the four samples from the three masses excluding Mon Kathing mass are potassium feldspar porphyritic biotite granite, and the sample from Mon Kathing mass is medium-grained muscovite-biotite granite.

In the potassium feldspar porphyritic biotite granite, the feldspar has notably altered by muscovite, and biotite has conspicuously replaced by chlorite, epidote and muscovite. In the batholith granite of the northeast and the southeast recrystallization was recognized as seen in Sample D–2 and the production of actinolite as in Sample D–3, which indicate the high possibility of having undergone thermal metamorphism.

In the muscovite-biotite granite of Mon Kathing mass, feldspar has turned into muscovite, but the biotite has slightly altered into chlorite.

The result of measurement is set forth as follows:

The three samples from the northeast mass and the southeast mass: 73.0 ± 1.5 Ma, 76.8 ± 1.6 Ma, and 80.6 ± 1.7 Ma; the center mass: 189.1 ± 3.9 Ma; the biotite of Mon Kathing mass: 40.4 ± 0.9 Ma, and the muscovite of the same mass: 42.5 ± 0.9 Ma.

(2) Observation

From the potassium feldspar portphyritic biotite granite, the widely differing ages of 73 to 80 Ma and 189 Ma were obtained. Out of these the values of 73 to 80 Ma from Sample D–1 to 3 of the northeast mass and southeast mass are roughly the same as 70 Ma obtained from the same rock bodies in the Omkoi area by JICA & MMAJ (1986). The value of 189 Ma of Sample D–4 from the center mass generally agrees with 236 to 190 Ma according to the Rb-Sr method and K-Ar method of Triassic granite distributed around the survey area. The Triassic granite in the surroundings of the survey area and the potassium feldspar porphyritic boitite granite in the survey area have the same lithofacies and mineral composition. It suggests that these granites intruded at the early Triassic to the early Jurassic. The young ages of the northeast mass and southeast mass are presumed to be ascribable to the samples having been subjected to remarkable alteration and thermal metamorphism. Also, taking a regional viewpoint, the development of fault systems in the direction of N-S to NW-SE in the batholith-granite bodies lying from the Omkoi area to the east of the survey area suggests the possibility that igneous activity and a hydrothermal process resulting from the faulting movement caused rejuvention.

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

Table 5 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}, $^{40}K/K = 1.167 \times 10^{-4}$

method (Braun et al., 1976). This suggests that the tin and tungsten bearing quartz veins were formed in the age of 73 to 80 Ma.

Mon Kathing mass, being on the extension of the above-mentioned Mae Lama mass, has been subjected to similar tin and tungsten mineralization of Mae Lama mass. In addition, dissemination of sulphide minerals is found in Mon Kathing mass, and the muscovite and biotite granite being replaced by arsenopyrite are disseminated. These facts are presumed that in this mass, after the intrusion of the muscovite and biotite granite, tin and tungsten mineralization took place about the age of 70 Ma, followed by the mineralization of sulphide minerals which continued until 40 Ma (the Paleogene).

CHAPTER 4 GEOCHEMICAL PROSPECTING

4–1 Sampling

The sampling was carried out in parallel with the geological survey along selected main rivers and their tributaries. The sampling intervals were 300 to 400 m as a rule. Each stream sediment was taken at the middle of the current and screened with a 80 mesh sieve, and the –80 fraction in a quantity of about 100 g was taken. At the same time panning samples were collected at the rate of one sample out of four points.

The total number of the collected stream sediment samples is 2,027 and that of the panning samples is 539. The location map of samples is shown in PL. 3.

The collected samples were air-dried, and then divided into halves: one halves for use in Thailand and the other halves for analysis in Japan.

4–2 Methods of Chemical Analysis

Since such useful elements as copper, zinc and molybdenum, besides niobium, tantalum, tin and tungsten is expected to occurrence in this survey area, path finder elements were decided to the twelve elements of niobium, tantalum, tin, tungsten, copper, zinc, molybdenum, antimony, gold, silver, arsenic, and fluorine.

The methods of chemical analysis were used inductively coupled plasma emission spectrography for tin, molybdenum, tungsten, zinc, tantalum, niobium, and copper; the atomic absorption analysis method for silver, arsenic, and antimony; the activity for fluorine; the neutron activation analysis method for gold.

The detection limit values for these elements were 1 ppb for gold, 0.1 ppm for silver and antimony, and 1 ppm for the other elements. The results of the analysis are set forth in Appendix 4.

4–3 Data Analysis

Statistical analysis was made to select geochemical anomaly areas from analytic values obtained by the chemical analysis.

It is known that usually geochemical analytic values present the normal distribution type or logarithmic normal distribution type in their distribution. In particular the values of the content of minor elements are closed to logarithmic normal distribution when the accuracy of analysis is enough. Accordingly, the analysis research mentioned in the following used the common logarithm values of the analytic values.

Among the analytic values there are those below the minimum detection limit value and those above the maximum detection limit value. In statistic processing of such values, the half of the minimum detection limit value, and the 1.5 times of the maximum detection limit value was employed for the sake of convenience.

(1) Basic Statistic Values

The maximum values, minimum values, mean values, and standard deviation of the analytic values of the elements are set forth in Table 6.

The distribution of element concentration on the basis of these statistic values is shown in PL. 4 to 13.

Table 6 Basic statistic quantities of geochemical analytic values

Item / Element	Maximum value *	Minimum value *	Mean value		Standard deviation (Logarithmic value)
			Natural value	Logarithmic value	
Sn	110	<1	7.129	0.853	0.381
Mo	14	<1	0.733	0.153	0.277
W	5500	<1	7.464	0.873	0.454
Zn	630	1	44.259	1.646	0.410
Ta	220	<1	1.393	0.144	0.453
Nb	170	<1	13.032	1.115	0.207
Cu	630	<1	8.954	0.952	0.482
Ag	4.7	0.1	0.105	–0.980	0.111
As	>10000	1	10.416	1.018	0.553
F	1710	40	286.418	2.457	0.218
Sb	22.0	0.1	0.270	–0.569	0.523
Au	67.0	<1	0.585	–0.233	0.232

Note: * Unit: ppm, ppb only for Au

(2) Distribution of Frequency

Relative frequency histograms and cumulative frequency histograms for the analytic values of the elements are set forth as Appendix Fig. 5 ~ 16. These historgrams indicate that the elements of tungsten, niobium, zinc and fluorine present logarithmic normal distribution. The elements of zinc, tin and arsenic indicate slightly unsymmetrical normal distribution. However, many of the samples of molybdenum, tantalum, antimony, silver and gold present values below the detection limit values, so that their distribution is in a L form or a comb form instead of the logarithmic normal type.

(3) Anomaly Values

The classification between the background and anomaly value was divided by finding the threshold, taking into consideration the cumulative frequency histogram and the straight lines of the logarithmic normal distribution of each of the elements.

The throshold valuc of each element was decided by the method of Lapertier (1969).

The classification of levels of background and anomaly value was arranged on Table 7.

The process of determining the threshold values is described in the following:

Niobium

In the cumulative frequency histogram (Appendix 5), deviation from the straight line of the logarithmic normal distribution was seen near $M + 2\sigma$, the level of $M + 2\sigma$ was made the threshold value. A gap is found in the element concentration distribution near $M + 3\sigma$ so that partition between the low anomaly area and high anomaly area was set at the level of $M + 3\sigma$.

Since in the high anomaly area there is a skew point near $M + 4\sigma$, this area was divided in two, naming the portion below $M + 4\sigma$ high anomaly area-1 and the portion not less than $M + 4\sigma$ high anomaly area-2.

Tantalum

Since in the cumulative frequency histogram (Appendix 6) an upward skew point was seen near $M + 2\sigma$, the level of $M + 2\sigma$ was made the threshold value. Near $M + 3\sigma$ there is a gap in the element concentration distribution, so that the level of $M + 3\sigma$ was made the partition between the low anomaly area and high anomaly area. Also, since there is another upward skew point near $M + 4\sigma$, the high anomaly area was divided in two, naming the portion below $M + 4\sigma$ high anomaly area-1 and the portion not less than $M + 4\sigma$ high anomaly area-2.

Tin

In the cumulative frequency histogram (Appendix 7) there is an upward skew point near $M + 1.5\sigma$, so that the level of $M + 1.5\sigma$ was made the threshold value. Another upward skew point is found near $M + 2.5\sigma$, and this level was made the partition between the low anomaly area and the high anomaly area.

Tungsten

Since in the cumulative frequency histogram (Appendix 8) deviation from the straight line of the logarithmic normal distribution to the high concentration side was seen near $M + 2\sigma$, the level of $M + 2\sigma$ was made the threshold value. A gap in the element concentration distribution was seen near the level of $M + 3\sigma$, which was therefore made the partition between the low anomaly area and the high anomaly area. Since an upward skew point was found near $M + 4\sigma$ in the later, this was divided in two, and the part below $M + 4\sigma$ was made high anomaly area-1, while the part not less than $M + 4\sigma$ high anomaly area-2.

Copper

In the cumulative frequency histogram (Appendix 9) an upward skew point was found near M + 2σ, so this level was taken as the threshold value. Since another upward skew point was seen near the level of M + 3σ, this was made the partition between the low anomaly area and the high anomaly area.

Zinc

In the cumulative frequency histogram (Appendix 10) an upward skew point was seen near M + 1.5σ, so this level was made the threshold value. Another upward skew point was seen near the level of M + 2.5σ, this was made the partition between the low anomaly area and the high anoamly area.

Antimony

Since in the cumulative frequency histogram (Appendix 11) an upward skew point was seen near M + 3σ, this level was taken as the threshold value.

Molybdenum

In the cumulative frequency histogram (Appendix 12) an upward skew point was seen near M+ 3σ, so that this level was made the threshold value. Since another upward skew point was found near M + 4σ, this was made the partition between the low anomaly area and the high anomaly area.

Arsenic

Since in the cumulative frequency histogram (Appendix 13) an upward skew point was found near M + 2σ, this was taken as the threshold value. A gap in the element concentration distribution was seen near M + 2.5σ, so that this level was made the partition between the low anomaly area and the high anomaly area. Since in the later area another upward skew point was seen near M + 3.5σ, the same area was divided in two, the portion below M + 3.5σ being named high anomaly area-1 and the one not less than M + 3.5σ high anomaly area-2.

Gold

In the cumulative frequency histogram (Appendix 14) a gap in the element concentration distribution was seen near M + 5σ, so this level was made the threshold value.

Silver

In the cumulative frequency histogram (Appendix 15) a gap in the element concentration distribution was seen near M + 3σ, so this level was made the threshold value.

Fluorine

In the cumulative frequency histogram (Appendix 16) a weak upward skew point was seen near M + 2σ, so that this level was made the threshold value. Another upward skew point was found near M + 2.5σ, so this level was made the partition between the low anomaly area and the high anomaly area.

Table 7 Division into Anomaly Value Levels

Division / Element	Background area	Low anomaly area	High anomaly area 1	High anomaly area 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	–

Note: Unit: ppm,
ppb only for Au

(4) Principal Component Analysis

In the analysis of geochemical analytic values, it is necessary to select pathfinder elements related with respective mineral indications. Since there are 12 analysis elements in this survey, it is difficult to grasp the whole only with the coefficients of correlation between the respective two elements. Accordingly, this analytical study was made by using the principal component analysis, which summarize without decrease in the quantities of information held by the coefficients of correlation.

Correlation matrixes (12 x 12) obtained from the geochemical analytic values are shown as Table 8. The result of the principal component analysis, which is eigenvalues, coefficients of determination, and matrixes of factor loading up to the eighth principal component, is set forth as Table 9.

Table 8 Correlation coefficients of geochemical data

	Sn	Mo	W	Zn	Ta	Nb	Cu	Ag	As	F	Sb	Au
Sn	1.000	−0.226	0.701	0.045	0.570	0.598	−0.224	0.162	−0.014	0.636	−0.226	−0.010
Mo	−0.226	1.000	−0.065	0.593	−0.107	0.156	0.684	0.141	0.643	−0.025	0.763	0.088
W	0.701	−0.065	1.000	0.115	0.574	0.504	−0.068	0.293	0.130	0.438	−0.014	0.024
Zn	0.045	0.593	0.115	1.000	−0.100	0.319	0.774	0.194	0.685	0.251	0.604	0.083
Ta	0.570	−0.107	0.574	−0.100	1.000	0.627	−0.268	0.126	−0.149	0.435	−0.095	−0.025
Nb	0.598	0.156	0.504	0.319	0.627	1.000	0.170	0.132	0.216	0.542	0.100	0.028
Cu	−0.224	0.684	−0.068	0.774	−0.268	0.170	1.000	0.231	0.744	0.023	0.676	0.107
Ag	0.162	0.141	0.293	0.194	0.126	0.132	0.231	1.000	0.193	0.040	0.236	0.054
As	−0.014	0.643	0.130	0.685	−0.149	0.216	0.744	0.193	1.000	0.081	0.699	0.137
F	0.636	−0.025	0.438	0.251	0.435	0.542	0.023	0.040	0.081	1.000	−0.045	−0.015
Sb	−0.226	0.763	−0.014	0.604	−0.095	0.100	0.676	0.236	0.699	−0.045	1.000	0.113
Au	−0.010	0.088	0.024	0.083	−0.025	0.028	0.107	0.054	0.137	−0.015	0.113	1.000

Table 9 Principal component analysis and quantities of factor loading

Principal Components Analysis

Principal component	Eigen-value %	C.D %	C.C.D %
Z 1	3.946	32.888	32.888
Z 2	3.353	27.948	60.837
Z 3	1.024	8.540	69.377
Z 4	0.957	7.980	77.357
Z 5	0.719	5.991	83.349
Z 6	0.514	4.288	87.638
Z 7	0.414	3.450	91.088
Z 8	0.281	2.342	93.431
Z 9	0.256	2.135	95.566
Z10	0.217	1.816	97.382
Z11	0.177	1.479	98.861
Z12	0.136	1.138	100.000

C.D : Coefficient of determination
C.C.D : Cumulative coefficient of determination

Quantities of Factor Loading

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
Sn	−0.098	0.888	−0.001	0.027	−0.205	−0.149	0.017	0.196
Mn	0.833	−0.137	−0.081	−0.007	0.315	0.026	0.182	0.082
W	0.076	0.807	0.211	−0.125	−0.021	−0.441	0.003	−0.208
Zn	0.850	0.115	−0.164	0.050	−0.249	0.069	−9.130	−0.278
Ta	−0.128	0.792	0.032	−0.032	0.499	0.105	0.011	−0.141
Nb	0.281	0.784	−0.158	0.107	0.201	0.212	−0.342	0.154
Cu	0.896	−0.145	−0.062	−0.007	−0.143	0.095	−0.184	−0.086
Ag	0.305	0.235	0.663	−0.549	−0.165	0.274	0.027	0.063
As	0.869	0.016	−0.019	0.036	−0.089	−0.291	−0.049	0.242
F	0.109	0.736	−0.295	0.182	−0.307	0.243	0.381	−0.006
Sb	0.851	−0.131	0.048	−0.072	0.269	−0.070	0.251	−0.009
Au	0.164	−0.006	0.621	0.764	−0.000	0.049	0.012	−0.015

According to the principal component analysis for the 12 elements in this survey, the eigenvalues of the principal components up to the fourth are more than one or close to one, and the cumulative coefficient of determination up to the fourth principal component is about 80%, which means that about 80% of the variation of the original analytic values are summarized by taking the values up to the fourth component. In particular, only the values of the first and second principal components are accounted for more than 60% of the total variation.

The correlations among the each principal component and the each element are described in the following:

The quantity of factor loading of the first principal component expresses positive and strong correlation with molybdenum, zinc, copper, and antimony. The other elements do not have very close correlation with the first principal components. Elements that have close correlation with these first principal components present, on the content distribution map (PL-8 ~ 11), show distribution closely related with the geology of the background area. Particularly their content is high in sedimentary rock areas and low in granite areas. This positively suggests that the first principal component indicates the difference of the geological background.

The quantity of factor loading of the second principal component shows strong positive correlation with tin, tungsten, tantalum, niobium and fluorine. The other elements do not have very close correlation with the second principal components. Elements of close correlation with second principal component include tin and tungsten, so that the second ones seem to be factor related with major mineralization in this survey area.

The quantity of factor loading of the third principal component is positive and somewhat strong with silver and gold. The fourth principal component has the quantity of factor loading that is negative with silver and positive with gold. This means that the third and fourth principal components are factors with close correlation with silver and gold. No conspicuous characteristics are particularly seen in the fifth to eighth principal components.

From the above-mentioned result, the 12 elements as the objects of the present analysis about this survey area are classified into the following three element groups:

1. Group of Mo, Zn, Cu, As and Sb
2. Group of Sn, W, Ta, Nb and F
3. Group of Ag and Au

4–4 Distribution of Anomaly Area

An anomaly area for each element was picked out on the basis of the above-mentioned division into anomaly value levels. The result is shown in PLs. 4 to 13 and Appendix 17 ~ 20.

The anomaly areas are distributed in the upper reaches of the Huai Sa Ngin and Huai U Tum, Huai Chi Non Luang, and around the villages of Yang Kiang and Mae Khong of the northeast mass and in the Mon Kathing area. All of these anomaly areas are small in scale, but the anomaly areas of Huai Sa Ngin, the surroundings of Yang Kiang village, and Huai Chi Non Luang present a relatively sizable distribution.

Tantalum

Almost all the anomaly areas overlap with those of niobium but display stronger anomalies. High anomalies are concentrated on Huai Chi Non Luang, the upper reaches of Huai Sa Ngin and Huai U Tum. An anomaly area extends from the villages of Mae Khong and Yang Kiang to the Nam Mae Hong.

Tin

Small-scale anomaly areas are distributed along Huai Chi Non Luang, around Yang Kiang village and Mae Khong village, and in the Mon Kathing area.

On the whole the anomalies are low, no distinct anomaly is displayed. However, anomalies relatively gather along Huai Chi Non Luang and around Yang Kiang village. A low anomaly area found along the upper reaches of the Nam Mae Ngao is not convergence.

Tungsten

Although the anomaly areas overlap with those of niobium and tantalum, their distribution is practically limited to the northeast area and the Mon Kathing area. Sizable high anomaly area is ranged around Yang Kiang village, along Huai U Tum, and in the Mon Kathing area.

Copper

Most of all are low anomaly areas which are broadly distributed from the northwest to the south as if to correspond to the distribution of sedimentary rocks.

Zinc

The anomaly areas are distributed in a similar way as copper.

Arsenic

The anomaly areas are distributed in similar way as copper and zinc. A high anomaly area is seen in the Mon Kathing area.

Molybdenum

No anomaly is practically seen because of low content, but slightly anomalous values are found in the south.

Antimony

Anomaly is hardly recognized because of low content, but anomalous values are seen at several places.

Gold

Anomalous values are scattered over the whole survey area, but most of them do not come up to 10 ppb.

Silver

Samples with several ppm are seen scatteringly over the whole survey area.

Fluorine

The anomaly areas are extensively distributed in both batholith granites. but they are not in a convergence form.

4–5 Study of Heavy Mineral Samples

In this survey, along with the collection of geochemical prospecting samples from stream sediment, heavy mineral samples were collected at the rate of one sample per four geochemical prospecting samples.

Firstly the samples were collected about 30 liters of stream sediment and concentrated into about 100 to 150 g by panning on the site, then the concentrated material was concentrated by panning again at the base camp to be megascopically examined. This examination used an ultraviolet lamp to identify scheelite, zircon and others.

The identified minerals were cassiterite, wolframite, scheelite, zircon, garnet, tourmaline and others. Opaque minerals as magnetite and ilmenite were recognized in only very small quantities or unrecognizable throughout the survey area.

The result of this study is shown in Fig. 14 ~ 16 and set forth in the following:

Cassiterite, whose distribution is comparatively limited, was recognized in the upper reaches of the Nam Mae Lop, Huai Sa Nigin, Huai U Tum, Huai Chi Non Luang, and the southwest foot of Doi Mon Kathing. Cassiterite is invariably accompanied by garnet excluding the vicinities of Doi Mon Kathing.

Wolframite was found only along the lower reaches of Mon Kathing mining area.

As for scheelite, the one of the size of a pinhole is relatively uniformly distributed over the whole survey area. However, the areas where large-size scheelite, more than 0.5 to 1 mm in diameter, is distributed in large quantities are limited to Huai U Tum, Huai Sa Ngin, and the upper reaches of the Nam Mae Lop. Areas where small amount of large-size scheelite is recognized are Huai Chi Non Luang, the Mon Kathing area, Huai Lui, and other places.

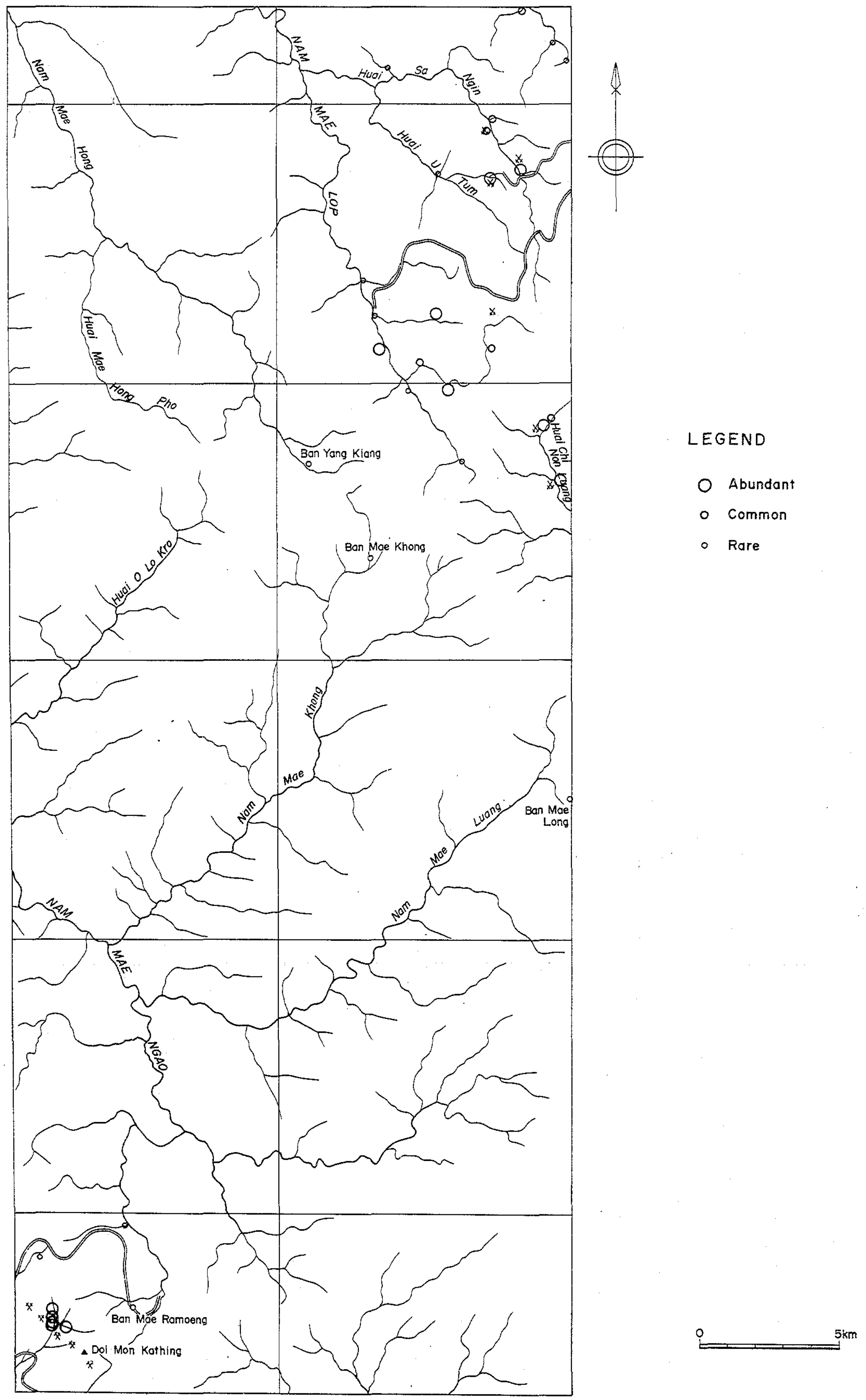

Fig. 14 Location of cassiterite under megascopic observation of heavy minerals

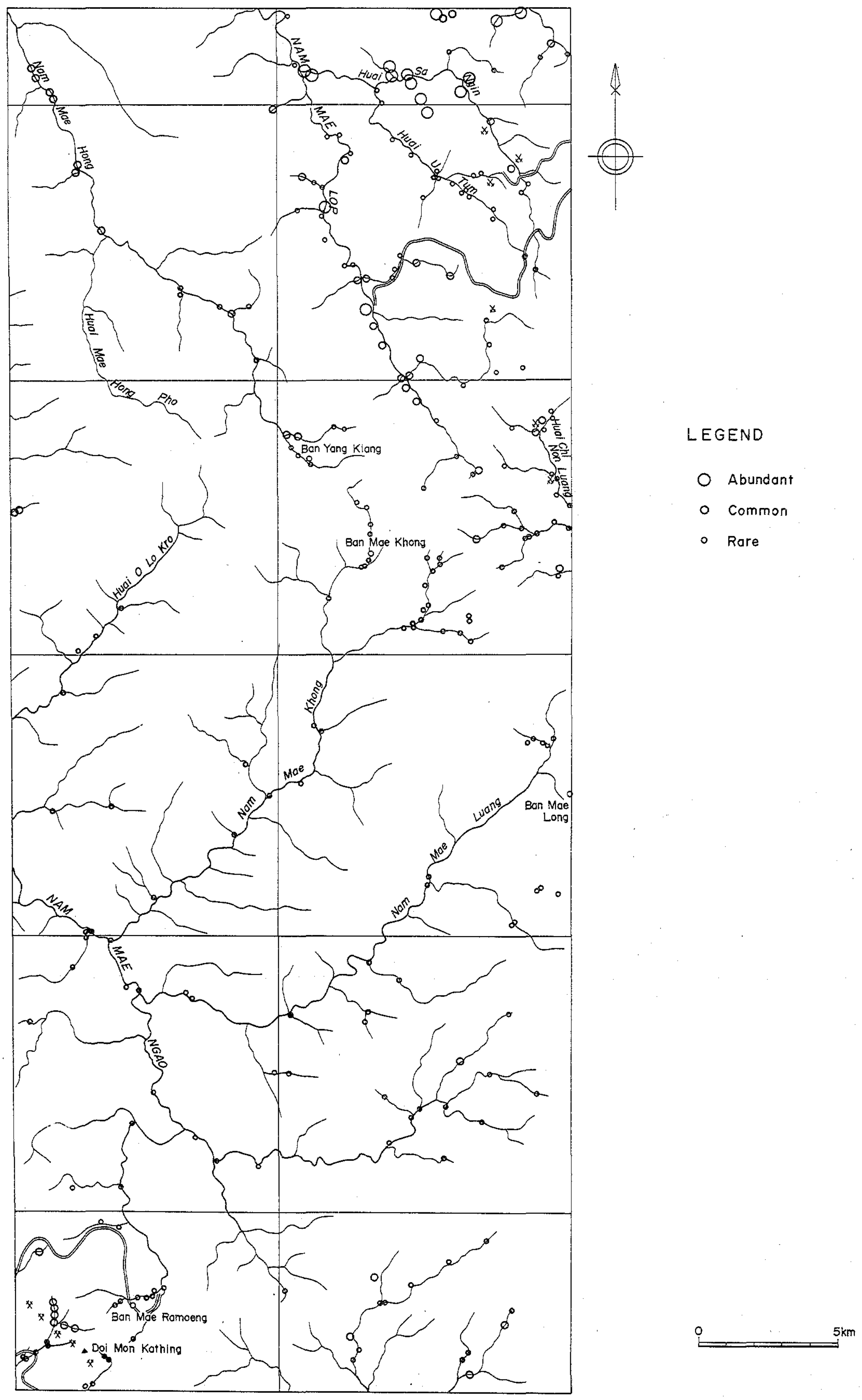

Fig. 15 Location of scheelite under megascopic observation of heavy minerals

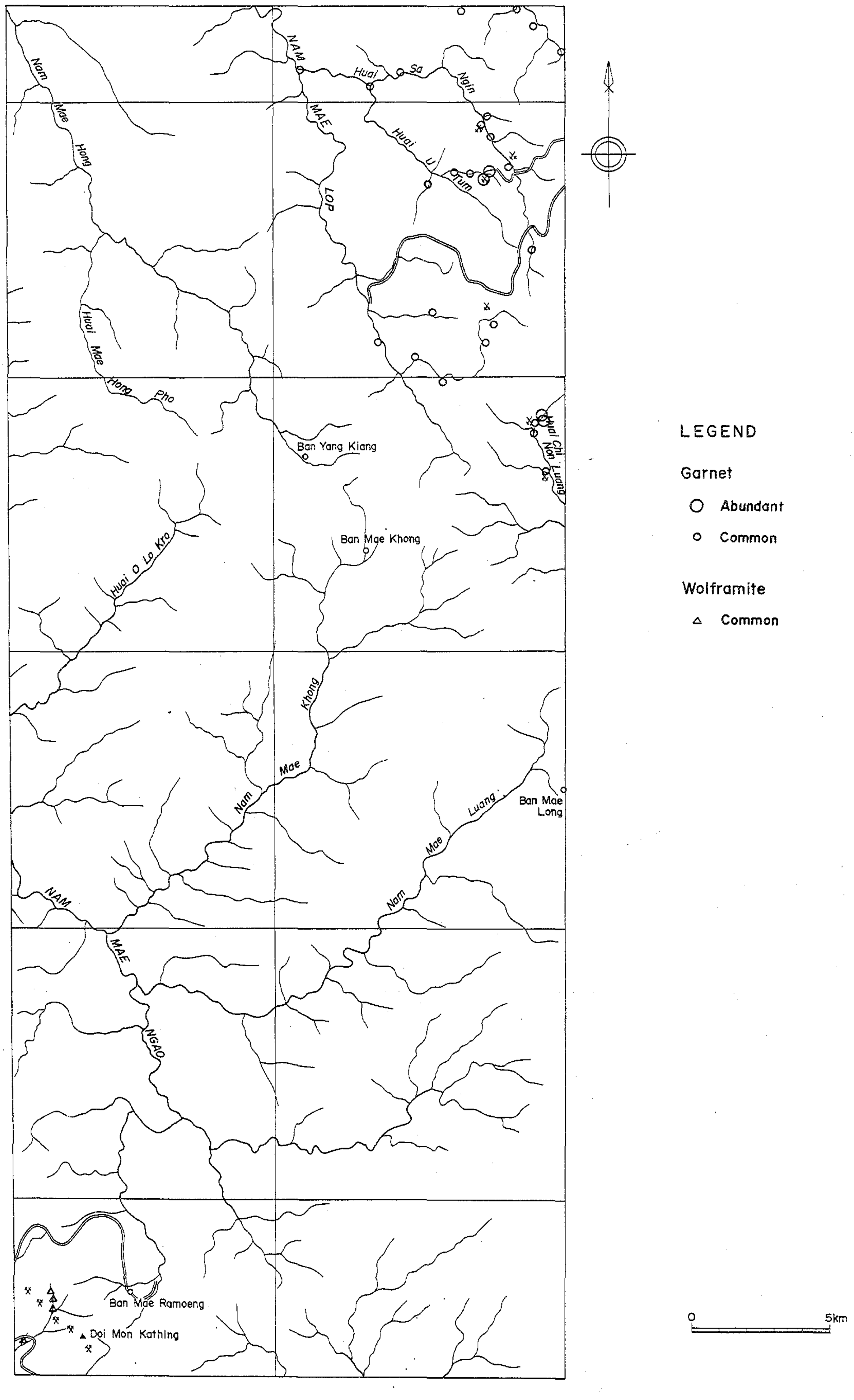

Fig. 16 Location of garnet and wolframite under megascopic observation of heavy minerals

Garnet is found plentifully on the northeast side of a line connecting Nam Mae Lop and Huai Chi Non Luang.

Zircon is distributed evenly throughout the survey area.

Samples that do not contain the above-mentioned minerals at all are often recognized from particularly the areas where Silurio-Carboniferous sedimentary rocks are distributed, and account for about 40% of the samples of those areas.

Tha above-mentioned result of this study indicates that areas with a promise for the occurrence of ore deposits are limited to the northeast and the Mon Kathing area.

4–6 Result of Geochemical Prospecting

Promising areas were studied from the distribution of anomaly areas and the relationship between the geology and ore deposits. This result is as follows.

The anomaly areas of niobium, tantalum, tin and tungsten overlap each other, and they are limited to the northeast granite mass and Mon Kathing granite mass. These anomaly areas are concentrated around Yang Kiang village in the upper reaches of the Nam Mae Hong, Mae Khong village in the upper reaches of Nam Mae Khong, the upper reaches of Huai U Tum and Huai Sa Ngin, Huai Chi Non Luang, and the Mon Kathing area (Fig. 17). These anomaly areas extend toward the lower reaches of streams, these extensions indicate that these elements were dispersed secondarily.

The sources of the anomaly around Yang Kiang and Mae Khong village are presumed to be on the northeast side of Nam Mae Hong and Nam Mae Khong, as the result of the distribution of element contents and that of scheelite contained in the heavy mineral samples.

As for the anomaly areas of the upper reaches of Huai U Tum and Huai Sa Ngin, especially high anomaly area of tantalum are found in U Tum Tai and further upper reaches of Huai Sa Ngin where old workings are scattered. Many pegmatites which contain large amount of muscovite, garnet and tourmaline develop in this high anomaly area.

In Huai Chi Non Luang, high anomaly of these elements is recognized in the neighborhood of a large old working and along the uppermost reaches of this valley. The background area of gravels is not positively at this old workings, but much of cassiterite and garnet are found in small branches of Huai Chi Non Luang. Presumably the supply source of gravel lies around this branches.

As the result of chemical analyses of panning concentrate taken from Huai Chi Non Luang and Huai Sa Ngin, relatively high content of niobium and tantalum was found. Since pegmatite intrusion is seen at places of these two areas and also much of big floats of pegmatite quartz and quatz veins are found at old workings, the high anomaly of niobium and tantalum possibly derives from these pegmatite and quartz veins.

The Mon Kathing area has a high anomaly area due to cassiterite and wolframite deposits. Niobium and tantalum were hardly detected in the result of chemical analysis of concentrates from the ore deposits of this area.

The another anomaly of tin is found in the uppermost reaches of the Nam Mae Ngao. Biotite-muscovite granite is distributed in this area. It is conceivable that this anomaly derives from this granite.

The anomaly area of copper, zinc and arsenic is recognized in Mon Kathing area. The contents of these components are mostly lower than the background values over the whole survey area except for Mon Kathing area, while their relatively high contents are distributed in the extent of Siluro Carboniferous sedimentary rocks.

The contents of molybdenum, antimony, gold and silver are low in this survey area, many samples are below the detection limits. So no anomaly area was detected. The samples with comparatively high contents of molybdenum and antimony are distributed in the Siluro-Carboniferous sedimentary rocks. The anomalous samples of gold and silver are scattered over the whole survey area.

High content samples of fluorine are distributed in the batholith granite in the east of this survey area, while there are comparatively concentrated area in the surroundings of Mae Khong village and the shouthwest part of Mae Long village.

From the above-mentioned result, geochemical anomaly areas of niobium, tantalum, tin and tungsten were recognized in the northeast area and the Mon Kathing area.

The Mon Kathing area has many tin and tungsten mines. This area has already been prospected.

There are several high anomaly areas in the northeast area. It is considered to be an area with a high possibility of primary deposit occurrence judging from the scale of the anomaly areas and the properties of the country rocks.

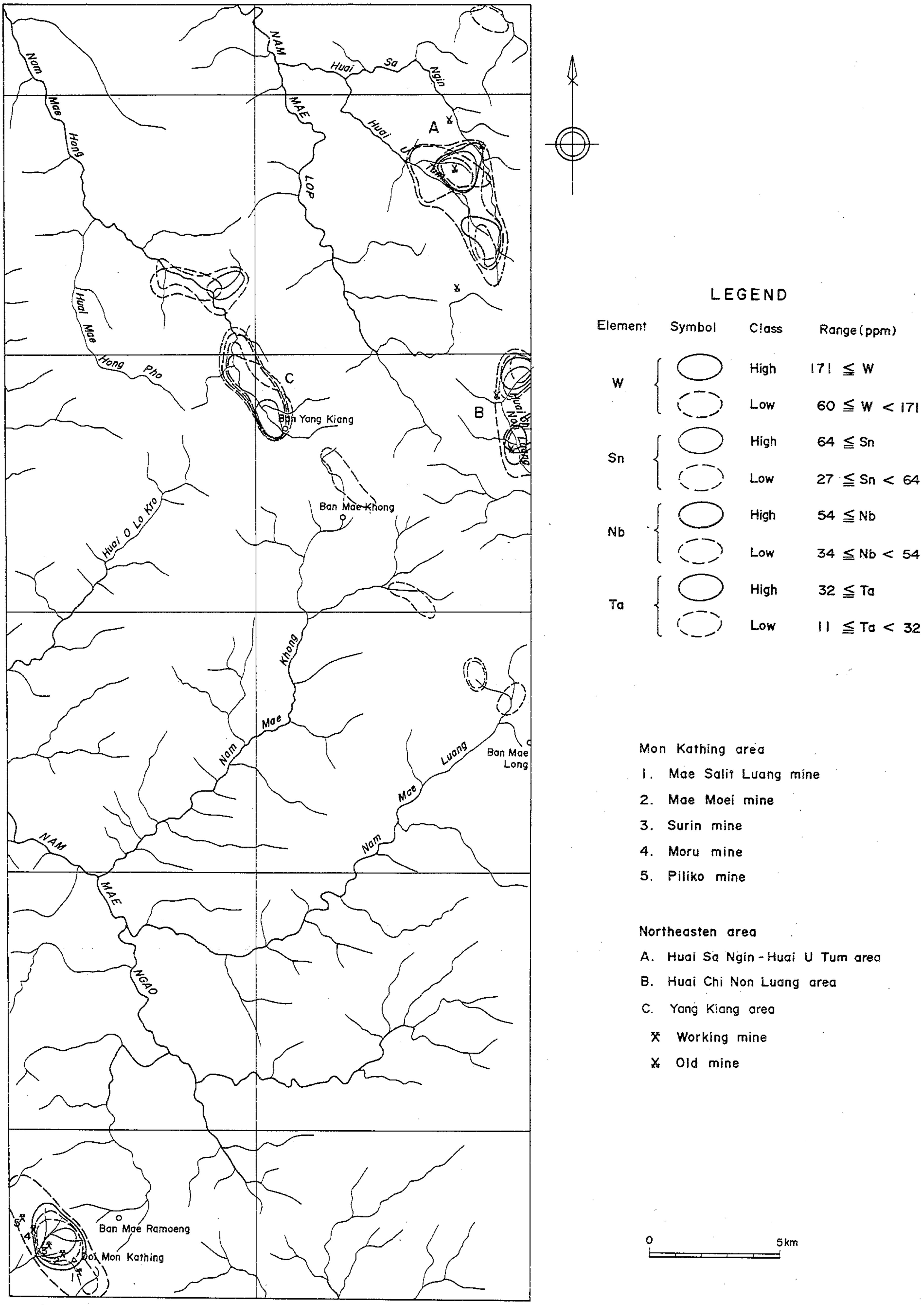

Fig. 17 Mines and geochemical anomalies of Nb, Ta, Sn, W

CONCLUSION AND RECOMMENDATION

CHAPTER 5 CONCLUSION AND RECOMMENDATION FOR THE SECOND PHASE SURVEY

5–1 Conclusion

As the result of the geological survey and geochemical prospecting in the Yang Kiang area, the following conclusions are obtained.

(1) The mineralization of tin, tungsten and others in northwestern Thailand is related with Mesozoic to Cenozoic granites. Five granitic masses of the Triassic age are broadly distributed in this survey area. Batholithic granites are northeast mass and southeast mass, and stock granites are northwest mass, center mass and Mon Kathing mass.

(2) These granitic masses have different isotopic ages by K-Ar method, 189 Ma, 73 to 80 Ma and 40 Ma. It is presumed that 189 Ma indicates the time of granite intrusion, 73 to 80 Ma is the time of tin and tungsten mineralization, and 40 Ma is the time of sulphide mineralization.

(3) These granites are determined to be the S-type granite by their chemical composition. And they are classified into the tin granite because of their high contents of tin. Therefore the granites of this survey area have high potential of occurrence of tin deposits.

(4) Secondary ore deposits of tin and tungsten occur in the small scale along the stream in the northeast mass. Tin and tungsten vein-type deposits and their secondary deposits occur in the Mon Kathing mass. Sulphide minerals are also disseminated in the surroundings of veins in the latter mass.

(5) The geochemical anomalies of stream sediments were detected by the geochemical prospecting of niobium, tantalum, tin and tungsten. They are concentrated in the northeast mass and the Mon Kathing mass. Remarkable high anomalies of niobium and tantalum are found only in the northeast mass.

(6) The contents of copper, zinc and arsenic are mostly lower than the background values for the whole survey area except for the Mon Kathing area, while their relatively high contents of these elements are distributed in the extent of sedimentary rocks. The area of high fluorine contents is distributed in the region of the batholithic granite, but no high anomalies are recognized. Any high anomaly values of molybdenum, antimony, silver and gold contents are not found in the stream sediments from this survey area.

5–2 Recommendation for the Second Phase Survey

From the above-mentioned result, three limited places in the northeastern part of survey area (Huai Chi Non Luang, Huai Sa Ngin to Huai U Tum area and Yang Kiang area) were selected as the anomaly areas of Sn, W, Nb and Ta. Therefore detailed geological survey and geochemical prospecting should be carried out in these places to evaluate the mineral potential.

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APPENDICES

Appendix 1 Microscopic observation of rock thin sections

No.	Sample No.	Location	Rock name	Texture	Primary mineral												Secondary mineral						
					qz	pl	kf	bi	ms	tl	ap	sp	zr	am	ga	op	ch	sr	ep	ca	bi	qz	hm
1	D–1	Ban Ko Phlai Lu	biotite granite	granitic, porphyritic	○	◎	○	○			◦		•			•	•	•	•				•
2	D–2	Huai Sa Ngin	biotite granite	granitic, porphyritic	○	○	○	○			•		•			•	•	•				•	
3	D–3	West of Ban Yang O Ro De Nue	biotite granite	granitic, porphyritic	○	○	◎	○			•		•				◦	◦					
4	D–4	Junction of Huai Mae Khong and Huai Sate Kro	biotite granite	granitic, porphyritic	○	○	◎	○		•	•		•				◦	◦	•				•
5	D–5	2km North-east of Doi Mon Kathing	two mica granite	granitic, porphyritic	○	○	◎	○	○		•		•					◦					
6	G–1	Doi Mon Kathing	two mica granite	granitic, cataclastic	○	○	◎	◦	◦		•		•					◦			◦	◦	
7	G–2	East of Ban Mae Long Luang	altered granite	granitic			◎				•					•	◦	•			◦		
8	G–3	South-west of Ban Pli Kro	biotite granite	granitic, porphyritic	○	○	◎	○			•		•			•	•	•					
9	G–4	Huai Mae Bang	biotite granite	granitic, porphyritic	○	○	○	◦			•		•	○		•	•	•	•				
10	G–5	Junction of Nam Mae Hong and Huai Thi Pho Kro	biotite granite	granitic, porphyritic	○	○	◎	◦			•		•			•	◦		•				•
11	G–6	Junction of Nam Mae Hong and Huai Klong Ta	biotite granite	granitic, porphyritic	○	○	◎	◦			•	•	•			•	•	•					•
12	G–7	East of Ban Mae Ha Khi	biotite granitic	granitic, porphyritic	○	○	◎	○			•		•	•			•			◦			
13	G–8	West of Ban Se Kra	biotite granite	granitic, porphyritic	○	○	◎	○		•	•		•			•	•	◦					•
14	JI–66	2km north of Doi Mon Kathing	biotite muscovite hornfels	hornfelsic	○	○		○	○		•		•			•							•
15	BU–30	Huai Sa Ngin	tourmaline pegmatite	mosaic	◎	○	○		•	○					○								

Abbreviations : qz; quartz, pl; plagioclase, kf; potassium feldspar, bi; biotite, ms; muscovite, tl; tourmaline, ap; apatite, sp; sphene, zr; zircon, am; amphibole, ga; garnet, op; opaque mineral, ch; chlorite, sr; sericite, ep; epidote, ca; calcite, hm; hematite

Symbols : ◎ ; abundant, ○ ; common, ◦ ; rare, • ; trace

Appendix 2 Microscopic observation of ore polished sections

No.	Sample No.	Locality	Description	Ore minerals											Gang minerals									
				cs	sh	wf	pr	ap	cp	co	ct	il	mt	hm	qz	kf	pl	sr	bi	ep	ga	tl	ru	zr
1	0–1	Huai Sa Ngin No.1	Panning concentrate	○		∘					•				∘	•			•		◎	∘		∘
2	0–3	Huai U Tum	Panning concentrate	○							•				∘						◎	∘		∘
3	0–5	Huai Chi Non Luang	Panning concentrate	∘		•					•				○		•				◎	∘	•	
4	0–7	Mae Moei Mine	Sn-W concentrate	◎		○		•	∘						◎			•		•				
5	0–8	Mae Salit Luang	W quartz vein			◎																		
6	0–9	Mae Moei Mine	Sn-W concentrate	○	∘	○		•		•			•											
7	0–10	Piliko Mine	Sn crude ore	◎											∘			∘						
8	0–11	Piliko Mine	W crude ore			◎	•							•	◎			∘						
9	0–12	Piliko Mine	Sulphide crude ore					◎	•			•	∘		○	○		∘						
10	0–13	Mae Moei Mine	Sulphide crude ore				◎	○	•	∘					◎					○				
11	0–14	Piliko Mine	Sulphide crude ore					◎	○	•					◎			∘						
12	0–15	Mae Moei Mine	Sn crude ore	◎								∘			○			○						∘
13	0–16	Mae Moei Mine	Sulphide crude ore					∘	•			•			◎	○		○						
14	0–17	Mae Moei Mine	Sulphide crude ore				∘	○	∘	∘					◎					•				
15	0–18	Piliko Mine	Sn crude ore	◎			∘	○	•						○			○		∘				

Abbreviations cs; cassiterite, sh; scheelite, wf; wolframite, pr; pyrite, ap; arsenopyrite, cpr, chalcopyrite, co; covellite, ct; columbite-tantalite; il; ilmenite, mt; magnetite, hm; hematite, qz; quartz, kf; potassium feldspar, pl; plagioclase, sr; sericite, bi; biotite, ep; epidote, ga; garnet, tl; tourmaline, ru; rutile, zr; zircon

◎ ; abundant, ○ ; common, ∘ ; rare, • ; very rare

Appendix 3 Results of X-ray diffraction of ore samples

No.	Sample No.	Location	Description	cs	sh	wf	ga	zr	apr	cp	pr	il	mc	fd	qz	tl	mo
1	0–1	Huai Sa Ngin	Panning concentrate	◎			◎	○					•	○	○	○	
2	0–2	Huai Sa Ngin (50m south of 0–1)	Panning concentrate	◎			○	○						•	○	•	
3	0–3	Huai U Tum	Panning concentrate	○			◎						•	•	○		
4	0–4	Huai U Tum (50m west of 0–3)	Panning concentrate	○			◎					∘	•	○	○	•	
5	0–5	Huai Chi Non Luang	Panning concentrate	○			◎							∘	○	∘	
6	0–6	Piliko mine	Sn-W concentrate	○	○	◎											
7	0–7	Mae Moei mine	Sn-W concentrate	◎		◎							∘				
8	0–8	Mae Salit Luang mine	W quartz vein			◎									○		
9	0–9	Mae Moei mine	Sn-W concentrate (fine grained)	◎		◎							∘				
10	0–10	Piliko mine	Sn ore	◎									∘				
11	0–11	Piliko mine	Sn-W quartz vein	◎		◎									∘		
12	0–12	Piliko mine	Sulphide ore						◎				○		○		
13	0–13	Mae Moei mine	Sulphide ore						◎	∘	∘				◎		○
14	0–14	Piliko mine	Sulphide ore						◎				○		•		○

Abbreviations: cs; cassiterite, sh; scheelite, wf; wolframite, ga; garnet, zr; zircon, apr; arsenopyrite, cp; chalcopyrite, pr; pyrite, il; ilmenite, mc; mica, fd; feldspar, qz; quartz, tl; tourmaline, mo; montmollironite

Symbols ◎; abundant, ○ ; common, ∘ ; rare, • ; trace