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THE KINGDOM OF THAILAND
REPORT ON GEOLOGICAL SURVEY
OF
THE OMKOI AREA, NORTHWESTERN THAILAND
(THE COLUMBITE-TANTALITE EXPLORATION PROJECT)

CONSOLIDATED REPORT

JUNE 1986

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Kingdom of Thailand, decided to conduct the mineral exploration in Omkoi area, northwestern Thailand and entrusted its execution to the Japan International Cooperation Agency. Considering its technical aspects, the agency sought collaboration with the Metal Mining Agency of Japan to accomplish the task.

The survey was carried out for three years since November, 1983 to May, 1986 and was brought to completion with the cooperation of the Government of the Kingdom of Thailand, in particular, the Department of Mineral Resources, Minister of Industry.

This final report summarized the results of all phase surveys.

We wish to express our heartfelt gratitude to the agencies of the Government of the Kingdom of Thialand and other authorities for their kind cooperation and support to the Japanese survey team.

May, 1986

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

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SUMMARY

The cooperative basic survey for development of mineral resources carried out for three years from November 1983 to May 1986 to investigate the possibilities of the occurrence of mineral resources of tin, tungsten and rare metals such as niobium and tantalum in the Omkoi area in the northwest of the Kingdom of Thailand. The surveyed area covers 1,000 km^2, extending 50 km in the north-south direction and 20 km in the east-west direction. The town of Omkoi, Omkoi District, Chiang Mai Province is in this area.

This area is situated in the tin belt running from the Malay Peninsula to the Thai-Burmese border. There is large possibility of the occurrence of tin and tungsten ore deposits. Besides it can be expected that these ore deposits contain niobium and tantalum.

In the survey program, geological surveys, geochemical prospecting, drilling and trenching were carried out by stages.

In the Phase I survey, general geological survey (including the survey of known ore deposits) and general geochemical prospecting by means of stream sediment sampling were performed over the whole Survey Area. This survey has revealed relation among the regional geology, mineralization and the geochemical anomalies in the Survey Area. And niobium, tantalum, tin and tungsten geochemical anomaly areas were picked out mainly in the surroundings of known deposits.

In the Phase II survey, the following areas, which have higher possibilities of the occurrence of ore deposits, were selected from the geochemical anomaly areas picked out by the Phase I survey. Area A: a niobium, tantalum, tin and tungsten high anomaly area near the Pha Pun Dong mine, Area B: a niobium, tantalum, tin and tungsten anomaly area near the Yong Ku mine, Area C: a tantalum high anomaly area to the northwest of the Pi Tu Khi mine. A detailed geological survey (including detailed investigations of known ore deposits) and geochemical prospecting by means of soil sampling (semi-detailed prospecting and detailed prospecting) were carried out in these areas. As the result, the relation among the geology, mineralization and geochemical anomalies in each area was made more clear, and geochemical anomaly areas with higher possibilities of the occurrence of ore deposits were delineated.

In the Phase III survey, drilling survey making 51 holes with a total length of 1,600 m and trenching survey cutting 57 trenches with a total length of 1,940 m were carried out over the four areas of A_1, A_2, B_1, and B_2 picked out by the Phase II survey to confirm the occurrence of ore deposits. The findings of these surveys are outlined as follows:

Area A_1 (13 drill holes totaling 390 m and 13 trenches totaling 670 m):

This is a tungsten geochemical anomaly area. Some tungsten mineral indications were found

in pegmatite veins and quartz veins, the maximum WO_3 content were 1.4%. But almost veins are of low grade and poor continuity.

Area A_2 (7 drill holes totaling 210 m and 6 trenches totaling 390 m):

This is a tin geochemical anomaly area. Granitic rock contains pegmatite veins and quartz veins. Tin content was found to be not less than 100 ppm in various parts of those veins and 250 ppm at maximum in granitic rocks.

Granitic rocks generally contain high tin content in spite of no tin-mineralized veins, and besides here are old workings of secondary tin deposit, so that this area has a condition and possibility of occurrence of tin-mineralized veins.

Area B_1 (5 drill holes totaling 150 m and 10 trenches totaling 270 m):

This is a niobium and tantalum geochemical anomaly area. Although it was revealed that the anomalies derived from pegmatite veins, mineral indication was not found practically. The pegmatite has been altered into white clay to a large extent.

Area B_2 (26 drill holes totaling 850 m and 28 trenches totaling 610 m):

This is a tin and tungsten geochemical anomaly area. Three drilling holes and one trench intersected mineral indication. The grains of scheelite are disseminated in quartz veins and calc-silicate rocks interlaid in paragneiss. Almost of them present WO_3 content of 0.48 to 1.56%. They are closely associated with gneissose structure of the country rock in the NW–SE direction. Other unknown mineralized veins can be expected to lie intermittently or in an echelon form along this gneissose structure.

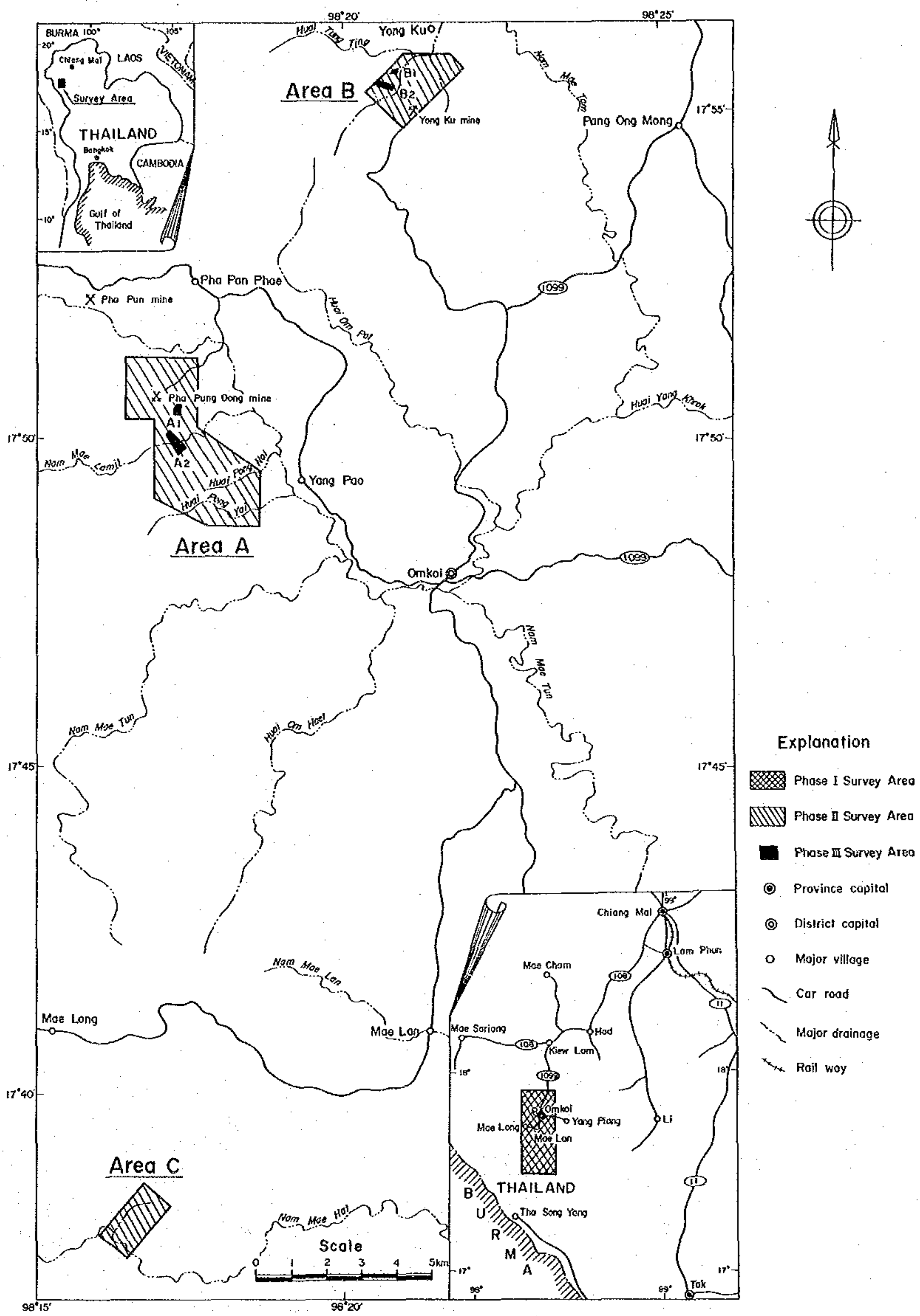


Fig. 1 Location Map of the Survey Area

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

1–1 Background and Objective of the Survey

Main mineral products of Thailand are tin, tungsten, fluorite, barite, antimony, and a variety of other minerals. Among these, tin is the most important kind of metallic mineral resources, and its production amount ranks fourth in the world following Malaysia, Indonesia and Bolivia.

The economic importance of the tin mining in Thailand is not limited to the large amount of production. The tin mining has yielded substantial quantities of such rare metals as niobium and tantalum as byproducts.

Thailand had exported these rare metals as tin smelting slag and ores, but is now making preparations for establishment of a processing plant. Owing to the need of assuring stable production of the raw minerals to be fed to the plant and in expectation of an increasing demand for such metals, the Government of Thailand requested the Japanese Government to conduct a cooperative basic survey for development of mineral resources including such rare metals as niobium and tantalum.

The Japanese Government, in response to this request, sent, in 1983, an advance survey team, which visited the locale together with the officials of the Department of Mineral Resources, the Ministry of Industry of the Kingdom of Thailand and made a negotiation with them for an agreement. And it was decided between the two governments that a cooperative basic survey for development of mineral resources extending over three years starting in 1983 as the initial year was to be carried out in the district of Omkoi in the north of Thailand where the occurrence of such rare metals as niobium and tantalum could be expected in addition to tin and tungsten.

The objective of this survey lied in selecting areas where the occurrence of mineral deposits of niobium, tantalum, tin, tungsten and other metals was hoped for by making an overall comprehension of the relations between the geology and geological structure on the one hand and mineralization and geochemical characteristics on the other hand in the Survey Area, and in eventually finding new deposits.

1–2 Contents of the Survey

The procedure of this survey was as follows:

The survey was started with a regional geological survey and reconnaisoace geochemical prospecting over the whole survey area; then by making a detailed geological survey and a detailed geochemical prospecting of promising areas that had been picked out as the result of the initial survey and prospecting, these areas were further narrowed down; and finally examinations were made for the existence of mineral indications by making drilling and trenching survey. The flow chart of the survey process is shown in Table 1.

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

(1) The 1st Phase survey in 1983

A regional geological survey over the whole Survey Area covering an area of 1,000 km^2 and a reconnaissance geochemical prospecting by stream sediment were conducted.

(i) Geological survey

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

Microscopic observation of representative rock samples and the chemical analysis of them for main and trace components were made. In particular, the relations between the mineral composition, chemical composition, and geochemical characteristics of granitic rocks distributed over the greater part of the Survey Area and the mineralization of tin and tungsten were studied.

Age determination was made of main rock bodies among the granitic rocks.

By surveying the existing mines, mine geologic maps were prepared, and the microscopic observation, X–ray analysis, chemical analysis and other tests of the ores and concentrates from the mines were made, putting into shape the occurrence of the mines.

(ii) Geochemical prospecting

Selecting drainage systems from the whole Survey Area so that they are of nearly uniform density, a total of 1,259 stream sediment samples, which are –80 mesh products, were collected from the systems and subjected to chemical analysis.

The chemical analysis of the collected samples was made for the seven pathfinder elements of Sn, W, Nb, Ta, Be, Li and F; after they were statistically processed, a geochemical anomaly map on a scale of 1 to 50,000 was prepared for each element, and correlations between the elements were studied.

(2) The 2nd Phase survey in 1984

From the results of the first Phase survey, three promising areas were selected Area A covering an area of 10.4 km^2 near Pha Pun Dong Mine, Area B covering an area of 3.25 km^2 near Yong Ku Mine, and Area C covering an area of 2.00 km^2 along the upper reaches of the Hat river, totalling 15.65 km^2. Over these areas a detailed geological survey and a detailed geochemical prospecting by soil were conducted.

(i) Geological survey

In parallel with the collection of geochemical samples, a geological survey was made, and a geologic map on a scale of 1 to 5,000 was prepared for each of the selected areas.

Microscopic observation of representative rock samples collected from the areas and the chemical analysis of them for main and trace components were made. Integrating the results of these works with the data from the Phase I survey, study was more closely made, in particular of the correlations with mineralization.

Making age determination of two rock bodies among the granitic rocks, synthetic study was made by adding the result to the data from the Phase I survey.

An additional survey of major known mines was made, and the information of their occurrence was put into shape.

(ii) Geochemical prospecting

A total of 5,313 soil samples (−80 mesh products) were collected from the points of a grid pattern formed of 100 m x 25 m units (for detailed prospecting) and 100 m x 50 m units (for semi detailed prospecting) laid out in the areas, and subjected to chemical analysis.

The collected samples were chemically analyzed for the four pathfinder elements of Sn, W, Nb and Ta. After the result was statistically processed, a geochemical anomaly map on a scale of 1 to 5,000 was prepared for each element, and correlations between the elements were studied.

(3) The 3rd Phase survey in 1985

From the results of the second Phase survey, four promising areas, two each from Areas A and B, were picked out, and a trenching survey and a drilling survey for ascertaining the mineral indications were carried out in these areas.

(i) Drilling survey

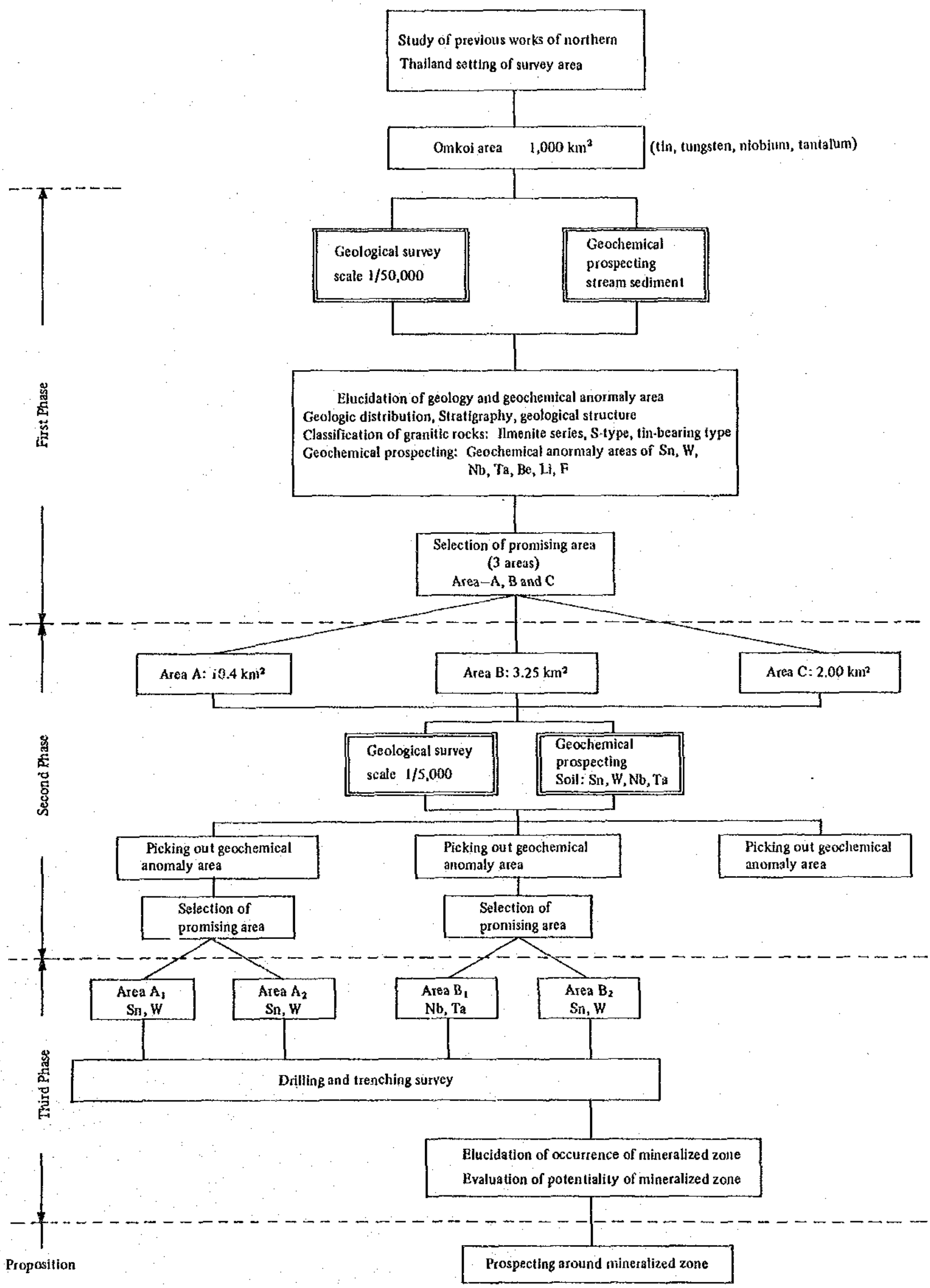
A total of 51 drill holes, all vertical, were made up to a 30 m depth, partly 40 m and 50 m, with a total drilling length of 1,600 m. The result was compiled in geologic logs on a scale of 1 to 100. A total of 381 samples for chemical analysis were taken from these holes.

(ii) Trenching survey

Trenches of principal dimensions of 1 m width and 2 m depth, with the length ranging from 10 to 100 m, were excated at 57 places, the total length coming up to 1,940 m. The result was compiled in geologic sketches on a scale of 1 to 100. A total of 542 samples for chemical analysis were collected.

By using the results of these surveys, a comprehensive evaluation was made on mineral indications, their scales and continuity, and the potentiality of ore deposit occurring in each area. The survey contents of each year are shown Table 2.

Table 1 Flow Chart of the Exploration Program



The quantities of surveys in each phase are shown in Table 2.

Table 2 Quantities of Surveys

Item			Phase I 1983	Phase II 1984	Phase III 1985	Note
Kind of survey			· Geological survey · Geochemical prospecting by stream sediment	· Geological survey · Geochemical prospecting by soil	· Drilling · Trenching	
Area and quantities			1,000 km²	Area A: 10.40 km² Area B: 3.25 km² Area C: 2.00 km² Total 15.65 km²	Drilling: Area A_1 13 holes 390 m Area A_2 7 " 210 " Area B_1 5 " 150 " Area B_2 26 " 850 " Total 51 holes 1,000 m	
					Trenching: Area A_1 13 tr. 670 Area A_2 6 " 390 " Area B_1 10 " 270 " Area B_2 28 " 610 " Total 57 " 1,940 "	3,680 m³
Indoor tests	Thin sections		20	17	10	
	Polished sections		10	11	0	
	X-ray diffraction		10	13	1	
	Age determination		5 (K-Ar method)	2 (Rb-Sr method)	1 (K-Ar method)	
	Chemical analysis	Rock	50	17	—	Granite
		Components for analysis	SiO_2, TiO_2, FeO, Fe_2O_3, MnO, MgO, CaO, K_2O, BaO, Na_2O, Al_2O_3, P_2O_5, Ig loss, F, Cl, Sn, W		—	
		Ore	10	17	923	
		Components for analysis	Sn, W, Nb, Ta, Au, Ag	Sn, W, Nb, Ta	Sn, W, Nb, Ta	
		Geochemical samples	1,259	5,313	—	
		Components for analysis	Sn, W, Nb, Ta, Be, Li, F	Sn, W, Nb, Ta	—	

1–3 Members of Survey Team

The members who participated in the planning and negotiations for the survey and in the field survey for each phase survey are listed as follows:

(i) The first phase (1983)

	JAPAN	THAILAND
Planning the Survey and Negotiations	Ryuhei Katsuno	Sivavong Changkasiri
	Yoshikazu Takedomi	Charoen Piancharoen
	Hiroshi Nakano	Sermsakdi Kulvanich
	Masao Tsuge	Phairat Suthakorn
	Kyoichi Koyama	Prachon Charoensri
	Shozo Sawaya	Paichit Pathnopas
	Jiro Osako	
	Hideyuki Ueda	
	Masao Watanabe	
	Sakashi Matsuda	
Field Survey	Iwao Uchimura	Sermsakdi Kulvanich
	Hiroshi Yoshida	Phairat Suthakorn
	Hiromitsu Nozawa	Metha Amornsirinukroh
	Akio Abe	Peerapong Khuenkong
		Patchara Jariyawat
		Surapol Udompornwirat
		Boonchu Panglinput

(ii) The second phase (1984)

	JAPAN	THAILAND
Planning the Survey and Negotiations	Makoto Ishida	Sermsakdi Kulvanich
	Toshio Sakasegawa	Phairat Suthakorn
	Jiro Osako	Prachon Charoensri
	Tadaaki Ezawa	Peerapong Khuenkong
	Hideyuki Ueda	

Field Survey	Iwao Uchimura	Sermsakadi Kulvanich
	Hiroshi Yoshida	Phairat Suthakorn
	Hiromitsu Nozawa	Peerapong Khuenkong
	Akio Abe	Patchara Jariyawat
		Aroon Tritrangan
		Boonchu Panglinput
		Sawang Wanlaiad

(iii) The third phase (1985)

	JAPAN	THAILAND
Planning the Survey and Negotiations	Makoto Ishida	Sermsakdi Kulvanich
	Tadaaki Ezawa	Phairat Suthakorn
	Yasuo Endo	
Field Survey	Iwao Uchimura	Peerapong Khuenkong
	Hiroshi Yoshida	Patchara Jariyawat
		Aroon Tritrangan
		Boonchu Panglinput
		Sawang Wanlaiad
Drilling	Sakari Kon	Werachat Jittamase
	Hisao Ataku	Sukhum Tawatchana
	Yoshikazu Sugawara	Wiwat Srisungworn
	Kyuya Fujii	Khanchai Saingthong
	Etsuo Hatakeyama	Sontaya Phungsuk
	Yukoh Sasaki	Vinai Trumong
		Chalong Pingsripang
		Sanea Kitpayap
		Sanit Kongsawi
		Suthep Raungcharean
		Sangwan Kattapong
		Piroj Theppitak
		Seree Hokkian
		Utain Ghoomvichitra

1–4 Previous Works

The Survey Area is located in the west of northern Thailand and comes under a part of the tin belt which runs from the peninsular part of Malaysia and Thailand to a region along the Thailand-Burma border.

For northern Thailand there are comprehensive reports by Brown et al. (1951), Javaraphet (1969), Baum et al. (1970), GGM* (1972) and others.

Among these reports GGM (1972) describes regional geology and mineral deposits by carrying out a systematic survey over northern Thailand from 1965 to 1971 and discusses the possibilities of occurrence of mineral resources in various areas. This report includes brief references to tin, tungsten and fluorite in the Omkoi area. On the basis of the result of this survey, geologic maps on a scale of 1 to 250,000 were prepared, constituting the basic geologic maps. The Omkoi area is covered by one of these, the Geological Map of Northern Thialand (compiled by E. von Braun, L. Hahn, and H.D. Maronde, 1981) Sheet 6 (Amphoe Li).

Vichit et al. (1983) describes the mineral deposits in the Omkoi area and discusses the relations between the geology and geological structure and mineralization.

* GGM: German Geological Mission

CHAPTER 2 OUTLINE OF THE SURVEY AREA

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2–1 Location and Accessibility

The Survey Area is located, as shown in Fig. 1, in the scope of Long. 98° 15′ 00″ to 98°26′30″ E. and Lat. 17°37′00″ to 17°56′30″ N.

About 110 to 160 km to the southwest of Chiang Mai City in northern Thailand, it is in the scope of 50 km in the north-south direction and 20 km in the east-west direction forming an area of 1,000 km^2. Most of this area comes administratively under Omkoi District, Chiang Mai Province, a part in the southwest extremity of this area falling under Tha Song Yang District, Tak Province. In nearly the middle of the north of the Survey Area exists Omkoi Town which is the administrative center of Omkoi District.

To travel from Chiang Mai City to Omkoi, one first takes National Highway No. 108, a paved road, which connects Chiang Mai, Mae Sariang, and Mae Hong Son, and turns at Kiuw Lom, which is at an about 120 km distance from Chiang Mai, to take National Highway No.1099, of which a section of about 50 km is under improvement work by paving, going south. The distance on road from Chiang Mai to Omkoi is about 170 km.

The paving improvement work of National Highway No. 1099 is planned to be completed in 1986. Under the present road condition a trip by car from Chiang Mai to Omkoi takes about three hours.

As for motorable roads in the Survey Area in addition to National Highway No. 1099, there are some leading from Omkoi as the center to such major villages as Yang Piang to the east, Yang Pao and Pha Pun Phae to the west, Sop Lan to the south, and Mae Lan and further Mae Long to the southwest.

Except for the road leading to the village of Yang Piang to the east, however, all the roads are narrow and rough, what is worse, have many steep slopes and curves, causing difficulty in safe driving unless one uses a four-wheel-drive car. Many of the roads often become impassable in the rainy reason.

In the Survey Area, besides these roads for automobiles, there are a large number of footways running in all directions which connect scattered clusters of homes with cultivated fields including rice paddies and slash-and-burn fields.

Among the survey areas in the 2nd and 3rd Phases, in Area A there is a road for automobiles for Pha Pun Dong Mine lying in the north of this area; in Area B there is a motorable road branching from National Highway No. 1099 to Yong Ku Mine lying in the southern extremity of this area; Area C is situated at a distance of about 13 km from the village of Mae Lan with no road for cars.

2–2 Topography

The northeast side of this Survey Area marked off by the Tun river running from northwest to southeast in the area's northern half and the Lamit river which lies in the upper reaches of the former river presents topography covered with relatively low hills, their altitude ranging from 700 to 1,100 m. The southwest side, on the other hand, is principally covered with a rugged mountainous land form, the altitude ranging from 700 to 1,700 m with height difference of about 1,000 m.

The mountainous area has been considerably dissected by main rivers running parallel with mountain ridges which are in the directions of NW–SE, NE–SW and N–S and their tributaries; and the slopes of the mountainsides are generally sharp.

The hilly area has a little difference of relative height, and in many parts of its lower areas there is the development of paddy fields centering around Omkoi.

2–3 Climate and Vegetation

The area around the town of Omkoi is in a tropical savannah-type climate, being influenced by a southwest monsoon lasting from May to October which causes the rainy season, and from November to February by a northeast monsoon bringing about the dry season. It comes under the hottest season in March and April when the northeast winds abate.

The average monthly temperature ranges from 16 to 28°C in a year; in the dry season daily variation of temperature is extreme, ranging from 3 to 35°C; in the high mountains the minimum temperature comes to as low as 0°C and at times it frosts.

Annual rainfall is in the range of 800 to 900 mm, and there scarcely is any rainfall from December to March.

Most of the vegetation in the Survey Area is formed of thin primeval woods of broadleaf trees mingled with such coniferous trees as pines, but locally some thick forests with a jungle-like aspect and bamboo thickets are distributed.

2–4 General Information

The town of Omkoi has, in its vicinities, an extensive paddy field area developed near the junction of the Nam Mae Tom river and the Nam Mae Tun river, and is the center of Omkoi District, with the district office, a police station, post office, hospital, primary school and junior high school.

At various points along main rivers in the Survey Area there are major villages, and small clusters of homes are scattered in narrow valleys in remote and secluded places among the mountains. In the surroundings of such villages and homes there are paddy fields and slash-and-burn fields.

Omkoi District has a population of about 24,000, about 85% of which is accounted for by hill tribes (Karen, Meo and Musaw), and the Thai are found in a small number. The hill tribes living in the Survey Area form clusters of homes scattered away from Omkoi, and the town of Omkoi serves as the base for obtaining subsistence goods for these people.

The principal part of industry is farming (rice culture), and the other kinds of industry are stock farming (beef cattle, buffaloes and swines), textile, and mining (tin and tungsten).

CHAPTER 3 GEOLOGY AND ORE DEPOSIT OF SURVEY AREA

CHAPTER 3 GEOLOGY AND ORE DEPOSITS OF SURVEY AREA

3–1 Geologic Setting of the Survey Area

Northern Thailand which includes the survey area is situated in the middle of the Indochina Peninsula.

The whole area of the Indochina Peninsula is an orogenic belt in Mesozoic to Cenozoic ages. The geological structure elements which are found in northern Thailand, in particular, are intensely dominated by faulting after the orogenic movements, which have continued after Tertiary until recent. According to the results of this faulting, northern Thailand is mainly divided into four geological provinces as follows (JICA, 1984):

i) Western Tectonic Province (along the Thai-Burmese border)

ii) Main Western Range Tectonic Province

iii) Central Northern Tectonic Province

iv) Eastern Tectonic Province (Khorat Plateau)

Among these, the Main Western Range Tectonic Province, in which the survey area is located, includes the main mountain zone in Thailand which lies between Mae Sariang and Chiang Mai, and its southward extension continues to Kanchanaburi. This tectonic province consists of the Precambrian metasedimentary rocks associated with archshaped granite intrusion, early-Palaeozoic, weakly metamorphosed continental shelf sediments which covers the above rocks unconformably, and granitic rocks of late Triassic age which brought about the mineralization of various minerals including tin, tungsten, fluorite, copper, lead and antimony.

3–2 Stratigraphy

The survey area is underlain by the sedimentary, metamorphic and granitic rocks. The sedimentary and metamorphic rocks have been classified into the Precambrian metamorphic rocks, Cambrian and Ordovician sedimentary rocks, pre-Carboniferous metamorphic rocks, Tertiary conglomerate and Quaternary alluvium; and the granitic rocks into the Carboniferous and Triassic granites (GGM, 1972).

By the current survey, more detailed distributions of those rocks were traced, but no evidence were found to change the stratigraphic relations. Therefore, the stratigraphy in this report is described based on the above-mentioned divisions. Nevertheless a part of Triassic granite were thought to belong in Cretaceous age on the basis of the isotopic age determination, which will be described at section of 3–7 in detail.

The geologic map of northern Thailand is shown in Fig. 2 and the schematic geological column is shown in Fig. 3 .

(1) Precambrian Metamorphic Rocks

The Precambrian rocks, consisting of paragneiss and schist, are distributed near the Yong Ku mine in the north end and to the northeast of Mae Lan in the middle of the survey area.

The paragneiss predominates in this sequence and characteristically shows a remarkable gneissosity by biotite as typically observed at the Yong Ku mine. The paragneiss is composed mainly of quartz, potassium feldspar, plagioclase and biotite. The accessory minerals are muscovite, sphene and opaque minerals. The schist contains much biotite and show a schistose structure.

Formerly, the gneissose and schistose rocks distributed in the mountainous region to the west and south of Chiang Mai had been lumped together as the pre-Permian metamorphic rocks (Brown et al., 1951). However, the most part of those metamorphic rocks has been reassigned to the Precambrian sequence and believed to be formed under the influence of the anatexis and granitization in the Precambrian age (Braun et al., 1970, GGM, 1972).

(2) Cambrian Sedimentary Rocks

The Cambrian rocks are distributed in the southeast end of the survey area, forming the rugged mountain masses. This system consists of whitish to gray, medium-grained, massive, crystalline limestone and local intercalations of gray to dark olive shale and fine-grained sandstone.

The limestone has been subjected to skarnization at the contacts with the granite to have formed garnet, pyroxene, epidote and actinolite.

The Cambrian rocks are separately distributed from the Precambrian metamorphic rocks. Therefore, the direct relationship of those two rocks can not be observed. Regionally the Cambrian rocks overlie uncomformably the Precambrian rocks (Braun et al., 1970).

(3) Ordovician Sedimentary Rocks

The Ordovician rocks are distributed in the various places, to begin with, in the surroundings of Mae Long in the west end of the survey area. The sequence consists of limestone, quartzite, schist and calc-silicate rocks.

The limestone shows two modes of occurrence; one is the massive thick beds, over 20 m thick; and the other is thin beds, 1 to 3 cm thick, alternated with the quartzite and schist. The former occurs to the east of the Yong Ku mine, surroundings of Mae Long and middle stream of the Hat river. The thick limestone is whitish to gray, fine-crystallized and fine-banded with limonitic and pelitic streaks. The latter occurs in the places other than those mentioned above and has been altered to the calc-silicate rocks.

The quartzite is thickly distributed in the northwest end and to the west of Sop Lan in the south of the survey area in addition to the alternation with limestone and schist. The rock consists mainly of quartz and feldspar. Minute biotite has been formed in quartz grains. The quartzite to the west of Sop Lan is dark purple and fine-grained, which was probably contained much of pelitic components in origin.

The biotite schist is accompanied with limestone and quartzite.

The calc-silicate rocks are mostly distributed as roof pendants over the granite bodies. These rocks are made from the alternation of the limestone, quartzite and pelitic rocks by contact metamorphism in relation to granites. The rocks are gray to dark olive and show a characteristic rugged outcrop surface; the siliceous layers, 1 to 3 cm thick, are protruded. The constituent minerals are mainly quartz, feldspar, garnet, pyroxene, epidote, wollastonite and calcite. Traces of rutile, sphene and opaque minerals are found. The ratio of the major constituent minerals in each layer is different to each other according to the original rock; wollastonite is abundant in the limestone layers; garnet and pyroxene predominate in the quartzite and pelitic layers.

The Ordovician system is believed to overlie the preceding Cambrian system comformably.

(4) Pre-Carboniferous Metamorphic Rocks

After the Precambrian tectonic movement, the Carboniferous and Triassic movements took place in the survey area. Both of the Precambrian metamorphic rocks and lower Paleozoic sedimentary rocks were metamorphosed by those movements. Therefore, in some places the metamorphic grade of the latter is high enough to rise up, which is difficult to be distinguished from the Precambrian rocks. Accordingly, in this report the metamorphic rocks, excluding those distributed to the east of the Yong Ku mine and to the northeast of Mae Lan (GGM, 1972), are lumped together as the pre-Carboniferous metamorphic rocks.

The pre-Carboniferous metamorphic rocks comprise of biotite paragneiss and biotite schist which are remained small-scale relics of the Paleozoic sedimentary rocks in local.

(5) Tertiary Conglomerate

The Tertiary rocks are widely distributed in the basin around Omkoi at the middle of the survey area. Another distributions are found near Pang Ong Muang in the north and in the vicinity of Sop Lan in the south.

The Tertiary sequence consists mainly of conglomerate, but locally sandstone predominates. The gravels of the conglomerate are mostly boulder-sized breccias and the ratio of the gravel species are controlled by the nearby source area as the granite boulder-predominant part or the metamorphic and sediments boulder-predominant part.

The Tertiary conglomerate covers the older rocks uncomformably.

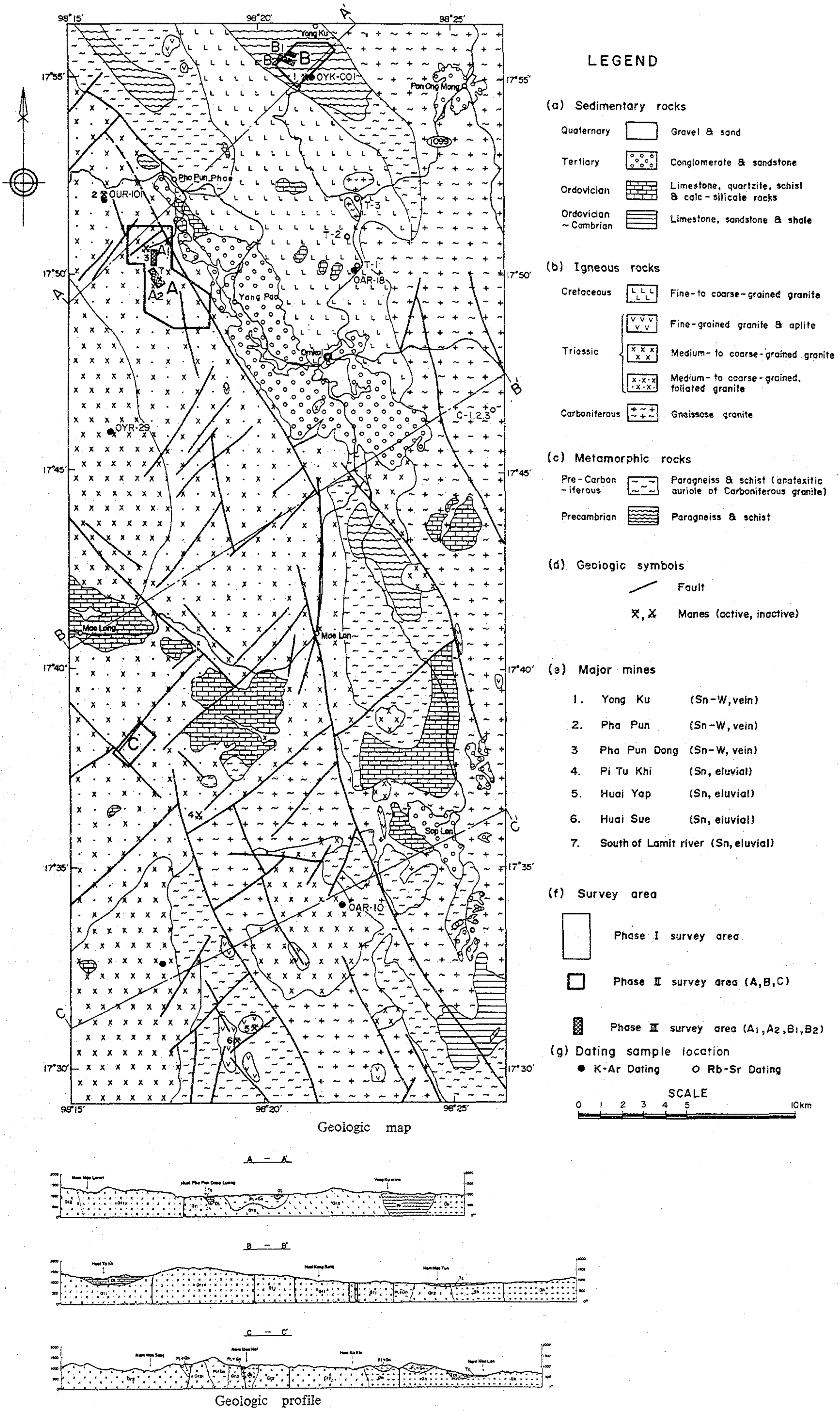


Fig. 2 Geologic Map of Omkoi Area

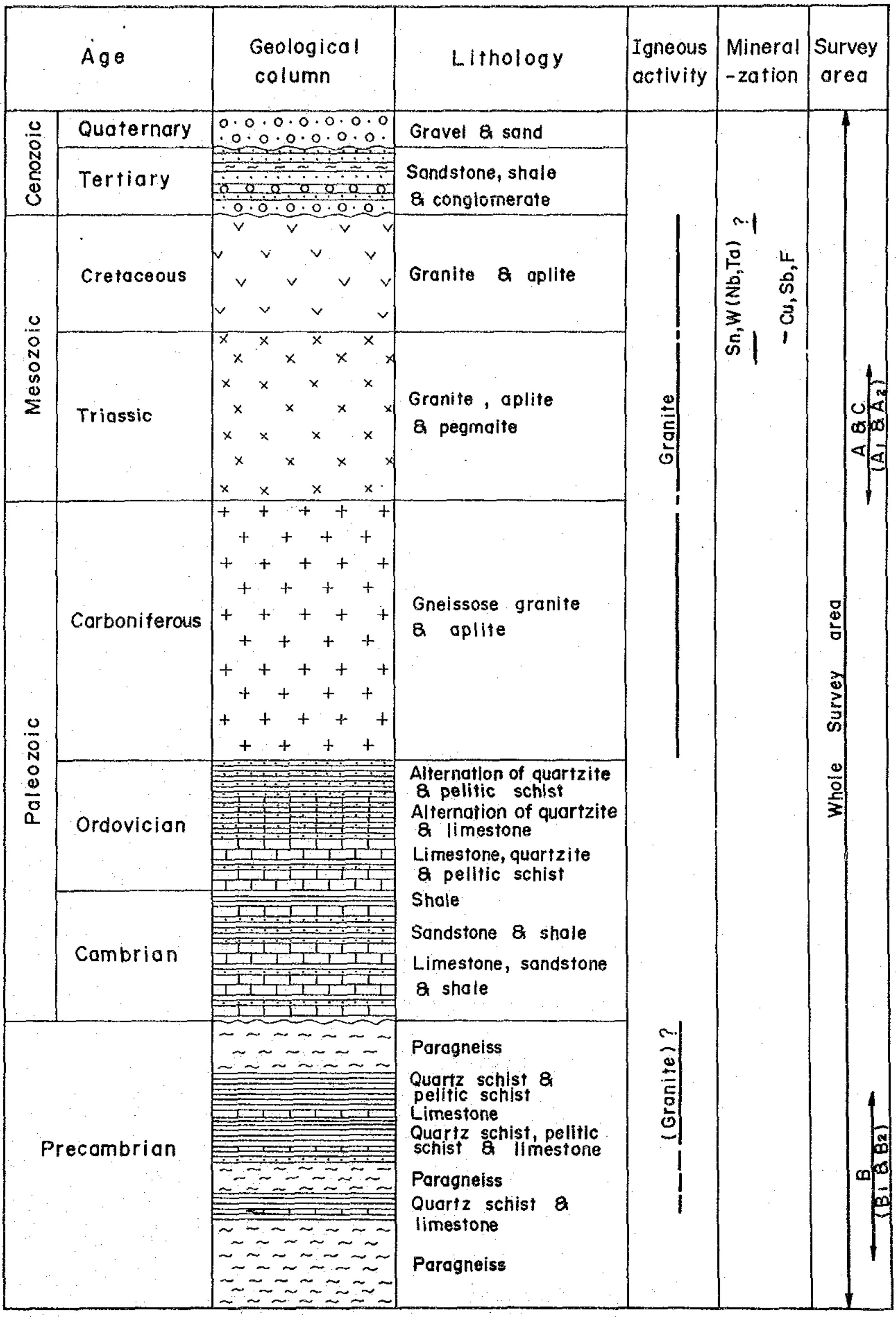


Fig. 3 Schematic Geologic Column

(6) Quaternary Alluvium

The Quaternary sediments are narrowly distributed along the major drainages and consist of unconsolidated gravel, sand and clay.

3–3 Igneous Activity

The granitic activities in northern Thailand took place in the Carboniferous, Mesozoic and Cenozoic ages. The Mesozoic granites are classified into the Triassic one and Cretaceous (extending to the Tertiary) one (GGM, 1972).

In the survey area batholith-shaped and stock-shaped granites widely occupy the most of area; they are classified into the Carboniferous granites, Triassic granites, and Cretaceous granites.

(1) Carboniferous Granites

The Carboniferous granites are extensively distributed in the east and south of the survey area, and forms part of a batholith which extends further eastward.

In most cases, they are holocrystalline, coarse-grained biotite granite including megacrysts of potassium feldspar 2 to 4 cm long, but there is one with fine grains rarely. Generally it presents gneissose structure, with biotite and potassium feldspar disposed in parallel.

Mineral compositions are mainly quartz, potassium feldspar, plagioclase, and biotite; apatite, zircon, and sphene are contained in extremely small quantities. This rock contains a little biotite more than the Triassic granites mentioned later. Opaque minerals are ilmenite and magnetite; the former is contained more than the latter, so that these granites belong to the ilmenite-series granitoid by Ishihara (1977).

(2) Triassic Granites

There are batholith-shaped bodies distributed widely in the west of the survey area, and in addition there are stock-shaped bodies intruded into the metamorphic rocks and the Carboniferous granites.

These granites are classified by the rock facies into the medium- to coarse-grained, foliated granite, medium- to coarse-grained granite, fine-grained granite, aplite and pegmatite.

The first two often contain 2 to 4 cm-long megacrysts of potassium feldspar.

The foliated granite, underlying the western half of the survey area, presents foliated structure with biotite disposed in parallel. This structure is not so distinct as the gneissose structure found in the Carboniferous granites.

The coarse-grained granite occurs as stocks. There are four bodies which are on a comparatively large scale.

The fine-grained granite is distributed as small-scale stocks or dikes.

Mineral compositions in the above-mentioned three facies are almost in common: the major minerals are quartz, potassium feldspar, plagioclase and biotite. Muscovite is contained usually in a small quantity, and not contained at all in some places. Besides these contained are extremely small quantities of apatite, sphene, zircon, rutile, and opaque minerals.

Usually potassium feldspar is contained much more than plagioclase, and almost all of these rocks belong to proper granite. Since there is more ilmenite than magnetite, these rocks belong to the ilmenite-series granitoid by Ishihara (1977).

The aplite and pegmatite occur as dikes in the granite bodies and metamorphic rocks usually in and around of granite mass. The dikes run in the directions of NNE–SSW, ENE–WSW, and NW–SE, which coincide with the directions of the main fracture system in the survey area.

The width of the aplite dikes ranges from 1 to 10 m approximately. The aplite is fine-grained, and its main component minerals are quartz, potassium feldspar and muscovite; locally biotite is found in a small quantity. In some places there are tourmaline and a small quantity of garnet.

The width of the pegmatite dikes widely varies from 0.01 to 5 m, but ordinarily it is in the range of 0.1 to 1 m.

This rock's main component minerals are coarse grains of quartz, potassium feldspar, plagioclase, and muscovite; occasionally biotite is found in a small quantity nearly Youg Ku mine.

(3) Cretaceous granites

The Cretaceous granites are distributed in the middle of northern area and intruded into the metamorphic rocks and Carboniferous granites with stock shape.

There are generally fine- to coarse-grained granite. These granites have no foliated structure and megascopically shows porphyritic texture.

Mineral compositions of these are entirely as same as Triassic granites. Also these granites belong to the ilmenite-series.

Hitherto the granites in question were classified into Triassic age. However, in this paper these are divided into Cretaceous granites. It was reason why the data of isotopic dating of these granites indecated the possibility of Cretaceous age.

3–4 Geological Structure

(1) Folds

Northern Thailand including the survey area has experienced four tectonic movements each in Precambrian, Carboniferous, Mesozoic, and Cenozoic ages, and the geological structure has been made complicated. In the survey area rock exposure is limited along valleys. The intrusion of the Carboniferous, Triassic and Cretaceous granites caused polymetamorphism to the preceding metamorphic and sedimentary rocks, making the age estimation of most of these rocks difficult.

Also their distribution is intermittent. These factors make it difficult to disclose the regional fold structure.

(2) Faults

In the survey area fractures in the directions of NNW–SSE, NW–SE and NE–SW are prevalent, and in addition there are ones in the directions of N–S and E–W. Although the principal structure system throughout northern Thailand is in the north-south direction, this is not so prominent in the survey area; the NNW–SSE and NW–SE systems are the principal structure in and around the survey area. The NE–SW and E–W systems are considered to be the secondary structures to the above.

These faults have remarkably affected the central and southern part of the survey area to become many blocks.

3–5 Ore Deposits

It is said that tin and tungsten ore deposits in northern Thailand are closely related with the Mesozoic granites (GGM, 1972). They are massive ore deposits consequent upon greisenization and skarnization at the top and the surroundings of granite bodies and vein-type deposits of quartz veins and pegmatite veins.

Tin and tungsten are deposits in this area comprise primary area and secondary ones and exist all in and around the Triassic and Cretaceous granites.

The primary ones ore of the vein-type emplaced in granite and in metamorphic rocks; there are three of such deposits: the mines of Yong Ku, Pha Pun and Pha Pun Dong.

The secondary ones are of the small-scale eluvial deposits. The ore exists at the bases of gravel layers which deposited in topographic depressions along streams. There are three of such deposits: the mines of Pi Tu Khi, Huai Yap, and Huai Sue. And so two small mining sites of this type exist.

The ore minerals in the primary ore deposits consist mainly of scheelite and wolframite, which are accompanied by cassiterite, while the ones in the secondary ore deposits consists primarily of cassiterite. The locations of the mines are shown in Fig. 2. The outline of the mines are shown in Table 3.

The states of each mine are as follows.

(1) Yong Ku Mine

This mine situated at the northern most of the survey area. At a distance of 0.4 km to the south of the mine there is the village of Yong Ku. The trip from Omkoi to Yong Ku is about an hour's drive by a four-wheel-drive car on National Highway No. 1099 first and then a mine road which branches off the highway.

This mine is formed of four remains of main opencut mining places in a scope about 200 m by 300 m, drifts in and outside the remains, and a large number of mining pits (Fig. 4).

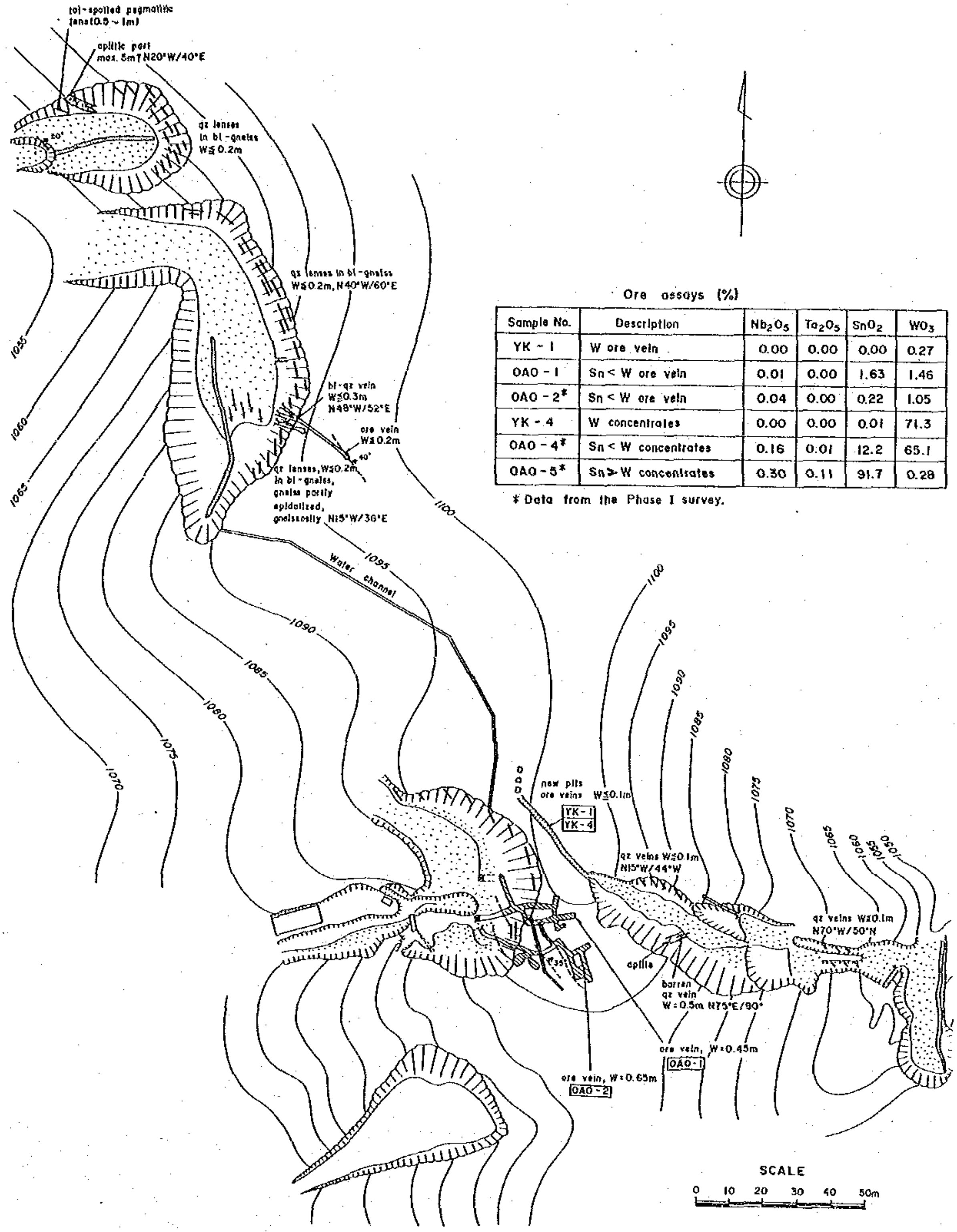
At Yong Ku Mine, since more than 10 years ago, the shallower tin and tungsten-mineralized part on the south side of a ridge, as the main mining object, has been exploited by the water jet mining method and partly by the manual drift excavation method. There are four main drifts, each of which has been driven to an extent from 30 to 50 m. The amount of production from 1981 to 1982 is said to be 300 to 500 kg a month in terms of tungsten concentrate (Vichit and Khuenkong, 1983). As the mining made progress high-grade portions were already exhausted and the excavation reached hard country rock, so that the mining operation has practically come to an end. At present about 10 inhabitants of the village of Yong Ku work on remaining walls and manually excavate drifts into remaining minor mineralized veins at an unexploited ridge.

The mineralized veins are pegmatite veins and quartz veins accompanied by cassiterite, wolframite, and scheelite; they occur in parallel with the gneissic structure of biotite paragneiss (N 25° to 50°W/35° to 70° E), which is the country rock. The scale of each of these veins is generally 2 to 60 cm in width and 10 to 30 m in strike extension, but a case in which a vein could be traced more than 80 m with discontinuities is reported (Vichit and Khuenkong, 1983). Some parts of the pegmatite veins and quartz veins contain tourmaline. Epidote is occasionally observed along quartz veins.

The cassiterite is dark brown or light brown; dark brown cassiterite shows moderate pleochroism. The cassiterite occurs only in local, but it is said that it was found out in more quantity of cassiterite at the remains of mining sites on the northeast side of the ridge.

The wolframite and scheelite are found in almost equal quantities. These minerals are observed in small amounts in the pegmatite veins and quartz veins, but rather are concentrated in hydrothermally biotitized zones developed at the boundaries of these veins in 1 to 10 cm wide. The wolframite is entirely opaque under microscope and rich in iron. The fluorescence of the scheelite under ultraviolet rays is mostly blue, but some grains are light white to light yellow, which suggests the existence of powellitic scheelite in a small quantity.

According to the result of analysis of two ore samples, the content of WO_3 in curde ore from the biotitized zone at the quartz vein boundary is 0.27%, while concentrate of



Ore assays (%)

Sample No.	Description	Nb_2O_5	Ta_2O_5	SnO_2	WO_3
YK - 1	W ore vein	0.00	0.00	0.00	0.27
OAO - 1	Sn < W ore vein	0.01	0.00	1.63	1.46
OAO - 2*	Sn < W ore vein	0.04	0.00	0.22	1.05
YK - 4	W concentrates	0.00	0.00	0.01	71.3
OAO - 4*	Sn < W concentrates	0.16	0.01	12.2	65.1
OAO - 5*	Sn ≫ W concentrates	0.30	0.11	91.7	0.28

* Data from the Phase I survey.

Fig. 4 Geologic Sketch and Ore Assays of Yong Ku Mine scheelite and wolframite has 71.3% of WO_3. The contents of niobium, tantalum, and tin are extremely low in both the two samples.

(2) Pha Pun Mine

This mine situated at the northwestern most of the survey area and to the southeast of Yong Kun mine at a distance of 10.5 km. The trip from Omkoi to Pha Pun mine is about an hour's drive by a car.

This mine is formed of two remains of main opencut mining places in a scope about 150 m by 250 m, and at present aproducing and a deserted draft.

The ore deposit is quartz veins containing tin and tungsten emplaced in the Triassic foliated granite; as a distinguishing mark the veins are accompanied with tourmaline.

The quartz veins have strikes of N 70° and dips of 80 to 90° S; the scale is in the extent of 0.1 to 1.0 m in width, averaging 10 to 30 cm, and a strike length of 10 to 30 m. More than 10 veins are distributed in an echelon form in a scope of 150 m by 250 m.

The ore minerals are formed mainly of scheelite, accompanied with wolframite and cassiterite. The results of analysis of the ore samples are given in Table .

The crude ore shows 5.65% WO_3, but tin is of low grade, and only small quantities of niobium and tantalum are contained.

The mining has been previously finished at opencut mining places and at preset is changed over to underground working. Its operation is mostly carried out by the hand of about ten workers.

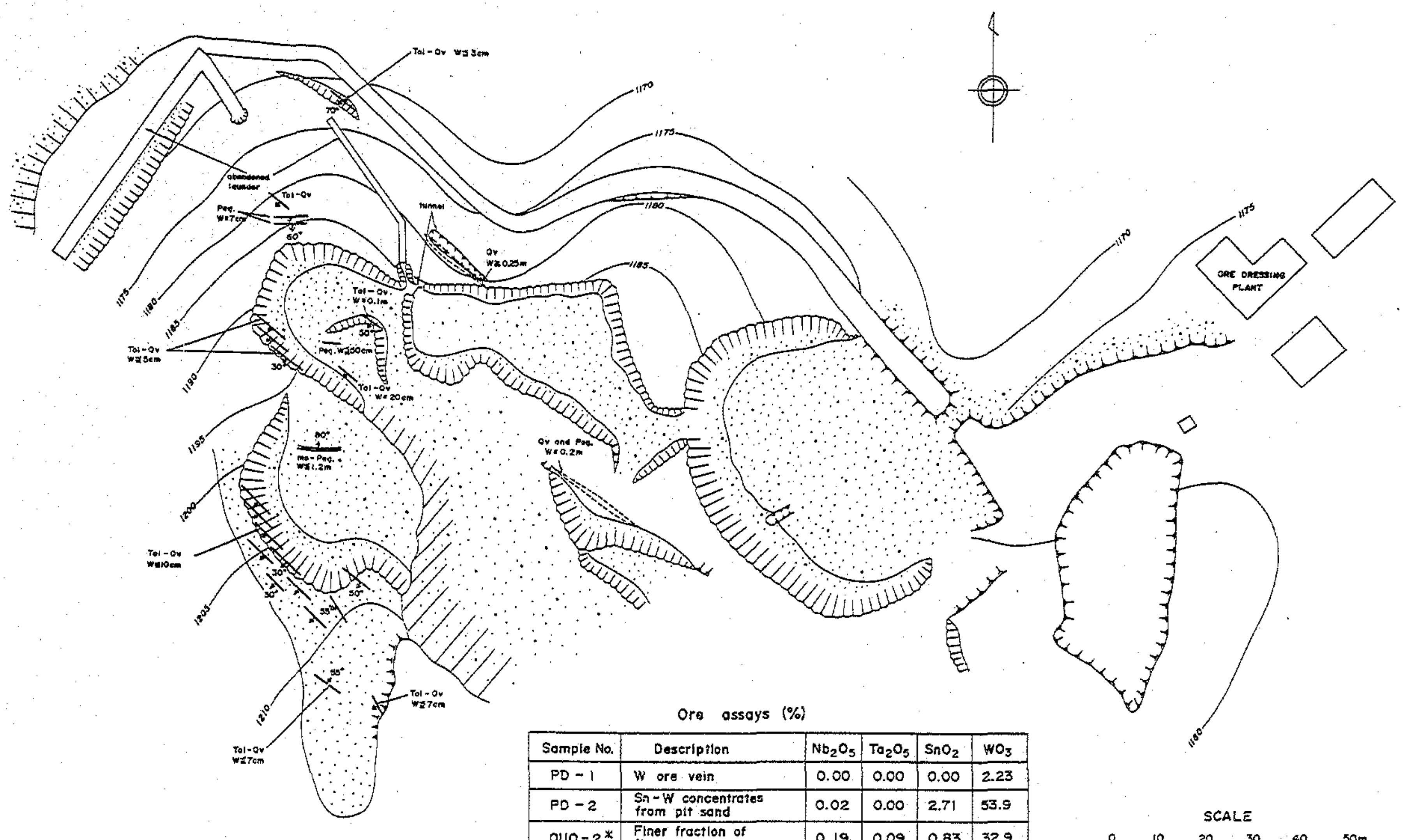
There is an ore dressing plant, though small in scale; the ore is crushed and concentrated with jiggers.

(3) Pha Pu Dong Mine

This mine locates in the northwestern of the survey area and is distanced about 3.5 km to the southeast of Pha Pun mine.

It is formed of a former site of main opencut mining operation (Fig. 5) attached with dressing plant and three former sites of small-scale mining operation located to its north, northwest (Fig. 6), and east-southeast respectively. Around these former mining sites and on main ridges there are a number of remains of trenches, pits and other works. To reach the former site of main opencut mining from Omkoi, one takes an auto road which passes the village of Pha Pun Phae and extends to the west of the area, and then drives on a mine road branching from the auto road. The time required to cover the distance from Omkoi to the former main mining site by a four-wheel-drive car is about an hour.

When a crusher for ore dressing was removed in the summer of 1984, the operation of



Ore assays (%)

Sample No.	Description	Nb_2O_5	Ta_2O_5	SnO_2	WO_3
PD - 1	W ore vein	0.00	0.00	0.00	2.23
PD - 2	Sn - W concentrates from pit sand	0.02	0.00	2.71	53.9
OUO - 2*	Finer fraction of jigger concentrates	0.19	0.09	0.83	32.9

* Data from the Phase I survey.

Fig. 5 Geologic Sketch and Ore Assays of the Main Working, Pha Pun Dong Mine

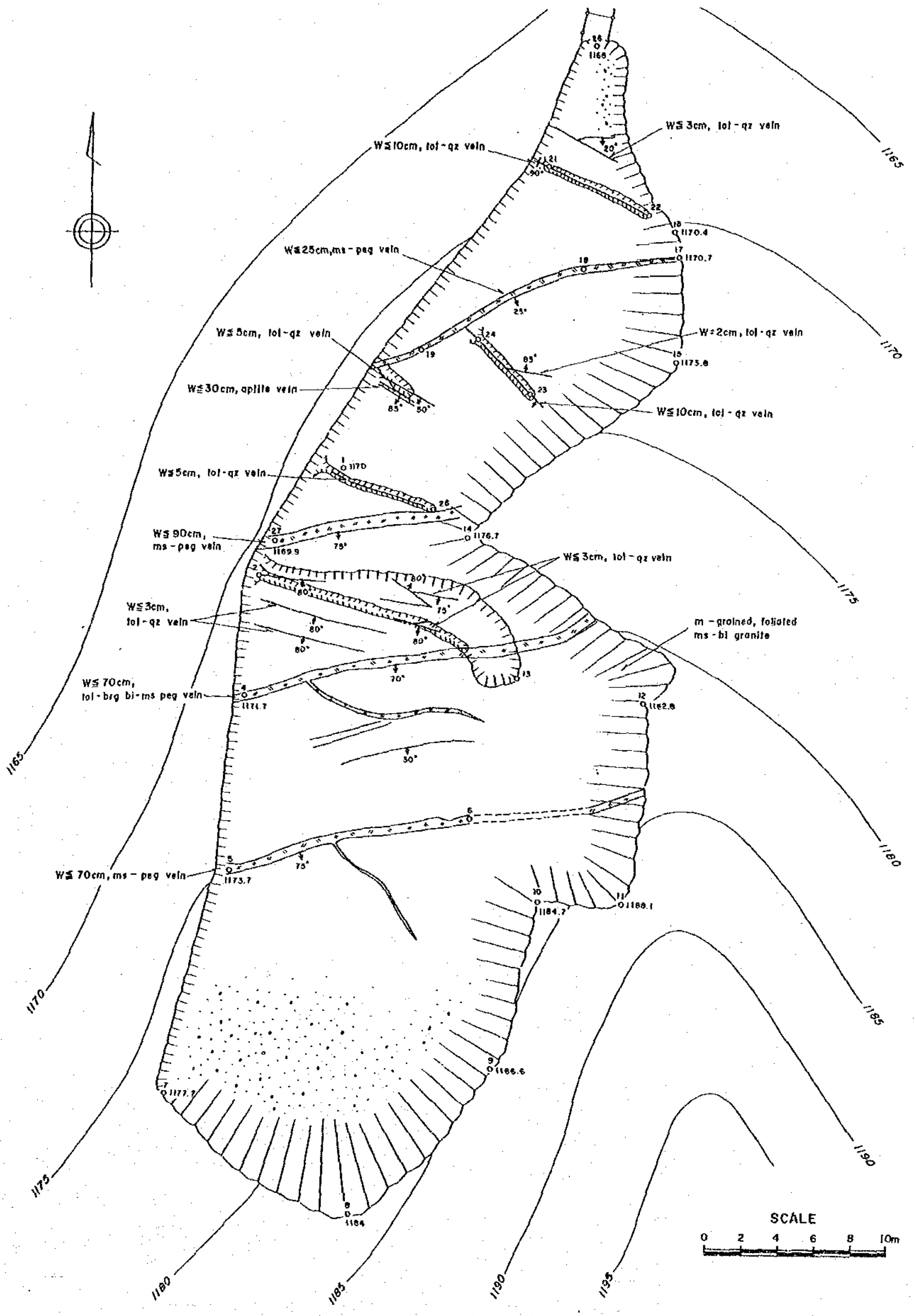


Fig. 6 Geologic Sketch of the Northwestern Old Working, Pha Pun Dong Mine

Pha Pun Dong Mine was suspended (in closed). In the past 15 years before that the mine was run intermittently and it is said that at the early period of operation concentrate of wolframite was produced at the rate of 4 to 5(?) tons a month from the eluvial gravel layer at the surface (Vichit and Khuenkong, 1983).

As the operation made progress, the object of mining shifted to primary mineralized veins in the weathered country rock. So the remain of main operation resulted in a space with an about 100 m by 200 m area and a height difference of about 25 m; and there remain short drifts excavated at three places. In 1983 a tunnel at the north most part was the main place of mining, producing concentrate, principally scheelite, at the rate of 0.4 ton in a month.

Among the former satellite mining sites, the one to the northwest was of a scale of 60 m by 20 m (Fig. 6); its main object of operation was wolframite, and the concentrate was produced at the rate of 0.3 ton a month in 1983. From the former mining site to the north, with an about 15 m x 30 m size, cassiterite was principally produced. The one to the east-southeast, which is of a scale of about 40 m x 80 m, was exhausted before the main mining site, and the production record is unknown.

The mineralized veins are tungsten-bearing pegmatite veins and tin and tungsten-bearing tourmaline-quartz veins with the country rock of medium-grained two-mica granite. At the former mining sites a number of pegmatite veins and tourmaline-quartz veins are found, but mineralized parts among them are only load.

The pegmatite veins are found at the former main mining site and the former small-scale mining site to the north. Their scale is 3 to 120 cm in width; their strike extension ranges from 5 to 30 m; their general strike and dip is in the range of N 70° E/75° S to EW/70° to 85° S. The main component minerals of the pegmatite veins are quartz, potash feldspar, plagioclase, muscovite, and biotite; tourmaline is found only rarely. It is said that pegmatite veins do not contain cassiterite (Vichit and Khuenkong, 1983).

Tourmaline-quartz veins are observed in all the former mining sites. The scale is 2 to 25 cm in width, the strike extension ranges from 5 to 20 cm; the general strike and dip is in the range of N 30° W/30° to 55° W to N 60° W/30° to 70° W, and veins with the strike of EW/85° N are recognized rarely. At the stope wall in the west of the former main mining site, fine tourmaline-quartz veins in the strike and dip of N 45°W/30 to 35°W are arranged in parallel at the intervals of 1 to 2 m.

Generally the pegmatite veins lie in the approximate direction of EW and the tourmaline-quartz veins in the general direction of NW. Regarding which of them precede in their formation, a pegmatite vein in the EW direction cuts across tourmaline-quartz veins at the stope wall in the west of the former main mining site, whereas a tourmaline-quartz vein in the NW direction cuts across an EW–oriented pegmatite vein in the former small-scale mining site to the northwest. These facts indicate that both the pegmatite veins and tourmaline veins were emplaced in multiple stages.

The ore minerals are brown cassiterite, wolframite and scheelite, and usually wolframite predominates. When the ore samples were observed under microscope, the cassiterite was found to be not pleochroic at all or very slightly pleochroic. The wolframite is entirely opaque indicating a high content of iron. Vichit and Khuenkong (1983) obtained the analytical value of the wolframite of this mine: 66.51% of WO_3 and 2.10% of MnO_2.

Also, though usually wolframite is replaced by scheelite along the circumferences and cleavages of its particles, Vichit and Khuenkong (1983) report the case of big scheelite grains (2 x 3 cm) being enclosed by wolframite particles. From this it is presumed that the formation of the wolframite and scheelite took place in multiple stages.

According to the result of chemical analysis of the ore samples, a mineralized vein in which wolframite can be recognized by the naked eye has WO_3 content of 2.23%. Ore concentrate obtained by panning the pit sand at the main site of mining was found to have a SnO_2 content of 2.71% and a WO_3 content of 53.9%.

The contents of niobium and tantalum were only 170 ppm of Nb_2O_5 and 8 ppm of Ta_2O_5 respectively even in the panned concentrate. The minerals of niobium and tantalum accompany pegmatite, and their contents are quite low in such cases as this mine where tourmaline-quartz veins prevail.

(4) Pi Tu Khi Mine

The Pi Tu Khi mine is situated in the southwestern of the survey area and in an eastern tributary of the upperstream of the Mae Hat river; there is a bulldozer road coming to the mine to the mine from Mae Lan.

The ore deposit is an eluvial tin deposit emplaced in the Quanternary sand and gravel

The mining operation was suspended three years ago. The two old mining sites have the area of 30 by 20 m and 50 by 30 m respectively, and the depth is 1.5 m more or less; the scale was evidently small.

The ore minerals are principally cassiterite, and tungsten minerals are contained in an extremely small quantity. Heavy minerals, which are composed mainly of cassiterite less than 1 mm in size, obtained by panning from sand and gravel layers of the remaining walls of an old mining site on the upper streamside, were yielded at the rate of only several grammes for 6.8 kg of its raw material; this suggests that high grade parts were worked out.

(5) Huai Yarp Mine

The Huai Yarp mine is situated in the southwestern most of the survey area and so in a creek branching from the uppermost stream of Mae Ra-a river; it can be reached by a bulldozer road from Mae Lan via Pi Tu Khi.

Its operation is mostly carried out by the hands of about 10 workers. The top soil is removed by bulldozer to expose the sand and gravel layers, then the gravels are eliminated by manual labor, and the concentrate is produced by panning. Wooden sluices are installed but not in use at the time of the survey.

The ore deposit is an eluvial tin deposit emplaced in the base of the Quaternary sand and gravel layer.

The sand and gravel layer, about 2 m thick, have a width of about 30 m at the place where the branching creek joins the river, but as one goes upstream about 100 m, the width becomes narrow to an extent of several meters. The gravels in the sand and gravel layer are mostly of boulder-sized breccia of the fine-grained granite and pegmatite, and accounts for more than 90% volume of the whole sand and gravel layer. Gravels of vein quartz are scarely found.

The ore minerals are mainly cassiterite. Almost of cassiterite is brown one contained in quartz veins; in addition there is a small quantity of black one contained in pegmatite veins. The results of analysis of a panning concentrate show 69.0% Sn and 0.71% WO_3, while niobium and tantalum contents are as low as 0.01% and 0.02% respectively.

In the creek where the mining is under way, the sand and gravel layer has been almost worked out. Mining is about to begin at a small creek on the opposite side, but it is said that tin content is low on this side.

(6) Huai Sue Mine

The Huai Sia mine is located in a branch creek 0.7 km upstream from the Huai Yarp mine. This mine can be reached from the Huai Yarp mine only through a path.

Since 3 or 4 years ago the mining has been carried out by manual labor of 2 or 3 workers.

The deposit is of eluvial tin-containing sand and gravel deposit as same as the Huai Yarp mine. The size of the gravel layer is: the maximum width is about 10 m, the length 60 m, and the thickness about 1 m. Here too gravels account for more than 90% volume of the layer, the ratio of sand fraction is very low. Both in size and ore grade, this mine is inferior to the Huai Yarp mine. The ore minerals are mainly brown cassiterite less than a few millimeters in size, accompanied with fine- to minute-grained scheelite and wolframite.

(7) Working Places at the South of the Lamit River

This working places are located in the south-southeast of Phan Pu Dong mine about

Table 3 List of Mines in the Survey Area

No.	Mine		History of operation	Mining method	Personnel	Production of concentrate	Occurrence			
							Host rock	Ore deposit	Ore minerals	Scope of distribution of mineralization
1	Yong Ku		More than 10 years	Main part: underground (2 tunnels) East side: opencut	10		Precambrian gneiss	Quartz veins: several veins with strike and dip of N10–15°W/30–40°E. Average width of veins underground is 40 to 50 cm, At opencut-mined part, 10 to 20 cm. In underground quartz veins there are biotite-concentrated lenses which contain much scheelite.	Underground: Sch > Wf, Cs	150 m x 250 m
2	Pha Pun		8 to 9 years	Underground and opencut	10~15	2t(?)/month	Triassic foliated granite	Quartz veins: over 10 veins with strike and dip of N70°E/80°–90°S Mean width of veins: 10 to 30 cm, maximum about 1 m strike length of veins is 15 to 30 m. There is much tourmaline.	Sch > Wf, Cs	150 m x 250 m
3	Pha Pun Dong		More than 10 years	Main mine: underground (depth 5 m) 2 nearby places: opencut	20	Main mine: 0.4 t/month Opencut places: {1. 0.3t/month {2. ?	Triassic foliated granite	Quartz veins: most of them with strike and dip of N30–60°W/40–80°S vein width: 2 to 25 cm, rarely 50 cm (?) strike length of veins is about 15 m Much tourmaline is found.	Tunnels: Sch > Wf, Cs Opencut places: {1 Wf(>Sch, Cs) {2 Cs	70 m x 100 m (including old openpit)
4	Pi Tu Khi		Unknown (Operation was suspended 3 years ago.)	(Opencut)	–	–	Quaternary eluvium	Eluvial gravel layer (1 to 1.5 m thick)	Cs > Wf, Sch	2 pits (30 m x 20 m) (50 m x 30 m)
5	Huai Yarp		14 years	Opencut	6	0.15 t/month	Quaternary eluvium	Eluvial gravel layer (2 m thick)	Cs ≫ Wf, Sch	30 m x 100 m
6	Huai Sue		3 to 4 years	Opencut	2 or 3	Very small amount	Quaternary eluvium	Eluvial gravel layer (1 m thick)	Cs ≫ Wf, Sch	10 m x 60 (?) m
7	South of the Lamit river	E	2 years	Opencut	2 or 3	0.05t/month	Quaternary eluvium	Eluvial gravel layer (0.5 to 1.0 m thick)	Cs ≫ Wf, Sch	10 m x 50 m
		W	4 years	Opencut	2 or 3	0.05t/month	Quaternary eluvium	Eluvial gravel layer (0.5 to 1.0 m thick)	Cs ≫ Wf, Sch	10 m x 70 m

Abbreviations: Cs; cassiferite, Sch; scheelite, Wf; wolframite.

1.5 km distant.

In this southern tributaries of the Lamit River in the middle of this area, there are two small-scale working places to exploit cassiterite in the gravel layer. Of the two the west-side one has been operated on and off since four years ago, and the east-side one was opened anew in 1984. The scale of mining operation is about 10 m by 70 m in the west-side working place and 10 m x 50 m in the east-side one, each being dug manually by two or three miners. The amount of production from each since the fall of 1984 has been 50 kg a month in terms of tin concentrate.

The thickness of the paydirt that is mined at the two working places is about 0.5 m in the creek and about 1 m at the footslope; the paydirt is covered by about 1 m-thick over-burden.

The cassiterite content in the paydirt, according to a miner, is 500 to 600 g/m^3 in the sand fraction remaining after the gravels have been removed, in other words, a half teaspoonful cassiterite from one time of panning.

The ore minerals are mainly dark brown to black cassiterite, and the quantities of wolframite and scheelite are small. Very small quantities of columbite-tantalite, struverite-ilmenorutile are contained in the concentrate. The cassiterite's size is 8 mm at maximum and usually 0.5 to 3 mm. Under the microscope it is pleochroic with weak light pink to colorless.

The wolframite is 0.2 to 3.0 mm in size and rich in iron content. Besides this an extremely small quantity of dark reddish brown struverite-ilmenorutile is recognized.

The result of chemical analysis of the panned concentrate was: in the concentrate from the west-side working place, 7.53% of SnO_2, 0.33% of WO_3, 0.2% of Nb_2O_5 and 0.07% of Ta_2O_5. Mineral contents in one cubic meter of the gravel layer was found to be: 35 g of SnO_2, 1.5 g of WO_3, 0.4 g of Nb_2O_5, and 0.1 g of Ta_2O_5. Chemical analysis value of only the cassiterite in the panned concentrate is: 92.3% of SnO_2, 0.06% of WO_3, 130 ppm of Nb_2O_5, and 87 ppm of Ta_2O_5, indicating that very small quantities of niobium and tantalum are contained in the cassiterite. Generally speaking, dark brown to black cassiterite is often contained in pegmatite. The cassiterite produced from the sand of the tributaries of the Mae Lamit River is almost all dark brown to black. It is considered that the cassiterite derives from pegmatite, which accounts for the very small quantities of niobium and tantalum being contained in it.

3–6 Geochemical Characteristics of Granites

Mentioned above, Carboniferous, Triassic and Cretaceous granites have extensively distributed in the Survey Area.

Regarding the origin of granitic magma, recently there have been the classification of granite into the S–type (Sedimentary type) and I–type (Igneous type) (Chappell & White, 1974; White & Chappell, 1977) and the study about the intial Sr isotopic ratio. In other hand, Ishihara (1977) studied that the classification of granite into the magnetite–series and ilmenite–series which is connected with tin · tungsten-molybdenum mineralization is made by the quantity and ratio of magnetite and ilmenite ingranite. In addition to this, Ishihara (1980) made a study of the granitec rocks in the peninsular part of Thailand, in which he designated the areas of tin granite and tin-barren granite according to the alkalilime diagrams.

In this survey of all phases, 67 samples of granitic rocks, which were mainly fine-granite, granite, aplite, pegmatite formed at the end of activities, were offered to the chemical analysis on the main and minor components.

These analyzed data were studied upon the relations between the change of the geochemical properties relating to the differentiation of the granitic rocks and mineralization of niobum, tantalum, tin and tungsten.

As the result of above, most of granites in the survey area were revealed to classify into proper granite in a narrow sense, and into S–type, ilmenite–series and tin-bearing granite.

(1) Classification on the Basis of Main Chemical Components

From the I.C.P.W normative composition in Table 5, corundum has been found in most of samples excepting for two samples (A–13–43 and A–15–41), which confirm the fact that the granitic rocks of the survey area are of peraluminous granite with some partial exceptions. The two samples that have no contain of normative corundum are tourmaline-epidote aplite at places to the east of Pha Pun Dong Mine. Their Al_2O_3 content is 17.1% and 16.9% respectively, which means that these are richest in alumina among the granitic rocks of the Omkoi area. However, their CaO content is 11.99% and 6.13% respectively, which are abnormally high values, bringing about the result that in the norm calculation most of Al_2O_3 is expended on anorthite, etc. Hence the normative corundum is not appeared by calculation.

From the differentiation indexes (D.I.) indicated by the total weight percentages of the normative quartz, orthoclase, albite, nepheline, and kalsilite, it is found that the gneissose granite of Carboniferous age presents D.I. = 68 to 86, but the granitic rocks of Triassic age, excluding the two aplite samples mentioned above, presents not less than 74, and in particular most of the fine-grained granite presents figures not less than 85 and the aplite and pegmatite not less than 90. Although one cannot point out the trend of differentiation over the whole area of the Carboniferous and Cretaceous granitic rocks because the data are limited, the values about the Traiassic granitic rocks, one may say, are in agreement with the change of the main components in course of differentiation from medium- to coarse-grained granite to fine-grained granite and further to aplite and pegmatite.

The exception is the above-mentioned aplite with high CaO content; partly because a large quantity of anorthite was calculated and also wollastonite and diopside were calculated, the differentiation indexes are as low as 44 and 66 respectively. This suggests that there occurred some abnormal phenomena in the process of differentiation of the aplite or the course of intrusion of it or the course of alteration after intrusion. The aplite is epidote-tourmaline aplite; of the two samples, sample A–13–43 has, in terms of the mode ratio, the mineral composition of 20% ± of epidote, 5% ± of tourmaline, 40% ± of plagioclase, 35% ± of quartz, 1% or less of potash feldspar, and 2% ± of opaque mineral; in the mineral composition of Sample A–15–41, epidote content is a little less than the above and tourmaline content is slightly higher. The high CaO content of these aplite samples derives from pidote, tourmaline and calcium-rich plagioclase existing in a large quantity. The calcium-rich plagioclase is contained in mafic rock, and it is usual that such plagioclase is extremely little in such felsic rock as aplite (example: B–15–20).

Although the cause of the high CaO content of the two samples cannot be established yet, the conceivable explanation is that it was formed by a differentiation of an originally high-clacium melt by assimilation of the granite and captured calcareous rock, or that it was affected by some calcium-rich emanation after the emplacement.

When one looks into the relations between the differentiation indexes and the main components and the minor components (Fig. 7), in the main component first, as the differentiation indexes increase, SiO_2 and Na_2 increase gradually, but CaO, FeO, MgO, TiO_2, MnO_2 and P_2O_5 decrease. Al_2O_3, Fe_2O_3 and K_2O do not indicate any distinct relations with the differentiation indexes, and, excluding exceptions, concentrate in the extents of 13 to 15%, 0.1 to 0.8% and 4 to 5.5% respectively. About the trends of these components for each lithofacies, when the Triassic medium- to coarse-grained granitic rocks are compared with the fine-grained granite, aplite and pegmatite, one may say the former generally has relatively high contents of CO, FeO, MgO, TiO_2 and P_2O_5, while the latter has relatively zones. As for the Carboniferous and Cretaceous granite, no particular trend can be grasped because the analytical data are few. About the relations between the minor components and the differentiation indexes, no distinct trend is found with any of niobium, tantalum, tin, tungsten, fluorine and chlorine.

In the classification of the granitic rocks by the diagram of normative quartz, plagioclase, and orthoclase, almost all the samples were plotted in the area of proper granite (Fig. 8 a), which nearly coincides with the results of the field and microscopic observations.

Regarding the origin of granitic magma, recently there have been the classification of granite into the S–type (sedimentary type) and I–type (igneous type) (Chappell and White, 1974;

White and Chappell, 1977) and study from initial Sr isotope ratio. In the classification into the S–type and I–type, four kinds of parameters by principal components are employed. The S–type is distinguished from the I–type as i) when K_2O is about 5%, $Na_2O < 3.2\%$ (while, when K_2O is about 2%, $Na_2O < 2.2\%$), ii) in terms of mole ratio $Al_2O_3/(Na_2O + K_2O + CaO) > 1.1$, iii) normative corundum weight percentage > 1.0%, iv) in the ACF diagram (Fig. 8 b) the values are plotted in the CaO–depleted area. When the collected samples were classified according to the above (Table 4), it was found that thet medium- to coarse-grained granitic rocks are of the S–type according to all the four parameters. This being combined with the data from the Phase I survey, almost all such rock bodies in the Omkoi area are considered the S–type granite, though there are exceptions indicating I–type.

Usually granitic rocks in an orogenic zone belong in the calcalkali rock series, but according to the MFA diagram (Fig. 9 a) some of granitic rocks in the Omkoi area seem to correspond to the tholeiitic rock series. Among the Triassic granitic rocks, coarse-grained biotite granite is relatively rich in MgO, and one can notice that MgO tends to decrease at parts subjected to muscovitization.

Almost all the granitic rocks of the Omkoi area are presumed to have been brought about the granitic magma originating from the sialic material like the case of the granite distributed over Southeast Asia including Thailand, because granite of the S–type is predominant.

(2) Classification on the Basis of Minor Components

In connection with granitic rock and tin · tungsten-molybdenum mineralization, classification of granite into the magnetite–series and ilmenite–series granite because magnetite content is less than ilmenite content according to microscopic observation.

Ishihara (1980) made a study of the granitic rocks of the peninsular part of Thailand, in which he designated the areas of tin granite and tin-barren granite according to the alkali-lime diagram (Fig. 9 b). Regarding the granitic rocks of the Omkoi area, almost all the lithofacies are plotted in the area indicated by the granite of the peninsular part except for the facts that samples of the Triassic medium- to coarse-grained, foliated granite are on the side of high Na_2O and that the pegmatite and aplite are greatly different in composition.

Of the minor components, fluorine and chlorine contents are 60 to 690 ppm and 10 to 130 ppm respectively. The granitic rocks of the Omkoi area have depleted fluorine content as compared with those of the peninsular part of Thailand. However, as for the fluorine/chlorine ratio (Fig. 10 a), they present a little high fluorine/chlorine ratio except for the Triassic fine-grained granite, showing a similar trend to that of the tranitic rocks of the peninsular part of Thailand.

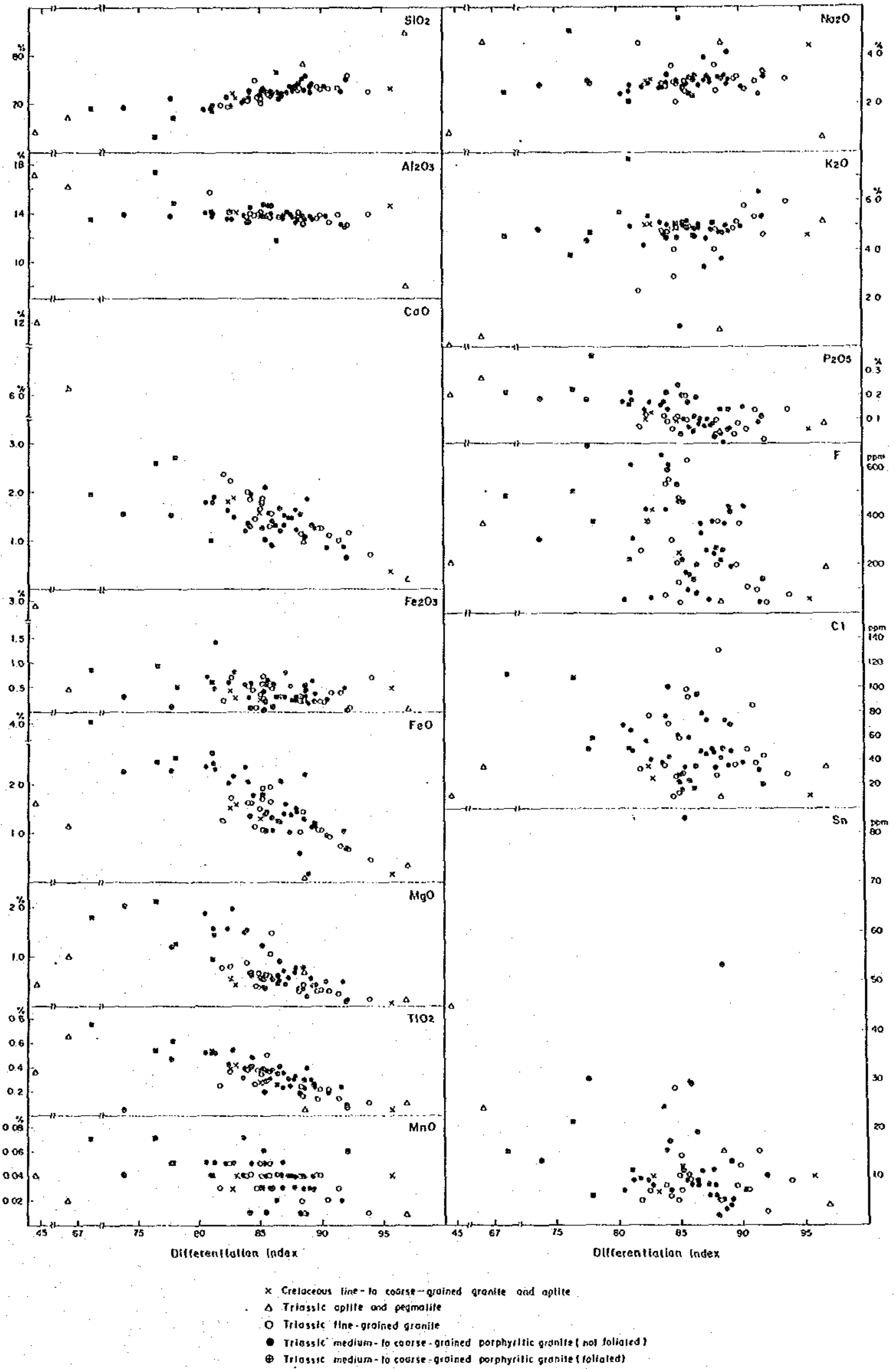


Fig. 7 Chemical Variation Diagrams of Granitic Rocks

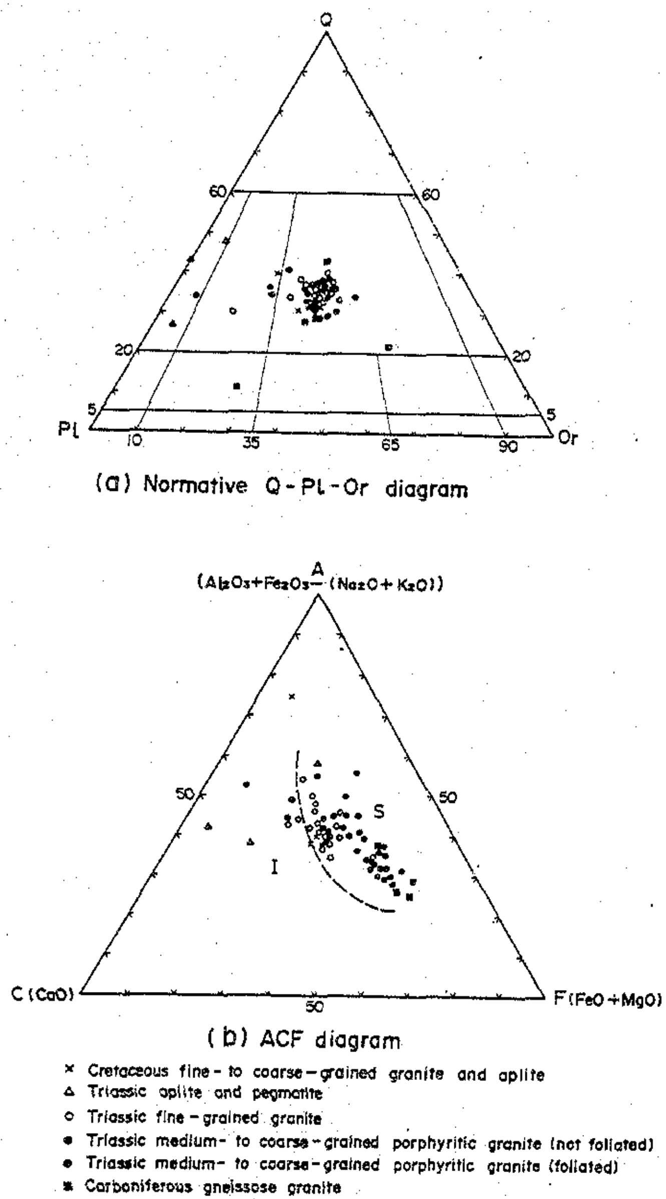


Fig. 8 Normative Q–PL–Or Diagram and ACF Diagram

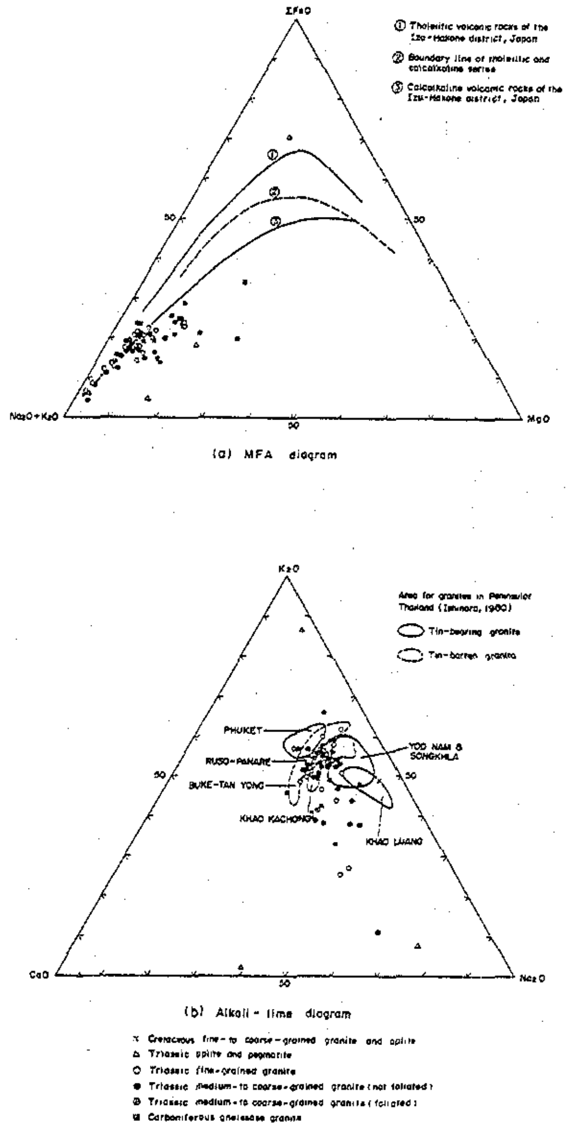


Fig. 9 MFA Diagram and Alkali-Line Diagram

Table 4 S–Type/I–Type Classification of Granitic Rocks

	Sample No.	K_2O/Na_2O	Mol. Al_2O_3/ (Na_2O+K_2O+CaO)	Norm C (%)	A-C-F
Peg.	ONR–14	S	S (1.16)	S (1.26)	I
Fine-grained Triassic granite	OAR– 3	S	S (1.12)	S (1.77)	S
	7	S	I (1.04)	I (0.70)	I
	9	S	S (1.11)	S (1.76)	S
	11	S	S (1.18)	S (2.23)	S
	13	I	I (1.07)	I (0.83)	S
	14	S	I (1.06)	I (0.98)	I
	16	I	I (1.10)	S (1.45)	I
	19	S	I (1.02)	I (0.53)	S
	ONR–16	I	I (1.03)	I (0.39)	I
	26	S	I (1.09)	S (1.13)	S
	42	S	I (1.09)	S (1.31)	S
	44	S	S (1.15)	S (1.96)	S
	OUR– 7	S	I (1.05)	I (0.96)	S
	10	S	S (1.14)	S (1.84)	S
	OYR– 4	S	I (1.10)	S (1.48)	S-I
	6	S	I (1.08)	I (1.05)	S
	15	S	I (1.03)	I (0.61)	I
	27	S	S (1.11)	S (1.65)	S-I
Medium- to coarse-grained Triassic granite	OAR–10	S	I (1.10)	S (1.44)	S
	12	S	I (1.09)	S (1.30)	I
	15	S	S (1.11)	S (2.51)	S
	18	S	I (1.05)	S (1.64)	S
	20	S	I (1.06)	I (1.06)	S
	ONR– 1	S	I (1.08)	I (1.01)	I
	12	S	I (1.06)	I (0.86)	S-I
	15	S	S (1.20)	S (2.64)	I
	27	S	I (1.09)	S (1.27)	S
	29	S	I (1.02)	I (0.62)	S
	30	S	I (1.07)	S (1.22)	S
	32	S	S (1.14)	S (1.82)	S
	33	S	I (1.08)	I (1.07)	S
	34	S	I (1.09)	S (1.24)	S
	35	S	S (1.13)	S (1.81)	S
	36	S	I (1.04)	I (0.96)	S
	39	S	I (1.08)	S (1.15)	S
	46	S	S (1.16)	S (2.19)	S
	61	S	S (1.15)	S (2.09)	S
Foliated Triassic granite	OUR–11	I	S (1.11)	S (1.55)	S
	OYR– 5	S	S (1.11)	S (1.55)	S
	29	S	I (1.08)	S (1.45)	S
	OAR– 1	S	S (1.12)	S (1.18)	S
	4	S	I (1.09)	S (1.50)	S
	17	S	S (1.17)	S (2.49)	S
	ONR– 7	S	I (1.07)	S (1.15)	S-I
	20	I	I (1.06)	I (0.85)	I
	OUR–101	S	S (1.13)	S (1.84)	S
	OYR– 9	I	I (1.07)	S (1.14)	S
Carb. granite	ONR–11	S	I (1.02)	S (1.15)	S
	31	I	I (1.01)	I (0.98)	S

Sample No.	Na_2O-K_2O	Mol. Al_2O_3 / (Na_2O+K_2O+CaO)	Norm C (%)	A-C-F
A–13–43	? (0.75–0.03)	I (0.74)	I (0.00)	I
A–15–41	I? (4.54–0.40)	I (0.89)	S (1.78)	I
B–15–20	I (4.36–4.60)	S (1.14)	S (1.91)	I
C–5–7	I? (4.65–0.72)	S (1.30)	S (3.17)	S
A–35–131	I (3.55–2.89)	S (1.19)	S (2.33)	S
T–2	S (2.84–5.02)	I (1.06)	I (0.95)	S
T–3	S (2.94–5.00)	I (1.03)	I (0.68)	S–I
T–1	S (2.90–5.06)	I (1.07)	S (1.03)	S
A–9–40	S (2.72–5.12)	S (1.16)	S (2.30)	S
A–15–15	S (2.94–4.34)	S (1.11)	S (1.78)	S
A–15–95	S–I (3.19–4.46)	S (1.15)	S (2.32)	S
A–29–146	S (3.11–5.37)	S (1.15)	S (2.01)	S
A–35–169	S (3.08–4.90)	S (1.20)	S (2.75)	S
C–10–13	S (2.73–4.81)	S (1.11)	S (1.74)	S
C–1	S (2.46–4.54)	I (1.08)	S (1.43)	S
C–2	S (2.08–7.69)	I (1.04)	I (0.80)	S
C–3	S (2.28–4.56)	I (1.06)	I (0.74)	S

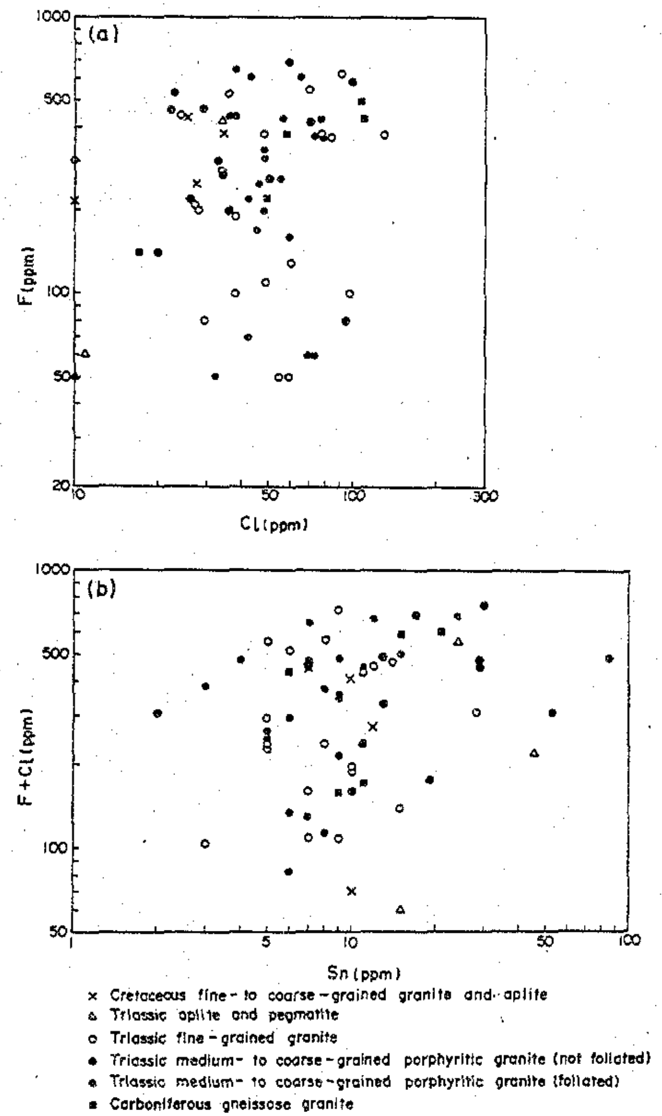


Fig. 10 Cl–F and Sn–(F + Cl) Variation Diagrams

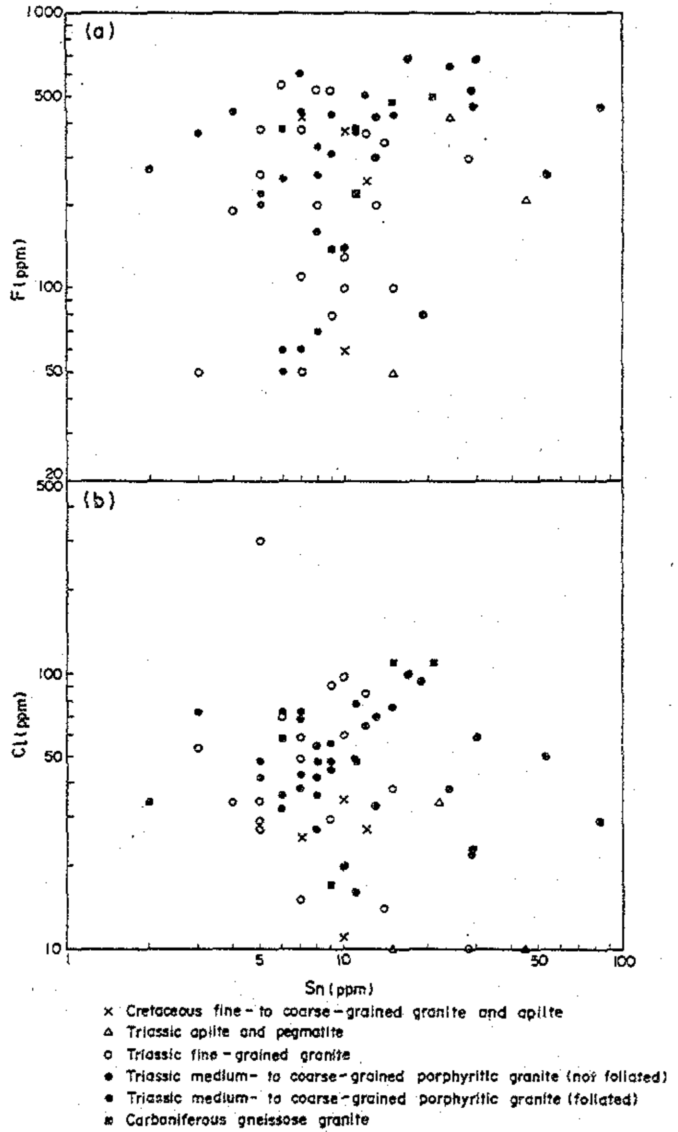


Fig. 11 Sn–F and Sn–Cl Variation Diagrams

The contents of niobium and tantalum are 1 to 58 ppm and 1 to 34 ppm respectively. The maximum value of niobium was obtained from the Carboniferous gneissose granite, and that of tantalum from the Triassic tourmaline-muscovite pegmatite. This pegmatite has a high content of niobium, and almost all niobium-tantalum minerals are presumed to be contained in such tourmaline-muscovite pegmatite. In other rocks, niobium and tantalum contents are practically in the range of 10 to 20 ppm and 1 to 3 ppm respectively, the average contents of them in granitic rocks.

Tin content is in the extent of 2 to 83 ppm; the rocks that present a high tin content of not less than 30 ppm are the Triassic medium-grained two-mica granite found near Pha Pun Mine and at a working face of Pha Pun Dong Mine, coarse-grained biotite granite to the northeast of Pha Pun Dong Mine, and tourmaline-epidote aplite to the east of the same mine. Taylor (1964) reported that the average tin content was 3 ppm; and Tischendorf (1977), with regard to tin mineralization, said the tin content of "normal granites" was 4.3 ppm and that of "metallogenetically specialized granites" 30 ± 15 ppm. Also Yeap (cited in Hosking, 1973) reported that the average value of tin content in tin granite in Malay Peninsula was 6.5 ppm and that in tin-barren granite 5.1 ppm. Ishihara and Terashima (1978) said tin granite in Japan had tin content of 4 to 9 ppm and tin-barren granite 1 to 2 ppm. Almost all the samples of granitic rocks of the Survey area indicate the tin content of not less than 6.5 ppm, which is the average tin content value of tin granite in Malay Peninsula, so the granitic rocks of the Omkoi area come under tin granite.

When the high tin content granite is assumed to have not less than 15 ppm of Sn according to Tischendorf (1977), not less than 15 ppm of Sn content is often recognized in various lithofacies of granitic rock bodies occupying the western half of the Omkoi district, and these granitic rock bodies may be termed high tin content granite.

As for tungsten content, it ranges from less than the detection limit to 500 ppm. The highest value was found from a fine-grained granite sample taken in the Phase I survey, and sample of medium-grained granite from a working face of Pha Pun Dong Mine presents the high value of 41 ppm. In the former, fine grains of scheelite are recognized in quartz veinlets, showing a distinct tungsten mineralization.

The latter has a high tin content, and can be regarded as a typical granite related with tin-tungsten mineralization, though no tin or tungsten mineral can be detected by the naked eye or under microscope. Similar to this is coarse-grained biotite granite at the southwest corner of this area, though its tungsten content is somewhat low.

Now when the correlations between the contents of trace components are considered, in (fluorine + chlorine)/tin ratio, fluorine/tin ratio, and chlorine/tin ratio (Fig. 10 b and Fig. 11

a, b), in a broad way they have a positive correlation respectively, though no obvious trend is indicated for individual lithofacies.

For the correlations between the other components, since the contents of niobium, tantalum, and tungsten are nearly equal except for a few cases, one cannot see any distinct correlation. However, as aforementioned, it is interesting that in this survey area high tin-tungsten granite was found at a working face of Pha Pun Dong Mine and at the southwest corner of the area.

3–7 Age Determination of Granitic Rocks

The granitic rocks distributed in the Omkoi district had been classified into two stage of Carboniferous and Triassic age. Meanwhile, the mineralization of tin and tungsten is closely related with granites and its pneumatolytic and pegmatic vein of Mesozoic and subsequent age. Therefore it is important for the selection of promicing areas to determine the ages of granitic rocks.

About the granitic rocks in northern Thailand, in which the Omkoi district is included, Baum et al. (1970), Braun (1970), Teggin (1975), Braun et al. (1976), and Beckinsale et al. (1979) reported the results of age determination by the Rb–Sr method and K–Ar method.

The granitic rocks are roughly classified, in terms of the Rb–Sr ages, into the early Triassic to the early Jurassic (236 to 190 Ma) and the early Cretaceous (130 ± 4 Ma). In terms of the K–Ar ages too, though generally a little younger values than those in terms of the Rb–Sr ages are presented, broadly speaking the ages agree with the latter in many cases. However, there are cases in which some of the K–Ar ages are much younger than those by the Rb–Sr method. This is interpreted as the result of rejuvenation owing to a hydrothermal process along faults after granitic rock was intruded or the result of subsequent tectonic uplift of granite which had been held at deeper level and at a higher temperature than the closing temperature of K–Ar system (Hutchison, 1983 and others).

Braun et al. (1976) made review of the complex to the northwest of Chiang Mai that was categorized preliminarily as the Carboniferous gneissose granite by Baum et al. (1970) and Braun (1970) and reported that no case had been found in which in northern Thailand the age determination by the Rb–Sr method indicated distinct Carboniferous age.

In this survey, age determination of several granitic mass was examined by K–Ar method using biotite in granite and Rb–Sr method by whole rock. As the result of this study, the granitic mass, which has been thought to be Carboniferous age, presents no exact age. In addition, it has been pointed out a possibility that some of Triassic granites are newly defined as Cretaceous granite.

Locality of samples for age determing shows in Fig. 2 and the result of age determination shows in Table 5 and 6.

(1) Result of Age Determination

Five samples which have been thought to be Triassic age were carried out the age determination by K–Ar method (Table 5). Among these samples, four samples obtained in two granite masses is indicated in late Cretaceous age (70.2 ± 3.5 ~ 65.1 ± 3.3 Ma). A sample in another mass is indicated in early Tertiary age (46.2 ± 2.3 Ma).

When the age determination by Rb–Sr method was examined on the mass which been said to be the Carboniferous, a good whole-rock isochron could not be obtained because the data of each sample deviated too much. So that the age of this mass was unable to be definitely determined. However, on the Tertiary-aged granite by K–Ar method, which is mentioned above, a tentative isochron was found. It was denoted that its Rb–Sr whole-rock age is 87.6 ± 61.2 Ma with a initial Sr isotopic ratio of 0.7115 ± 0.005 shown in Table 6 and Fig. 12. There is a large posibility that this mass is involved in Cretaceous age.

(2) Consideration

(i) Carboniferous grenite mass

The granite mass which was examined in this survey presents a distinct gneissic structure and has undergone intense metamorphism. The sample was taken from a place blasted in the process of dam construction. According to microscopic observation of thin section of the sample, only slight chloritization of biotite and sericitization of feldspar are recognized, but it is the freshest sample so far as one can obtain in the district. The cause of the measurement values not being able to be plotted on one isochron is generally attributed to the following factors: i) assimilation of the crustal materials into magma, ii) complicated magmatic differentiation during a long-time magmatic activity, iii) differentiation of magmas from different original materials although the products appear geologically and petrologically of same origin or iv) effects of weathering, alteration or metamorphism after the solidification of magma (Kagami and Shuto, 1977).

It is usual that considerable dispersion of measurement values takes place with igneous rocks that has been subjected to strong metamorphism (Kagami and Shuto, 1977). It is considered that in many parts of the so-called Carboniferous granite the original Rb–Sr closed system had been broken by metamorphism.

Braun et al. (1976) take a skeptical view of the granitic activity of Carboniferous age in northern Thailand. However, as decisive data are unavailable, these rocks in the Omkoi area are regarded as the Carboniferous granitic rocks as in the past.

(ii) Triassic granite mass

The granite mass indicating the Rb–Sr age of the probably Cretaceous age but the K–Ar age of the Tertiary is distributed to the north of Omkoi with stock form and does not present foliate structure. The K–Ar age of this mass by its biotite is 46.2 ± 2.3 Ma, which means an age difference of about 41 Ma from the Rb–Sr age (87.6 ± 61.2 Ma).

Compared the Rb–Sr ages with the K–Ar ages of the same granite masses in peninsular Thailand, the latters tend to give younger ages; the reason of those inconsistencies are considered to be attributable to the thermal effect caused by faulting and shearing, hydrothermal alternation and igneous activity, etc. (Ishihara, 1980). The similar results have been obtained from the granite belt along the Thai-Burmese border including the survey area; in many cases the Rb–Sr ages are older than the K–Ar ages about the same granite masses. Some granites to the north of the survey area generally show the Rb–Sr ages more than 200 m.y. while the K–Ar ages are in a range from 35 to 108 m.y. (Thanasuthipitak, 1978).

The Rb–Sr whole-rock age expresses the time of a magma being differentiated from its original materials and does not always indicate the time of its solidification. However, in the case of such a small rock body as this, the time from the generation of the magma until its intrusion and solidification can hardly be presumed so long as this age difference. It would be rather presumable that the K–Ar age was affected by a hydrothermal process or the like after the solidification of the magma.

The rock bodies that occupy the western half of the Survey area usually present well-developed foliation, but lack it partially. The K–Ar age of these rock bodies by its biotite is 70 ± 3.5 to 65.1 ± 3.3 Ma (late Cretaceous) with both the lithofaies, and there hardly is any age difference between the two lighofacies. The parts that lack foliation take on the same lithofacies as that of the above-mentioned late Cretaceous granite, which suggest the possibility that these rocks may derive from some magma originating in the later period of the Cretaceous. In the meantime, in northern Thailand, all the granite bodies on the same scale as these complex rock bodies indicate the age of the Triassic. This makes one presume that the foliated parts are of the Triassic. That is, it is possible that, after the intrusion and solidification of a magma in the Triassic, the foliation was formed by a tectonic movement that brought about the Cretaceous granite and that the K–Ar age was reset by the activities of the Cretaceous granitic rocks. However, about these complex rock bodies there is no datum by the Rb–Sr method, and one cannot say anything definite, so that the complex and other small masses are tentatively estimated to be of Triassic age.

As Cretaceous granitic rock in northern Thailand, there is the Mae Lama granite body (130

Table 5 K-Ar age determination of granitic rocks and biotite paragneiss

Sample No.	Coordinates E	Coordinates N	Rock description	Mineral	K (%)	^{40}Ar rad (scc/gm x 10^{-5})	Atm.^{40}Ar (%)	Age (Ma)
OAR–10	433.1	1942.4	Coarse-grained muscovite-bearing biotite granite	Biotite	4.60 4.63	1.19 1.19	74.3 76.8	65.1±3.3
OAR–18	433.9	1972.2	Fine-grained muscovite-biotite granite	ditto	4.90 4.91	0.882 0.901	73.9 68.3	46.2±2.3
ONR–61	424.2	1939.3	Coarse-grained muscovite-bearing biotite granite	ditto	7.02 7.06	1.96 1.96	84.9 85.4	70.2±3.5
OUR–101	422.3	1975.4	Medium-grained, foliated muscovite-biotite granite	ditto	7.48 7.56	2.09 2.09	87.0 84.2	70.1±3.5
OYR–29	422.8	1964.4	Coarse-grained biotite granite	ditto	6.50 6.51	1.79 1.79	83.6 85.4	69.4±3.5
OYK–001	431.4	1981.0	Yong Ku mine Biotite paragneiss	ditto	5.07 5.08	0.579 0.588	64.4 63.4	29.3±1.5

The analysis was performed in duplicate.
The constants for the age calculation are: $\lambda\beta = 4.96 \times 10^{-10}$ year^{-1}, $\lambda e = 0.581 \times 10^{-10}$ year^{-1}, $^{40}K/K = 1.167 \times 10^{-4}$.

Table 6 Rb-Sr age determination of granitic rocks

Sample No.	Rock description	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Model age (Ma)
C–1	Coarse-grained gneissose, porphyritic melanocratic biotite granite	417.04	107.81	11.19	0.75333±0.00006	
C–2	Medium-grained gneissose, porphyritic biotite-granite	538.55	149.37	10.43	0.73854±0.00007	
C–3	Medium-grained gneissose, leucocratic biotite granite	315.18	91.84	9.93	0.75473±0.0013	
T–1	Medium-grained porphyritic muscovite-biotite granite	314.09	120.40	7.55	0.71983±0.00004	
T–2	Fine-grained biotite granite	297.20	129.33	6.65	0.72086±0.00004	87.6±61.2
T–3	Fine-grained muscovite-bearing biotite granite	271.29	153.62	5.11	0.71784±0.00013	

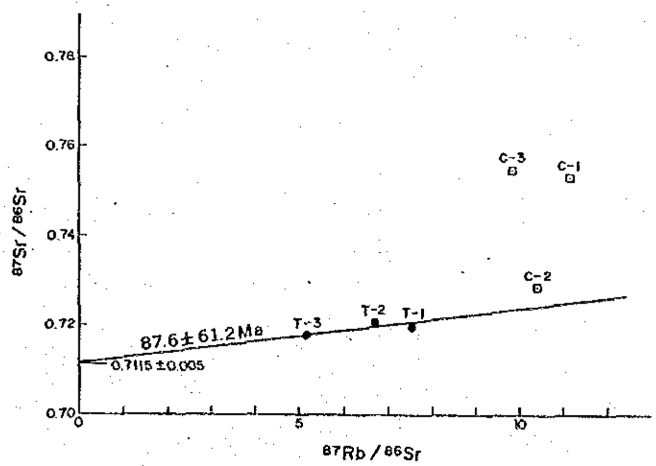


Fig. 12 Rb-Sr isochron diagram

± 4 Ma of the Rb–Sr age; Beckinsale et al., 1979) lying about 50 km west of the Omkoi district. On the margin of this rock body and in its surrounding sedimentary rocks, there occur tin and tungsten-mineralized veins, which are mined by Mae Lama Mine and other mines. Braun et al. (1976) consider the Rb–Sr age of greisenized parts along mineralized veins to be 78 Ma, the K–Ar age of the muscovite of the rock body 72 Ma, and the K–Ar age of biotite 53 Ma. From these data, Beckinsale (1979) says that the Mae Lama rock body, after being intruded at 130 Ma (earliest Cretaceous), was subjected to a hydrothermal process and mineralization accompanied by tin and tungsten about 70 Ma (latest Cretaceous). In the peninsular part of Thailand the Cretaceous granitic rocks are closely associated with tin and tungsten mineralization (Garson et al., 1975 and others).

So that the possibility of the Cretaceous granite in this area following the Mae Lama granite would offer a significant piece of data for studying the relations between the granitic activities and mineralization of tin tungsten and other metals in northern Thailand.

For reference, the K–Ar age by biotite in precambrian paragneiss adjacent to lead of Yong Ku mine was 29.3 ± 1.5 Ma in the late Tertiary (Table 5). There is a large possibility that the age of gneiss was repeatedly rejuvenated by the influence of hydrothermal process. On the other hand, it is also considered that these tipical gneissose structure occured with mineralization, because this structure is parallel to a lead swarm and particularly develops around the ore deposits.

CHAPTER 4 GEOCHEMICAL PROSPECTING BY STREAM SEDIMENT

CHAPTER 4 GEOCHEMICAL PROSPECTING BY STREAM SEDIMENT

4–1 Method of Sampling and Chemical Analysis

(1) Sampling

The geochemical sampling work was made along the main rivers in parallel with the geological survey. The samples were collected from the tributaries of the main rivers, with intervals of 400 to 500 meters as a rule. At each sampling point sand at a depth of 20 to 30 cm at the middle of a stream was taken and screened with 80 mesh sieves, and the –80 mesh fraction, 50 to 100 g, was taken as a geochemical sample.

The total number of the collected samples is 1,259; and the sampling density is one sample per 0.79 km^2.

These samples were air-dried, and offered to chemical analysis.

(2) Method of Chemical Analysis

(i) Pathfinder elements

Since the object mineralization zones of this prospecting were tin/tungsten deposits accompanied with niobium and tantalum, pathfinder elements were selected to be the seven elements of niobium, tantalum, tin, tungsten, beryllium, lithium and fluorine.

(ii) Chemical analysis

The chemical analysis were made by inductively coupled plasma emission spectrography for niobium, tantalum, tin, tungsten and beryllium, by flame emission spectrography for lithium, and by ion electrode method for fluorine.

4–2 Data Analysis

(1) Classification of Anomaly

As mentioned above, the geochemical data were classified into four populations according to the bedrock lithofacies, and for each pathfinder element, it was tried to determine the threshold applying the method of Lepeltier (1969) using by diagram of cumulative frequency distributions.

Using the thresholds, mean values (M), and standard deviations (σ), the classification of the anomaly and background levels was made as shown in Table 7.

Table 7 Classification of Geochemical Background and Anomaly

ppm

Element	Background		Anomaly		
	Low	High	Low	High-1	High-2
Nb	25	38	80	160	
Ta	8	12	20	50	
Sn	10	20	33	56	
W	16	32	120	270	
Be	4.0	7.0	10.5	–	
Li	20	42	82	–	
F	230	440	850	–	

(2) Distribution of Anomaly Areas

On the basis of the classification of geochemical anomaly described in the preceding section, anomaly areas for each element were picked out. It has been premised that an anomaly area here is formed of two or more anomaly points adjacent to each other in a certain drainage system. For an isolated anomaly point in a drainage system, just its anomaly level was shown. The anomaly areas in the above-mentioned plans are described as follows:

i) Niobium

Around the Yong Ku mine, at an area to the west of Yang Pao Tai Village, and an area in the south of the survey area, anomaly areas are distributed.

In the surroundings of the Yong Ku mine, small- to medium-scale anomaly areas were found as if they encircled a stock-like granite body, but no high anomaly values were included.

To the west of Yang Pao Tai Village a comparatively large anomaly area including both high anomaly areas is distributed.

In view of its location, it is considered to derive from some ore showings other than the two mines of Pha Pun and Pha Pun Dong which are situated to its north.

In the south of the survey area small-scale anomaly areas are scattered, and three of them on the west side are aligned in the north-south direction.

ii) Tantalum

The anomaly areas are distributed almost overlapping with those of niobium. Around the Yong Ku mine, to the west of Yang Pao Tai Village, and at the west end of the survey area, disposed in the north-south direction, anomaly areas were found.

Around the Yong Ku mine, there are two anomaly areas located near the mine and along the gneiss distribution extending to the southeast; only near the mine high anomaly values were recognized.

The anomaly area to the west of Yang Pao Tai Village is a relatively large one including both high anomaly areas, almost overlapping with the niobium anomaly area.

At the west end of the survey area several anomaly areas are distributed, arranged in the north-south direction; the biggest one among them is a wide area, distributed in the form of a belt extending north and south and including several high anomaly value areas.

iii) Tin

Around the Yong Ku mine, to the west of Yang Pao Tai Village, and from the middle west to the south of the survey area; anomaly areas are found.

Around the Yong Ku mine there is only a small-scale anomaly area deriving from the mine.

The anomaly area to the west of Yang Pao Tai Village almost overlaps with the niobium and tantalum anomaly areas and includes high anomaly areas, but its distribution is a little smaller than the niobium and tantalum anomaly areas.

In the middle west to south area, there is a large low anomaly area enveloping midium-class anomalies originating from the Huai Yarp and Huai Sia mines; in addition scattered are small-scale anomaly areas around this area.

iv) Tungsten

Anomaly areas are distributed in the surroundings of the Yong Ku mine, around the Pha Pun and Pha Pun Dong mines, and from the middle to the south of the survey area.

The anomaly area in the surroundings of the Yong Ku mine is a high anomaly value area originating from this mine, presenting no halo.

The anomaly area around the Pha Pun and Pha Pun Dong mines is a comparatively large one including high anomaly value areas deriving from these mines. The anomaly areas of niobium, tantalum and tin mostly overlap with this though they shift north to a little extent.

In the middle to the south, small-scale low anomaly value areas are scattered in the granite area, particularly corresponding with the granite stocks. Around the Huai Yarp and Huai Sia mines high anomaly value areas are found but do not spread out.

v) Beryllium

There are several medium- to small-scale, low anomaly value areas of beryllium which are distributed, arranged in the north-south direction, at the west end of the survey area.

vi) Lithium

There are low anomaly value areas of lithium distributed broadly from the middle to the south of the survey area; they nearly correspond with the distribution

vii) Fluorine

There are low anomaly value areas widely distributed from the middle to the south of the survey area ; their distribution is similar to those of lithium but occupies an area expanding a little wider eastward.

(3) Evaluation of Geochemical Anomaly Areas

As the result of the above-mentioned geochemical prospecting, it has been revealed that the anomaly areas for the four elements, niobium, tantalum, tin and tungsten, present overlapping distribution particularly near the known ore deposits. Accordingly, the highest potentialities of mineral indications in the Survey Area are considered to lie in these areas of overlapping anomaly distribution (Fig. 13).

When one attaches importance to this point and narrows down the picked-out anomaly areas further to promising areas, the following three areas are offered. The evaluation of them is described in the following:

i) Niobium-tantalum-tin-tungsten overlapping anomaly area near the Yong Ku mine

The ore deposits of the Yong Ku mine consist of quartz veins and pegmatite veins accompanied by tin and tungsten mineralization, which form groups of thin veins along the gneissic structure of the country rock in the NE–SW direction. The picked-out anomaly area is distributed in the direction of known vein groups and their extensions, and possibly suggests the existence of mineralized veins on the extensions of known mineralized veins or in parallel with them.

ii) Niobium-tantalum-tin-tungsten overlapping anomaly area near the Phan Pun and Pha Pun Dong mines

The ore deposits of these two mines consist of quartz veins and pegmatite veins accompanied by tin and tungsten minerals; thin mineralized veins occur in large numbers, forming vein groups, in the NW–SE or E–W direction, which is the principal geological structure at the respective two mines. In the picked-out anomaly area, high anomalies are recognized in the southeast extensions of particularly the Pha Pun Dong mine vein group, including known vein groups. There the possible occurrence of a mineralized vein is suggested.

iii) Tantalum anomaly area to the west of Pi Tu Khi mine

Niobium anomaly areas are found locally in an overlapping form. Although no particular signs of mineral indications have been found on the surface, there is a possibility that the picked-out anomaly area indicates the occurrence of a primary ore deposit, which has brought about the secondary tin ore deposit around this area.

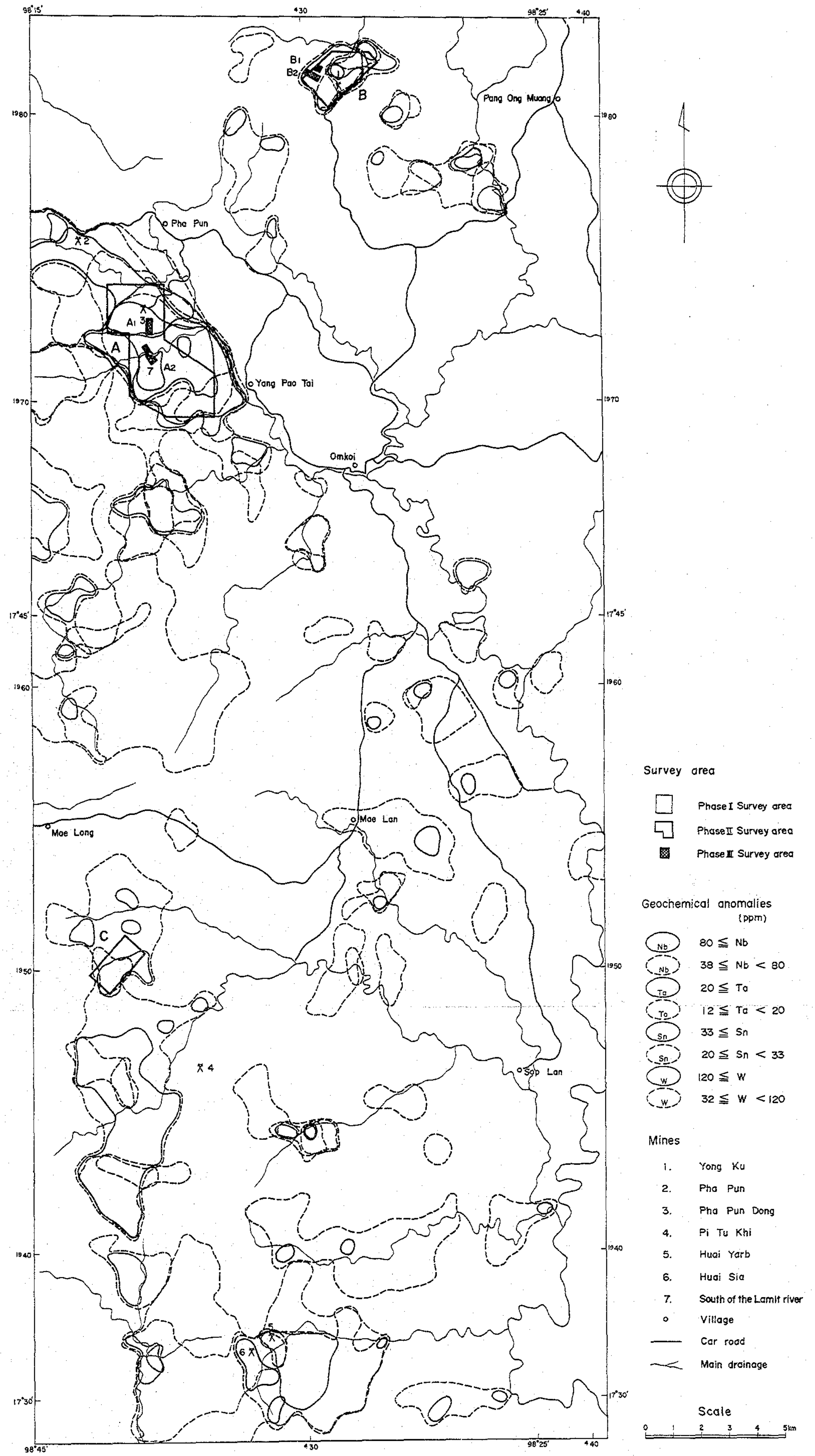


Fig. 13 Location of Mines and Distribution of Nb, Ta, Sn, W Geochemical Anomaly Area

CHAPTER 5 SURVEY OF AREA A

CHAPTER 5 SURVEY OF AREA A

5–1 Location

The Area A is situated about 10 km northwest of the town of Omkoi, and Pha Pun Don Mine is located in the north of this area. Its area is 10.4 km^2.

The three rivers of Huai Pha Pun Dong, Lamit and Huai Pong run eastward in the north, middle, and south of the area respectively, and join the river of Tun. The survey area, encircled or divided by these rivers, is a rugged mountainous district with relative height between an altitude of 800 m and one of 1,300 m.

On the northeast side of this area an auto road runs northwest from Omkoi, passes the villages of Ban Yang Pao and Pha Pun Phae, and extends westward; a road for exclusive use by Pha Pun Dong Mine branches from this road. The south of this area can be approached only by footpaths.

In this area, as the result of the geochemical prospecting in the preceding year, high anomalies of niobium, tantalum, tin, and tungsten were found to be overlapping each other. Among them the anomaly of tungsten was found to center on Pha Pun Dong Mine, but the high anomaly areas of niobium, tantalum, and tin are some way away southward from it, suggesting existence of another mineralization zone.

5–2 Geologic Mapping

(1) Geology

This area is situated in the north of the Triassic foliated granite body distributed over the western half of the Omikoi area. Almost all of the area is occupied by granitic rocks, but Quaternary alluvium is distributed along major rivers (Fig. 14).

The Triassic granitic rocks are classified by the lithofacies and component minerals into medium- to coarse-grained biotite granite, medium- to coarse-grained two-mica granite, fine-grained biotite granite, aplite, and pegmatite. Among these, the first two kinds of granite and part of the aplite have development of foliation by mafic minerals.

(i) Medium- to coarse-grained biotite granite (Gtlb)

This granite, distributed mostly over the periphery of the area, has the features of porphyritic texture due to potash feldspar phenocrysts, ordinarily 1 to 3 cm in size, and of foliation due to biotite. According to microscopic observation of representative samples, out of primary minerals, quartz, perthitic orthoclase, plagioclase, and brown biotite as main component minerals, and apatite and ilmenite as accessory minerals, are observed. As for secondary minerals, chlorite which has replaced part or the whole of biotite, acicular sericite which has replaced part of plagioclase and pyrite are recognized.

(ii) Medium- to coarse-grained two-mica granite (Gtlm)

This rock, mostly distributed over the middle of the area, has the features of porphyritic texture due to potash feldspar phenocrysts, ordinarily 0.5 to 2 cm in size, and foliation due to brown biotite. On the other hand, in the south of the area some of the above-mentioned medium- to coarse-grained biotite granite, subjected to muscovitization along large numbers of aplite veins and pegmatite veins, has been reduced to fine grains; this also is included in this category. According to microscopic observation of the representative samples of this rock which is porphyritic, main component minerals are quartz, perthitic orthoclase, plagioclase, brown biotite, and muscovite; accessory minerals are apatite, rutile, zircon, sphene and opaque mineral. As for secondary minerals, epidote has formed as a minute-grained crystalloblastic mineral; chlorite has replaced part of biotite; sericite has replaced the inside of feodspar. Muscovite, though the quantities varies from sample to sample, has often replaced biotite along the peripheries or cleavages.

(iii) Fine-grained biotite granite (Gt3)

This granite is distributed as small-scale dikes or sheets in the north-south direction. Among them dikes distributed to the southwest of Pha Pun Dong Mine are usually yellowish brown and contain potash feldspar phenocrysts of a 1 cm size. On the other hand, a small dike in the lower reaches of the Pong Noi Creek does not contain potash feldspar phenocrysts. Main component minerals of all of these are quartz, orthoclase, plagioclase, and biotite.

(iv) Aplite (Ap)

Aplite is found in various parts of the area as small-scale dikes or sheets. Among them aplite in the surroundings of Pha Pun Dong Mine presents conspicuous foliation due to tourmaline and/or epidote. According to microscopic observation of these, main component minerals are quartz, plagioclase, orthoclase, tourmaline, and opaque mineral, but the quantity of orthoclase is remarkably smaller than that of plagioclase. Aplite which appears light yellow green to the naked eye contains epidote at the rate of more than 20% of model composition. On the other hand, garnet-bearing biotite aplite is recognized in the Pong Noi Creek in the south of the area. The poikilitic garnet, about 4 mm in size, contains quartz, biotite, and muscovite. This aplite contains an almost equal amount of quartz, orthoclase, and plagioclase, and presents a mineral composition which may rather be classified into granite. Along the Lamit River the light pinkish muscovite aplite has intruded into two-mica granite in the northwest trend.

(v) Pegmatite (Pg)

Pegmatite occurs at various parts of the area in the form of small-scale veins of a width ranging from 0.1 to 2 m. Most of it is muscovite pegmatite. It contains biotite, tourmaline and garnet at some places. The direction of pegmatite veins is almost E–W/30° to 80° S at Pha Pun Dong Mine and a former site of mining to its northwest, but often is WNW–ESE/30° to 90° S in the other places.

(vi) Alluvium (a)

The Quaternary alluvium is distributed in narrow and small forms along the middle reaches of the Lamit River and Pong Yai Creek. It is formed of gravels and sands derived from the Triassic granitic rocks and quartz veins.

(2) Geological Structure

The medium- to coarse-grained biotite granite, medium- to coarse-grained two-mica granite, and some aplite which take up almost all of this area have well-developed foliation, and as mentioned later great numbers of quartz veins and silicification zones owing to quartz veins are distributed over this area. The foliation in the granitic rocks could suggest the form of intrusion of rock bodies or their internal structure. However, since generally there are only a small number of outcrops in the area and reliable data are not available because of creeping except for some parts along valleys, the intrusion form or the like has not been presumed yet. However, the general strike of measurable foliation was found to be NNW to NW, which coincides with the direction of extension of the rock bodies.

On the other hand, the dikes and quartz veins are considered to indicate the fracture systems in the area. In this area faults in the direction of NE to NNE are presumed to run over a zone covering the middle reaches of the Lamit River, Pong Noi Creek and Pong Yai Creek. Also lineaments can be roughly divided into NS to NNE, NE to NNE, and NW to WNW by aerial photographs. The dikes and quartz veins can be reduced largely to the directions of NNW to NS to NNE, NE to NNE, E to W, and NW to WNW; their directions generally coincide well with those of the faults and lineaments except for the direction of E–W.

When the period of the formation of the dikes and quartz veins biotite granite was intruded, so it is judged that this is the direction of fissures formed in a comparatively early stage.

This is followed by aplite, pegmatite and high-temperature quartz veins containing tourmaline. These are oriented mostly in NW to NNW or NE, and it is presumed that fissures in these two directions were formed following the fissures in the NS direction.

As for low-temperature quartz veins which are inferred to have been formed at the final stage of mineralization and alteration, the NE direction is predominant, and the fissures in the NE direction are considered to be relatively younger ones in this area.

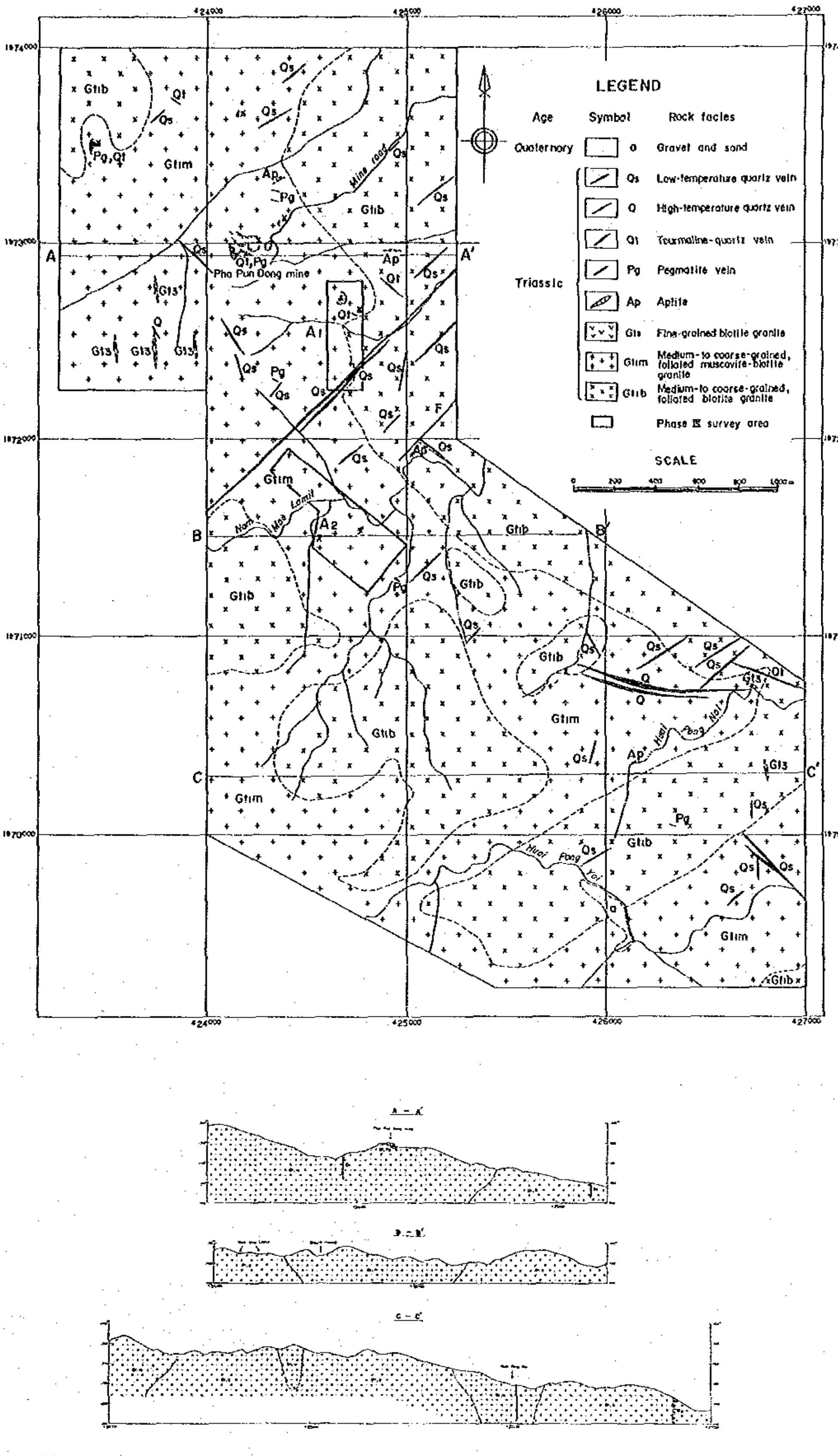


Fig. 14 Geologic Map of the Area A

(3) Alteration

Muscovitization of the medium- to coarse-grained biotite granite and silicification owing to the low-temperature quartz veins are observed in this area, except for weathering. Regarding muscovitization, generally two-mica granite in Southeast Asia including Thailand occurred when biotite granite was subjected to pneumatolysis or a hydrothermal process and part of the biotite was replaced by muscovite (Hutchison, 1983); this was confirmed by microscopic observation of these two rocks of this area. In the area pegmatite that suggests a remarkable pneumatolytic stage is found only partially, and the muscovitization is considered to have been caused by some hydrothermal process that brought about the high-temperature quartz veins containing tourmaline. From the viewpoint that the quantity of contained muscovite indicates the extent of the hydrothermal process, comparatively high content of muscovite found frequently in the surroundings of Pha Pun Dong Mine, the former site of mining to its northwest, and both the banks of the middle reaches of the Lamit River, suggests that the high-temperature hydrothermal process in this area was intense at these places.

Silicification caused by the low-temperature quartz veins is recognized at various places. Their width comes up to about 10 m at times; they are milk-white to gray, fine-grained to aphanitic, and have fine-banded agate at some places.

The silicification extends to a width of five meters at maximum from the boundary of a quartz vein, and the structure of the country rock remains occasionally in the form of breccia.

According to microscopic observation, the silicified rock is an aggregate of chalcedonic quartz, 0.1 μm in size, but in some parts there are cases of an aggregate of such quartz, 10 μm in size, being enclosed as breccias, which makes one infer that silicification took place in repetition. The silicification is accompanied by very small quantities of pyrite mineralization, which has brought about slight iron stain to the outcrops or floats of the silicified rocks.

(4) Mineral Deposits and Mineralization

As known mineral deposits in this area, there are Pha Pun Dong Mine where primary tin and tungsten mineral veins are exploited and small-scale working sites to the south of the Mae Lamit River where the eluvial tin-bearing gravel layer is exploited. In addition, as unexplored mineral indications, pegmatite and quartz veins are found at various places in the area.

Details of both mines are described in Chapter 3, 5–3 (3).

(i) Pha Pun Dong Mine (in at pause, see in Fig. 5 and 6)

Outline of this mine is as follows.

The mineralized veins are tungsten-bearing pegmatite vein and tin and tungsten-bearing tourmaline-quartz vein within medium-grained two mica granite. Exploited mining sites were wolframite-bearing eluvial ore deposit at surface, a master lode of primary vein containing a large quantity of wolframite and scheelite and satellite mining site of wolframite and tin-bearing vein.

At the each mining site a number of pegmatite veins and tourmaline-quartz veins are found, but mineralized parts among them are very localized. Pegmatite is composed mainly of quartz, potash feldspar, plagioclase, muscovite and biotite, but rarely associating with tourmaline. It is said that pegmatite veins do not contain cassiterite.

It is considered that pegmatitie veins and tourmaline-quartz veins were intruded differing in time, since the both veins were cutting each other.

The ore minerals are brown cassiterite, scheelite and predominately wolframite. Though wolframite is usually replaced by scheelite along peripheries and cleavages, it was reported that big scheelite grains were enclosed by wolframite. From this fact, it is presumed that the formation and scheelite took place is multiple stages.

The minerals of niobium and tantalum are usually accompanied by pegmatite, but their contents are quite low in such cases as this mine where tourmaline-quartz veins prevail.

(ii) Working places at the south of the Lamit River

The ore minerals of placer deposits mainly consist of dark brown to black cassiterite, and the quantity of wolframite and scheelite are small. Very small quantity of columbite-tantalite, struverite-ilmenorutile and also such heavy mineral as monazite, rutile, zircon, ilmenite, magnetite and garnet are contained in the concentrate.

Generally dark brown to black cassiterite is contained in pegmatite. The cassiterite from river sands of tributaries of the Lamit River almost shows dark brown to black color. It is considered that this cassiterite derived from pegmatite with the very small quantities of niobium and tantalum.

(iii) Unexplored mineral indication zones

Besides the above-mentioned known mineral deposits, pegmatite veins and tourmaline-quartz veins are found at various places of this area. In addition high-temperature quartz veins not accompanied by tourmaline and low-temperature quartz veins accompanied by silicification are distributed. No tin, tungsten, niobium and tantalum minerals have been confirmed by the naked eye in any of these.

The pegmatite veins, which lie in the direction of NW to WNW, have width of 0.1 to 2 m. Most of them are muscovite pegmatite, and at some places garnet or small quantities of tourmaline and biotite are contained. Among the tourmaline quartz veins the biggest size is found at the east end of this area; though there are few outcrops, large quantities of boulders are distributed over the extent of 20 m in width and 300 m in strike extension. The strike is estimated to be in the direction of N 60° W. The result of analysis of samples did not indicate remarkable mineral contents (Nb_2O_5 1 ppm, Ta O_5 < 1 ppm, SnO_2 0.00%, WO_3 0.02%). The size of the other tourmaline quartz veins is in the range of 0.3 to 1 m. At some places long prismatic tourmaline, 0.5 to 1 cm in diameter and 5 to 10 cm in length, is recognized.

The high-temperature quartz veins not accompanied by tourmaline, the representative ones of which exist at the east end of the area, are found at various places in the area. These representative ones, two veins extending in the direction of WNW to EW, have the maximum width of 25 m and 15 m and the length of 700 m and 500 m respectively. These veins are formed of granular quartz, 2 to 5 mm in size. Unlike the low-temperature quartz veins described later, these are not accompanied by silicification.

The low-temperature quartz veins have been found at various parts of the area, lying in the directions of NS, NNE, NE, NNW to NW, and EW. The ones of the greatest size are two quartz veins, 3 to 10 m in width, which cross the middle of the area diagonally in the NE direction. The low-temperature quartz veins caused silicification and weak pyritization to the country rock, but are not considered to have been related with the mineralization of tin and tungsten (and possibly niobium and tantalum). Also the contents of gold and silver are extremely low (Au < 0.2 ppm, Ag 2 ppm).

As mentioned above, though no mineralization parts were found in the outcrops of pegmatite veins or quartz veins, judging from the extent of muscovitization of the biotite granite and the frequency of appearance of aplite veins, pegmatite veins and quartz veins, occurrence of mineralization zones was expected, besides the surroundings of Pha Pun Dong Mine, along the Mae Lamit River, Pong Noi Creek and Pong Yai Creek. Therefore, as supplementation of the geological mapping, heavy minerals in stream sediment were collected, and the mineral species and the contents were preliminarily studied.

As the result of this work, cassiterite and very small quantities of wolframite, scheelite, columbite-tantalite, struverite-ilmenorutile, monazite, xenotime, zircon, ilmenite magnetite, and graphite were found.

It was also brought to light that, compared with the areas along the Lamit River, the areas along the Pong Noi and Pong Yai Creeks yield garnet in large amounts. Since garnet is contained in aplite veins and pegmatite veins, the yield of garnet in large maounts in the stream sediment substantiates the high frequency of these veins appearing in the Pong Noi and Pong Yai Creeks and their vicinities.

From the mineral contents in the stream sediment obtained from the chemical analysis values of the heavy minerals, the content of tin is in the range of 35 to 90 g per cubmic meter in the vicinities of the Mae Lamit River and Pong Noi Creek. The contents of niobium and tantalum are 8 to 15 g/m^3 and 1 to 3 g/m^3 respectively in the vicinities of the Pong Noi Creek and Pong Yai Creek. The content of tungsten is only less than 10 g/m^3 and very low. As a whole the degree of concentration of all the components is low.

5–3 Geochmical Prospecting

(1) Sampling

In this survey B–horizon soil samples were collected in the rectangular grid syotems. These were under 80 mesh fraction and offered to chemical analysis.

The spacing between sampling lines was 100 m, and the interval between sampling points was 25 m in this area. The sampling points were settled by the easy land survey using pocketable compass and tape measure according to the maps of sampling plan. Therefore total number of number of samples are 4,200. The direction of sampling lines was decided to be laid out in the N–S direction to pick out effectively mineralized zones of the general directions of NE–SW, ENE–WSW and fracture systems of NE–SW direction.

(2) Chemical analysis

(i) Pathfinder element

Since it was at the stages of detailed survey, for the pathfinders the four elements of tantalum, niobium, tin and tangsten, which directly indicate the existence of mineralization zones, were taken up.

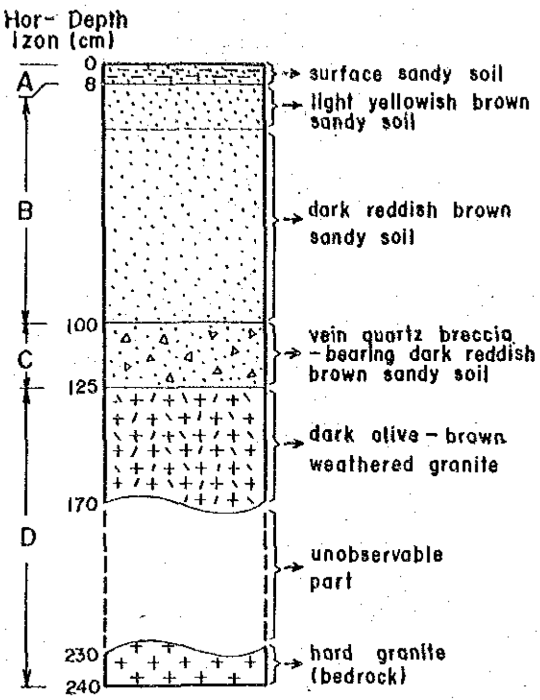
(ii) Method of analysis

Quantification is made with a plasma emission spectrometer.

(3) Soil Profile and Content of Pathfinder Elements by the Difference of Depth and Grain Size of Soils

In this area light brown sandy soil is predominant.

The depth of the sampling of B–horizon soil in this survey was usually 25 to 35 cm from the surface. Chemical analysis was made of –80 mesh fractions. For the purpose of reference, from the pit walls of opencut mining in Pha Pun Dong Mine, which are representative mineralization zones in the survey area, soil samples from each extent of depth in the whole soil profiles were collected. And chemical analysis was made of 30–80 mesh fractions and –80 mesh fractions respectively (Fig. 15).



	Sample No.	Nb	Ta	Sn	W (ppm)
I	PPD - 1	20	<1	27	33
		3	<1	7	31
I	PPD - 2	27	2	33	49
		3	<1	8	23
I	PPD - 3	25	3	33	52
		4	<1	10	12
I	PPD - 4	25	3	33	51
		5	<1	11	11
I	PPD - 5	26	2	32	41
		10	<1	16	9

Geochemical values are as below :

upper row ; of −30 and +80 mesh fraction
lower row ; of −80 mesh fraction

Pha Pun Dong mine

Fig. 15 Representative Soil Profile and Geochemical Data

From the result no significant difference in contents according to the depth was seen. However, as for contents of elements for each class of particle size, for all the four elements, 30–80 mesh fractions, except for tungsten near the surface, presented values about 2 to 9 times, mostly 3 to 5 times, those of −80 mesh fractions. In this survey, though −80 mesh fractions were adopted, geochemical anomaly areas are detected in each area. However, the higher contents in the coarser fraction suggest that application of coarser fraction to tin-tungsten (-niobium-tantalum) geochemical prospecting might be useful to delineate high-contrasted anomaly areas than that the contents only shift to the upper order.

(4) Classification of Geochemical Anomaly Values

In this survey, though the frequency distribution graphs and the cumulative frequency distribution graphs are referred for determination of the thresholds for the pathfinder elements and subdivision of the background and anomaly zones, the mean value (M) and standard deviation (σ) which are the primary statistically calculated values, were used. That is to say, the thresholds for the pathfinder elements in the three areas were made to be the approximate values of the values of $M + \sigma$. In Areas A and B, the background zones were subdivided by the approximate values of the values of M + 2σ and M +3σ into the low anomaly zones, moderate anomaly zones and high anomaly zones.

The detail of the above-mentiond is shown in Table 8.

Table 8 Classification of Geochemical Background and Anomaly Zones (Area A)

ppm

Element	Background		Anomaly		
	Low	High	Low	Moderate	High
Nb	– 27	28 – 38	39 – 54	55 – 77	78 –
Ta	– 2	3 – 4	5 – 8	9 – 15	16 –
Sn	– 31	32 – 43	44 – 62	63 – 84	85 –
W	– 5	6 – 11	12 – 25	26 – 52	53 –

(5) Distribution of Geochemical Anomaly Area

On the basis of the classification of geochemical anomaly in the preceding section, anomaly areas of each element were picked out, as shown in Fig. 16. This map shows that anomaly areas of niobium and fantalum are situated in the southeast part of Area A, Tin anomaly area in central part and tungsten anomaly area in north part. Distinctly the distribution of each geochemical anomaly is differed.

Distribution of anomaly areas for each element are described as follows:

(i) Niobium

Moderate and high anomaly areas are distributed in the southeast. The moderate anomaly areas are found in a space with an about 1,300 m by 1,000 m, and include small-scale high anomaly area. These anomaly areas are distributed in an irregular shape and seen not to show any trend. Besides these anomaly areas, small-sized low anomaly areas are scattered in the north.

(ii) Tantalum

The moderate anomaly areas are distributed in the southeast overlapping the above-mentioned niobium anomaly areas, and are small in size than those of niobium.

Three small-sized high anomaly areas are scattered in the moderate ones. Numerous low anomaly areas are recognized in the eastern half of the north.

(iii) Tin

The moderate anomaly areas in an area of 300 m by 1,300 m extend in the NW–SE direc-

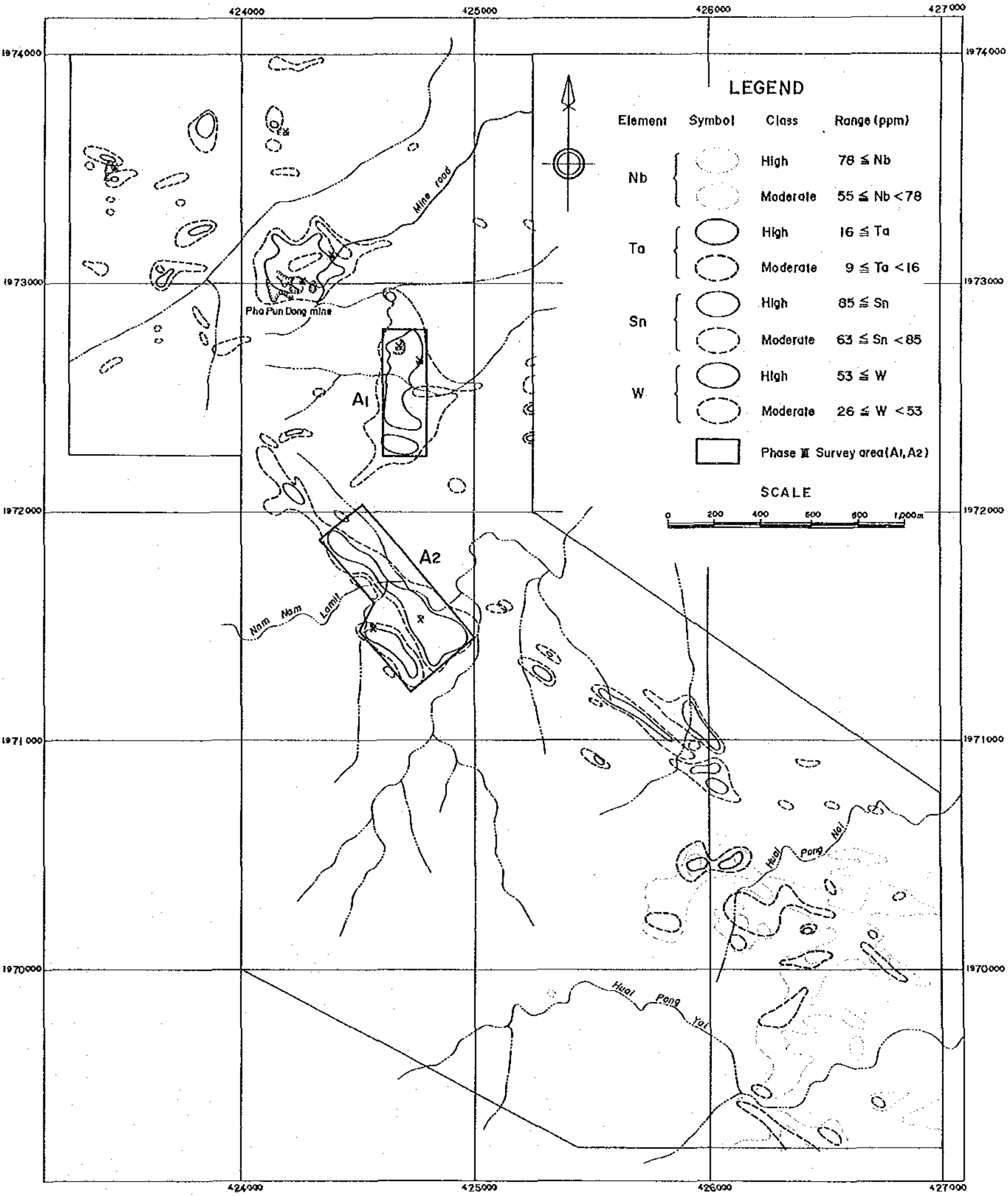


Fig. 16 Geochemical Anomaly Map of the Area A

tion crossing the Mae Lamit river, including a high anomaly area of 200 m by 700 m with maximum anomaly vaue of 200 ppm.

Low anomaly area including these high and moderate ones are distributed in the NW–SE direction in an area of 500 m by 3,000 m.

Besides these anomaly areas, low anomaly areas are scattered near the Pha Pun Dong mine.

(iv) Tungsten

High anomaly areas are scattered only in the north only. A high anomaly area covering the Pha Pun Dong mine has a size of 400 m by 300 m with maximum value of 880 ppm. Another one, 400 m southeast to that and extending in the N–S direction. Another one, 400 m southeast to that and extending in the N–S direction, occupies an area of 400 m by 250 m with maximum value of 310 ppm.

Besides these, small-sized moderate and high anomaly areas are scattered in the north. Most of those cover mine and prospecting site. There is no anomaly area in the south.

(6) Evaluation of Geochemical Anomaly Area

Above-mentioned geochemical anomaly areas were appraised in the use of the relationship among geological structure, alteration and mineralized zones as follows. However, anomaly area directly related to the Pha Pun Dong mine was excepted.

(i) Tungsten anomaly area on the southeast of the Pha Pun Dong mine.

In this area, there are recognized to the fault systems of N–S, NE–SW and NE–SW direction and muscovitization of country rock. Also old mining site is situated in the northern of anomaly area. There is a possibility that a mineralized zone of the same scale as the Pha Pun Dong mine may occur.

(ii) Tin anomaly area in the central part

This area involves a concentrated high anomaly zone and the scale of this area is bigger than other anomaly areas. Though tin-bearing eluvial ore deposit is explored in small scale, tin contents in stream sediment are very low. The possibility of existence of promising mineralized zone is only a little, even if the ore veins in the direction of NE–SW would be found. However, it is necessary to further consideration in view of the scale of this area.

(iii) Niobium and tantalum anomaly area in the southeastern part

There is a dispersive low anomaly zone. It is no correspondence between the distribution of anomaly zone and alteration of country rocks, and quartz veins which are found at places. Therefore, it is considered that this anomaly zone is not directly suggested the existence of promising mineralized zone.

5–4 Drilling Survey and Trenching Survey

The present surveys are a following-up survey through drilling and trenching in Phase III in Areas A_1 and A_2, which were selected as target areas in the geochemical anomaly areas to the southeast of the Pha Pun Dong mine; these anomaly areas had been picked out from Area A as the result of the Phase II survey.

In both the two areas, to find mineralized veins with efficiency, survey sites were arranged by combining drilling and trenching so that they may cross the directions of presumable mineralized veins at right angles (Fig. 17).

Area A_1 is adjacent to the main old mining site of the Pha Pun Dong mine on its south, and there is a small-scale old mining site in the northern extremity of this area. In this area, which is a tungsten geochemical anomaly area, the occurrence of a mineralized veins similar to those of the Pha Pun Dong mine was expected. Here 13 drill holes (30 m each; 390 m in total) were made and 13 trenches with a total length of 670 m were excavated.

Area A_2 is situated about 1 km south of Area A_1 and there are old workings of secondary tin deposit in this area. Over this area a tin geochemical anomaly area is distributed in a belt form in the directon of NW–SE. Since this direction coincides with the one of main mineralized veins was inferred. Here seven drill holes (30 m each; 210 m in total) were made and six trenches with a total length of 390 m were excavated.

The results of the surveys in these areas are as follows:

(1) Area A_1

This area is divided into the north and south by a drainage running eastward.

In the north, there are small-scale former mining sites on the northwestern side and southeast side of a hillock. In these mining sites thin parallel tourmaline bearing quartz veins in a strike of NW–SE and a SW dip seem to have been mined, but no content of ore minerals was recognizable in the naked-eye observation of the quartz veins and waste in the working faces.

Four drill holes in a total length of 120 m were drilled and four trenches in a total length of 210 m were excavated here, but no veins with high tungsten content mentionable as mineralized ones were found though the drilling survey seized quartz and pegmatite veins in all the holes. No high tungsten content was found at the topsoil layer or in the bedrock at the hole bottom, the former indicating medium- to high anomaly values in the geochemical anomaly levels and the latter not exceeding the threshold values.

The trenching survey took hold of numbers of quartz veins and pegmatite veins. Among them in Trench A_1–6 (consisting of the north, middle and south trenches) which was excavated in three divisions in a manner of crossing the two former mining sites, the north trench encountered a tungsten-mineralized vein with WO_3 content of 0.33% and 0.29%, and the middle trench another with 0.81% of W (Fig.18). Both these mineralized veins accompany a quartz vein containing tourmaline or a pegmatite vein and lie on the extension of a group of veins that were mined. In the other trenches quartz veins and pegmatite veins with somewhat high tungsten content, for instance, 280 ppm and 240 ppm of W in Trench A_1 –1 and 110 ppm of W in Trench A_1 –10, were found here and there, and no particularly notable vein was discovered.

On the other hand, in the south, nine holes in a total length of 270 m were drilled and nine trenches in a total length of 460 m were excavated, and numbers of quartz veins and pegmatite veins were found as in the north. Among them, in the results of the drilling veins with weak tungsten mineralization, as 0.19% of WO_3 in Hole MJT–2 and 850 ppm of W in Hole MJT–4, were found. In the trenching survey tungsten-mineralized veins as seen in Trench A_1 –7 with 1.4% of WO_3, Trench A_1 –4 with 0.23% of WO_3, Trench A_1 –3 with 0.28% of WO_3, and Trench A_1 –9 with 0.49% of WO_3 were found. These mineralized veins accompany thin tormaline veins, aplite veins, and tourmaline-containing pegmatite veins. Besides the above-mentioned, a tourmaline-containing quartz vein and a pegmatite vein with a little high tungsten content, W ranging from 810 to 870 ppm, were seen at places, and not particularly mentionable ones were recognized. The tungsten content from the channel sampling in Trenches A_1 –9 and A_1 –12 were in the range of the medium to high geochemical anomaly values according to the geochemical anomaly classification.

As set forth in the above, all the mineral indications found by this survey are parts of numbers of tourmaline-containing quartz veins and pegmatite veins occurring in the NW–SE direction, which is in line with the main geological structure, accompanied by tungsten mineralization, and a few of these are seen as mineralized veins. However, the width of individual mineralized veins is as small as 5 to 10 cm, their tungsten content is generally on the level of 0.2 to 0.3% of WO_3 with local exception as 1.4%, and the veins lack continuity. So that mineral indications on a very small scale on the whole are scattered in this area, and there is little possibility of a substantial veins being distributed.

(2) Area A_2

In Area A_2 seven holes in a total length of 210 m were drilled and six trenches in a total length of 390 m were cut, and a number of thin pegmatite veins and partially some thin quartz veins and altered rocks were found.

However, none of these presented a level of mineral content mentionable as mineral indications; the highest values found by drilling and trenching were 250 ppm of Sn and 230 ppm of Sn respectively. The result of panning prospecting made in each trench yielded small amount of cassiterite only in very limited parts.

While the topsoil layer and country rock at the hole bottoms in the drilling results presented comparatively high content generally coming under the medium to high anomaly level according to the geochemical anomaly level classification, there is the tendency of higher tin content being found on the southeast side of this area, and there is a former site of mining of secondary tin deposit about this side.

This secondary ore deposit is presumed to derive from mineralized pegmatite veins, because there are a number of pegmatite veins here and cassiterite obtained by panning is dark brown. Since granitic rock as the country rock has high tin content, there seems to have been enough conditions for being a place for mineralization.

Although no mineralized vein was found by these surveys, there is the possibility of the occurrence of small-scale mineralized veins.

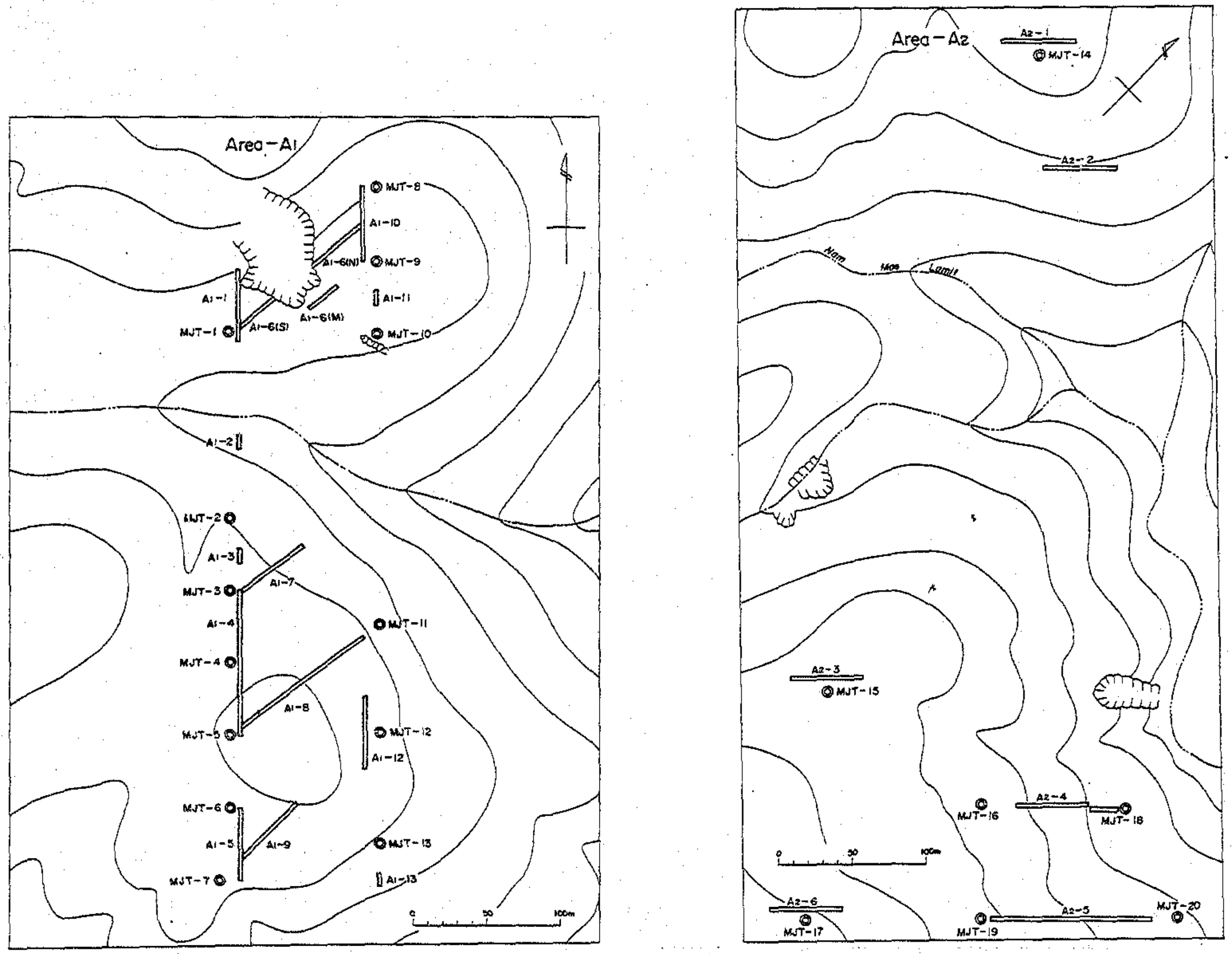


Fig. 17 Location Map of Drilling and Trenching Points of the Area A

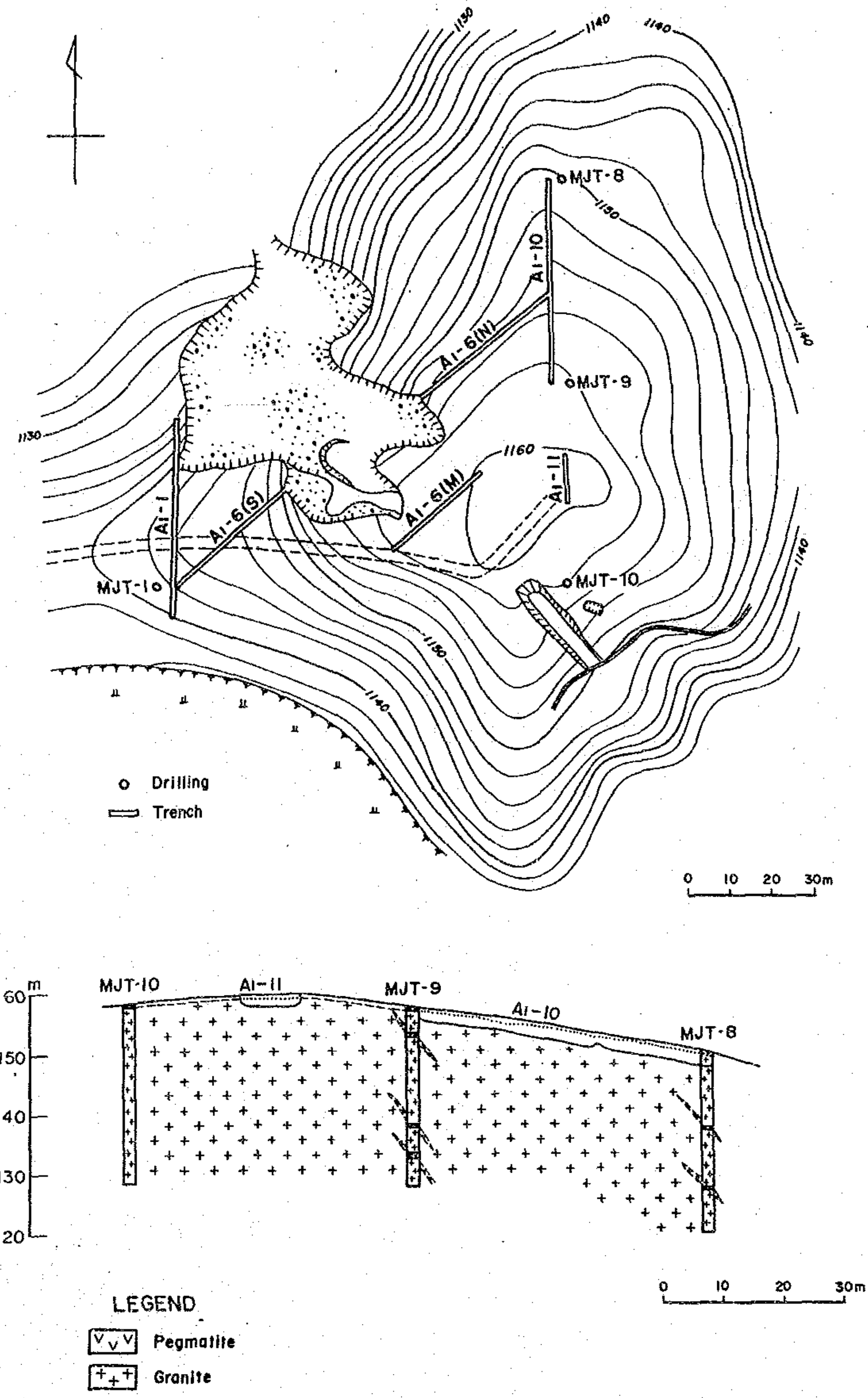


Fig. 18 Geological Profile of Drilling (MJT–8, 9, 10)