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

PHASE II

APRIL 1985

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 the 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.

For the work 1984, the second phase, the Metal Mining Agency of Japan dispatched the survey team consisting of four geologists to Thailand between October 31, 1984 and January 30, 1985.

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

This report summarizes the results of the survey of the second phase and also forms a part of the final report.

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

April, 1985

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

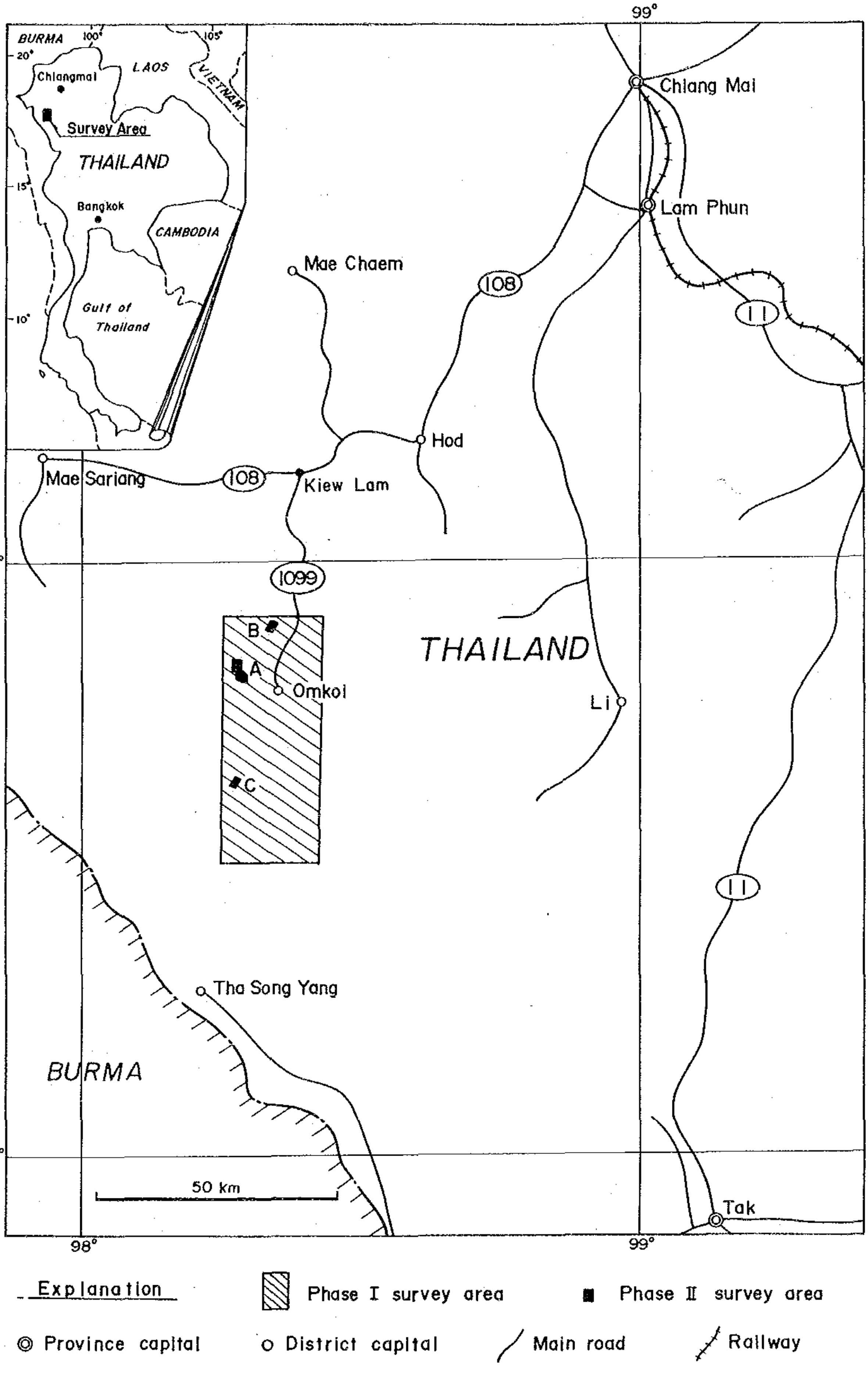

Fig. I Location map of the survey area

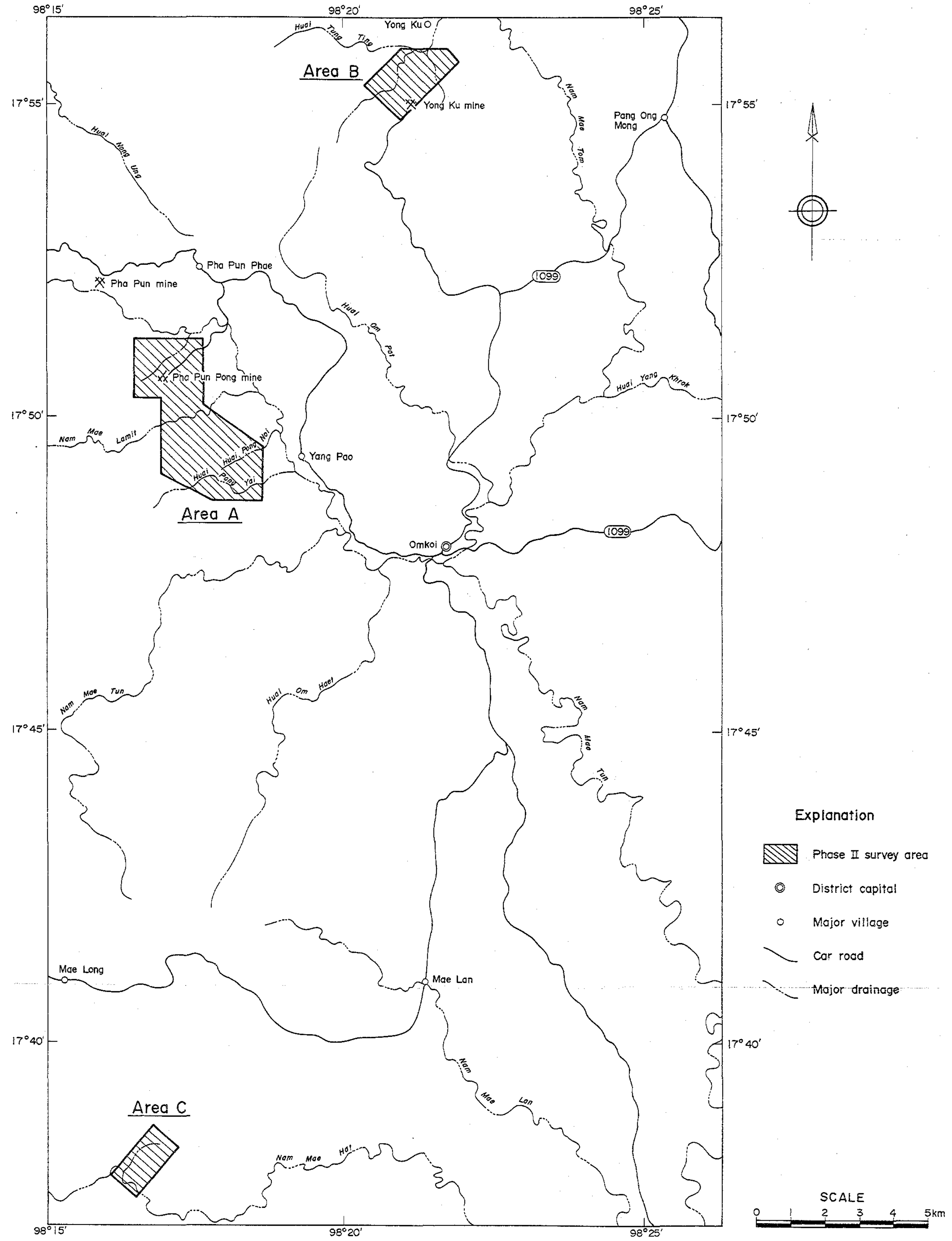

Fig. 2 Access map of the Phase II survey areas.

SUMMARY

The contents here reported is the results of the Phase II cooperative basic survey for mineral resources development carried out in the Omkoi area, the Kingdom of Thailand. The survey areas were the three areas of A, B and C selected as promising areas from the result of the Phase I survey.

In this survey the geological mapping and geochemical prospecting were executed with the object of picking out areas with high possibilities of occurrence of mineral deposits by bringing light to characteristics of granites, geological structure, mineralization and so forth in the selected areas and studying their correlations with geochemical anomalies.

The geology of the Omkoi area including the Phase II survey areas is formed of the Precambrian metamorphic and sedimentary rocks, Cambrian and Ordovician sedimentary rocks, pre-Carboniferous metamorphic rocks, Carboniferous, Triassic and Cretaceous granitic rocks intruded into the above-mentioned rocks, Tertiary conglomerate, and Quaternary alluvium.

In the Area A, the Triassic granitic rocks are extensively distributed. They are classified, by the lithofacies, into the medium-to coarse-grained biotite granite, medium- to coarse-grained two-mica granite, fine-grained biotite granite, aplite, and pegmatite. As known mineral deposits there are the Pha Pun Dong mine located in the north of this area and secondary deposits along the tributaries of the Mae Lamit river in the middle of the area. The former consists of the tungsten-bearing pegmatite veins and tin-and tungsten-bearing tourmaline quartz veins with the country rock of medium-grained two-mica granite. The latter is the eluvial tin-bearing gravel layers.

As the result of the geochemical prospecting, it was found that the niobium and tantalum anomaly areas are distributed in the southeast of this area, tin anomaly area in the middle, and tungsten anomaly areas in the north, indicating differences in distribution to each other.

The tungsten anomaly areas are those concentrating around the Pha Pun Dong Mine and a place to its southeast. The latter includes a high anomaly

area, and occurrence of mineralized veins can be expected.

The tin anomaly area is distributed in a belt shape crossing the Mae Lamit river. It includes the workings of the eluvial deposits, but tin content is low in the stream sediment in the anomaly area, and the possibility of occurrence of promising mineralized veins is low.

The niobium and tantalum anomaly areas occupy an extensive area in the southeast of this area, but the anomalies are not concentrated; and high anomaly areas, which are of a small scale, are scattered. The anomaly values are low on the whole, and the possibility of finding occurrence of promising mineralized veins is low.

In the Area B, the Precambrian metamorphic rocks are widely distributed, but locally are found the Cretaceous(?) aplite, pegnatite, and quartz veins. The metamorphic rocks are classified into the migmatitic biotite paragneiss, biotite paragneiss, quartz schist, quartzite, pelitic schist, and calc-silicate rocks; they intercalate thin limestone. These rocks generally strike NW and dip to NE.

The Yong Ku Mine is the only mineral deposit in this area. The mineralized veins are pegmatite and quartz veins accompanied by cassiterite, wolframite and scheelite. They are emplaced along the gneissic structure of the host biotite paragneiss.

The result of the geochemical prospecting indicates that tungsten has the most remarkable anomaly. A moderate tungsten anomaly area extends in a narrow stripe in the northwest direction from the Yong Ku Mine, and continue up to the northwest-side hill ridge. This direction is NW-SE and coincides with the direction of the gneissic structure of the metamorphic rocks and of the mineralized veins. A tin anomaly area is distributed overlapping with this anomaly area; and large quantities of cassiterite are found in the stream sediment in the vicinities of the northwest anomaly area. Both these tin and tungsten anomaly areas include high anomaly areas, and there are possibilities of occurrence of promising mineralized veins.

In the northeast of the Area B niobium, tantalum and tin anomaly areas are distributed nearly overlapping with each other; out of these the tin anomaly is the highest. Here quartzite and quartz schist intercalating limestone are distributed, and skarnization is recognized in some places. The anomaly areas are distributed in the NW - SE direction. Occurrence of mineralized veins in this direction is possible, but the contents of cassiterite and niobium and tantalum minerals in stream sediment are low; the possibility of emplacement of sizeable mineralized zone is low except for minor mineralized veins.

Over the whole of the Area C distributed are the Triassic granitic rocks, which are classified into the medium- to coarse-grained biotite granite, fine-grained biotite granite, aplite and pegmatite. As the result of the geochemical prospecting, it was found that with all the elements small-scale low anomaly areas are scattered and that medium- to high anomaly values are found at several places but are not concentrated.

In the area, tourmaline-muscovite pegmatite veins are locally found, and also sericitization, chloritization, and silicification are occasionally recognized but no prominent mineralized outcrop is comfirmed. Heavy minerals in stream sediment were found to contain niobium, tantalum, tin, and tungsten, but in extremely small quantities. Therefore, the possibility of finding promising mineralized veins is low.

From the above-mentioned survey results, the tungsten anomaly areas to the southeast of the Pha Pun Dong Mine in the north of the Area A, tin and tungsten anomaly area extending northwest from the Yong Ku Mine and niobium and tantalum anomaly area situated to its north in the Area B are considered promising. It is recommended to make a survey to confirm and evaluate the mineralized zones in the foregoing areas in the next phase programme.

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Chapter 1. Introduction

Chapter 1 INTRODUCTION

1. GENERAL DESCRIPTION OF THE SURVEY

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.

In the past Thailand had exported these rare metals as raw materials, 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 a mission for negotiating a scheme before the survey in 1983. As the result an agreement was reached between the two governments to set about the above-mentioned survey starting in 1983 as the Phase I over the Omkoi area in northern Thailand, which offers high hopes of occurrence of rare metals including niobium and tantalum in addition to tin and tungsten.

The Phase I survey was conducted for a period of three months, from December 1983 to February 1984. The survey area was a rectangle, 50 Km in the north-south direction by 20 Km in the east-west direction (1,000 Km^2) and a geological survey and geochemical prospecting by stream sediment were carried out over this area.

As the result of the survey, the regional geology and geological structure were brought to light, the mineral deposits such as the Yong Ku, Pha Pun and Pha Pun Dong mines were investigated, and some geochemical anomaly areas were picked out.

The survey for this year, the Phase II survey was conducted with the objectives of making an overall comprehension of the relations between geological conditions and geological structure on the one hand and mineralization and geochemical characteristics on the other hand in the areas of A,B and C which are considered most promising among the anomaly areas picked out in the 1st year survey and of picking out areas offering high possibilities of occurrence of mineral deposits.

1-2 Survey Works

The geological survey and geochemical prospecting were made over the three areas shown in Fig. 2 among the promising areas picked out as the result of the Phase I survey.

The geological survey was proceeded with along traverse lines for the geochemical prospecting which had been planned beforehand, adding some routes along streams according to the conditions; and route maps on a scale of 1 to 5,000 were drawn. Over mineral indication zones with outcrops, geological sketch was carried out with semi-detailed surveying.

The geochemical prospecting, with B-horizon soil samples, was conducted by the rectangular grid pattern method. The direction of traverse lines was decided for each area in consideration of geological structure and the direction of mineralized veins; the spacing between the lines was always 100m. The intervals between sampling points were 25m in Area A and 50m in Areas B and C. The total number of samples came up to 5,313.

A semi-detailed topographical survey was made in parallel with the above-mentioned works, and topographical maps on a scale of 1 to 5,000 were prepared by making reference to the existing topographical map on a scale of 1 to 50,000, to be used in arranging the results of the survey.

After the completion of the field works, the survey team made a preliminary report of the survey results to the Department of Mineral Resources of the Thai Government. And the outcome of detailed analytical study was incorporated into this report after making analyses and tests of various samples brought back to Japan and conducting comprehensive analyses and studies. The items of the laboratory examinations are set forth in Table 1.

Table 1. Laboratory examinations.

Examination and element	Numbers
Microscopic observations of thin section	17 samples
Microscopic observations of polished sections	11 samples
X-ray diffractions	13 samples
Rb-Sr datings	2 samples
Chemical analyses Rocks: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, MnO, CaO, BaO, Na_2O, K_2O, P_2O, LOI, Cl, F, Sn, W. Ore: Sn, W, Nb, Ta, Au, Ag.	17 samples (289 elements) 17 samples (68 elements)
Chemical analyses of geochemical samples Soil: Sn, W, Nb, Ta	5,313 samples (21,252 elements)

1-3 Members of the Survey Team

The members who participated in the planning and negotiations for the Phase II survey and in the field works are listed in the following:

(1) Planning the Survey and Negotiations

Japan

Makoto Ishida	Metal Mining Agency of Japan
Toshio Sakasegawa	- do. -
Jiro Osako	- do. -
Tadaaki Ezawa	- do. -
Hideyuki Ueda	- do. -

Thailand

Sermsakdi Kulvanich	Department of Mineral Resources
Phairat Suthakorn	- do. -
Prachon Charoensri	- do. -
Peerapong Khuenkong	- do. -

(2) Field Survey

Japan

Iwao Uchimura	Geologist, Leader
Hiroshi Yoshida	Geologist
Hiromitsu Nozawa	Geologist
Akio Abe	Geologist

Thailand

Sermsakadi Kulvanich	Project Director
Phairat Suthakorn	Project Manager
Peerapong Khuenkong	Geologist, Field Survey Leader
Patchara Jariyawat	Geologist
Aroon Tritrangan	Geologist
Boonchu Panglinput	Surveyor
Sawang Wanlaiad	Surveyor

1-4 Previous Works

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

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

Among these reports the German Geological Mission (1972) describes regional geology and mineral deposits by carrying out a systematic survey over a wide scope 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 published. The Omkoi area is covered by the Geological Map of Northern Thailand: Scheet 6; Amphoe Li (compiled by E. von Braun, L. Hahn and H.D. Maronde, 1981).

Vichit et al. (1983) describe the mineral deposits located in and around the area and discuss the relations between the geology and geological structure and mineralization.

2. OUTLINE OF THE SURVEY AREA

2-1 Location and Accessibility

The Omkoi area is situated, as shown in Fig. 1, about 160 km southwest of Chiang Mai City, the biggest city in northern Thailand. The almost part of the Phase I survey area belongs administratively to Omkoi District,Chiang Mai Province.

To proceed to the town of Omkoi, the district capital, which lies almost in the middle of the survey area, one first takes National Highway No. 108 going southwest, and turns at Kiew Lam, which is about 120 Km distance from Chiang Mai, to take National Highway No. 1099 going south. The former road is entirely paved, but the latter is unpaved. A trip by car takes three to four hours from Chiang Mai to Omkoi.

In the survey area villages and cultivated fields (paddies and fields made by the slash-and-burn method) are found here and there, and many lanes connecting these run in all directions.

As for roads for automobiles, there are some routes which lead, from the town of Omkoi as the hub, to Ban Yang Piang to the east, Ban Yang Pao and Ban Pha Pun Phae to the west, Ban Sop Lan to the south, Ban Mae Lan - Ban Mae Long to the southwest, and other communities. However, these roads, excluding the one leading to Ban Yang Piang lying to the east, have many steep slopes and curves, allowing only four-wheel-drive cars to pass; they become hardly passable in the rainy season.

Among the selected survey areas for this year, access to Area A depends on a motor road for mining operation connecting with Pha Pun Dong Mine which is in the north of this area. About Area B there is a motor road connecting Yong Ku Mine lying at the south extremity of Area B with National Highway No. 1099. Area C can be reached by walking about 13 Km from Ban Mae Lan.

2-2 Topography

This is a mountainous district with relative height of about 1,000 m between elevations of 700 m more or less and 1,700 m approximately. It presents a rugged topography with mountain ridges running in the directions of NW-SE, NE-SW, and N-S and streams flowing parellel with them. The northeast part of the survey area demarcated by the Mae Tun River running through the northern half of the area from northwest to southeast and the Mae Lamit River, which is the upper stream of the river, takes on a somewhat gentler topography.

2-3 Climate and Vegetation

The survey area is under a tropical savannah-type climate, being influenced by a southwest monsoon from May to October causing the rainy season and by a northeast monsoon from November to February bringing about the dry season, and 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 temperatures varies from 3 to 35°C while in the rainy season it varies from 18 to 32°C. Annual rainfall is in the range from 800 to 900 mm, and there scarcely is any rainfall from December to March.

2-4 General Information

Omkoi town, situated at the middle of the survey area, is the administrative center of Omkoi District, and there a district office, police station, post office, hospital, primary school and middle school.

This district has a population of about 24,000, consisting of major hill tribes (Karen, Meo and Musaw) and minor Thai people.

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

2-5 Geologic Setting of the Survey Area

The geology of the Omkoi area which includes the Phase II survey area is summed up as follows from the Geological Map of Northern Thailand, Sheet 6 (Braun, 1981), German Geological Mission (1972), and the result of the survey in the preceding phase.

(1) Stratigraphy

The geology of this district is formed of sedimentary rocks, metamorphic rocks, and granitic rocks as illustrated in Fig. 3, the geological map, and Fig. 4, the schematic geological column. The sedimentary rocks and metamorphic rocks are formed, in the order of the lower to the upper, the Precambrian metamorphic rocks, the Cambrian to Ordovician sedimentary rocks, the pre-Carboniferous metamorphic rocks, the Tertiary and Quaternary sedimentary rocks.

The granitic rocks are classified into the Carboniferous, Triassic and Cretaceous ones.

The Precambrian metamorphic rocks consist of paragneiss, schist, limestone, and calc-silicate rocks distributed in the north and middle of the district. The paragneiss, accounting for the greater part of the metamorphic rocks, has the characteristic of distinct gneissic structure due to biotite. Most of the schist is quartz schist and mica schist originating from pelitic rock. The limestone and calc-silicate rocks are intercalated in the paragneiss and schist in a lenticular form.

The Cambrian sedimentary rocks are distributed over the southeast of the district forming rugged mountains. They consist of white to gray, medium-grained crystalline, massive limestone, and partly interlaid with gray to dark yellowish green shale and fine-grained sandstone.

The limestone has been skarnized near the parts of contact with granite, where garnet, pyroxene, epidote, actinolite, and others have been formed.

The Ordovician sedimentary rocks are distributed at various parts of the district besides its middle; they consist of limestone, quartzite, schist, and calc-silicate rocks.

The pre-Carboniferous metamorphic rocks are formed of paragneiss containing biotite and schist which are distributed in the north and south of the district; they, at some parts, contain small-scale reli s of sedimentary rock.

The Tertiary conglomerate, in addition to being extensively distributed in the Omkoi basin, is developed in the north and south. The Tertiary sedimentary rocks are mainly formed of conglomerate, but at some parts sandstone is predominant. The kinds of the component gravels reflect the geology of respective backgrounds of them.

The Quaternary alluvium are distributed in a long and narrow form along major streams; they consist of unsolidified gravels, sand and clay.

(2) Igneous Rocks

In the survey area, granitic rocks in the forms of batholith and stock are widely distributed, they are largely classified into those of Carboniferous, Triassic and Cretaceous ages.

The Carboniferous granite is porphyritic, coarse-grained biotite granite containing potash feldspar phenocrysts, 2 to

4 cm in size, which is extensively distributed over the east and south; biotite and potash feldspar are arranged in parallel, and the granite often presents gneissic structure.

In the Triassic granitic rocks, in addition to rock bodies in a batholith form extensively distributed over the western half, there are rock bodies in a stock form intruded into the metamorphic rocks and the Carboniferous granitic rocks. These granitic rocks are classified, by the lithofacies, into medium- to coarse-grained foliated granite, medium- to coarse-grained granite, fine-grained granite, aplite and pegmatite. The first two often contain potash feldspar phenocrysts, 2 to 4 cm in size.

The Cretaceous granitic rocks occur as a stock in the north. The stock mostly consists of medium- to coarse-grained porphyritic two-mica granite. At the marginal part fine-grained biotite granite and aplite dikes are locally recognized.

(3) Geological Structure

The fracture systems that prevail in the area are those in the directions of NNW-SSE, NW-SE, and NE-SW; next to these come those in N-S and E-W. These faults have caused the block feature from the middle to the south of the area.

(4) Mineral Deposits

As the tin and tungsten deposits seen in the area, there are primary ore deposits and secondary ore deposits. The deposits are found in the parts where the Triassic or Cretaceous granite is distributed and in their vicinities.

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

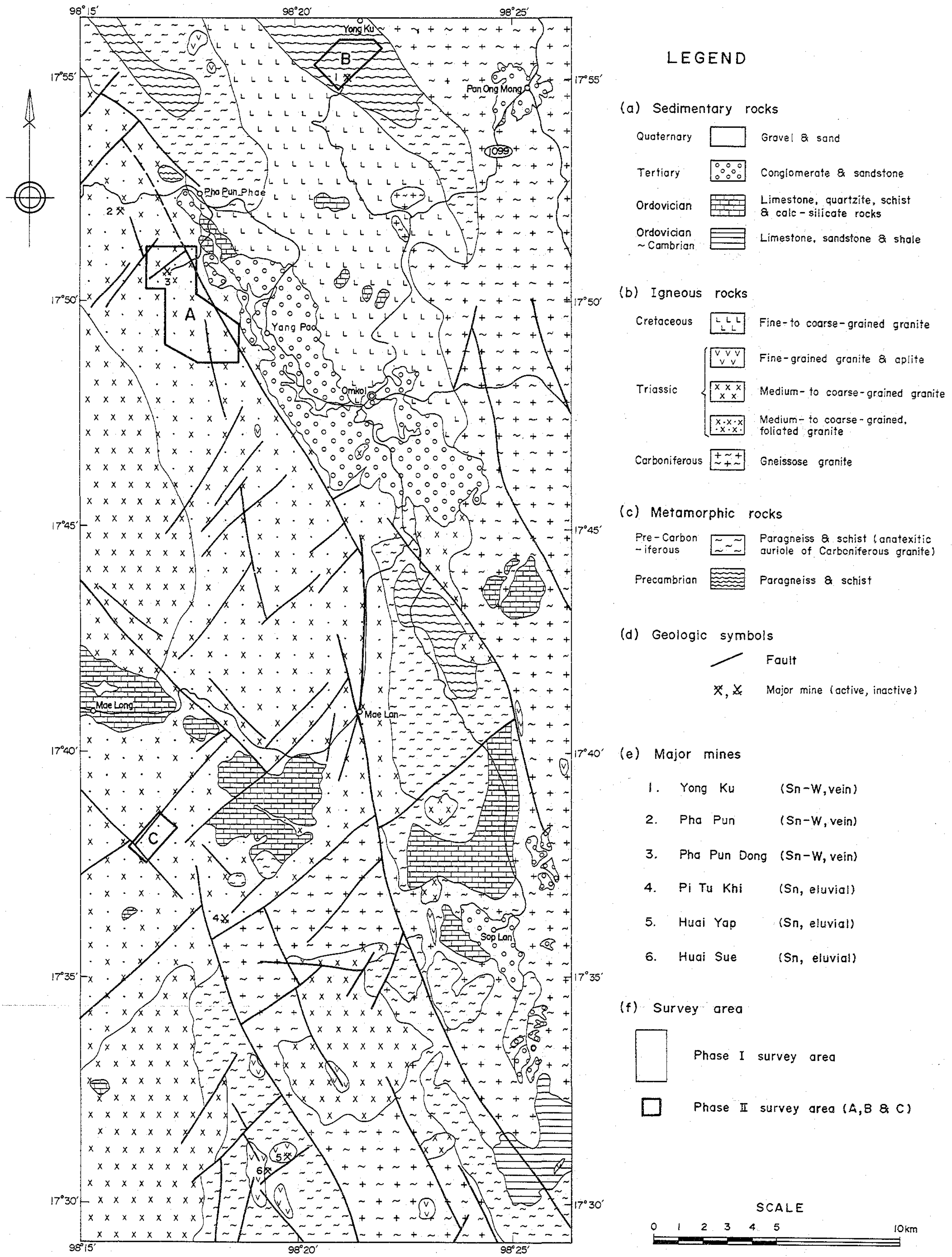


Fig.3 Geologic map of the Omkoi area.

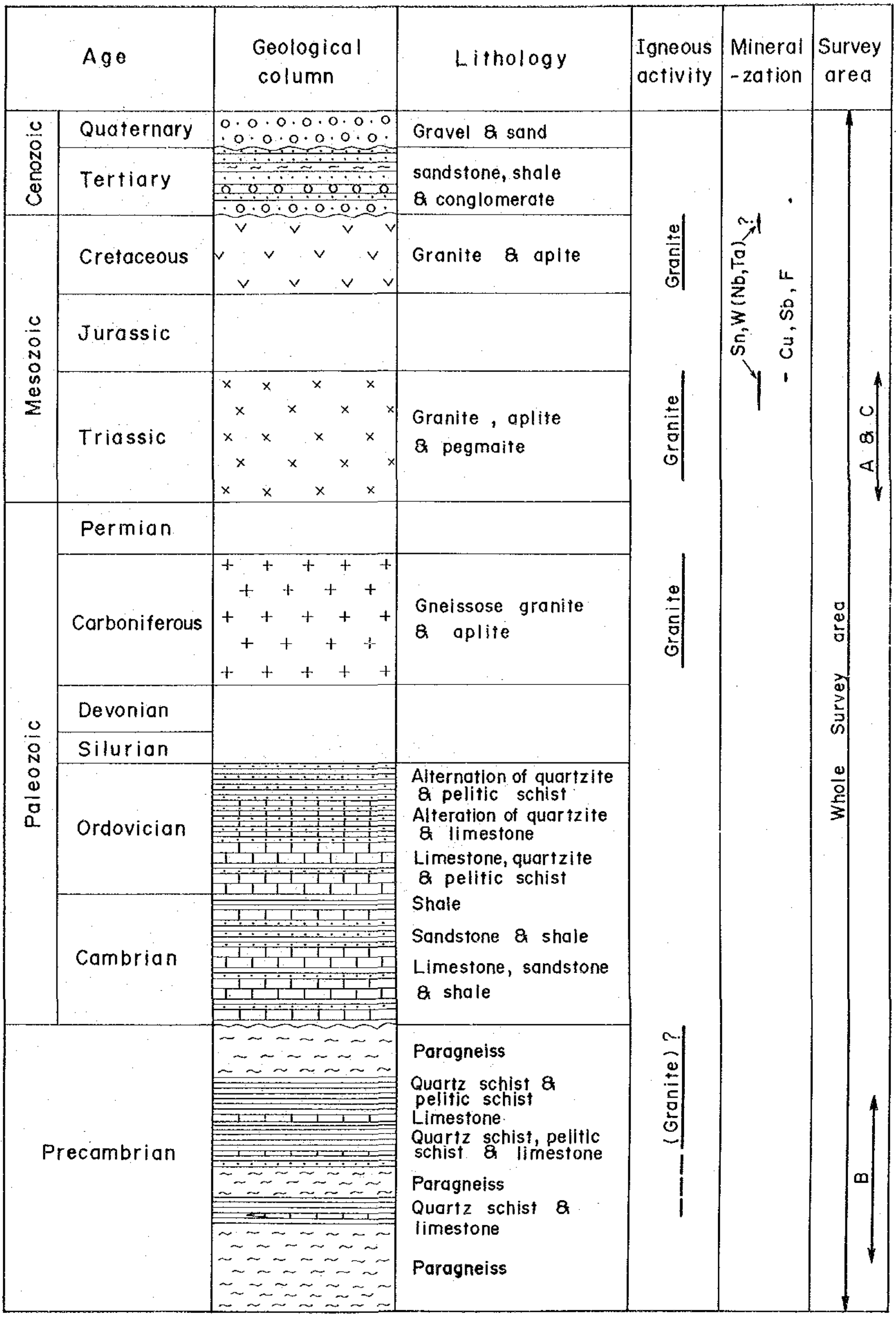


Fig.4 Schemitic geological column.

The secondary ones are of the small-scale eluvial deposits containing ore which exist at the bases of gravel layers deposited in topographic depressions along streams; there are three of such deposits: the mines of Pi Tu Khi, Huai Yap, and Huai Sue.

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 consist primarily of cassiterite. The locations of the mines are shown in Fig. 3.

Chapter 2. Geological Survey

Chapter 2 GEOLOGICAL SURVEY

1. AREA A

1-1 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, Nam Mae Lamit and Huai Pong run eastward in the north, middle, and south of the area respectively, and join the river of Nam Mae 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.

1-2 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. 5, PL.1).

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 the principal component minerals, and apatite and ilmenite as the accessory component 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,the principal component minerals are quartz, perthitic orthoclase, plagioclase, brown biotite, and muscovite; the secondary component minerals are epidote, apatite, rutile, zircon, sphene, chlorite, sericite, and opaque mineral. Among these the epidote has formed as a minute-grained crystalloblastic mineral; the chlorite has replaced part of biotite; the sericite has replaced the inside of feldspar; and 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 Don 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. The principal 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 or tourmaline and epidote. According to microscopic observation of these, the principal component minerals are quartz, plagioclase, orthoclase, tourmaline, epidote, 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 % in terms of mode rate. On the other hand, garnet-bearing biotite aplite is recognized in the Pong Noi Creek in the south of the area. The garnet, about 4 mm in size, poikilitically 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 Mae Lamit River the light pinkish muscovite aplite has intruded the two-mica granite in the northwest trend.

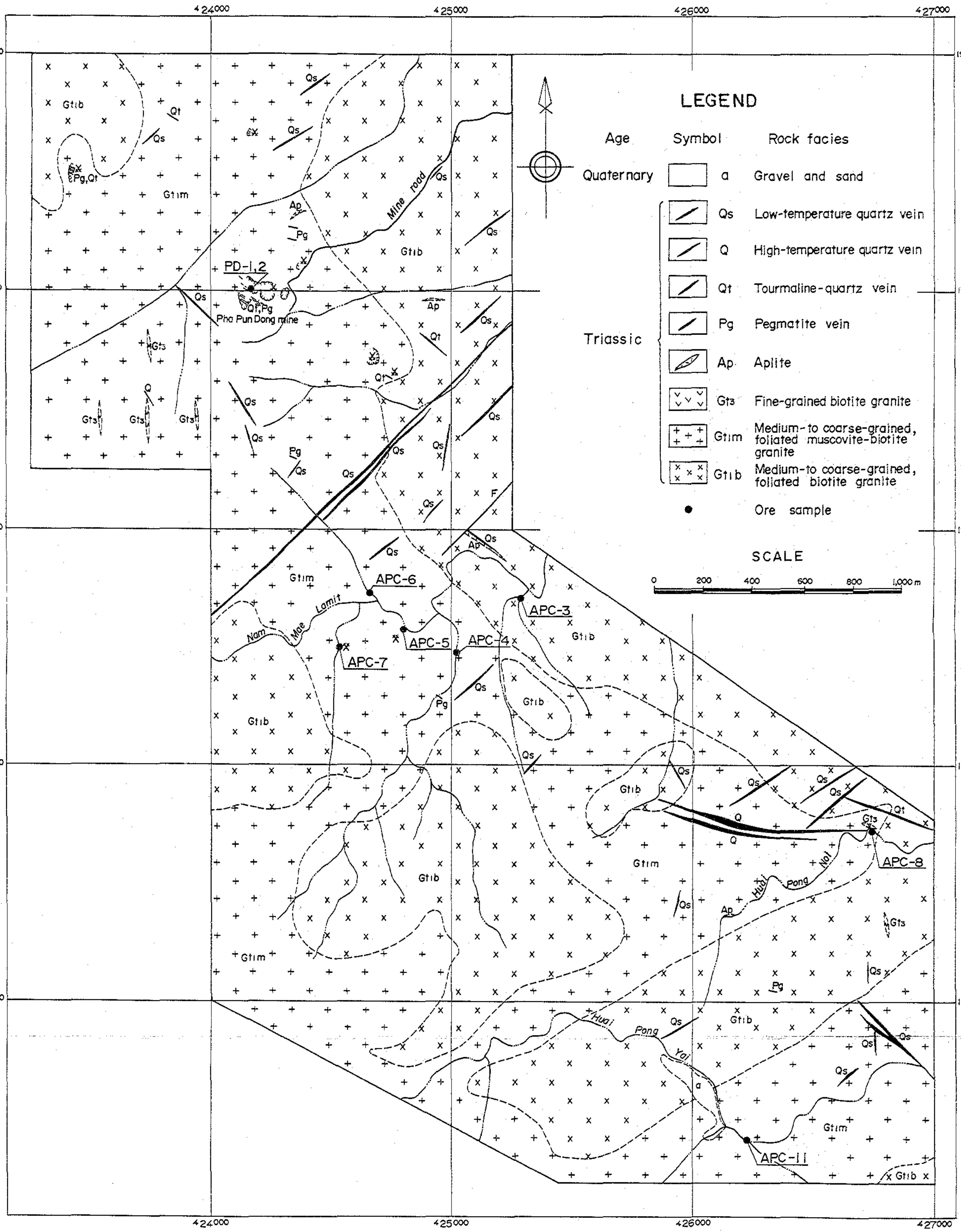


Fig.5 Geologic map of the Area A.

(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, but it contains biotite, tourmaline and garnet at some places. The direction in which the pegmatite veins lie 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 Mae Lamit River and Pong Yai Creek. It is formed of gravels and sands derived from the Triassic granitic rocks and quartz veins.

1-3 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 foliation that was measured 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 Mae 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 is considered, the direction of NS is the direction in which the fine-grained 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 EN, 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.

1-4 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 Mae 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.

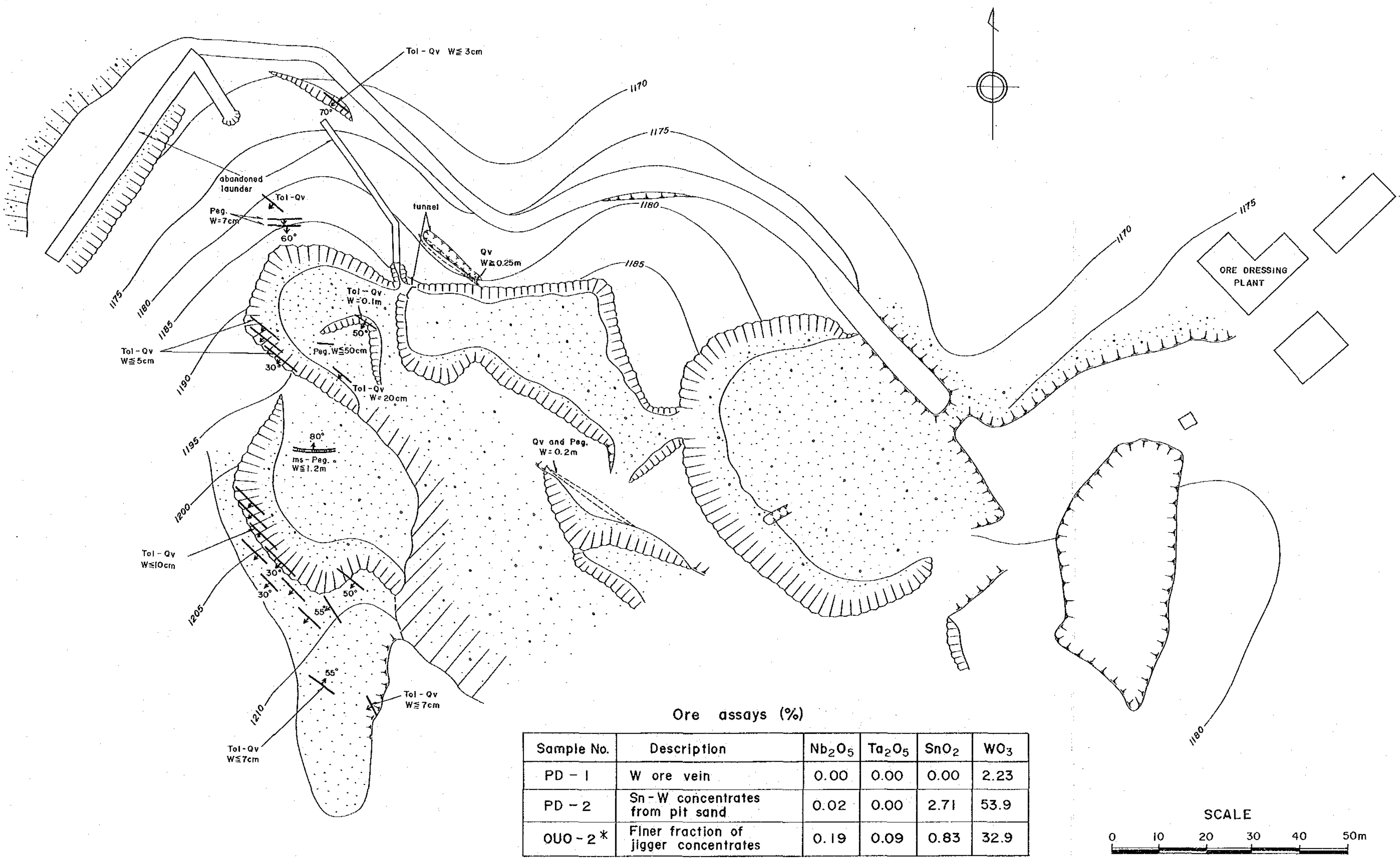
According to microscopic observation, the silicified rock is an aggregate of chalcedonic quartz, 0.1 μm in size, but in some parts there are cases of an aggregate of such quartz, 10 μm in size, being enclosed as breccias, which makes one infer that silicification took place in repetition. The silicification 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.

1-5 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 quarts veins are found at various places in the area.

(i) Pha Pun Dong Mine

This mine is situated on a ridge in the middle of the area. It is formed of the former site of main opencut mining operation (Fig. 6) with an attached are dressing plant and the former sites of small-scale mining operation located to its north, northwest, and east-southeast respectively. Around these former min ing sites and on main ridges there are a number of remains 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. 6 Geologic sketch and ore assays of the main working, Pha Pun Dong mine.

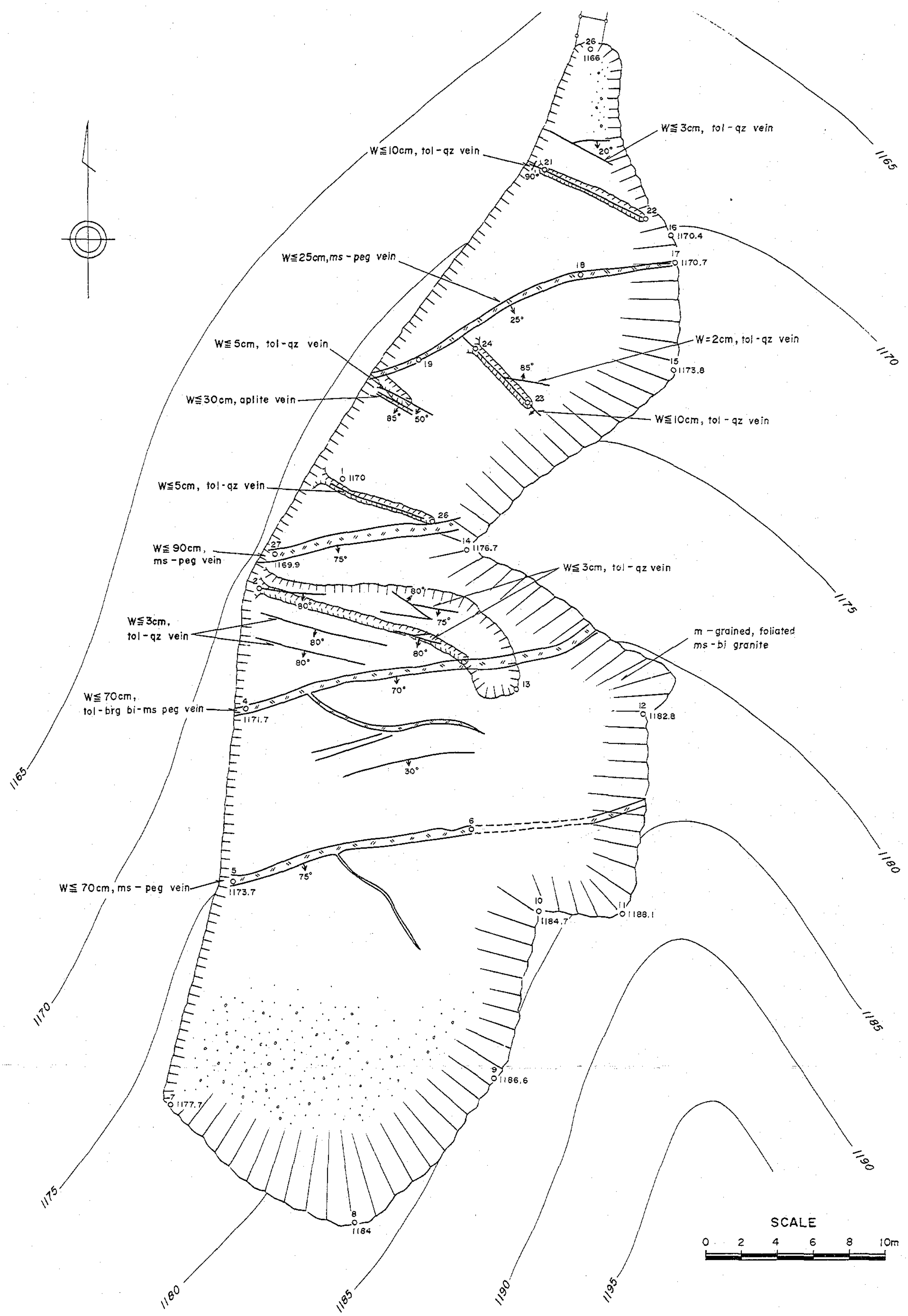


Fig. 7 Geologic sketch of the northwestern old working, Pha Pun Dong mine.

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. From this former mining site to a former mining place to its east-southeast there is a bulldozer road.

When a crusher for ore dressing was removed in the summer of 1984, the operation of Pha Pun Dong Mine was suspended. 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, though this figure is not confirmed, from the eluvial gravel layer at the surface (Vichit and Khuenkong, 1983).

As the operation made progress the object of mining shifted to primary mineralization veins in the weathered country rock. So the former area of main operation resulted in a space with an about 100 m by 200 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 extremity was the main place of mining, producing concentrate, principally scheelite, at the rate of 0.4 ton a month.

Among the former satellite mining sites, the one to the northwest was of a scale of 60 m by 20 m (Fig. 7); 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 with the country rock of medium-grained two-mica granite and tin and tungsten-bearing tourmaline-quartz veins. At the former mining sites a number of pegmatite veins and tourmaline-quartz veins are found, but mineralized parts among them are only local.

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 principal 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 seen in all the former mining sites. The scale is 2 to 25 cm in width, the strike extension ranges from 5 to 20 m; the general strike and dip is in the range of N30°W/30° to 55°W to N60°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 N45°W/30 to 35°W are arranged in parallel at the intervals of 1 to 2 m.

Generally speaking, 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.

Table 2. Results of chemical analyses of ore samples (Area A)

No.	Sample No.	Locality	Description	Nb_2O_5 (ppm)	Ta_2O_5 (ppm)	SnO_2 (%)	WO_3 (%)	Au (ppm)	Ag (ppm)
1	PD-1	Pha Pun Dong mine	W-bearing tourmaline-quartz vein	8	<1	0.00	2.23	<0.2	<1
2	PD-2	do.	Sn-W concentrates from pit sand	170	8	2.71	53.9	-	-
3	A-19-51	1 Km E of the Pha Pun Dong mine	Trace-sulfide-disseminated low-temperature quartz vein	-	-	-	-	<0.2	2
4	A-37-128	3.5Km SE of the Pha Pun Dong mine	Tourmaline-quartz vein	1	<1	0.00	0.02	-	-
5	APC-3	Southern tributary of the Mae Lamit river	Bulk panned concentrates from stream sediment	900	260	4.65	0.69	-	-
6	APC-5	do.	Cassiterite from panned concentrates	130	87	92.3	0.06	-	-
7	APC-7	do.	Bulk panned concentrates from stream sediment	2,000	720	7.53	0.33	-	-
8	APC-8	Pong Noi creek	do.	4,290	1,000	2.58	0.19	-	-
9	APC-11	Pong Yai creek	do.	3,290	610	0.05	0.12	-	-

Table 3. Contents of niobium, tantalum, tin and tungsten in pit sand and stream sediment (Area A)

No.	Sample No.	Locality	Raw material (l)	Heavy mineral (g)	Nb_2O_5 (g/m^3)	Ta_2O_5 (g/m^3)	SnO_2 (g/m^3)	WO_3 (g/m^3)
1	PD-2	Pha Pun Dong mine	40	24	0.10	0.00	16.3	323.4
2	APC-3	Southern tributary of the Mae Lamit river	16	18	1.0	0.29	52.3	7.8
3	APC-7	do.	32	15	0.94	0.34	35.3	1.5
4	APC-8	Pong Noi creek	40	140	15.0	3.5	90.3	6.7
5	APC-11	Pong Yai creek	16	42	8.6	1.6	1.3	3.2

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.

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

In the southern tributaries of the Mae 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 1m-thick overburden.

The cassiterite content in the paydirt, according to a miner, is 500 to 600 $8/m^3$ 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, and also such heavy minerals as monazite, rutile, zircon, ilmenite, magnetite, and garnet are contained in the concentrate. The cassiterite's size is 8 mm at maximum and usually 0.5 to 3mm. Under the microscope it is pleochroic with weak light pink.

The wolframite is 0.2 to 3.0 mm in size and rich in iron content. As niobium - tantalum minerals, there is a very small amount of columbite-tantalite; 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.

(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 or 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 N60°W. The result of analysis of samples did not indicate remarkable mineral contents (Table 2). 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 (Table 2).

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 Mae 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 amounts in the stream sediment substantiates the high frequency of these veins appearing in the Pong Noi and Pong Yai creeks and their vicinities.

The mineral contents in the stream sediment obtained from the chemical analysis values of the heavy minerals (Table 2) are set forth in Table 3. 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 $3g/m^3$ respectively in the vicinities of the Pong Noi Creek and Pong Yai Creek. The content of tungsten is only less than $10g/m^3$ and very low. As a whole the degree of concentration of all the components is low, and it is considered that the possibility is low that a promising mineralization zone occurs in the above-mentioned areas.

2. AREA B

2-1 Location

This area is located about 14 Km north of Omkoi, and there is Yong Ku Mine at the south end of it. Its area is $3.25Km^2$. It presents a relatively gentle landform with an altitude between 1,000 m and 1,100 m.

From Yong Ku Mine extends an auto road for exclusive use by the mine, which connects with National Highway 1,099.

As the result of the survey in the preceding year, the anomalies of niobium, tantalum, tin and tungsten were found to overlap with each other in this area. When one see these more minutely, however, one finds there is an extensive high tungsten anomaly area around the mine; the niobium and tantalum anomaly lies a little away to the northeast side of the mine; and the tin anomaly overlaps with the tungsten anomaly but is limited to the neighborhood of the mine.

2-2 Geology

This area is in a zone at the north extremity of the Omkoi area where the Precambrian metamorphic rocks and limestone are distributed. Almost all this area is occupied by metamorphic rocks which intercalate limestone, but the Cretaceous (?) aplite, pegmatite and quartz veins appear locally, and the Quaternary alluvium is distributed along major streams (Fig. 8, PL. 2).

The Precambrian metamorphic rocks are roughly classified, from their lithofacies, into migmatitic biotite paragneiss, biotite paragneiss, quartz schist, quartzite, pelitic schist, and calc-silicate rocks.

The metamorphic rocks and limestone have a general strike of NW and dip to the northeast.

(i) Migmatitic biotite paragneiss (Gm)

This rock, distributed in the southwest end of the area, apparently corresponds to the lowest part of the metamorphic rocks. Generally it is massive and fine- to medium-grained. At some places it lacks distinct gneissic structure, and is very similar to the Cretaceous granite distributed to the west of this area. However, the facts that in most cases it presents fine gneissic structure due to biotite and that it is at some places interlaid with lenticular biotite paragneiss which is explained later, made the writer classify it as migmatitic paragneiss. According to microscopic observation of representative samples, its principal minerals are quartz, perthitic orthoclase, plagioclass and biotite. The part of the feldspar has been sericitized from inside, and part of the biotite has been sericitized or chloritized.

(ii) Biotite paragneiss (Gp)

Two relatively thick strata of this rock are distributed in the middle of the area, and additionally it is found in the form of thin layers in the northeast of the area. Ordinarily gneissic structure due to biotite is distinct, and the fine-grained part and the medium- to coarse grained part often lie one upon another in an alternate layer form at intervals of 0.5 to 5 m. In the medium- to coarse grained part the porphyroblasts of potash feldspar, 0.5 to 2 cm in size, are observed showing an eyed gneiss structure. According to microscopic observation of samples of the medium-grained part, the principal minerals are quartz, potash feldspar, plagioclass, and biotite; potash feldspar is found in a small quantity except for the porphyroblasts. The biotite is often yellowish green, and as a whole considerable chloritization is found. Feldspar that has been replaced by sericite from its peripheries is comparatively fresh.

In the areas with distribution of this rock, boulders and small outcrops of the calc-silicate rocks are occasionally found. The biotite parageiss intercalates thin lenses of calcareous rocks.

(iii) Quartz schist, quartzite, and pelitic schist (Qs)

These rocks are distributed in three horizons from the middle to the northeast of the area.

Among the three horizons, the quartz schist is predominant in the lower horizon and the upper horizon; it is light pink to light gray, and has distinct schistose structure, about 1 to 2 mm in size. The component minerals of quartz schist is almost all fine-grained quartz, but a small amount of muscovite is recognized in some parts.

The quartzite is gray and fine-grained and lacks distinct schistose structure; in most cases it is found as thin layers in pelitic schist.

The pelitic schist is relatively predominant in the area along the southeastern tributary of the Tung Ting Creek; besides this area it is intercalated in quartz schist as thin layers. This rock is dark gray to dark brown, being dark green at times; it has distinct schistose structure, 1 to 5 mm in size. The dark gray to dark brown schist has the principal minerals of quartz, feldspar, biotite, muscovite, and graphite.

The dark green schist, which is found very rarely, is mainly formed of chlorite.

(iv) Limestone (Ls) and calc-silicate rock (Cs)

These rocks often occur in the form of small lenses or thin layers, 10 m or less in width, in biotite paragneiss, quartz schist, and pelitic schist.

However, in the northeast of the area, the calc-silicate rock layer with an apparent maximum width of about 70 m is distributed.

The limestone is found in the Tung Ting Creek and its tributary on its southeast. It is light gray to gray and fine-grained; narrow banding, 1 to 2 mm, are clearly seen. It contains grayish white flint nodules, 1 to 10 cm in size. Its principal mineral is fine-grained calcite; it also contains small quantities of quartz and feldspar.

The calc-silicate rock is distributed at various parts of the area. It is light green to dark green; almost all of it has schistose structure, but it is massive in part. In some parts of this rock the intrusion of lenticular quartz veins is recognized. Particularly, at the calc-silicate layer of the maximum width of about 70 m found in the northeast of the area, white quartz veins, less than 1.5 m in thickness, is found in a gently inclining sheet form (N45°W/35°E) or in parallel with the schistose structure (N45°W/60° to 80°E).

This calc-silicate layer gradually change, toward the northwest, into light gray, fine-banded limestone. Its principal minerals are diopside, chlorite, quartz, orthoclase, and plagioclase. At some parts it is disseminated with very small quantities of pyrite and scheelite.

(v) Aplite (Ap) and pegmatite (Pg)

The Cretaceous (?) aplite and pegmatite are found in the forms of small dikes and sheets cutting across the metamorphic rocks.

The aplite appears with comparatively high frequency in the vicinities of Yong Ku Mine, but in the other parts it is distributed only sporadically.

It is light yellowish white and fine grained. It is found as dikes and sheets 3 m or less in width.

The main direction of the intrusion of the dikes is N70° to 80°E/90°. In the case of sheets, their direction is N35° to 45°W/35° to 50°E, which is nearly parallel with the schistose structure of the metamorphic rocks.

According to microscopic observation, the principal minerals are quartz, plagioclase, and orthoclase; in addition it contains very small quantities of muscovite and opaque mineral, which has turned into leucoxene.

The pegmatite appears with high frequency in the neighborhood of Yong Ku Mine like the aplite, and is also found in the middle and northeast of the area. It takes the two forms of dikes less than 5 m and ordinarily 0.3 to 2 m in width.

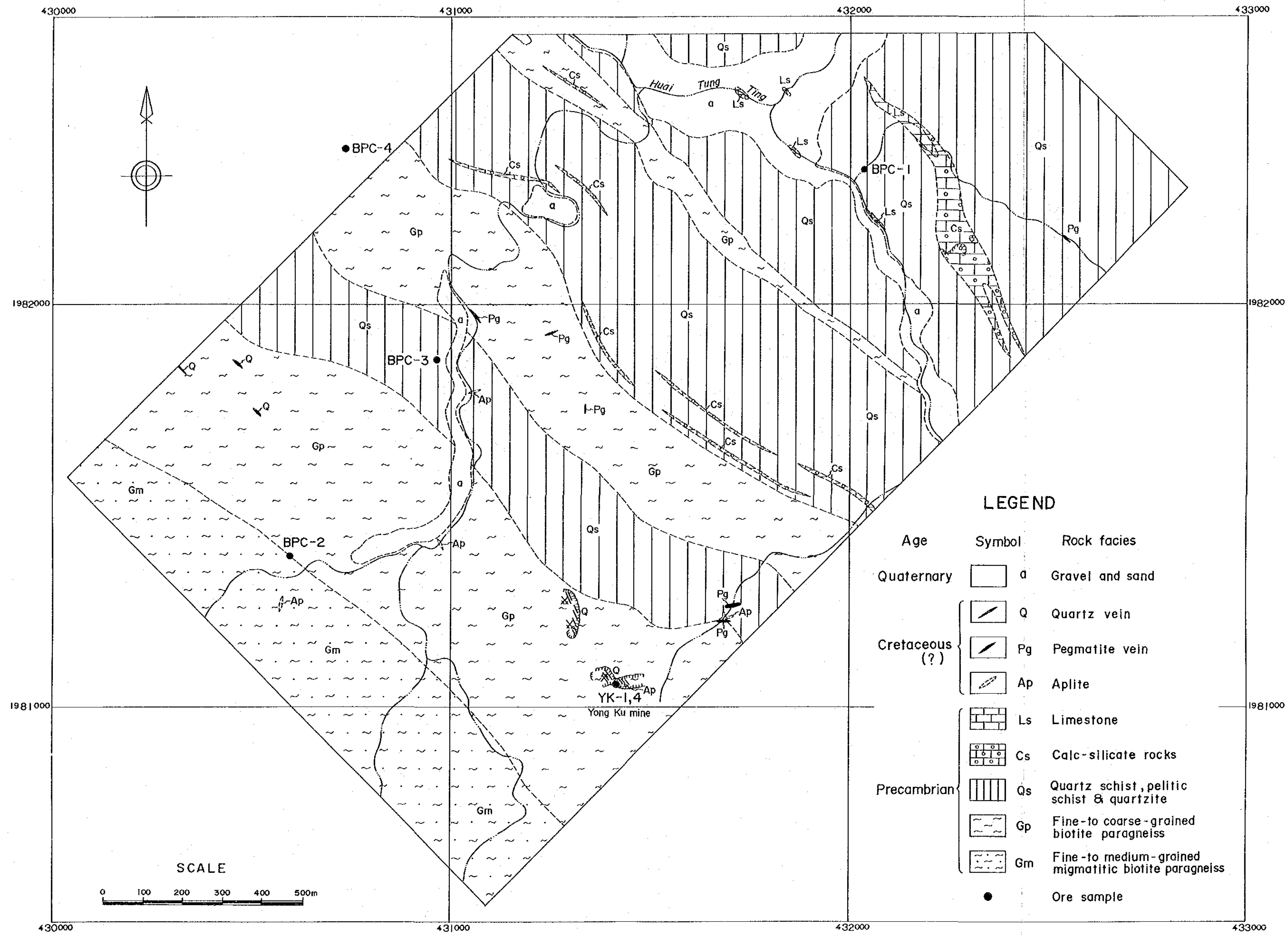


Fig.8 Geologic map of the Area B.

The direction of the intrusion of the pegmatite in a dike form is N 70° to 80°E/80°S to 90° in the surroundings of Yong Ku Mine, and N45°W/90° in the northeast of the area. The pegmatite in a sheet form lies in the direction of N40° to 50°W/30° to 60°E, which is parallel with the schistose structure of the metamorphic rocks. Its component minerals are quartz, orthoclase, plagioclase, muscovite, biotite, and tourmaline; at some places biotite and tourmaline do not exist.

(vi) Alluvium (a)

The Quaternary alluvium is distributed along the Tung Ting Creek and its tributaries; it is formed of unsolidified gravels, sand and clay.

2-3 Geological Structure

At some parts of the outcrops of the metamorphic rocks and limestone distributed in this area, there is development of drag folds in the extent of 3 to 8 m. In addition, one finds small-scale faults and fracture systems indicated by the directions of the intrusion of dikes of aplite and pegmatite and quartz veins and lineaments found from aerial photographs.

The drag folds show in almost all cases the form that as against the northeast-dipping fold axis the northeast wing inclines gently toward northeast and the southwest wing inclines sharply toward northeast. And it is indicated that a main anticline axis exists to the southwest of the area and that this area is located on the northeast wing of the anticline. This leads one to the presumption that the metamorphic rocks and limestone in this area, as a whole, have a strike of northwest and lie one upon another with a dip of about 45° toward northeast, though there are some repetitions due to small-scale foldings

As for the fracture systems, three ones in the directions of NW, NS, and NNE to NE are recognized. Of these the NW system is predominant in the area and is parallel with the fold structure and the schistose structure of the Precambrian, indicating the main structure direction around the area. The NS and NNE to NE systems are considered to be fracture directions secondary to that in the NW direction.

2-4 Alteration

In the area, in addition to regional metamorphism in the Precambrian and subsequent periods, skarnization and kaolinization due to hydrothermal process are found.

The skarnization extended to limestone and calcareous rock of Precambrian age, and caused the formation of diopside-epidote skarn (calc-silicate rock). The greater part of the calc-silicate rock in the area is considered to have been formed by the regional metamorphism affecting limestone and calcareous mudstone, but some of it is penetrated by scheelite-containing quartz veins, and is disseminated with a very small quantity of scheelite. Particularly, in the northeast of the area there is a case that, though a part cut through by large quantities of quartz veins has been skarnized, some place in the part's northeast extension remains as light gray banded limestone because the quantities of quartz veins is small. Also in its vicinity there is tourmaline pegmatite, 4m wide, that indicates igneous activity. These facts make one presume that, in some part of the calc-silicate rocks distributed in this area, there are places of skarnization owing to hydrothermal process.

The kaolinization is recognized along the creek in the northeast of the area, where there is massive white rock which seems to originate from pelitic schist. Also, at some part, pelitic schist has been turned into white kaolin along thin pegmatite veins, indicating the fact of kaolinization owing to pneumatolysis or hydrothermal process.

2-5 Mineral Deposit and Mineralization

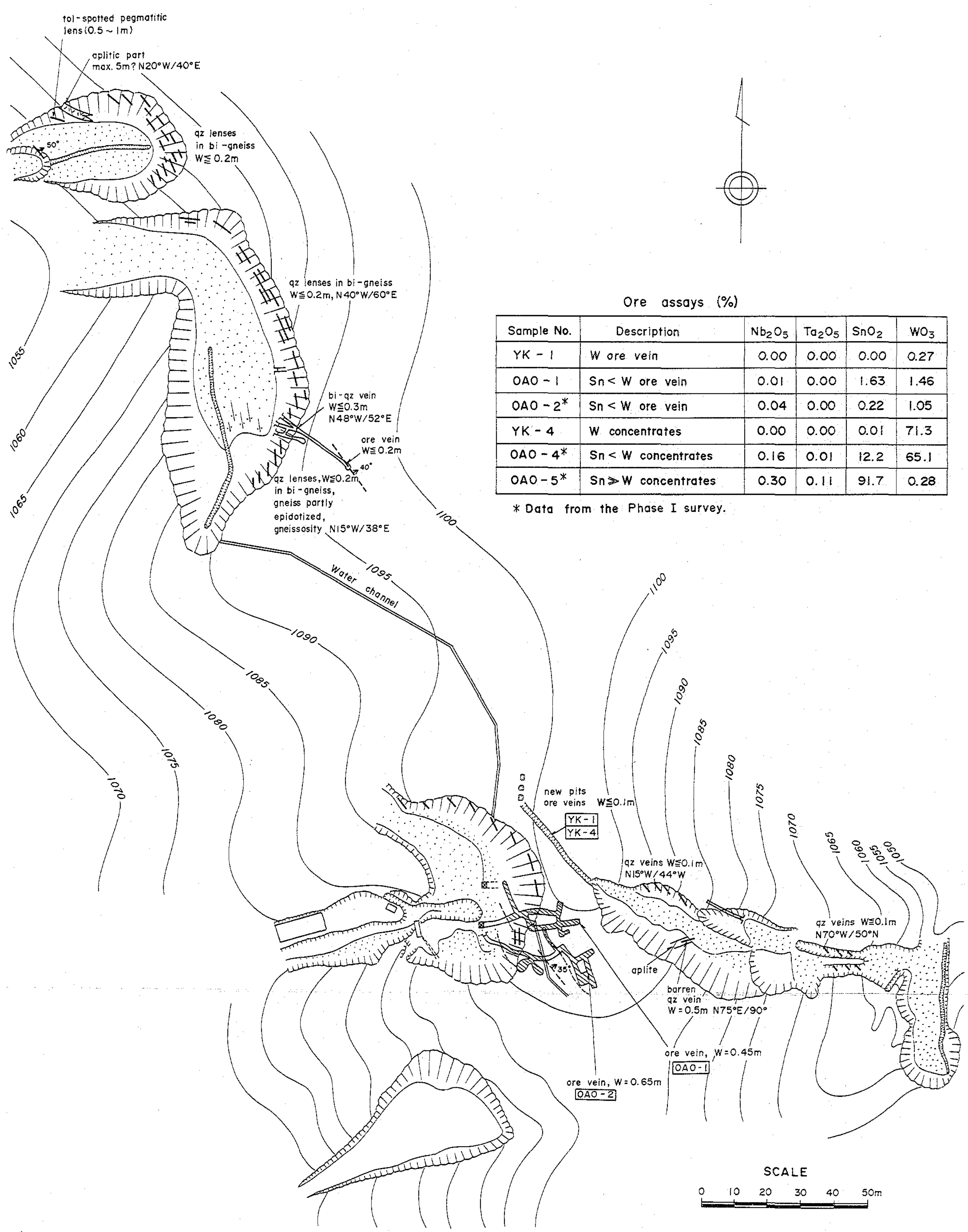
In this area as a known mineral deposit, there is Yong Ku Mine. Besides this there are unexplored mineral indication zones supported by pegmatite veins, quartz veins and skarn zones.

(i) Yong Ku Mine

This mine (Fig. 9), situated at the southeast corner of the area, 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. 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.

At Yong Ku Mine, since more than 10 years ago, the shallower tin and tungusten-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 of 30 to 35 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 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



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. 9 Geologic sketch and ore assays of the Yong Ku mine.

(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 locally, but it is said that it was found in relatively large quantities 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 1 to 10 cm wide, hydrothermally biotitized zones developed at the boundaries of these veins. 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 the ore samples (Table 4), the content of WO_3 in crude ore from the biotitized zone at the quartz vein boundary is 0.27%, while concentrate of scheelite and wolframite has 71.3% of WO_3. The contents of niobium, tantalum, and tin are extremely low in both the two samples.

(ii) Unexplored mineral indication zones

In Area B, mineral indications due to pegmatite veins, quartz veins, and skarnized zones are distributed at various parts, but the mineralized part that can be confirmed by the naked eye and under microscope is only the skarn disseminated very slightly with scheelite at a point about 0.9 Km northwest of Yong Ku Mine. This skarn is cut through by a thin quartz vein containing scheelite 5 mm in size, and in the skarn itself scheelite grains 1 mm in size are seen sporadically. However, the ore grade as a whole is extremely low, and the WO_3 content is presumed to be 0.00n % by the naked eye. Among the pegmatite veins the one of the biggest scale is a tourmaline-two-mica pegmatite vein found in the northeast of the area, 4 m in width, with a strike and dip of N45°W/90° (?). Near this vein a few pegmatite veins, about 5 cm in width, running in parallel are found. Among the quartz veins, at a point along a mountain ridge 0.9 Km northwest of Yong Ku Mine, big floats of quartz from high-temperature coarse-grained quartz veins are found in a large quantity, though the size of the outcrops and the vein direction are not known certainly. Some of the floats contain tourmaline, and some others have thin bands of biotite.

Since, in this area, judging from the scale and frequency of appearance of pegmatite veins and quartz veins, the scale of skarnized zones, and the result of analysis of geochemical prospecting samples, occurrence of mineralized parts was expected in the northeast of the area and in the vicinity of the ridge 0.9 Km northwest of Yong Ku Mine, the heavy minerals in stream sediment in these areas were collected and studied about the mineral species and their contents as the complementary work to the geological mapping. As the result, a large quantity of cassiterite (3.1 Kg/m^3) was found in a small creek 0.9 Km northwest of the mine, and also at various other places cassiterite, wolframite, scheelite, and very small quantities of columbite-tantalite, struverite-ilmenorutile, monazite, xenotime, zircon, ilmenite, magnetite, and limonite were found. Also, from the values of chemical analysis of the heavy minerals (Table 4), the contents of niobium tantalum, tin, and tungsten were studied (Table 5).

Table 4. Results of chemical analyses of ore samples (Area B)

No.	Sample No.	Locality	Description	Nb_2O_5 (ppm)	Ta_2O_5 (ppm)	SnO_2 (%)	WO_3 (%)	Au (ppm)	A (ppm)
1	YK-1	Yong Ku mine	W-bearing biotitized zone(crude ore)	11	<1	0.00	0.27	-	-
2	YK-4	Yong Ku mine	W concentrates	9	<1	0.005	71.3	<0.2	<1
3	BPC-1	1.8Km NNE of the Yong Ku mine	Bulk panned concentrates from stream sediment	8,010	2,560	5.40	0.06	-	-
4	BPC-2	0.9Km WNW of the Yong Ku mine	Cassiterite from panned concentrates	6	<1	93.0	0.06	-	-
5	BPC-3	0.9Km NNW of the Yong Ku mine	Bulk pann ed concentrates from stream sediment	170	120	14.9	1.46	-	-
6	BPC-4	1.5Km NNW of the Yong Ku mine	do.	4,000	1,470	0.10	0.04	-	-

Table 5. Contents of niobium, tantalum, tin and tungsten in stream sediment (Area B).

No.	Sample No.	Locality	Raw material (1)	Heavy mineral (g)	Nb_2O_5 (g/m^3)	Ta_2O_5 (g/m^3)	SnO_2 (g/m^3)	WO_3 (g/m^3)
1	BPC-1	1.8 Km NNE of the Yong Ku mine	104	22	1.7	0.54	12.5	0.13
2	BPC-2	0.9 Km WNW of the Yong Ku mine	16	58	-	-	3,125*	-
3	BPC-3	0.9 Km NNW of the Yong Ku mine	80	29	0.06	0.04	54.0	5.3
4	BPC-4	1.5 Km NNW of the Yong Ku mine	64	35	2.2	0.80	0.55	0.22

* Calculated from 50g of cassiterite in 16-1-volume stream sediment.

The large quantity of cassiterite found in the small creek 0.9 Km northwest of Yong Ku Mine is 1 cm in maximum grain size, ordinarily 3 to 8 mm, and its roundness is very low, which suggests that the source is very near. The cassiterite is light yellow or light purple to light brown, and originate from quartz veins. The contents of nibium and tantalum in this cassiterite are extremely low (Table 4).

In another small creek north of this creek small quantities of light brown to light yellow cassiterite, wolframite and scheelite were found. These facts suggest that there is a high possibility of occurrence of a mineralized area with a high grade of tin at some part associated with quartz veins near the mountain ridge. Stream sediment in a creek 1.5 Km north-northwest of Yong Ku Mine contains more niobium-tantalum minerals than tin and tungsten minerals, but all of these are in extremely small quantities. On the other hand in the northeast of the area there are very small quantities of niobium-tantalum minerals and cassiterite. The cassiteriate is dark brown and pleochroic to some extent, so that it is presumed that it originates from those tourmaline pegmatite whose outcrops have been confirmed, together with the niobium-tantalum minerals. However, the contents of the niobium, tantalum, tin and tungsten minerals in the stream sediment are low, and it is estimated that the possibility of occurrence of a large-scale, high-grade mineralized zone is low in this area.

3. AREA C

3-1 Location

Area C is situated about 20 Km southwest of Omkoi. Its area is 2 Km^2. This is a rugged mountainous area with altitudes between 1,100 m and 1,300 m.

There is an auto road from Omkoi to Ban Mae Lan which is 14 Km away from Omkoi. From this to the selected survey area the distance is about 13 Km along the Mae Hat River.

This area is the one where a high tantalum anomaly was detected as the result of the geochemical prospecting in the preceding year.

3-2 Geology

This area is located in the middle of the Triassic foliated granite body which occupies the western half of the Omkoi district. Almost all of the area is covered with granitic rocks, but minor basalt dike has been intruded into the granite; also the Quaternary alluvial sediment is distributed along the Mae Hat River and its tributaries (Fig. 10, PL.3)

The Triassic granitic rocks are classified, by the lithofacies, into medium-to coarse-grained biotite granite, fine-grained biotite granite, aplite and pegmatite.

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

This rock is distributed over the whole of the area and has the features of porphyritic structure due to potash feldspar phenocrysts, 1 to 4 cm in size generally, and foliation due to biotite. According to microscope observation of samples of coarse-grained parts, the principal minerals are quartz, perthitic orthoclase, plagioclase, and brown biotite; the secondary component minerals are opaque minerals. The potash feldspar phenocrysts are perthitic orthoclase, which poikilitically contain small grains of quartz, orthoclase, and plagioclase. The biotite has been partly chloritized; part of the feldspar has been sericitized from inside; part of the opaque minerals is pyrite.

(ii) Fine-grained biotite granite (Gt3)

This rock appears as NS-oriented dikes, less than 25 m in width, in the southwest and the northeast corner of the area. The middle of a dike is gray and formed of porphyritic, fine-grained biotite granite containing potash feldspar phenocrysts, less than 1 cm in size, but the closer to the peripheries, the more dimunitive become the phenocrysts, and at the boundaries they show light gray, aphanitic chilled margin. In the chilled margin silicification and pyritization are observed.

(iii) Aplite (Ap) and pegmatite (Pg)

The aplite appears as NS-oriented dikes, less than 5 m in width, at the southeast corner and the southeast extremity of the area. All of the aplite is light gray to light pink and fine-grained. The principal minerals are quartz, plagioclase, potash feldspar, and muscovite. The aplite found at the southeast corner is accompanied by pegmatite.

The pegmatite, in addition to appearing as dikes with the maximum width of 5 m in the southwest of the area, occurs as large boulders at various parts of the area. Most of it is tourmaline-muscovite pegmatite, but at times the pegmatite contains beryl, and rarely lack tourmaline.

The pegmatite of the biggest scale in the area is NS-oriented tourmaline-muscovite pegmatite, 5 m in width, which accompanies aplite at the southeast corner. The other pegmatite dikes have a width of 0.2 to 0.5 m; they lie in either of the two directions: NNE or ENE.

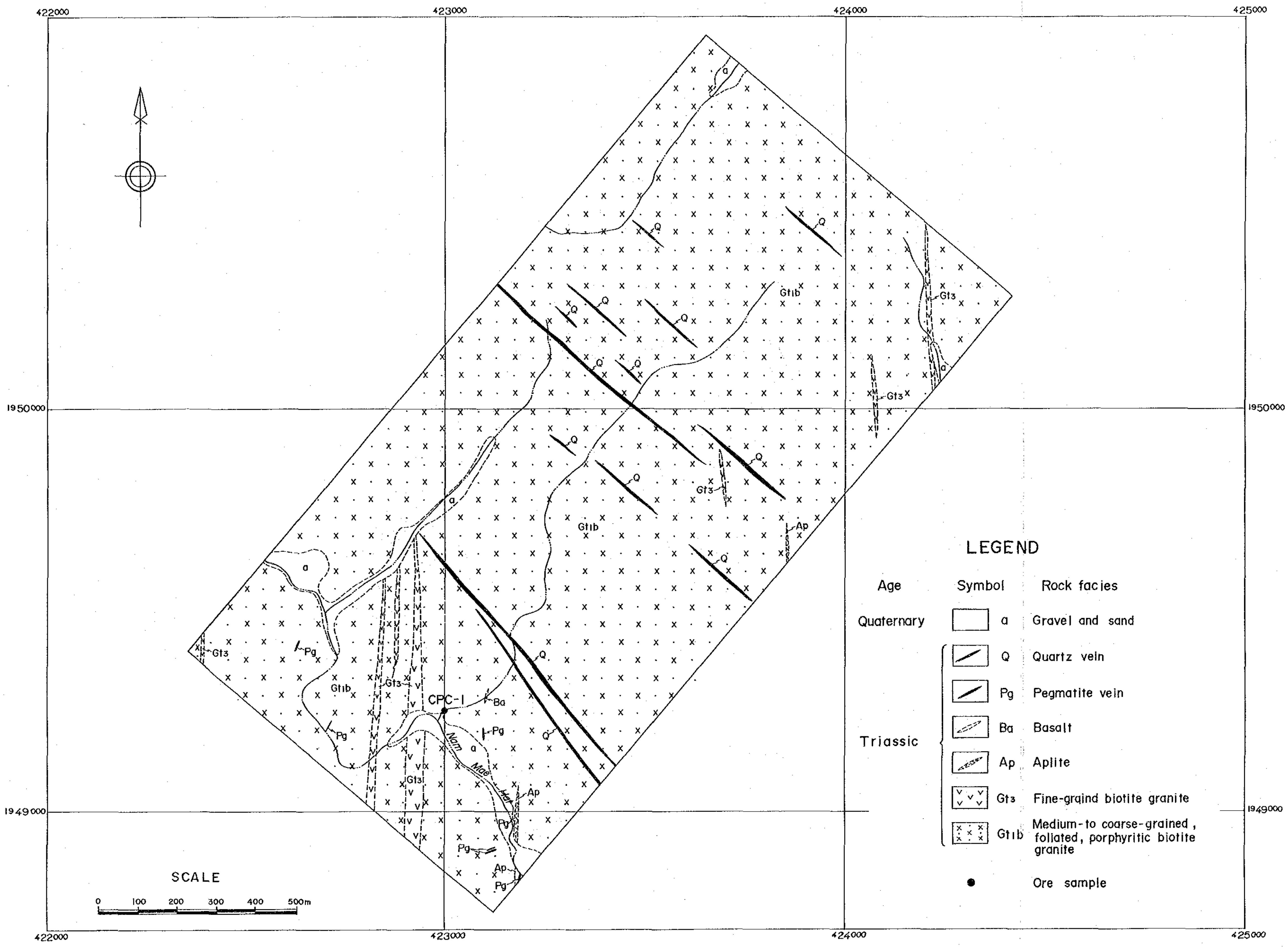


Fig.10 Geologic map of the Area C.

(iv) Basalt (Ba)

This rock is found in the form of a minor dike in the NNE direction, 1.2 m in width, intruded into the medium-to coarse-grained biotite granite in the lowest reaches of a tributary of the Mae Hat River on its north. It is dark gray, and fine-grained; its principal minerals are pyroxene, plagioclase, and opaque minerals. Although the time of its formation is not definitely known, it is presumed to be of Triassic age.

(v) Alluvium (a)

The Quaternary alluvium, distributed in lowlands along the Mae Hat River and its tributaries, mainly composed of gravels and sand of granitic rocks and quartz veins.

3-3 Geological Structure

The medium-to coarse-grained biotite granite distributed in this area has the feature of foliation due to biotite. Here also seen is the development of fracture systems indicated by dikes, pegmatite veins, quartz veins, and lineaments known from aerial photographs.

Most of the foliation has the orientation of NS to NNW and a medium to steep dip toward the northeast. This nearly concurs with the direction of the intrusion of the medium-to coarse-grained biotite granite bodies.

The fracture systems are roughly divided into the directions of NS to NNE, NW, ENE and NE. The NS to NNE direction is the direction of the intrusion of dikes of fine-grained biotite granite, aplite dikes, and some of the pegmatite dikes, and corresponds with the direction of the regional intrusion of the medium-to coarse-grained biotite granite bodies.

The fractures in the NW direction, which is the direction of the intrusion of quartz veins, are developed at various parts of the area, and form a major fracture system in the area.

The fractures in the NNE direction, which is the direction of the intrusion of pegmatite veins, appear less frequently.

The fractures in the NE direction, which is the direction of the intrusion of 1 to 3 cm wide quartz veins, appear only locally as outcrops, but the lineaments known by the aerial photographs are developed in this direction as well.

3-4 Alteration

In this area, except for weathering, sericitization, chloritization and silicification owing to hydrothermal process are found. The sericitization and chloritization is recognized in medium-to coarse-grained biotite granite in the surroundings of NW-oriented quartz veins developed in the area. The biotite in the medium-to coarse-grained biotite granite along quartz veins has been entirely replaced by sericite or chlorite; and notable gneissic structure parallel with the veins is found.

At parts where sericitization is most intense, the medium-to coarse-grained biotite granite presents an appearance which might be called gray sericite schist over a width of about five meters from the quartz vein.

The silicification is recognized at some parts of the surroundings of NW-oriented quartz veins and at the circumferences of the fine-grained biotite granite dikes.

At the silicified parts of the medium-to coarse-grained biotite granite, the original rock, occasionally remains in the breccia form. The circumferences of fine-grained biotite granite dikes present the original chilled margin, but they have been intensely turned grayish white and aphanitic. The silicification is accompanied by extremely small quantities of pyrite and chalcopyrite.

3-5 Mineralization

Pegmatite veins and quartz veins are found in the area. Most of the pegmatite veins are tourmaline-muscovite pegmatite, and some of them at the southeast corner of the area have a width of about 5 m. Large boulders containing beryl, about 2cm in diameter, are found in the southeast of the area.

The quartz veins are principally formed of fine-grained quartz; and tourmaline, muscovite, and biotite are found very rarely. Almost all the quartz veins in this area are NW-oriented; the biggest ones have a 10 m width and strike extension of more than 700 m; they have caused sericitization, chloritization and silicification to the country rock.

The silicified parts of the medium-to coarse-grained biotite granite and fine-grained biotite granite are disseminated with very small quantities of pyrite and chalcopyrite.

In the area niobium - tantalum minerals, cassiterite, wolframite and scheelite were not found by the naked eye in any of the outcrops of pegmatite veins or quartz veins or their boulders. So that, to complement the geological mapping, heavy minerals in stream sediment of a tributary of the Mae Hat River on its north were collected, and a study was made of the kinds of the minerals and the contents of niobium, tantalum, tin, and tungsten in the stream sidement.

As the result, as heavy minerals, besides orange-colored garnet and tourmaline, extremely small quantities of columbite - tantalite, struverite-ilmenorutile, cassiterite, wolframite, scheelite, monazite, xenotime, zircon, rutile, ilmenite, and magnetite were confirmed. However, the contents of niobium, tantalum, tin, and tungsten in the stream sediment obtained from chemical analysis values of the bulk heavy minerals were found extremely low (Table 6) so that the possibility of occurrence of promising mineralization zones in this area is considered low.

Table 6. Results of chemical analyses of ore sample and contents of niobium, tantalum, tin and tungsten in stream sediment (Area C).

Sample No.	Location	Sample	Nb_2O_5	Ta_2O_5	SnO_2	WO_3
CPC-1	Northern tributary of the Mae Hat River	Bulk panned concentrates from stream sediment	ppm 2,290	ppm 2,560	% 2.16	% 0.08
			g/m^3 1.0	g/m^3 1.1	g/m^3 9.6	g/m^3 0.36

Upper figures are chemical analyses of bulk panned concentrates and lower figures are contents in the stream sediment.

4. AGE DETERMINATION OF GRANITIC ROCKS

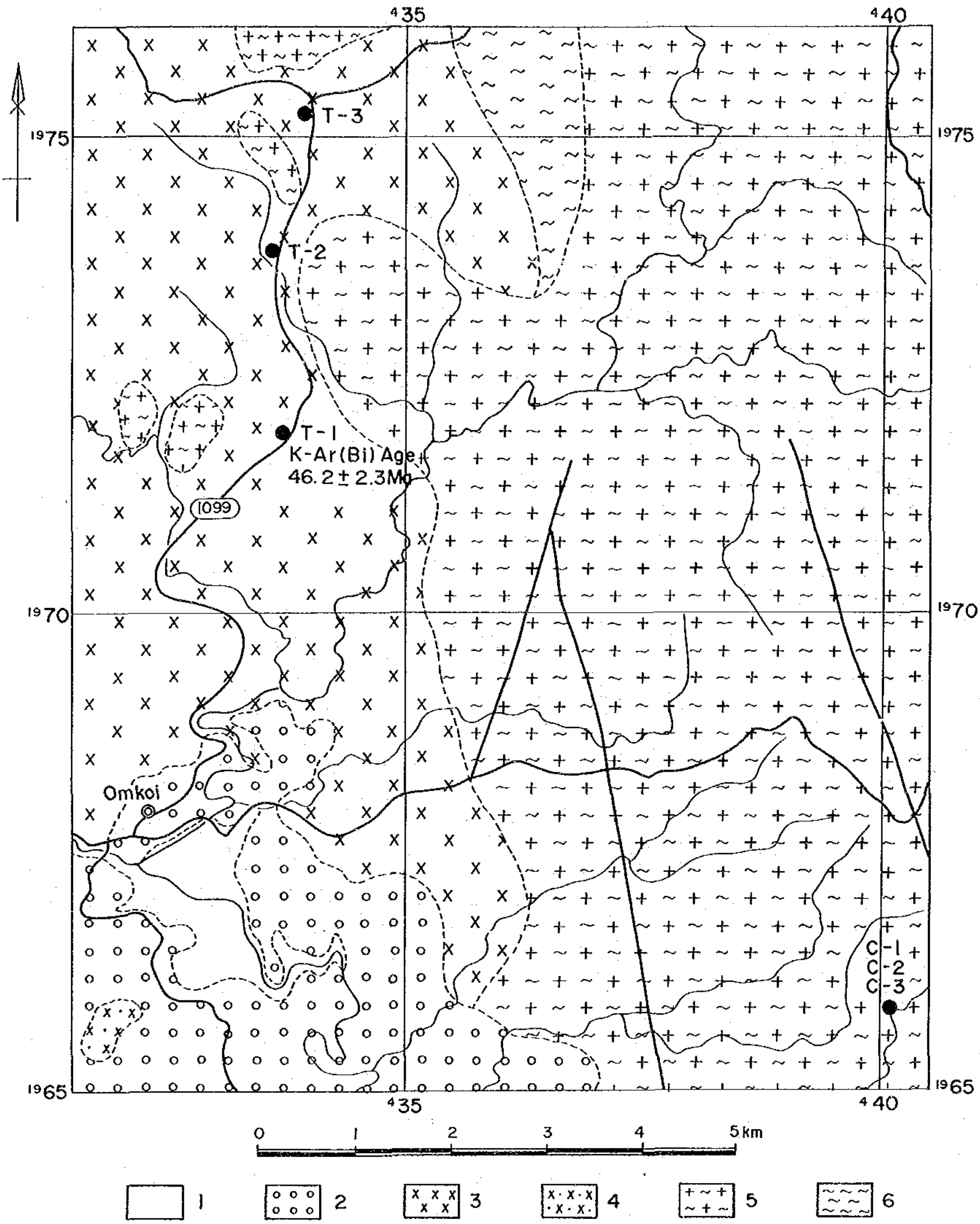
The granitic rocks distributed in the Omkoi district have been broadly classified into the Carboniferous gneissose granitic rocks and the Triassic granitic rocks. In the Phase I survey, age determination by the K-Ar method was made by using biotite from three rock bodies (five samples) excluding gneissose granitic rocks. As the result two rock bodies (four samples) indicated the age of the Cretaceous to the Tertiary (70.2 $\pm$3.5 to 65.1 $\pm$3.3 Ma) and one rock body (one sample) the age of the Tertiary (46.2 $\pm$2.3 Ma).

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 $\pm$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 widely differ from 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 depth at a higher temperature than the blocking temperature (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 view of the above-mentioned, in this phase the age determination by the Rb-Sr method was made for the gneissose granite that have been classified as the Carboniferous and the granite that indicate the Tertiary by the K-Ar method (Table 7 and Figs. 11 and 12).



1 ; Quaternary alluvium

2 ; Tertiary conglomerate

3 ; Cretaceous granite

4 ; Triassic foliated granite

5 ; Carboniferous gneissose granite

6 ; Pre-Carboniferous metamorphic rocks

Fig. 11 Locality and geologic setting for Rb−Sr whole-rock dating samples.

Table 7. Results of Rb-Sr whole-rock datings

Sample No.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Model age
C - 1	417.04	107.81	11.19	0.75333±0.00006	
C - 2	538.55	149.37	10.43	0.73854±0.00007	
C - 3	315.18	91.84	9.93	0.75473±0.0013	
T - 1	314.09	120.40	7.55	0.71983±0.00004	87.6±61.2 Ma
T - 2	297.20	129.33	6.65	0.72086±0.00004	
T - 3	271.29	153.62	5.11	0.71784±0.00013	

C - 1; coarse-grained, gneissose, porphyritic melanocratic biotite granite,

C - 2; medium-grained, gneissose, porphyritic biotite granite,

C - 3; medium-grained, gneissose luecocratic biotite granite,

T - 1; medium-grained, porphyritic muscovite-biotite granite,

T - 2; fine-grained biotite granite,

T - 3; fine-grained muscovite-bearing biotite granite.

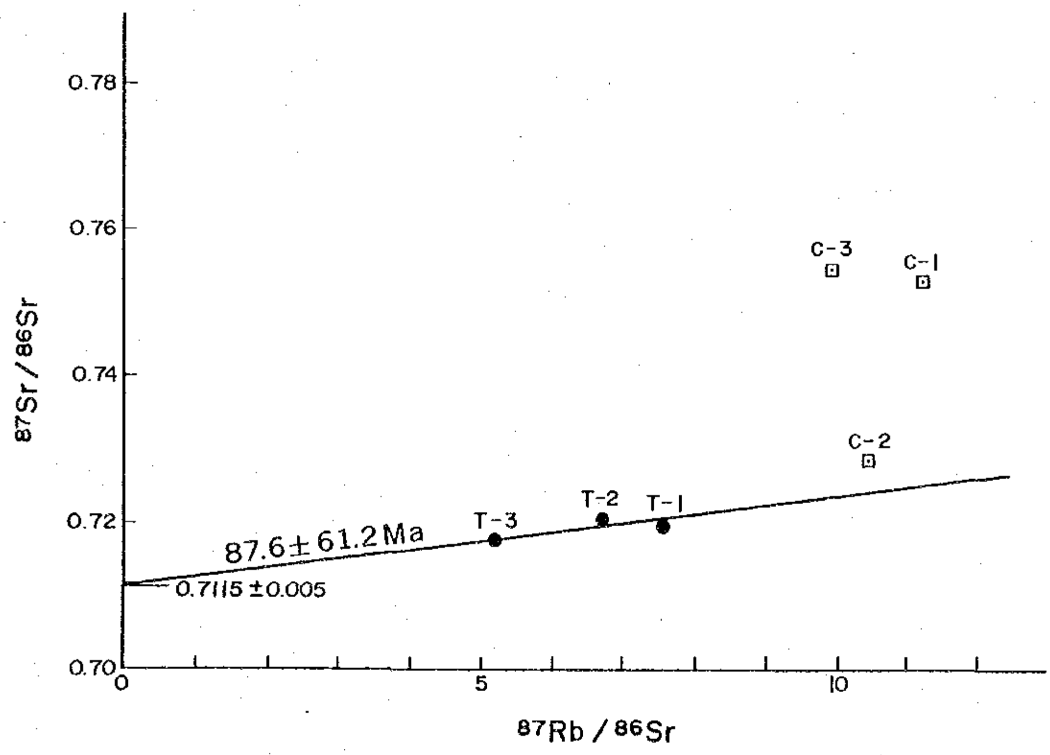


Fig.12 Rb-Sr isochron diagram.

As the result of the determination, on the rock body that has been said to be of the Carboniferous, proper whole-rock isochron could not be obtained because the measurement values from sample to sample dispered too much. So that the age of this rock body was unable to be definitely determined. However, on the Tertiary-aged granite by the K-Ar method a tentative isochron was found ; it was inferred that its Rb-Sr whole-rock age is 87.6 $\pm$61.2 Ma with a initial Sr isotope ratio of 0.7115 $\pm$0.005.

The rock body that has been thought to be of Carboniferous age presents a distinct gneissic structure and has undergone intense matamorphism. The sample used for the age determination 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, and it may be said the freshest sample as far as one can obtain in the district. The cause of the measurement values not being able to be plotted in one isochron is generally attributed to the following factors: 1) assimulation 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 and others).

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.

On the other hand, the rock body indicating the Rb-Sr age of the probable Cretaceous age is distributed to the north of Omkoi in a stock form and does not present foliation. The K-Ar age of this rock body by its biotite is 46.2 ±2.3 Ma (Tertiary; JICA and MMAJ, 1984), which means an age difference of about 41 Ma from the Rb-Sr age. 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 Omkoi 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 ±4 Ma of the Rb-Sr age; Beckinsale et al., 1979) lying about 50km west of the Omkoi district. In the sedimentary rocks on the margin of this rock body and in its surroundings, 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 130 Ma ago (earliest

Cretaceous), was subjected to a hydrothermal process and mineralization accompanied by tin and tungsten. 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.

5. GEOCHEMISTRY OF GRANITIC ROCKS

In the Omkoi area the granitic rocks of Carboniferous, Triassic and Cretaceous ages are extensively distributed. In the Phase I survey, the chemical analysis for the principal components and trace components (fluorine, chlorine, tin and tungsten) of the 50 samples taken from the granite bodies was made, and the relations between geochemical properties of the granitic rocks and the tin and tungsten mineralization were regionally studied. As the result it was found that almost all the granitic rocks distributed over the Omkoi area belong to the proper granite and correspond to the S-type(sedimentary-type) granite categorized by Chappell and White (1974) and White and Chappell (1979), and are the tin granite in which the fluorine/chlorine ratio is high and tin content is also high.

In the survey this year, from granitic rocks, including, particularly, fine-grained granite, aplite, and pegmatite formed at the end of the activities, in the surroundings of niobium, tantalum, tin and tungsten mineral indication zones in the selected survey areas, 17 samples were taken (Table 8, PL.4 to 6, and Fig. 11), and analysis was made for the principal components and trace components (fluorine, chlorine, niobium, tantalum, tin, and tungsten) of the samples (Table 9); and, together with the data from the Phase I survey (Table 10), a study was made of the relations between the change of the geochemical properties resulting from differentiation of the granitic rocks and the niobium, tantalum, tin and tungsten mineralization.

From the normative mineral composition calculated from the principal components (Table 9), it is found that corundum has been calculated from all the samples for the first year, and for this year too corundum is calculated except for two samples (A-13-43 and A-15-41), which confirm the fact that the granitic rocks of the Omkoi area are of peraluminous granite with some partial exceptions. The two samples that do not contain normative corundum exceptionally 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, diopside, etc. and no corundum is calculated.

From the differentiation indexes indicated by the total weight percentages of the normative quartz, orthoclase, albite, nepheline, and kalsilite, it is found that, when the date from the first year survey are combined, the gneissose granite of Carboniferous age presents 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 principal 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 epidote, 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-calcium 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 principal components and the trace components (Fig.13), in the principal component first, as the differentiation indexes increase, SiO_2 and Na_2O 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 compon ents 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 high contents of SiO_2 and Na_2O, though there are exceptions and overlapping 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 trace 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 normative quartz, plagioclase, and orthoclase, almost all the samples were plotted in the area of proper granite (Fig. 14 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 $Na_2O < 3.2\%$ (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. 14 b) the values are plotted in the CaO-depleted area. When the collected samples were classified according to the above (Table 11), it was found that the 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 calc-alkali rock series, but according to the MFA diagram (Fig. 15a) 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.

In connection with granitic rock and (tin-) tungsten-molybdenum mineralization, classification of granite into the magnetite-series and ilmenite-series is made by the quantity and ratio of magnetite and ilmenite in granite (Ishihara, 1977). The granitic rocks of the Omkoi area have been found to belong to the 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. 15 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 trace 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. 16 a), they present a little high fluorine/chlorine ratio except for the Triassic fine-grained granite, showing a similar trend to that of the granitic rocks of the peninsular part of Thailand.

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 $\pm$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 Omkoi 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

Table 8. Granitic rock samples for whole-rock chemical analyses

No.	Sample No.	Locality	Rock name
1	A-9-40	Pha Pun Dong mine	Medium-grained, porphyritic, foliated muscovite-biotite granite
2	A-13-43	0.4 Km east of the Pha Pun Dong mine	Fine-grained, foliated tourmaline -epidote aplite
3	A-15-15	1Km northeast of the Pha Pun Dong mine	Coarse-grained, porphyritic, foliated biotite granite
4	A-15-41	0.6 Km east of the Pha Pun Dong mine	Fine-grained, foliated epidote - tourmaline aplite
5	A-15-95	Mae Lamit river	Medium-grained, porphyritic, foliated muscovite-bearing biotite granite
6	A-29-146	Pong Noi creek	Fine-grained garnet-bearing biotite granite
7	A-35-131	do.	Fine-grained muscovite-bearing biotite granite
8	A-35-169	Pong Yai creek	Coarse-grained, porphyritic,foliated muscovite-biotite granite
9	B-15-20	0.3 Km northeast of the Yong Ku mine	Fine-grained muscovite-bearing aplite
10	C-5-7	North of the Mae Hat river	Tourmaline-muscovite pegmatite
11	C-10-13	do.	Coarse-grained, porphyritic,foliated biotite granite
12	C-1	8 Km east-southeast of Omkoi	Coarse-grained,porphyritic,gneissose, melanocratic biotite granite
13	C-2	do.	Medium-grained,porphyritic,gneissose biotite granite
14	C-3	do.	Medium-grained,gneissose, leuco-cratic biotite granite
15	T-1	4Km north-northeast of Omkoi	Medium-grained,porphyritic muscovite-biotite granite
16	T-2	6Km north-northeast of Omkoi	Fine-grained biotite granite
17	T-3	7.5Km north-north-east of Omkoi	Fine-grained,porphyritic,muscovite -bearing biotite granite

Table 9. Results of whole-rock chemical analyses of granitic rock samples (1)

	A-9-40	A-13-43	A-15-15	A-15-41	A-15-95	A-29-146
SiO_2 (%)	72.7	64.0	71.1	67.1	72.7	75.2
TiO_2	0.28	0.36	0.47	0.65	0.40	0.09
Al_2O_3	13.7	17.1	13.7	16.9	14.3	13.9
Fe_2O_3	0.20	2.88	0.12	0.47	0.09	0.03
FeO	1.40	1.06	2.28	1.15	1.36	0.68
MnO	0.02	0.04	0.05	0.02	0.01	0.06
MgO	0.63	0.42	1.20	0.98	0.68	0.10
CaO	1.00	11.99	1.52	6.13	1.30	0.66
BaO	0.064	0.099	0.083	0.007	0.069	0.029
Na_2O	2.72	0.75	2.94	4.54	3.19	3.11
K_2O	5.12	0.03	4.34	0.40	4.46	5.37
P_2O_5	0.20	0.24	0.18	0.27	0.21	0.11
LOI	0.84	0.60	0.59	0.22	0.52	0.36
Total	98.87	99.48	98.57	98.84	99.29	99.70
Q (%)	31.98	37.06	27.91	25.03	31.19	34.06
C	2.30	0	1.78	0	2.32	2.01
or	30.26	0.18	25.65	2.36	26.36	31.74
ab	23.00	6.34	24.86	38.39	26.98	26.30
an	3.78	43.20	6.53	24.56	5.22	2.61
di	0	2.26	0	3.28	0	0
(en)	(0)	(1.05)	(0)	(1.22)	(0)	(0)
(fs)	(0)	(0)	(0)	(0.34)	(0)	(0)
(wo)	(0)	(1.21)	(0)	(1.71)	(0)	(0)
hy	7.10	0	12.78	3.13	6.95	2.87
(en)	(3.14)	(0)	(5.97)	(2.44)	(3.39)	(0.50)
(fs)	(3.96)	(0)	(6.81)	(0.69)	(3.56)	(2.37)
(wo)	(0)	(0)	(0)	(0)	(0)	(0)
wo	0	4.94	0	0	0	0
mg	0.29	2.50	0.17	0.68	0.13	0.04
il	0.53	0.68	0.89	1.23	0.76	0.17
ap	0.47	0.57	0.43	0.64	0.50	0.26
Salic total	91.32	86.79	86.72	90.35	92.06	96.73
Femic total	8.39	10.95	14.28	8.96	8.33	3.35
D.I.	85.49	44.59	77.65	66.24	84.20	92.03
Nb (ppm)	18	22	22	30	5	10
Ta	1	2	2	2	1	1
Sn	83	45	30	24	17	10
W	41	3	1	2	1	3
F	460	210	690	420	590	140
Cl	29	10	59	34	100	20

(2)

	A-35-131	A-35-169	B-15-20	C-5-7	C-10-13	C-1
SiO_2 (%)	74.7	72.2	73.2	78.3	69.6	69.2
TiO_2	0.26	0.37	0.04	0.05	0.49	0.75
Al_2O_3	13.8	14.4	14.6	13.2	13.9	13.5
Fe_2O_3	0.03	0.10	0.50	0.24	0.30	0.84
FeO	1.15	1.33	0.14	0.11	2.26	4.06
MnO	0.03	0.03	0.04	0.01	0.04	0.07
MgO	0.41	0.56	0.03	0.67	2.01	1.79
CaO	1.44	0.90	0.37	0.95	1.54	1.96
BaO	0.044	0.077	0.020	0.001	0.130	0.068
Na_2O	3.55	3.08	4.36	4.65	2.73	2.46
K_2O	2.89	4.90	4.60	0.72	4.81	4.54
P_2O_5	0.06	0.17	0.06	0.05	0.18	0.21
LOI	0.87	0.66	0.70	0.32	1.02	0.95
Total	99.23	98.78	98.66	99.27	99.01	100.40
Q (%)	37.27	30.72	29.52	44.62	23.55	23.38
C	2.33	2.75	1.91	3.17	1.74	1.43
or	17.08	28.96	27.19	4.26	28.43	26.83
ab	30.02	26.05	36.87	39.32	23.09	20.80
an	6.83	3.50	1.48	4.39	6.71	8.49
di	0	0	0	0	0	0
(en)	(0)	(0)	(0)	(0)	(0)	(0)
(fs)	(0)	(0)	(0)	(0)	(0)	(0)
(wo)	(0)	(0)	(0)	(0)	(0)	(0)
hy	5.47	6.40	0.15	3.34	16.34	20.22
(en)	(2.04)	(2.79)	(0.15)	(3.34)	(10.01)	(8.91)
(fs)	(3.43)	(3.61)	(0)	(0)	(6.33)	(11.30)
(wo)	(0)	(0)	(0)	(0)	(0)	(0)
wo	0	0	0	0	0	0
mg	0.04	0.14	0.47	0.24	0.43	1.22
il	0.49	0.70	0.08	0.09	0.93	1.42
ap	0.14	0.40	0.14	0.12	0.43	0.50
Salic total	93.54	91.98	96.97	95.76	83.52	80.93
Femic total	6.15	7.65	0.83	3.79	18.13	23.36
D.I.	84.64	86.05	95.68	88.60	73.85	68.10
Nb (ppm)	12	16	21	51	18	58
Ta	1	2	3	34	2	4
Sn	28	29	10	15	13	15
W	6	2	1	8	3	1
F	300	530	60	50	300	480
Cl	10	23	11	10	33	110

	C − 2	C − 3	T − 1	T − 2	T − 3
SiO_2 (%)	68.6	76.5	72.4	71.9	71.6
TiO_2	0.53	0.25	0.27	0.39	0.41
Al_2O_3	14.1	11.7	13.9	14.1	14.1
Fe_2O_3	0.60	0.31	0.26	0.41	0.30
FeO	2.66	1.26	1.33	1.51	1.58
MnO	0.04	0.02	0.03	0.03	0.04
MgO	0.94	0.46	0.38	0.56	0.42
CaO	1.00	1.30	1.54	1.78	1.87
BaO	0.170	0.039	0.063	0.072	0.088
Na_2O	2.08	2.28	2.90	2.84	2.94
K_2O	7.69	4.56	5.06	5.02	5.00
P_2O_5	0.16	0.05	0.09	0.10	0.12
LOI	0.45	0.47	0.85	0.82	0.73
Total	99.02	99.20	99.07	99.53	99.20
Q (%)	19.18	40.22	30.28	29.24	28.52
C	0.80	0.74	1.03	0.95	0.68
or	45.45	26.95	29.90	29.67	29.55
ab	17.59	19.28	24.52	24.02	24.86
an	4.23	6.19	7.17	8.31	8.66
di	0	0	0	0	0
(en)	(0)	(0)	(0)	(0)	(0)
(fs)	(0)	(0)	(0)	(0)	(0)
(wo)	(0)	(0)	(0)	(0)	(0)
hy	11.86	5.65	5.57	6.48	6.19
(en)	(4.68)	(2.29)	(1.89)	(2.79)	(2.09)
(fs)	(7.18)	(3.36)	(3.67)	(3.69)	(4.10)
(wo)	(0)	(0)	(0)	(0)	(0)
wo	0	0	0	0	0
mg	0.87	0.45	0.38	0.59	0.43
il	1.01	0.47	0.51	0.74	0.78
ap	0.38	0.12	0.21	0.24	0.28
Salic total	87.26	93.39	92.90	92.19	92.27
Femic total	14.11	6.70	6.67	8.05	7.69
D.I.	81.11	86.38	85.07	82.73	82.97
Nb (ppm)	37	16	18	17	15
Ta	2	1	1	1	1
Sn	11	9	12	10	7
W	2	1	3	1	3
F	220	140	250	380	430
Cl	49	17	27	34	25

Table 10. Niobium and tantalum contents in the granitic rock samples collected by the Phase I survey

	OAR-1	OAR-3	OAR-4	OAR-7	OAR-9	OAR-10	OAR-11	OAR-12	OAR-13	OAR-14
Nb	3	13	20	14	12	13	14	14	4	14
Ta	1	3	3	2	2	3	3	2	1	2

	OAR-15	OAR 16	OAR-17	OAR-18	OAR-19	OAR-20	ONR-1	ONR-7	ONR-11	ONR-12
Nb	12	3	20	14	14	15	1	13	7	16
Ta	2	1	5	2	3	2	1	2	2	2

	ONR-14	ONR-15	ONR-16	ONR-20	ONR-26	ONR-27	ONR-29	ONR-30	ONR-31	ONR-32
Nb	4	15	7	23	11	10	17	16	20	13
Ta	1	3	1	6	2	1	3	3	3	2

	ONR-33	ONR-34	ONR-35	ONR-36	ONR-39	ONR-42	ONR-44	ONR-46	ONR-61	OUR-7
Nb	12	12	12	15	12	13	12	12	9	15
Ta	2	2	4	3	3	2	1	2	2	2

	OUR-10	OUR-11	OUR-101	OYR-4	OYR-5	OYR-6	OYR-9	OYR-15	OYR-27	OYR-29
Nb	13	16	16	16	14	11	18	11	10	10
Ta	2	2	3	2	2	1	3	1	2	1