JICA THE KINGDOM OF THAILAND
REPORT ON THE COOPERATIVE MINERAL EXPLORATION
OF YANG KIANG AREA PHASE II MARCH 1988 MJ MI AC

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(THE COLUMBITE-TANTALITE EXPLORATION PROJECT)

PHASE II

MARCH, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

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

The JICA and MMAJ sent a survey team headed by Mr. Iwao Uchimura to the Kingdom of Thailand from 5 Novemver, 1987 to 16 January, 1988.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Yang Kiang area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

February, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato
President
Metal Mining Agency of Japan

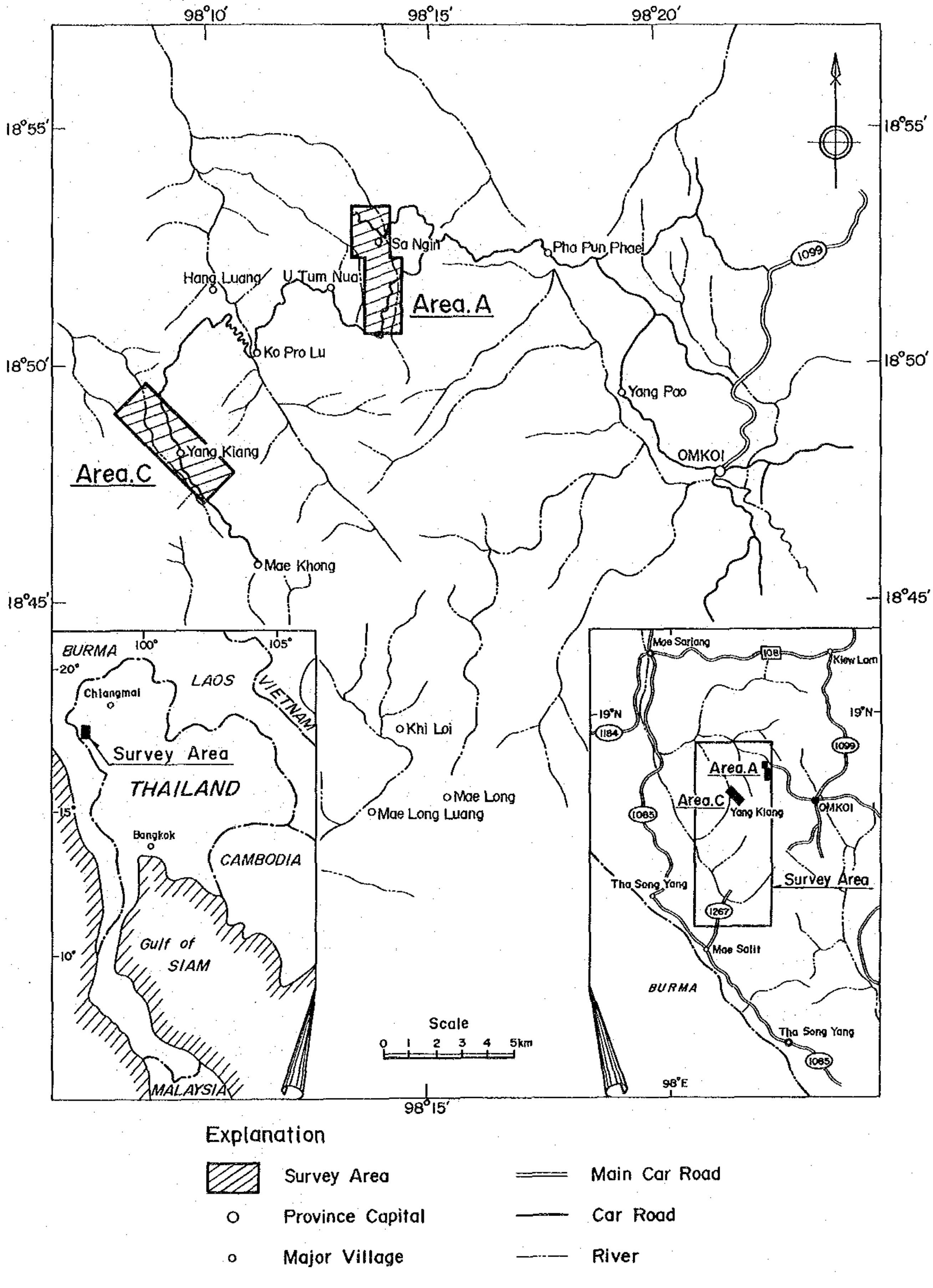

Fig. 1 Location map of the survey area

SUMMARY

This survey is the second phase of Cooperative Mineral Exploration in Yang Kiang area, in the Kingdom of Thailand.

In the first phase, geological survey and geochemical survey on stream sediment were carried out in the 1,000km^2 area centered on Yang Kiang village.

This second phase survey was carried out in two areas, Area A (7.5km^2) and Area C (8.0 km^2), which were singled out as highly potential areas for niobium, tantalum, tin, and tungsten by the first phase survey.

In the second phase, geological and geochemical survey were carried out to identify areas of high potential for economic minerals by studying characteristics of granites, geological structure, mineralization and other geologic features in the areas.

The Yang Kiang area, including the survey area, is composed of sedimentary rocks of the pre-Carboniferous to the Triassic, intruding granites as batholith or stock, and alluvium.

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

Old workings of placer deposits of tin and tungsten are in the upper and the lower stream of Huai Sa Ngin and tributaries of Huai U Tum in the survey area. Placer deposit indications are found along these main rivers.

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

This fact indicates that placer deposits originated from pegmatite dikes.

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

Locations of anomalous zones rich in the aforementioned elements coincide around old workings along tributaries of Huai U Tum and mineral indications in the middle course of Huai

Sa Ngin. Therefore, it is expected that there might be undiscovered pegmatites rich in niobium, tantalum, tin, and tungsten.

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

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

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

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

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

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

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

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

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

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

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

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

The gossan zone and the kaolinite zone are arranged in NNW-SSE direction.

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

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

Because geochemical anomalies of over 1,000 ppm of tin and tungstens are detected in many places in the anomolous zones and old workings rich in iron, copper and zinc distributed in this zone, it is anticipated that promising mineralized zones are present.

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PART I GENERAL REMARKS

Chapter 1 Introduction

1–1 Background and objective of the survey

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

The survey in the Omkoi area revealed the geology, geological structure, related igneous rocks and the characteristics of mineral deposit, and found come out with new discovery of some new mineral indication zones of niobium, tantalum, tin, and tungsten.

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

In response to this request the Japanese Government has sent a mission in July 1986 and has negotiated with Department of Mineral Resources, the Ministry of Industry. As a result of this negotiation the two governments reached an agreement of setting about the above mentioned survey.

This survey in the Yang Kiang area started at 1986 as the Phase I survey of the three years, cooperative activity. And the survey at 1987 was Phase II survey.

In the Phase I survey geological and geochemical prospecting were carried out to select some high possibility area of mineral deposits and also to understand geological structure, igneous activity, and mineralization.

As a result of the Phase I survey, Huai Sa Ngin to Huai U Tum area (Area A), Huai Chi Non Luang area (Area B) and Yang Kiang area (Area C) were extracted as the areas with high possibility of mineral deposit of niobium, tantalum, tin, and tungsten.

Area A and Area C were selected for the Phase II survey from among these areas.

The objective of the Phase II survey is to make clear the relationship between mineralization and geochemical properties and the geology and geological structure with detailed geological survey and geochemical prospecting.

1–2 Contents of the Survey

The geological survey and geochemical prospecting were conducted in the Phase II survey.

The geological survey was made along geochemical sampling lines, trials, and streams. Route maps were prepared on a scale of 1 to 5,000.

The detailed survey on a scale of 1 to 200 was conducted at mineral indication areas.

As for the geochemical prospecting, B-horizon soil samples were collected in the rectangular grid systems. The direction of the sampling lines was decided by the principal geological structure and the direction of anomalies was extracted by the Phase I survey. Each sampling line was spaced of 100m, and each sampling point on these lines was arranged at an interval of 50m. The measurement of sampling lines and sampling points was made with the use of pocket compasses and measuring tapes. As a result of the measurement, the maps on a scale of 1 to 5,000 were prepared.

Contents of the Phase II survey are shown in Table 1.

Table 1 Contents of survey and their quantities

Item	Quantity
Detailed survey Geological survey Geochemical prospecting	Area A Covered area 7.5 km^2 Route length 76.5 km Area C Covered area 8.0 km^2 Route length 95.0 km
Microscopic observation of thin sections	15 pieces
Microscopic observation of polished sections	21 pieces
X-ray diffraction tests	24 samples
Chemical analysis	
Rock: SiO_2, Al_2O_3, CaO, MgO, Na_2O, K_2O, Fe_2O_3, FeO, TiO_2, P_2O_5, BaO, L.O.I.	11 samples
Ore: Nb, Ta, Sn, W	17 samples
Soil: Nb, Ta, Sn, W	Area A 1,591 samples Area C 1,658 samples 3,249 samples

1–3 Schedule and Personnel of the Survey

1. Negotiation and Planning of the Survey

Japan

Takeshi Izumi	Metal Mining Agency of Japan
Seiichi Ishida	ditto
Yositaka Hosoi	ditto
Yasuo Endo	ditto
Toshihiko Hayashi	Japan International Cooperation Agency

Thailand

Sivavong Changkasiri	Department of Mineral Resources	(Director General)
Thawat Japakasetr	ditto	(Director of Economic Geology Div.)
Chanin Rasrikriengkrai	ditto	(Project Director)
Phairat Suthakorn	ditto	(Project Manager)
Prachon Charoensri	ditto	
Kasem Chancharoonpong	ditto	
Samai Chiemchindaratana	ditto	
Sunoj Uenguoom	ditto	

2. The Phase II Survey

(i) Period: November 5, 1987 to January 16, 1988

(ii) Members of survey team

Japan

Geological and geochemical survey

Iwao Uchimura	Geologist
Jun Matsunaga	ditto
Yasunori Ito	ditto
Takamasa Horikoshi	ditto
Junichi Maeno	ditto
Makoto Miyoshi	ditto

Thailand

Geological and geochemical survey

Peerapong Khuenkong	Geologist
Patchara Jariyawat	ditto
Wason Chanseang	ditto
Sawang Wanlaid	Field Assistant

Chapter 2 Geographical Information of the Survey Area

2–1 Location and Accessibility

The phase I survey covers an area of 50 km in the north-south direction and 20 km in the east-west direction. Yang Kiang village is the central part of the survey area.

The survey area is located about 200 km southwest of Chiang Mai City in the north of Thailand. Administratively, its eastern half falls under Omkoi district, Chiang Mai province, its northwest under Mae Hong Son province, and its southwest and south under Tha Song Yang district, Tak province.

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

The base camp in Omkoi town is accessible from Chiang Mai by National Highway No. 108 and then National Highway No. 1099. These national highways are fully paved.

There is a bus service to Omkoi making one trip in a day on this route. The distance from Chiang Mai to Omkoi is approximately 180 km and it takes about three hours by car.

Two areas were surveyed this year. One is Huai Sa Ngin and the upper reaches of Huai U Tum (Area A). The other is around Yang Kiang village (Area C).

An unpaved car road from Omkoi to Mae Khong village leads to these two areas. As this road is very steep and winding, four-wheel drive car is convenient, and it becomes hardly passable in the rainy season.

The distance from Omkoi to Area A is about 25 km and it takes about 1 and ½ hours by car. The distance from Omkoi to Area C is 55 km and it takes about 3 and ½ hours by car.

2–2 Topography

In the Yang Kiang area main rivers run in the direction of NW-SE and their tributaries run at right angle to them. Mountains lie in the direction of NW-SE or NE-SW.

This area can be divided into three zones by Nam Mae Lop which flows northwest in the northeast part and Nam Mae Ngao which flows northwest in the southwest.

The northeast region of Nam Mae Lop is composed of a plateau, 700 to 1,100 m above sea level, with relatively developed dissection. The greater part of this survey area forms rugged mountains with a relative height difference of about 1,600 m at the altitude of 200 to 1,800 m.

The northwest region of Nam Mae Ngao becomes gently higher toward the mountains which lie in the direction of NW-SE with Doi Mon Kathing. The southwest side of these mountains is a very steep cliff.

2–3 Climate and Vegetation

The Yang Kiang area is under a climate of the tropical savanna type. The period from May to October is the rainy season influenced by the southwest monsoon, while the period from November to February is the dry season under the influence of the northeast monsoon. The months of March and April are the hottest season in a year as the northeast wind becomes weak.

Generally the monthly average temperature is in the range of 16 to 28°C. But diurnal range in the dry season is large in the range of 3 to 35°C. In high mountain areas the lowest temperature comes down to about 0°C and it frosts at times. Annual precipitation ranges from 800 to 900 mm, with very little rainfall in the dary season.

In the north to east of the Yang Kiang area, most of the vegetation consists of primeval thin forests of broadleaf trees mingled with such coniferous trees as pine trees.

However, jungle-like thick forests in which palm trees are found are prevailing in the southwest.

2–4 General Information

Karen people, one of the hill tribes, live dominantly in the survey area. Their small villages, which consist of several to scores of houses, are scatteringly constructed on flat places of valleys and hills in the whole survey area.

There are primary schools at major villages such as Yang Kiang, Mae Khong, and Mae Ramoeng and a travelling clinic visits them. Therefore people are civilized step by step, but most of them live self-sufficient lives because car roads are still undeveloped.

Their main industry is rice culture on paddy fields and dry fields made by the slash-and-burn method; in addition there are stock farming (cattle, buffaloes and hogs), textile work, mining (tin and tungsten), forestry (mainly teak wood), and others.

The base camp of the survey team was set up in Omkoi town. This town is an administrative and commercial center of this region. There is the office of Omkoi district, in addition there are primary schools, junior high school, hospital, post office, police station, general shops, restaurants, gas station, and others.

Chapter 3 Geological Information of the Survey Area

3–1 Previous Works

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

A German geological mission conducted a regional survey in northern Thailand in cooperation with the Department of Mineral Resources from 1965 to 1971, and evaluated its mineral potential based on the stratigraphy and geological structure established by the survey. The report describes tin, tungsten, fluorite, and antimony deposits in the Omkoi area. Based on the results of the survey, the Geological map of Northern Thailand, compiled by E.V. Broun, L. Hahn, and H.D. Maronde, 1981, was prepared. Hahn and Siebenhüner described fossils from the map area in 1982. Vichet and Khuenkong described tin and tungsten occurrences and characteristics in the Omkoi area in 1983. At the same time, they discussed the relationship between tin deposits and niobium-tantalum minerals found in stream sediment from the area.

3–2 Summary of Geology and Ore Deposits

Geology in the Yang Kiang area including the survey area is summarized from i) the Geological map of Northern Thailand "Sheet 6-Amphoe Li" scale 1:250,000 compiled by Broun, et. al, 1981, ii) the report of the German geological mission, 1972, and iii) the results of the first phase survey by the Japanese mission, as follows.

1. Stratigraphy

The area is underlain by sedimentary, metamorphic, and granitic rocks as shown in Fig. 2 (Geological Map of the Yang Kiang area) and Fig. 3 (Schematic geological column). The stratigraphy of the area is classified from the bottom to the top as follows: Pre-Carboniferous metamophic rocks, Cambrian to Ordovician System, Ordovician System, Silurian to Devonian System, Devonian to Carboniferous System, Carboniferous to Permian System, Permian to Triassic System, and Quaternary System.

These sedimentary systems are divided into two parts by a fault, running in a northwest to southeast direction, and each part shows a different sedimentary environment. In the northeastern part, the rocks of the Ordovician are predominant as limestone overlain by the Ordovician to Carboniferous and the Permian to the Triassic. In contrast, the southeastern part is the Ordovician as alternation of limestone and shale in the ordovician overlain by the Carboniferous to Permian without the Silurian and Devonian. This suggests that these two parts are under different geological environments, the former in the Western Range Tectonic Province and the latter in the

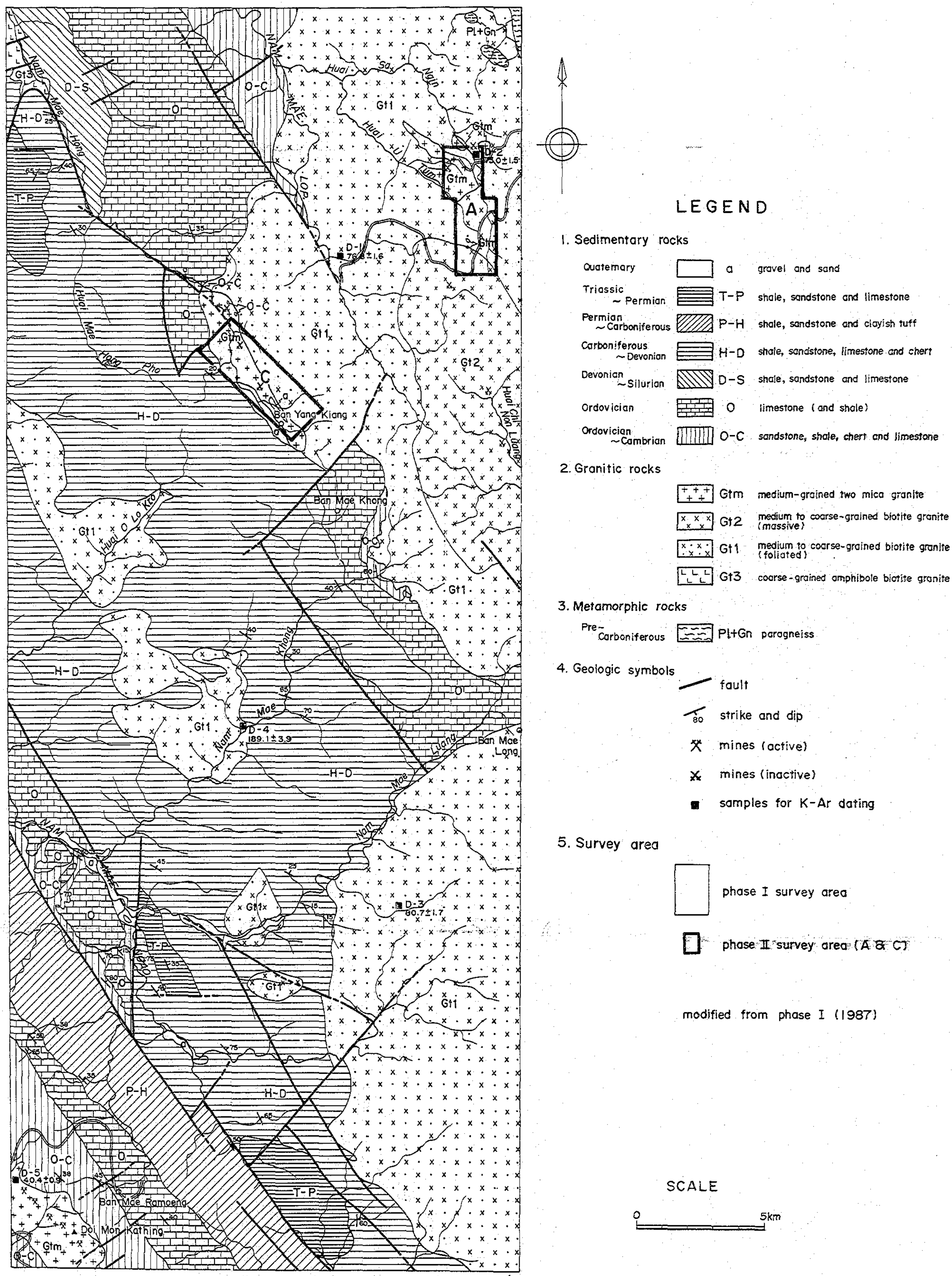


Fig. 2 Geologic map of the Yang Kiang area

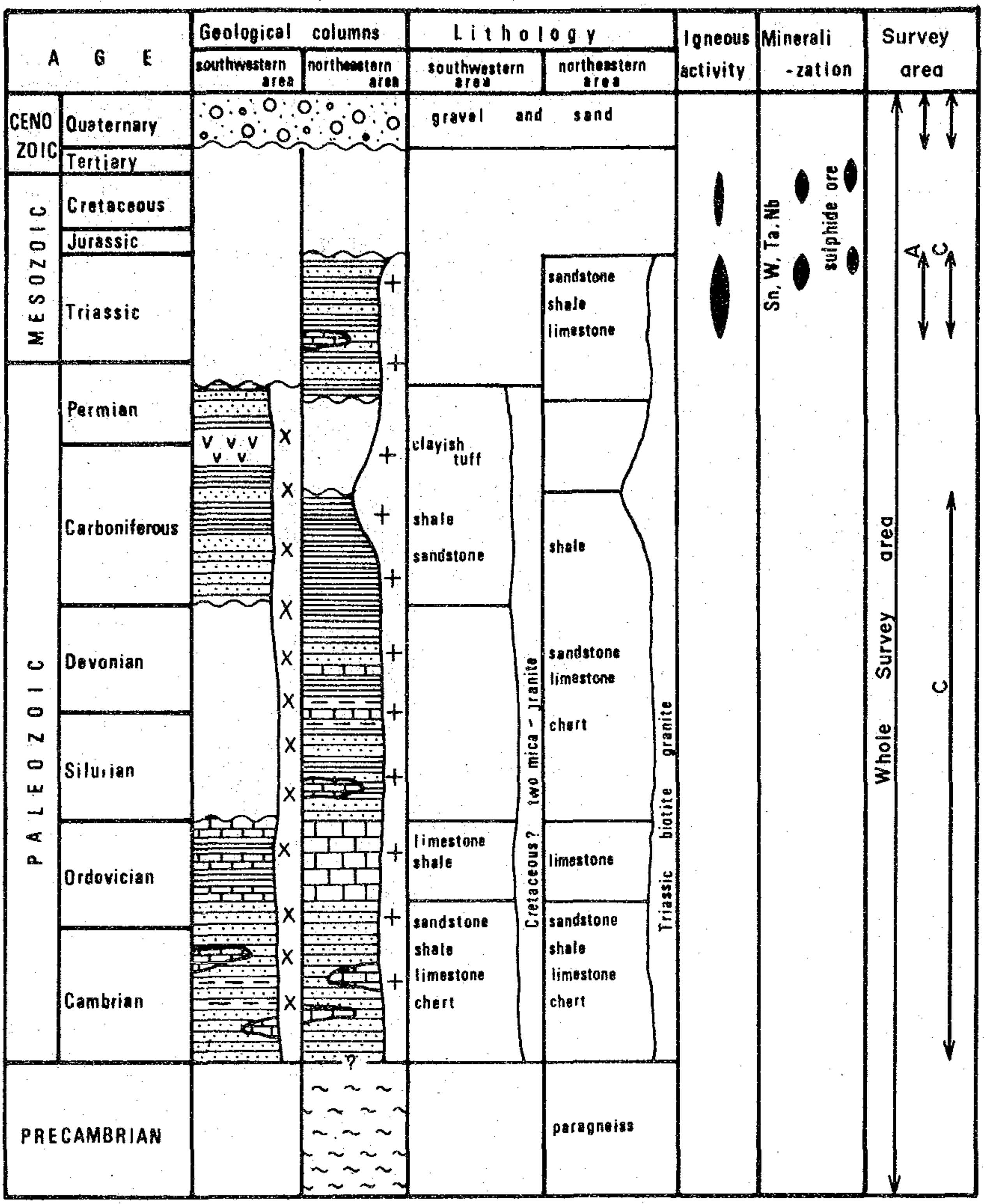


Fig. 3 Schematic geological column

West Tectonic Province, based on the classification by the JICA study 1984.

The Pre-Carboniferous Metamorphic Rocks are in a small area in the northern corner of the area. They are included in the granitic intrusive bodies as xenolith, showing large-scale extension of several hundreds of meters. Its principal constituent minerals are quartz, K-feldspar, plagioclase, and biotite. They have clear gneissic texture.

The Cambrian to Ordovician Sedimentary Rocks are distributed in small areas in the drainage area of the Nam Mae Lop, near Ban Mae Khon in the central area, in the western bank of the Nam Mae Ngao in the southwestern area, and around Doi Mon Kathing. They are composed of alternations of fine to medium-grained sandstone and shale, and fine-grained sandstone and chert, intercalating thin beds of calcareous shale and limestone.

The Ordovician Limestone Formation is distributed in a large area between Nam Mae Lop and Nam Mae Hong in the northern area, between Nam Mae Khon and Nam Mae Long in the eastern area, and in the middle stream area of Nam Mae Ngao and near Mae Ramoeng in the eastern area. The formation mainly consists of white to gray amorphous to microcrystalline limestone, partly intercalating thin beds of shale and chert. Near Mae Ramoeng it consists of an alternation of limestone and shale.

The Silurian to Devonian Sedimentary Rocks are in a small area in the eastern bank of Nam Mae Hong in the northern area. They mainly consist of shale and sandstone accompanied by lenses of limestone.

The Devonian to Carboniferous Sedimentary sequence are largely distributed in the central area. They mainly consist of black shale with lenses of chert and limestone intercalating alternations of chert and limestone.

The Carboniferous to Permian Sedimentary sequences are only in the southwestern area, extending northwest to southeast. They mainly consist of shale and sandstone accompanied by argillized tuff.

The Permian to Triassic Sedimentary sequences are distributed in small areas in the northwestern and southwestern areas. They consist of sandstone and shale intercalating lenses of limestone.

Alluvium is deposited along principal rivers, and consists of unconsolidated sand and gravel. It is largely distributed in the lower drainage area of Nam Mae Ngao and upper drainage area of Nam Mae Hong.

2. Igneous Activity

The igneous activity in northern Thailand took place in Carboniferous, Triassic, and Cretaceous to Tertiary ages (GGM, 1972).

In the area, two granitic batholiths in the eastern area and six granitic stocks in the central to southwestern area are recognized. They are presumed of Triassic activity, and are classified into five rock masses, the Northeastern mass, Southeastern mass, Northwestern mass, Central mass, and Mon Kathing mass, based on their facies and distributions.

The former two batholiths are extensively distributed in the eastern half area, and divided into two sides by the Ordovician System in the Mae Long district. They are mainly of medium to coarse-grained biotite granite, and partly of medium-grained two mica granite, pegmatite, and aplite. The biotite granite contains characteristically 2 to 4 centimeters-long K-feldspar phenocrysts, and usually shows gneissose texture with parallel alignment of biotite. The two mica granite is scattered in the biotite granite and ranges 2 x 4 kilometers or less in size. Pegmatites and aplites are several centimeters to several meters in width, and trend NW-SE, WNW-ESE, N-S, and NE-SW.

The Northwest mass is partly in the downstream drainage area of the Nam Mae Hong, and extends to the north. The rock mass also consists of biotite granite showing porphyritic texture by K-feldspar phenocrysts, but it is different from other rocks mass because of its amphibole content.

The Central rock mass is a stock located in the central area, consisting of medium to coarse-grained biotite granite showing porphyritic texture by K-feldspar phenocrysts.

The Mon Kathing granitic mass which is host rock of Mon Kathing ore deposits locates in the southwestern area. This is lithologically apart from other bodies because of no significant porphyritic texture by K-feldspar.

3. Geological Structure

As mentioned above, sedimentary rocks are divided into northeastern side and southwestern side by a NW-SE fault through Nam Mae Ngao, and the sedimentary environment is different on both sides. The geological structures are also different on both sides. The northeastern side shows a syncline structure having an axis trending NW to SE, containing minor anticlinal structures. On the contrary, the southwestern side shows a monoclinic structure with NW to SE trend and NE dip.

Fracture systems in the area are dominantly NW to SE, NE to SW, and partly N to S. General strike of the sedimentary formations in the area are NW to SE, which is contrary to the main tectonic trend in northern Thailand. The NW to SE trend is the principal tectonic trend in the area, and others are sub-trends.

4. Ore Deposit

It is assumed that tin and tungsten ore deposits in northern Thailand are closely associated with the granites of post-Mesozoic age (GGM 1972). There are primary ore deposits such as massive ores, quartz veins, and pegmatite veins being associated with greisenization and skarnization at tops and surrounding areas of granite bodies, and secondary ores originated from them. Both type of ore deposits exist in the area, and they are in the granite batholiths in the northeastern area and granite stocks in the southwestern area.

In the northeastern area, placer deposits are in sand and gravel beds in the drainage area of Huai Sa Ngin and Huai Chi Non Luang. In the southwestern area, vein type ore deposits and secondary ore deposits originated from them are in two mica granite stocks concentrating in the Mon Kathing in the southwestern area.

Chapter 4 Comprehensive Discussion

Many data regarding geology, geological structure, mineral occurrences, and geochemical characteristics of the area have been collected from this year's survey. The results have integratedly been studied based on summarized data shown in Figure 4 and 5. Results of the study are as follows.

4–1 Area A.

The area is widely underlain by biotite granite and two mica granite, which are intruded by pegmatites, aplites, and quartz veins, ranging in width from several centimeters to several meters.

It is generally said that two mica granites in Sotheast Asia resulted from pneumatollysis or hydrothermal process, which turned a part of biotite into muscovite (Hutchison 1983).

Biotites in the biotite granite in the area have undergone alteration nearby pegmatites, being altered to muscovite. However, a large amount of primary muscovites also exist in the granite. The biotite granite generally contains mega phenocrysts of K-feldspar; on the contrary, the two mica granite does not. Judging from these evidences, it is possible that the two mica granite intruded into the batholith-like biotite granite.

Pegmatites are dominant compared with aplites and quartz veins. These dikes and veins generally intruded in the batholith-like biotite granite, and are assumingly associated with the two mica granite. Minerals of tin, tungsten, niobium, and tantalum are found by panning in the pegmatites, specially in beryl rich pegmatites. Outcrops of pegmatites are limited in stream areas, and seemingly are concentrated in placer deposits. This suggests that the pegmatites are the source of the secondary ore deposits.

Geochemical anomalous zones of niobium, tantalum, tin, and tungsten are roughly overlapped with each other, but it is difficult to find a prevailing tendency. This suggests that pegmatites are scatered everywhere in the area.

The anomalous zones in the upperstream area of the Huai U Tum and the downstream area of the Huai Sa Ngin correspond to the areas of pegmatites and secondary ore deposits, and they extend to the surrounding mountain flanks and ridges. This suggests that pegmatites containing tin, tungsten, etc. are possibly distributed there.

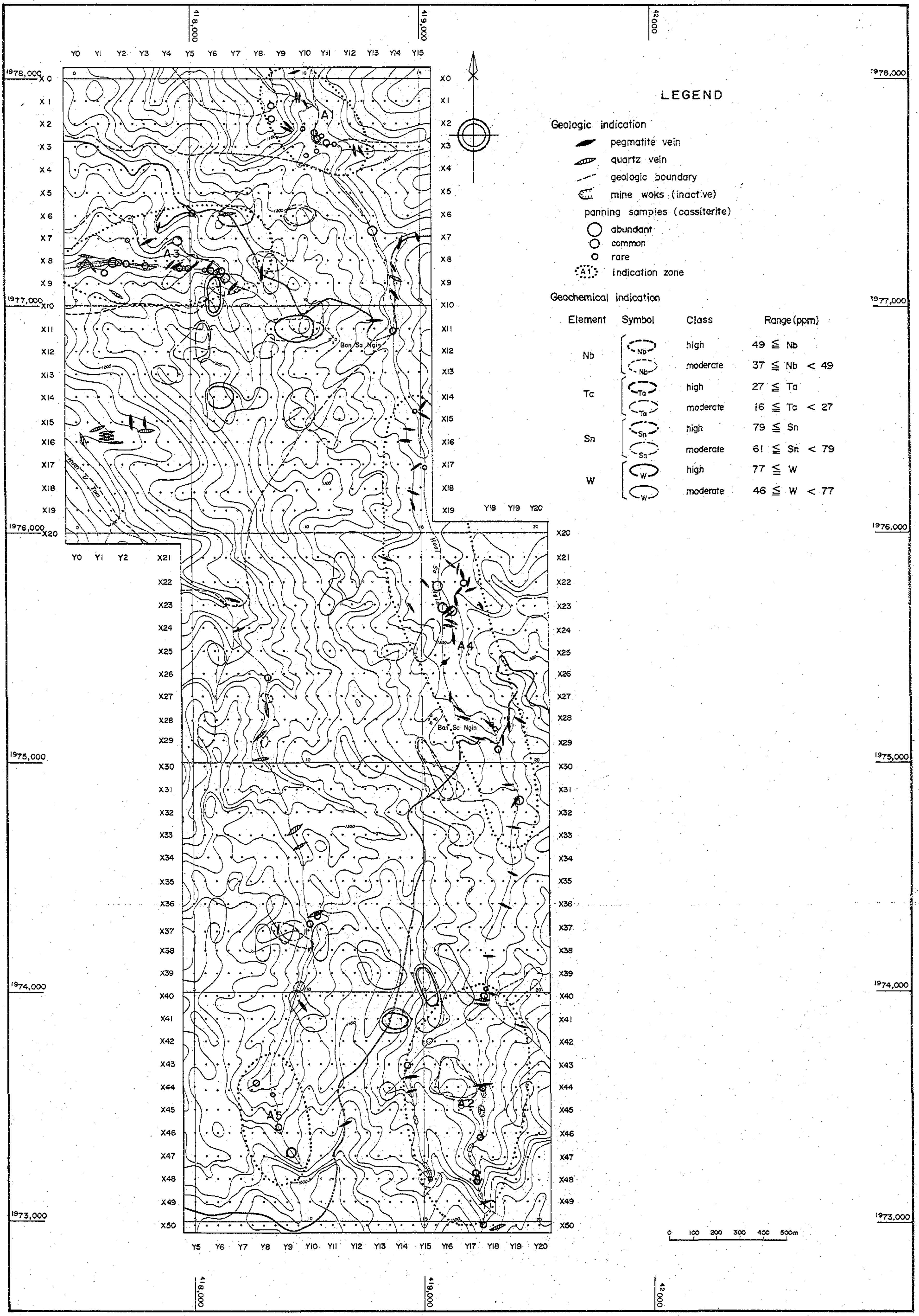


Fig. 4 Mineral indication map (Area A)

4–2 Area C

The area is underlain by Cambrian to Carboniferous sedimentary rocks, Triassic granites and alluvium. The sedimentary rocks are classified into two, the Ordovician and the Devonian to Carboniferous distributed in a long belt in the southwestern area, and the Cambrian to Ordovician scattered in roof pendants on a small-scale.

The area is dominantly underlain by granites consisting of biotite granite and two mica granite. As with Area A the two mica granite is much different from the biotite granite in its rock type and texture, and shows significantly higher geochemical background values of tin, tungsten, and tantalum than those of the biotite granite. Therefore the two types of granites are presumably of different intrusions.

In the area of the two mica granite, gossans are scattered from the north to the center, and form a zone extending north-northwest to south-southeast. Also a kaolin zone exists in the southern part. The gossan zone is underlain by skarn zones and silicified zones, which are associated with chalcopyrite, pyrite, and magnetite.

Mineralization in the area is presumably derived from pneumatolysis and hydrothermal process associated with the two mica granite intruded into the biotite granite. Chalcopyrite, pyrite, magnetite, and other minerals are in zones of skarnization, silicification, and kaolinization. The geochemical anomalous zones of tin and tungsten overlap on the gossan zones, and those of niobium and tantalum overlap on the kaolin zones. These anomalous zones are distributed in the central area extending north-northwest to south-southeast. This suggests that this trend structurally controls the alteration and mineralization in the area. Some tin and tungsten anomalous zones show as high as over 1,000 ppm; therefore mineralized zones are most possibly expected there. On the other hand, tourmaline and muscovite have been found in kaolin zones in the southern area, and they possibly change to zones of greisenization at greater depths.

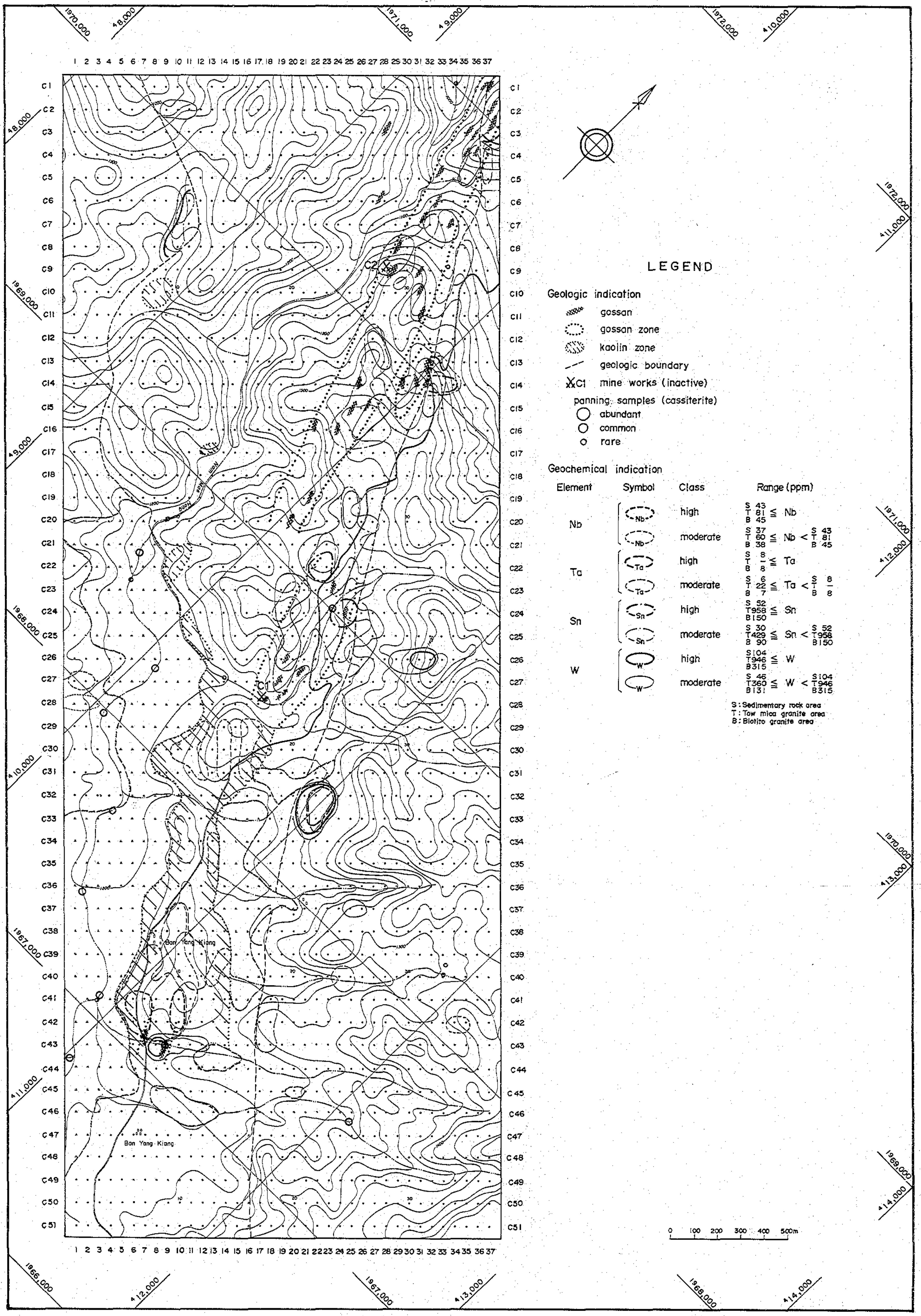


Fig. 5 Mineral indication map (Area C)

Chapter 5 Conclusion and Recommendation

5–1 Conclusion

For the second phase, geological and geochemical survey were carried out in Area A and Area C which were identified as potential areas by the first phase survey. The results of the second phase survey area as follows:

Area A

(1) The area is underlain by biotite granite, two mica granite, pegmatite, aplite, and quartz as the Triassic.

(2) It is inferred from difference of lithology, texture, distribution, and form that after the biotite granite batholith was formed, the two mica granite intruded and the pegmatite, aplite, and quartz veins subsequently intruded into both granites.

(3) It is confirmed by chemical analyses of panning concentrates that the pegmatites contain nibobium, tantalum, tin, and tungsten. The pegmatites supplied placer deposits with tin and tungsten in the area. The pegmatites with beryl show high contents of all the aforementioned elemetns.

(4) Placer deposits and mineral indications correspond to the locations of the pegmatites.

(5) Locations of geochemically anomalous zones rich in all analized elements generally coincide, especially around old workings along tributaries of Huai U Tum and mineral indications in the middle course of Huai Sa Ngin. Those anomalous zones have potentiality for existence of pegmatites rich in niobium, tantalum, tin, and tungsten.

Area C

(1) The area is underlain by Cambrian to Carboniferous sedimentary sequence, Triassic granites, and alluvium.

(2) The sedimentary rocks consist of Cambrian to Ordovician System, Ordovician System, and Devonian to Carboniferous System. The first one is distributed in small areas as roof pendants and the latter two are distributed long and narrowly in the southwestern part.

(3) The granites are biotite granite and two mica granite same as Area A. It is inferred from lithology and texture distribution that the latter granite intruded the former one. Pegmatite is not seen in the area.

(4) Many small gossans are seen in the two mica granite area and is aligned in NNW-SSE direction. They form a gossan zone in approximately 200m wide and 3km long strip.

(5) Some gossans accompany skarn zones and silicified zones and show mineralization of tin, tungsten, copper, zinc, and others. It is inferred that the mineralization is controlled in NNW-SSE direction.

(6) A kaolin zone which consists of kaolinite, quartz, muscovite, and tourmaline is in the two-mica granite zone in the center to the southern part. The kaolin zone seems to be continuous to the gossan zone.

(7) Geochemically anomalous zones rich in tin and tungsten are distributed in a NNW-SSE strip and overlap the gossan zone. An anomalous zone rich in niobium and tantalum is continuous to the aforementioned anomalous zone and overlaps the kaolin alteration zone. These anomalous zones contain many high assay values of tin and tungsten suggesting high potential for economical mineralization zones.

5–2 Recommendation for the Third Phase Survey

As a result, the following two places are identified as highly potential areas for economical ore deposits:

(1) Around the old workings along a tributary of Huai U Tum, and a geochemically anomalous zones in the middle course of Huai Sa Ngin in Area A.

(2) A geochemically anomalous zone extending NNW-SSE which overlaps the gossan zone and the kaolin zone in Area C.

The geochemically anomalous zone in Area C has the highest potential in containing more promising ore deposit because of mineral content and extent of anomalous zone.

Therefore, we recommend for the third phase survey that trench survey and shallow drilling to 30 to 50m deep should be carried out to confirm existence of mineral indications and extent of mineralized zone at the geochemically anomalous zone in Area C.

PART II REGIONAL DISCUSSION

Chapter 1 Area A

1–1 Location

As Fig. 1 shows, the surveyed area is about 15km west northwest from Omkoi, covering an area of 7.5km^2, with the point at 17°52'N, 98°14'E as the center approximately.

In the area, two major streams, the Huai Sa Ngin in the east and the Huai U Tum in the west flow to the north with many tributaries trending E-W to NW-SE.

The surveyed area is steep mountaneous terrain with relative relief of 400m, varying in altitude from 1,100 to 1,500m. The mountain range stretches mainly N and S.

An unpaved road connecting Omkoi to Mae Khong at the southwest passes through the surveyed area from NE to SW. The distance between Omkoi and the area is about 25km and it takes about 1 and ½ hours by four-wheel drive vehicle in the dry season. This road becomes hardly passable in the rainy season.

The geochemical exploration, taking stream sediment as samples, conducted in the phase I survey revealed that the geochemical high anomalies of niobium, tantalum, tin, and tungsten are overlapping in this area. Especially niobium and tantalum anomalies are classified as highly anomalous area (Huai Sa Ngin – Huai U Tum geochemical anomaly zone) and are estimated to have high possibility of containing ore deposits.

1–2 Geological Survey

1–2–1 Geology

The area covers the central part of Triassic granite batholith (so called northeast granite mass) widely distributed in the northeastern area of the Yang Kiang area. The whole area is covered by granitic rocks, except the minor alluviam along streams (Fig. 6).

The lithofacies included in the granitic rocks are medium to coarse grained K-feldspar bearing porphyritic biotite granite, fine to medium grained two mica granite, pegmatite and aplite.

1. Medium to coarse grained K-feldspar bearing porphyritic biotite granite

This rock covers a wide area of the southern and northeastern part of the area. The characteristic megaphenocryst of K-feldspar varies in size from 1 to 5 cm. Intensive weathering prevails in the area and this rock also becomes friable and crumbly over the surface.

The local distribution of gneissose foliated facies with oriented biotite have been observed along the Huai Sa Ngin stream flowing to the north in the eastern part of the area. Massive facies prevail in most of the remaining area.

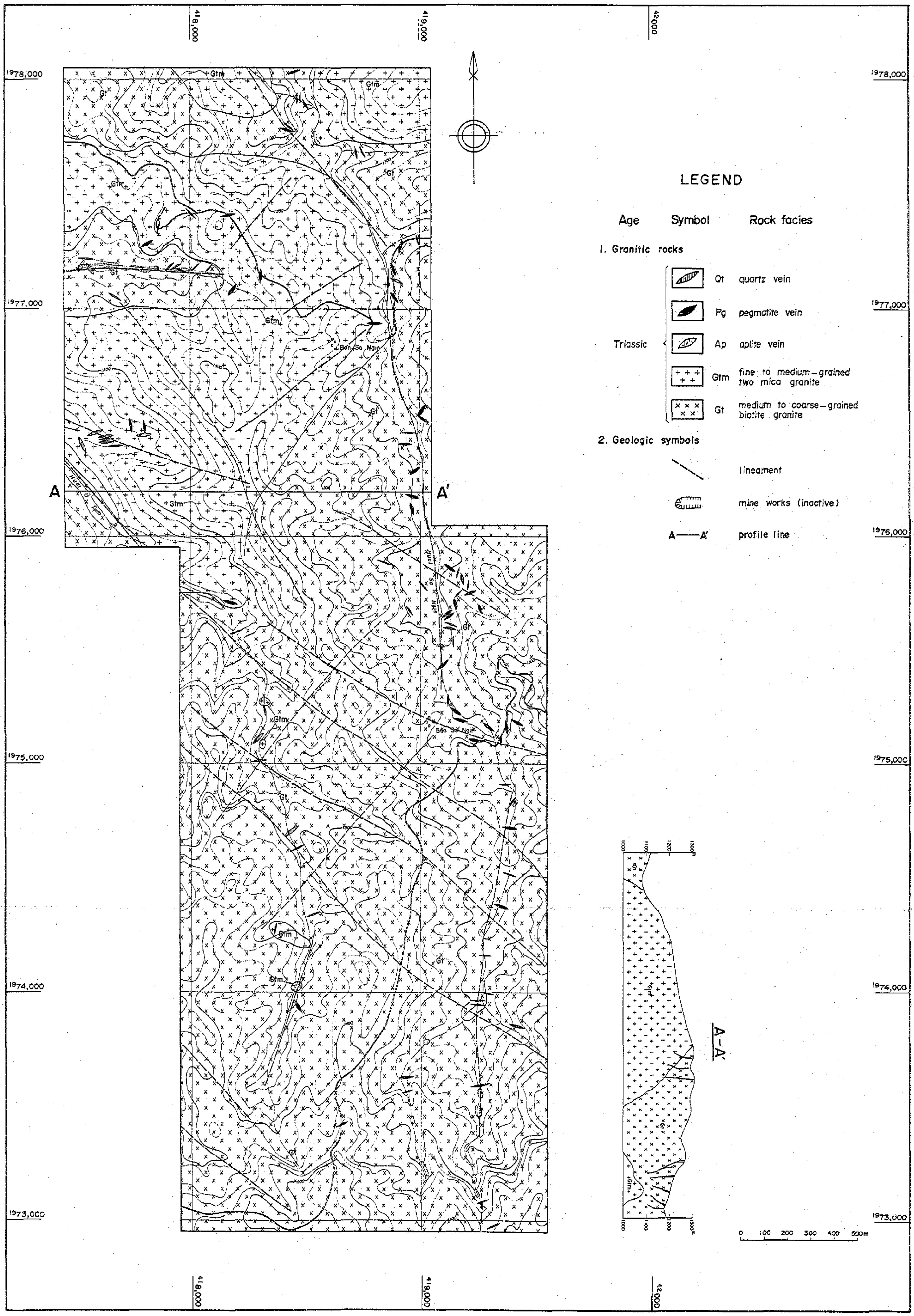


Fig. 6 Geologic map and profile (Area A)

The age of 73±1.5 Ma determined by K/Ar method is reported by the phase I geological survey conducted in the area.

The main primary rock-forming minerals are quartz, K-feldspar, plagioclase and biotite. Zircon, apatite and opaque minerals occur as accessory minerals.

The opaque minerals are ilmenite, and the amounts are minor. As secondary minerals, fine microscopic muscovite after plagioclase, chlorite and muscovite formed along the cleavage and/or outer rim of biotite, and leucoxene after ilmenite have been observed.

2. Fine to medium grained two mica granite

This rock is distributed in the northern and northwestern part of the area. Small scattered rock bodies are observed in the forementioned biotite granite. The porphyritic texture of K-feldspar commonly observed in the biotite granite is not marked.

The main primary rock-forming minerals are quartz, K-feldspr, plagioclase, muscovite and biotite, and sometimes the amount of primary muscovite is equal to or exceeds the biotite. Zircon, apatite and ilmenite are the observed accessory minerals. The secondary minerals are the same as for biotite grantie, being minor amounts of muscovite and biotite both of which have replaced plagioclase, and leucoxene after ilmenite.

3. Pegmatite and Aplite

These rocks occur as a narrow vein or dike of 5cm to 5m wide and sporadically exposed in the area. The size and density of distribution tend to increase in and around the biotite granite area rather than the area of two mica granite.

The prevailing trend of the dike swarm is E-W in the southern part of the area, and three trends, N-S, NW-SE and NE-SW prevail in the northern part of the area.

The main rock-forming minerals are K-feldspar, quartz, plagioclase and muscovite. Tourmaline, garnet, zircon, monazite, rutile and beryl are the accompanying main accessory minerals, and a small amount of cassiterite and columbite-tantalite series minerals are found in some samples.

In this area rocks are poorly exposed and all of the observed outcrops of the pegmatite are limited only to the area along the stream; but the pegmatite floats and boulders are observed in various parts of the area suggesting many blind pegmatites to exist in the area.

1–2–2 Geological Structure

The phase I geological survey revealed major structural trends in and around the area, i.e., NW-SE, NE-SW and N-S. That is to say, the structural trend of the sedimentary rocks and the prevailing fracture system trend are NW-SE, and the other two trend directions of NE-SW and N-S, are observed as secondary.

The abovementioned regional geological structure trend is well reflected in the geological structure of the area. That is, the three trends of NW-SE, NE-SW and N-S, are clearly observed in or expressed by the distribution of two mica granite, intrusive orientation of dike swarm and drainage system anomaly as well as the lineaments connecting the saddles on the ridges.

The NW-SE structural system is expressed by the longer axis of distribution of two mica granite body as well as the direction of straight valley of the Huai U Tum extending to the north out of the area, and the parallel straight valley as well as the lineaments connecting the saddles on the ridges.

The N-S structural system is represented by the straight valley of Huai Sa Ngin and the extension of the mountain system.

Furthermore, dikes and veins considered to be the clear indicator of fracture systems are roughly classified into three groups, i.e., NW-SE to E-W, NE-SW and N-S. These structural systems are harmoneous with the lineaments in the surrounding area.

1–2–3 Alteration

In this area, except for the weathering, plagioclase in the medium to coarse grained K-feldspar bearing porphyritic biotite granite has been altered to muscovite, and also chloritization and muscovitization of biotite are the alterations commonly observed. The muscovitization is quite obvious in the periphery of pegmatites and aplites suggesting that pneumatolytic and/or hydrothermal activity genetically related to those dikes may have caused the formation of muscovite. At the northeastern end of the area, biotite granite is partially recrystalized suggesting the possibility of having undergone thermal metamorphism.

The plagioclase in the fine to medium grained two mica granite is also subjected to the alteration, namely muscovitization, but it is rather weak than the one observed in the biotite granite.

1–2–4 Ore deposits and mineralization

In the area, there are three known ore deposits: two deposits (A-1 and A-2) along the Huai Sa Ngin and one deposit (A-3) along the Huai U Tum. All of these are the placer of cassiterite bearing sand and gravel bed, and have been worked on a small scale. A-1 deposits and A-3 deposits were worked for about one year around 1980, with 10 to 20 workers producing 2 tons/

month of shipping grade ore. A-2 ore deposits have been reportedly worked by the local residents, but no results are recorded.

Primary tin deposits have not yet been discovered in the area. As a supplementary geological survey, heavy minerals in the stream sediment and pegmatite veins were collected by the panning method along the main streams to study the mineral composition and the heavy mineral contents (Appendix 4).

As a result, cassiterite and scheelite were found in most of the area. Among the findings, consolidated mineral indications (A-4 and A-5) were found in the middle stream of Huai Sa Ngin and the tributary of Huai U Tum.

The known ore deposits and the consolidated mineral indications will be described in detail.

1. A-1 ore deposit

This ore deposit is located in the downstream of Huai Sa Ngin at the northeastern part of the area.

With the soil sampling point X-3 : Y-0.5 as the center, about 30m x 20m of old workings are scattered in an area of 500m x 100m.

The ore deposit is cassiterite bearing sand and gravel bed along the Huai Sa Ngin, and thickness is 1 to 2m. Cassiterite is the main ore mineral and a minor amount of scheelite and columbite – tantalite series minerals are found in the heavy mineral concentrate of stream sediment. Garnet and zircon are the main minerals in the concentrate. The result of chemical analysis of the panned sample (O–1, O–2) is shown in Table 2, and the calculated grade of the crude ore is estimated as follows; SnO_2 : 27 to 30g/m^3, WO_3 : 0 to 1g/m^3, Nb_2O_5 : 1g/m^3, Ta_2O_5 : 2g/m^3.

In the vicinity and the upstream of the ore deposits a number of pegmatites of 3m or less width intruded into the biotite granite have been observed. The trend of intrusion is NW-SE to E-W and N-S. No tin and tungsten ore minerals were identified by ocular observation, but a small to extremely small amount of cassiterite was found in the heavy mineral concentrate by panning. These pegmatite veins are estimated to be the original supplier of the placer deposits.

2. A-2 ore deposits

This ore deposit is located in the upstream of Huai Sa Ngin at the southeastern part of the area. Small old workings of 10 to about 30m long are scattered in the area of soil sampling point X-44 to 49 : Y-17.5 as well as soil sampling point X-42 to 48 : Y-15 along the Huai Sa Ngin and its tributaries.

Table 2. Chemical analyses of ore samples (Area A)

No.	Sample No.	Locality	Description	Sn(%)	W(%)	Nb(%)	Ta(%)	Raw material (ℓ)	Heavy mineral (g)	SnO_2 (g/m^3)	WO_3 (g/m^3)	Nb_2O_5 (g/m^3)	Ta_2O_3 (g/m^3)
1	AO–13	Huai Sa Ngin (X11, Y14)	weathered pagmatite	9.03	0.40	0.43	0.99	100	5	5.7	0.3	0.3	0.6
2	A0–20	Huai Sa Ngin (X25, Y16)	weathered pegmatite	1.87	0.41	0.43	0.91	50	2	1.0	0.2	0.3	0.4
3	A0–31	Huai Sa Ngin (X31, Y19)	stream sediment	55.8	0.54	0.74	2.93	100	22	155.9	1.5	2.3	7.9
4	A0–43	Branch of Huai U Tum (X6, Y5)	weathered pegmatite	14.4	0.25	2.38	2.77	30	10	60.9	1.1	11.3	11.3
5	A0–57	Branch of Huai U Tum (X8, Y1.5)	stream sediment	46.9	0.89	1.08	2.52	40	32	476.3	9.0	12.3	24.6
6	A0–70	Branch of Huai U Tum (X47, Y9.5)	stream sediment	66.5	3.10	0.79	4.78	70	4	48.1	2.2	0.6	3.3
7	0–1*	Huai Sa Ngin (X1, Y8.5)	stream sediment	6.49	0.08	0.28	0.36	30	10	27.4	0.3	1.3	1.5
8	0–2*	Huai Sa Ngin (X2, Y8.5)	stream sediment	11.3	0.32	0.35	0.57	30	8	38.3	1.1	1.3	1.9
9	0–3*	Branch of Huai U Tum (X8, Y3.5)	stream sediment	17.2	0.35	0.33	0.56	25	15	131.0	2.6	2.8	4.1
10	0–4*	Branch of Huai U Tum (X8, Y3)	stream sediment	1.92	0.27	0.22	0.35	60	10	4.1	0.6	0.5	0.7

* from the phase I survey

The ore deposit is cassiterite bearing sand and gravel bed along the stream, and the thickness is 1 to 2m from the river bed and the width is 2 to 4m across the river.

Cassiterite is the main ore mineral in the heavy mineral concentrate from the stream sediment and a small amount of scheelite is found to occur. Garnet and zircon are the minerals in the concentrate. The number of observed pegmatites in this area is limited, suggesting the ore minerals in the area might be either transported from the pegmatites in the upstream or supplied from the undiscovered pegmatite nearby.

3. A-3 ore deposit

This ore deposit is located in the upstream of the Huai U Tum at the northwestern part of the area. Small old workings of 10 to 50m long are scattered in an area for about 500m along the tributary of Huai U Tum. The center of the area of old workings is approximately at soil sampling point X-8 : X-4.

The ore deposit is cassiterite bearing sand and gravel bed along the stream, and the thickness is 1m to about 2m from the river bed and the lateral extension is generally 1 to 10m across the river.

Cassiterite is the main ore mineral in the heavy mineral concentrate of stream sediment along with an extremely small amount of scheelite and columbite – tantalite series minerals. The main mineral in the concentrate is garnet. The results of chemical analysis of the panned samples (AO–57, O–3,4) are shown in Table 2 and the calculated grade of the crude ore is estimated as follows; SnO_2 : 4 to 476g/m^3, WO_3 : 1 to 9g/m^3, Nb_2O_5 : 1 to 12g/m^3, Ta_2O_5 : 1 to 25g/m^3. Comparing the result to the other known deposits and mineral occurrences, especially the contents of Nb_2O_5 and Ta_2O_5 are rather high.

In the vicinity and upstream of the ore deposits many pegmatites and quartz veins of 1m and lesser width intruding the granitic rocks are commonly observed. The trend of intrusion is NW-SE and NE-SW. Some of these pegmatites contain about 1cm long crystals of beryl and the concentrated heavy mineral from the pegmatite (AO–43) shows relatively high contents of cassiterite and columbite – tantalite series minerals. The result of chemical analysis is shown in Table 2, and the calculated grade of the crude ore is estimated as follows; SnO_2 : 61g/m^3, WO_3 : 1g/m^3, Nb_2O_5: 11g/m^3, Ta_2O_5: 11g/m^3.

Quartz vein carries tourmaline but no ore minerals have been observed megascopically.

4. A-4 mineral indication zone

This zone is located in the middle stream of Huai Sa Ngin and covers the area from the soil sampling point X14 : Y14 to X-38 : Y-19. This mineral indication zone is located in the center of the known two ore deposits, A-1 and A-2 which are separated by 4km.

In this zone, many pegmatites of width of 2m or less intrude biotite granite, and trend N-S and NW-SE.

The ore minerals in the heavy mineral concentrate from the stream sediment is mainly cassiterite with a small amount of scheelite. Garnet is the main gangue mineral in the concentration. The result of chemical analysis of the panned sample (AO-31) is shown in Table 2, and the calculated grade of the crude ore is estimated as follows; SnO_2 : 156g/m^3, WO_3 : 2g/m^3, Nb_2O_5: 2g/m^3, Ta_2O_5 : 2g/m^3, Ta_2O_5 : 8g/m^3.

The heavy minerals are garnet, cassiterite, zircon and beryl. A minor amount of columbite – tantalite series mine, monazite, xenotime, rutite, and anatase are accompanied in some cases. The result of chemical analysis of the panned samples (AO-15, 20) are shown in Table 2. Tin, tungsten, niobium, and tantalum are included in both samples, although the grade is low.

Consequently the ore minerals in the stream sediment are considered to be derived from pegmatites in the vicinity and upstream area.

5. A–5 mineral indication zone

This zone is located in the upstream of a tributary of Huai U Tum and covers the area from the sampling point X-43 : Y-8 to the point X-47 : Y-10.

The ore minerals in the heavy mineral concentrate from the stream sediment are mostly cassiterite with a subordinate amount of scheelite. Gangue minerals in the concentrate are composed of a major amount of garnet, occasionally occurring with monazite and zircon. The result of chemical analysis of panned sample (AO-70) is shown in Table 2 and the calculated grade of the crude ore is as follows; SnO_2 : 48g/m^3, WO_3 : 2g/m^3, Ta_2O_5 : 3g/m^3.

In the around this zone, the number of exposed pegmatite veins are quite limited and the ore minerals in the stream sediment are presumably derived from the surrounding area as well as undiscovered pegmatites.

1–3 Geochemical Prospecting

1–3–1 Survey method

1. Sampling and preparation

B-horizon soil samples were collected in the rectangular grid systems in this survey.

Each sampling line was spaced of 100 m, and each sampling point on these lines was arranged at an interval of 50m.

Phase I survey found the anomalies of niobium, tantalum, tin, and tungsten lying in the direction of NNW-SSE from Huai Chi Non (Area B) to Huai U Tum and Sa Ngin (Area A), therefore this prospecting area was set along the latter valleys to cover these anomalies. The direction of sampling lines was decided to E-W direction to find mineral indication effectively.

Sampling lines and sampling points were set by pocket compasses and mesuring tapes according to the plan.

The soil samples of B-horizon were usually obtained at the depth of 20 to 40 cm from the surface. The thickness of A-horizon varies from 0 to 60 cm.

The collected soil samples were natural air-dried and screened, and −80 mesh fraction was taken for chemical analyses.

The number of samples is 1,591 in Area A.

The localities of samples are shown in PL.2.

2. Pathfinder elements and chemical analyses

The objective of this prospecting is to reveal the mineral deposits area of niobium, tantalum, tin, and tungsten.

These four elements which directly indicate mineralization zone were selected to analize, though the analyses of such elements as lithium, beryllium, fluorine and boron would be also effective.

The quantities of these four elements in soil samples were studied by means of the inductively coupled plasma emission spectrography method. The detection limit value for these elements were 1 ppm.

Analyses data for each samples are shown in Appendix 5.

1–3–2 Analyses of Geochemical data

1. Statistical analysis

Generally it is said that the distributions of geochemical data of trace elements often present a logarithmic normal type distribution, if the accuracy of analyses is sufficient. Because of this, the common logarithmic values of analytical data were used in this analytical work.

Geochemical data for each elements were treated collectively in the whole area A, because the background value of each elements in the biotite area is almost equal with the values in the two mica granite area.

The maximum values, minimum values, mean values and standard deviations of the contents of the elements in Area A are shown in Table 3.

Table 3 Basic statistic quantities of geochemical analytic values (Area A)

Item / Element	Minimum value	Maximum value	Mean value M	Standard deviation σ	M + σ	M + 2σ	M + 3σ
Nb	8	77	1.33 21.6	0.12	1.45 28.2	1.57 36.8	1.68 48.0
Ta	1	51	0.68 4.8	0.25	0.93 8.6	1.18 15.2	1.43 26.9
Sn	16	130	1.54 34.7	0.12	1.66 45.7	1.78 60.1	1.90 79.0
W	3	260	1.21 16.1	0.23	1.43 27.1	1.66 45.4	1.88 76.3

Upper row ; Logarithmic value
Lower row ; Natural value, unit : ppm

The frequency histograms and cumulative frequency histograms for the contents of the elements are shown in Appendix 7 to 8.

The correlation coefficients between the pathfinder element are shown in Table 4.

The correlation between niobium and tantalum and between tin and tungsten are strong. The correlation between tin and niobium is weak. Tungsten has hardly correlation with niobium-tantalum.

Table 4. Correlation coefficients of geochemical data (Area A)

Element	Nb	Ta	Sn	W
Nb	–	0.68	0.28	0.12
Ta	0.68	–	0.48	0.14
Sn	0.28	0.48	–	0.42
W	0.12	0.14	0.42	–

2. Classification of anomaly values

To decide the threshold values and to classify geochemical data into anomaly values and background values, there are such methods as the one using a natural gaps in the distribution of frequency, the one using cumulative frequency histograms, and the one depending on statistics including mean values and standard deviation.

Mean values (M) and standard deviations (σ) were used to decide the threshold values and the subdivisions of the background and anomaly zone in this report.

And the frequency distribution and cumulative frequency distribution histogram were also used to confirm these subdivisions.

For the threshold values in this area, approximate $M + \sigma$ values were adopted. The background zone was subdivided into the low background zone and high background zone by mean value. The anomaly zone was subdivided into the low anomaly zone, medium anomaly zone and high anomaly zone by approximate $M + 2\sigma$ value and $M + 3\sigma$ value.

The division of anomaly values of each elements is shown in Table 5.

Table 5. Division into anomaly value levels (Area A)

Division / Element	Background area		Anomaly area		
	Low	High	Low	Middle	High
Nb	~21	22 ~ 28	29 ~ 36	37 ~ 48	49 ~
Ta	~ 4	5 ~ 8	9 ~ 15	16 ~ 26	27 ~
Sn	~34	35 ~ 45	46 ~ 60	61 ~ 78	79 ~
W	~16	17 ~ 27	28 ~ 45	46 ~ 76	77 ~

Unit : ppm

3. Distribution of geochemical anomalies

The anomalies in area A were extracted from the content distribution maps (PL. 3 to PL. 6)

The distribution of the anomalies is described as follows;

The anomalies are rather scattered in area A in all the elements, but some small-scale anomalies form anomaly groups.

The anomalies of all the elements seem to overlap with each other in the northern tributary of Huai U Tum, but the distribution of anomalies in the middle and south of area isn't related to each other element except for niobium and tantalum.

(i) Niobium

The investigation area provides three niobium anomaly zones.

The first one ranges from Line x6 to Line x12 around the upper reaches of a tributary of Huai U Tum. This zone consists of five large to small sized anomalies in an irregular form and the maxium value is 72 ppm.

The second one ranges from Line x24 to Line x36 around the middle of Huai Sa Ngin and in this zone, seven anomalies are scattered the maximum value is 52 ppm.

The last one is distributed on the south side of Line x39 in the upper reaches of Huai Sa Ngin. In this zone, there are small sized medium to low anomalies.

(ii) Tantalum

The investigation area provides three tantalum anomaly zones neary overlapping niobium anomaly zones. Each anomaly zone consists of many small to large sized, low to moderate anomalies.

The first zone is distributed around the upper reaches of a tributery of Huai U Tum in the north west of this investigated area. Some moderate anomalies are scattered and the maximum value is 35 ppm.

The second zone is distributed in the middle of this investigation area. There are some medium to high anomalies from Line x27 to Line x35.
It seems that these anomalies are oriented in direction of NW-SE.

The last zone is distributed in the upper reaches of Huai Sa Ngin in the southeast.

In this zone, medium to high anomalies are scattered. In particular, there are medium anomaly, 100 m by 150 m in size, from Line x43 to Line x44, presenting the maximum value of 31 ppm.

In addition, there are some small sized anomalies along Huai Sa Ngin.

(iii) Tin

Anomalies spread in a comparatively form around a tributary of Huai U Tum in the north and the middle to upper reaches of Huai Sa Ngin in the east to south east.

In the north medium anomalies are scattered in a low anomaly which extends from Line x6 to Line x16, the maximum value is 84 ppm.

In the east to south east a low anomaly ranges over a zone along Huai Sa Ngin on the south side of Line x39. In this zone medium to high anomalies, including the maximum value of 83 ppm, are scattered.

In addition low to medium anomalies lie sporadically in the upper reaches of Huai U Tum in the middle.

(iv) Tungsten

The investigation area shows two tungsten zones.

The first zone ranges generally from Line x8 to Line x15 around the upper reaches and tributary of Huai U Tum. There are five different sized medium to high anomalies in an irregular form, including the maximum value of 180 ppm.

The second zone ranges from Line x36 to Line x44 in the south. Many high anomalies are found particularly around the ridges, presenting the maximum value of 260 ppm.

1–4 Discussion

Based on the geological and geochemical data obtained so far, the geology, geological structure and ore deposits will be discussed hereunder.

Biotite granite and two mica granite both belonging to the Triassic igneous activity cover most of the area, and pegmatite, aplite and quartz vein intrude these granites.

In general, the two mica granite in southeast Asia including Thailand is considered to be the product of biotite granite subjected to pneumatolytic to hydrothermal activity and forming muscovite after biotite. (Hutchson 1983)

In this area, muscovitization of biotite is observed along the pegmatite vein intrudingju the biotite granite. But most of the muscovite in the two mica granite is primary muscovite. judging from the fact that the porphyritic texture of K-feldspar common in the biotite granite is not recognized in the two mica granite, and the chemical composition of those two granites is not the same, the biotite granite and the two mica granite i this area are considered to be two independent rock masses.

The direct relation between the two granites was not discerned in the field. The occurrence and distribution of the two types of granite suggest that after the formation of biotite granite batholith, the two mica granite intruded as stock, and subsequently pegmatite, aplite and quartz vein intruded into both granites.

The fracture system observed in the Yang Kiang Area is composed of the prominent NW-SE system and subordinate systems of NE-SW and N-S. The trend of lineaments, elongated distribution of two mica granite as well as the intrusive trend of dikes are harmoneous with the regional geological structure suggesting that the geological structure in this area is fully controlled by the regional structure.

In this area the placer deposits and mineral indications of tin and tungsten are found along the main streams. These mineral occurrences are tin and tungsten bearing sand and gravel bed, and belong to the placer deposit type. In this area alluvium is poorly developed so that the ore deposits and mineral occurrences are rather small in scale.

On the other hand, in the upstream of these ore deposits and mineral occurrences, a considerable number of pegmatites are observed in the granitic rocks. The weathered pegmatite was examined by panning and yielded tin, tungsten, niobium and tantalum minerals, suggesting that these ore minerals in the placer deposits in the area have originated from the pegmatites. Noteworthy high grade contents of columbite-tantalite series minerals were found in the beryl bearing pegmatite in the tributary of Huai U Tum.

This kind of beryl bearing pegmatite is also observed along the creek of the stream of Huai Sa Ngin, suggesting that more undiscovered beryl bearing pegmatite covered by soil may exist in the area.

In general, the pegmatite carrying minerals of berylium, lithium, secium, tantalum, tin and so on, are considered to be formed around the top of the granitic intrusive body at the depth of 3.5 to 4 km in shallow cases and 6 to 7 km in deep cases. When the pegmatite was formed in the intruded country rock it would be within 2 km from the intruding granite body. Following this general principle, the igneous rock genetically related to the ore deposits in this area can be inferred to be the two mica granite now cropping out its top portion of intrusive body.

The geochemical exploration revealed that the locations of geochemical anomalies of niobium, tantalum, tin, and tungsten roughly coincide, and are distributed at the topographical upper slope of the known ore deposits and mineral occurrences.

Especially, around the placer deposit in the tributary of Huai U Tum as well as in the middle stream of Huai Sa Ngin, highly anomalous areas of these elements are overlapping in the same area suggesting the possibility of finding promising tin, tungsten, niobium, and tantalum bearing pegmatite in the area.

Chapter 2 Area C

2–1 Location

As Fig. 1 shows, the surveyed area is about 20 km west of Omkoi, covering an area of 8.0 km^2 with the point at 17°48'N, 98°16'E as the center.

The main stream in the area is Nam Mae Hong flowing from the southwestern corner of the area to the northeastern corner. The Nam Mae Hong flows to the northwest forming at straight course at the south to central portion of the area. Between the central and north portion the river abruptly changes its course to due north, forming an anomalous drainage system. The tributaries of the river run mainly perpendicular to the Nam Mae Hong. Topography of the surveyed area is steep mountaneous terrain with relative relief of 500 m, varying in altitude from 1,000 to 1,500 m, except for the flat lowland along the Nam Mae Hong. The mountain range stretches mainly NW-SE.

An unpaved road connecting Omkoi to Mae Khong at the southeast passes through Area C from north to the south. The distance between Omkoi and Area C is about 55 km and it takes three and half hours by four wheel drive vehicle in the dry season. Access by motor vehicle in the rainy season is not possible.

Geochemical exploration using stream sediment was conducted in the phase I survey and revealed that the geochemical high anomalies of tin, tungsten, niobium, and tantalum are present in the area. Especially the niobium anomaly is classified as a highly anomalous area (the geochemical anomaly in the vicinity of Yang Kiang village) and is estimated to have a high possibility of containing ore deposits.

2–2 Geological Survey

2–2–1 Geology

Area C is composed of Cambro-Ordovician sedimentary sequence, Ordovician Limestone Formation, Devono-Carboniferous sedimentary sequence, Granitic rocks intruding into all rocks mentioned above and alluvium overlaying all of the rocks unconformably (Fig. 7).

1. Cambro-Ordovician sedimentary sequence

The distribution of the sequence is limited to the crest of the mountain system east of Nam Mae Hong, forming a narrow intermittent zone stretching NW-SE. The sequence is mainly composed of sandstone and shale but has suffered skarnization caused by intrusion of granite as well

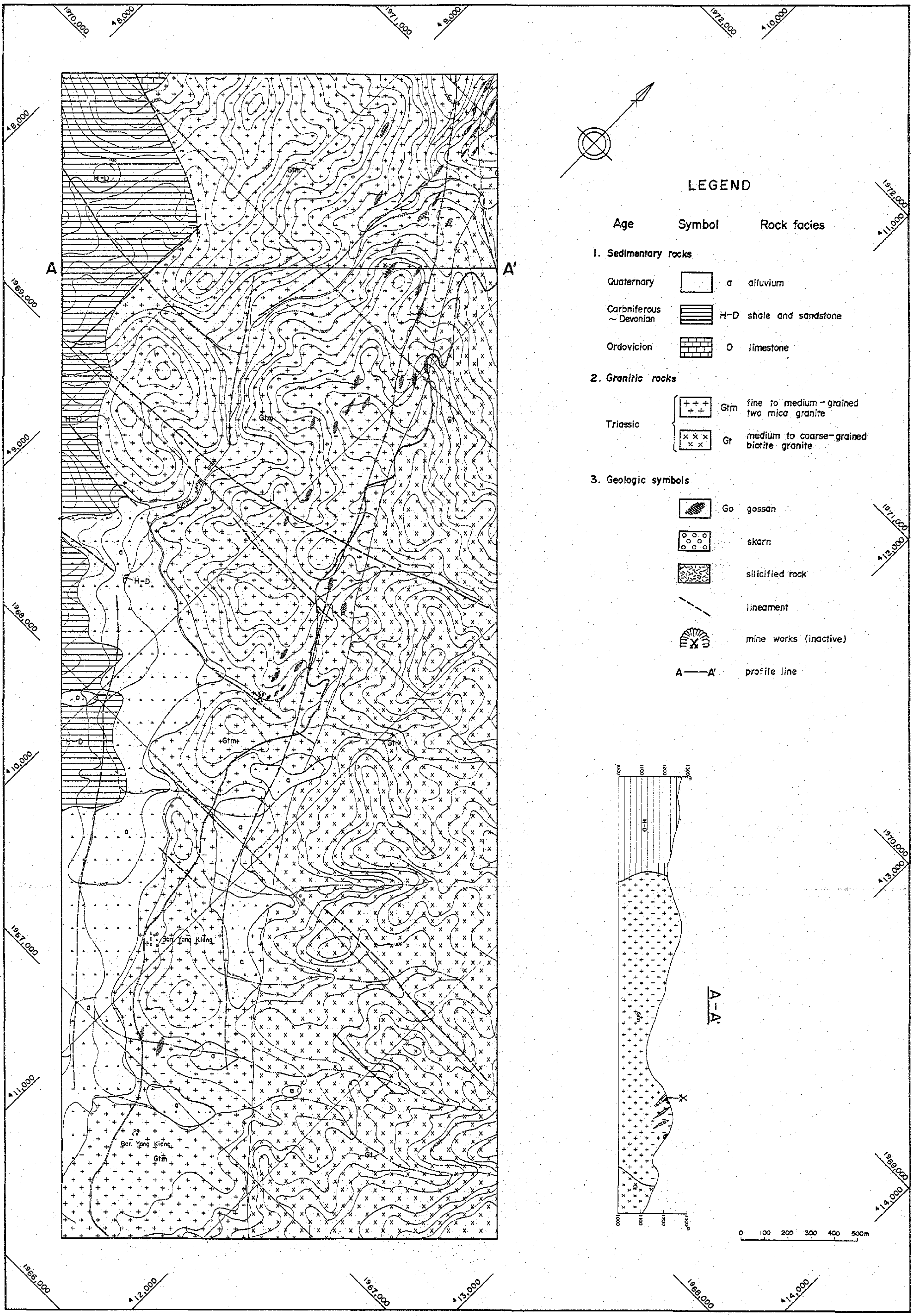


Fig. 7 Geologic map and profile (Area C)

as severe oxidation on the ground surface resulting in original rock texture being illegible.

Judging from the regional geo structural setting, the sequence might be roof-pendant on the two mica granite mass. The distribution is seemingly controlled by the NW-SE trending geological structure.

2. Ordovician Limestone Formation

Distribution of Ordovician limestone formation in the area is limited to the northwestern corner, but the formation itself continues to the north out of the area, covering a wide area.

The limestone is grey and stratified. At the contact with two mica granite the limestone is partly recrystallized and pale green skarn minerals were observed.

Structurally, the limestone strikes NW-SE and dips east, and is in the NE-SW fault contact with the younger Devono-Carboniferous sedimentary sequence.

3. Devono-Carboniferous sedimentary sequence

This sequence is distributed on the western bank of Nam Mae Hong and the lithofacies are predominantly black shale and red shale. In the area close to the contact with granite, phylitic and/or schistose texture is partly observed, and weakly skarnization is identified.

This sedimentary sequence is covered by alluvium in the southern part of the area. In the northern part of the area the extension of the geological unit is estimated by the distribution of floats because of lack of outcrops.

4. Alluvium

Alluvium widely covers the area along the main stream of Nam Mae Hong. These sediments are composed of unconsolidated loose sand and gravel, and thickness varies 1 to 3 m.

5. Granitic rocks

The granitic rocks are composed of medium to coarse grained K-feldspar bearing porphyritic biotite granite, fine to medium grained two mica granite and aplite.

These granitic rocks are attributed to the igneous activity in Triassic time.

(i) Medium to coarse grained K-feldspar bearing porphyritic biotite granite

This rock covers a wide portion of the eastern part of the area, forming a batholith mass including characteristic megaphenocryst of K-feldspar varies in size from 1 to 5 cm. Foliation or gneissose texture was not observed, and massive facies are prominent.

The main primary rock-forming minerals are quartz, K-feldspar, plagioclase, and biotite.

Accompanying accessory minerals are zircon, apatite and opaque minerals. The amount of opaque minerals composed of ilmenite is quite limited. As secondary minerals, fine muscovite after biotite, chlorite after biotite, and leucoxene after ilmenite are observed.

(ii) Fine to medium grained two mica granite

This rock is distributed in the central part of the area as stock-like elongated rock mass of 1.5 km x 5 km size extending NW-SE. The relation with the surrounding rocks is estimated as intrusive contact.

The main primary rock-forming minerals are quartz, K-feldspar, plagioclase, muscovite, and biotite. This granite is characterized by the amount of primary muscovite exceeding that of biotite. Accessory minerals are zircon, apatite, and ilmenite. Observed secondary minerals are muscovite after plagioclase, chlorite and muscovite both after biotite and leucoxene after ilmenite.

At the western boundary of the two mica granite, that is, the contact with Ordovician Limestone Formation and Devono-Carboniferous sedimentary sequence, the granite has undergone white argilization (Kaolinization). Round the eastern boundary where contact is with biotite granite chloritization is prevalent. Also, at the boundary with the roof-pendant Cambro-Ordovician sedimentary sequence, severe silicification of fine grained granite is observed.

(iii) Aplite

This rock is observed mainly as scattered floats of 5 to 60 cm, and observed outcrops were limited. The main rocks forming minerals are quartz, K-feldspar and muscovite.

2–2–2 Geological structure

The phase I geological survey revealed major structural trends in and around the area of NW-SE, NE-SE and N-S. The general trend of sedimentary rock and prevailing fracture systems is NW-SE, and the NE-SW and N-S trending directions are secondary.

The regional geological structure is well reflected in the geological structure of the area. The major structural trends, NW-SE, NE-SW and N-S are clearly expressed by the oriented distribution of rock units and the lineaments shown by the drainage pattern anomaly, and also by the distribution of saddles on the ridge,

The NW-SE structural system is expressed by the trend of intrusion of the two mica granite as well as the straight valley of Nam Mae Hong and the extension of ridges.

The NE-SW structural system is expressed by the direction of the fault bounding the Ordovician Limestone Formation and the Devono-Carboniferous sedimentary sequence, which is also the direction of the straight valley of tributaries of Nam Mae Hong as well as the lineaments

The N-S structural system is expressed by the abrupt change of the stream course of Nam Mae Hong at the northern part of the area and by the straight tributaries of Nam Mae Hong.

2–2–3 Alteration

The observed alterations of the area, except for the surface weathering, are skarnization, silicification, kaolinization and muscoviti-chloritization.

The skarnization forming hedenbergite-epidote skarn is marked in the Cambro-Ordovician sedimentary sequence scattered as roof pendant on the two mica granite. The skarn zone carries dissemination of chalcopyrite, sphalerite, pyrrhotite, pyrite and scheelite. The skarn has undergone severely from oxidation on the ground surface, forming gossan mainly composed of goethite.

Silicification is prominent in the lower part of the skarn zone, also a silicified zone is formed in the two mica granite surrounding the skarn zone. Dissemination and/or stringer of magnetite and chalcopyrite occur in the silicified zone.

The kaolinization is widely noticeable in the two mica granite, and is particularly marked in and around the contact with sedimentary rocks forming a 50 to 400 m wide and 2 to 3 km long kaolin zone, stretching NW-SE. In the southeastern part, this kaolin zone becomes wider and alteration is more intense. This zone is mainly composed of kaolinite, muscovite, quartz, and tourmaline and the relic minerals of K-feldspar and quartz are also present.

The muscoviti-chloritization is marked in the skarn zone, and also widely occurs in the granitic rocks. In the case of skarnization of granite, plagioclase has been replaced by muscovite and biotite has been replaced by chlorite and/or muscovite.

Most of these alterations are considered to be genetically related to the intrusion of two mica granite, and to subsequent pneumatolytic to hydrothermal activity.

2–2–4 Ore deposit and mineralization

In this area, no ore deposits are recorded, but a number of scattered small scale gossans manifest the occurrence of ore minerals. These small gossans are distributed in a zone 200 m wide and about 3 km long approximately, stretching NNW-SSE, forming a gossan zone which continues to the north out of the area for about 1.5 km.

These gossans are mainly composed of geothite with relic minerals of magnetite and hematite.

Old workings are found in the gossan zone including two ancient gallery (C-1 ore deposits and C-2 ore deposits, respectively).

1. C1 ore deposits

The C1 ore deposit is located in the central part of the area, and the location is in the river side close to the soil sampling points C28–17. The ore deposit was formed in the skarnized Cambro-Ordovician sedimentary sequence as well as in the underlying silicified two mica granite.

Skarn zone crops out for about 5 meters. The main component minerals are fine grained garnet, hedenbergite, quartz and calcite with a minor amount of disseminated sphalerite, chalcopyrite and scheelite. In the weakly skarnized zone, original texture of sandstone and shale remains as relic suggesting that the original rock might be the Cambro-Ordovician sedimentary sequence. Boulders of 2 to 3 m in diameter, composed of goethite, lie sporadically in the area of apparent upper horizon of the skarn zone.

Silicified zone is distributed in the apparent lower horizon of skarn zone forming a small water fall 3 m high. In this silicified zone a small gallery along the ore vein is found. This gallery N30°E direction presently measures 2 m long with deeper part of the drift buried by collapse. The ore deposit occurs as both network and dissemination in the two mica granite. Because of the poor exposure of rock, the mineralized area is not delineated. The ore minerals in the stringer are mainly magnetite with a small amount of chalcopyrite, while in the dissemination the main ore mineral is pyrrhotite with chalcopyrite and pyrite. The two mica granite, the host rock of the ore deposit, has undergone hydrothermal alteration forming quartz, muscovite, and chlorite.

The assay results of the ore samples taken from the disseminated ore in the silicified zone and from the skarn zone are shown in Table 6. The former contains 1,900 ppm of tungsten and 6,600 ppm of copper, and the latter contains 4,800 ppm of zinc.

2. C2 ore deposit

C2 ore deposit is located near the soil sampling point C9-28 to 29 in the northern part of the area. As with the C1 ore deposit, the ore body was formed in the skarn zone and silicified zone. The confirmed mineralized area is about 80m x 40m x 50m and is the largest mineral manifestation in the area (Fig. 8).

The ore deposit is divided into four zones, namely in descending order, the surface oxidized zone (gossan), skarn zone, silicified zone and two mica granite zone.

The gossan forms crust covering the surface and the thickness is estimated at 5 to 60cm thick. The gossan is mainly composed of goethite and gradually changes to the underlying skarn zone.

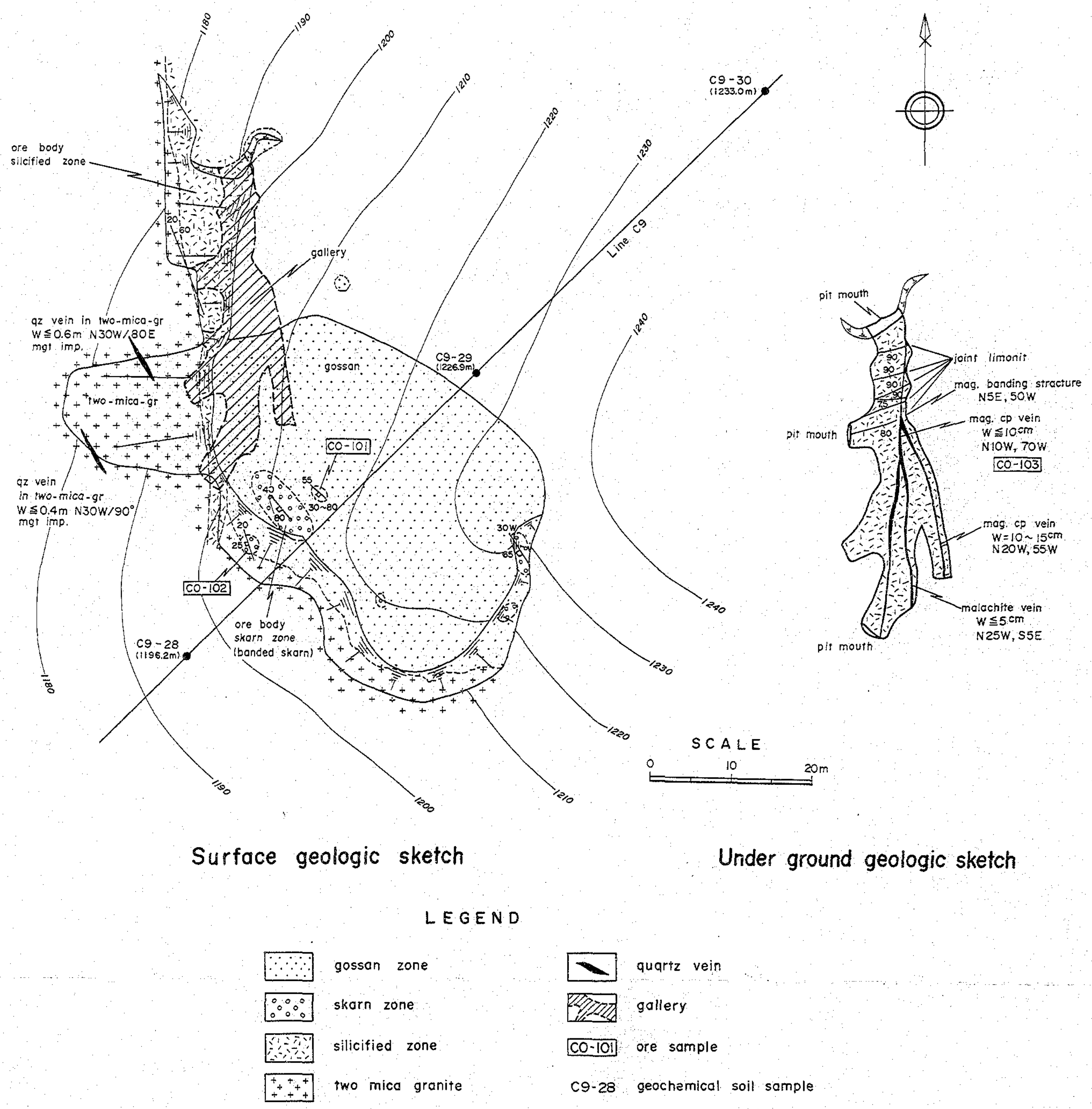
The exposure of the skarn zone is limited. It occurs in the gossan zone as a small fenster of 10m or less in diameter.

Table 6. Chemical analyses of massive ore samples (Area C)

No.	Sample No.	Locality	Discription	Sn(ppm)	W(ppm)	Nb(ppm)	Ta(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ag(ppm)
1	CO–101	C2 ore body (C9–29)	Green skarn (banded)	2,000	310	15	8	20,500	48	720	92
2	CO–102	C2 ore body (C9–29)	Green skarn	2,300	140	8	3	3,400	<5	160	12
3	CO–103	C2 ore body (C9–29)	Silicified ore	3	5	<2	2	580	<5	90	1
4	CO–107	C1 ore body (C28–17)	Sulfide ore	56	1,900	13	3	6,660	17	310	9
5	CO–108	C1 ore body (C28–17)	Green skarn	230	79	27	12	240	230	4,800	8
6	CO–109	Near C2 ore body (C11–31)	Oxidized ore (Gossan)	73	390	5	4	2,780	68	4,900	2

Table 7. Chemical analyses of panning ore samples (Area C)

No.	Sample No.	Locality	Discription	Sn(%)	W(%)	Nb(%)	Ta(%)	Raw Material (ℓ)	Heavy mineral (g)	SnO_2 (g/m³)	WO_3 (g/m³)	Nb_2O_5 (g/m³)	Ta_2O_5 (g/m³)
1	CO–11	Nam Mae Hong (C41–3)	Stream sediment	18.5	1.17	0.23	0.13	100	12	28.2	1.8	0.4	0.2
2	CO–19	Branch of Nam Mae Hong (C24–24)	Stream sediment	3.85	0.43	0.26	0.09	70	250	174.6	19.3	13.2	3.9
3	CO–24	Branch of Nam Mae Hong (C30–28)	Stream sediment	1.08	0.13	0.14	0.04	30	6	2.7	0.3	7.1	0.1
4	CO–27	Branch of Nam Mae Hong (C43–9)	Stream sediment	6.41	3.78	0.04	0.03	20	225	915.8	536.6	6.8	4.5
5	CO–29	Branch of Nam Mae Hong (C46–25)	Stream sediment	5.07	1.29	0.23	0.09	10	6	38.6	9.8	2.0	0.7



Ore chemical analyses (ppm)

Sample No.	Description	Sn	W	Nb	Ta	Cu	Pb	Zn	Ag
CO-101	Green skarn (Banded)	2,000	310	15	8	20,500	48	720	92
CO-102	Green skarn	2,300	140	8	3	3,400	<5	160	12
CO-103	Magnetite chalcopyrite disseminated silicified ore	3	5	<2	2	580	<5	90	1

Soil chemical analyses (ppm)

Sample No.	Description	Sn	W	Nb	Ta
C9 - 28	Brown silt	690	600	18	5
C9 - 29	Reddish brown silt	1,700	390	16	5
C9 - 30	Light brown silt	690	320	22	3

Fig. 8 Geologic sketch of the C2 ore body

connecting the saddles on the ridges.

Epidote, K-feldspar, quartz and muscovite are the main skarn minerals. 1 to 5mm thick banded skarn rock composed of the skarn minerals and goethite is the predominant facies in the skarn. Main ore minerals are goethite and pyrrhotite with minor amount of pyrite and chalcopyrite.

Apparently, silicified zone occurs in vein form, underlying the skarn zone. The main component mineral is quartz with disseminated and/or stripe patterned magnetite and chalcopyrite. The old workings is excavated in this silicified zone about 50m long N-S and 5 to 7m (max, 10m) wide E-W, and the maximum depth of digging is about 10m at the eastern side. The boundary with the wall rock, that is two mica granite, is relatively clear with strike of N 20°E and dip of 60°NW. This dip and strike highly coincides with the elongated old workings.

The two mica granite around the silicified zone has undergone hydrothermal alteration and formed muscovite and quartz. Magnetite bearing quartz vein of 40 to 60cm wide also occurs in the two mica granite, with strike of NNW-SSE and dip to the E.

Assay results of ore samples (CO-101, 102, 103) from each zone are shown in Table 6. As is shown in the table, the grade of skarn zone is Sn: 2,000 to 2,300 ppm, W: 140 to 310 ppm, Cu: 3,400 to 20,500 ppm. However, in the silicified zone the contents of these elements are confined to low values.

As supplement to the field survey, heavy minerals in the stream sediment were collected, and the component mineral species and the grade were examined (Appendix 4).

The results show widespread cassiterite, xenotime, ilmenite, scheelite, wolframite and columbite-tantalite series minerals along the entire course of Nam Mae Hong and its tributaries in the area.

The mineral content of the stream sediment calculated from the result of the chemical analysis of heavy minerals is shown in Table 7. The samples CO-19 and CO-29 obtained near the gossan indicate highly anomalous content of tin, tungsten, niobium, and tantalum.

Aside from the manifestations mentioned above, there is a widely spreading kaolin zone at the southeastern part of the area formed of two mica granite having undergone strong alteration.