THE KINGDOM OF THAILAND
REPORT ON GEOLOGICAL SURVEY
OF
THE OMKOI AREA, NORTHWESTERN THAILAND

(THE COLUMBITE-TANTALITE EXPLORATION PROJECT)

PHASE I

MAY 1984

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 of 1983, the first phase, the Metal Mining Agency of Japan dispatched the survey team consisting of four geologists to Thailand between November 20, 1983 and February 14, 1984.

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.

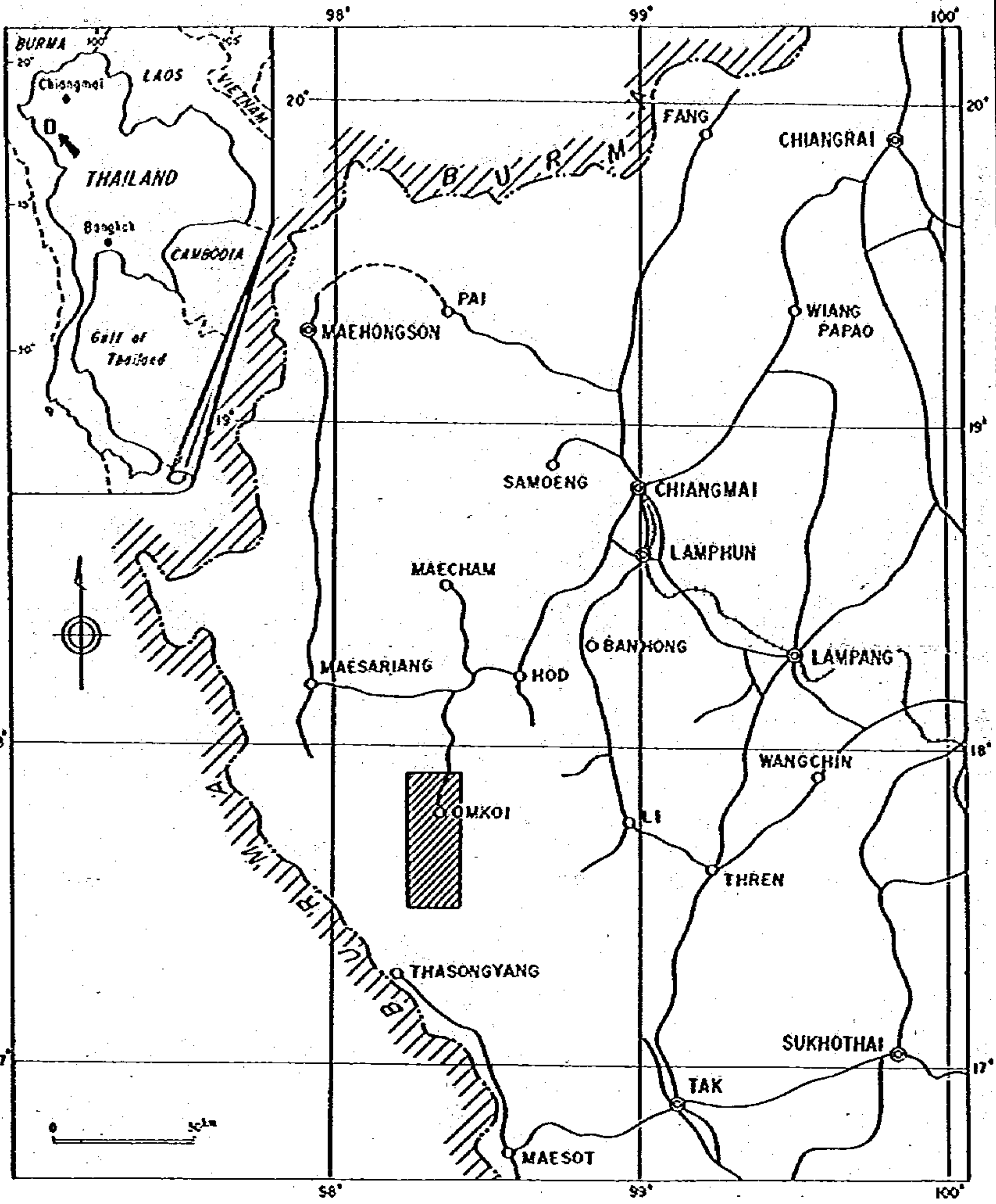
This report summarizes the results of the survey of the first phase and also forms a part of the final report.

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.

May, 1984

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan



Explanation

Survey area

Changwat

Amphoe

Main road

Railway

Fig. I Location map of the survey area.

SUMMARY

This report represents the results of the survey of the first phase for mineral exploration in the Omkoi area, northwestern Thailand.

The survey area is a scope of 1,000 Km^2, 50 Km north and south by 20 Km east and west, centering about Omkoi Village, Omkoi District, Chiang Mai Province.

The objective of this survey was to select promising areas for ore deposits by the investigations of stratigraphy, geological structure, igneous activity, mineralization and distribution of trace components in stream sediment. To attain this objective, the geological survey and geochemical prospecting were conducted.

The geology of the Omkoi area is formed of the metamorphic and sedimentary rocks of Precambrian to Ordovician ages, granites of Carboniferous and Triassic ages and sedimentary rocks of Tertiary age. Of these rocks, granites are distributed over the greater part of the area. The granites, in terms of the ratio of opaque minerals, contain much more ilmenite than magnetite, belonging to the ilmenite-series granitoid.

From the result of the chemical analysis of 50 samples of the granites which are considered related with tin and tungsten mineralization, no mentionable difference in the contents of major components was recognized, indicating that they are almost of homogeneous natures. As for the content of tin, more than half of the samples presented values not less than 6.5 ppm, so the granites of this area fall under the tin-bearing granite.

The principal geological structures are in the directions of NW-SE, N-S and NE-SW. The structures in the directions of NW-SE and N-S are considered fractures deriving from the orogenic belt along the Burmese border, showing itself as the directions of main faults and lineaments. The structures in the direction of NE-SW are found as the direction of faults and drainage systems; those are mostly on a small scale.

As for ore deposits, there are primary ones of tin and tungsten and their secondary ones. Found in and around the Triassic granites, these are ore deposits related with the activity of such granites. There are three primary deposits in the north of the survey area. In these mines, tin and tungsten-bearing quartz veins are emplaced in the gneiss or granite. The width of those veins ranges from 10 to 100 cm. The ore minerals are mainly scheelite accompanied

with wolframite and cassiterite.

The secondary deposits are small-scale eluvial ones emplaced along creeks; there are three mines in the south. The ore minerals are principally cassiterite accompanied with scheelite and wolframite in small quantities.

In addition to the existing mines, some parts of the survey area present alteration related with mineralization such as greisenization of granite and skarnization of calcareous rock; in addition fine grains of scheelite are occasionally seen in stream sediment.

In the geochemical prospecting, 1,259 samples of stream sediment were collected and subjected to chemical analysis for the seven elements, i.e., niobium, tantalum, tin, tungsten, beryllium, lithium and fluorine.

The analytical values were statistically processed, studies were made into relations between each element and geology and into correlations between the elements, and anomaly areas for each element were picked out. Among the picked-out anomaly areas, niobium, tantalum, tin and tungsten showed relatively distinct anomaly areas. These anomaly areas centered about the Yong Ku, Pha Pun-Pha Pun Dong and Huai Yarb-Huai Sia mines. All of these anomaly areas include high anomaly values deriving from the ore deposits of the existing mines. In the surroundings of the Pha Pun-Pha Pun Dong mines, anomalies of the elements were found overlapping with each other over a relatively broad area. Out of them, the tungsten anomaly centers round the mines, but the centers of anomalies of niobium, tantalum and tin deviate south from the mines to some extent. Judging from the locations, this seems to suggest some ore showings other than the existing mines.

Synthetic judgement of the results of the geological survey and geochemical prospecting leads to conclude that a zone extending from the vicinities of the Pha Pun and Pha Pun Dong mines to the south of them offers the highest potential of occurrence of new ore deposits in the survey area on the following grounds: this zone is distributed with the Triassic granites: there are known ore deposits; there are anomaly areas of niobium, tantalum, tin and tungsten most sizable in the survey area, and those of niobium, tantalum and tin particularly include high anomalies which are considered to derive from ore showings other than those of the known mines.

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INTRODUCTION

Chapter 1. GENERAL DESCRIPTION OF THE SURVEY

1-1 Background and Objective of the Survey

Mineral commodities of Thailand consist of more than 30 kinds, i.e., tin, to begin with, tungsten, lead, tantalum, barite, fluorite, lignite, niobium, antimony and gypsum, etc.

In terms of the amount of mineral production, tin occupies an overwhelming share; tin concentrate accounts for 7,950.6 million bahts, about 78% out of 10,169.3 million bahts of the total production in 1982.

Notable about this tin mining is not only the large amount of tin production but the fact that tin contains considerable quantities of rare metals, such as niobium and tantalum yielded as by-products. These rare metals are partly recovered in the ore dressing process, but most of the production are from tin slags.

Thailand, who has exported tin slags, is making preparations for construction of a processing plant for the purpose of raising value added. In need for securing of the resources and also in anticipation of an increasing demand for rare metals, the Government of Thailand requested the Japanese Government to conduct a cooperative mineral exploration of rare metals including niobium and tantalum. In response to this request, the Japanese Government sent a team for prior investigation and made a field inspection before this survey together with Department of Mineral Resources, the Ministry of Industry of the Government of Thailand and negotiated with the Department for concluding an agreement. As the result, it was decided that a cooperative mineral exploration was to be carried out in the Omkoi area, northern Thailand, which offers high hopes of occurrence of deposits of rare metals including niobium and tantalum.

The objective of this survey lied in finding ore deposits of niobium, tantalum, tin, tungsten and other metals and narrowing down promising areas by revealing the geological conditions of the 1,000 km^2-wide area centering round Omkoi Village, Omkoi District, Chiang Mai Province.

1-2 Contents of the Survey

In the survey for the first phase, by course of doing a regional survey over the whole area, a geological survey, geochemical prospecting, and laboratory examinations accompanying these were conducted.

In doing the geological survey and geochemical prospecting, drainage systems for investigation and sampling were selected so that they might be made with a uniform density over the whole area. The laboratory examinations of samples collected during these field works are itemized on Table 1.

In developing the field survey, topographical maps on a scale of 1 to 25,000, which had been enlarged from existing topographical maps on a 1 to 50,000 scale, were used. The results of the survey were compiled in geological maps and geochemical anomaly maps on a scale of 1 to 50,000 and other maps. The field survey was made in the 73 days from November 29, 1983 to February 10, 1984. The analysis of the various collected samples and the analytical study were made in Japan.

1-3 Personnel of Survey Team

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

(1) Planning and Negotiation

JAPAN

Ryuhei Katsuno	Ministry of International Trade and Industry
Yoshikazu Takedomi	– do –
Hiroshi Nakano	– do –
Masao Tsuge	Metal Mining Agency of Japan
Kyoichi Koyama	– do –
Shozo Sawaya	– do –
Jiro Osako	– do –
Hideyuki Ueda	– do –
Masao Watanabe	Japan International Cooperation Agency
Sakashi Matsuda	– do –

THAILAND

Sivavong Changkasiri	Department of Mineral Resources
Charoen Piancharoen	– do –
Sermsakdi Kulvanich	– do –
Phairat Suthakorn	– do –
Prachon Charoensri	– do –
Paichit Pathnopas	– do –

(2) Field Survey

JAPAN (Metal Mining Agency of Japan)

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

THAILAND (Department of Mineral Resources)

Sermsakdi Kulvanich	Project Director
Phairat Suthakorn	Project Manager
Metha Amornsirinukroh	Geologist, Field survey leader
Peerapong Khuenkong	Geologist
Patchara Jariyawat	Geologist
Surapol Udompornwirat	Geologist
Boonchu Panglinput	Surveyor

Table 1 List of laboratory examinations

Examination and element	Numbers
Microscopic observations of thin sections	20 samples
Microscopic observations of polished sections	10 samples
X-ray diffractions	10 samples
K/Ar datings	5 samples
Chemical analyses: Rocks: SiO_2, TiO_2, FeO, Fe_2O_3, MnO, MgO, CaO, K_2O, BaO, Na_2O, Al_2O_3, P_2O_5, LOI, Cl, F, Sn, W Ores: Sn, W, Nb, Ta	 50 samples (850 elements) 10 samples (40 elements)
Chemical analyses of geochemical samples Stream sediment: Sn, W, Nb, Ta, Be, Li, F	 1,259 samples (8,813 elements)

Chapter 2. GEOGRAPHIC INFORMATION OF THE SURVEY AREA

2-1 Location and Accessibility

The survey area is located about 180 kilometers southwest of Chiang Mai City in the north of Thailand (Fig. 1).

As a matter of an administrative district, most of the area is included in Omkoi District, Chiang Mai Province, and it is, at its southwestern edge, partly covered by Tha Song Yang District, Tak Province.

To go from Chiang Mai to Omkoi, first one takes National Highway No. 108 connecting Chiang Mai, Mae Sariang and Mae Hong Son; and, halfway along this highway, starting at Kiew Lan Village turns into National Highway No. 1099 which goes south. There is bus service making a round trip a day.

National Highway No. 108 is entirely paved. National Highway No. 1099, though unpaved, has a wide width, is equipped with side ditches, and allows passage even in the rainy season. It takes cars about four hours to cover the distance between Chiang Mai and Omkoi.

Between Chiang Mai and Bangkok, the capital, the distance of about 570 km in a straight line is flown in approximately 50 minutes by domestic air liners operated at the rate of four or five flights a day. The railway between the two cities is 751 km long, which is covered by an express train in about 13.5 hours. Also there is a highway and it takes an express bus about 10 hours to cover the distance.

As for roads within the survey area there are paths running like a cobweb to connect the hill tribes' villages and cultivated areas. Roads for automobiles, however, are only those connecting Omkoi with Haui Manuang to the west, Yang Kaeo to the east, Mae Long, Mae Lan, Sop Lan and other major villages to the south. And these are all unpaved roads with frequent steep slopes and curves, passable only by four-wheel-drive cars. In addition to that, they become muddy and hardly passable when it rains.

2-2 Topography

Thailand is formed of a vast plain and mountainous regions.

Topographically, it is divided into four regions: the mountainous highland in the north and northwest, the Khorat plateau in the northeast, the Chao Phraya plain in the middle, and the peninsula in the south.

In these topographic regions reflected are the tectonic movements in four times (in the Precambrian, Carboniferous, Mesozoic and Paleogene ages) that took place in Southeast Asia including Thailand, and sedimentations and igneous activities occurring about these times.

The northwest part in which the survey area is located is a mountainous region where mountain ranges starting from Yunnan Province runs in the north-south direction along the Thai-Burmese border and continues down to the Malay Peninsula and where high mountains of Thailand including Mt. Inthanon, 2,595 m, the highest in this country, are concentrated.

The survey area is covered with mountain ranges which run in the direction of almost north-south to northwest-southeast. Rivers and their tributaries which run in parallel with the mountain ranges form a rugged topography. There is a distinct topographic contrast in this area between the northeast side and the southwest side as it is demarcated by the Mae Tun river which runs through the northern half of this area in the northwest-southeast direction and the Mae Lamit river which lies upstream. Whereas the northeast side ranges from 800 to 1,200 meters in altitude and presents a gentle hilly topography with rather wide valleys, the southwest side is a mountainous region, 1,000 to 1,700 meters high, formed of narrow and deep ravines and steep ridges.

2-3 Climate and Vegitation

The climate of Thailand is influenced by the tropical monsoon climate of Southeast Asia. Regionally, this country is divided into the climate of the tropical rain forest type in the peninsular part where there are rainfalls throughout the year and the tropical savanna-type climate in the continental part where the summer monsoon period accounts for 85% of the precipitation and extreme dryness prevails in the dry season.

The survey area has the tropical savanna-type climate; the period from May to October is the rainy season governed by the southwest monsoon, the period from November to February is the dry season influenced by the northeast monsoon, and the time of March and April is the hottest season in the year as the northeast wind is weak.

Temperature and precipitation of the Omkoi district in 1983 and in the latest five years are shown in Fig. 2 and Table 2. The period most suitable for a field survey is considered to be the dry season from November to February.

Most of the survey area is covered by open forests of miscellaneous trees including such coniferous trees as pine, but in some parts it is densely grown with miscellaneous trees, shrubs and grass of natural growth. Among these plants small villages and cultivated areas of the hill tribes are scattered.

2-4 General Information

Omkoi Village, situated almost at the middle of the survey area, is the administrative center of Omkoi District, and there are a primary school, middle school, hospital, post office and police station in addition to the district office.

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

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

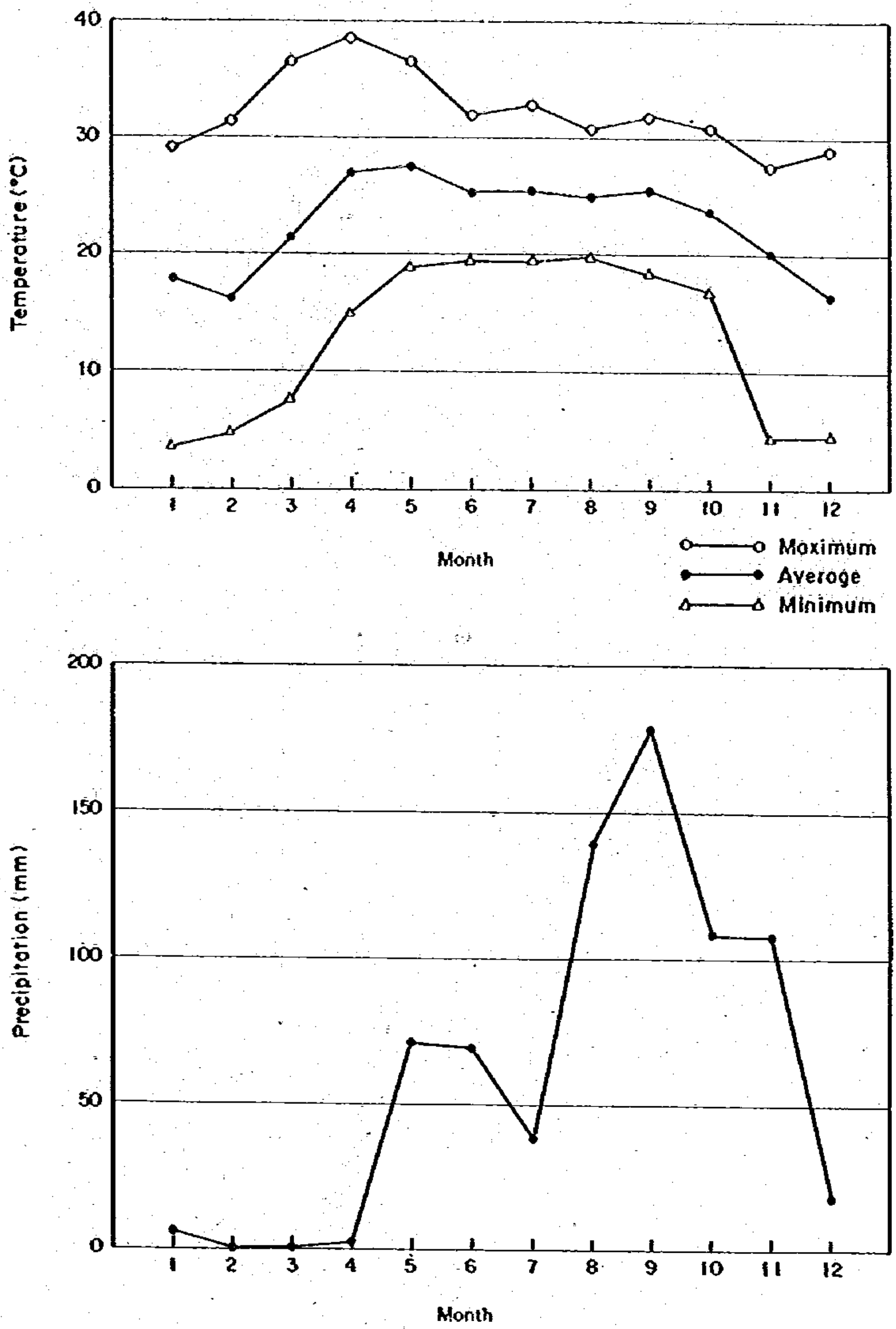


Fig.2 Monthly temperature and precipitation in 1983

Table 2 Statistics of temperature and precipitation in the Omkoi district

	Year \ Month		1	2	3	4	5	6	7	8	9	10	11	12
Rainfall (mm)	1983		5.9	-	-	2.4	71.4	69.6	38.4	139.8	177.7	108.8	108.2	18.3
	1982		-	-	27.3	16.1	285.6	116.4	121.4	103.5	297.5	117.3	19.8	-
	1981		-	-	-	32.0	189.9	112.9	130.9	108.4	156.1	134.2	20.8	10.7
	1980		-	-	90.2	68.4	214.0	111.2	91.2	25	34.3	28.9	17.6	-
	1979		-	-	-	30.7	184.1	183.5	105.7	130.8	201.3	82.2	-	-
Temperature (°C)	1983	Av.	17.89	16.31	21.52	27.05	27.60	25.45	25.41	25.14	25.60	23.78	20.13	16.57
		Max.	29.1	31.4	36.6	38.4	36.6	32.0	32.8	30.7	31.8	30.8	27.7	28.9
		Min.	3.6	4.8	7.7	15.1	19.0	19.50	19.4	19.8	18.3	17.0	4.2	4.4
	1982	Av.	17.43	18.63	23.07	24.42	25.54	24.54	38.64	23.87	24.21	23.29	21.83	16.90
		Max.	29.5	32.8	35.5	34.8	35.1	31.7	30.2	28.9	31.5	30.4	30.8	30.2
		Min.	3.0	3.9	7.8	14.8	18.2	20.0	18.2	19.2	17.5	15.2	11.8	2.7
	1981	Av.	17.4	19.99	22.04	22.81	20.54	23.42	23.89	23.99	24.36	23.63	22.2	17.99
		Max.	28.6	34.6	34.1	35.2	34.7	29.0	30.4	30.0	32.3	31.1	32.2	29.9
		Min.	4.3	5.0	9.0	12.4	17.10	18.6	18.0	19.1	17.3	16.2	12.4	6.0
	1980	Av.	26.87	18.48	23.27	23.27	25.82	22.97	42.35	24.36	23.93	23.90	21.12	19.05
		Max.	30.4	31.4	34.6	35.4	34.8	31.4	30.0	32.0	30.7	31.8	30.4	30.2
		Min.	0.5	1.5	6.7	15.0	17.6	18.9	19.1	18.2	17.0	11.4	11.9	6.4
	1979	Av.	18.97	18.84	22.46	25.43	35.06	25.07	24.32	29.05	28.7	19.72	19.53	17.77
		Max.	31.4	34.7	34.5	35.7	34.8	32.1	31.1	31.3	32.1	31.6	29.9	29.5
		Min.	5.5	4.4	6.1	12.6	18.1	19.5	18.8	18.4	16.0	15.5	8.4	6.2

DETAILED DESCRIPTION

Chapter 1. GEOLOGICAL SURVEY

1-1 Objective

The objective of this survey was to pick out potential areas of ore deposits through the investigations of the geology, geological structure and mineralization.

1-2 Outline of Geology and Mineralization

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

The whole area of the Indochina Peninsula is an orogenic belt of Mesozoic and Cenozoic ages. In this belt are included, as a stable craton, the metamorphic rocks, called Kontum massif, of latest Precambrian or earliest Paleozoic age and the peripheral orogenic zone of late Paleozoic (Hercynian) age.

From the immediately west side of this craton to the Malay Peninsula there is the orogenic belt of Indochina (Triassic to Jurassic) age; further west, in the west of Burma, the orogenic belt of Himalayan (Cretaceous to Recent) age has been formed. This suggests that the continental crust has grown outward successively with the progress of time.

The effects of the Alpine-Himalayan orogeny on the Indochina craton appeared in the form of gentle warping and block faulting which took place in the Cretaceous, Tertiary and Quaternary periods. The geological structure elements which are found in northern Thailand were brought about by plural orogenic movements in which geological ages and the extent of intensity vary. In particular faultings after the orogenic movements intensely dominate, and faultings have continued after the Tertiary until recent and affects the upper Tertiary system and the Pleistocene terraces.

According to the results of this faulting, northern Thailand is divided, from the west, into the West Tectonic Province (along the Thai-Burmese boundary), Main Western Range Tectonic Province, Central North Tectonic Province and East Tectonic Province (Khorat Plateau).

Among these, the Main Western Range Tectonic Province, in which the survey area is located, includes the main mountain zone in Thailand which lies between Mae Sariang and

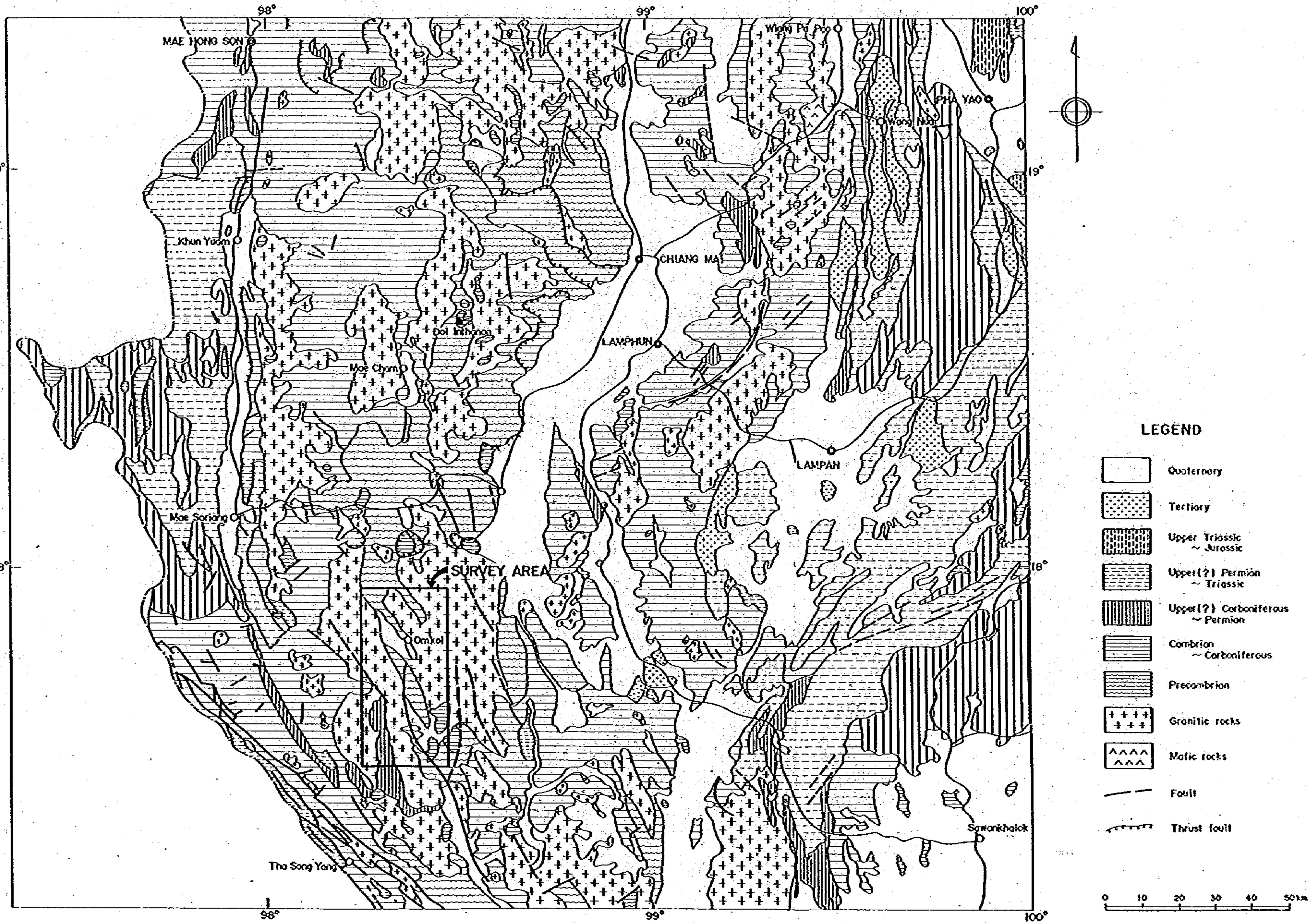


Fig.3 Geologic map of northern Thailand

Chiang Mai, and its southward extension continues to Kanchanaburi. The rocks forming this tectonic province consist of the Precambrian metasedimentary rocks accompanied by arch-shaped granite intrusion, early-Palaeozoic, weakly metamorphosed continental shelf sediments which covers the above rocks unconformably, and granitic rocks of late Triassic age which brought about the mineralization of various minerals including tin, tungsten, fluorite, copper, lead and antimony.

As the result, in northern Thailand scattered are ore showings of copper, lead, zinc, antimony, iron, manganese, celium, beryllium, and uranium as well as large numbers of mines and ore showings of tin, tungsten and fluorite.

The mineralization of these minerals excluding manganese is closely related with the granites. However, the Carboniferous granites have not been found so far to be accompanied with remarkable mineralization; granites of Mesozoic and subsequent ages have brought about various mineralizations.

In particular, tin and tungsten coexist ordinarily; tin and tungsten deposits have been formed, associated with the granites of Mesozoic and subsequent ages and quartz veins deriving from them, at the top and margin of the stocks and in the overlying metasedimentary rocks.

The granites of Mesozoic and subsequent ages forms, in northern Thailand, the Inthanon range to the west of the Chiang Mai basin and the Khuntan range to the east of the basin.

In the former in which the survey area is included, tin and tungsten ore showings at Pai, Samoeng, Mae Cham, Omkoi, Tha Song Yang and other places have been reported.

These are found at contact of the granites (principally Triassic) and limestone, or in pneumatolytic quartz and pegmatite veins. In addition, eluvial deposits concentrated in topographic depressions are known.

1-3 Stratigraphy

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

By the current survey, more detailed distributions of those rocks were traced, but no evidence were found to change the stratigraphic relations. Therefore, the stratigraphy in this report is described based on the above-mentioned divisions. The schematic geological column is shown in Fig. 4 and the geology is shown in PLs. 1 and 2.

(1) Precambrian Metamorphic Rocks

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

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

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

(2) Cambrian Sedimentary Rocks

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

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

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

(3) Ordovician Sedimentary Rocks

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

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

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

The schist is of biotite schist accompanied with limestone and quartzite.

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

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

(4) Pre-Carboniferous Metamorphic Rocks

After the Precambrian tectonic movement, the Carboniferous and Triassic movements took place in the survey area. Both of the Precambrian metamorphic rocks and lower Paleozoic sedimentary rocks were polymetamorphosed by those movements. Therefore, in

Age		Column	Lithology	Igneous activity	Minerali-zation
Cenozoic	Quaternary		Gravel, sand		
	Tertiary		Conglomerate, sandstone		
Mesozoic	Cretaceous				
	Jurassic				
	Triassic		Granite, aplite, pegmatite	Granite	Sn, W, Ta, Nb
Paleozoic	Permian				
	Carboniferous		Gneissose granite, aplite	Granite	
	Devonian				
	Silurian				
	Ordovician		Quartzite Alternation of limestone and quartzite Limestone		
	Cambrian		Sandstone Limestone, sandstone, shale		
Precambrian			Paragneiss, schist	Granite ?	

Fig.4 Schematic geological column

places where the metamorphic grade is high enough to make the both rocks to show similar metamorphic phases it is difficult to distinguish the Precambrian rocks from the lower Paleozoic rocks. Accordingly, in this report the metamorphic rocks excluding those distributed to the east of the Yong Ku mine and to the northeast of Mae Lan (GGM, 1972) are lumped together as the pre-Carboniferous metamorphic rocks.

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

(5) Tertiary Conglomerate

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

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

The Tertiary conglomerate covers the older rocks uncomformably.

(6) Quaternary Alluvium

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

1-4 Igneous Activity

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

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

(1) Carboniferous Granites

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

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

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

(2) Triassic Granites

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

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

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

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

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

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

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

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

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

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

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

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

(3) Result of Dating of Granites

The result of dating of the Triassic granites distributed in this area is given in Table 3. As for the Carboniferous granites, it is presumed to have been rejuvenated by the Triassic granites, so that no dating was made.

According to the result, four samples date back to the latest Cretaceous to earliest Tertiary, and one sample to the Tertiary age.

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

Table 3 K-Ar Datings of granitic rocks

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

The analysis was performed in duplicate.

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

while the K-Ar ages are in a range from 35 to 108 m.y. (Thanasuthipitak, 1978).

The granites in the survey area have been cut by many faults by the post-Triassic tectonic movements and the granites have the gneissose structure or foliation. In addition, the Cretaceous granite stock occurs in the Mae Lama area, 50 km west of the survey area.

As for the post-Triassic ages of the granites in Thailand, the Cretaceous to early Tertiary and middle Tertiary ages have been known. The results of dating by this survey coincide with those ages. However, because the K-Ar ages obtained here are believed to indicate the rejuvenated ages of the granites under the influence of above-mentioned tectonic movements or some igneous activity, the granites are assigned to the Triassic age in this report following the previous conception and avoiding the direct application of the measured values.

(4) Chemical Characteristics of Granites

In order to study the relations between the granites distributed over the survey area and mineralization of tin, tungsten, niobium and tantalum, 50 samples in total were taken from all the facies of the granites and analyzed for 13 major components and 4 trace elements (tin, tungsten, fluorine and chlorine). The breakdown of the samples is: 2 samples from the Carboniferous granites, 22 from the Triassic, medium- to coarse-grained porphyritic granite, 18 from the Triassic, fine-grained granite, 7 from the Triassic, medium- to coarse-grained, foliated granite, and 1 from the Triassic pegmatite. The sample locations and the rock names are shown in Table 4, and the result of analysis and the norm values in Table 5.

In terms of the norms, corundum is calculated from all samples to show that the granites in the survey area are of peraluminous granites. The differentiation indexes (D.I. = normative quartz + normative feldspar) are slightly different by each rock facies; the range of the Carboniferous granites is from 76 to 78 while that of the Triassic granites is more than 80; especially more than half of the Triassic fine-grained granites are over 85. The difference of the differentiation indexes, though not so clear about the Carboniferous granite because of insufficient data, corresponds with the change of the chemical components in the differentiation process of the Triassic granites from the coarse- to medium-grained granites to fine-grained granite and further to final pegmatite.

The classification of the granites by the normative quartz, plagioclase and orthoclase shows that most granites belong to proper granite (Fig. 6) as same as the classification by the field and microscopic observations.

In terms of the relations among the major components, trace elements and differentiation indexes, SiO_2 and Na_2O increase gradually and CaO, FeO, MgO, TiO_2, MnO and P_2O_5 decrease as the differentiation indexes increase (Fig. 5). Al_2O_3, Fe_2O_3 and K_2O do not have apparent relations with the differentiation indexes; those 3 components are concentrated respectively in the ranges from 13 to 15%, 0.3 to 0.8% and 4 to 5.5% except for the rare abnormal values. In terms of the rock facies of the Triassic granite, though some overlappings are recognized, it can be said that the fine-grained granites are comparatively enriched in SiO_2 and Na_2O and the medium- to coarse-grained granites are comparatively enriched in CaO, FeO, MgO, TiO_2, MnO and P_2O_5. The Triassic pegmatite, although abnormal in Al_2O_3 and Na_2O, is plotted on the elongation of the average lines of the Triassic granites in terms of CaO, FeO, MgO, TiO_2 and MnO indicating that the pegmatite is of the products at the final stage of the differentiation. From the viewpoint of the trace elements, neither of fluorine, chlorine nor tin shows any tendency related to the differentiation indexes and rock facies. The variation diagram about tungsten is not given here because obviously there is no relation between tungsten contents and differentiation indexes nor rock facies. Tungsten contents are below detection limit in more than 80% samples of all and the other tungsten-bearing samples are from various rock facies.

Recently, granitic rocks have been classified into the S (sedimentary)-type and I (igneous)-type (Chappel and White, 1974; White and Chappel, 1977) or into the magnetite-series and ilmenite-series granitoids (Ishihara, 1977). The former classification is made by 4 parameters calculated from the chemical components. According to the result of this classification (Fig. 6 and Table 6), there is no case in which the 4 parameters coincidently indicate the alternative type about the same sample. Therefore, the clear S/I-type classification of the granites in the survey area is difficult. The latter classification is made by the microscopically observed ratio of magnetite and ilmenite in the granitic rocks. In terms of this classification the granites in the survey area have already confirmed to belong to the ilmenite-series granitoids because the included magnetite is fewer than ilmenite.

In spite that the granites which occur in the orogenic belt generally belong to the calc-alkaline rocks, more than half of the granites in the survey area seem to belong to the tholeiitic rocks according to the MFA diagram (Fig. 7). However, because all granites are unevenly plotted to the alkali side in the diagram those are not strictly classified into the two rock series. There is no clear tendency among the rock facies.

In the alkali-lime diagram (Fig. 7), almost samples of each rock facies are plotted in the same area excluding the high-Na_2O sample of the Triassic foliated granite and high-K_2O sample of the Triassic pegmatite. This area corresponds well to that of the granites in

Peninsular Thailand (Ishihara, 1980).

From the viewpoint of the trace elements, at first, fluorine ranges from 60 to 650 ppm and chlorine from 14 to 130 ppm. The ratio of fluorine to chlorine is generally high although the ratio in the Triassic granites has a wide range. This tendency is similar to that of the granites in Peninsular Thailand (Ishihara, 1980).

Tin varies from 2 to 53 ppm. The maximum value is from the Triassic foliated granite near the Pha Pun mine. In the Malay Peninsula the average value of tin-bearing granites is 6.5 ppm while that of tin-barren granites is 5.1 ppm (Yeap, cited in Honsking, 1973). On the other hand, in Japan, the former ranges from 4 to 9 ppm and the latter ranges from 1 to 2 ppm (Ishihara and Terashima, 1978). Compared with these data, the granites in the survey area can be said to be tin-bearing granites because more than half of the samples give tin contents not less than 6.5 ppm and because only one sample give tin content of 2 ppm. In the survey area, four granites which give the higher tin contents than 20 ppm are recognized; one from the Carboniferous granites; one from the Triassic foliated granite; and other two from the Triassic coarse-grained granite. However, those are not necessarily close-distributed nor aligned.

The ratios between fluorine and tin, chlorine and tin, and (fluorine + chlorine) and tin suggest that those elements are briefly in the positive correlation although there is no clear tendency among the rock facies (Fig. 8, 9). The contents of tungsten are mostly below the detection limit. Six samples give 1 to 6 ppm and two samples give 20 and 500 ppm. Therefore, the correlations between tungsten and other trace elements are not clearly mentionable. The abnormal tungsten content as high as 500 ppm is from the Triassic fine-grained granite in the middle of the survey area. However, this granite is not so rich in tin as low as 5 ppm. In contrast, the another high tungsten content of 20 ppm is from the Triassic coarse-grained granite in the southwest end of the survey area. In this case, the granite contains 24 ppm of tin indicating that this granite is the high tin and tungsten-bearing granite in the survey area.

1-5 Geological Structure

(1) Folds

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

Table 4 · Granitic rock samples for whole-rock chemical analyses

Sample No.	Coordinates		Age	Description
	E	N		
OAR–1	430.7	1,975.5	Trias.	wk-gs m-g bi-gr
3	367.7	1,972.3	"	f-g bi-gr (dike)
4	429.5	1,964.3	"	wk-gs c-g bi-gr
7	440.3	1,952.7	"	f-g bi-gr
9	437.5	1,948.4	"	f-g bi-gr
10	433.1	1,942.2	"	c-g porph. bi-gr
11	430.9	1,939.8	"	f-g bi-gr
12	429.9	1,939.8	"	c-g porph. bi-gr
13	427.6	1,940.6	"	f-g bi-gr
14	434.9	1,945.4	"	f-g bi-gr (dike?)
15	424.2	1,933.6	"	c-g porph. bi-gr
16	428.2	1,934.8	"	f-g bi-gr
17	426.1	1,958.8	"	gs bi-gr
18	433.9	1,972.2	"	c-g porph. bi-gr
19	433.6	1,973.8	"	f-g bi-gr
20	434.1	1,975.4	"	c-g porph. bi-gr
ONR–1	434.7	1,977.4	"	c-g porph. bi-gr
7	425.0	1,977.0	"	wk-gs porph. bi-gr
11	423.0	1,979.2	Carb.	m-g gs bi-gr
12	428.1	1,967.6	Trias.	m-g porph. bi-gr
14	425.0	1,967.1	"	c-g bi-ms peg.
15	424.6	1,966.9	"	m-g porph. bi-gr
16	427.7	1,966.4	"	f-g ga-brg gr
20	436.3	1,957.1	"	wk-gs m-g bi-gr
26	435.0	1,951.9	"	f-g bi-gr
27	435.0	1,951.9	"	c-g porph. bi-gr
29	425.0	1,947.8	"	c-g porph. bi-gr
30	423.3	1,944.8	"	c-g porph. bi-gr
31	428.4	1,945.3	Carb.	f-g gs bi-gr
32	431.2	1,944.6	Trias.	c-g porph. bi-gr
33	434.6	1,947.3	"	m-g porph. bi-gr
34	433.0	1,947.0	"	c-g porph. bi-gr
35	420.6	1,939.4	"	c-g porph. bi-gr
36	421.6	1,935.5	"	c-g porph. bi-gr
39	435.6	1,937.3	"	m-g bi-gr
42	425.9	1,981.1	"	f-g bi-gr
44	425.4	1,982.1	"	m-g porph. bi-gr
46	426.6	1,982.3	"	m–c-g porph. bi-gr
61	424.2	1,939.3	"	c-g porph. bi-gr
OUR–7	435.3	1,969.0	"	f-g bi-gr
10	426.5	1,969.0	"	f-g bi-gr
11	433.1	1,958.2	"	wk-gs m-g bi-gr
101	422.3	1,975.4	"	wk-gs m-g bi-gr
OYR–4	433.9	1,968.9	"	f-g bi-gr
5	434.2	1,970.2	"	c-g porph. bi-gr
6	431.3	1,965.0	"	f-g bi-gr
9	432.6	1,960.6	"	m-g porph. bi-gr
15	438.1	1,944.6	"	f-g bi-gr
27	424.0	1,967.0	"	c-g porph. bi-gr
29	422.8	1,964.4	"	c-g porph. bi-gr

wk-gs; weak gneissic, f-g; fine grained, m-g; medium grained, c-g; coarse grained, bi; biotite, porph; porphyritic, gr; granite, peg; pegmatite, Carb; Carboniferous, Trias; Triassic

Table 5 Chemical analyses and C.I.P.W. norms of granitic rocks

Sample No.	OAR-001	OAR-003	OAR-004	OAR-007	OAR-009	OAR-010	OAR-011	OAR-012	OAR-013	OAR-014
SiO_2 (%)	74.20	73.33	71.18	71.01	72.09	73.76	73.26	71.76	72.82	73.07
TiO_2	0.18	0.16	0.41	0.37	0.50	0.25	0.24	0.24	0.17	0.21
Al_2O_3	13.61	13.81	13.69	13.76	13.86	13.89	13.52	13.79	14.06	13.80
Fe_2O_3	0.31	0.40	0.30	0.27	0.57	0.26	0.23	0.31	0.26	0.20
FeO	0.61	0.76	2.05	1.84	1.94	1.37	1.44	1.58	1.01	1.08
MnO	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.02	0.04
MgO	0.36	0.24	0.90	0.55	1.02	0.50	0.38	0.44	0.30	0.32
CaO	1.52	0.98	1.20	1.83	1.31	1.47	1.14	1.50	1.56	1.23
BaO	0.450	0.022	0.074	0.078	0.077	0.051	0.060	0.059	0.180	0.052
Na_2O	2.39	2.90	3.14	2.78	2.94	3.15	2.54	2.86	3.60	3.15
K_2O	5.09	5.36	4.85	4.96	4.90	4.44	4.84	4.86	4.09	5.14
P_2O_5	0.03	0.14	0.19	0.11	0.20	0.10	0.10	0.10	0.03	0.08
Ign. loss	0.60	0.81	0.43	0.63	0.84	0.85	0.51	0.57	0.46	0.41
Total	99.36	98.94	98.45	98.23	100.29	100.13	98.30	98.10	98.56	98.78
Q (%)	36.50	33.49	29.60	30.18	31.36	33.91	36.23	31.85	31.76	31.46
C	1.18	1.77	1.50	0.70	1.76	1.44	2.23	1.30	0.83	0.98
or	30.08	31.68	28.66	29.31	28.96	26.24	28.60	28.72	24.17	30.38
ab	20.21	24.52	26.55	23.51	24.86	26.64	21.48	24.19	30.44	26.64
an	8.16	4.00	4.86	8.51	5.34	6.74	5.12	6.90	7.87	5.68
hy	1.48	1.45	5.15	3.99	4.88	3.21	3.08	3.40	2.14	2.34
(en)	(0.90)	(0.60)	(2.24)	(1.37)	(2.54)	(1.24)	(0.95)	(1.10)	(0.75)	(0.80)
(fs)	(0.59)	(0.86)	(2.91)	(2.62)	(2.34)	(1.96)	(2.13)	(2.30)	(1.40)	(1.55)
mg	0.45	0.58	0.43	0.39	0.83	0.38	0.33	0.45	0.38	0.29
il	0.34	0.30	0.78	0.70	0.95	0.47	0.46	0.46	0.32	0.40
ap	0.07	0.33	0.45	0.26	0.47	0.24	0.24	0.24	0.07	0.19
Salic. Tot.	96.13	95.46	91.17	92.22	92.28	94.96	93.66	92.96	95.08	95.13
Femic. Tot.	2.34	2.67	6.82	5.34	7.13	4.30	4.10	4.54	2.91	3.22
D. I.	88.14	91.40	86.56	85.09	85.68	87.44	88.29	86.93	88.15	89.96
F (ppm)	270	100	80	50	100	60	380	370	200	370
Cl	34	38	94	59	98	73	130	78	28	85
Sn	2	15	19	7	10	6	5	11	5	12
W	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	500	1	N. D.	N. D.

Table 5 (Continued)

Sample No.	OAR-015	OAR-016	OAR-017	OAR-018	OAR-019	OAR-020	ONR-001	ONR-007	ONR-011	ONR-012
SiO_2 (%)	70.88	69.83	71.57	72.91	70.85	70.86	75.75	72.36	67.19	72.60
TiO_2	0.39	0.26	0.39	0.30	0.38	0.48	0.04	0.34	0.62	0.26
Al_2O_3	13.21	15.69	13.78	13.59	13.72	14.49	13.48	13.70	14.85	13.00
Fe_2O_3	0.30	0.24	0.39	0.23	0.53	0.57	0.16	0.51	0.50	0.47
FeO	2.05	1.26	1.80	1.51	1.66	1.77	0.18	1.22	2.52	1.01
MnO	0.04	0.03	0.05	0.04	0.04	0.05	0.01	0.04	0.05	0.02
MgO	1.50	0.78	1.21	0.67	0.87	0.61	0.19	0.58	1.24	0.48
CaO	1.36	2.35	1.26	1.63	1.97	1.94	1.82	1.67	2.69	0.83
BaO	0.094	0.160	0.059	0.056	0.068	0.089	0.050	0.076	0.220	0.054
Na_2O	2.68	4.55	2.81	2.95	2.84	2.84	3.14	2.94	2.80	2.40
K_2O	4.65	2.35	4.53	4.73	4.76	5.09	3.66	4.52	4.70	6.34
P_2O_5	0.17	0.07	0.24	0.80	0.11	0.14	0.00	0.11	0.36	0.09
Ign. loss	0.75	0.86	0.81	0.79	0.88	0.61	0.55	0.70	0.98	0.27
Total	98.07	98.43	98.90	100.21	98.68	99.54	99.03	98.77	98.72	97.82
Q (%)	31.42	27.47	32.92	34.38	29.93	29.18	39.20	33.17	24.66	31.61
C	1.64	1.45	2.49	2.51	0.53	1.06	1.01	1.15	0.98	0.86
or	27.48	13.89	26.77	27.95	28.13	30.08	21.63	26.71	27.78	37.47
ab	22.66	38.48	23.76	24.95	24.02	24.02	26.55	24.86	23.68	20.30
an	5.82	11.49	4.80	3.02	9.18	8.88	9.12	7.71	11.41	3.63
hy	6.68	3.68	5.44	3.83	4.22	3.60	0.62	2.78	6.37	2.27
(en)	(3.73)	(1.94)	(3.01)	(1.67)	(2.17)	(1.52)	(0.47)	(1.44)	(3.09)	(1.19)
(fs)	(2.95)	(1.74)	(2.43)	(2.16)	(2.06)	(2.08)	(0.15)	(1.33)	(3.28)	(1.07)
mg	0.43	0.35	0.57	0.33	0.77	0.83	0.23	0.74	0.72	0.68
il	0.74	0.49	0.74	0.57	0.72	0.91	0.08	0.65	1.18	0.49
ap	0.40	0.17	0.57	1.89	0.26	0.33	0.00	0.26	0.85	0.21
Salic Tot.	89.02	92.78	90.75	92.81	91.79	93.22	97.52	93.61	88.50	93.87
Femic Tot.	8.26	4.69	7.32	6.63	5.97	5.67	0.93	4.42	9.12	3.66
D. I.	83.85	81.91	85.09	87.77	83.95	84.22	88.76	86.46	77.96	91.64
F (ppm)	430	260	460	380	530	610	370	200	380	50
Cl	76	34	22	49	36	43	73	36	58	32
Sn	15	5	29	11	8	7	3	8	6	6
W	N. D.	N. D.	6	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.

Table 5 (Continued)

Sample No.	ONR-014	ONR-015	ONR-016	ONR-020	ONR-026	ONR-027	ONR-029	ONR-030	ONR-031	ONR-032
SiO_2 (%)	84.65	73.64	75.88	72.99	73.68	72.27	69.65	68.95	63.17	73.51
TiO_2	0.10	0.19	0.08	0.20	0.15	0.30	0.54	0.54	0.54	0.30
Al_2O_3	8.05	13.72	12.96	14.64	13.56	13.88	13.46	14.05	17.29	13.61
Fe_2O_3	0.04	0.23	0.09	0.54	0.21	0.56	0.82	0.69	0.92	0.63
FeO	0.32	0.94	0.68	1.04	1.08	1.01	2.16	2.38	2.45	1.15
MnO	0.01	0.02	0.06	0.06	0.04	0.03	0.05	0.05	0.07	0.03
MgO	0.15	0.48	0.14	0.39	0.31	1.45	1.96	1.84	2.07	0.54
CaO	0.20	0.85	1.14	2.08	1.23	1.38	1.47	1.78	2.56	1.03
BaO	0.069	0.050	0.071	0.054	0.048	0.110	0.150	0.140	0.130	0.064
Na_2O	0.61	2.73	3.34	5.52	3.03	2.77	2.82	2.39	5.06	2.80
K_2O	5.14	4.96	4.62	0.92	4.87	5.21	5.39	5.52	3.78	5.00
P_2O_5	0.08	0.15	0.02	0.04	0.04	0.07	0.17	0.17	0.22	0.06
Ign. loss	0.31	0.60	0.20	0.52	0.52	0.30	0.23	0.55	0.37	0.65
Total	99.73	98.56	99.28	98.99	98.77	99.34	98.87	99.05	98.63	99.37
Q (%)	60.76	36.06	35.61	31.85	33.66	30.79	25.79	26.38	9.88	34.68
C	1.26	2.64	0.39	0.85	1.13	1.27	0.62	1.22	0.66	1.82
or	30.38	29.31	27.30	5.44	28.78	30.79	31.86	32.62	22.34	29.55
ab	5.16	23.09	28.25	46.68	25.62	23.43	23.85	20.21	42.79	23.68
an	0.60	3.34	5.65	10.15	5.93	6.59	6.46	7.98	11.51	4.84
hy	0.78	2.45	1.50	2.22	2.41	4.56	7.37	7.58	8.13	2.50
(en)	(0.37)	(1.19)	(0.35)	(0.97)	(0.77)	(3.61)	(4.88)	(4.58)	(5.15)	(1.34)
(fs)	(0.41)	(1.26)	(1.15)	(1.24)	(1.64)	(0.95)	(2.49)	(3.00)	(2.98)	(1.15)
mg	0.06	0.33	0.13	0.78	0.30	0.81	1.19	1.00	1.33	0.91
il	0.19	0.36	0.15	0.38	0.28	0.57	1.03	1.03	1.03	0.57
ap	0.19	0.36	0.05	0.09	0.09	0.17	0.40	0.40	0.52	0.14
Salic Tot.	98.16	94.44	97.21	94.97	95.13	92.87	88.57	88.41	87.18	94.57
Femic Tot.	1.22	3.50	1.83	3.47	3.09	6.11	9.99	10.01	11.01	4.12
D. I.	96.90	90.32	92.04	85.30	89.66	85.89	82.68	80.48	76.39	89.08
F (ppm)	190	440	50	220	200	160	70	60	500	440
Cl	34	38	54	16	36	59	42	69	107	36
Sn	4	7	3	11	8	8	8	7	21	4
W	N. D.	5	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.

Table 5 (Continued)

Sample No.	ONR-033	ONR-034	ONR-035	ONR-036	ONR-039	ONR-042	ONR-044	ONR-046	ONR-061	OUR-007
SiO_2 (%)	75.06	73.43	71.39	69.91	74.17	71.12	72.03	72.91	70.61	70.56
TiO_2	0.24	0.31	0.44	0.51	0.25	0.41	0.38	0.38	0.52	0.37
Al_2O_3	13.00	13.25	13.48	13.94	13.38	14.11	13.90	14.66	13.80	14.01
Fe_2O_3	0.29	0.31	0.59	1.43	0.36	0.44	0.37	0.61	0.54	0.56
FeO	2.23	1.44	2.02	2.30	1.12	1.69	1.51	1.44	2.38	1.73
MnO	0.03	0.03	0.05	0.05	0.04	0.04	0.03	0.04	0.07	0.05
MgO	0.39	0.76	1.55	1.43	0.40	0.67	0.69	0.63	1.48	0.59
CaO	1.05	1.22	1.59	1.89	1.25	1.84	1.64	1.56	1.17	1.78
BaO	0.029	0.079	0.083	0.100	0.046	0.095	0.120	0.098	0.120	0.078
Na_2O	3.06	2.88	2.71	2.76	2.98	2.71	2.90	2.64	2.63	2.86
K_2O	4.68	4.80	4.25	4.96	4.78	4.76	4.02	5.05	5.13	4.94
P_2O_5	0.04	0.08	0.14	0.18	0.06	0.09	0.10	0.10	0.16	0.12
Ign. loss	0.33	0.50	0.88	0.49	0.81	0.42	0.85	0.92	0.60	0.70
Total	100.43	99.09	99.17	99.95	99.65	98.40	98.54	101.04	99.21	98.35
Q (%)	35.02	33.86	32.81	28.09	34.77	31.42	34.57	33.44	29.88	29.61
C	1.07	1.24	1.81	0.96	1.15	1.31	1.96	2.19	2.09	0.96
or	27.66	28.37	25.12	29.31	28.25	28.13	23.76	29.85	30.32	29.20
ab	25.88	24.36	22.92	23.34	25.20	22.92	24.52	22.33	22.24	24.19
an	5.00	5.68	7.13	8.39	5.89	8.72	7.70	7.27	4.99	8.19
hy	4.49	3.82	6.45	5.85	2.42	3.80	3.61	3.16	6.88	3.66
(en)	(0.97)	(1.89)	(3.86)	(3.56)	(1.00)	(1.67)	(1.72)	(1.57)	(3.68)	(1.47)
(fs)	(3.51)	(1.93)	(2.59)	(2.29)	(1.42)	(2.14)	(1.90)	(1.59)	(3.20)	(2.20)
mg	0.42	0.45	0.86	2.07	0.52	0.64	0.54	0.88	0.78	0.81
il	0.46	0.59	0.84	0.97	0.47	0.78	0.72	0.72	0.99	0.70
ap	0.09	0.19	0.33	0.43	0.14	0.21	0.24	0.24	0.38	0.28
Salic Tot.	94.63	93.49	89.78	90.09	95.26	92.49	92.51	95.07	89.52	92.15
Femic Tot.	5.46	5.05	8.47	9.32	3.56	5.43	5.11	5.00	9.03	5.46
D. I.	88.48	87.86	82.28	81.22	89.28	84.22	84.87	85.55	83.65	85.03
F (ppm)	220	250	430	310	200	550	210	170	650	130
Cl	42	46	56	48	48	70	27	45	38	60
Sn	5	6	9	9	5	6	5	9	24	10
W	N. D.	N. D.	5	N. D.	N. D.	N. D.	N. D.	N. D.	21	N. D.

Table 5 (Continued)

Sample No.	OUR-010	OUR-011	OUR-101	OYR-004	OYR-005	OYR-006	OYR-009	OYR-015	OYR-027	OYR-029
SiO_2 (%)	70.26	72.33	72.88	71.76	72.21	73.37	72.60	69.47	72.61	69.17
TiO_2	0.28	0.30	0.31	0.37	0.35	0.22	0.26	0.38	0.10	0.52
Al_2O_3	13.85	14.03	13.53	13.60	13.72	13.26	13.54	14.16	13.92	13.70
Fe_2O_3	0.72	0.51	0.44	0.48	0.79	0.41	0.21	0.69	0.17	0.47
FeO	1.08	1.04	1.30	1.66	1.40	0.94	1.22	1.73	0.47	2.45
MnO	0.03	0.04	0.04	0.05	0.05	0.02	0.03	0.05	0.01	0.04
MgO	0.58	0.59	0.78	0.60	0.74	0.31	0.40	0.79	0.14	1.55
CaO	1.75	1.46	1.03	1.54	1.31	1.11	1.29	2.20	0.70	1.77
BaO	0.075	0.040	0.055	0.069	0.069	0.044	0.034	0.100	0.035	0.120
Na_2O	2.10	3.89	3.04	2.52	2.74	2.62	4.12	2.82	2.98	2.52
K_2O	5.09	3.30	4.72	4.96	5.01	5.54	3.32	4.74	5.92	4.90
P_2O_5	0.10	0.07	0.14	0.10	0.08	0.06	0.14	0.12	0.14	0.21
Ign. loss	2.44	0.87	0.36	0.75	0.75	0.48	0.52	0.53	0.97	0.70
Total	98.36	98.47	98.63	98.46	99.22	98.38	97.68	97.78	98.17	98.12
Q (%)	33.74	32.76	33.40	33.19	32.72	33.75	32.18	28.36	31.03	28.65
C	1.89	1.55	1.84	1.48	1.55	1.05	1.14	0.61	1.65	1.45
or	30.08	19.50	27.90	29.31	29.61	32.74	19.62	28.01	34.99	29.98
ab	17.76	32.90	25.71	21.31	23.17	22.16	34.84	23.85	25.20	21.31
an	8.17	6.86	4.30	7.12	6.10	5.20	5.55	10.32	2.63	7.64
hy	2.43	2.54	3.53	3.63	3.28	1.83	2.69	4.04	0.92	7.18
(en)	(1.44)	(1.47)	(1.94)	(1.49)	(1.84)	(0.77)	(1.00)	(1.97)	(0.35)	(3.86)
(fs)	(0.98)	(1.07)	(1.59)	(2.13)	(1.43)	(1.06)	(1.69)	(2.07)	(0.58)	(3.33)
mg	1.04	0.74	0.64	0.70	1.14	0.59	0.30	1.00	0.25	0.68
il	0.53	0.57	0.59	0.70	0.66	0.42	0.49	0.72	0.19	0.99
ap	0.24	0.17	0.33	0.24	0.19	0.14	0.33	0.28	0.33	0.50
Salic Tot.	91.64	93.57	93.16	92.41	93.16	94.90	93.33	91.15	95.49	88.01
Femic Tot.	4.24	4.01	5.09	5.26	5.27	2.99	3.82	6.04	1.69	9.35
D.I.	85.09	87.27	88.57	85.81	86.86	90.57	89.18	82.54	93.86	81.06
F (ppm)	470	260	260	630	330	110	420	380	80	610
Cl	14	55	50	91	48	49	70	77	29	65
Sn	14	8	53	9	8	7	13	7	9	12
W	2	N. D.	3	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.

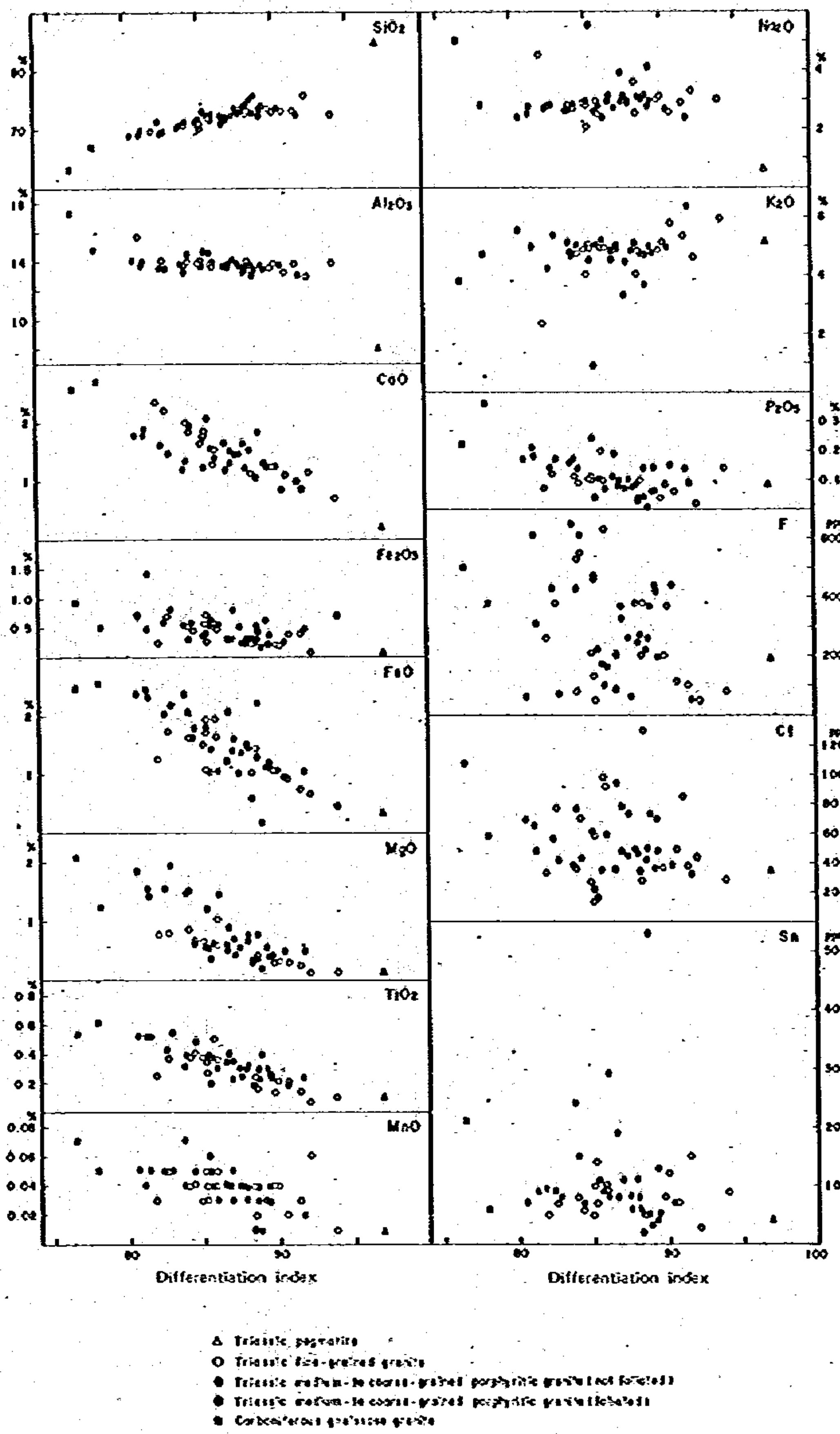
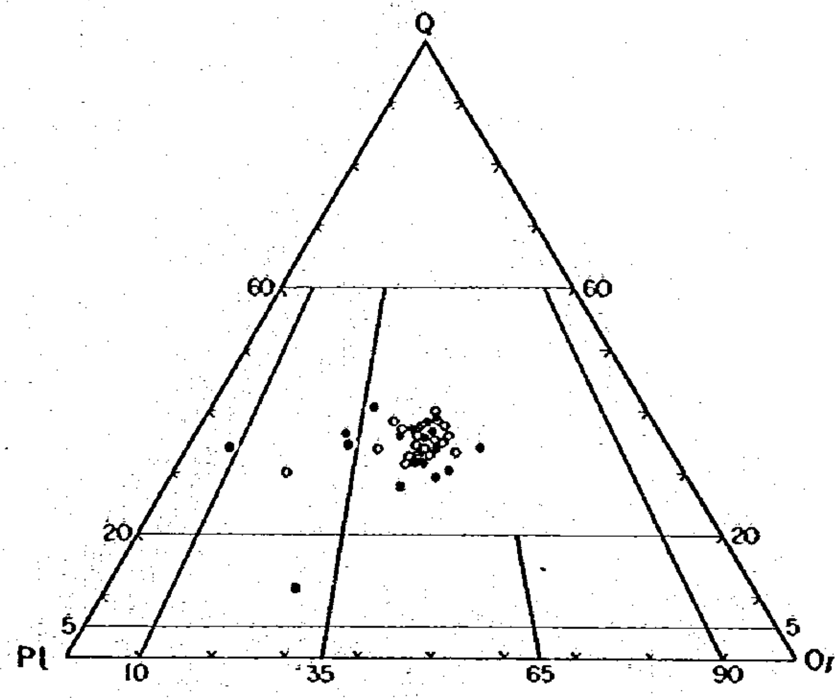
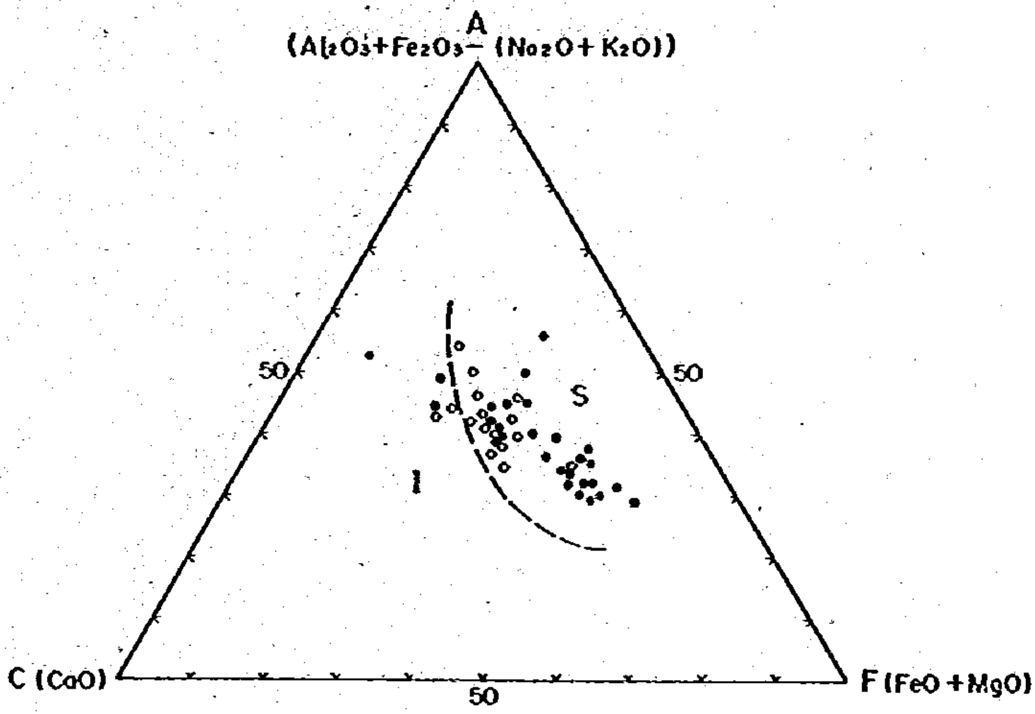


Fig.5 Chemical variation diagrams of granitic rocks



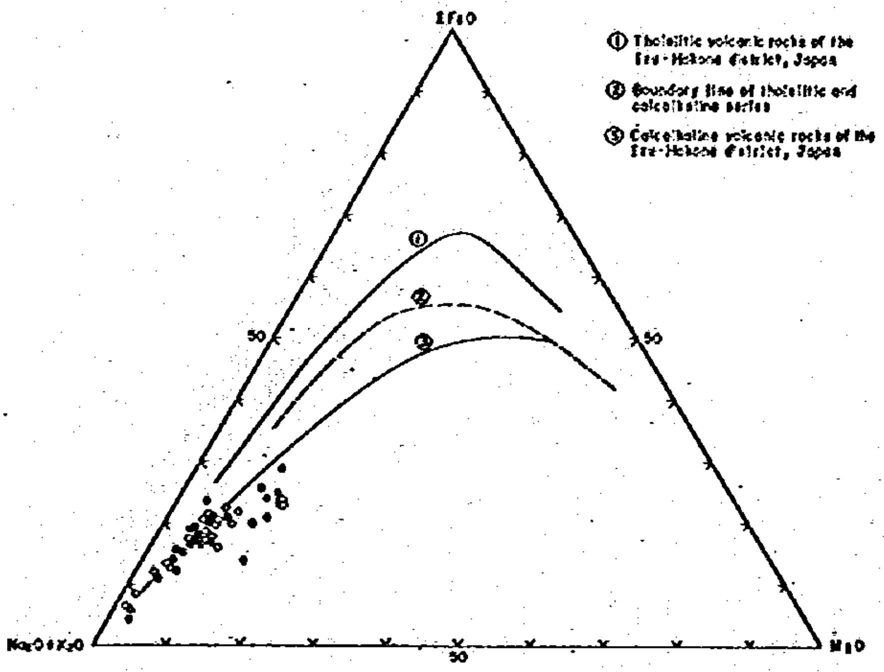
Normative Q - Pl - Or diagram



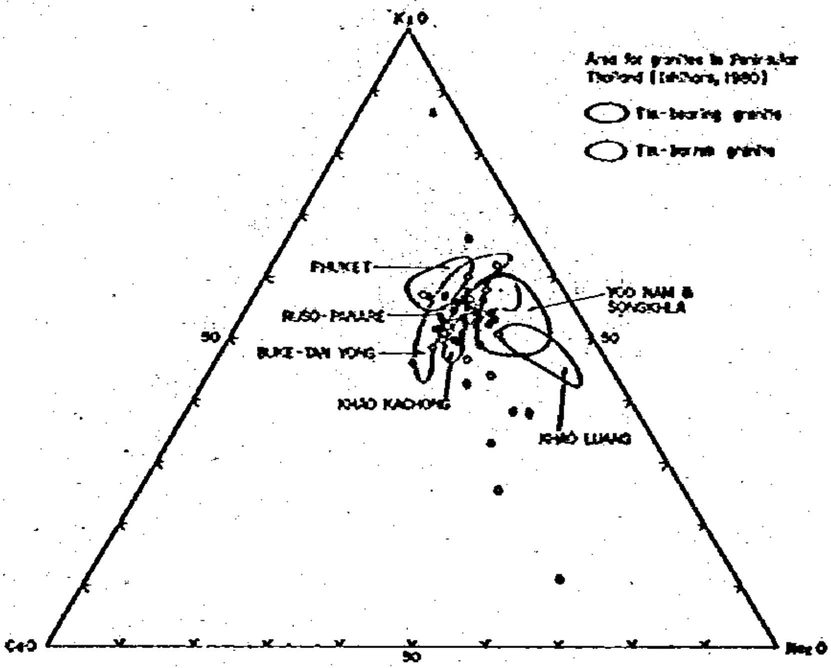
ACF diagram

o Triassic fine - grained granite
• Triassic medium- to coarse-grained porphyritic granite (not foliated)
• Triassic medium- to coarse-grained porphyritic granite (foliated)
▪ Carboniferous gneissose granite

Fig. 6 Normative Q - Pl - Or and ACF diagrams



MFA diagram



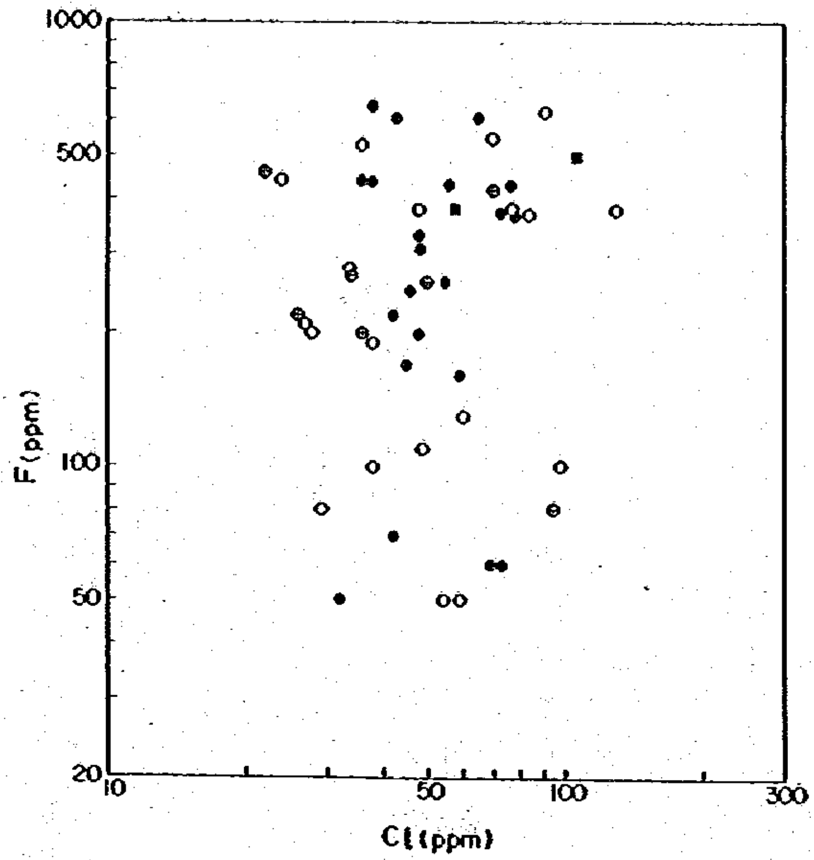
Alkali-lime diagram

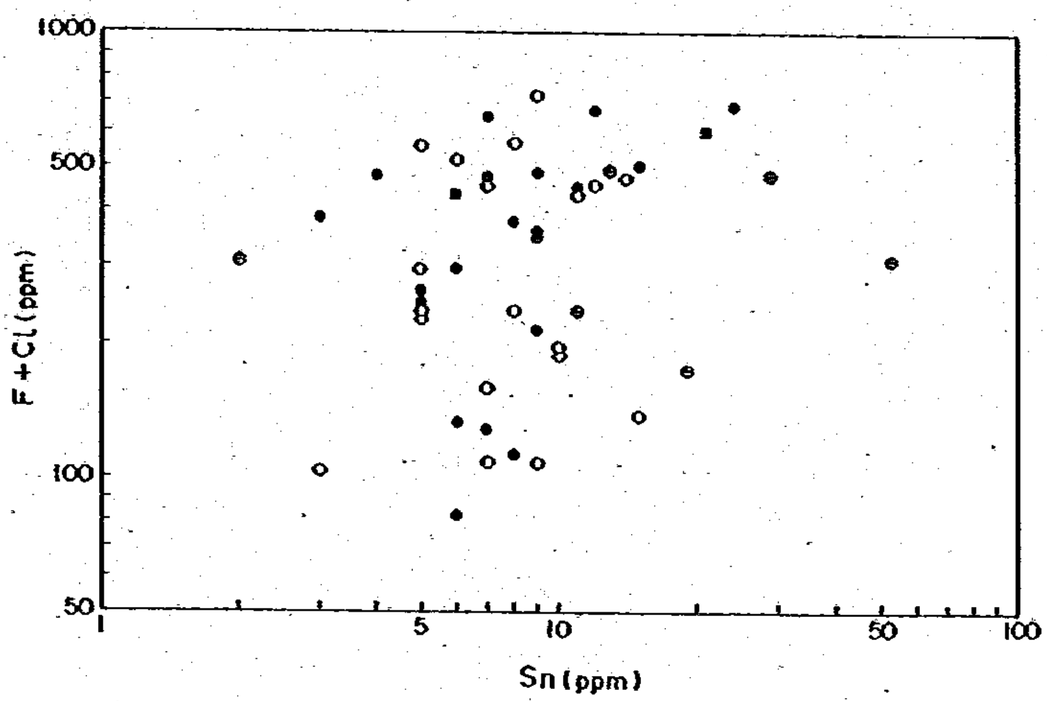
△ Triassic pegmatite
○ Triassic fine-grained granite
● Triassic medium- to coarse-grained granite (not foliated)
● Triassic medium- to coarse-grained granite (foliated)
■ Carboniferous gneissose granite

Fig.7 MFA and alkali-lime diagrams

Table 6 S-type/I-type classification of granitic rocks

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





- ○ Triassic fine-grained granite
- ● Triassic medium- to coarse-grained porphyritic granite (not foliated)
- ⊖ Triassic medium- to coarse-grained porphyritic granite (foliated)
- ■ Carboniferous gneissose granite

Fig.8 Cl-F and Sn-(F+Cl) variation diagrams

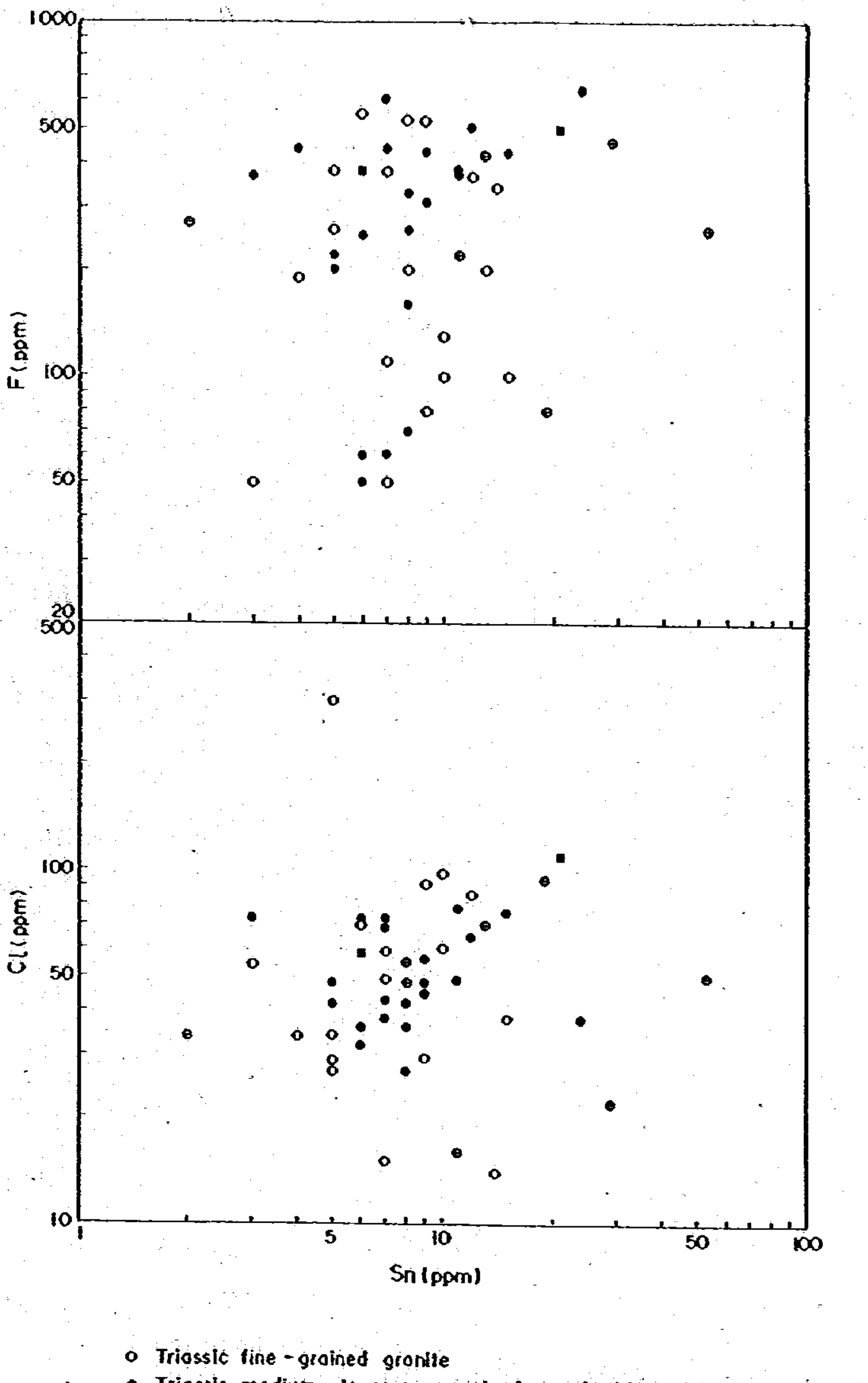


Fig. 9 Sn-F and Sn-Cl variation diagrams

these rocks difficult.

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

However, in the northeast of the survey area the Precambrian paragneiss is distributed as if it surrounds the Ordovician system, and this distribution makes one infer a synclinal axis in the NW–SE direction.

(2) Faults

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

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

1-6 Ore Deposits

Tin and tungsten ore deposits in this area, as listed in Table 7, comprise primary ones and secondary ones.

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

The ore deposits shown in Table 7 exist all in or near the Triassic granites.

The primary deposits are vein-type ones emplaced in the granites or in the roof-pendant metamorphic rocks. The secondary deposits are small-scale, eluvial ones which contain the ore minerals at the basal part of the gravel layer deposited in depressions along creeks.

The ore of primary deposits is principally of tungsten accompanied with tin, while that of secondary deposits is mainly tin.

In the granites or stream sediment in the survey area, fine grains of scheelite are occasionary found, but they are not concentrated in particular places.

Also skarnization is often found in the sedimentary rocks, particularly limestone; and in the granites found are quartz and pegmatite veins and local greisenization.

In the following described are the ore deposits.

(1) Yong Ku Mine

The Yong Ku mine is situated on a hill on the southeast side of Yong Ku Village in the north edge of the survey area. A dirt road leads to this village along a ridge on its south side branching off the National Highway No. 1099.

This mine has been operated for about 10 years, having more than 20 employees at its peak production, but now is worked with 10 workers because the prices of the products stay low.

The ore deposit is of quartz veins containing tungsten and tin. The veins have intruded into the host rock of the biotite paragneiss of distinct gneissose structure.

The quartz veins, intruding in a sheet form along the gneissose structure of the host rock, are several parallel veins with strikes of N 10° to 15° W and dips of 30° to 40°E. All the veins have width ranging from 20 to 80 cm, averaging 40 to 50 cm. These veins presumably have the scale of a strike extent of about 40 m and a dip length of about 30 m.

The ore minerals consist mainly of fine-grained scheelite disseminated in the quartz veins, accompanied with wolframite and cassiterite.

In the surroundings of the quartz veins there are parts where biotite is concentrated and scheelite is enriched.

The results of analysis of the ore samples are given in Table 8.

The contents of tungsten are 1.46% and 1.65% of WO_3 respectively at two working faces. Also from the quantity of scheelite found by application of ultraviolet rays, 1 to 2% of WO_3 as the grade of the veins can be estimated.

As for tin, there is a wide variance from 0.17% to 1.28% of Sn. This could be accounted for by uneven distribution of cassiterite, being scattered as crystals of several millimeters in the quartz veins. Niobium and tantalum are of low content even in the concentrate.

Formerly the mine was operated by opencut mining, but the working faces have come down by degrees, and now underground mining is made along the veins. As the working faces shifted deeper, the wall rock has become harder; this problem, together with those of drainage and ventilation, has made the operation difficult (Fig. 10).

The mined ore is crushed, concentrated by jiggers, panned to eliminate fine particles, and shipped as the concentrate, which is a mixture of heavy minerals including tin and tungsten.

(2) Pha Pun Mine

The Pha Pun mine is situated on the southern hill slope lying between the Pha Pun Dong and Tai creeks which are the tributaries of the Pha Pun Luang river; there is a road good for automobiles leading to this mine.

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

The quartz veins have strikes of N70°E and dips of 80 to 90°; the scale is in the extent of 0.1 to 1.0 m in width, averaging 10 to 30 cm and a strike length of 10 to 30 m. More than 10 veins are distributed in an echelon form in a scope of 150 m by 250 m.

The ore minerals are formed mainly of scheelite, accompanied with wolframite and cassiterite. The results of analysis of the ore samples are given in Table 8.

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

The mining had been advanced in a ditch form along the outcrop of the veins, and now the opencut mining is being changed over to underground mining (Fig. 11).

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

(3) Pha Pun Dong Mine

The Pha Pun Dong mine is located about the top of a hill to the south of the Pha Pun Dong river; there is a road passable by cars to the mine.

The ore deposit is of tin/tungsten-bearing quartz veins in the Triassic foliated granite as same as the Pha Pun mine. The strike and dip of the vein are N30 to 60°W and 40 to 80°S respectively, both varying to some extent. The width of the veins is generally in the range of 2 to 25 cm, though more than 50 cm rarely. As a feature of the veins tourmaline is recognized. The ore minerals are principally scheelite, accompanied with wolframite and cassiterite.

Judging from the scales of the old openpit and abandoned launders, this mine seems to have the record of the biggest operation in this area, but at present it has ore dressing equipment of small size and operates only during the period when ore dressing water is available.

Until three years ago networked quartz veins, together with the weathered host rock near the surface, were mined by opencutting. As the mining work shifted deeper, the operation has been changed over to the underground mining of the major veins (Fig. 12).

Although the detail is unknown because the tunnels are under water, it is said that the major veins are of the scale of about 50 cm in vein width and about 15 m in strike length. No prominent ore showings are found in the old workings. The result of analysis of the finer fraction of the jigger concentrate indicates that the contents of tin, niobium and tantalum are low (Table 8).

(4) Pi Tu Khi Mine

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

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

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

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

(5) Huai Yarb Mine

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

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

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

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

The ore minerals are mainly cassiterite less than 1 cm in size, accompanied with small quantities of scheelite and wolframite. Almost of cassiterite is brown one contained in quartz veins; in addition there is a small quantity of black one contained in pegmatite veins. The results of analysis of a panning concentrate show 69.0% Sn and 0.71% WO_3, while niobium and tantalum contents are as low as 0.01% and 0.02% respectively.

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

(6) Huai Sia Mine

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

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

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

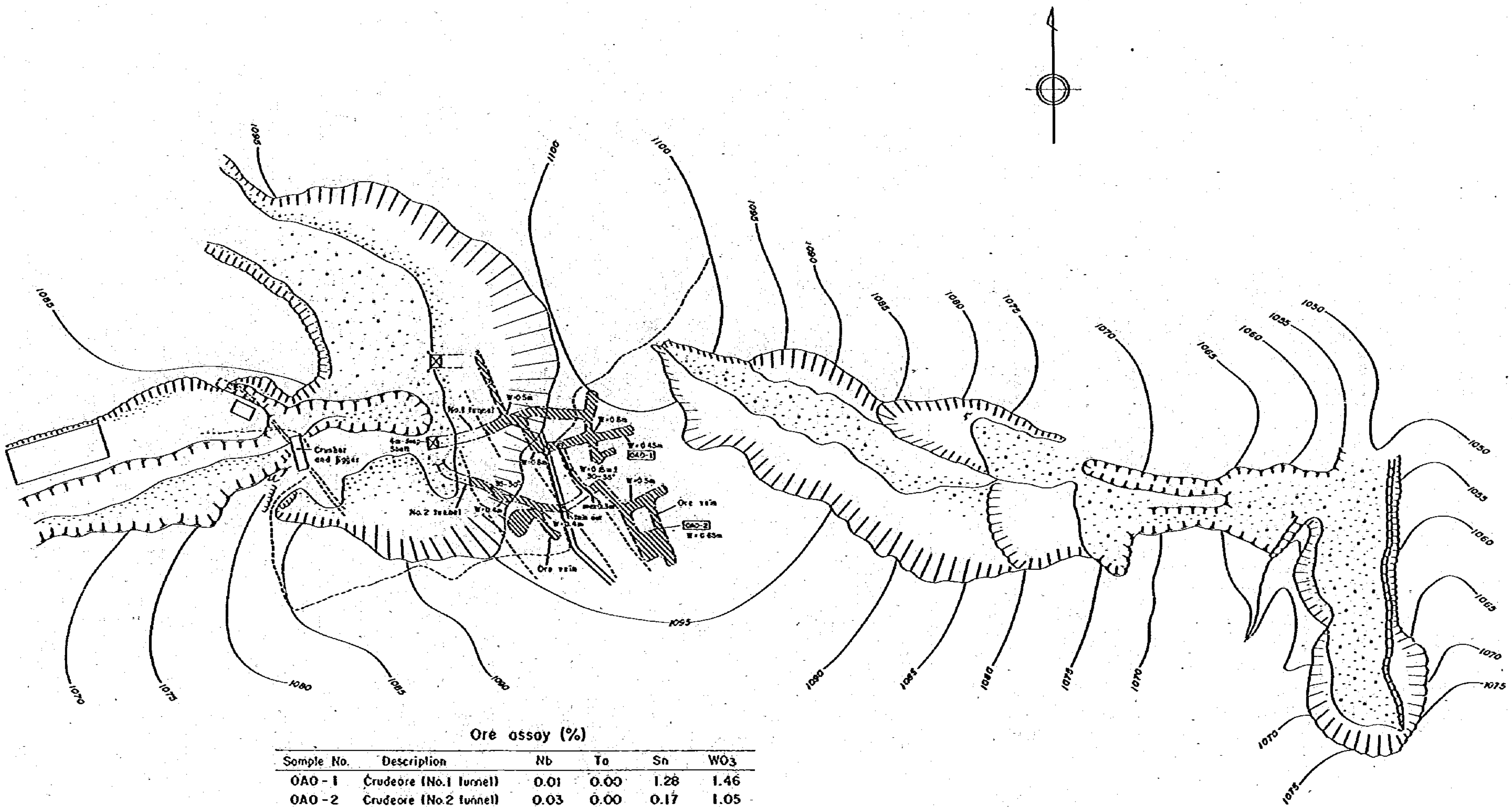
Table 7. List of Mines in the Survey Area

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

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

Table 8 Assay of ore samples

No.	Sample No.	Location	Description	Nb (%)	Ta (%)	Sn (%)	WO_3 (%)
1	OAO-1	Yong Ku mine	Sn-W crude ore (No. 1 tunnel, W=45 cm)	0.01	0.00	1.28	1.46
2	OAO-2	ditto	Sn-W crude ore (No. 2 tunnel, W=65 cm)	0.03	0.00	0.17	1.05
3	OAO-4	ditto	Sn-W concentrate	0.11	0.01	9.60	65.1
4	OAO-5	ditto	Sn > W concentrate	0.21	0.09	72.2	0.28
5	ONO-1	Huai Yarb mine	Sn > W concentrate	0.01	0.02	69.0	0.71
6	OUO-2	Pha Pun Dong mine	Finer fraction of jigger concentrate	0.13	0.07	0.65	32.9
7	OYO-1	Pha Pun mine	Sn-W crude ore (ore dump for dressing)	0.02	0.00	0.05	5.65
8	OYO-2	ditto	Sn < W concentrate	0.02	0.00	0.04	69.6
9	OYO-5	ditto	Primary tailing	0.08	0.01	0.28	2.95
10	OAS-27	Huai Om Pat	Panning concentrate of stream sediment	0.31	0.03	0.03	0.89

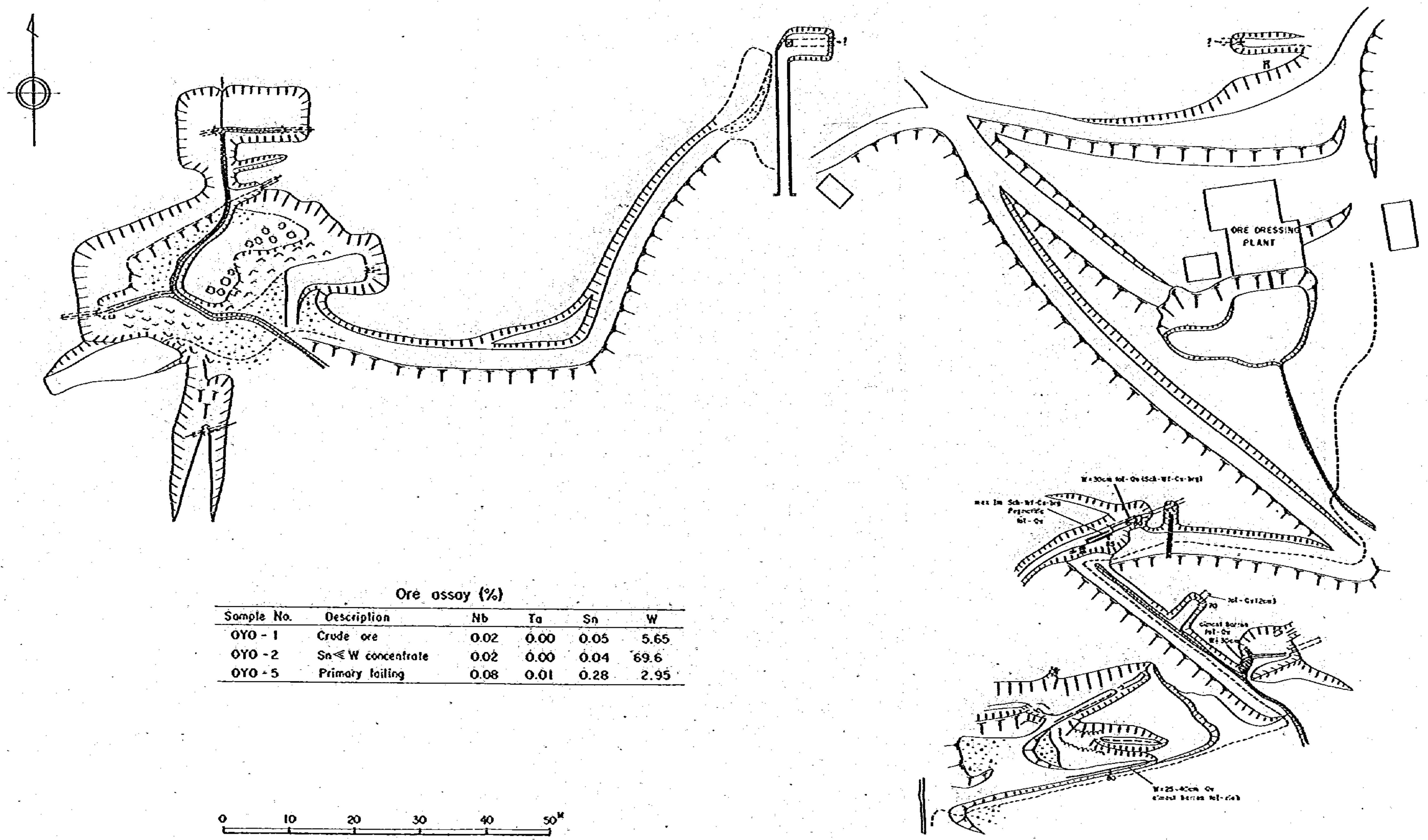


Ore assay (%)

Sample No.	Description	Nb	Ta	Sn	WO_3
OAO - 1	Crudeore (No.1 tunnel)	0.01	0.00	1.28	1.46
OAO - 2	Crudeore (No.2 tunnel)	0.03	0.00	0.17	1.05
OAO - 4	Sn<W concentrate	0.11	0.01	9.60	65.1
OAO - 5	Sn≥W concentrate	0.21	0.09	72.2	0.28

0 10 20 30 40 50 M

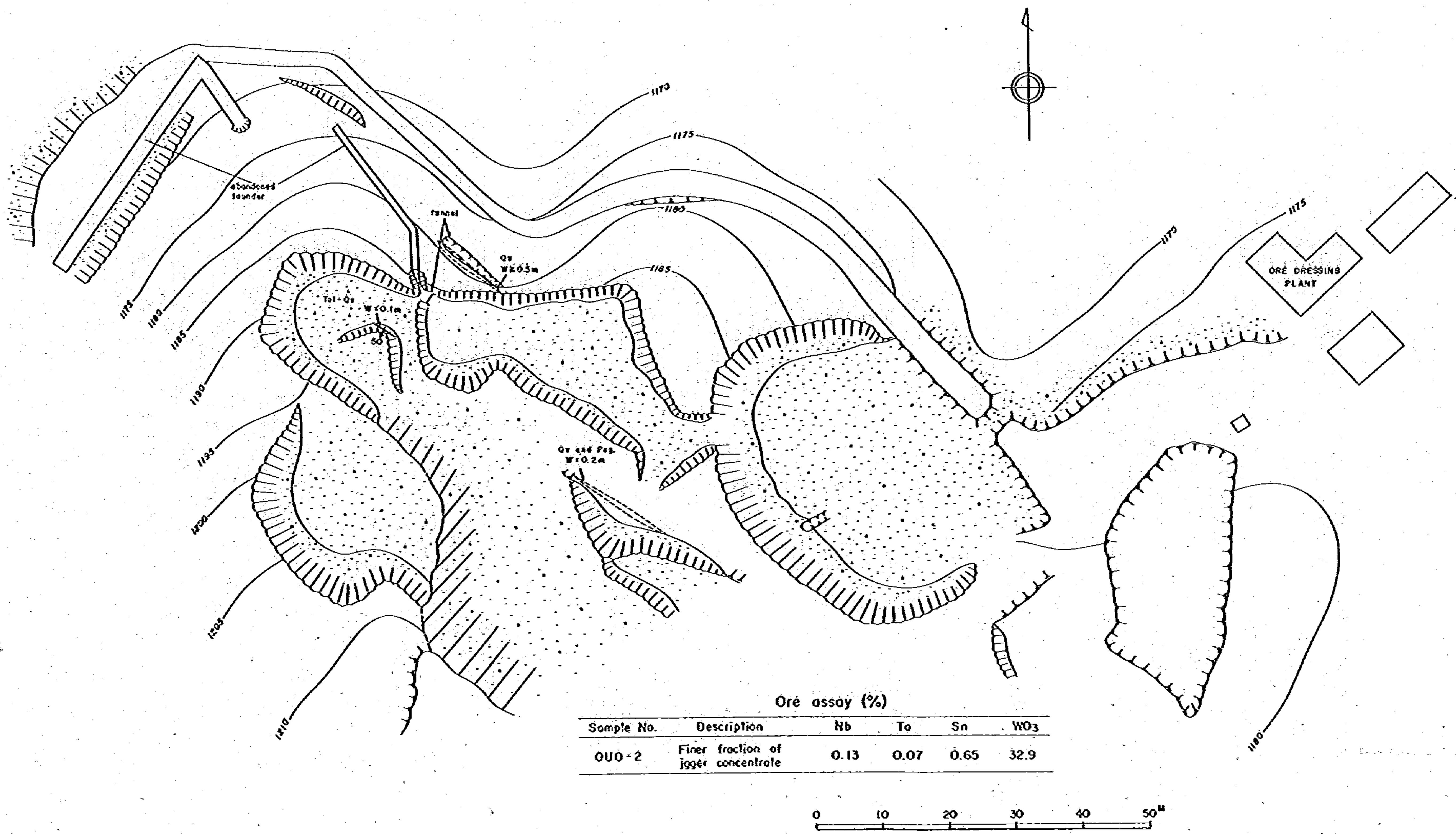
Fig.10 Plan of the Yong Ku mine



Ore assay (%)

Sample No.	Description	Nb	Ta	Sn	W
OYO - 1	Crude ore	0.02	0.00	0.05	5.65
OYO - 2	Sn≪W concentrate	0.02	0.00	0.04	69.6
OYO - 5	Primary tailing	0.08	0.01	0.28	2.95

Fig.11 Plan of the Pha Pun mine



Ore assay (%)

Sample No.	Description	Nb	Ta	Sn	WO_3
OUO-2	Finer fraction of jigger concentrate	0.13	0.07	0.65	32.9

Fig.12 Plan of the Pha Pun Dong mine

Chapter 2. GEOCHEMICAL PROSPECTING

2-1 Objective

The objective of the geochemical prospecting lied in picking out geochemical anomaly areas deriving from mineralization by statistical analysis of the behaviors of elements in stream sediment in the survey area, and in obtaining basic data for the future survey of this area.

2-2 Sampling

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

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

The samples collected were air-dried, and then divided into halves; one halves for Japan and other halves for Thailand.

2-3 Chemical Analysis

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

The samples were ground to -200 mesh with vibrating mills for chemical analysis.

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

In conducting the analysis, the produced analytical values were periodically confirmed checking the values of the parallelly analyzed standard sample (JG-1).

The analysis procedures are briefly described as follows:

(1) Niobium, Tantalum, Tin, Tungsten and Beryllium

After 2.0 g of a sample is weighed, it is put into a teflon beaker. Together with 15 ml of fluoric acid, 3 ml of nitric acid, and 3 ml of perchloric acid, the sample is decomposed on heating plate until evaporation is completed. After cooling off, the dried material is dissolved with 10 ml of hydrochloric acid and 20 to 30 ml of purified water. The solution is diluted to the constant volume of 50 ml with purified water. Then the supernatant solution obtained by centrifugal separator is subjected to measurement with inductively coupled plasma emission spectrometer.

(2) Lithium

The solution obtained in the above-mentioned procedure is subjected to measurement with flame emission spectrometer.

(3) Fluorine

After 1.0 g of a sample is weighed, it is put into a porcelain combustion boat and thermally hydrolyzed in a tubular electric furnace. The produced florine gas is absorbed by collecting liquid; then adjusted to pH 5, and diluted to the constant volume of 100 ml with purified water.

This test solution is subjected to measurement by the ion electrode method.

2-4 Data Analysis

(1) General Statistics

The statistics of the result of chemical analysis of the geochemical samples are given in Table 9. The result of analysis for each sample is shown at the end of this report.

(2) Statistics by Bedrock Lithofacies

Various lithofacies are distributed over the survey area, and characteristics obtained from the geochemical data are considered to reflect the geochemical properties of the bedrocks. Therefore, the geochemical data were briefly classified into four populations according to the bedrock lithofacies of the sampling points, and the behavior of the pathfinder elements was studied. Of samples indicating high contents of tin, tungsten, etc., those obviously subjected to artificial contamination (for instance, mine waste) and those of extremely high values though such contamination has not been confirmed, were excluded in the data processing.

The number of samples for each lithofacies is shown in Table 10, and the statistics for each rock facies in Table 11.

As the result of the above-mentioned grouping, it has been found that the elements show the following tendencies for each bedrock area.

i) Niobium:

When comparison is made by the mean value, the Tertiary conglomerate area shows the highest, and is followed by the Triassic granite area. Considering that most part of the former is backed by the latter, it may be said that the Triassic granite contains niobium in the largest quantity. The highest value was also found in the Triassic granite area. In contrast with the above, the Carboniferous granite area presents the lowest mean value among the four areas, showing the tendency of being comparatively depleted in niobium.

ii) Tantalum:

In the Triassic granite and Tertiary conglomerate areas, the mean values are high. The highest value is found in the former.

In the Carboniferous granite area, the lowest mean value among the four areas is shown, which is the same tendency as in the case of niobium.

iii) Tin:

As a matter of mean values, the highest value is found in the Triassic granite area, followed by the Tertiary conglomerate area. The highest value is obtained from the former. As compared with the above, the values are low more or less in the Carboniferous granite area and gneiss and sediments areas.

Table 9 Statistics of whole geochemical data

ppm

Element	Maximum	Minimum	Mean	S.D.	C.V.
Nb	1,150	2	26.63	47.95	1.73
Ta	410	0*	8.65	18.79	2.07
Sn	270	0*	12.83	12.54	0.99
W	10,000	0*	43.39	172.52	5.62
Be	16.0	0.40	4.03	2.29	0.58
Li	85	2	25.45	15.57	0.60
F	1,460	20	276.91	172.53	0.63

* Not detected.

Table 10 Classification of geochemical data by bedrock lithofacies

Lithofacies	No. of samples	No. of excluded samples in data processing	No. of samples used in data processing
1. Triassic granite	647	11	663
2. Carboniferous granite	375	0	375
3. Gneiss and sediments	171	5	166
4. Tertiary conglomerate	66	0	66
Total	1,259	16	1,243

Table 11 Statistics of geochemical data (excluding contaminated and abnormaly high-content data)

ppm

El.	Area	Max.	Min.	Mean	σ	c.v.	M + σ	M + 2σ
Nb	Wh	530	2	25.51	30.31	1.15	55.82	86.13
	Tgr	530	3	28.05	33.58	1.20	61.64	95.22
	Cgr	160	2	21.39	17.54	0.82	38.93	56.48
	Mgn	130	5	24.18	23.29	0.96	47.47	70.77
	Tcg	130	7	31.15	31.03	1.00	62.18	93.21
Ta	Wh	220	0*	8.28	15.10	1.69	23.29	31.57
	Tgr	220	1	9.58	14.88	1.55	24.46	39.34
	Cgr	93	0*	6.54	9.01	1.38	15.55	24.56
	Mgn	69	1	7.24	9.65	1.33	16.90	26.55
	Tcg	69	2	9.58	12.56	1.31	22.14	34.70
Sn	Wh	150	0*	11.50	8.68	0.70	20.18	28.86
	Tgr	150	1	12.82	9.31	0.73	22.12	31.43
	Cgr	31	1	10.36	5.20	0.50	15.55	20.75
	Mgn	52	0*	9.99	6.67	0.67	16.65	23.22
	Tcg	38	3	10.97	6.33	0.58	17.30	23.64
W	Wh	570	0*	21.23	38.58	2.00	59.81	98.39
	Tgr	360	0*	20.71	35.35	1.71	56.06	91.41
	Cgr	400	0*	22.94	38.94	1.70	61.88	100.82
	Mgn	570	0*	20.45	57.92	2.83	78.37	136.30
	Tcg	340	0*	21.97	50.76	2.31	72.73	123.49
Be	Wh	21.0	0.4	3.73	2.34	0.59	6.07	8.41
	Tgr	21.0	0.4	4.24	2.44	0.57	6.68	9.12
	Cgr	10.0	0.4	3.59	1.57	0.44	5.15	6.72
	Mgn	7.9	0.6	2.72	1.35	0.50	4.07	5.43
	Tcg	6.6	1.1	2.77	1.12	0.40	3.89	5.00
Li	Wh	85	2	23.81	15.30	0.60	39.11	54.41
	Tgr	85	2	27.98	16.38	0.59	44.36	60.73
	Cgr	71	2	21.59	14.64	0.68	36.23	50.86
	Mgn	51	3	17.23	10.14	0.59	27.37	37.51
	Tcg	49	5	16.86	7.99	0.47	24.85	32.84
F	Wh	1,290	20	254.30	175.01	0.63	429.31	604.32
	Tgr	1,290	20	279.50	179.32	0.64	458.81	638.13
	Cgr	1,230	20	235.97	145.44	0.62	381.42	526.86
	Mgn	730	20	236.02	132.22	0.56	368.25	500.47
	Tcg	540	60	203.94	96.62	0.47	300.56	397.19

* Not detected.

Wh; whole area, Tgr; Triassic granite area, Cgr; Carboniferous granite area, Mgn; Precambrian - Paleozoic gneiss and sediments area, Tcg; Tertiary conglomerate area.

iv) Tungsten:

In terms of the mean values, the Carboniferous granite area shows a value slightly higher than other areas, but there is no significant difference among the four areas.

v) Beryllium and Lithium:

In terms of the mean values, the gneiss and sediments and Tertiary conglomerate areas show lower values than both of the granite areas, clearly indicating these elements are related with granites.

vi) Fluorine:

In terms of the mean values, the Triassic granite area presents a higher value than the other three areas.

The above-mentioned phenomena are summurized as follows:

Comparing the content of each element in the four lithologic areas, 1) niobium, tantalum, tin and fluorine are high in the Triassic granite area, 2) beryllium and lithium are high in the Carboniferous and Triassic granite areas, 3) tungsten does not show any significant difference among the four lithologic areas.

(3) Correlations between Pathfinder Elements

The correlation coefficients between the pathfinder elements are shown in Table 12. As a result of studying the correlations by making classification into the four lithologic areas as the case of mean values and others, the following can be said.

i) Niobium and tantalum are strongly correlative with each other throughout the four lithologic areas.

ii) Niobium and tantalum are moderately correlative with tin and tungsten throughout the four lithologic areas. However, these correlation in the Triassic granite area are a little weaker than in the other three areas. However, in this area there is a case in which at a point with actually high values of tin and tungsten the values of niobium and tantalum were also high. So such a tendency cannot hold good in every case.

Table 12 Correlation coefficients

i) Whole area

	Nb	Ta	Sn	W	Be	Li	F
Nb	(1.00)	0.83	0.46	0.45	0.24	0.14	0.11
Ta	0.83	(1.00)	0.47	0.44	0.35	0.18	0.17
Sn	0.46	0.47	(1.00)	0.59	0.63	0.66	0.56
W	0.45	0.44	0.59	(1.00)	0.29	0.40	0.28
Be	0.24	0.35	0.63	0.29	(1.00)	0.65	0.54
Li	0.14	0.18	0.66	0.40	0.65	(1.00)	0.66
F	0.11	0.17	0.56	0.28	0.54	0.66	(1.00)

ii) Triassic granite area

	Nb	Ta	Sn	W	Be	Li	F
Nb	(1.00)	0.79	0.34	0.34	0.17	-0.04	0.05
Ta	0.79	(1.00)	0.43	0.36	0.44	0.20	0.24
Sn	0.34	0.43	(1.00)	0.50	0.61	0.58	0.55
W	0.34	0.36	0.50	(1.00)	0.30	0.33	0.27
Be	0.17	0.44	0.61	0.30	(1.00)	0.68	0.61
Li	-0.04	0.20	0.58	0.33	0.68	(1.00)	0.67
F	0.05	0.24	0.55	0.27	0.61	0.67	(1.00)

iii) Carboniferous granite area

	Nb	Ta	Sn	W	Be	Li	F
Nb	(1.00)	0.88	0.56	0.50	0.25	0.26	0.27
Ta	0.88	(1.00)	0.43	0.43	0.19	0.10	0.14
Sn	0.56	0.43	(1.00)	0.64	0.46	0.72	0.63
W	0.50	0.43	0.64	(1.00)	0.23	0.48	0.39
Be	0.25	0.19	0.46	0.23	(1.00)	0.52	0.40
Li	0.26	0.10	0.72	0.48	0.52	(1.00)	0.67
F	0.27	0.14	0.63	0.39	0.40	0.67	(1.00)

iv) Precambrian – Paleozoic gneiss and sediments area

	Nb	Ta	Sn	W	Be	Li	F
Nb	(1.00)	0.87	0.58	0.50	0.35	0.22	0.19
Ta	0.87	(1.00)	0.61	0.56	0.38	0.23	0.22
Sn	0.58	0.61	(1.00)	0.67	0.58	0.52	0.35
W	0.50	0.56	0.67	(1.00)	0.33	0.39	0.22
Be	0.35	0.38	0.58	0.33	(1.00)	0.69	0.55
Li	0.22	0.23	0.52	0.39	0.69	(1.00)	0.60
F	0.19	0.22	0.35	0.22	0.55	0.60	(1.00)

v) Tertiary conglomerate area

	Nb	Ta	Sn	W	Be	Li	F
Nb	(1.00)	0.85	0.57	0.46	0.41	0.31	0.48
Ta	0.85	(1.00)	0.60	0.56	0.51	0.36	0.49
Sn	0.57	0.60	(1.00)	0.66	0.69	0.74	0.69
W	0.46	0.56	0.66	(1.00)	0.42	0.53	0.33
Be	0.41	0.51	0.69	0.42	(1.00)	0.80	0.71
Li	0.31	0.36	0.74	0.53	0.80	(1.00)	0.63
F	0.48	0.49	0.69	0.33	0.71	0.63	(1.00)

iii) Tin and tungsten are moderately correlative with each other throughout the four lithologic areas.

iv) The three elements of beryllium, lithium and fluorine are correlative so a strong to a medium extent with each other, throughout the four lithologic areas.

v) Tin and tungsten are moderately correlated with beryllium, lithium and fluorine among the four lithologic areas except for some cases.

vi) Niobium and tungsten are weakly correlative with beryllium, lithium and fluorine except in the Tertiary conglomerate area; particularly in the Triassic granite area there seems to be no correlation between niobium and lithium and between niobium and fluorine.
But this could be a matter of just appearance because beryllium has only a narrow range of its values against those of niobium and tantalum. Also against niobium and tantalum, the case of lithium might be attributable to the fact that considerable amount of mica, the major lithium-containing mineral, was eliminated at the time of sampling.
In the case of fluorine, the apparent little correlation is indicated because the ranges of the values of niobium and tantalum are lower by one or two decimal places than that of the values of fluorine.

2-5 Classification of Anomaly

As mentioned above, the geochemical data were classified into four populations according to the bedrock lithofacies, and for each pathfinder element, it was tried to determine the threshold applying the method of Lepeltier (1969). The cumulative frequency distributions for the pathfinder elements are shown in Figs. 13 to 19. The logarithmic statistics for the overall geochemical data and their values transformed into natural numbers are given in Table 13.

Although the determination of thresholds should preferably be made, to be exact, for each bedrock areas, the behaviors of the pathfinder elements do not vary much according to the lithofacies, so that it was decided that one threshold was taken as the representative value for each pathfinder element.

Using the thresholds, mean values (M), and standard deviations (σ), the calssification of the anomaly and background levels was made as shown in Table 14.

The procedure of determining the threshold for each pathfinder element is described in the following:

(1) Niobium

In the cumulative frequency graph (Fig. 13), there is one or more upward skew point for each lithofacies. As the threshold, the skew point of the Carboniferous granite area which has the least mean content of niobium was selected.

On the background value side, the first skew points of the Triassic granite, gneiss and metasediments, and Tertiary conglomerate areas were taken as the border to divide the low background and high background zones. On the anomaly value side, the value of $M + 2\sigma$ of the Triassic and Carboniferous granite areas and the upward skew point of the Triassic granite area were taken to subdivide the anomaly zone into the low anomaly zone, high anomaly zone-1, and high anomaly zone-2 respectively.

(2) Tantalum

The threshold was taken at the middle point between two upward skew points of the Carboniferous granite area which has the least mean content of tantalum in the cumulative frequency graph (Fig. 14).

On the background value side, the found value of the first upward skew points of all the four areas were taken as the border to divide the low background and high background zones. On the anomaly value side, the second upward skew point of the Carboniferous granite area and the approximate value to the value of $M + 3\sigma$ from the logarithmic calculation of the whole data, which corresponds with the value of $M + 2\sigma$ of the Triassic granite area, were taken to subdivide the anomaly zone into the low anomaly zone, high anomaly zone-1, and high anomaly zone-2.

(3) Tin

In the cumulative frequency graph (Fig. 15), the values of the Triassic granite area show a behavior different from those of the other three areas. If only this is taken into consideration, there is no choice but to take at least the second upward skew point as the threshold, but if this is actually taken, most of the survey area should be anomaly areas, which is practically inappropriate. In the other areas too it is difficult to determine appropriate thresholds according to the graph, so that the threshold was decided to be the value of logarithmic $M + \sigma$ of the whole

Table 13 Logarithmic statistics of geochemical data and natural number-transformed values

		Maximum	Minimum	Mean	M + σ	M + 2σ	M + 3σ
Log	Nb	2.73	0.60	1.34	1.60	1.86	2.12
	Ta	2.34	0.30	0.83	1.15	1.47	1.79
	Sn	2.18	0	1.06	1.29	1.57	1.75
	W	2.76	0	1.01	1.49	1.96	2.43
	Be	1.34	0.15	0.66	0.84	1.02	1.20
	Li	1.93	0.48	1.34	1.63	1.92	2.21
	F	3.11	1.32	2.36	2.64	2.93	3.22
Natural	Nb	530	2	22	40	72	132
	Ta	220	0	6.7	14.1	29.5	61.6
	Sn	150	0	11.5	20	30	56.3
	W	570	0	10.2	31.6	91	270
	Be	21	0.4	4.6	6.9	10.5	16
	Li	85	2	21.9	43	83	162
	F	1,290	20	229	437	853	1,660

Table 14 Classification of geochemical background and anomaly

ppm

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

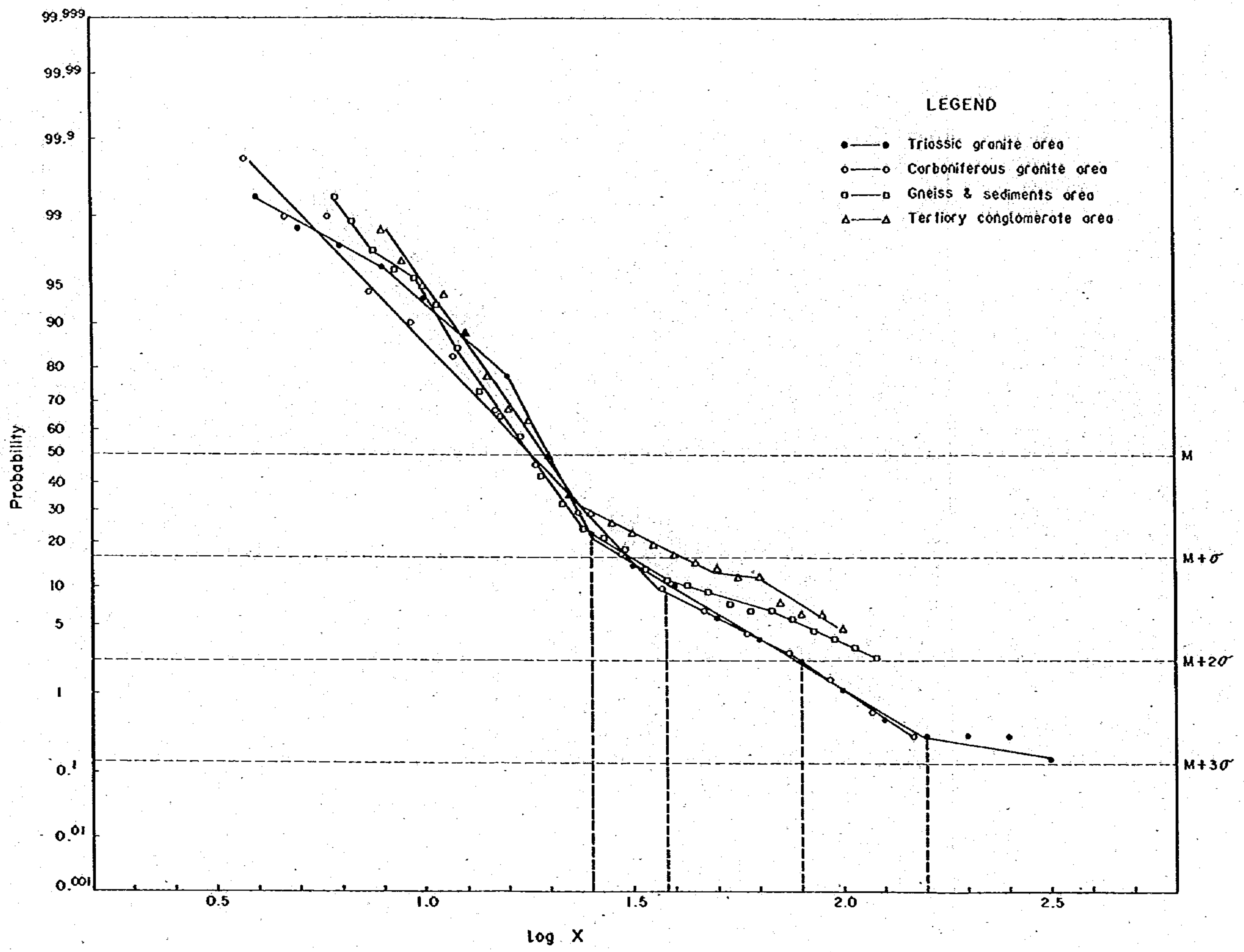


Fig. 13 Cumulative frequency distribution for Nb

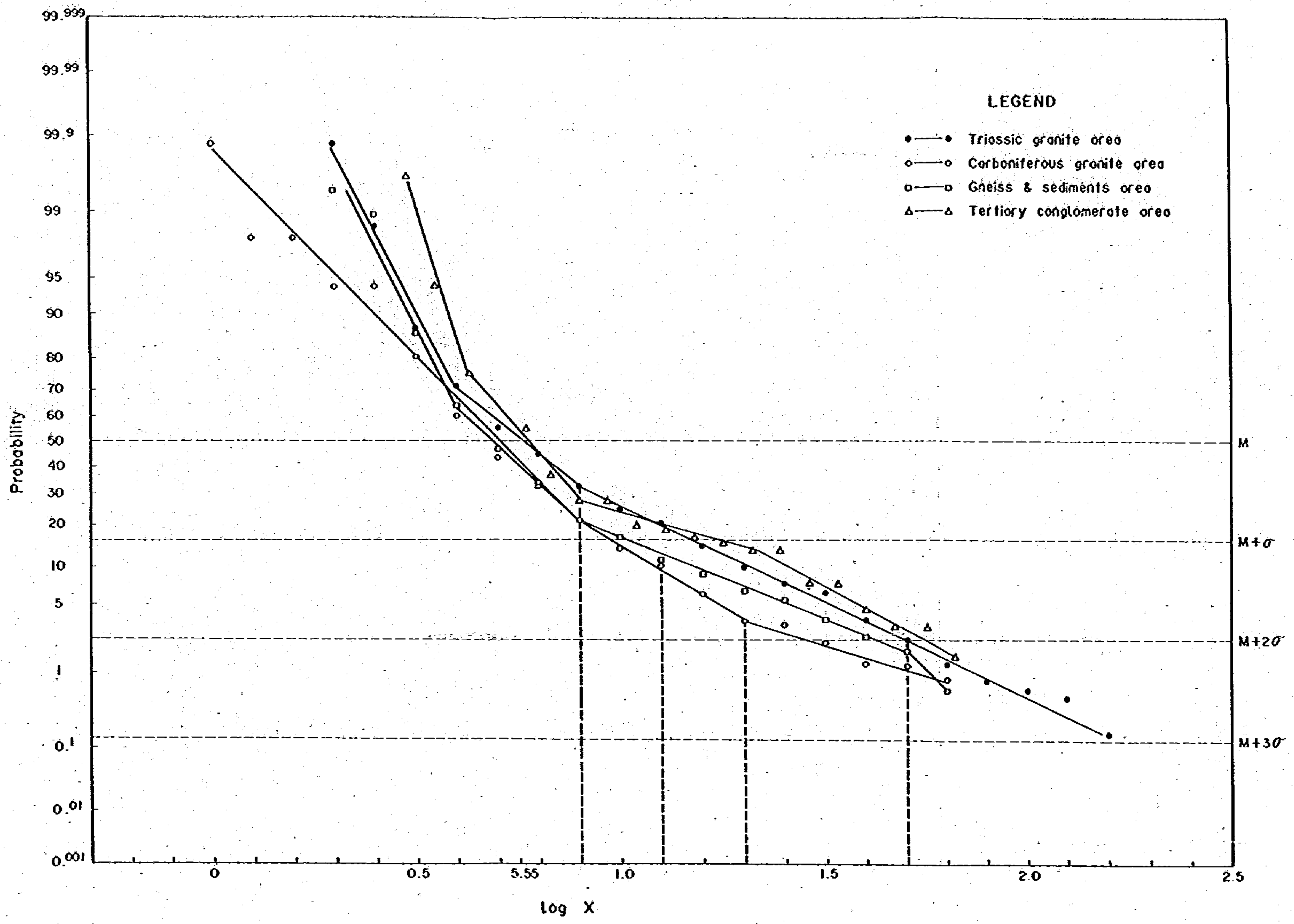


Fig. 14 Cumulative frequency distribution for Ta

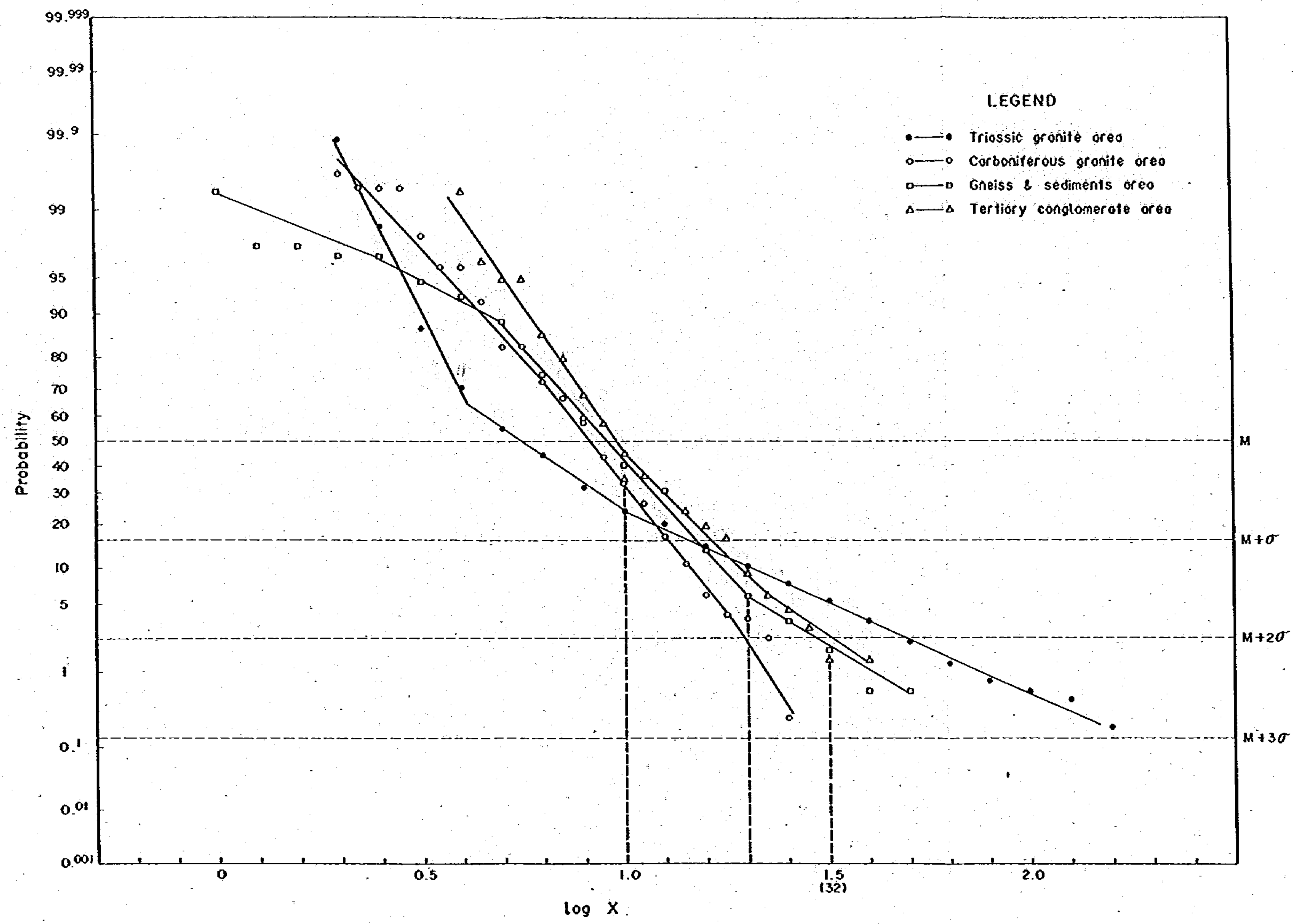


Fig. 15 Cumulative frequency distribution for Sn

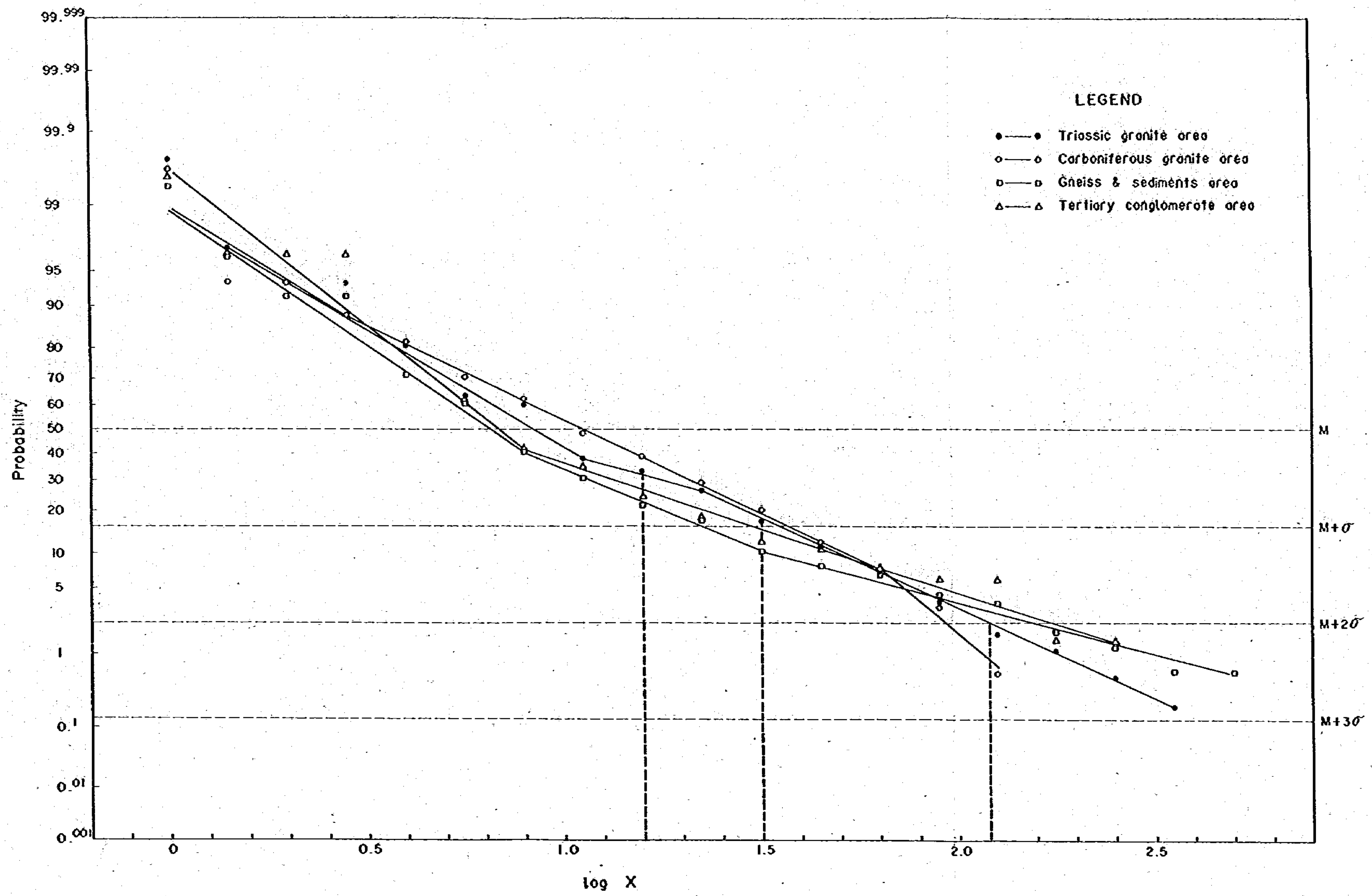


Fig. 16 Cumulative frequency distribution for W

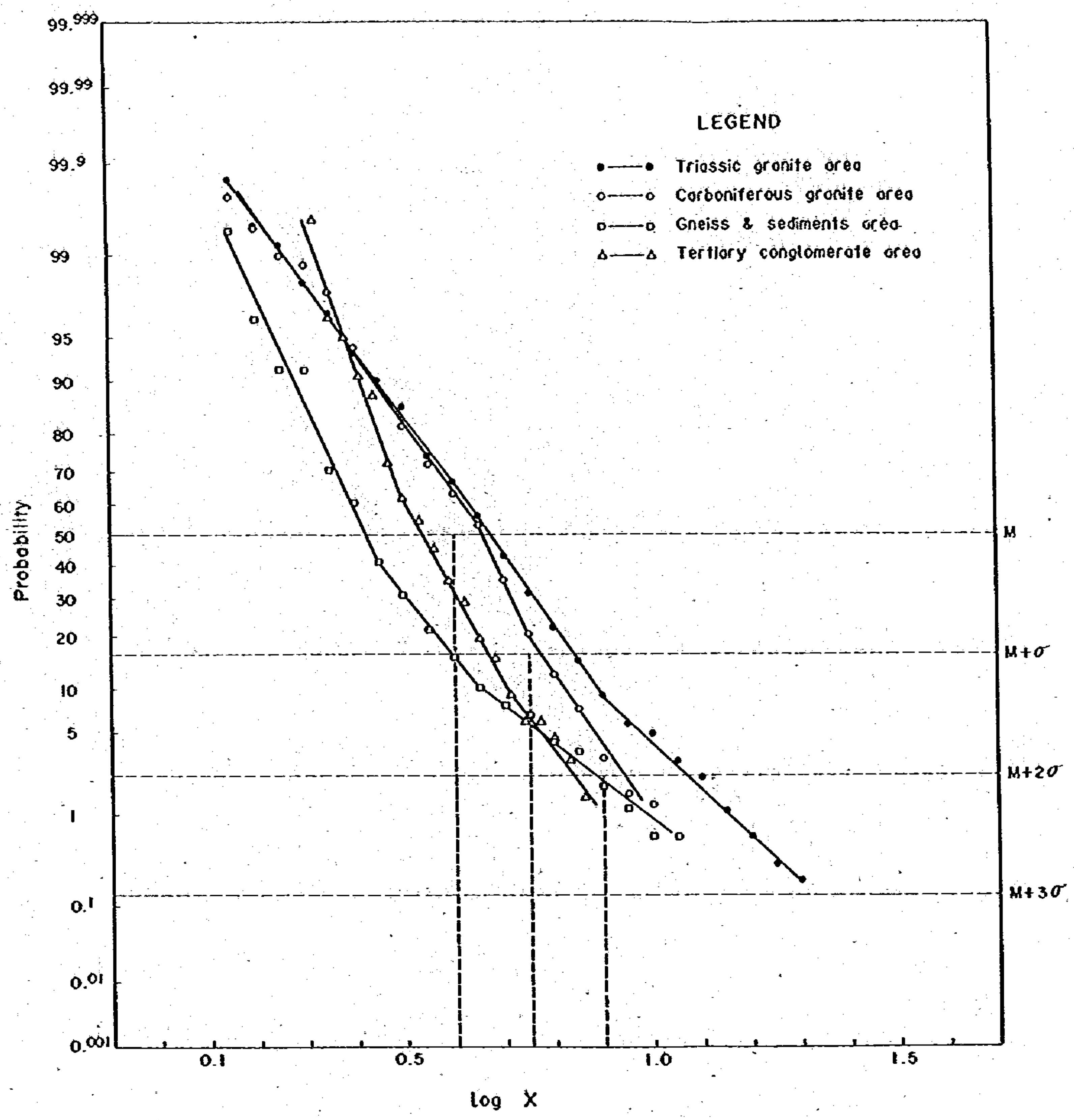


Fig. 17 Cumulative frequency distribution for Be

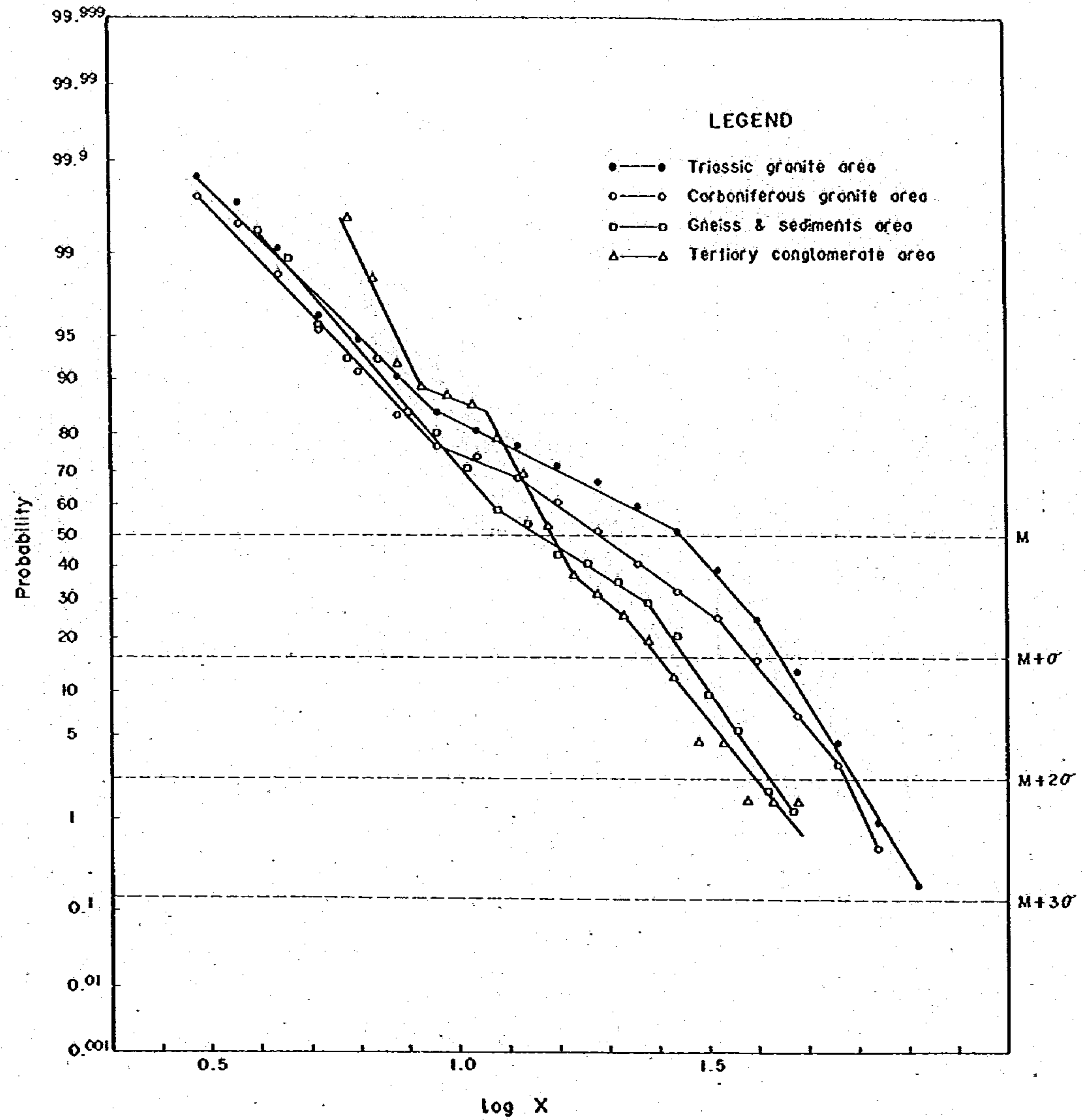


Fig. 18 Cumulative frequency distribution for Li

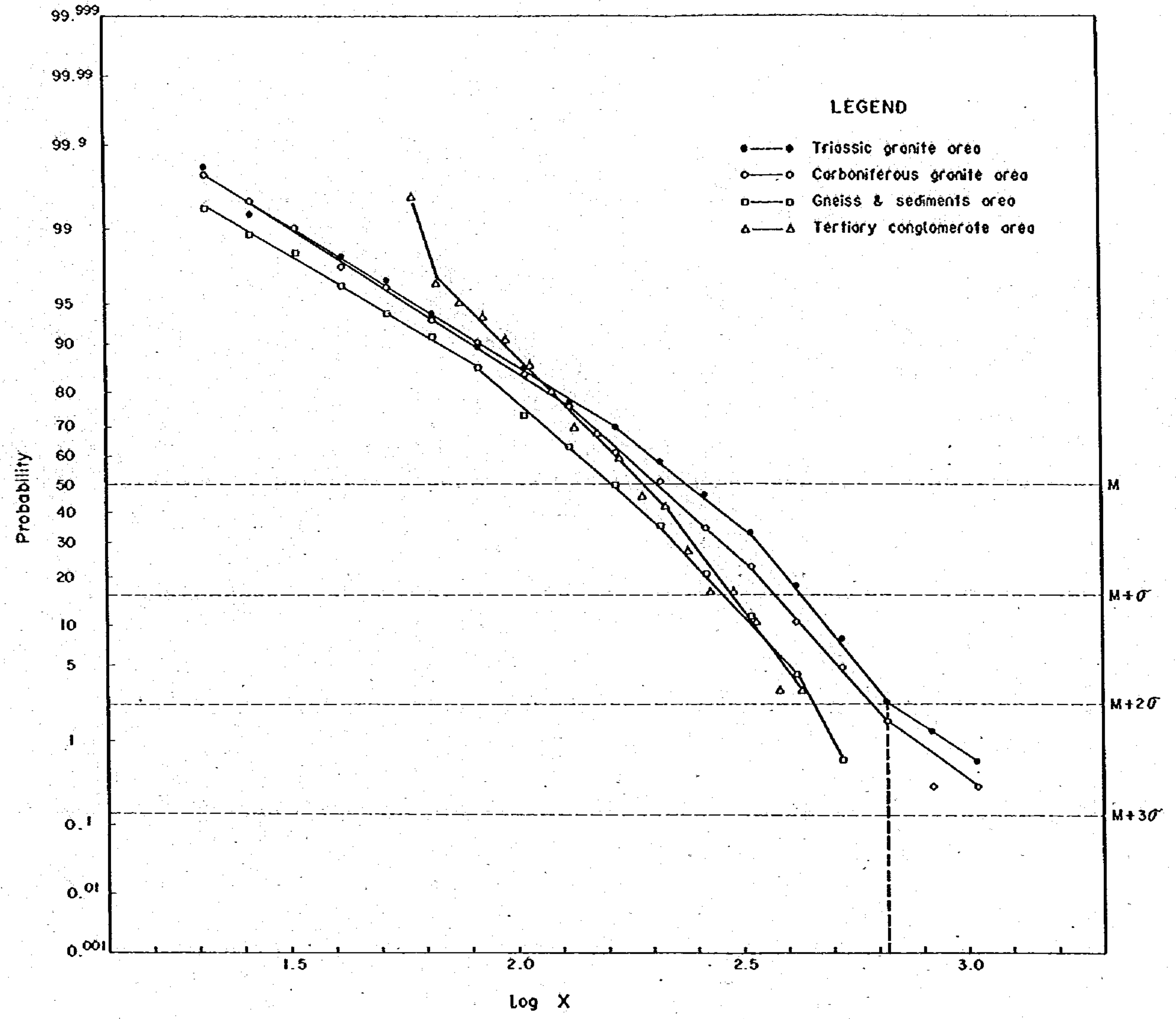


Fig. 19 Cumulative frequency distribution for F

data. On the background value side, taking the above-mentioned skew point as the border subdivision was made between the low background and high background zones for convenience's sake. On the anomaly value side, the values of logarithmic $M + 2\sigma$ and $M + 3\sigma$ were taken to subdivide the anomaly side into the low anomaly zone, high anomaly zone-1, and high anomaly zone-2.

(4) Tungsten

In the cumulative frequency graph (Fig. 16), all the areas, excluding the Carboniferous granite area, have upward skew points. In particular, the Triassic granite area seems to be evidently formed of two populations. However, if a middle value between the skew points is employed as the threshold, considerable part of the survey area should be anomaly zone, that is practically inappropriate. So that, for the threshold the value of logarithmic $M + \sigma$ of the whole data was taken. On the background value side, the logarithmic mean value (M) was used as the border for subdivision of the low background zone and high background zone. On the anomaly value side, subdivision was made likewise into the low anomaly zone, high anomaly zone-1, and high anomaly zone-2 by the values of logarithmic $M + 2\sigma$ and $M + 3\sigma$.

(5) Beryllium, Lithium and Fluorine

Since it was difficult to find effective thresholds in the cumulative frequency graphs of these three pathfinder elements (Figs. 17 to 19), the values of logarithmic M, $M + \sigma$, and $M + 2\sigma$ of the whole data were used to make classification into the low background, high background, low anomaly, and high anomaly zones.

2-6 Distribution of Anomaly Areas

On the basis of the classification of geochemical anomaly described in the preceding section, anomaly areas for each element were picked out, as shown in Fig. 20 and PLs. 5 to 11. It has been premised that an anomaly area here is formed of two or more anomaly points adjacent to each other in a certain drainage system. For an isolated anomaly point in a drainage system, just its anomaly level was shown. The anomaly areas in the above-mentioned plans are described as follows:

(1) Niobium

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

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

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

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

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

(2) Tantalum

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

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

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

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

(3) Tin

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

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

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

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

(4) Tungsten

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

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

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

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

(5) Beryllium

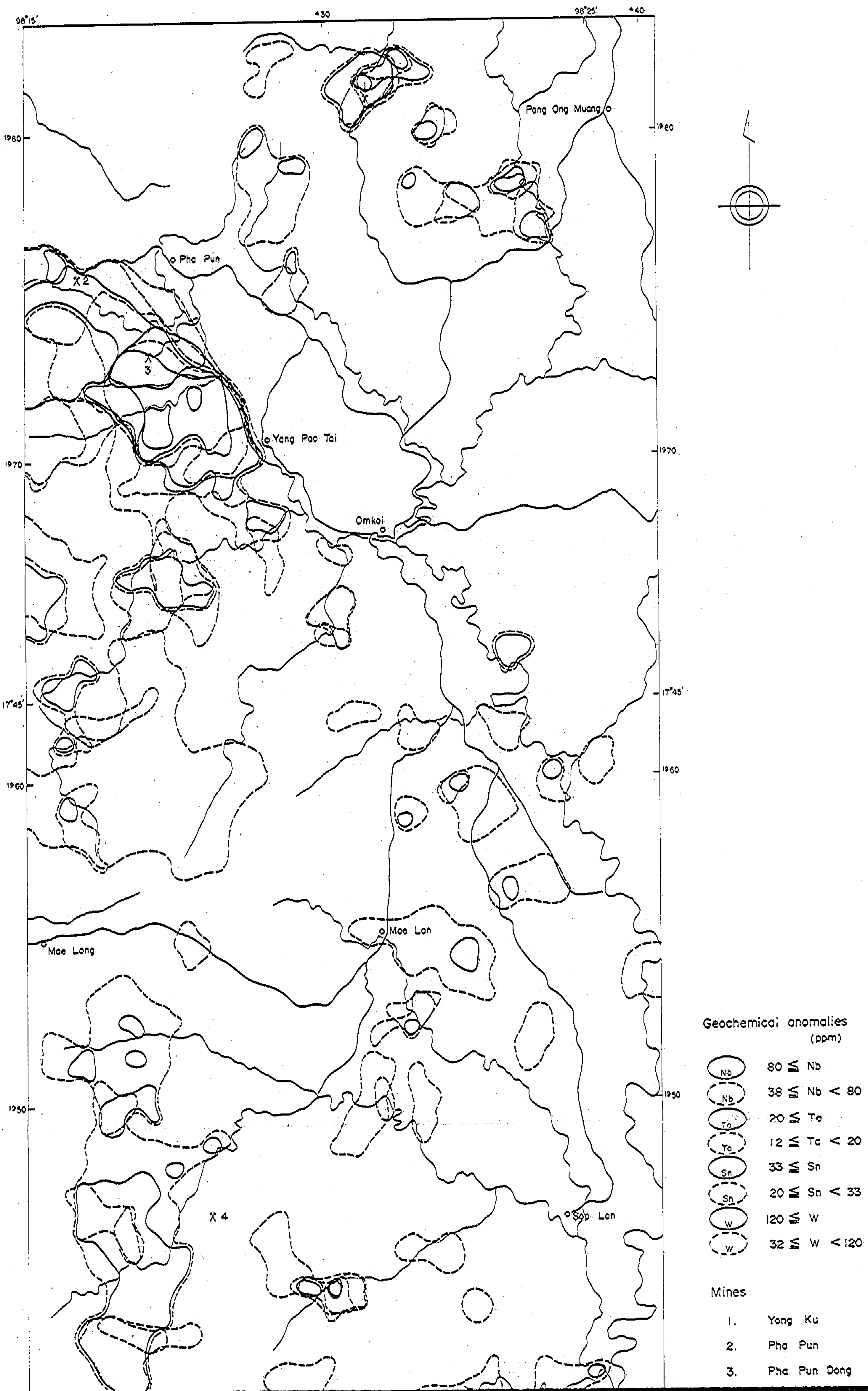
There are several medium- to small-scale, low anomaly value areas of beryllium which are distributed, arranged in the north-south direction, at the west end of the survey area.

(6) Lithium

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

(7) Fluorine

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


98°15'
430
98°25'
440
Pang Ong Muang
1980
1960
Pha Pun
X2
X3
Yang Pao Tai
1970
Omkoi
17°45'
Mae Lan
Mae Long
1950
X4
Sop Lan
Geochemical anomalies (ppm)
Nb 80 ≦ Nb
Nb 38 ≦ Nb < 80
Ta 20 ≦ Ta
Ta 12 ≦ Ta < 20
Sn 33 ≦ Sn
Sn 20 ≦ Sn < 33
W 120 ≦ W
W 32 ≦ W < 120
Mines
1. Yong Ku
2. Pha Pun
3. Pha Pun Dong

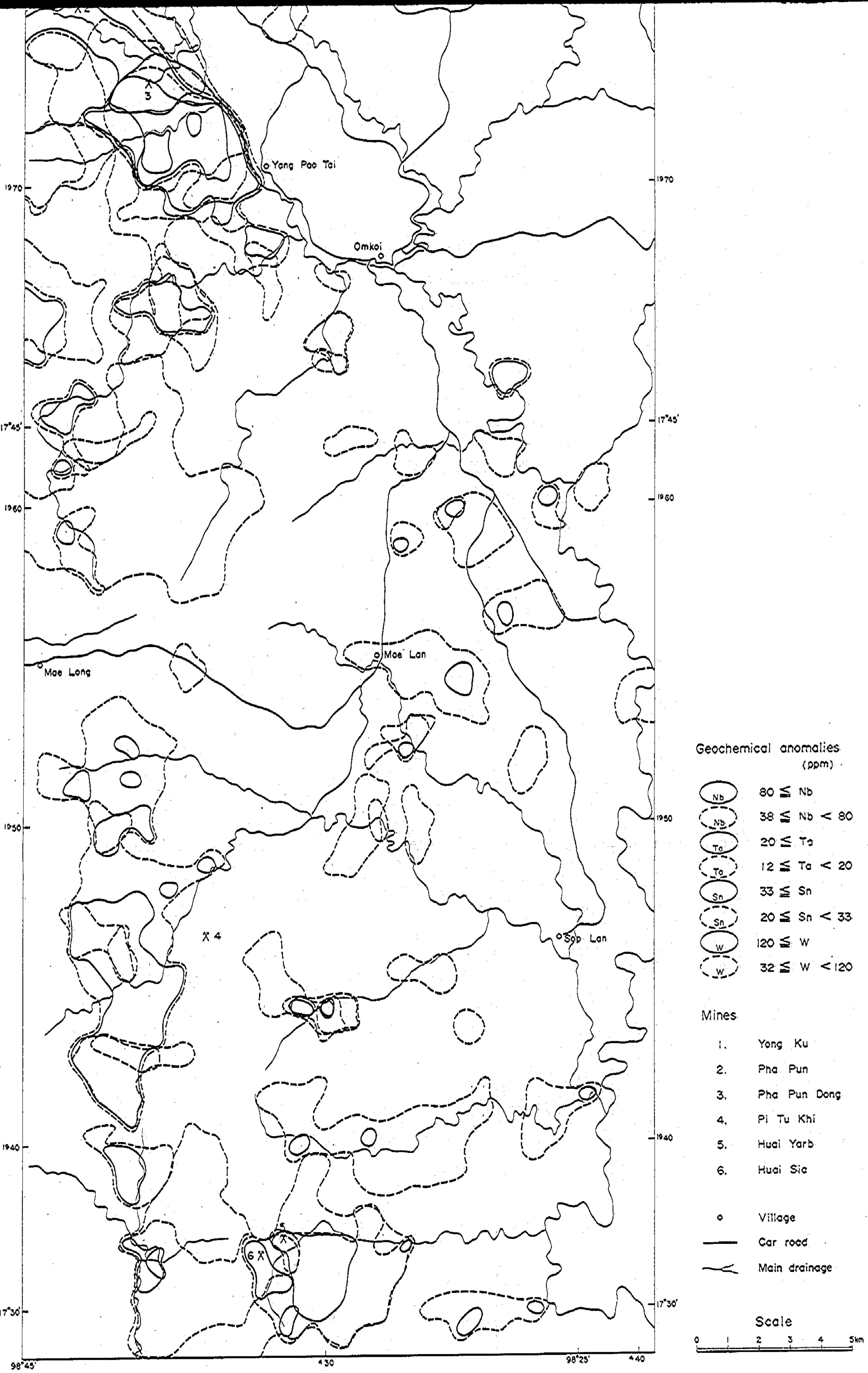


Fig. 20 Location of mines and geochemical anomalies of Nb, Ta, Sn and W

CONCLUSION

CONCLUSION AND RECOMMENDATION

1. Conclusion

The survey of the first phase was carried out by means of geological and geochemical survey to select the promising area from the survey area of first phase (1,000 Km^2).

The results were as follows:

(1) Granites account for the greater part of the various rocks distributed in this area, and the granites are classified, according to the time of activity, into the Carboniferous granites and Triassic granites.

(2) This area comes under the north extension of the tin belt of the Malay Peninsula, and tin and tungsten deposits occur in the Triassic granites in the area.

(3) The Carboniferous granites are coarse-grained, holocrystalline biotite granites with a distinct gneissic structure. The Triassic granites are mdeium- to coarse-grained, muscovite-bearing biotite granites, and their peripheral parts are fine-grained and leucocratic. The K-Ar ages of the Triassic granites have been found to be 40 to 70 m.y.; it is probable that they might have been rejuvenated by the subsequent orogenic movement.

(4) The Triassic granites belong petrologically to the ilmenite-series granitoid, and in terms of the quantity of tin, fluorine, etc. they present a character similar to the tin-bearing granite of the Malay Peninsula.

(5) According to the result of the geochemical prospecting by stream sediment, all the pathfinder elements presented high contents in areas distributed with the Triassic granites. Between niobium, tantalum, tin and tungsten, there is comparatively strong correlation with each other.

(6) Among the picked-out geochemical anomaly area, anomaly areas of niobium, tantalum, tin and tungsten overlap with each other over an area in and around the Pha Pun and Pha Pun Dong mine. Of these, the tungsten anomaly area centers about the mines, but the centers of the niobium, tantalum and tin anomaly areas deviate

southward in a measure from the mine. Judging from the locations this seems to suggest some ore showings other than the existing mines.

Based on the results of the above mentioned survey, a zone extending from the vicinities of the Pha Pun and Pha Pun Dong mines to these south is selected as the highest potential area.

2. Recommendation

The following survey are recommended as the survey of the next phase:

(1) The detailed geological survey should be conducted to investigate the lithology, fissure and alteration, and to find out ore showings.

(2) The detailed geochemical prospecting should be conducted by panning and soil sampling to select the target area.

REFERENCES

Chappel, B.W. and White, A.J.R., 1974:
Two constracting granite types. Pacific Geology, 8.

Department of Mineral Resources, 1983:
Mineral Statistic of Thailand 1978–1982

German Geological Mission, 1972:
Final Report of the German Geological Mission to Thailand 1966–1971, Geol. Surv. of Fed. Rep. of Germany

Garson, M.S. et al, 1975:
The geology of the tin belt in Peninsular Thailand around Phuket, Phangnga and Takua Pa, oversea Mem. Inst. Geol. Sci., No. 1

Ishihara, S., 1977: The magnetite series and ilmenite series granitic rocks, Min. Geol., vol. 27

Ishihara, S. and Others, 1979:
The magnetite-series and ilmenite-series granitoids and their bearing on tin mineralization, paticularly of the Malay Peninsula region, Geol. Surv., Malaysia, Bulletin, 11, Dec.

Ishihara, S. et al, 1980: Granites and Sn-W deposits of Peninsular Thailand, Min. Geol., Spec. Issue, No. 8

Japan International Cooperation Agency, 1984:
The Pre-Feasibility Study for the San Kampaeng Geothermal Development Project in the Kingdom of Thailand, Technical Report

Lepeltier, C. 1969: A simplified statistical treatment of geochemical data by graphical representation, Econ. Geol., vol. 64

Miyashiro, A., 1979: Outline of Tectonics of the Asian Continent. The Earth Science 16, Iwanami Shoten (in Japanese)

Metal Mining Agency of Japan, 1976:
Tectonic Belt and Ore Deposit in Southeast Asia

Metal Mining Agency of Japan, 1978:
Geological Survey Report, Northern Thailand

Metal Mining Agency of Japan, 1979:
Geological Survey Report, Northern Thailand

Metal Mining Agency of Japan, 1980:
Geological Survey Report, Northern Thailand

Metal Mining Agency of Japan, 1981:
Geological Survey Report, Mae Sariang Area, Thailand

Okano, T., 1981: On the niobium and tantalum mineral resources, Min. Geol. 31 (5)

Payome Aranyakanon 1980:
Tin Deposits in Thailand Econo. Geol. Spec. Iss. No. 1, Dep. of Mine Res. Bangkok, Thailand

Sato, T. 1979: Geological Structure of The Indoshina Peninsula, The Earth Science 16, Iwanami Shoten (in Japanese)

Tantisukrit, C., 1978: Review of the metallic mineral Deposits of Thailand, third regional conference on geology and resources of Southeast Asia

Thanasuthipitak, T., 1978:
A Review of Igneous Rocks of Thailand, Third Regional Conference on Geology and Mineral Resources of Southeast Asia.

Vearaburus, N., et al, 1981:
Outline of Geology and Ore Deposits of Thailand, Report of Geological Survey of Japan, No. 261

White, A.J.R. and Chappell, B.W., 1977:
Ultrametamorphism and granitoid genesis. Tectonophysics, 43.

APPENDICES

Apex. 1 Microscopic observations of thin sections

No.	Sample No.	Location X	Location Y	Description	Texture	q	kf	pl	bi	ms	tl	ap	sp	ru	ga	wo	px	ep	ch	kn	sr	ac	ca	op	cs	sh	wf	zr	mz	be
1	OAR-2	431000	1972600	calc-silicate rock	mosaic	o	o	o					•		◎	◎	◎	o	•					•						
2	OAR-9	437500	1948400	granite	mosaic	◎	◎	O	o										•		•			•						
3	OAR-10	433100	1942200	granite	mosaic	◎	◎	O	o	•			•								o			•						
4	OAR-18	433900	1972200	granite	mosaic	◎	◎	O	o	o			•								•			•						
5	ONR-16	427700	1966400	aplite	mosaic	◎	◎	O	o	•			•		o						•							•		
6	ONR-17	434000	1959700	quartzite	laminated	◎	◎	◎					•		◎		◎							o						
7	ONR-31	428400	1945300	gneissose granite	gneissose	◎	◎	O	O				•								•			•				•		
8	ONR-39	435600	1937300	granite	mosaic	◎	◎	O	o	•			•								o			•						
9	ONR-41	424000	1980400	quartzite	mosaic	◎	◎	◎	•					•						o	o			•						
10	ONR-61	424200	1939300	granite	mosaic	◎	◎	O	o	•			•								•			•				•		
11	OUR-25	425500	1953400	quartz vein	mosaic	◎	•				o										•			•						o
12	OUR-101	422300	1975400	granite	foliated	◎	◎	O	o	o			•								•			•				•		
13	OYR-21	437500	1934500	skarn	mosaic	o	o						•		◎		◎	o	•			o	o	•						
14	OYR-29	422800	1964400	granite	mosaic	◎	◎	O	o				•						•		•			•						
15	OAO-4	431400	1981000	Sn concentrate					•	•			•	•										•	O	◎	◎		•	
16	ONO-1	428500	1936800	Sn concentrate		O							•	•										•	◎	•	•	•	•	
17	OUO-1	424600	1973200	Sn-W ore	mosaic	◎	O				◎										•						o			
18	OUO-2	424600	1973200	Sn-W primary tailing		◎					◎													•		o	O		o	
19	OYO-3a	422200	1975500	W ore	mosaic						◎										•					◎	o			
20	OYO-3b	422200	1975500	Sn ore	mosaic	◎	O	o													•				O					

Abbreviations: q; quartz, kf; potassium feldspar, pl; plagioclase, bi; biotite, ms; muscovite, tl; tourmaline, ap; apatite, sp; sphene, ru; rutile, ga; garnet, wo; wollastonite, px; pyroxene, ep; epidote, ch; chlorite, kn; kaolin, sr; sericite, ac; actinolite, ca; calcite, op; opaque, cs; cassiterite, sh; scheelite, wf; wolframite, zr; zircon, mz; monazite, be; beryl.

◎ ; abundant, O ; common, o ; rare, • ; very rare.

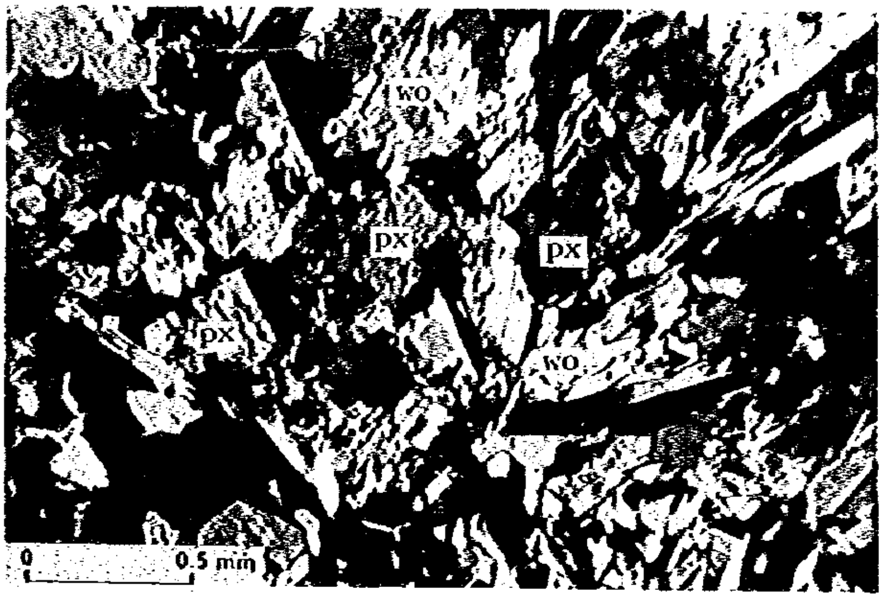
Apex. 2 Microscopic observations of polished sections

No.	Sample No.	Location	Description	cs	sh	wf	cp	il	mg	tl
1	OAO-3b	Yong Ku Mine (431400E, 1981000N)	W crude ore		∘	◎				
2	OAO-4	ditto	Sn-W concentrate	○	◎	◎				
3	OUO-2	Pha Pun Dong mine (424600E, 1973200N)	Finer fraction of jigger concentrate		∘	◎		•	•	○
4	OUO-3	ditto	W crude ore		•	○	•	•		○
5	OYO-2	Pha Pun mine (422200E, 1975500N)	Sn-W concentrate	○	◎	◎		•	•	
6	OYO-3c	ditto	Sn-W crude ore		∘	◎	•			
7	OYO-3d	ditto	ditto	○	•	○				◎
8	OAS-27	Huai Om Pat (430500E, 1974800N)	Panning concentrate of stream sediment		•	•		◎	○	
9	OAR-18	Route 1099 (433600E, 1973800N)	Porphyritic granite					•	•	
10	ONR-31	Nam Mae Ra-a (428400E, 1945300N)	Gneissose granite				•	•	•	

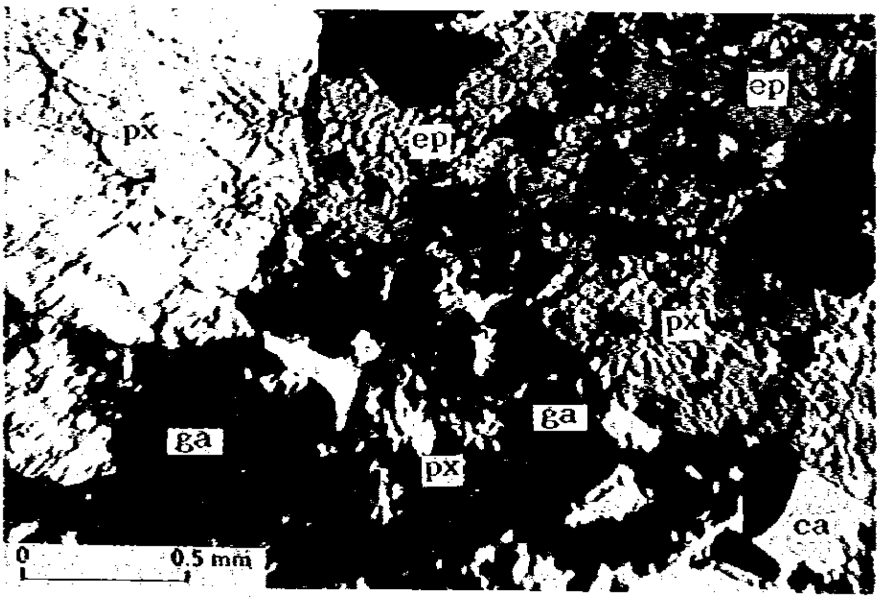
Abbreviations: cs; cassiterite, sh; scheelite, wf; wolframite, cp; chalcopyrite, il; ilmenite, mg; magnetite, tl; tourmaline.

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

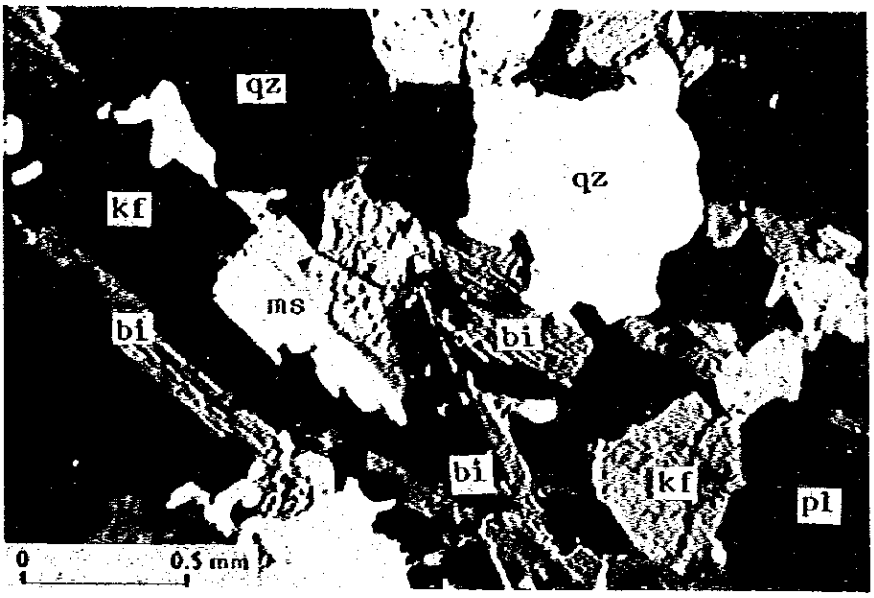
Apex. 3 Photomicrographs of rock and ore samples



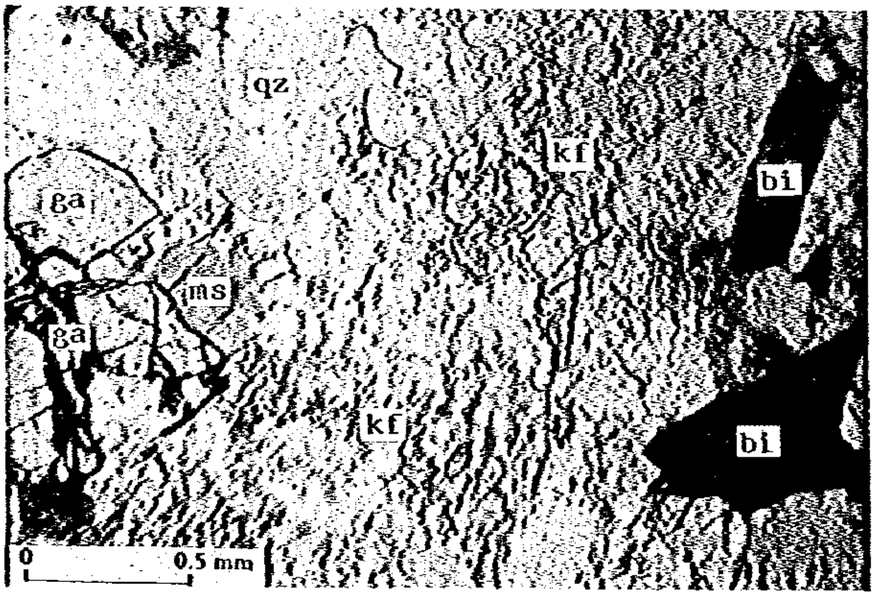
1. Calc-silicate rock (OAR-2): px; pyroxene, wo; wollastonite: transmitted light, crossed nicols.



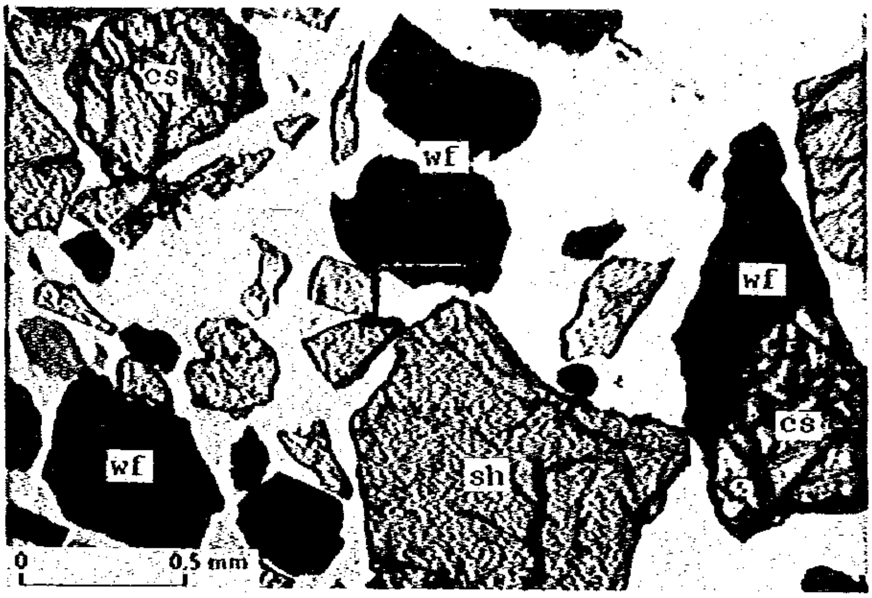
2. Skarn (OYR-21): px; pyroxene, ga; garnet, ep; epidote, ca; calcite: transmitted light, crossed nicols.



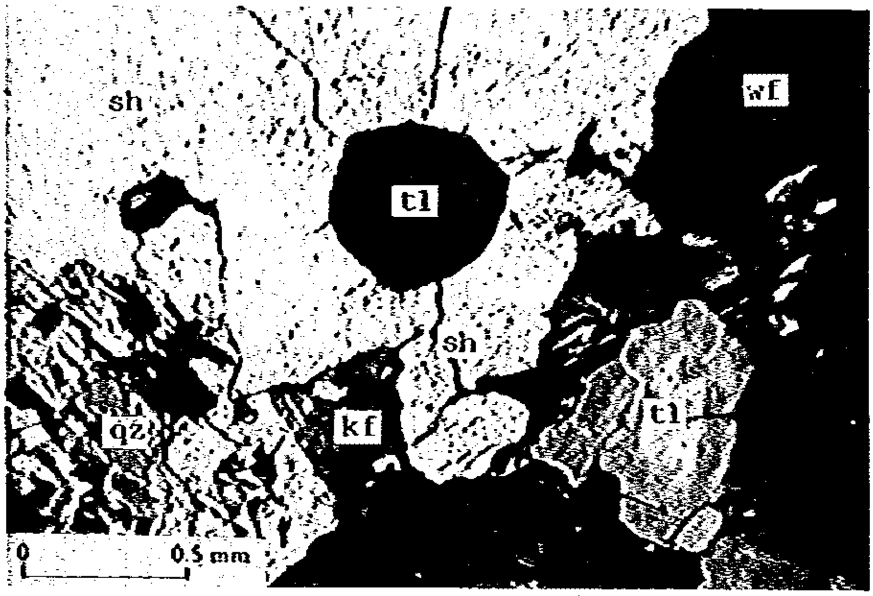
3. Triassic foliated granite (OUR-101): bi; biotite, ms; muscovite, qz; quartz, kf; potassium feldspar, pl; plagioclase: transmitted light, crossed nicols.



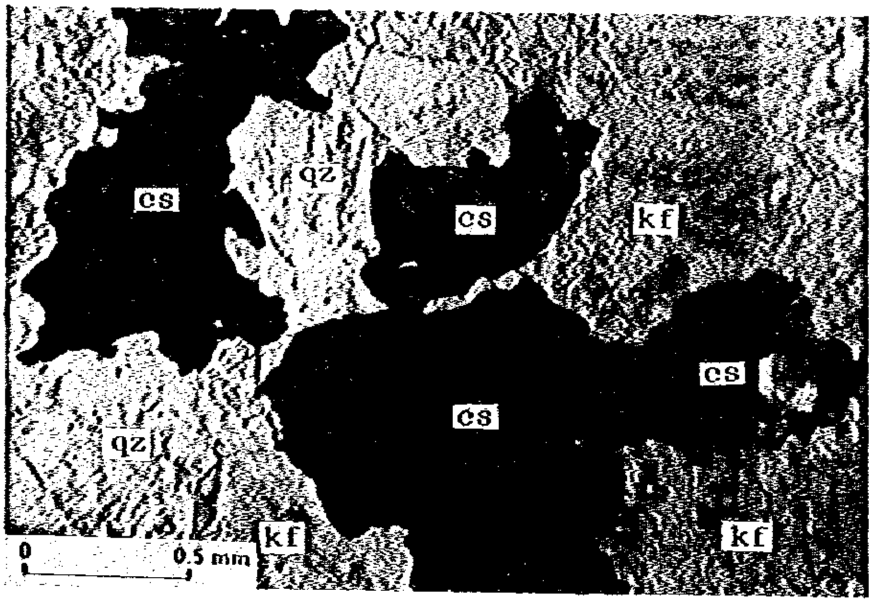
4. Triassic aplite (ONR-16): ga; garnet, bi; biotite, ms; muscovite, qz; quartz, kf; potassium feldspar: transmitted light, open nicol.



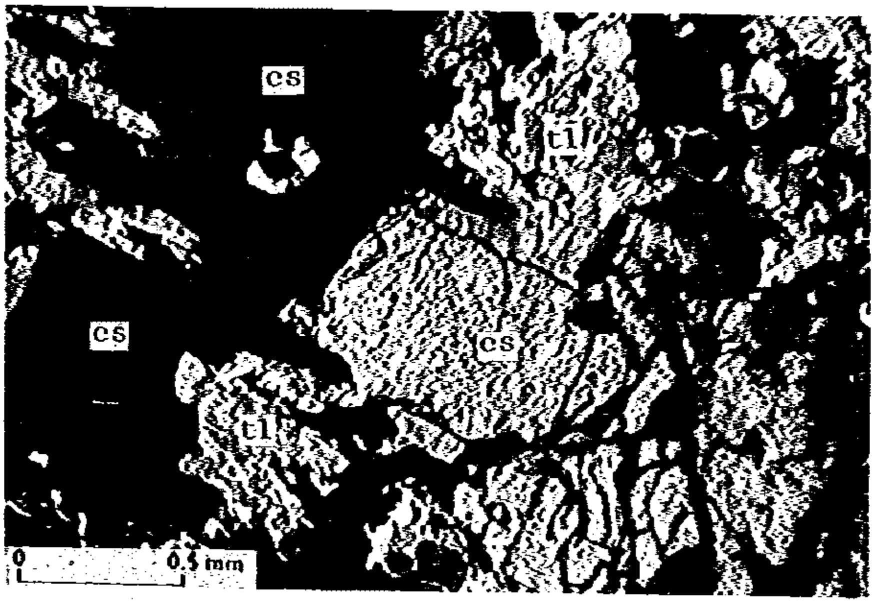
5. Sn-W concentrate (OAO-4, Yong Ku mine): cs; cassiterite, sh; scheelite, wf; wolframite: transmitted light, open nicol.



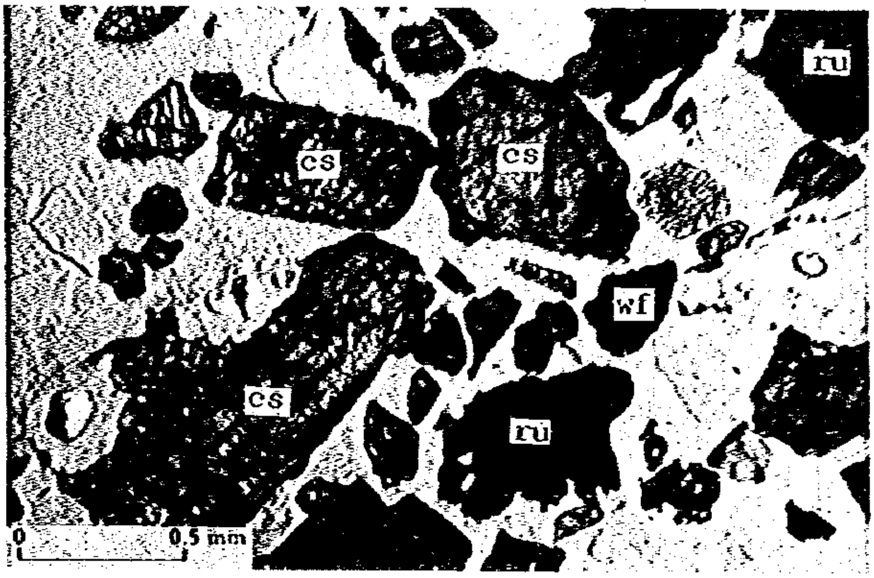
6. W-bearing quartz-tourmaline vein (OYO-3a, Pha Pun mine): sh; scheelite, wf; wolframite, tl; tourmaline, qz; quartz, kf; potassium feldspar: transmitted light, crossed nicols.



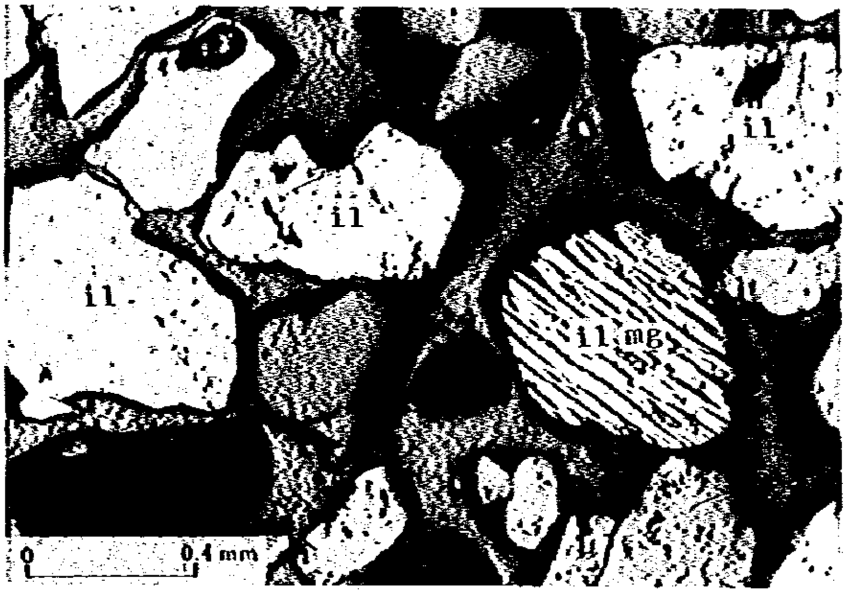
7. Sn-disseminated aplite (OYO-3b, Pha Pun mine): cs; cassiterite, qa; quartz, kf; potassium feldspar: transmitted light, open nicol.



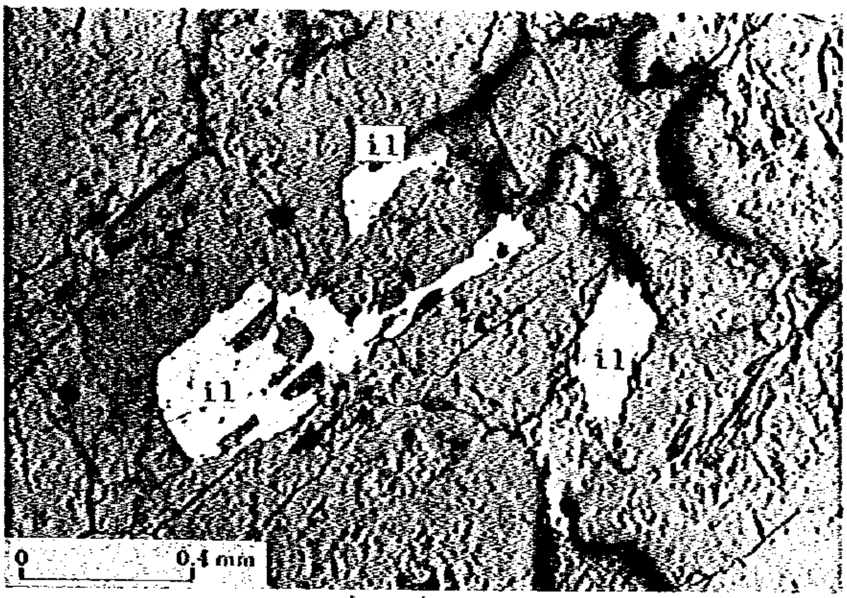
8. Sn-bearing quartz-tourmaline vein (OUO-1, Pha Pun Dong mine): cs; cassiterite, tl; tourmaline: transmitted light, crossed nicols.



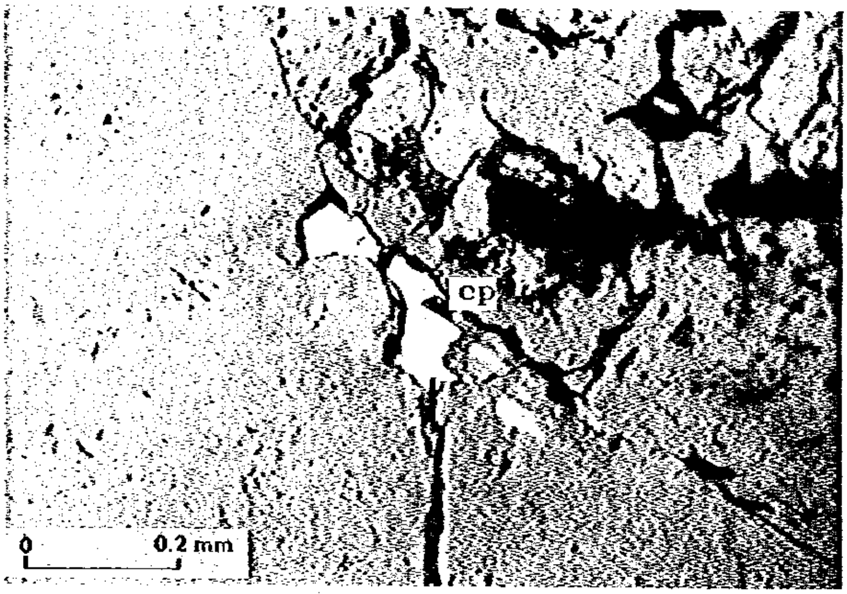
9. Sn-W concentrate (ONO-1, Huai Yarb mine): cs; cassiterite, wf; wolframite, ru; rutile: transmitted light, open nicol.



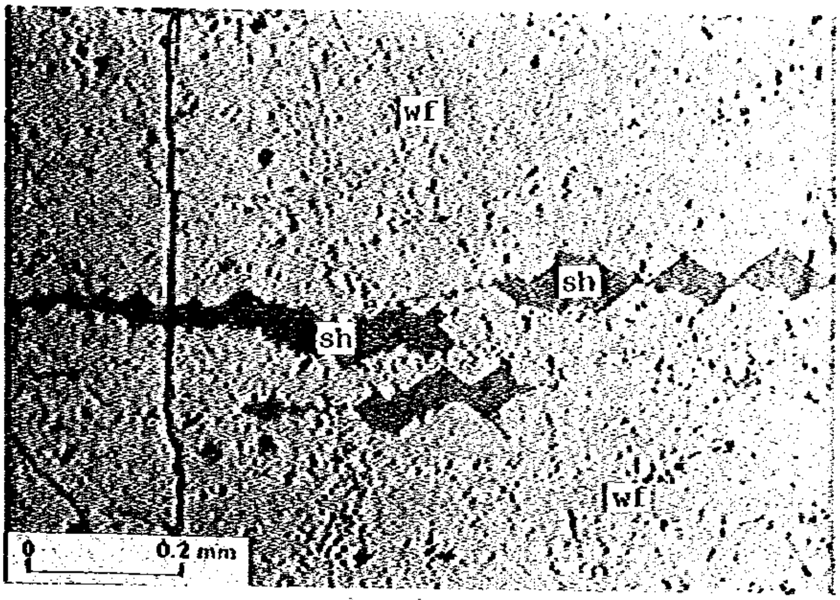
10. Ilmenite-rich panning concentrate of stream sediment (OAS-27): il; ilmenite, mg; magnetite: reflected light, open nicol.



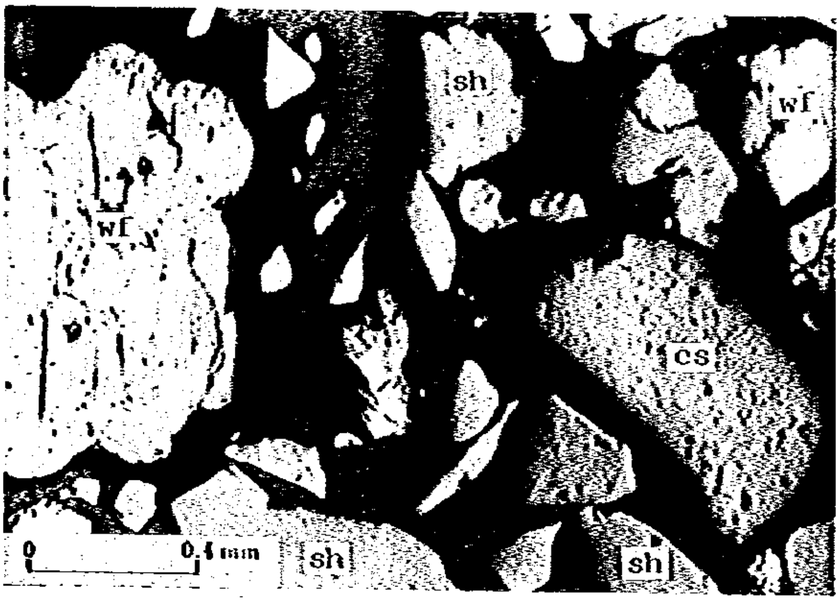
11. Ilmenite-series granite (OAR-18): il; ilmenite: reflected light, open nicol.



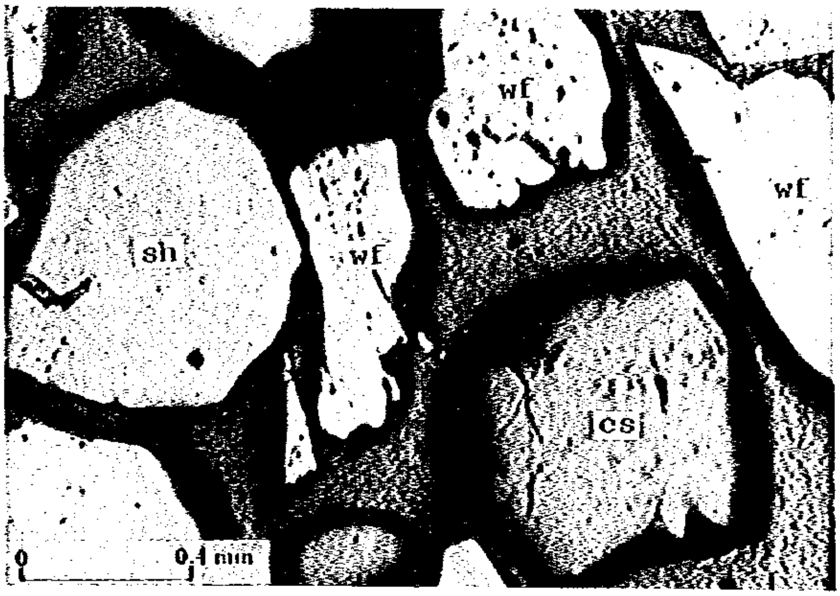
12. Sulfide dissemination in granite (OAR-18): cp; chalcopyrite: reflected light, open nicol.



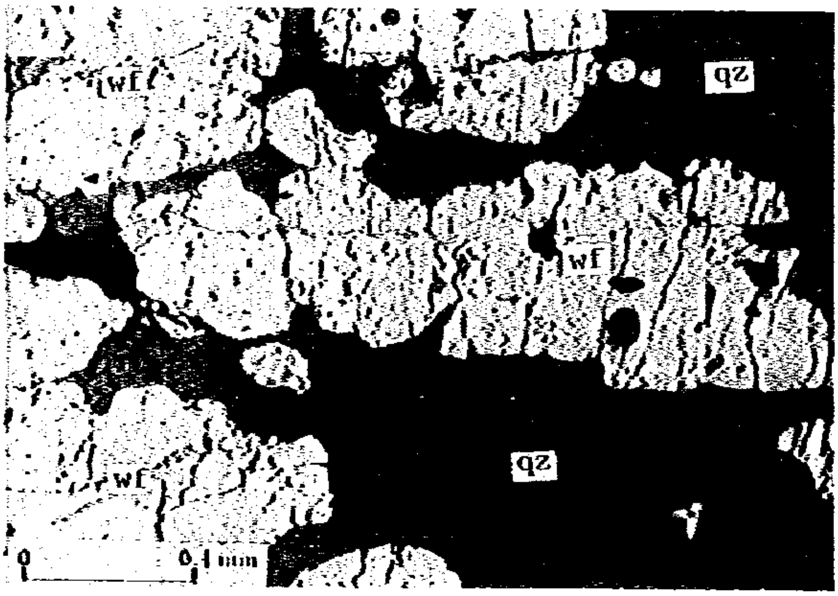
13. W crude ore (OAO-3b, Yong Ku mine): sh; scheelite, wf; wolframite: reflected light, open nicol.



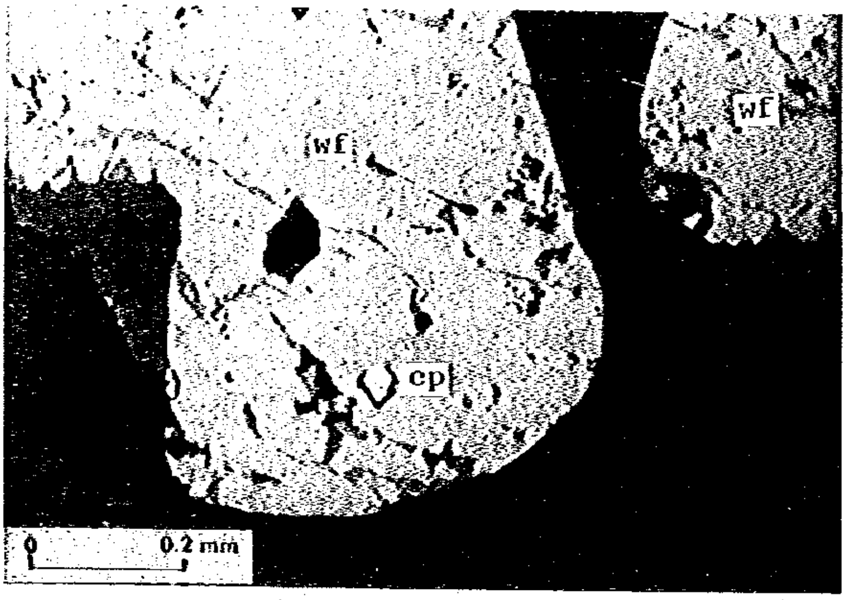
14. Sn-W concentrate (OAO-4, Yong Ku mine): cs; cassiterite, sh; scheelite, wf; wolframite: reflected light, open nicol.



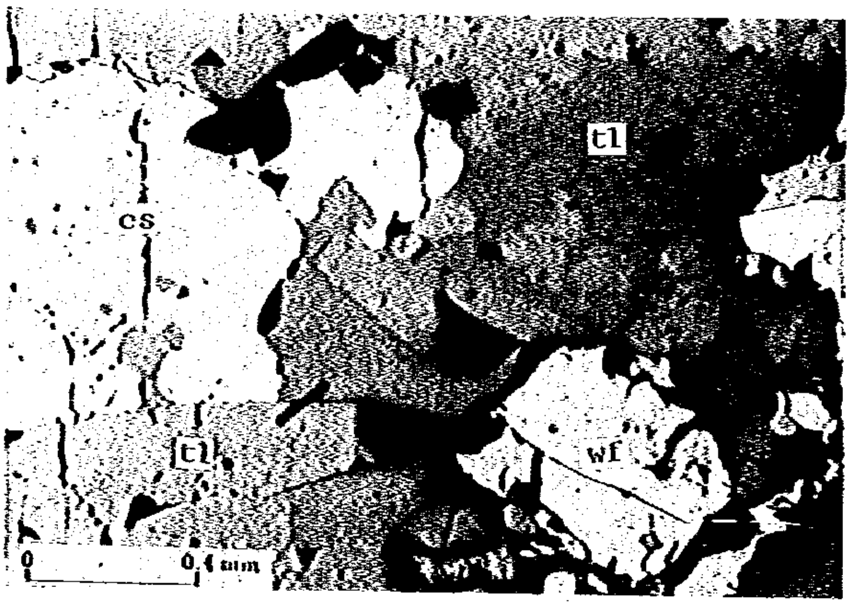
15. Sn-W concentrate (OYO-2, Pha Pun mine): cs; cassiterite, sh; scheelite, wf; wolframite: reflected light, open nicol.



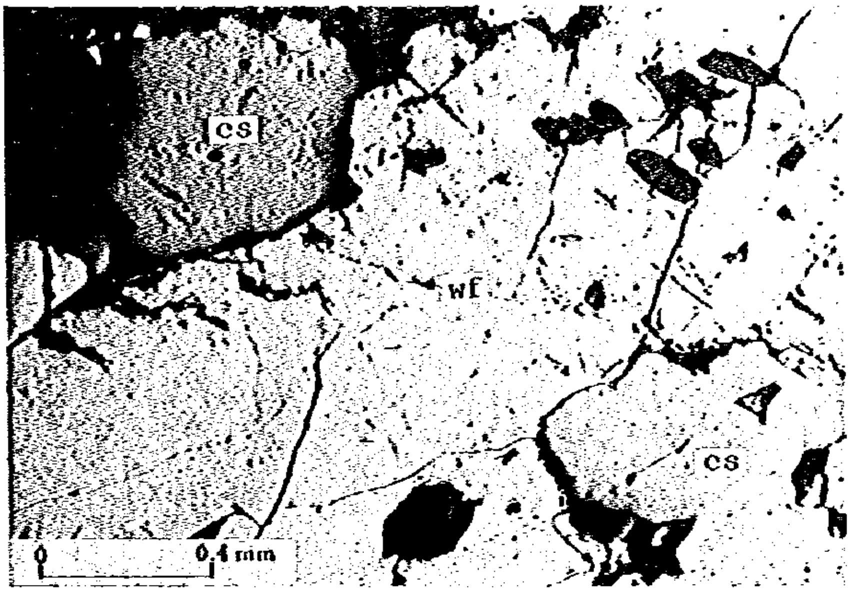
16. Sn-W-bearing tourmaline-quartz vein (OYO-3c, Pha Pun mine): wf; wolframite, qz; quartz: reflected light, open nicol.



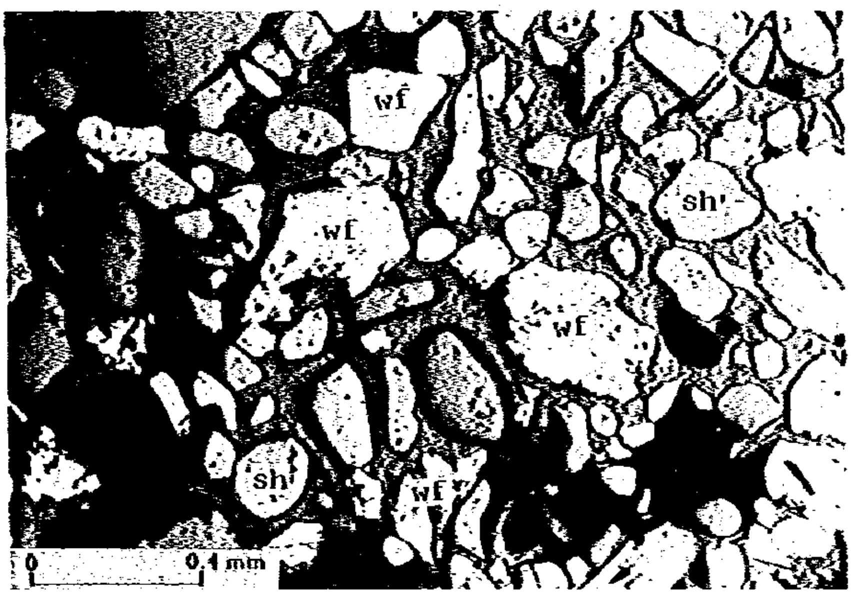
17. Sulfide inclusion in wolframite (OYO-3c, Pha Pun mine): cp; chalcopyrite, wf; wolframite: reflected light, open nicol.



18. Sn-W-bearing tourmaline-quartz vein (OYO-3d, Pha Pun mine): cs; cassiterite, wf; wolframite, tl; tourmaline: reflected light, open nicol.



19. Sn-W-bearing tourmaline-quartz vein (OYO-3d, Pha Pun mine):
cs; cassiterite, wf; wolframite: reflected light, open nicol.



20. Finer fraction of jigger concentrate: (OUO-2, Pha Pun Dong mine):
sh; scheelite, wf; wolframite: reflected light, open nicol.