Geol. Soc. Malaysia, Bulletin, 11, Dec. 1979; pp. 137–159.

Review of the geology of Thai Tin Fields

PRINYA NUTALAYA[1], K.V. CAMPBELL[1], A.S. MACDONALD[2],
PAYOME ARANYAKANON[3] and PHAIRAT SUTHAKORN[3]

INTRODUCTION

The tin belt of Southeast Asia extends over 2,900 kilometres from Burma via peninsular Burma, Thailand, and West Malaysia to the "Tin Islands" of Indonesia. A 1,800 kilometre portion of this belt lies in Thailand but only a few papers dealing with the genesis and paragenesis of the tin deposits in this country exist. This paper attempts to review the existing knowledge of the tin fields in Thailand. Tin occurrence is always spatially associated with granites and therefore these rocks are reviewed first. This is followed by classification and typical characteristics of each type of tin deposit, concluding with a description of known tin districts of Thailand.

GRANITES IN THAILAND

Ages of Granitic Rocks

The oldest and least known plutonic episode is of Upper Carboniferous-Permian age and is recorded, significantly, only by a few Rb/Sr whole-rock ages. Of the intrusions dated, all occur in katazonal environments associated with high-grade schists and gneisses. This is in distinct contrast to the situation in the Malaysian peninsula where the equivalent intrusions were emplaced in the epizone (Hutchison, 1972).

Recently, Braun, *et al* (1976) have cast doubt on the existence of Carboniferous granites in northern Thailand. These authors concluded that there is no radiometric proof for such granite in that area.

The main plutonic episode in Thailand occurred from late Permian to Jurassic time. Although the apparent climax was in the Upper Triassic (Fig. 1), Besang *et al* (1975) have shown by their detailed Rb/Sr isochron and K/Ar studies that in the north, at least, intrusion probably occurred in earliest Triassic whereas uplift and cooling (setting most of the K-Ar ages) probably followed in Upper Triassic-Lower Jurassic time.

The distinct Cretaceous-Tertiary episode occurred which appears to have been more of a widespread thermal than intrusive event. Thus over wide areas of Thailand K/Ar (and perhaps also Rb/Sr) mica ages have been disturbed or reset (Fig. 1), and and there are only a few Rb/Sr whole-rock ages (from Ranong and Mae Lama) which fall in this range. Indeed, plutonic activity was probably more limited in intensity and in distribution than has generally been realized, although more intensive Rb/Sr whole-rock dating will be required to demonstrate this.

[1]Dept. of Geotechmical Engineering, AIT, Bangkok.
[2]Dept. of Geological Sciences, Chiang Mai University, Chiang Mai, Thailand.
[3]Dept. of Mineral Resources, Bangkok, Thailand.

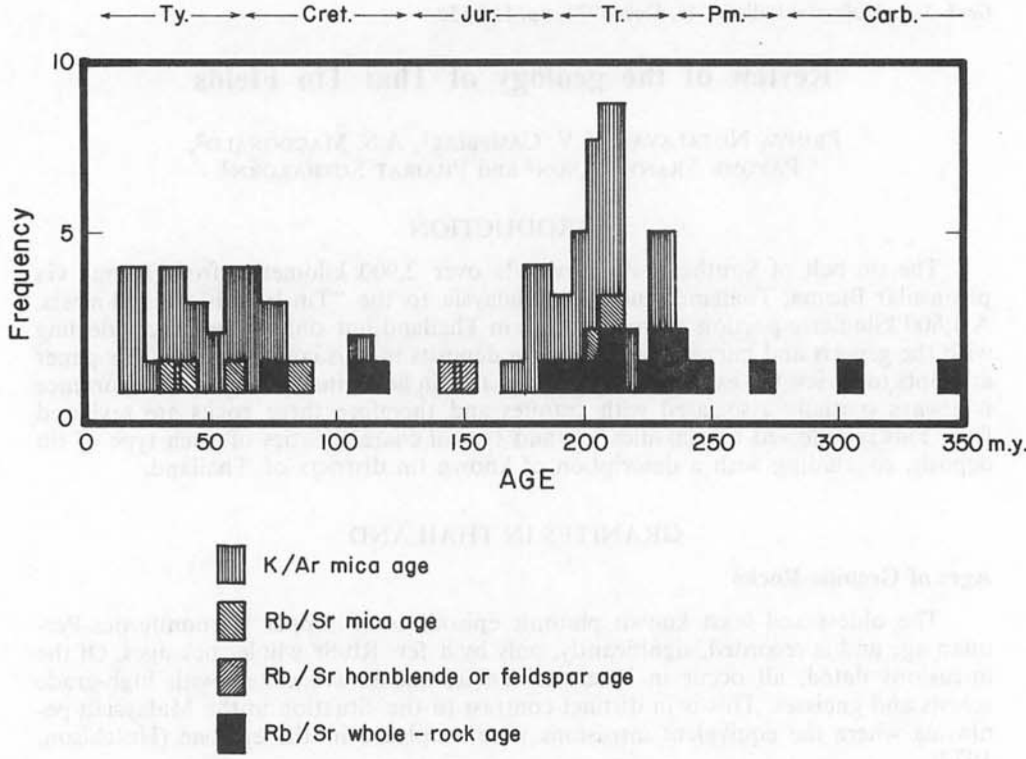


Fig. 1. Histogram of radiometric age of granitic rcoks in Thailand.

Distribution of Granites

An attempt has been made in Fig. 2 to show the distribution of the various ages of plutonic intrusions. Several observations can be made on the basis of this figure:-

(a) Upper Carboniferous intrusions are closely associated with exposed areas of basement complex.

(b) Triassic-Jurassic plutonism is the most abundant and most widespread, distributed in a N-S zone some 200–300 km wide.

(c) There is apparent coincidence of the loci of Upper Carboniferous and Triassic-Jurassic plutonism. There is no discernible E-W age zoning in volving these plutonic rocks, as has been observed in the Malaysian peninsula (Hutchison, 1972).

(d) The Cretaceous-Tertiary thermal effects may be likewise coincident but there are insufficient data to define the distribution of granitic intrusions of this age. However, it is generally considered that the latter tend to be concentrated on the west along the Thailand-Burma borders, although perhaps occurring as sporadic isolated intrusions elsewhere.

This broad coincidence of repeated magmatism/thermal activity probably has important implications for (1) the origin and evolution of the granitic rocks in general, and (2) the genesis and concentration of Sn-W mineralization in the region.

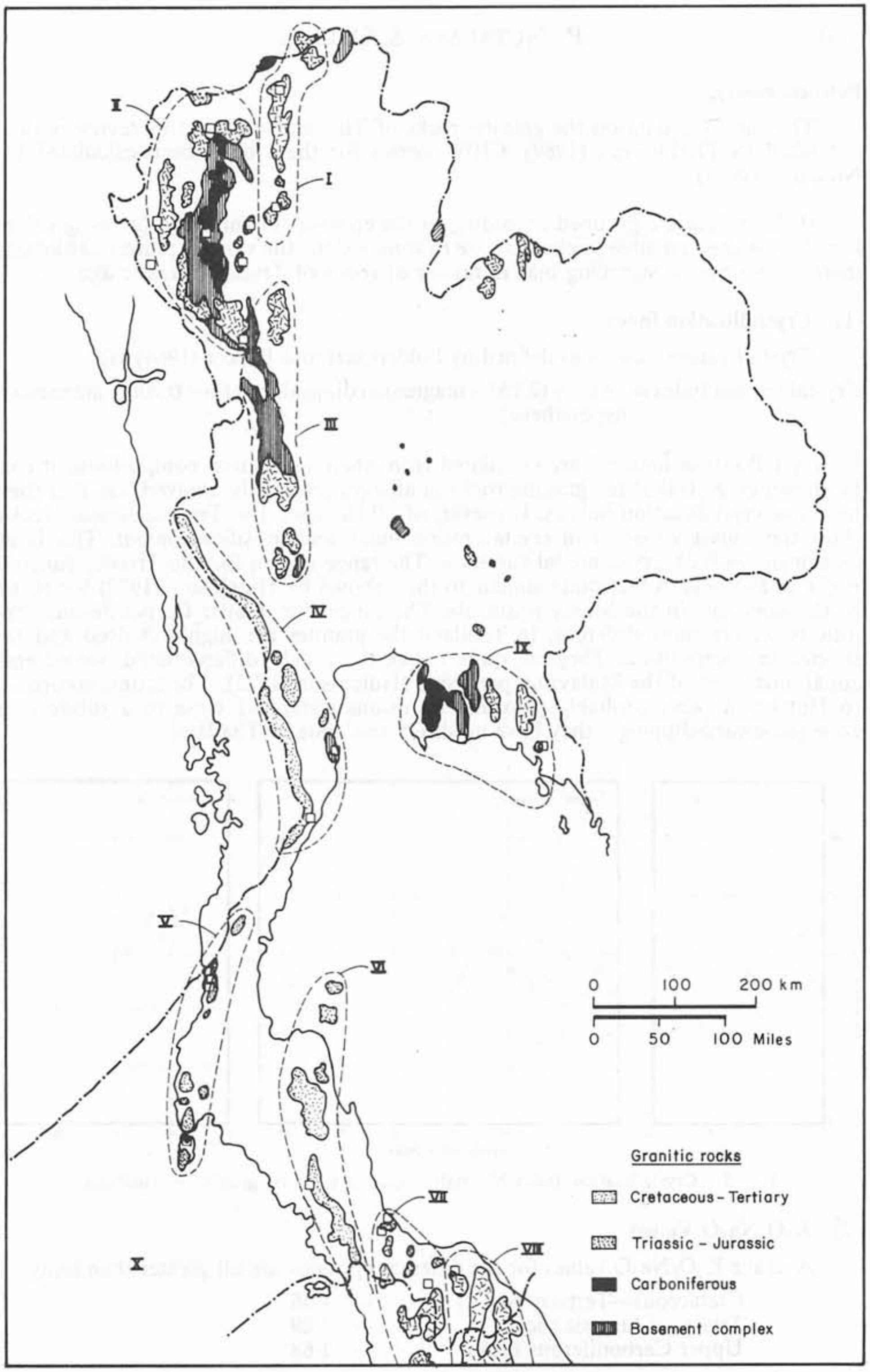


Fig. 2. Distribution of granites and tin deposits in Thailand.

Petrochemistry

The chemical data on the granitic rocks of Thailand used in this review is that published by Pitakpaivan (1969), CIPW norms for these have been calculated by Nutalaya (1975).

If these data are grouped according to the episodes of intrusion (as assigned in Fig. 2), it is then possible to characterize to some extent the various plutons, although there is an obvious sampling bias in favour of rocks of Triassic-Jurassic age.

(1) **Crystallization Index**

Crystallization index was defined by Poldervaart and Parker (1964) as:

Crystallization index= An + (2.157 × magnesian diopside) + (Fo + 0.700 × magnesian hypersthene)

If "crystallization indices" are calculated from their normative composition, it can be shown (Fig. 3) that the granitic rocks of all ages are highly evolved, i.e. that they have low crystallization indices. However, of all the ages, the Triassic-Jurassic rocks show the widest variation in crystallization index and in silica content. This is in agreement with observed modal variation. The range shown for the Triassic-Jurassic rocks in Fig. 3 is in fact quite similar to that shown by Hutchison (1972) for rocks of the same age in the Malay peninsula. The ranges for Upper Carboniferous granitic rocks are quite different. In Thailand the granites are highly evolved and restricted in composition. They are quite unlike the widely differentiated, varied epizonal intrusions of the Malaysian peninsula (Hutchison, 1972). The latter, according to Hutchison, were probably proximal intrusions generated close to a subduction zone (westward-dipping); they have no direct analogue in Thailand.

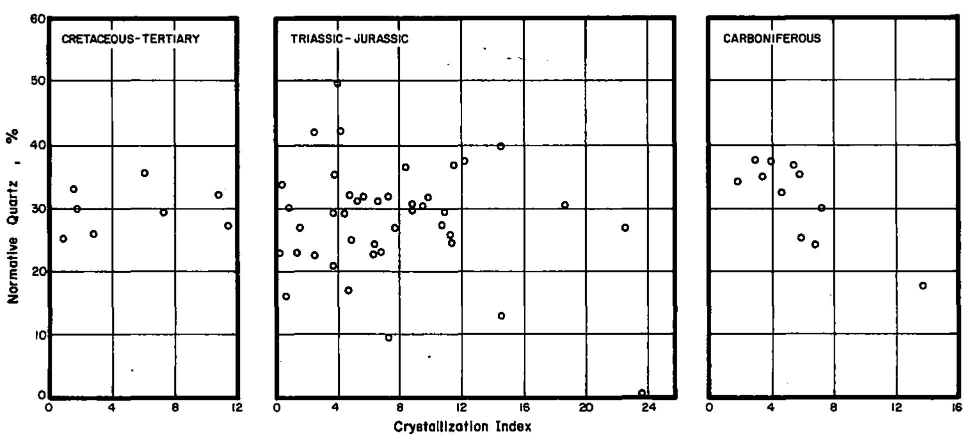


Fig. 3. Crystallization Index-Normative Quartz plots of granite in Thailand.

(2) **K_2O/Na_2O Values**

Average K_2O/Na_2O values for the different episodes are all greater than unity:

Cretaceous—Tertiary rocks	—	1.46
Triassic—Jurassic rocks	—	1.29
Upper Carboniferous rocks	—	1.68

Suggesting that they have all evolved in mature arc or continental sites (Engel *et al*, 1974).

(3) Rb/Sr and Initial Sr^{87}/Sr Ratios

Using the radiometric data of Besang *et al* (1975), it can be shown that the Triassic-Jurassic granitic rocks of North Thailand have:

(a) high Rb/Sr ratios averaging 1.13 (0.43—2.83), and

(b) highly radiogenic initial Sr^{87}/Sr^{86} ratios averaging 0.7257 (0.7220–0.7281).

These data suggest derivation from relatively uniform radiogenic source rocks such as basement metasediments and gneisses. Note that cratonic crust has average Rb/Sr of 0.15 and initial Sr^{87}/Sr^{86} of 0.719 (Faure and Powell, 1972).

There is, at present, insufficient data to characterize the granitic rocks in other areas and of other ages except that they all appear to have high Rb/Sr ratios (Burton and Bignell, 1969).

Origin of the Granitic Rocks

The available petrochemical data indicate that the granitic rocks of Thailand are, in general, rather restricted in composition, highly evolved and probably formed within continental crust by anatexis of upper crustal rocks.

A similar anatectic origin, but higher level emplacement, can be invoked for the slightly more varied Triassic-Jurassic intrusions. These are exposed at various structural levels but in general appear to be classified as upper mesozonal intrusions. It is interesting to note that these intrusions do not appear to show any discernible E-W variation in K_2O contents (Fig. 4, admittedly the sampling is rather sparse) such as have been observed across Cordilleran-type plutonic arcs (Bateman and Dodge, 1970, Baird *et al*, 1974). It is suggested that these rocks were distal intrusions generated at some considerable distance from an active subduction zone by upward transfer of heat into continental crust. The polarity of this Late Paleozoic—Early Mesozoic subduction zone could perhaps be determined using other parameters such as K_2O variation in volcanic rocks (Lipman *et al*, 1971) and/or metallogenic zoning.

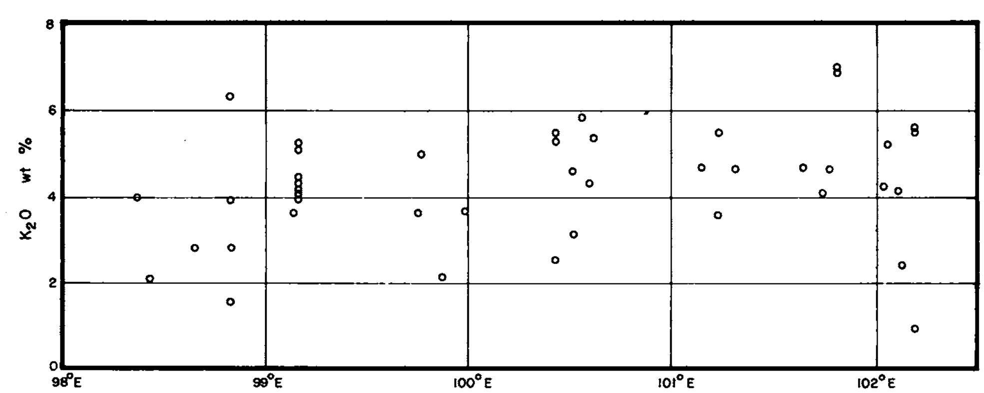


Fig. 4. K_2O Content of Triassic-Jurassic granites plotted on E-W line.

TYPES OF TIN DEPOSITS

There is no comprehensive descriptive work on the types or classification of tin deposits in Thailand. There is, however, a very extensive bibliography on individual tin deposits. This has been reviewed most ably by Tantisukrit (1975) .The interested reader is referred to that review for a complete pre-1975 review and bibliography on the subject. This discussion is confined to specific information on types of tin deposits first reported and reviewed by Aranyakanon (1969).

There are seven types of tin deposits in Thailand. These types are hydrothermal lode and greisen, disseminated cassiterite in altered granite, disseminated cassiterite in country rock, pegmatite, contact metasomatic, eluvial and placer deposits (Aranyakanon, 1969). The occurrence of these types throughout Thailand is shown in Table 1 (Puwakool, 1977).

Hydrothermal Lodes and Greisen

Cassiterite-bearing hydrothermal lodes and greisens are the most abundant type of tin deposit in Thailand. In the majority of cases the smaller lodes contain more tin ore than the large veins, and many small veins of width from 0.5 to 15 cm are composed entirely of cassiterite. Most tin-bearing quartz veins are shallow, extending to depths of 10 to 30 metres. In deeper lodes, such as those that reach depths of 200 to 300 metres, tin ore is confined to the upper part.

Minerals associated with cassiterite in various quartz lodes are wolframite, rhodochrosite, flourite, and sulphides of copper, lead, mercury, silver, bismuth, and zinc.

Greisen is normally associated with tin-bearing quartz veins. Pneumatolytic minerals such as topaz, flourite, apatite, and tourmaline are usually found in the greisen. In some places quartz veins yield little or no tin, but the associated greisens are tin-bearing.

Disseminated Cassiterite in Altered Granite

Tin and tungsen are normally disseminated throughout altered granite. In some localities the cassiterite is segregated as ore deposits which are large enough to be mined. The altered granite generally has a medium grained texture.

The texture of the altered granite is produced by pneumatolysis, through the action of F, B, and H_2O on the parent granite. The resulting phenomena associated with these actions are tourmalinization, muscovitization, kaolinization, albitization, and silicification. A commonly observed case is porphyritic biotite granite altered to muscovite-tourmaline (kaolinized) granite of a finer grain size. The gradation of the altered granite to its original parent rock can be clearly demonstrated in many places.

The following relationships are based on observation of many altered granites. (Aranyakanon, 1961 and 1969).

(1) The temperature of formation of tin-bearing granites is considered to be lower than that of tin-barren granites. The latter crystallized at temperatures higher than 600 °C. Exceptions to this observation are (a) the temperature of formation of the tin-bearing granites may be higher than 600 °C where Ca-enrichment from limestone country rock has occurred, and (b) where

TABLE 1

TYPES OF TIN DEPOSITS FOUND IN VARIOUS PROVINCES (AFTER PUWAKOOL, 1977)

Province	Hydrothermal lode & greisen	Disseminated cassiterite in the altered granite	Disseminated cassiterite in country rock	Pegmatite	Contact metasomatic	Eluvial Alluvial
Northern Region						
Chiang Rai	x	x	—	—	—	x
Mae Hong Son	x	—	—	—	—	x
Chiang Mai	x	—	—	x	—	x
Lampang	x	—	—	—	—	x
Tak	x	—	—	—	—	x
Uthai Thani	x	x	—	x	—	x
Central Region						
Kanchanaburi	x	—	—	—	—	x
Ratchaburi	x	—	—	x	—	x
Phetchaburi	x	—	—	—	—	x
Rayong	x	—	—	—	—	x
Prachuap Kiri Khan	x	—	—	—	—	x
Southern Region						
Chumphon	x	x	—	x	—	x
Ranong	x	x	—	x	—	x
Surat Thani	x	—	—	x	x	x
Takua Pa	x	x	—	x	x	x
Nakon Si Thammarat	x	—	x	x	x	x
Phangnga	x	—	—	x	—	x
Phuket	x	x	—	x	—	x
Trang	x	—	—	x	—	x
Songkhla	x	x	x	—	—	x
Pattani	x	x	—	—	—	x
Yala	x	x	—	—	x	x
Narathiwat	x	—	—	x	—	x

the K-feld-spar of the rock is coarsely perthitic the temperature of the formation of tin-bearing granite may be higher.

(2) The occurrence of disseminated cassiterite in altered granites is not restricted to those granites in contact with Ca-bearing country rock.

(3) Albitization is one of the frequent signs of the pneumatolytic changes in the altered granites. The main effect of albitization is the progressive accumulation of Na and expulsion of Ca and K. The typical occurrence grades from porphyritic biotite granite into tourmaline-muscovite granite. The latter is richer in albite and poorer in K-feldspar. In some places albite granite is produced. Microcline is normally found in the granites which have been albitized.

Disseminated Cassiterite in Country Rock

In a few areas tin ore is found disseminated in country rock adjacent to tin lodes or stringers. The grain size of the cassiterite varies from very fine up to 2 cm. The cassiterite occurs in schists or sandstones with tourmaline as a gangue mineral. Replacement relations have not been reported.

Pegmatite

Tin-bearing pegmatites are generally found in all granite masses. Besides cassiterite, columbium and tantalum minerals and many other rare earth minerals are often found associated with pegmatite. Lepidolite locally occurs as bands or/zones in pegmatite bodies. Beryl is frequently found in pegmatites, but not in concentration.

Brown *et al* (1951) reported that in Phangnga Province the tin-bearing pegmatite was injected concordantly to the schistosity of the enclosing country rock, quartzite and calcareous schist. In reporting on deposits in other southern provinces Aranyakanon (1969) noted that the tin-bearing pegmatites "traversed" gneiss and schist, and were metamorphosed.

Contact Metasomatic Deposits

Cassiterite deposits of the contact metasomatic types are of minor occurrence and are found only at some of the contacts between limestone and granite. Various kinds of calcium-bearing minerals in the tactite zone have been formed by the chemical reaction between mineralizing solutions and the limestone or calcareous rock. In a few places two zones can be recognized; an inner contact zones of actinolite, hypersthene, hedenbergite, magnetite, garnet and other iron minerals, and an outer zone of a variety of garnets. Cassiterite occurs in both zones, and in the outer zone other skarn minerals are pseudomorphously replaced (Aranyakanon, 1969).

In other localities the direct intrusion of granite into calcareous rocks does not show any contact metasomatism, the only change being a recrystallization of calcite.

Eluvial Deposits

Rich deposits of tin in eluvium are rarely found at the present time. The thickness of eluvial deposits varied from 1 to 2 metres and the maximum depth was seldom over 3 metres (Aranyakanon, 1969). In general the value of eluvial ground was high, and the ore was evenly distributed throughout the eluvial layer.

Placer Deposits

Alluvial tin deposits are the main source of tin in Thailand at the present time. The placer deposits are derived from the reworking of the preceeding types of deposits. They are found in mountain basins or along old stream channels, stream deposits beach sands, and offshore areas. Of these areas the offshore deposits warrent mention, due to the renewed prospecting for this type in the last 20 years.

Offshore tin deposits in Thailand are mainly found along the western side of the peninsula. This is due to granitic parent rocks adjacent to the western side of the peninsula that are exposed parallel to the coast line from Ranong Province to Takuapa, Phangnga and to Phuket Island. The main offshore tin deposits in Thailand are derived from offshore granites (Lowatanatrakul, 1969) and they have accumulated as residual concentrations rather than as transported deposits. A high frequency of tin deposits are closely associated with the contact zone between granite and country rocks with altered granites.

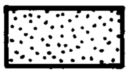
DESCRIPTION OF TIN FIELDS IN THAILAND

Tin deposits in Thailand are found primarily along the N-S trending granitic ranges extending from Chinese Yunnan through West Malaysia and in the alluvial aprons of these ranges both on land and offshore. One isolated area of tin occurrence is also found in the granite hills of the southeast gulf coastal area. In general these deposits can be divided by their geographic proximity and mode of occurrence into 10 districts (Fig. 2). These districts are listed according to their geographical distribution from north to south as follows:

(1) Mae Chan-Khung Tan District
(2) Pai-Mae Sod District
(3 Tak-Suphanburi District
(4) Thon Pha Phum Tap Sakae District
(5) Ranong-Phuket District
(6) Phangan-Trang District
(7) Songkhla-Betong District
(8) Narathiwat District
(9 Cholburi-Chantaburi District
(10) Offshore Area

Mae-Chan—Khun Tan District

The Mae-Chan—Khun Tan District extends from north of Chiang Rai Province passing through east of Chiang Mai and to southwest of Lampang Province (Fig. 5). The district is over 250 km long and approximately 30 to 40 km wide. The area is underlain by north-south trending porphyritic biotite granite of Triassic age intruded into the Paleozoic metasedimentary rocks. Tin mines are concentrated in four areas of this district namely: San Salee, Wiang Papao, Chae Hom, and Hang Chat-Koh Ka. In the San Salee field cassiterite is found in quartz veins and as disseminated grains within the altered granite. At Wiang Pa Pao heavily weathered granite and basic rocks have been intruded by several narrow quartz veins and pegmatites containing abundant schorlite as well as cassiterite and scheelite. The veins are frequently closely spaced and branching (GGM, 1972). Placer deposits are also found in this field. At Chae Hom, the granites are heavily altered and disseminated along the con-


Cretaceous - Tertiary granite , granodiorite including fine grained dike rocks.


Triassic - Jurassic porphyritic biotite (partly muscovite) granite , adamellite, granodiorite. Including granodiorite of Upper Permian – Lower Triassic age in the northeastern region.


Carboniferous granite ; mainly stressed granite , partly porphyritic texture.


Anatexitic aureole of pre - Carboniferous granite , including Pre - Cambrian paragneiss , orthogneiss and dike rocks.

A = Pegmatitic deposit

C = Contact metasomatic deposit

D = Disseminated deposit

E = Eluvial deposit

G = Greissen deposit

H = Hydrothermal deposit

P = Placer deposit

B = Radiometric age by K/Ar from biotite

M = Radiometric age by K/Ar from muscovite

Rb = Radiometric age by Rb/Sr whole rock

Legend for Fig. 5 to Fig. 10.

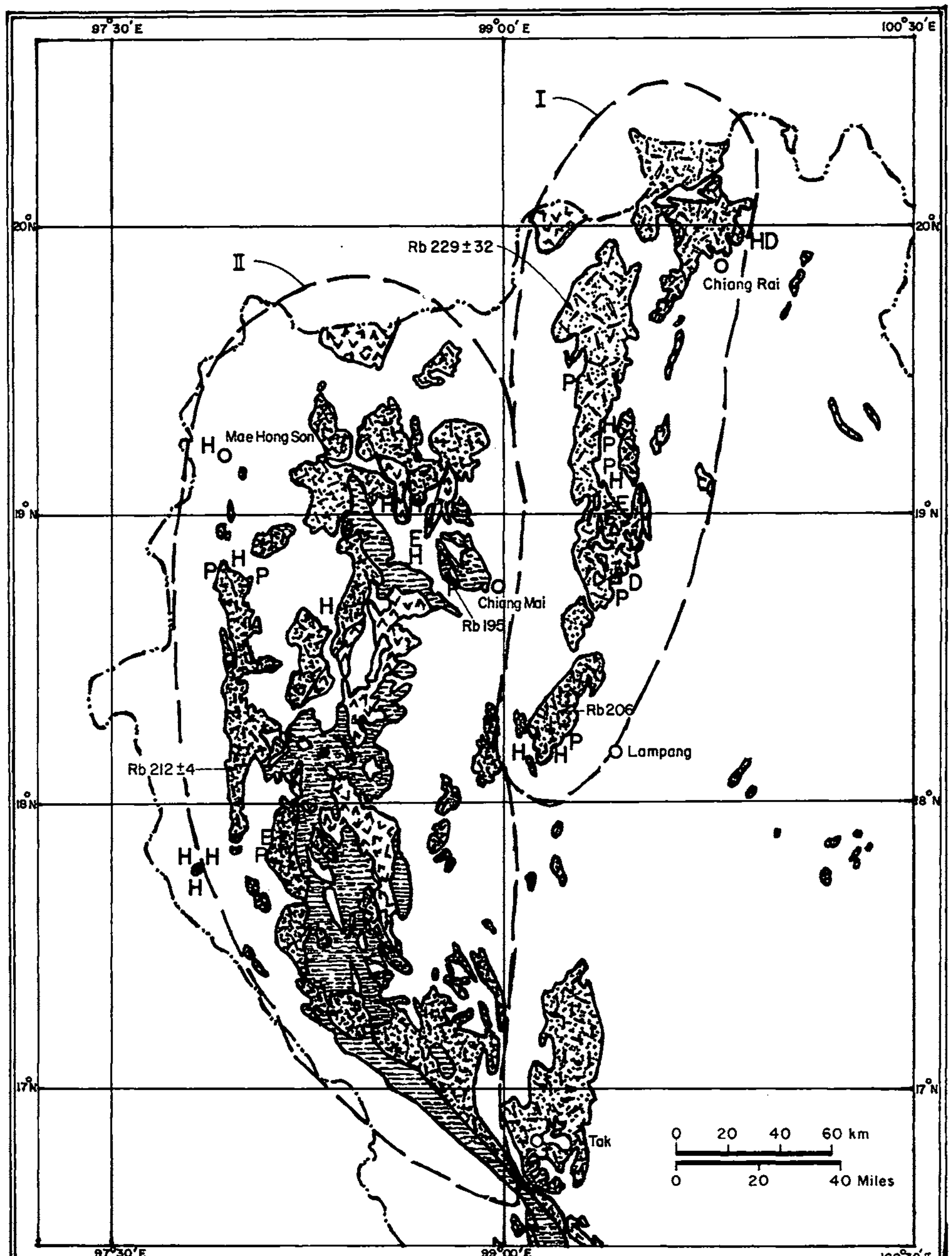


Fig. 5. Distribution of tin deposits and granites in Mae Chan-Khun Tan (I) and Pai-Mae Sod Districts (II), Northern Thailand.

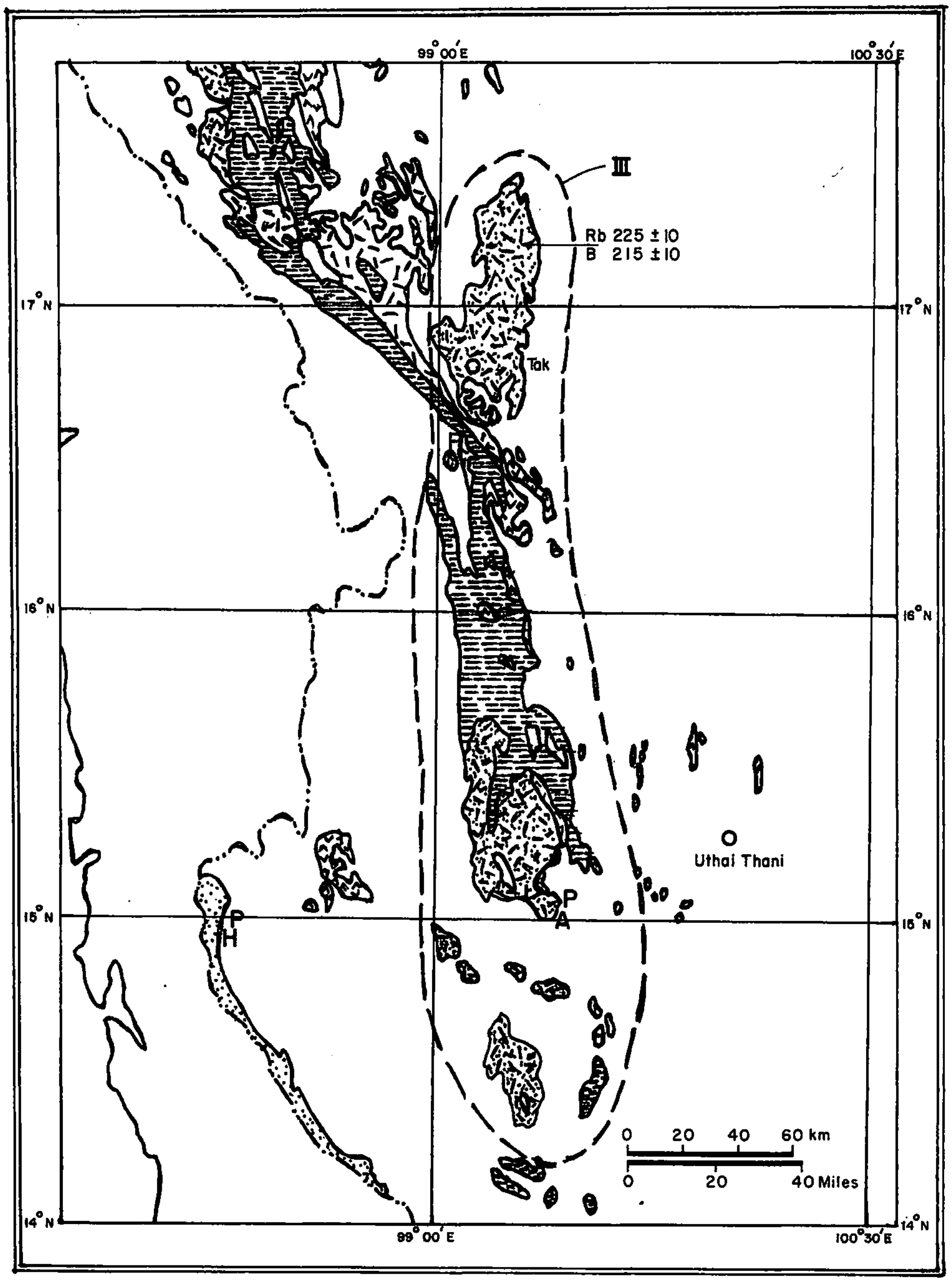


Fig. 6. Distribution of tin deposits and granites in the Tak–Suphanburi District (III), Western Thailand.

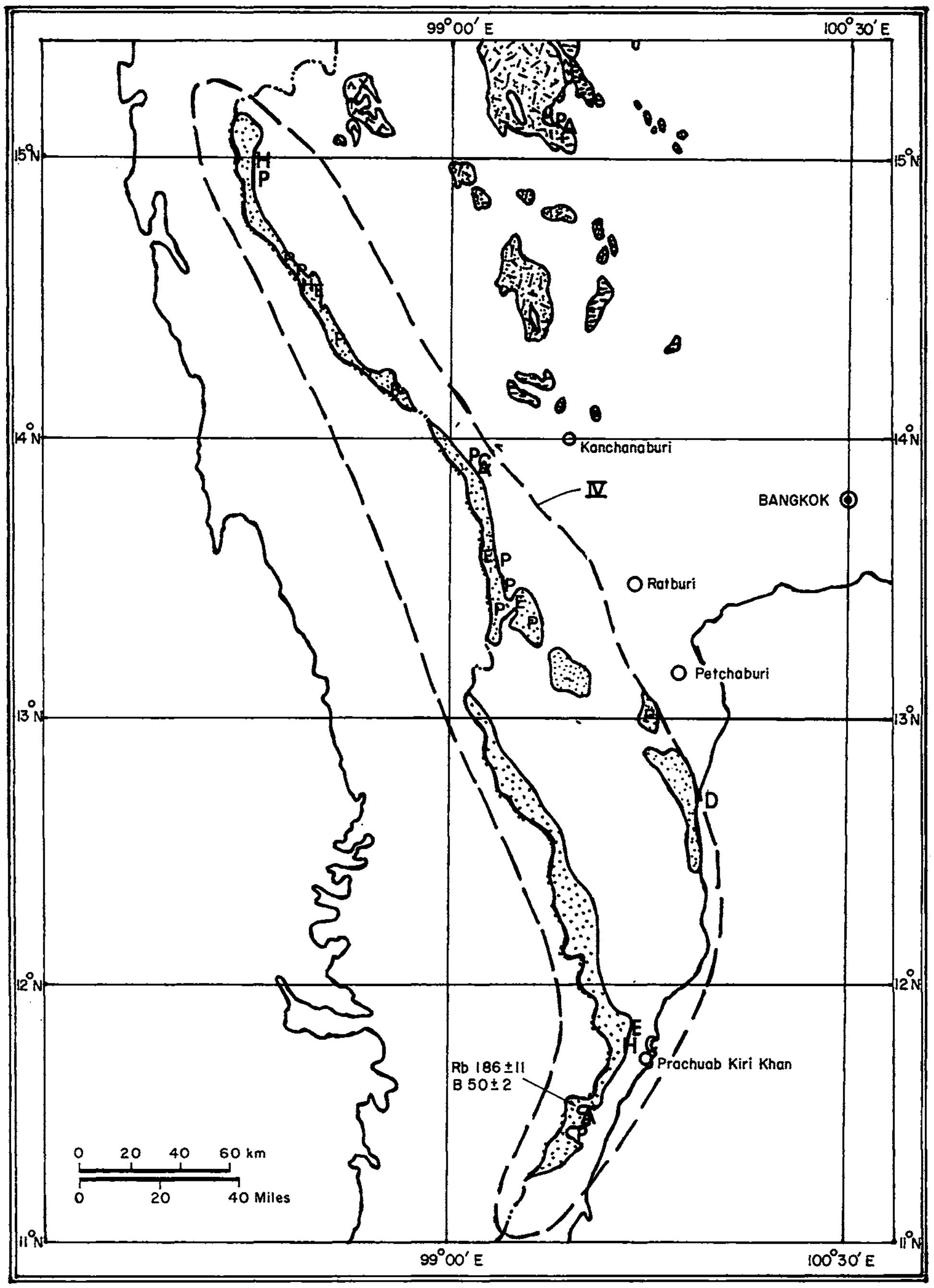


Fig. 7. Distribution of tin deposits and granites in the Thong Pha Phum–Tap Sakae District (IV) Southern Thailand.

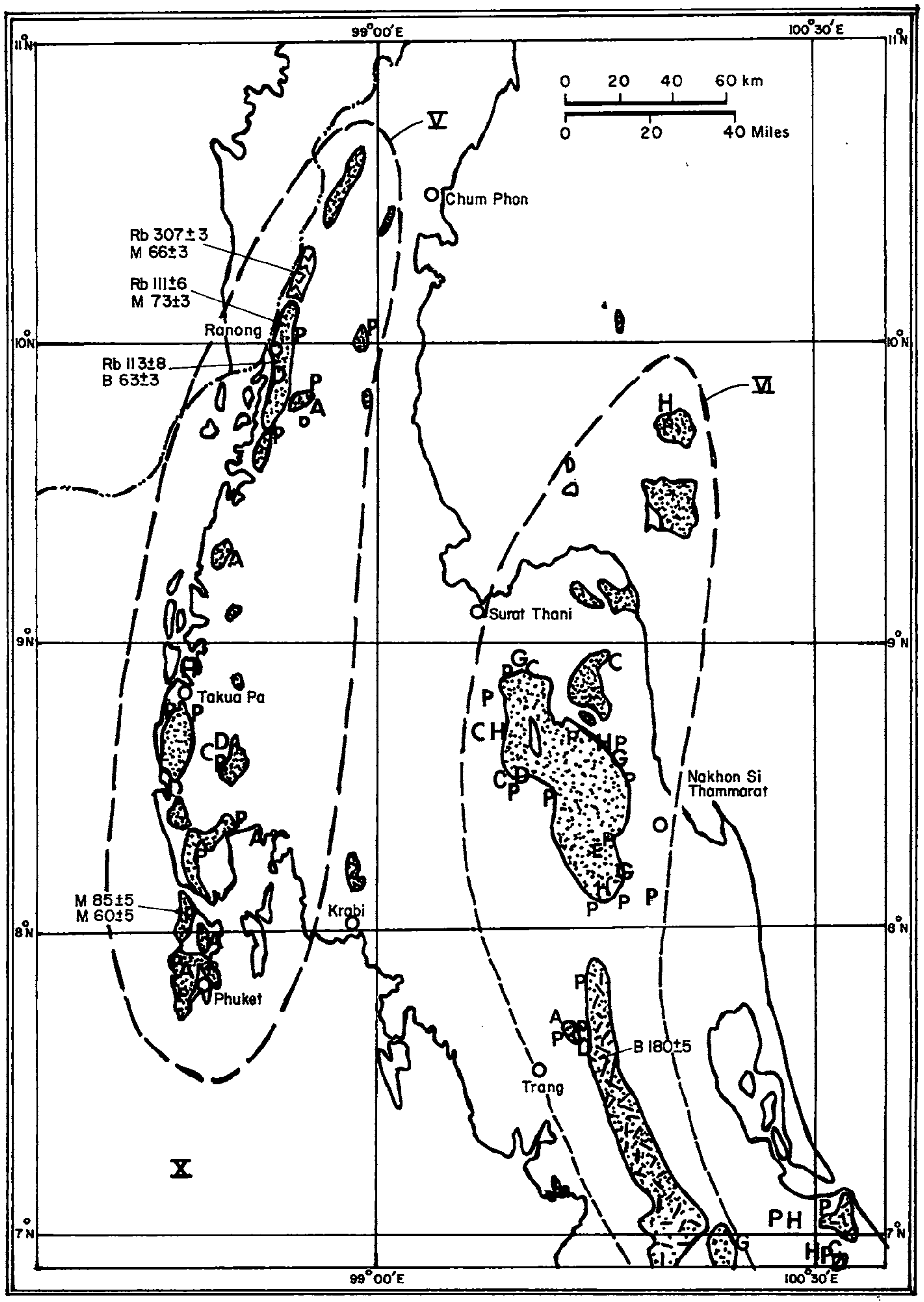


Fig. 8. Distribution of tin deposits and granites in the Ranong-Phuket (V) and Phangan-Trang (VI) Districts and offshore area (X) Southern Thailand.

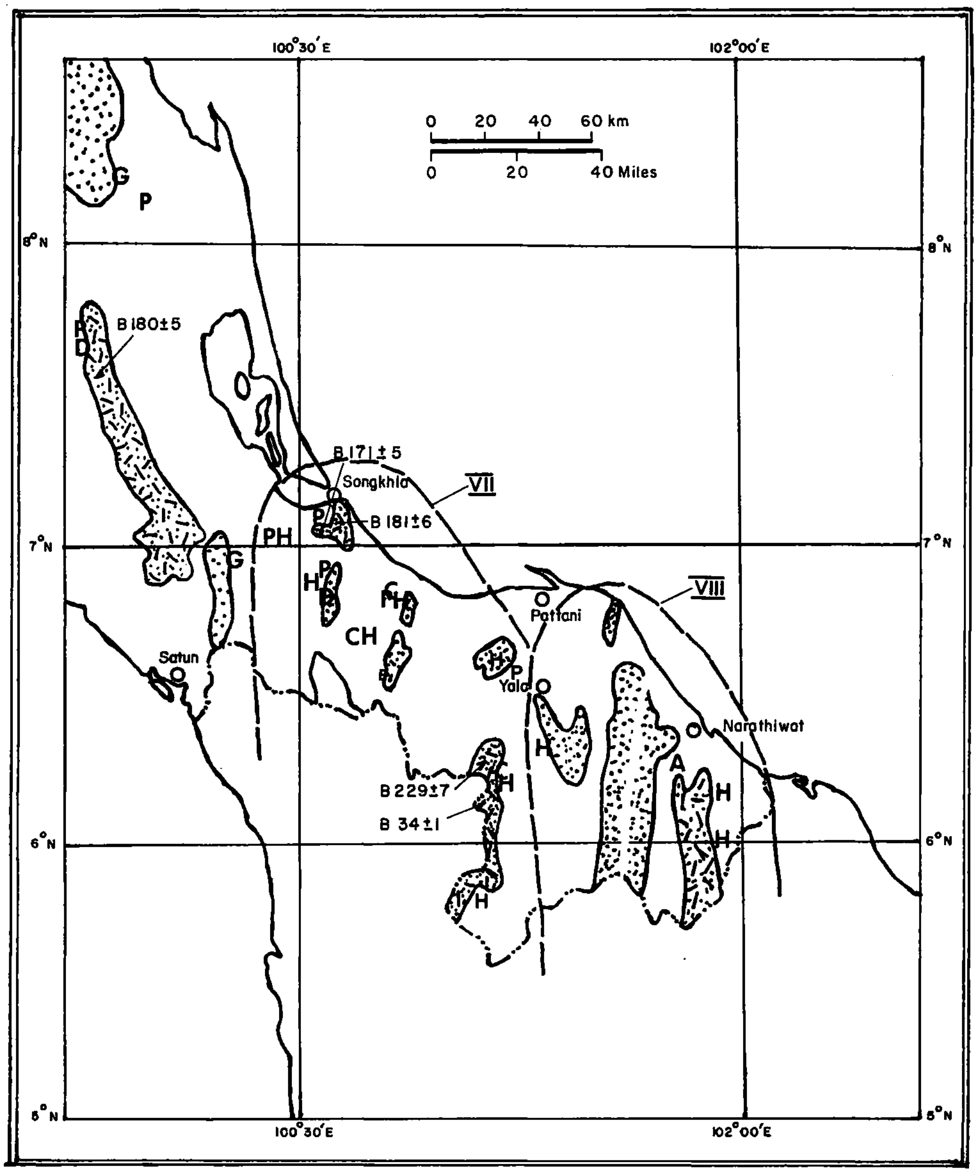
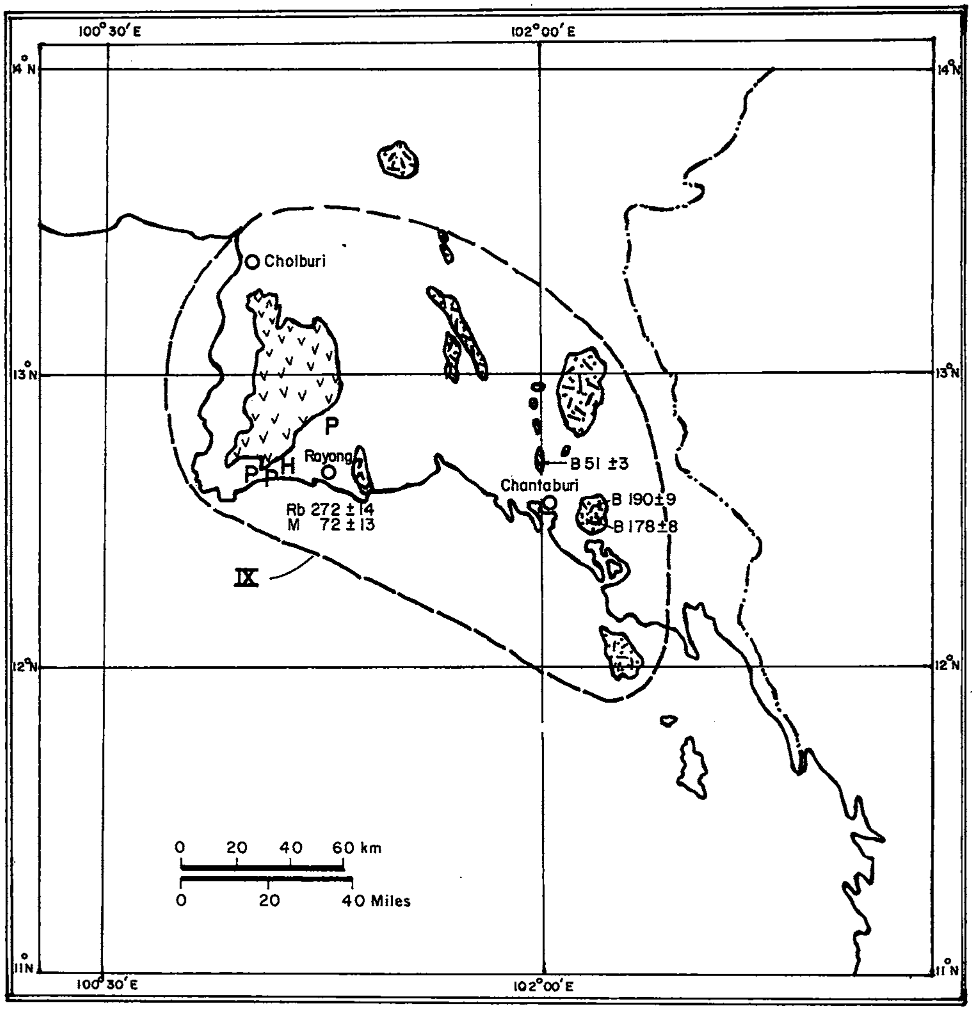


Fig. 9. Distributions of tin deposits and granites in the Songkhla–Betong (VII) and Narathiwat District, Southern Thailand.



Figr 10. Distribution of tin deposits and granites in the Cholburi-Chantaburi District (IX), Eastern Thailand.

tacts with tourmaline and cassiterite metasedimentary rocks (slate, quartzite). Placer deposits are found along the foothills (Araynakanon, 1964). At Hang Chat-Koh Ka cassiterite is found in association with ilmenite, tourmaline, zircon and allanite in placer deposits (Vichit, 1971). Cassiterite is also found disseminated along the contact between Triassic porphyritic biotite granite and Paleozoic phyllite, hornfels, and quartzite. Other modes of occurrence are quartz veins containing cassiterite and pegmatites containing white mica and cassiterite cutting across both the granite and metasedimentary rocks. The average grain size of the cassiterite ranges from 1 to 4mm and color ranges from honey yellow to black.

Pai-Mae Sod District

The Pai-Mae Sod District lies to the west-southwest of Mae Chan-Khuntan Mae Sod, a distance of about 280 km. The width is approximately 60 to 80 kilometres. The area is underlain by a highly complex sequence of gneisses, schists, marble, slate, quartzite and limestone intruded by Triassic to Cretaceous granites (Braun *et al*, 1976). Six areas of mine working and prospects can be identified in this district namely Pai, Samoeng, Khun Yuam, Mae Chaem, Mae Sariang, and Mae Lama. Placer deposits occur in all areas. In the Pai area porphyritic hornblende biotite granite and muscovite-biotite granite of unknown age crop out to the southeast. White pegmatite with black cassiterite and white to cream quartz veins are seen cutting these granites. Cassiterite grains are purplish brown and 1 to 2 mm in diameter. (Vichit *et al*, 1971). At Samoeng a cassiterite-scheelite deposit is genetically associated with Mesozoic or Tertiary granite dikes and their contact with overlying Paleozoic limestone. The contacts consist of dense calcsilicate rocks which are cut by numerous branching cassiterite-quartz-veins up to 30–40 cm width, (GGM, 1972). The approximate dimensions of the mineralized zone are 500 m long, 100 m wide and over 20 m deep. In the Khun Yuam prospects the hydrothermal cassiterite-quartz veins and cassiterite-bearing pegmatites cut across the Triassic porphyritic biotite granite and the marine Triassic country rocks. In the Mae Chaem area Triassic granites cut by coarse grained tourmaline pegmatite occur. Paleozoic meta-sedimentary rocks were contact metamorphosed by the granites (GGM, 1972). Cassiterite is found in placer deposits in stream beds draining off the area. Tin was also found as placers in stream beds which flow off from the Triassic porphyritic biotite granite and in greisens along the contact zones of granite east of Mae Sariang. At Mae Lama small amount of tin has been found in the wolframite-cassiterite-quartz lodes. The bed rock in this area is medium to coarse grained biotite granite intruded into slate, quartzite, phyllite and marble (GGM, 1972, Teggin, 1975).

Tak-Suphanburi District

The Tak-Suphanburi District, over 340 km long and about 30 to 40 km wide, lies directly south of the Mae Chan-Khuntan District (Fig. 6). The rocks are mostly porphyritic hornblende biotite granite of Triassic age intruded into granite gneiss, schist, and marble of Precambrian age (?) and surrounded by Paleozoic metasedimentary sequence. Several prospects and a few mines are known to occur in this district but no report has ever been made.

At Ban Rai, west of Uthai Thani, tin has been mined for several years. The only existing data available are that cassiterite is found in pegmatite dikes in association with columbite and tantalite. Mining was done within these dikes as well as in the placers. Farther south toward Suphanburi the cassiterite is always found in cassiterite-quartz veins cutting the granite and country rock.

Thong Pha Phum—Tap Sakae District

This district covers a distance of about 480 km lying along the boundary between Thailand and Burma from north of Thong Pha Phum to Tap Sakae in the south. The width is generally less/than 5 km (Fig. 7). West of Ratburi this granite range splits up into two sub-parallel belts trending southeasterly. The geologic setting of this district consists of north-northwest trending biotite-muscovite granite of Cretaceous-Tertiary age intruded into the Paleozoic slate, quartzite, and limestone. (Kokcharoensop, V., 1972). Six areas of mine working which include Pilok, Huai Nam Khao, Chom Bung, Tha Lao, Prachuab and Tap Sakae are known.

At Pilok pegmatite dikes and cassiterite-wolframite-quartz veins cut into weathered granite and slate, phyllite, and quartzite. The quartz veins in the Pilo area strike E-W and N-W. The E-W veins are within the granite and are composed almost entirely of cassiterite; locally gold is observed. In contrast, the N-S veins frequently are within the country rocks, are coarsely pegmatitic and contain wolframite, scheelite and cassiterite. Mining activity is located in both primary veins and in alluvial placers (GGM, 1972).

At Huai Nam Khao the mineralization zone occurs along the contacts between the biotite-muscovite granite and Permian limestone. Cassiterite is found in the quartz veins as well as in pegmatite dikes. Disseminated cassiterite has also been reported at the contacts of both rock types. Mining activities are now concentrated on placer deposits at the top of the contact zones.

In Chom Bung tin mineralization also occurs along the contact between the biotite-muscovite granite of Cretaceous-Tertiary age and the Paleozoic slate, phyllite, and quartzite. Primary tin deposits are/found in quartz veins and pegmatite dikes at the proximity of the granite contact. Wolframite is locally found in tin-bearing quartz veins. Disseminated cassiterite in the quartzite has been observed in some areas. Placer and eluvial deposits are the most important sources of both cassiterite and wolframite in the area (Veeraburus and Japakasetr, 1969).

In the Tha Lao Basin the bed rocks are biotite-muscovite granite of Cretaceous-Tertiary age intruded into quartzite of Upper Paleozoic age. The tin mineralization is concentrated around the granite-quartzitic hornfels contact. Numerous quartz veins have been observed cutting into both the granite and quartzite. Eluvial and placer deposits are mined in this area. The cassiterite grains are purplish brown to black and are 2–3 mm in diameter (Kokcharoensup and Vichit, 1977).

At Prachuab Kiri Khan eluvial remnants of N-S trending cassiterite-wolframite quartz veins yield enough secondary ores for mining. Wolframite-cassiterite veins, however, have yet not been mined.

At Tap Sakae the tin-bearing pegmatite dikes seem to be the most important primary sources of tin in the area. The entire field is surrounded by biotite-muscovite granite on the west, south, and north and is underlain by the Upper Paleozoic metasedimentary sequence on the east. At present tin mining is limited to placer deposits.

Ranong-Phuket District

This district is perhaps the most important and best known tin producing district of the country. Several writers (Brown *et al*, 1951; Aranyakanon 1961, 1969;

Hummel and Phawandon, 1967; and Garson *et al*, 1975) have dealt with the geology and mineralization of various deposits in this district. There are well over a hundred mines operating in this area as well as several thousand squatters in the offshore areas. This district extends from north of Ranong Province to Phuket Island in the south with a total length of over 270 km. The average width is less than 20 km (Fig. 8). This district can be further divided into the Ranong subdistrict and the Takuapa-Phuket subdistrict. The tin-bearing granites of this area are the biotite-muscovite granites of Cretaceous-Tertiary age which have intruded slate, phyllite, quartzite, and limestone of Paleozoic age. Most of the tin in this district is derived from placer deposits which are found in the immediate vicinity of the granitic contact zones, stockworks, and pegmatites and along stream beds which drain off the granitic hills. Several types of primary deposits have also been reported and they are described here.

In the Ranong subdistrict the major type of deposit is of disseminated cassiterite and wolframite is pneumatolytized granite. This type of deposit is found in several localities in Ranong subdistrict, e.g. Haad Som Pan, Ban Non, Kurod, and Thungka (Aranyakanon, 1969). The other type of primary deposit found in this area are the tin-bearing pegmatite dikes, especially around Pha To area.

In the Takuapa-Phuket subdistrict four main types of intrusions occur. These are hornblende adamellite, muscovite-biotite granite, lineated biotite granite and tourmaline granite (Garson *et al*, 1975). No cassiterite has been found in any of the adamellites. The cassiterite in the alluvial deposits was derived from the various types of biotite granite, associated stockworks and pegmatite. Cassiterite occurs as disseminated grains and in quartz stringers throughout the granitic mass. Associated minerals include monazite, ilmenite, yttrotantalite, ilmenorutile and garnet. Wolframite is found in two mines (Garson *et al*, 1975).

Phangan-Trang District

The Phangan-Trang district lies to the southeast of the Ranong-Phuket district. It extends from Phangan Island in the Gulf of Thailand southward through Surat Thani-Nakon Si Thammarat and ends at Trang (Fig. 8). The entire length is about 240 km and the maximum width at Khao Luang, Nakon Si Thammarat is about 50 km. Tin mineralization in this area occurs in and around the large biotite-muscovite granite batholith of Khao Luang, Nakon Si Thammarat Province. The age of this granite is believed to be late Cretaceous-Tertiary. It intrudes into a Paleozoic sequence of quartzite, limestone, slate, and phyllite.

In Phangan Island cassiterite-wolframite-quartz veins in granite have been mined. Pegmatite containing both cassiterite and wolframite are also found. Placer deposits have been revealed by test boring (Brown *et al*, 1951). North of Khao Luang at Klong Sra, Kanchanadit, greisens associated with quartz veins yield considerable amount of cassiterite. Other minerals found in the greisens include topaz, fluorite, apatite, and tourmaline.

At Na San, south of Surat Thani, on the northwestern edge of Khao Luang Range, four types of tin mineralization are found. These are contact metasomatic deposits, greisen, cassiterite-quartz veins and placers. All of them occur along the contact zones of granite and the quartzitic phyllite and limestone country rocks.

West of Si Chon, on the eastern contact of this range contact metasomatic deposits and disseminated tin minerals have also been found. In this area, the tourmaline granite intruded limestone, resulting in a contact skarn. In the skarn brownish black cassiterite crystals 1–3 mm in diameter are associated with tourmaline, garnet, scheelite and pyrite (Suthakorn, 1973). Tin production is from the placer deposits derived from the disseminated cassiterite bearing granite and the skarn rocks. Farther south along the same contact zone cassiterite si found in quartz veins and in the adjacent greisen (for example, at Khao Manora, Tha Sala).

Generally, on the eastern slope of Khao Luang, the quartz veins strike in the E-W direction. At the southeastern border of the Khao Luang batholith another area of greisen mineralization is found in the vicinity of Ron Phibun. In the vicinity of Huai Yod, Trang Province, primary tin deposits are found associated with small biotite muscovite granite stocks. Types of mineralization include disseminated cassiterite in altered granite and hydrothermal veins.

Songkhla-Betong District

The Songkhla-Betong District comprises the area between Songkhla-Satun-Betong and Yala (Fig. 9). The intrusive rocks in this area are mostly small stocks of biotite-muscovite granite of Cretaceous-Tertiary age. The majority of the country rocks are conglomerates, shales and sandstones of Triassic age with subordinate Permain limestone and Silurian-Devonian quartzite. Tin mineralization usually occurs around the contacts of the granites and the Triassic tocks (Suthakorn, 1971).

The principal type of mineralization in this area is hydrothermal tin-bearing quartz lode with tourmaline, fluorite, and pyrite as associated minerals. Tin production, however, is mostly from the placer deposits. Farther south the cassiterite hydrothermal lodes which are closely associated with greisen, are common. Several mines and prospects in Na Thawi district of Songkhla Province and in Yala Province (Tam Talu to Betong) work the placer or alluvial deposits which were derived from the erosion of the cassiterite-bearing quartz veins cutting across granite and Triassic shale and sandstone (Aranyakanon, 1969).

In Pin Yoh and Tam Talu of Yala area another contact metasomatic deposit is found. Here a skarn 10 to 50 m thick is formed at the contact between Permian limestone and granite. The mineral association includes actinolite, hypersthene, magnetite, iron pyroxene, garnet and cassiterite in sufficient amount to form mineral deposits. Some cassiterite in the outer zone developed acicular pseudomorphs after fibrous minerals (e.g. tremolite). This indicates that cassiterite replaced minerals in the metasomatic zone. Zinc, lead, and copper minerals are also found in the skarn area.

Narathiwat District

This district lies in southeastern most part of the peninsula extending from Narathiwat southward to the Malaysian border (Fig. 9). The bedrocks are coarse grained porphyritic biotite granites whose ages are poorly defined. They may be mainly of Triassic-Jurassic age as suggested by dating in Malaysia. Tin deposits are found on the eastern side of the granite masses. Types of mineralization includehy drothermal lodes and greisens and pegmatite dikes.

Cholburi-Chantaburi District

The Cholburi-Chantaburi district lies on the northeastern shore of the Gulf of Thailand (Fig. 10). The bedrocks consist of Carboniferous and Triassic-Jurassic granites intruded into Paleozoic quartzite, limestone and slate. Tin has been discovered at several localities in this area, i.e. Khao Khiew, Cholburi Province, Ban Kai, and Khao Chamao, Rayong Province, and Khao Sabap and Khao Soi Dao, Chantaburi Province (Aranyakanon, 1968; Kuentak, 1971; Kokcharoensup, 1972). Cassiterite is mostly fine grained and can be found in stream and beach sands. The reconnaissance geochemical survey by Hughes & Bateson (1967) and by Kokcharoensup (1972) revealed tin miner-alization at Khao Sabap, Khao Klaet, and Khao Soidaotai of Chantaburi Province. Significant quantities of tin were located around Khao Klaet and between Khao Klaetand between Khao Chak Lao in alluvium. Cassiterite is also found in beach sand inRayong Province. Aranyakanon (1969) considered that there was a possibility of tinin offshore areas.

Offshore Areas

Offshore tin has been mined in Thungka Harbour since 1907. Offshore tin production by means of offshore dredges and suction boats accounts for about 30% of the total production. The known offshore tin fields are in Takua Pa, Phangnga, and Phuket Provinces (Fig. 8). These offshore placers are usually found on and around granitic sea beds and are believed to be drowned placers, the result of sea level rises after the Pleistocene. Other offshore areas which have been explored for placer tin include: (1) the offshore areas Cholburi-Chantaburi districts (out of 24 drilled holes, only traces of tin were found in a few holes). (2) west and south of Samui island in the Gulf (dissapointing results after 18 holes). (3) Adang-Rawee archipelago area of Satun Province (promising result—see Aranyakanon *et al*, (1974), and (4) in the lake of Songkhla (Puwakool, 1977).

REFERENCES

ARANYAKANON, P., 1961. *The cassiterite deposit of Haad Som Pan, Ranong Province, Thailand.* Rep. Invest. no. 4, Roy. Dept. Mines, Bangkok, 182 p.

ARANYAKANON, P., 1964. *The Jae Son tin deposit, A. Joe Hom, Lampang:* Report of Mining Conference (1964), Dept. Min. Resources, Bangkok, (in Thai, unpublished).

ARANYAKANON, P., 1968. Potentials of tin ore in Thailand. *Min. Res. Gazette,* 13, no. 4, 11–15 (in Thai).

ARANYAKANON, P., 1969. Tin deposits in Thailand: Prepared for the 2nd Technical Conferences on Tin of the Intern. Tin Council, Bangkok, 32 p. (unpublished).

ARANYAKANON, P., SUTHAKORN, P., JANTARAMIPA, W., VICHIT, P., and KOKCHAROENSUP, W., 1974. *Tin exploration in the Adang-Rawee Archipelago Area, Satun Province, Southern Thailand.* Fourth World Conference on Tin, Kuala Lumpur, 29 p.

BAIRD, A.K., MORTON, D.M., WOODFORD, A.O., and BAIRD, K.W., 1974. Transverse Ranges Proince: A unique structural-petrochemical belt across the San Andreas Fault System. *Bull. Geol. Soc. America,* 85, 163–174.

BATEMAN, P.C., and DODGE, F.C.W., 1970. Variations of major chemical constituents across the central Sierra Nevada batholith. *Bull. Geol. Soc. America,* 81, 409–420.

BESANG, C., VON BRAUN, E., EBERLE, W., HARRE, W., KREUZER, H., LENZ, H., MULLER, P., and WENDT, I., 1975. *Radiometric age determinations of granites in Northern Thailand.* Proceedings of the CCOP Seminar on Radiometric Age Dating, Bangkok, 28 p.

BROWN, G.F., BURAVAS, S., CHARALJAVANAPHET, J. JALICHANDRA, N., JOHNSTON, D., SRESTHAPUTRA, V., and TAYLOR, C.G., 1951. *Geological reconnaissance of the mineral deposits of Thailand: Bull. U.S. Geol. Surv.,* 984; Mem. Geol. Surv., Roy. Dept. Mines, Bangkok, Thailand, 1, 183 p.

BRAUN, E. VON, BESANG, C., EBERLE, W., HARRE, W., KREVZER, H., LENZ, H., MULLER, P. and WENDT, I, 1976. Radiometric Age Determinations of Granites in Northern Thailand. *Geologisches Sahrbuch,* 21, part B, 171–204.

BURTON, C.K., and BIGNELL, J.D., 1969. Cretaceous-Tertiary events in Southeast Asia. *Bull. Geol. Soc. America*, 80, 681–688.

CHANTRANIPA, V. and RACHATASUWAN, N., 1975. *Geochemical survey of the tin deposits in Ampoe Takuapa and Kapong, Phangnga Province.* Economic Geology Division, Department of Mineral Resources, Thailand. 40 p. (in Thai).

ENGEL, A.E.J., ITSON, S.P., ENGEL, C.G., STIKENEY, D.M., and CRAY, E.J. Jr., 1974. Crustal evolution and global tectonics: A petrogenic view. *Bull. Geol. Soc. of America*, 85, 843–858.

FAURE, G. and POWELL, J.L., 1972. *Strontium isotope geology.* Springer-Verlag, New York.

GARSON, M.S., YOUNG, B., MITCHELL, A.H.G., and TAIT, B.A.R., 1975. *The geology of the tin belt in Peninsular Thailand around Phuket, Phangnga and Takua Pa:* Inst. Geol. Sci. Overseas Memoir, 1, 112 p.

GERMAN GEOLOGICAL MISSION (GGM), 1972. *Final report of the German Geological Mission to Thailand* 1965–1971. Hannover 94 p.

HUMMEL, C.L., and PHAWANDON, P., 1967. *Geology and mineral deposits of the Phuket mining district, South Thailand:* Rep. of Investigation, Department of Mineral Resources, Thailand, no. 5, 118 p.

HUGHES, I.G., and BATESON, J.H., 1967. *Reconnaissance geological and mineral survey of the Chantaburi area of southeast Thailand:* Inst. Geol. Sci., London Overseas Div. Rep. no. 7, 20 p. (unpublished).

HUTCHISON, C.S., 1972. Tectonic evolution of the Malay Peninsula and Sumatra—a personal view. Abstracts of papers, Regional Conference on the Geology of Southeast Asia, Kuala Lumpur, Malaysia, 20–25 March, 1972. Annex to *Newsletter Geol. Soc. Malaysia*, no. 34, 29–32.

KOKCHAROENSUP, V., 1971. *Aerial photo-interpretation of geology of Ampoe Tong Phabhume, Kanchanaburi Province.* Economic Geology Division, Department of Mineral Resources, Thailand. 7 p (in Thai).

KOKCHAROENSUP, V., 1972. *Geological survey of the Khao Klaed tin deposits, Ampoe Thai Mai, Chantaburi Province.* Economic Geology Division, Department of Mineral Resources, Thailand. 30 p. (in Thai).

KOKCHAROENSUP, V., and VICHIT, P., 1977. *Geological and geochemical survey of the tin deposits in Tha Lao Basin, Ampoe Tha Yang and Cha Am, Petchburi Province.* Economic Geology Division, Department of Mineral Resources, Thailand. 55 p., (in Thai).

KUENTAK, C. 1971. *Geochemical survey of the Khao Soi Dao National Game Resources Ampoe Thai Mai, Makham, and Pong Namron, Chantaburi Province and Ampoe Sra Kaew, Prachinburi Province.* Economic Geology Division, Department of Mineral Resources, Thailand. 26 p. (in Thai).

LIPMAN, P.W., PROSTKA, H.J., and CHRISTIANSEN, R.L., 1971. Evolving subduction zones in the western United States, as interpreted from igneous rocks. *Geol. Soc. Am. Abstracts with Program*, 3, 148.

LOWATANATRAKUL, K., 1969. Offshore tin deposits of Thailand. *Thai Min. Res. Gazette*, 14, 42–45 (in Thai).

NUTALAYA, P., 1975. CIPW norms of Thai granites (unpublished).

PITAKPAIVAN, K., 1969. Tin bearing granites in Thailand. *Proc. 2nd Tech. Conf. on Tin, London*, 283–298.

POLDERVAART, A., and PARKER, A.B., 1964. The crystallization index as a parameter of igneous differentiation in binary variation diagram: *Am. Jour. Sci.*, 262, 281–289.

PUWAKOOL, S., 1977. *The potential and exploration work on tin in Thailand.* Inter. Tin Symposium, La Paz, Bolivia, 12 p.

SUTHAKORN, P., 1971. *Geological survey of tin deposits in Songkhla Province.* Economic Geology Division, Department of Mineral Resources; Thailand. 61 p.

SUTHAKORN, P., 1973. *Klong Paw tin deposits, Ampoe Sichol, Nakhonsithammarat Province.* Economic Geology Division: Department of Mineral Resources, Thailand, 5 p.

TANTISUKRIT, C., 1975. Review of metallic mineral deposits (of Thailand): *Proceedings of the Conference on the Geology of Thailand*, Special Publication, Department of Geological Sciences, Chiang Mai University, 1, 186–189.

TEGGIN, D.E., 1975. *The granites of Northern Thailand*. Ph.D. Thesis, Univ. of Manchester, England, 198 p.

VEERABURAS, M., and JAPAKASETR, T., 1969. Metallogenic provinces in Thailand. *Proc. 2nd Tech. Conf. on Tin, London*, 275–282.

VICHIT, P., 1971. *Geological Survey of the tin deposits in Tung Kwian Teak Plantation, Ampoe Hang Chat, Lampang Province*. Economic Geology Division, Department of Mineral Resources, Thailand, 72 p.

VICHIT, P., ISRANGKUR, P., RACHATASUWAN, N., 1971. *Geological Survey the tin deposits, Ampoe Pai, Mae Hong Son Province*. Economic Geology Division, Department of Mineral Resources.