Development Geology for Thailand into the Year 2000
Chulalongkorn University, Bangkok, Thailand, 13-14 December 1990

With the compliments of the authors.
Dr. Punya Charusiri

GEOLOGY AND SN-MINERALIZATION AT PINYOK MINE YALA, SOUTHERN THAILAND

B. CHARUSIRI* and P. CHARUSIRI**

ABSTRACT

Sn - (W) ore deposit at Pinyok mine situates in an extensive contact zone between Late Triassic (218-220 Ma, 40 Ar/39 Ar method) monzogranite and Permian limestone.

According to field evidences and mineral associations, skarn area can be classified into 3 zones; namely, inner zone, transitional zone, and outer zone. The inner zone is an economic zone for cassiterite production. Diopside - hedenburgite - actinolite- K-feldspar-cassiterite- malayaite is an assemblage for the inner zone whereas clinozoisite-chlorite-magnetite-diopside - garnet - cassiterite - malayaite - is for the transitional zone and garnet - wollastonite - vesuvianite - magnetite - pyrite - arsenopyrite - cassiterite is for the outer zone. Calcite and quartz are found throughout the skarn area.

The presence of malayaite, Sn-bearing garnet and Ba-bearing K-feldspars together with geochronological investigation indicates that Sn-mineralization in skarn area may be the hydrothermal effect and is induced later than skarnization. A mid-Cretaceous Sn-mineralization in this area is most probable.

The Pinyok Sn - (W) skarn has been simply classified as a metasomatic exoskarn. Moderate proportion of magnetite to pyrite and retrograde epidote found in the inner zone may indicate oxidizing environment of skarnization. It is concluded, based on Kwak 1987's classification, that the Pinyok Sn - (W) skarn is the magnetite-tin skarn type.

---

* *Economic Geology Division, Department of Mineral Resources, Bangkok 10400, Thailand.*

** *Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand.*

INTRODUCTION

Location and accessibility

The Pinyok area situates at Tambon Tamtalu, Amphoe Bannang Sata, Changwat Yala southern Thailand at latitude 6° 03′ and 6° 22′ N and longtitude 101° 01′ and 101° 18′ E. It is located on the topographic map scale 1:50,000 series 7071 map sheet 5221 III (King Amphoe Tarn To) at approximate horizontal grid reference 687 to 691 and vertical grid reference 738 to 741.

The mine is accessible from Amphoe Muang Yala via highway no.410 (Yala-Bannang Sata-Betong). It is approximately 54 km from Amphoe Muang Yala to junction at Ban Klong Tung Kradeng, and from there, turn right to the west, 1.5 km on a dirt road to the mine.

Previous work

The Pinyok tin mine has been operated since 1940's and investigated in various aspects by several authors. Geological recconnaissance of this mine was recorded by Brown et al., (1951). Geological settings of the mine and adjacent areas were provided by Charusiri et al. (1975), Muenlek et al., (1979) and Chonglakmani et al. (1983). John (1967) and Aranyakanon (1969) studied the geological and mineralogical relationships of the deposit and proposed that this deposit is of metasomatic type. Rachadawong and Gamo (1966) described the general features of the mine and emphasized upon the dressing technique for the extremely fine complex tin ore. Geochronological work on granite of tin-tungsten deposits of Thailand including granite at Pinyok area was held by Ishihara et al. (1980) and Pongsapich et al. (1983). Charusiri et al. (1989) recently proposed new dating method (Ar/Ar step heating) for age of granite and mineralization at Pinyok and other several nearby deposits where granite concerned.

Purposes of Study and Methods of Investigation

Most of economic minerals obtained from skarn deposit type, e.g. W - SN - Cu - Pb - Zn - and Fe, are generally of low grade ore. However, when other economic viability such as geometry, overburden, metallurgy, politics, infrastructure, and market condition are taken under the consideration, it maintains the skarn deposits as the most productive source of the world for such minerals especially tin and tungsten. Understanding of the geology and ore genesis of tin-tungsten skarn is, therefore, important to all economic geologists. Tin and tungsten skarn deposits in southern part of Thailand are of small size but evidently found in many areas in Changwat Yala and Surat Thani (Aranyakanon, 1969). The Pinyok mine has produced medium to low grade cassiterite ore (varying grade 21-50% Sn) since 1940's but little has been known on the skarnization and mineralogy of the deposit. This study aims to provide the better understanding of mineralogy, mineralization, and also skarn classification.

Petrographic studies using X-ray diffraction, electron microprobe analysis and ore-microscopy are processed on the rock and ore samples from the mine in order to gain the details of mineralogy and mineralization. Geochronological data referring to the record of Charusiri (1989) are used in this paper where sequential geological episodes are mentioned.

Geology

The study area is underlain by 2 major rock types; granitoid rock and more extensive carbonate rock. Skarn zone enclosing Sn-ore deposit is found along the contact zone of the two rock types. Most of the area is covered by Permian limestone which includes mainly light to dark grey, massive to thickly bedded limestone interbedded with shale (Figure 1). Granite exposure is found about 50 m SE of the contact zone where medium-grained, homogeneous granite facies are predominant. Granitoid rock is mainly corse-grained biotite ± (muscovite) granite. They are generally uniform in mineralogy but grade from coarse-grained and porphyritic biotite granite to medium-grained and equigranular biotite-muscovite granite. Chemical and modal analyses of these rocks shown in table 1 display (A/CNK) ratio ranging from 1.02 to 1.24) which indicate the monzogranite rock type with paraluminous composition. Granite rock samples are collected from locations nearby the contact zone for dating investigation. Biotite is seperated and dated using the $^{40}Ar/^{39}Ar$ metohd (see details in Charusiri, 1989). The study yields ranging age of granite from 217.8 to 220 Ma (Late Triassic). Sn-mineralization is inferred, however, to form as a result of hydrothermal solution from Mid-Cretaceous (90-100 Ma) granite body.

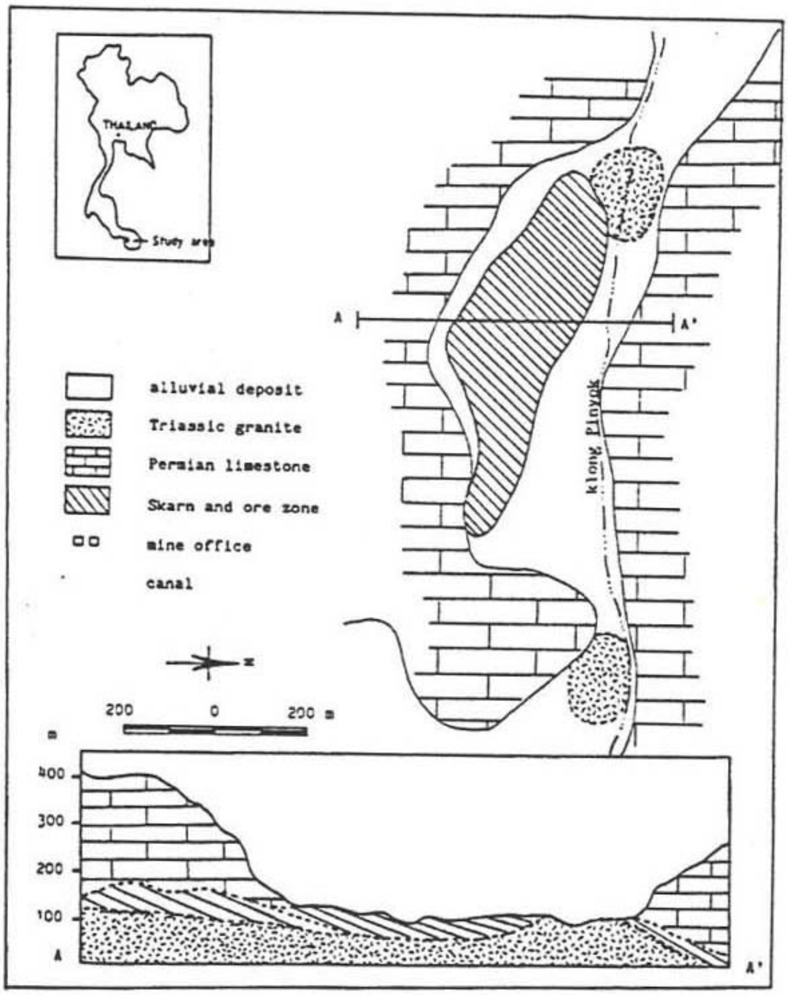


Fig. 1. Geologic map of Pinyok area, Yala, southern Thailand (modified after Siribumrungsukha, B. and others, pers. comm.).

Table 1. Whole - rock analyses and CIPW Norm of granitoid rock, Pinyok mine

whole rock analyses			CIPW Norm		
	PY-5	PY-18		PY-5	PY-18
SiO_2	68.35	72.76	Q	25.36	28.30
TiO_2	0.04	0.26	Or	29.84	34.04
Fe_2O_3	0.95	<0.25	ab	22.42	28.77
FeO	2.01	1.02	an	10.33	3.55
Al_2O_3	14.45	13.70	c	0.84	0.57
MnO	0.05	0.02	hy	7.02	2.15
MgO	1.60	0.35	mt	1.38	0.36
CaO	2.32	0.82	il	0.08	0.49
Na_2O	2.65	3.40	ap	0.42	0.19
K_2O	5.05	5.76	di	0.00	0.00
P_2O_5	0.18	0.08	DI	77.62	91.11
LOI	0.00	0.90			
Total	98.49	99.32			
A/CNK	1.02	1.03			
Fe/Fe (t)	0.32	<0.18			

A/CNK = Molecular proportion ($Al_2O_3/CaO+Na_2O+K_2O$)

DI = Differentiation Index

Fe/Fe(t) = $Fe^{+3}/Fe^{+3}+Fe^{+2}$

SKARN ZONE

Cassiterite from the Pinyok mine has been recovered from the open-cut mining area, eluvial and residual deposit and, in part, from old tailings. It is evident that the concentration of cassiterite ore varies from place to place. Most of economic cassiterite is obtained from the skarn zone which is adjacent to granitic bodies (Aranyakanon, 1969 and Charusiri , 1989) and decrease southwardly. Granitic intrusion, as usual, has irregular outlines below the carbonate rock. This gives rise to local granite exposures in the contact zone and also variation of grade-ore. However, the general trend of the contact zone is lying in E-W direction and the skarn area is approximately 200 meter wide (Rachadawong and Gamo 1966).

With the connection of ore concentration, field evidence, and mineral associations, the skarn area can be defined, outwardly from the contact line, into 3 zones; inner zone, transitional zone, and outer zone (Figure 2).

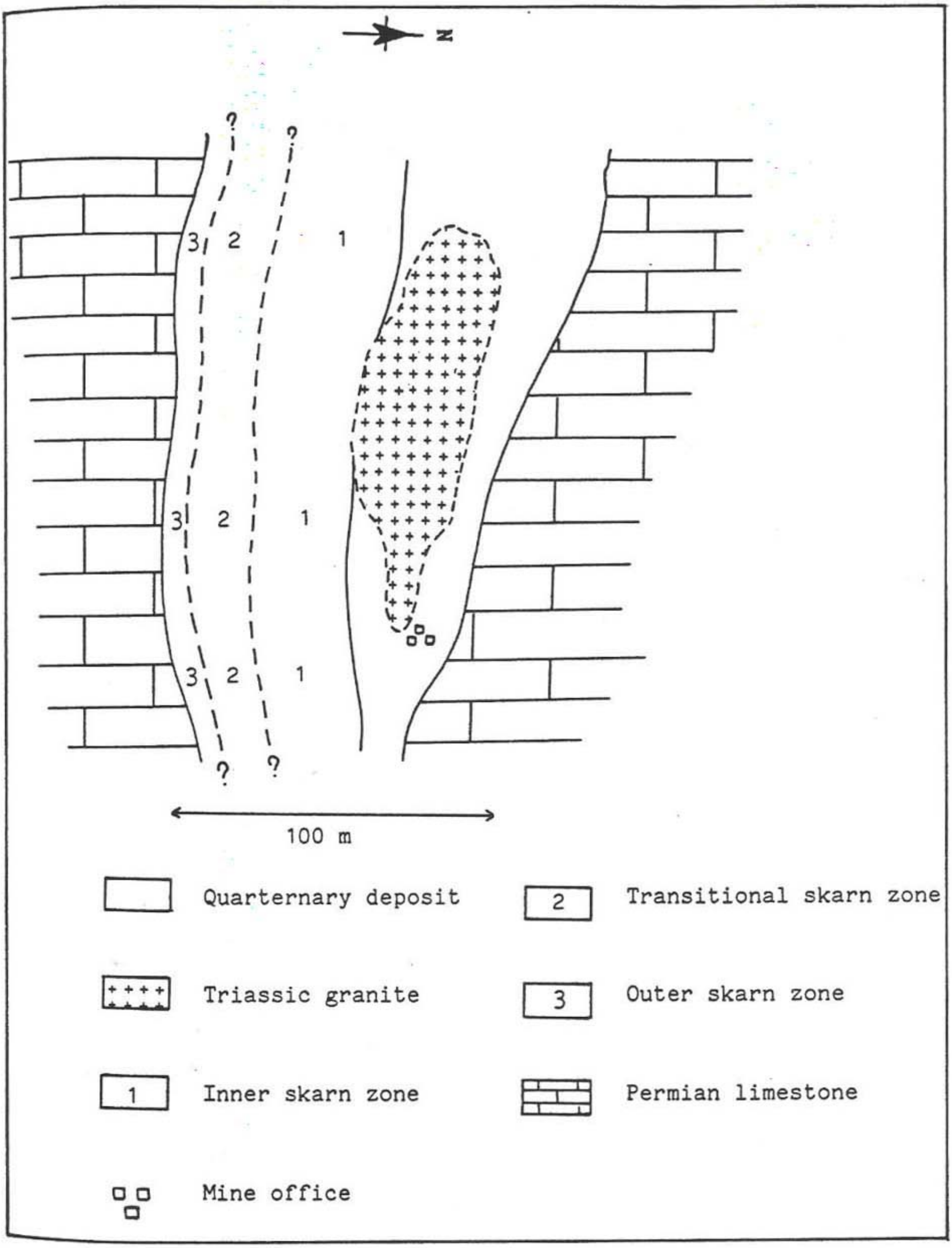


Fig. 2. Sketch skarn zones of the Pinyok area.

Inner zone

This zone yields the highest cassiterite production of the mining area. It is characterized by the assemblage of pyroxene (diopside, hedenburgite)-actinolite-cassiterite-malayaite-K-feldspar (Figure 3). Magnetite, garnet, and chlorite are accessory minerals. Calcite and quartz are commonly found. Epidote and fluorite are usually found in vein and are considered to be included in retrograde metamorphic facies (Figure 4). Cassiterite is present in very fine-granied and acicular forms with average diameter of 0.01 mm. (Figure 5) distributed throughout this zone.

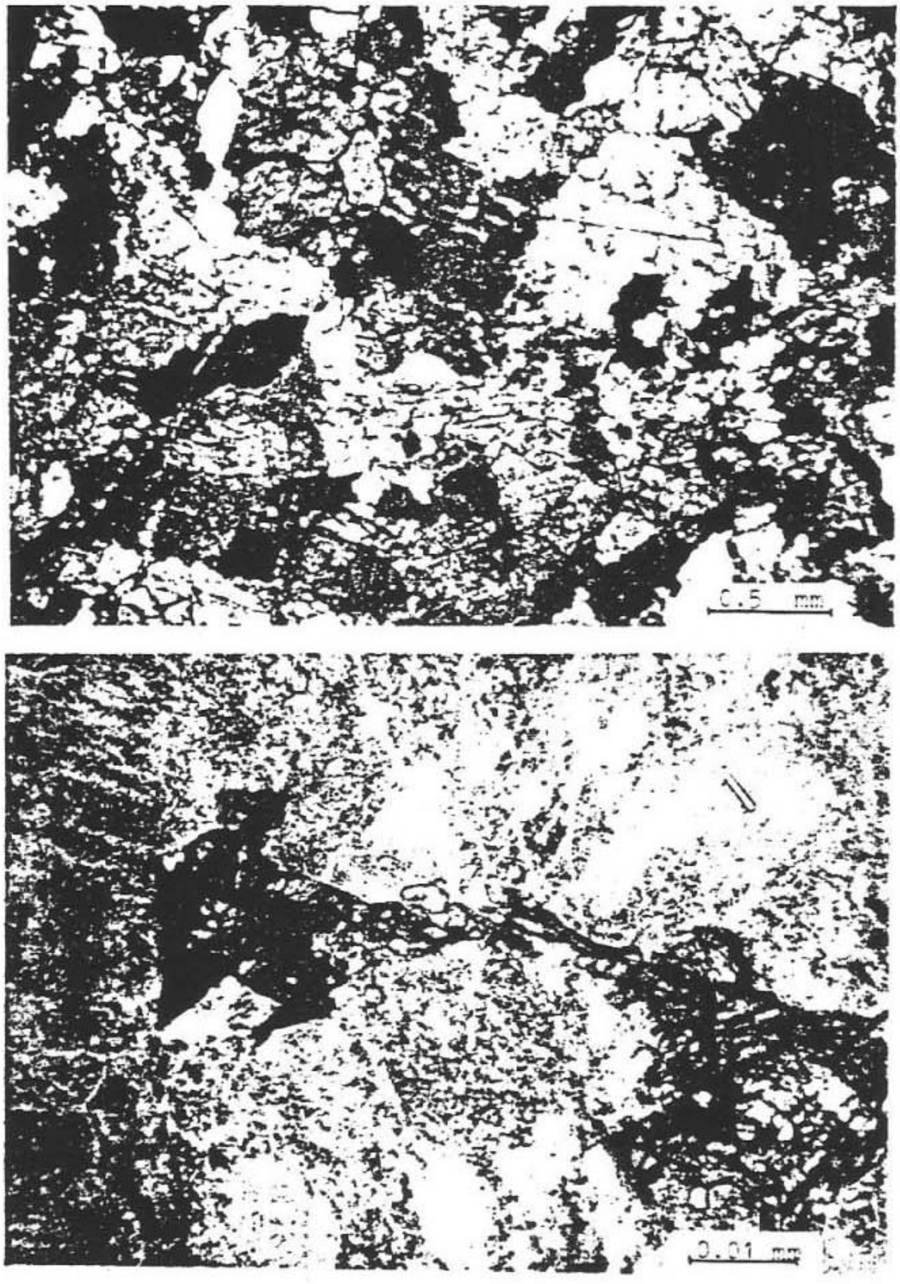


Fig. 3. Photomicrographs of Inner skarn zone.

3a. diopside-hedenburgite-tremolite-actinolite are of major metamorphic assemblage in Piyok skarn (magnification 25, crossed polars).

3b. brown cassiterite and slender malayaite as inclusions in K-feldspar of inner skarn zone (magnification 160).

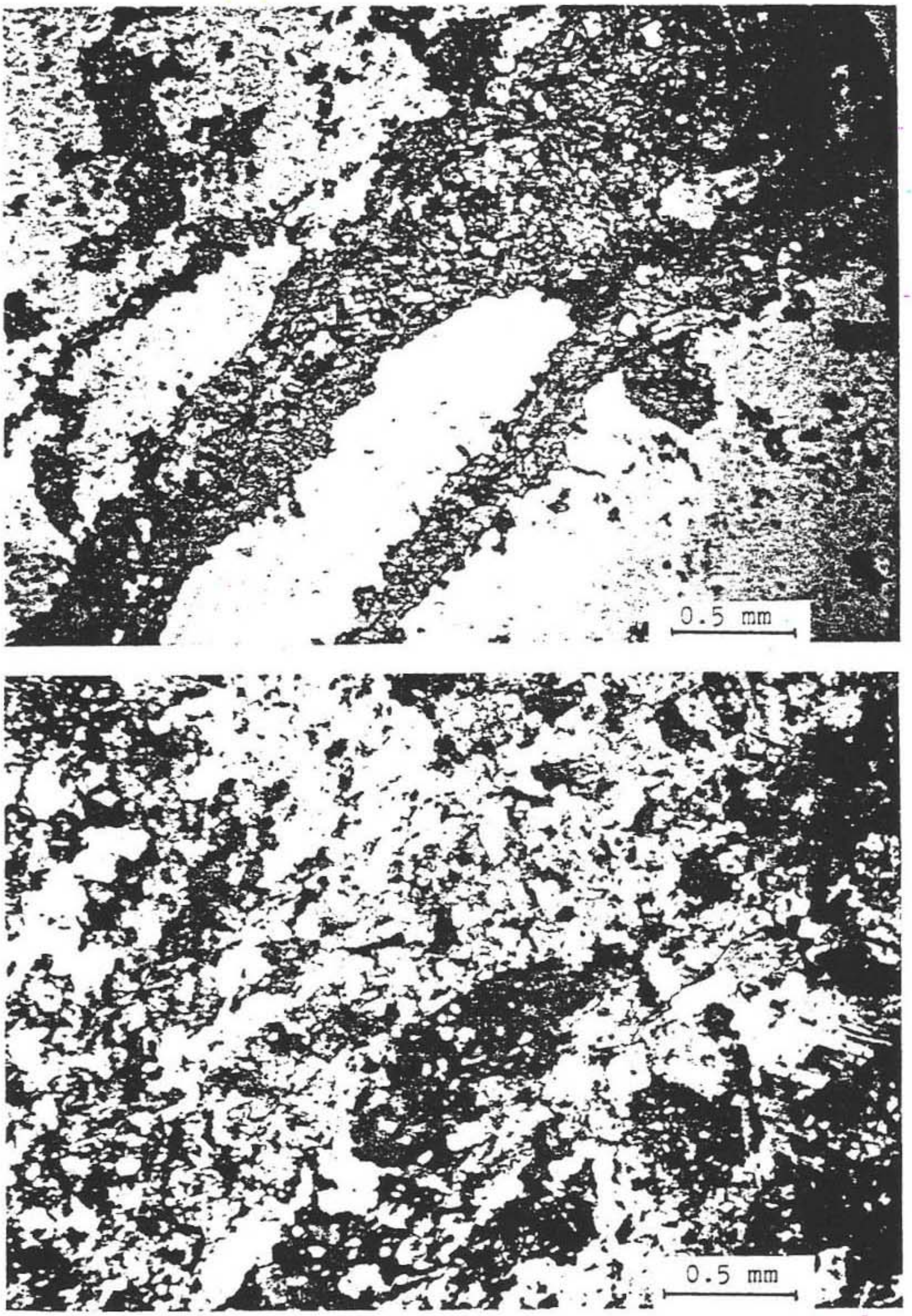
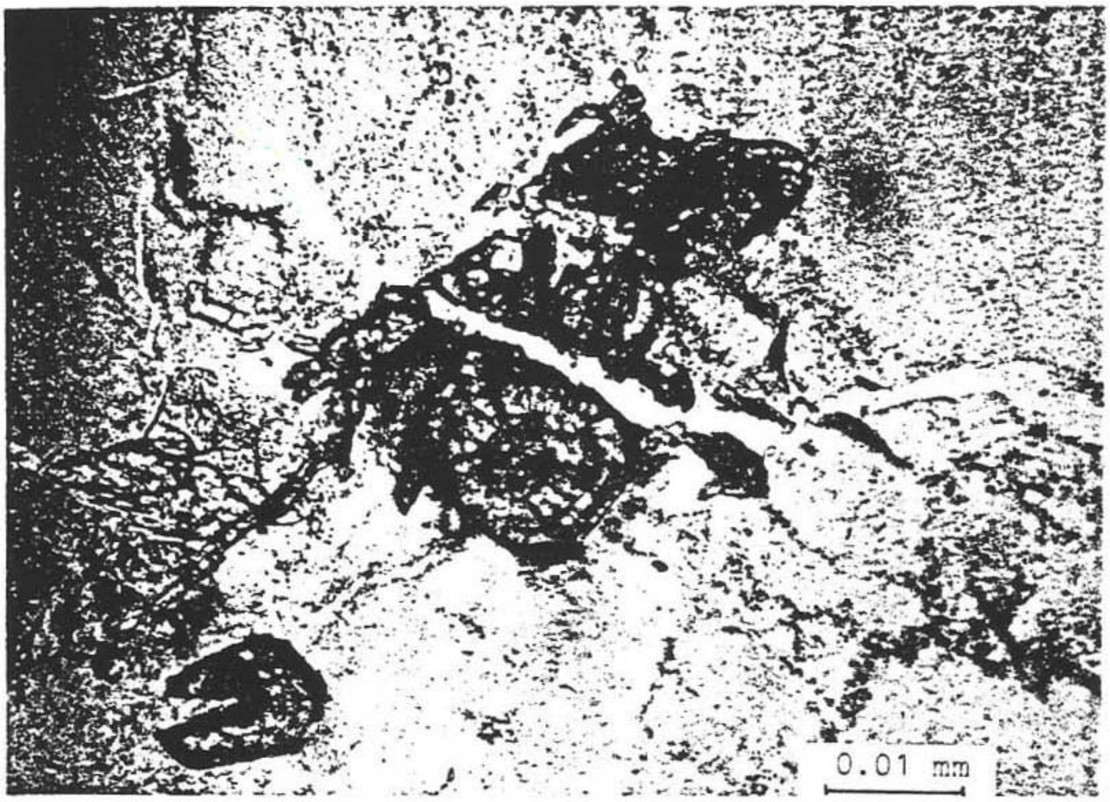


Fig. 4. Retrograde epidote and fluorite vein in K-feldspar, magnification 25 (4a. without crossed polars, 4b with crossed polars).



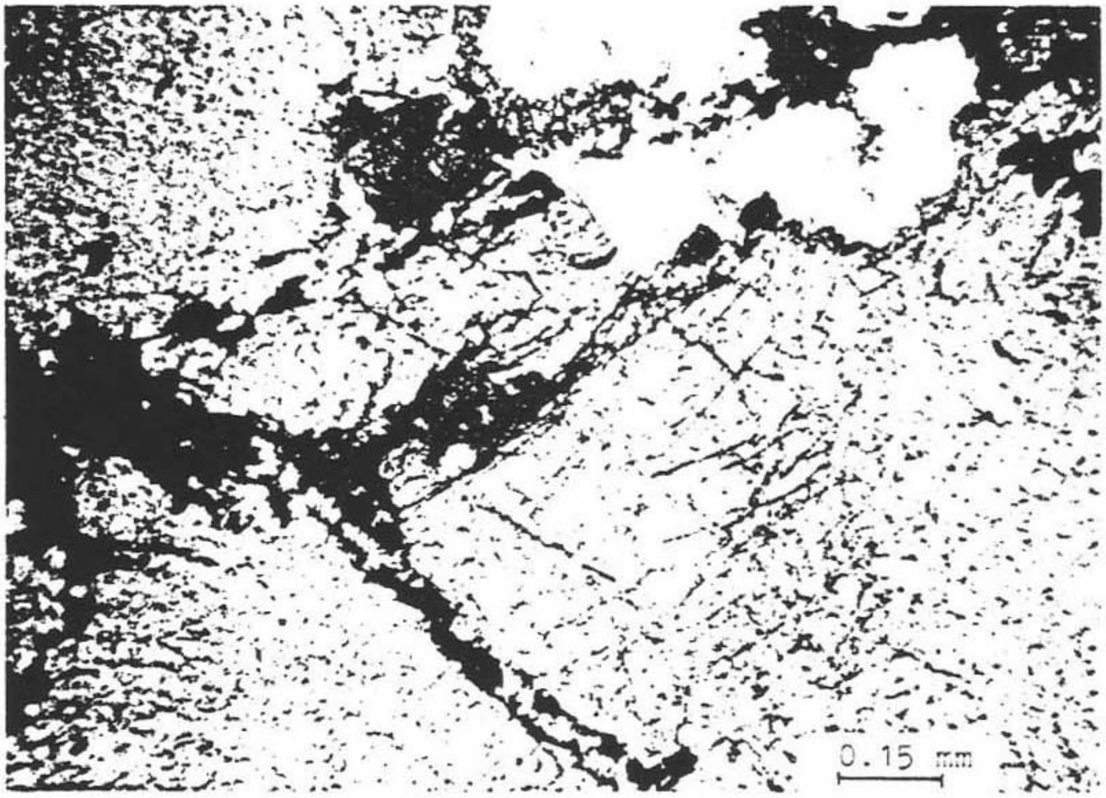


Fig. 5a. Cassiterite crystals in K-feldspar, Pinyok mine (without crossed polars).

5b. Brown very fine-grained cassiterite emplaced in metamorphic assemblage (without crossed polars).

Transitional zone

Transitional zone is differentiated from the others by an assemblage of clinozoisite-chlorite-magnetite. Diopside is found in less amount than that of the inner zone. Fine-grained garnet is locally present. Cassiterite and malayaite also distribute in this zone but of less concentration. Quartz and calcite are associated minerals. No distinct boundary between this zone and others is observed. Malachite and cuprite are found in weathered part of this zone. It is reported by Nutalaya et al., (1979) that lead, zinc, and copper minerals are also found in this skarn zone.

Outer zone

Outer zone is the outermost zone which is equivalent to garnet zone stated by Aranyakanon (1969). This zone is very rich in garnet. Due to the resistance of garnet, this zone can be noticed as long ridge parallel to the contact strike (Aranyakanon, op cit.). The associated minerals in this zone include calcite, quartz, wollastonite and idocrase. Magnetite, pyrite, arsenopyrite, and minor chalcopyrite are important opaque minerals in this zone (Figure 6).

DISTINGUISHED MINERALOGY

Skarnization in Pinyok area originate several minerals in the skarn zone as mentioned in the skarn area. The distinguished minerals including malayaite, Ba-bearing K-feldspars, and garnet have been emphazised in details in order to gain the better understanding of skarnization and mineralization.

Malayaite

Malayaite, CaSnOSiO4 was firstly found at Perak, Malaysia by Ingham and Bradfood 1960 and later named by Alexander and Flinter (1965). In Thailand, this mineral was recorded only from this mine by John 1967 and Aranyakanon 1969. The crystal is of monoclinic with the lattice constants a = 6.66°A, b = 8.89°A, c = 7.15°A and β = 113° 20′ (Ramdohr and Strunz, 1967). Under microscope (Figure 7), malayaite displays slender wedge shape with pale brown colour, faint pleochroism; light and dark brown, extreme birefringence, and extinction parallel to the elongation of the crystal. Optic sign is biaxial (+) with moderate 2v angle. Generally speaking, it displays similar shape and optical properties to those of sphene. The existing of tin-bearing sphene and ordinary sphene was recorded by Ramdohr (1935) and Ti-bearing (10-20%) malayaite was found from Pirak (Ingham and Bradfood, 1960). It is tentatively presumed that a solid solution of the two minerals is probable. In such case, malayaite is isomorphous with sphene. It was confirmed by the study of Takenuochi (1978) who synthesized a malayaite by hydrothermal experiment. He found that a complete solid solution exists in malayaite-sphene system. However, the immissibility phase diagram of malayaite-sphene (Figure 8) is evident that Ti-rich malayaite and Sn-rich sphene ends would not formed in skarn environment because they require forming-temperature which is lower than that of skarn.

Electron microprobe analyses have been done on Pinyok malayaite which intergrows with K-feldspar and reported in Table 2. SnO_2 content in malayaite varies from 6.86 to 9.65 wt % With relevant to those studies, The plot of SnO_2 versus TiO_2 shown in Figure 9 indicates that titanium in crystal structure is probably partially substituted for by tin. The mineral is, therefore, considered to be Sn - bearing mineral with of no economic value at present.

Table 2. Electron microprobe analyses of malayaite. Pinyok mine

(wt %)	#1	#2	#3	#4	#5	#6	#7
SiO_2	28.64	32.35	29.46	30.11	28.32	26.28	28.11
TiO_2	32.61	31.11	31.45	30.25	33.10	34.25	32.66
Al_2O_3	-	-	0.15	0.05	0.06	0.35	0.07
SnO_2	7.11	8.29	8.11	9.65	6.97	6.86	7.89
FeO	1.35	1.62	1.45	0.39	1.89	2.11	1.96
MnO	0.27	0.11	0.32	0.15	0.11	0.05	0.14
MgO	-	-	0.05	0.06	0.05	0.11	0.07
CaO	29.25	26.55	26.11	28.32	28.92	28.99	27.86
Na_2O	-	-	0.05	0.06	0.07	0.02	0.11
K_2O	-	-	0.13	0.14	0.17	0.16	0.14
Total	99.23	100.03	97.28	99.18	99.66	99.18	99.01

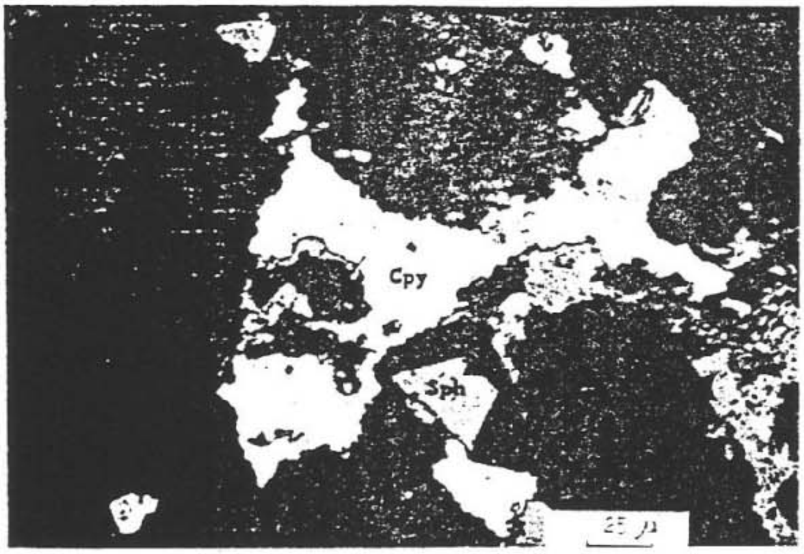


Fig. 6a. Concentric precipitation of very fine-grained to massive pyrite is major opague minerals. Arsenopyrite (blue tint) veinlet with crystalline pyrite are lying along fracture of massive pyrite. (magnification 500 in oil lens).

6b. Chalcopyrite, sphalerite, and hematite fill in pore space of skarn rock.(magnification 320).

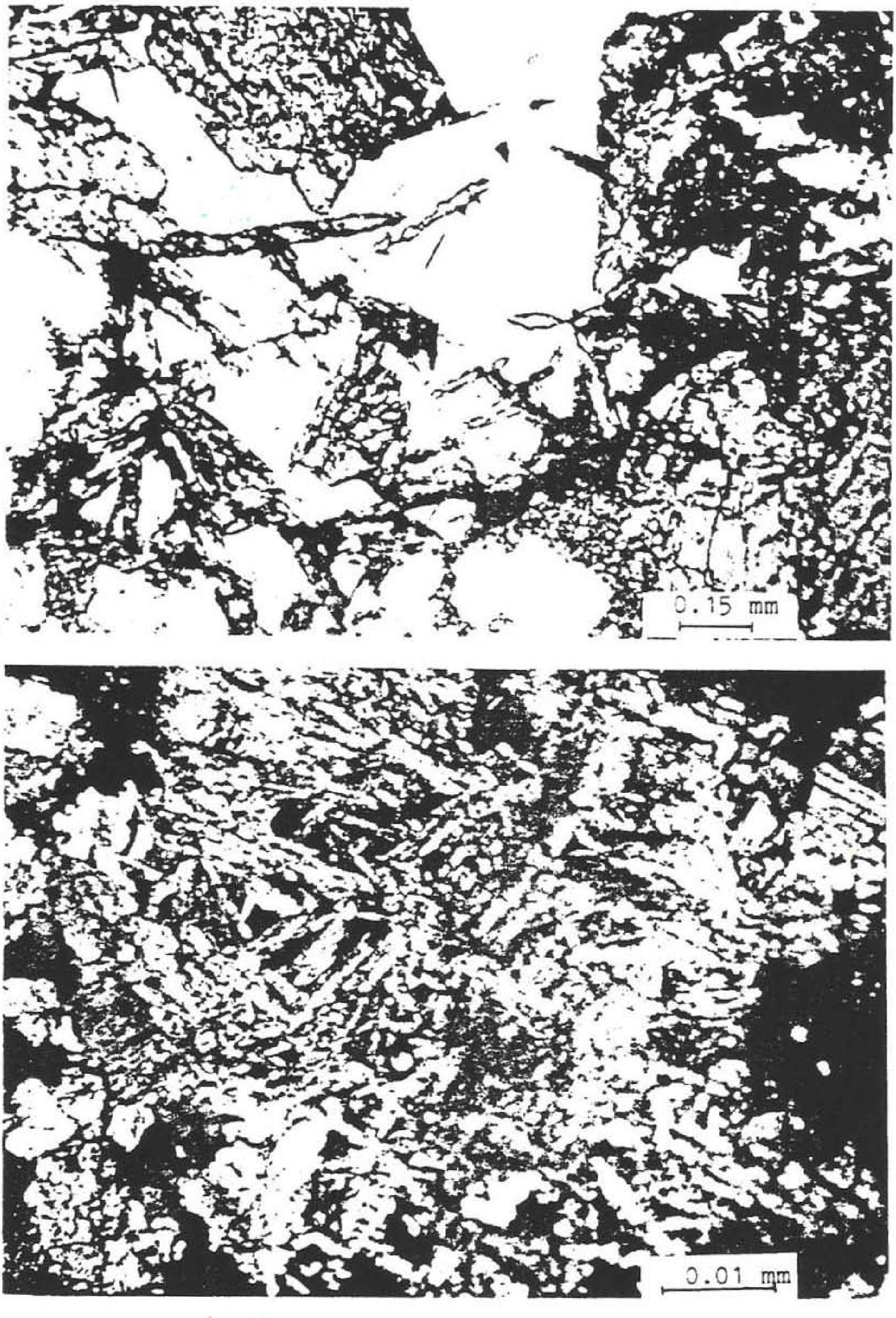


Fig. 7. Spindle shaped crystal of malayaite and less amount of epidote in Ba-bearing K-feldspar (7a; magnification 63, 7b; magnification 160, with crossed polars).

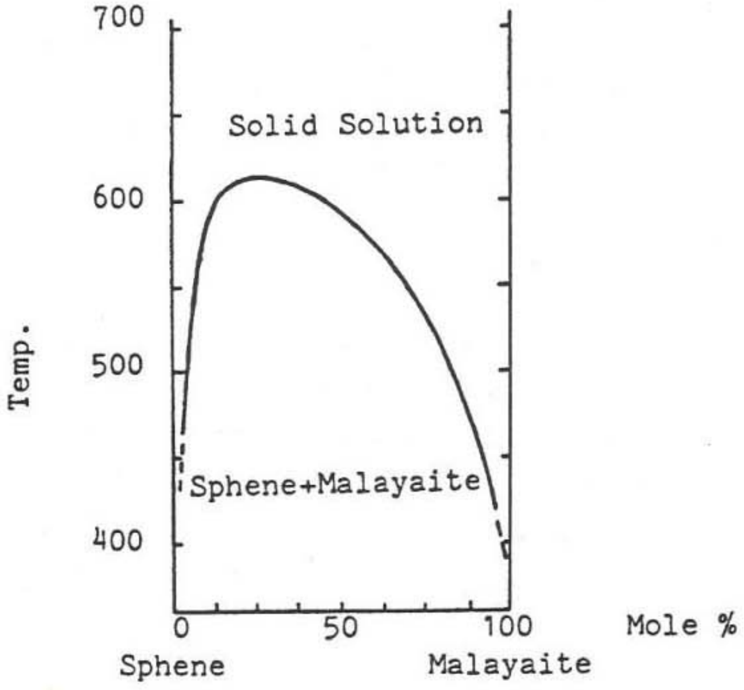


Fig. 8. Phrase diagram of the malayaite-sphene solid solution at 1 Kb. (after Takenouchi, 1971).

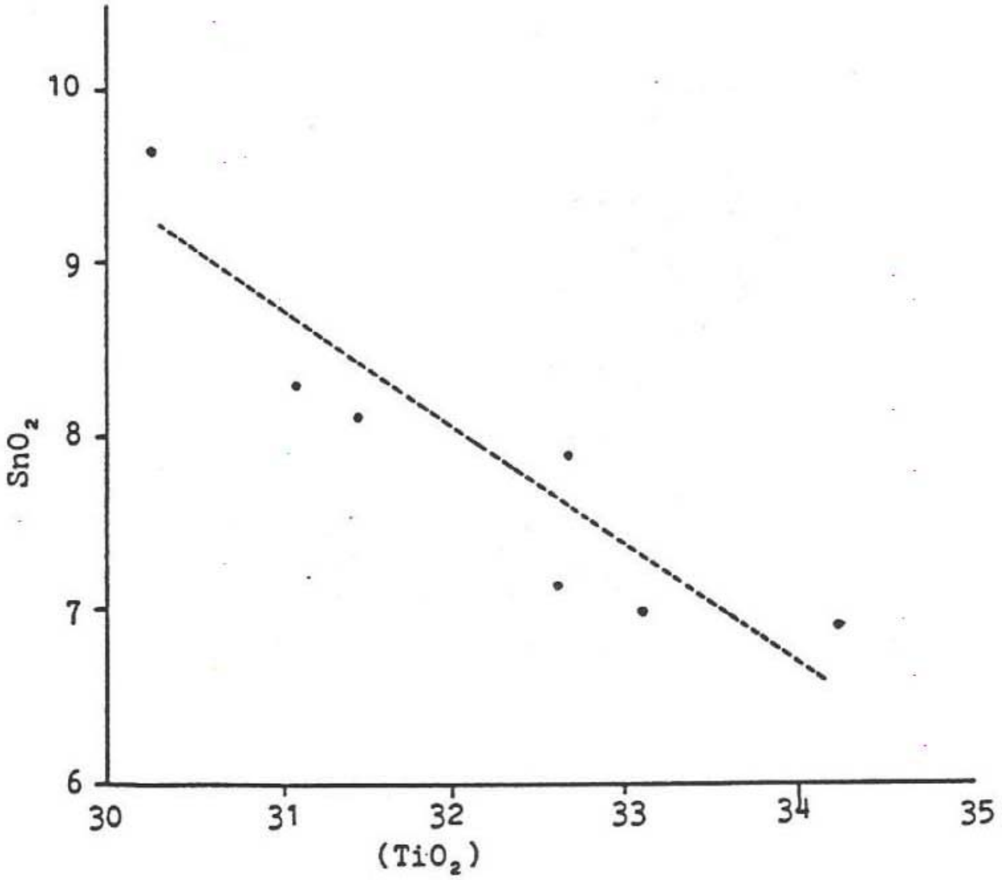


Fig. 9. Plot of Sno_2 and TiO_2 (wt.%) of Malayaite, Pinyok mine.

Ba bearing K-Feldspar

K-feldspar is mainly found in the inner skarn zone. It is commonly intergrown with malayaite and contained sericite as inclusion (see Figure 7). Besides petrographic investigation, X-ray diffraction study (Figure 10) has been done for concentrated K-feldspar from skarn zone, The result reveals an Al-Si ordering intermediate between those of orthoclase and microcline. Moreover, electron microprobe scanning of the K-feldspar displays the presence of Barium which situates in the molecular structure.

Ba-bearing potassium feldspar was selected and dated using step-heating technique (details in Charusiri 1989). It is found that age of Ba-bearing potassium feldspar, which is closely related to cassiterite, is about 185 Ma. It is interpreted, at this point, that mineralization of cassiterite together with K-feldspar is not coeval with the emplacement of granite of 218-200 Ma but may indicate subsequent hydrothermal effects introduced afterward.

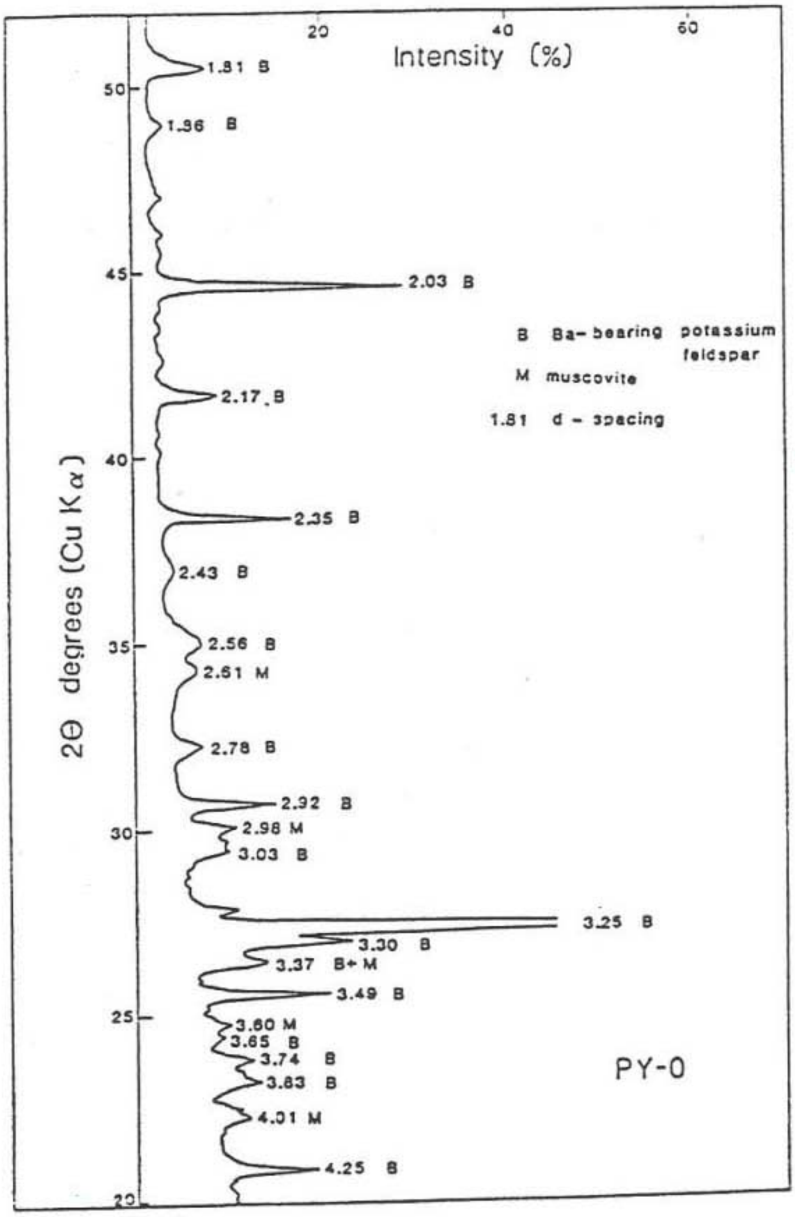


Fig.10. X-ray diffraction pattern of Ba-bearing K-feldspar, Pinyok mine.

Garnet

Garnet is an predominant mineral found in the outer zone. It is mainly found in form of euhedral to subhedral crystals with varying colours: brown, green, and yellow. The average diameter is 0.5 cm but, locally, it is also found as fine-grained and massive intergrowth. Garnet at Pinyok is invariably zoning and displays anomalous interference colour (Figure 11). Electron microprobe analyses shown in Table 3 indicate that Pinyok garnet is of andradite composition. Furthermore, spectrum scanned by electron microprobe reveals the presence of Sn in garnet. It is considered to be stanniferous andradite. Aranyakanon (1969) reported that cassiterite presented in this zone is found as acicular crystals and radiating aggregates. It is interpreted to be the product of replacement of the pre-existng tremolite for by tin. Similarily, the existing of Sn in garnet may evident that the mineralization of cassiterite is introduced after and replaced garnet and other contact minerals.

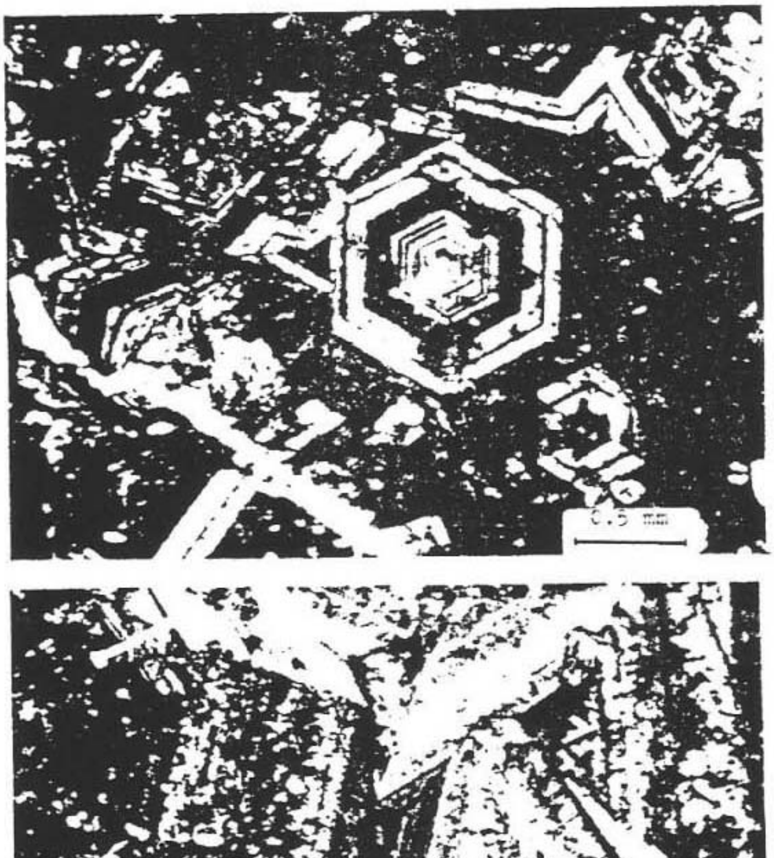


Fig.11. Zoned garnet crystals abnormally show birefringence. Deep brown biotite inclusions are common (magnification 25, crossed polars).

Table 3. Electron Microprobe Analysis of garnet, Pinyok mine.

(wt %)	#1	#2	#3	#4	#5	#6	#7
SiO_2	35.80	34.28	35.22	35.20	35.47	36.62	36.57
TiO_2	-	-	-	-	-	0.56	0.55
Al_2O_3	5.14	0.27	4.22	2.31	2.25	8.08	8.07
Cr_2O_3	0.09	0.12	-	0.05	0.06	-	-
FeO	21.77	27.37	22.25	25.37	25.23	19.34	17.80
MnO	0.65	0.53	0.54	0.46	0.53	0.83	0.33
MgO	0.07	0.17	0.07	-	0.06	-	0.06
CaO	33.14	32.39	32.98	32.93	33.02	32.95	34.18
Na_2O	-	-	-	-	-	-	-
K_2O	-	-	-	-	-	-	-
Total	96.64	95.09	95.30	96.33	96.63	98.36	97.56

SOME ASPECTS ON SKARN NOMENCLATURE AND CLASSIFICATION

Definition

Skarn deposits have been mined since at least Roman time and probably long before. The term "skarn" originated in central Sweden by miners to represent coarse-grained garnet-pyroxene-epidote gangue minerals associated with magnetite and chalcopyrite ore depposits (Geijer and Magnusson, 1952). It was generally referred to only gangue minerals until the time of V.M. Goldschmidt (1911). He considered skarn as a rock having calcic- or magnesiam-rich assemblages associated with ore in replaced carbonate near igneous contacts. Obviously, the meaning has been slightly diversed and considerably restricted to the real sense "sensu stricto". Since then researchs in the field of skarn related to mineral deposits have distributed worldwide and nomenclature was also compatable varying. In the skarn reviews (Smirnov, 1976, Einaudi et al., 1981; and Kwak, 1987), metasomatism, mineralogy, and petrography have been emphasized from hundreds skarn-ore deposits. It is the fact that many of those were not spatially related to igneous contacts. The nomenclature of Goldschimdt was, therefore, inadequate. The broardened viewpoint of skarn has been approached by Einaudi (1981), Shabynin (1981), and Kwak (1987) to include rocks produced by the replacement of calcic or dolomitic marble independent of whether calcic or magnesian silicates are abundant or rare. The replacement of non-carbonate rocks by calcic or magnesian silicates are also included.

Skarn can be originated by both purely metamorphic and purely metasomatic processes as well as by a wide range of a combination of the two. The formations of skarn deposits in terms of geologic setting, size, texture, and mineralogy span abroad range between the two end member processes. From field observations by early workers such as Lingren (1902, 1925), Goldschmidt (1911), Umpleby (1913), and Knorf (1918), the skarn forming processes were grouped, relying on the similar criterions, by Einaudi 1981 and Kwak 1986. The skarn-forming processes and their equivalent terms are listed in Table 4.

Table 4. Skarn-forming patterns and the related terms (after Einaudi, 1981 and Kwak, 1987).

1. Metamorphic recrystallization with no or little introduction of chemical component. Terms: calc silicate hornfels, recrystallized skarn, skarnoid, metamorphic skarn.	1. Replacement of a carbonate unit independent on amount of calcic or magnesian silicates minerals. Terms: skarn (Goldschmidt), distal skarn
2. Local exchange of components between unlike lithologies during high grade metamorphism. Terms: reaction skarn, bimetasomatic diffusional skarn	2. Replacement by greisen solution where F, B, Li-rich assemblages result. Terms: greisen skarn, apo* carbonate exogreisen
3. Local exchange at high temperature of components between magma and carbonate rocks. Terms: primary skarn, skarn of magmatic stage	3. Replacement of previous carbonate unit (1) and greisen skarn (2). Terms: retrograde skarn, apo skarn exogreisen
4. Large scale transfer of components over wide range of temperature between hydrothermal fluid (presumably from magmatic origin) and predominant carbonate rocks. Terms: skarn, secondary skarn, replacement skarn, ore skarn, skarn of the post magmatic stage, infiltrational skarn, metasomatic skarn	4. Replacement of non carbonate units including granitic pluton, basic to ultrabasic pluton, hornfels, and meta volcanic rocks. Terms: endoskarn, autoreactional skarn
	5. Rocks present in regionally metamorphosed terrains in which calcic and/or magnesian silicates are major constituents. There are of uncertain origin. Terms: reduced proximal calcic skarn (only for mineralogy)

* apo is a prefix expresing "after" or "replacing" often used in U.S.S.R.

In spite of the fact that metamorphic process in ore skarn deposits, in most cases, forms zoned aureole and, at this stage, is essentially barren of ore minerals, many ore skarn deposits originate during continued metasomatism overprinting the metamorphic assemblages. The metamorphic portions in ore skarn forming process are, however, important because they provide brittle calc-hornfels due to loss of volatile substances (O_2, CO_2, and H_2O). Moreover, this change takes place at constant volume and, thus, initiates the increased porosity. Those are considered to be ground preparation for extensive ore skarn deposits. The distinct differentiation between the two processes seems very difficult if possible. Only in calc-silicate skarn, Einaudi (1981) suggested the following useful criterions for such circumstance.

1. metamorphic rocks generally contain a large number of phrases for the number of components, whereas metasomatic rocks contain very few phrases for the number of components.

2. Bulk composition of all zones formed by metamorphism are identical, whereas discontinuities in bulk composition are common in metasomatism or introduced metasomatic elements (W, Sn, F, Li, etc.) are present.

Skarn Classification

Various authors have attempted to distinguish and classify ore skarn deposits using different parameters and nomenclature. Those previous works and their referrences are listed in Table 5.

The complexity of such classification is due to that those parameters are difficult to measure and their global scale variation. The classification of ore skarn deposits by Einaudi et al. (1981) is probably the most consistent available. This classification is based firstly on the dominant economic metals including Fe, W, Cu, Pb-Zn, Mo, and Sn that were found in the deposits and secondly on various mineralgical and geological features. The criterias used by the previous workers are still useful and are also taken under the consideration in the classification. Basis on the W-Sn skarn of Einaudi (1981), Kwak (1987) has modified and proposed the classification of W-Sn skarn (used as referrence in this paper). He classified W-Sn skarn into the seperated W-skarn and Sn-skarn and classified into subclasses using the above mentioned parameters as shown in Table 6.

Table 5. Useful criteria in ore skarn classification (after Kwak, 1987).

criterions	terms (- skarn)	references
1. depth	hypabyssal/abyssal	Zharikov,1970; Shabynin,1981
2. temperature	high/low	numerous
3. process	diffusional/infiltrational, bimetasomatic, exchange diffusional metamorphic/metasomatic	Zharikov,1970; Shabynin,1981; Korzhinski,1959; Kerrick,1976
4. stage relative to magma evolution	magmatic/postmagmatic	Zhaikov,1970
5. nature of ore fluid	pneumatolitic/hydrothermal	Lesnyak,1965
6. internal structure	massive,rhythmically layered (=wrigglite), laminar	Kwak and Askins, 1981
7. host rock	magnesian/calcic; autoreactional (=ultramafic); endoskarn (granitoid); aposkarn (skarn)	numerous including Zharikov, 1970; Einaudi,1982
8. relation to other units; structure	vein; frontal, column-like, brecciated, interstratal normal/ inverse (skarn around pluton or reverse	Burt,1978; Shabynin,1981
9. mineralogy	numerous, e.g., "tactite",cassiterite type; co-arsenide, copyrite; scheelite/ molybdoscheelite	numerous, Smirnov,1976 Sato,1982
10. distance to pluton	proximal/distal	Einaudi et al.,1982
11. inferred oxygen	reduced/oxidized	Einaudi et al.,1982
12. state of alteration of related pluton	mineralized pluton/barren stocks (Cu-skarns)	Einaudi et al.,1982
13. economic metals	Fe, Cu, W, Zn-Pb, Sn, Mo,	Einaudi et ai., 1981
	W-Mo-Cu, W,-Sn-F	Kwak and White, 1982
	Fe, Fe-Co, Cu, Pt, W, Mo, Pb-Zn Au, Sn, U, B, Be	Smirnov,1976
	Fe, W, Cu, Zn-Pb,Mo,Sn, Au,C, Be Pt, Ce	Knopf, 1933,
	W-Cu(-Zn-Mo), W-Mo(-Zn-Pb-Cu) Zn-Pb(W-Cu-Ag), Zn-Pb-Ag(-Cu-Bi-Sn)	Dawson and Dick, 1978

Table 6. Classification of W - Sn skarns (after Kwak, 1987).

I W-skarns containing little or no Sn
1. Oxidized examples, related to granitoids
(a) Magnetite-Andradite type
(b) Andradite type
2. Reduced examples, related to granitoids
(a) Grossularite (-Andradite or Almandine) type
(b) Grossularite-almandine type
3. Polymetallic with only minor W, related to granitoids
4. W-skarns in regional metamorphic terrains unrelated to granitoids
II Sn-skarns with or without high W
A. Proximal, high temperature, non-greisen
1. Oxidized examples
(a) Mangnetite type
(b) Andradite type
2. Reduced examples
(a) Magnetite-fluorite-visuvianite type
(b) Forsterite-pyroxene-spinel type
B. Usually proximal, high temperature, greisen
1. Greisenized skarn type
2. Greisen skarn type
C. Distal, low temperature, non-greisen
1. Magnetite type
2. Pyrrhotite type
3. Pyrite type

SUMMARY AND DISCUSSION

Skarn at the Pinyok mine is mineralogically composed of diopside-tremolite-actinolite-wollastonite-clinozoisite-vesuvianite-magnetite and garnet. These minerals are proximal to the contact and locate in 3 zones; inner-, transitional-, and outer zone. Cassiterite, the economic mineral in this mine is found mainly in the inner zone and closely related to Ba-bearing K-feldspar. Minor is found as fibrous replacement after tremolite. Furthermore, stannite is also located in garnet structure. Other ore minerals found in the Pinyok mine include pyrite, chalcopyrite, arsenopyrite sphalerite and hematite. Direct relationship of these ore minerals and cassiterite is not obvious. However, it is evident that the sulfide ore minerals have been formed after the contact metamorphic assemblage.

From geochronological aspect, it confirms that granite at Pinyok area emplaced at about 218-220 Ma (Late Triassic) in Permian limestone. K-feldspar which is strictly found in the inner skarn zone is dated and yielded the inferred age of 170 Ma (Charusiri, 1989). K-feldspar is, thus, interpreted to be one of the minerals introduced by later hydrothermal event. This also supported that the granite in Pinyok mine is not strictly parental to the mineralization.

Skarn classification has been briefly referred in this paper. Due to the fact that 1. economic metal in Pinyok is only Sn with no W 2. the presence of rather significant amount of magnetite and retrograde epidote which both prefer Fe^{+3}, the skarn at Pinyok could represent oxidizing environment and is considered to be magnetite-tin skarn type.

ACKNOWLEDGEMENT

The authors would like to thank Profs. Tongchai Pungrasmi and Dr. Boonsom Siribumrungsukha of Dept. of Mining and Metallurgical engineering, Prince of Songkla University, and Mr. Supachai Pongsiriwan of Mining Div., DMR who provide ore samples and most valuable information. Mr. Suwit Jearakongmun of Econ. Geol. Div., DMR kindly assists in printing this paper.

REFERENCES

Alexander, J.B. and Flinter, B.H., 1965. A note on Varlamoffite and associated minerals from the Batang Pedang district, Perak, Malaya, Malaysia: Mineral Mag., 35, p. 622-627.

Aranyakanon, P., 1969. Tin deposits in Thailand: unpublished paper prepared for the Second Techinical Conference on Tin, International Tin Council, Bangkok, 32 p.

Brown, G.F., Buravas, S., Javanaphet, J., Jalichandra, N., Johnstone, W.D., Sethaput, V. and Taylor, G.C., 1951. Geologic recconnaissance of the mineral deposits of Thailand: U.S. Geol. Surv. Bull. 984, 183 p.

Burt, D.M., 1978. Tin silicate-borate-oxide equilibrin in skarns and greisen-the system $CaO-SnO_2-SiO_2-H_2O-B_2O_3-CO_2-F_2O_{-1}$: Econ. Geol. 73, p. 269-282.

Charusiri, P., Pornratanapitak, P., Chanasit, M. and Thiptanasap, C., 1975. Note on Geology and mineral resources of Bang Rang Dam, Amphoe Bannang Sata, Changwat Yala: An unpublished report submitted to the Electricity Generating Authority of Thailand, July, 1975, 53 p.

Charusiri, P., 1989. Lithophile metallogenic epochs of Thailand: A geological and geochronological investigation: unpublished Ph.D. Thesis, Queen's University, Kingston, Canada, 891 p.

Dawson, K.M. and Dick, L.A., 1978. Regional metallogeny of the northern Cordillera, Tungsten and base metal-bearing skarn in southern Yukon and southwestern Mackenzie : Canada Geol. Survey, current research, Pt. A, paper 78-1A, p. 287-292.

Einaudi, M.T., Meinert, L.D. and Newberry, R.J., 1981. Skarn deposits: Econ. Geol. 75th anniversary volume, p. 317-391.

Einaudi, M.T. and Burt D.M., 1982. Introduction-terminology, classification and composition of skarn deposits: Econ. Geol. 77, p. 745-754.

Geijer, P. and Magnisson, N.H., 1952. The iron ores of Sweden: Internat. Geol. Congr., 19th Algiers, 1952, v. 2, p. 477-499.

Goldschimdt, V.M., 1911. Die kotakmetamophose in kristianiagebeit: Oslo Vindensk. Skr.,I., Mat.-Natur v.1, 483 p.

Ingham, F.T. and Bradfood, E.T., 1960. The geology and mineral resources of the Kinta Valley, Perak: Federation of Malaya, Geol. Surv. District Mem. 9, 347 p.

Ishihara, S., Sawata, H., Shibata, K., Tarashima, S., Arrykul, S. and Sata, K., 1980. Granites and Sn-W deposits of peninsular Thailand: Mining Geol., Special issue, p. 223-241.

John, Y.W., 1967. On the malayaite occurring in Pinyok mine Thailand: J. Japan. Assoc. Mineral. Petrol. Econ. Geol., 58, p. 116-120.

Kerrick, D.M., 1976. The genesis of zoned skarn in the Sierra Nevada, California: Jour. Petrology, 18, p. 144-181.

Knopf, A., 1933. Pyrometasomatic deposits In: Ore deposits of western States (Lindgram vol.): New York, Am. Inst. Mining Metall. Engineer, p. 537-557.

Korzhinski, D.S., 1959. Physicochemical basis of the analysis of the paragenesis of minerals: New York, Consultants Bureau, 143 p.

Kwak, T.A.P. and Askins, P.W., 1981. The nomenclature of carbonate replacement deposits with emphasis on Sn-F(Be-Zn) "Wrigglite" skarns: Geol. Soc. Aust. Jour., 28, p. 123-136.

Kwak, T.A.P., 1987. W-Sn skarn deposits and related metamorphic skarns and granitoids, Developments in Economic Geology, 24: Elsevier Press, 451 p.

Lesnyak, V. F., 1965. Mineralothermoetric research at the Tyrny-Auz skarn ore complex, North Caucassus In: Yermakov, N.P., et al., eds., research on the nature of mineral forming solution, Oxford, Pergamon Press, p. 458-489.

Lingren, W., 1902. The character and genesis of certain contact deposits: Am. Ist. Mining Engineers Trans., 31, p. 226-244.

Lingren, W., 1925. Metasomatism: Geol. Soc. Am. Bull., 36, p. 247-261.

Muenlek, S., Meesuk, A., and Tongchit, P., 1979. Geologic map of Changwat Narathiwat-Kolabaharn, Amphoe Betong, scale 1:250,000, Geol. Sur. Div., Dept. of Min. Resources, Bangkok, Thailand.

Nutayala, P., Cambell, L., V., Macdonald, A.S., Aranyakanon,P. and Suthakorn, P., 1979. Review of the geology of Thai tin fields: Bull. Geol. Soc. Malaysia, no. 11, p. 137-159.

Pongsapich, W., Pisutha-arnond, V., and Charusiri, P., 1983. Reviews of felsic plutonic rocks in Thailand: Proceeding of the workshop on stratigraphic correlation of Thailand and Malaysia, Haadyai, Thailand, September, 1983, p. 213-232.

Rachadawong, S., and Gamo, T., 1966. Dressing practice of Complex lode-tin ore of Pinyok mine, Yala: unpublished paper prepared for the Asian Mining Conference VI, Chiangmai, 22-27 February, 1966, Dept. of Min. Resources, Bangkok, Thailand, p. 244-281.

Ramdohr, P. and strunz, H., 1967. Lehrbuch der Mineralogie, Enke, Stuttgart, 820 p.

Takenuochi, S., 1978. Malayaite, In: Imai, H., ed., Geological studies of the mineral deposits in Japan and East Asia, Tokyo, Univ. Tokyo Press, p. 212-216.

Sato, K., 1982. Characteristics of tungsten skarns in Japan, two contrasting types, In: Symposium on Tungsten Geology, Jiangxi, China, October, 1981. Hepworth, J.V. Anayu, H.Z., eds., ESCAP/RMRDC and Geological Publishing House Beijing, China, p. 203-210.

Shabynin, L.I., 1981. Prediction-estimate and prospecting criteria for ore deposits in magnesian and calc skarn: Inter. Geol. Rev., 24, no. 7, p. 819-828.

Smirnov, V.I., 1976. Geology of mineral deposits: Moscow, MIR Pub., 520 p.

Umpleby, J.B., 1916. the occurrence of ore on the limestone side of garnet zones: Calif. Univ. Dept. Geol. Bull., 10, p. 25-37.

Zharikov, V.A., 1970. Skarns: Internat. Geol. Rev., 12, p. 541-559, 619-647, 760-775.

♠♠♠