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Tin and tungsten mineralization of the Mae Lama mining district, N-W Thailand

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Abstract: The tin-tungsten deposits of the Mae Lama mining district are closely associated with the Late Cretaceous (?) Mae Lama "Granite" (adamellite in composition). The mineralization occurs mainly in a hydrothermal quartz vein system, also in pegmatite and disseminated in the adamellite itself. The ore deposits are found within the contact zone of the adamellite and the adjacent Cambrian-Ordovician sedimentary/metasedimentary rocks which include sandstone, shale, laminated limestone, phyllite, slate and marble. Six productive cassiterite-wolframite-scheelite mines exist.

The alignments of the mineralized quartz veins and pegmatites are controlled mainly by one coherent fracture system striking east-west and north-south. The mineral assemblages include high temperature minerals such as cassiterite, wolframite, scheelite, arsenopyrite, pyrite, pyrrhotite, sphalerite, and chalcopyrite, and also lower temperature hydrothermal minerals such as native bismuth, bismuthinite and fluorite. Geothermometry, using the methods of solid solubility of Mg in calcite, amounts of As in arsenopyrite, and fluid inclusions in quartz, calcite and fluorite, indicates temperatures of mineralization from 100 °C to 475 °C. Both the adamellite stock and the ore bodies show greisenization.

INTRODUCTION

The Mae Lama mining district is situated in Ban Tha Rua, Tambon Mae Yuam and Mae Sariang District, Mae Hong Son Province, Northwest Thailand at about Latitude 17° 49' N and Longitude 95° 51' E. The district occupies about 25 sq. km. around a granitic stock called the Mae Lama Granite. The area is located in a mountainous terrain 400–900 metres above sea level. There are six tin and tungsten mines operating in the region around the stock and an abandoned mine is recorded.

These deposits were mined for tungsten shortly after World War II in 1948. At that time only wolframite was recognised, extracted and sold. Cassiterite and scheelite were found later. Today mining is by underground and open pit methods.

GEOLOGY OF THE MAE LAMA MINING DISTRICT

Regional geology

Tin and tungsten deposits in northern Thailand are mainly associated with granitic rocks of Mesozoic of Tertiary age (Fig. 1). These granitic batholiths are intruded into host rocks ranging from Precambrian to pre-Permian in age. The Mae Sariang granite chain extends north-south for more than 150 km.

The Mae Lama granite stock (Fig. 2) may be part of a "higher level feature" of the Mae Sariang granite batholith, 15 km. to the northeast (Teggin and Suensilpong, 1973). The exposed granite body occupies approximately 16 sq. km. Braun and others (1976) reported that the composition of this granitic rock is mainly adamellite. Characteristic of this pluton is a gradual change from porphyritic-biotite granite to muscovite granite. The upper parts may be changed to muscovite greisen granite.

Only a single sample of this medium grained muscovite greisen granite has been

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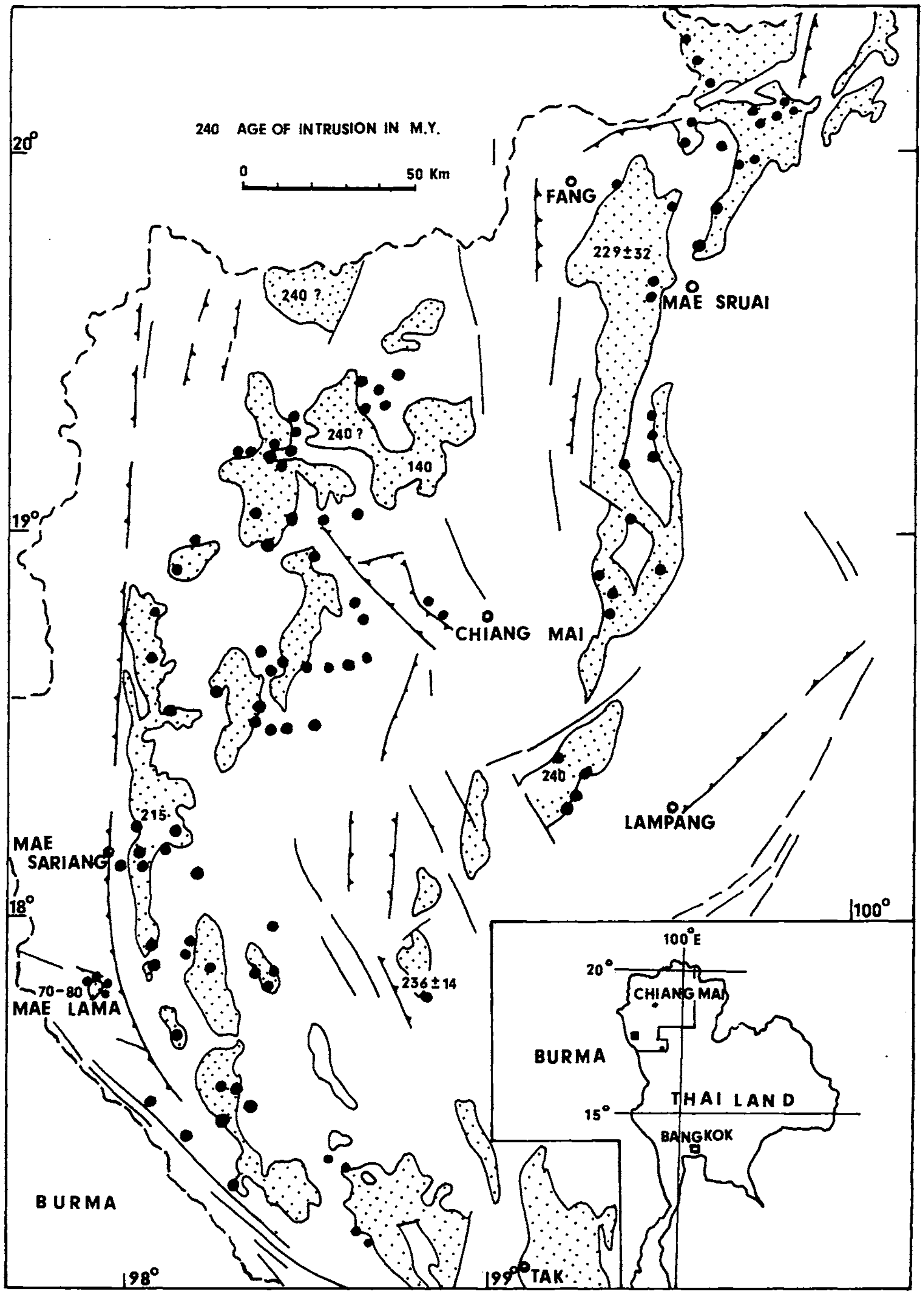


Fig. 1 General map of the Mesozoic granite ranges and ages of intrusions. Tin-tungsten occurrences are in dots. (Adapted from Besang, 1975 and Suensilpong, 1975)

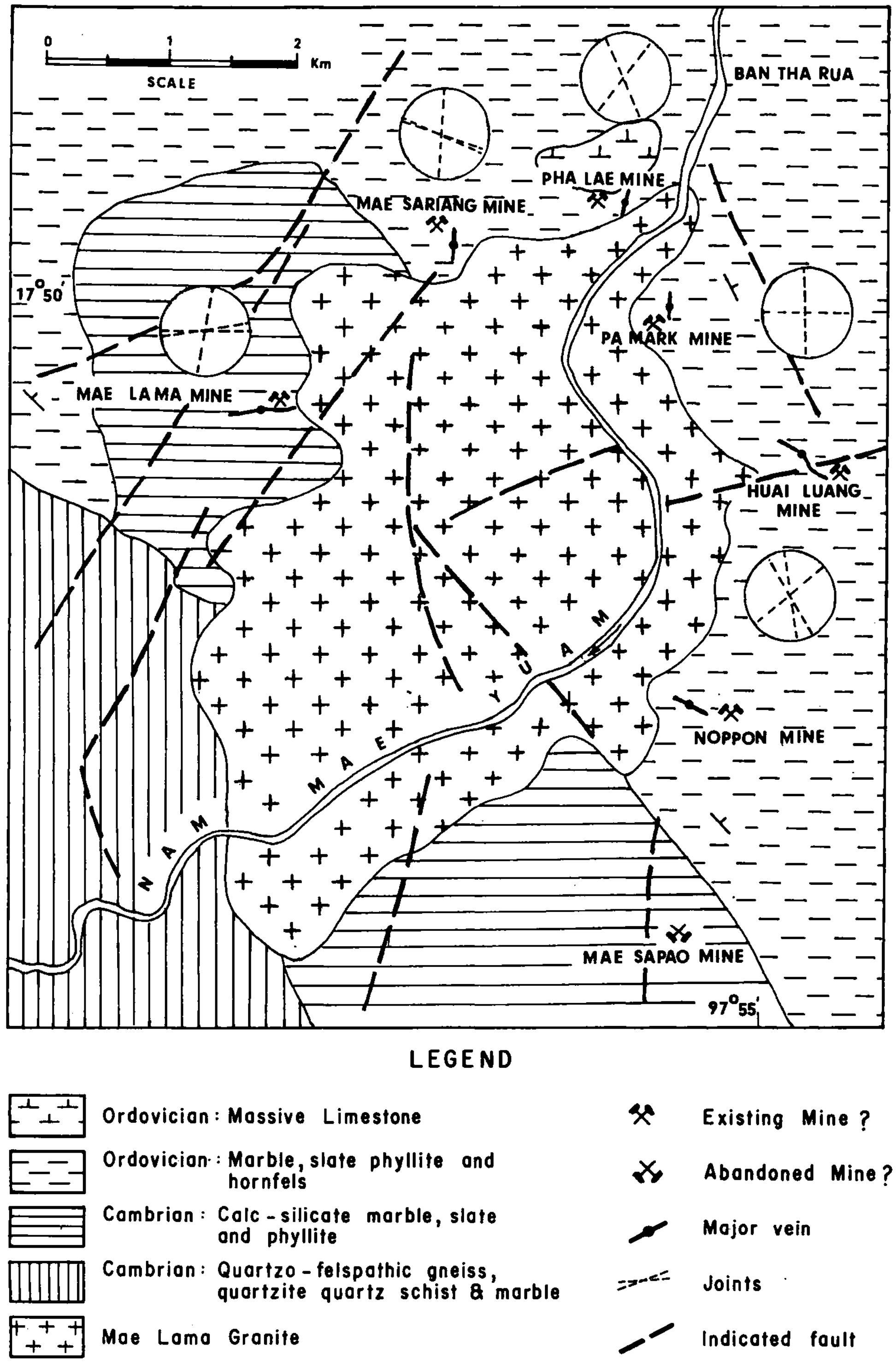


Fig. 2. Geology of Mae Lama Mining District also showing joint system and major mineralized veins. (Adapted from Suensilpong, 1975 and Panupaisal, 1977).

dated (Besang, and others, 1975). The radiometric dates determined by whole rock and muscovite analyses respectively were 70–80 m.y. (Rb/Sr) and 60–69 m.y. (K/Ar). These dates indicate that the Mae Lama granite was intruded not later than Late Cretaceous.

The surrounding country rocks are a sequence of lower Paleozoic metasediments. They consist of quartzite, quartz-schist, marble, calcsilicate, slate and phyllite (Baum and other, 1970). These Paleozoic rocks are conformable and generally strike N 45° W dipping moderately to the northeast. Folded strata are also found on the eastern region. The metasedimentary rocks show alteration to epidote in every mine in the district (Plate 1).

The contact between the Mae Lama granitic stock and the country rock is usually sharp. Veins of pegmatite, aplite and hydrothermal quartz are generally discordant to the regional strike of the monoclinally folded strata. At the northern rim of the cupola at Mae Lama and Mae Sariang mines the vein systems occur in 2 sets trending east-west and north-south (Fig. 2). These data coincide with the regional joint system in the area (N 85° ± 5° E and N 15° ± 5° E).

Faults in the mining district are located within the granitic stock and in the nearly area (Fig. 2). Some are probably of Tertiary age (Suensilpong, 1975) and some of post Tertiary age (Baum and others, 1970). Faults offset mineralized quartz veins at Mae Lama mine. The productive sill-like vein is displaced 2 to 5 m. Microfractures and undulatory extinction in quartz grains, and kinking and curvature of muscovire crystals in the vein may be the result of tension or shear stress due to the Post Tertiary faulting event.

Mineralization

Mae Lama Mine

The ore bodies are dominated by the Mae Lama wolframite-quartz veins producing mostly tungsten (90% wolframite, 10% scheelite) with traces of some cassiterite. The wolframite-bearing quartz vein at Mae Lama mine is from 1.1 to 1.5 metres wide and 460 metres long and extends at least 150 metres below the surface. It strikes east-west and dips steeply to the south (N 85° E/75–80° S). Wolframite was found in pockets and small lenses in the vein. Wolframite crystals weighing up to several kilograms are common. This productive vein is sandwiched on both sides by sericitic vein or fluorite-mica selvages approximately 10 cm. wide. Barren quartz veins from few to 80 cm. in width extend as stringers from this main quartz vein.

Information from six diamond drill holes and recent data obtained in 1978 show that there is only one large wolframite-bearing quartz vein. Stringers are common. Pinching splitting and joining of this single quartz vein has been suggested by Mr. Suwat Pinya, geologist of the mine. Ore grade in Mae Lama varies from 1% wolframite by weight up to more than 10% in some richer parts.

Common associated minerals in the wolframite quartz vein are arsenopyrite, pyrite, pyrrhotite, sphalerite, goethite, limonite, and muscovite.

Mahawat (1974) found some mineralization within the associated muscovite granite and quartz veinlets half a kilometre east of the productive vein at the Mae Lama Mine. He concluded that the mineralization is of the metasomatic replacement type.

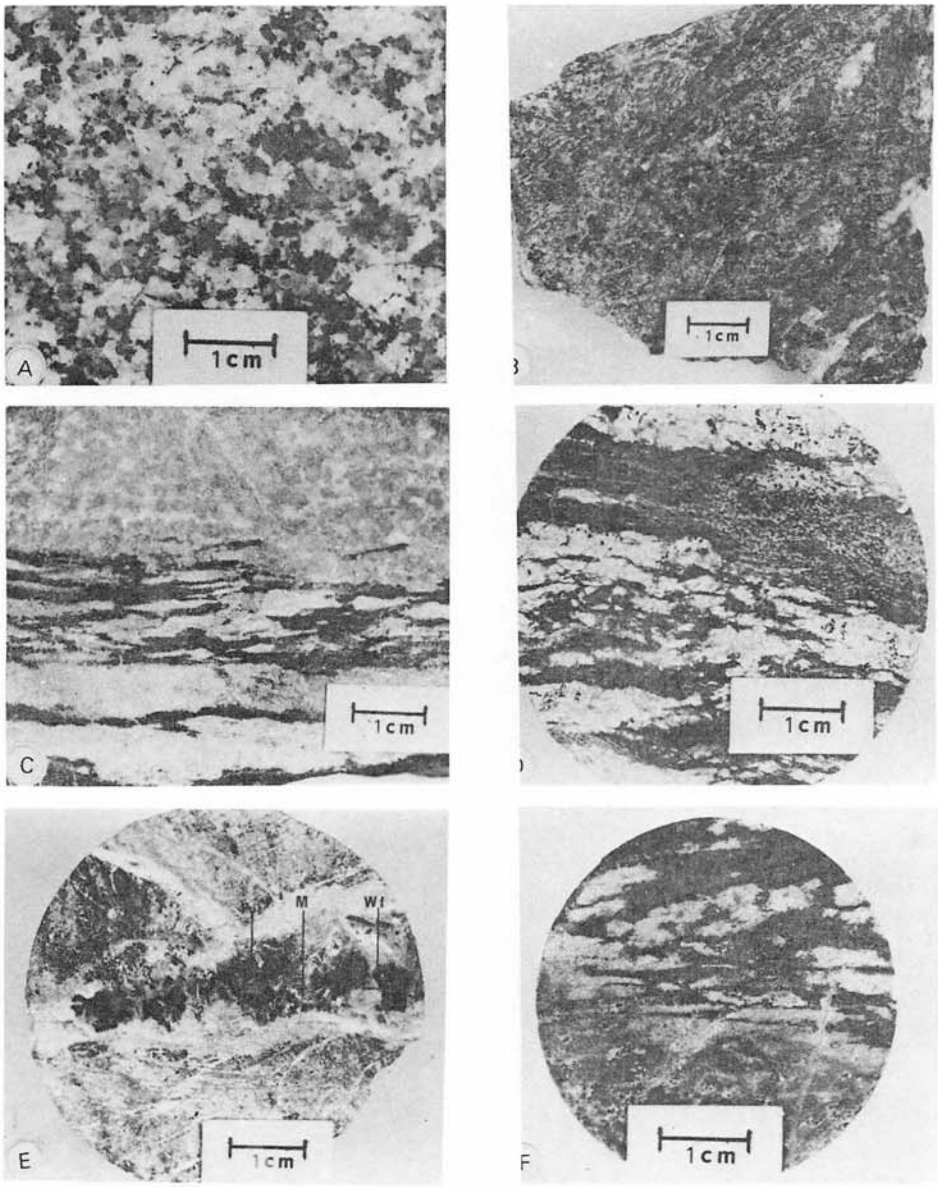


Plate 1. Photographs of the common rocks found at the Mae Lama mine. (After Panupaisal, 1977).

A: NR-2, Hand specimen of granitic rock from the eastern part of the Mae Lama Mine. A typical medium-grained adamellite.

B: MLM 1–34, Hand specimen of skarn. Microcline-epidote skarn showing radiated texture of elongate prismatic epidote.

C: MLM 1–32, Hand specimen of prophylitic rock. Shows compositional layers in epidotic rock.

D: MLMC–29, Core specimen of phyllite from DHA_2 at 29 feet. Shows foliation texture of muscovite layer (dark dray) in phyllite.

E: MLMC–83, Core of the mineralized rock, DHA_2 at 83 feet. Phyllite, penetrated by quartz-muscovite vein, showing fractured or brecciated pyrite (Pry), wolframite (Wf) and muscovite (M) within the vein.

F: MLMC–203, Core specimen, DMA_2 at 203 feet. Epidotic rock (light gray) interbedded with calcic phyllite (dark gray), transposed bedding is also shown.

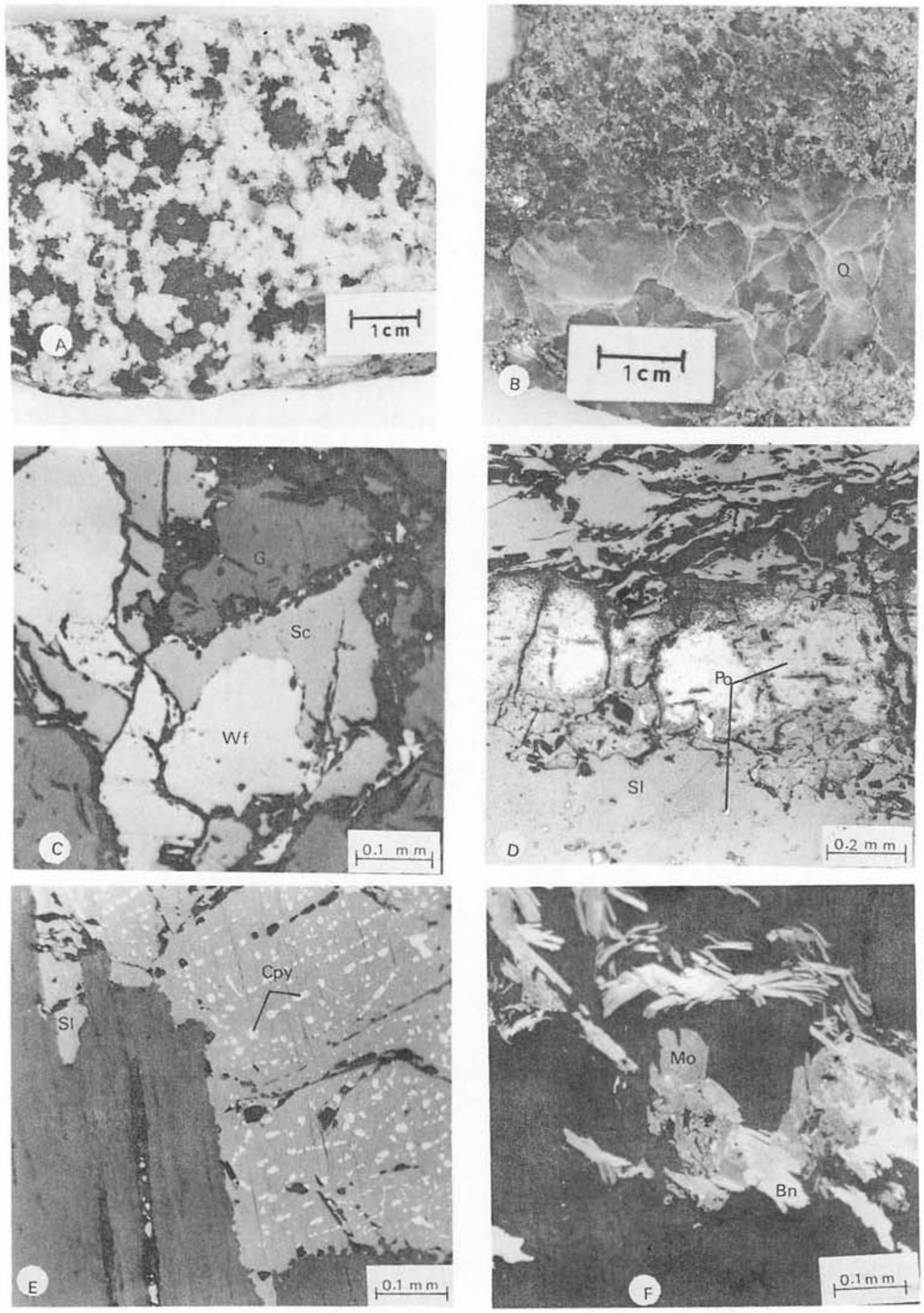


Plate 2. Photographs and photomicrographs of rocks and minerals at the Mae Lama mine (After Panupaisal, 1977).

A: Hand specimen of the greisenized granite from Huai Luang mine. Shows wolframite (Wf) disseminated in the rock. (Sample no. HL-9).

B: Hand specimen of a quartz-muscovite greisen. Fractured quartz vein (Q) cross cuts the greisen. (Sample no. MLM–21).

C: Corroded equant-grained wolframite (Wf) replaced at the rim and surrounded by scheelite (Sc) in gangue (G) matrix. (Sample no, HL–9, reflected light, air, 64 x).

D: Pyrrhotite (Po) replaced by Sphalerite (Sl). Intense alteration occurs along the contact zone with sphalerite. (Sample no. PM–13, reflected light, air, 32 x).

E: Zonal arrangement in exsolution of chalcopyrite (Cpy) 2 and random exsolution of chalcopyrite 1 in sphalerite (Sl). Also showing sphalerite-chalcopyrite exsolution replacing muscovite cleavage. (Sample no. MLM–22, reflected light, air, 64 x).

F: Curved crystal molybdenite (Mo) included in and replaced by fibrous bismuthinite (Bn) in quartz matrix. (Sample no. MLMA–7, reflected light, air, 64 x).

Mae Sariang Mine

Mae Sariang Mine is located at the northern margin of the Mae Lama granitic stock. The granite rock is exposed close to the ore-bearing quartz veins. These veins cross cut the country rock of phyllite, slate and shale, and trend north-south with steep dip westward. Wolframite, scheelite and cassiterite are mined. Andalusite crystals are not uncommon in the contact zone (Col. S. Piyasin, personal communication, 1978). He also suggested that the granite was intruded at high temperature.

Pha Lae Mine

At Pha Lae Mine, approximately 1.5 km. from Mae Sariang mine, the granitic rock is found underneath calc-silicate rock and crystalline massive limestone. Mineralized quartz veins are concentrated within the calc-silicate rock below the limestone cliff face. These mineralized veins show similar trends to those at Mae Sariang and Pa Mark mines. They strike north to north-northeast and dip moderately to the west.

Wolframite and scheelite are associated with arsenopyrite and fluorite in quartz veins within the jointed calc-silicates and limestone. An eluvial deposit of cassiterite is also found in the lower part.

Pa Mark Mine

Wolframite, scheelite and also cassiterite are found in hypothermal quartz veins which intrude the greisenized granite and Ordovician (?) phyllite, slate and black limestone. Some aplitic veins are also found. Strike is commonly north-south and dip is vertical.

Arsenopyrite is abundant and commonly occurs in big crystals. Other associated minerals are pyrite, chalcopyrite, sphalerite and fluorite. Rich ore occurs in the contact zone of granite and country rock and where greisenized granite cross cuts the phyllite, slate and laminated limestone.

Huai Luang Mine

Huai Luang Mine is located approximately 2.5 km. south of Pa Mark mine. In the report to the mine owner, Sithipong (1972) subdivided the deposit into:

1) Cassiterite in quartz veins
2) Cassiterite in greisen
3) Cassiterite in pegmatite
4) Cassiterite in quartz veinlets
5) Wolframite in quartz veins
6) Cassiterite in residual deposit.

Noppon Mine

Noppon Mine is on the eastern flank of the Mae Lama granite stock, about 3 km. south-southwest of Huai Luang mine. Here, the limestone and phyllite reach the Mae Lama granite and form a zone of skarn rock.

MINERALOGY AND PARAGENESIS OF ORE MINERALS

Samples were collected from Mae Lama, Mae Sariang, Pha Lae, Pa Mark and Huai Luang mines. Details of each mineral and its paragenetic sequences are as follows:

Hydrothermal deposits

Tin and tungsten mineralization in quartz veins of hydrothermal type have been found in every mine surrounding the Mae Lama granite stock (Tables I and II). Cassiterite is found as fine to coarse grained crystals with colours ranging from gray, brown and honey coloured. They are commonly not associated with wolframite, Wolframite is one of the earliest and most important ore mineral of these deposits. It generally occurs as elongate or short tabular crystals, or as equant grains of various sizes. Scheelite is normally much less abundant than wolframite. It always occurs in irregular massive forms. Commonly, it forms rim and vein replacements (100 μ) in wolframite (Plate 2).

Arsenopyrite is found as coarse grains and crystals. It occurs in fractures and is penetrated by euhedral pyrite, sphalerite, chalcopyrite and quartz. Arsenopyrite is the most abundant sulphide mineral and is commonly found as big crystals. However, pyrite is generally the most abundant metallic mineral in quartz veins in the Mae Lama mining district. Two formations of pyrite are found: pyrite 1, euhedral pyrite, occurs as inclusions in wolframite and along fractured arsenopyrite; while pyrite 2, anhedral pyrite, is often found in veinlets and as a rim replacement in wolframite. Other sulfide minerals are pyrrhotite, sphalerite, chalcopyrite, bornite, molybdenite and bismuthinite. Native bismuth occurs in irregular masses, replacing pyrite, and as exsolution grains on sphalerite-chalcopyrite.

Secondary minerals are of supergene origin and form alteration products commonly of iron and copper minerals. They include covellite, chalcocite, cuprite, malachite, azurite, hematite and goethite.

Fluorite commonly occurs in separate veins from the wolframite-bearing veins in the Mae Lama mine. But on our last visit to those mines, small crystals of light green fluorite were found within the cassiterite-bearing quartz vein at Pa Mark mine. One specimen from a collection in Huai Luang mine's guest house also shows fluorite in cassiterite-wolframite bearing greisen.

Pegmatite veins

The pegmatitic type of tin-tungsten mineralization is represented by a sill like pegmatite at the Huai Luang mine. Cassiterite bearing pegmatite was recognised there by Sithipong (1972). He reports that several pegmatite veins varying in size up to one metre in width, penetrate discordantly into the limestone in different directions. At least three of them in the eastern part of the deposit were mined primarily for cassiterite. No details are known of the mineralization since the eastern part has been closed down. Samples of pegmatitic veins were collected from the west side of the lease, close to the granite contact. Wolframite here is associated with the pegmatite, (Table III), typically as elongate tabular idiomorphic crystals. Cleavage planes are often sites of replacement by scheelite and sometimes by muscovite. Pyrite is the only sulfide mineral present. Goethite is often found replacing mica along cleavages and grain boundaries.

Aplite veins

Mineralization in aplitic rocks was recognized in five samples taken from Pa Mark and Huai Luang mines (Table IV). Metallic minerals in aplite are mainly arsenopyrite and pyrite. Other ores present are chalcopyrite, sphalerite, pyrrhotite, covellite and bornite. Wolframite is rarely found and is commonly replaced by chalcopyrite.

TABLE I

PARAGENESIS OF ORE MINERALS IN HYDROTHERMAL QUARTZ VEINS AT MAE LAMA MINE. (AFTER PANUPAISAL, S., 1977.)

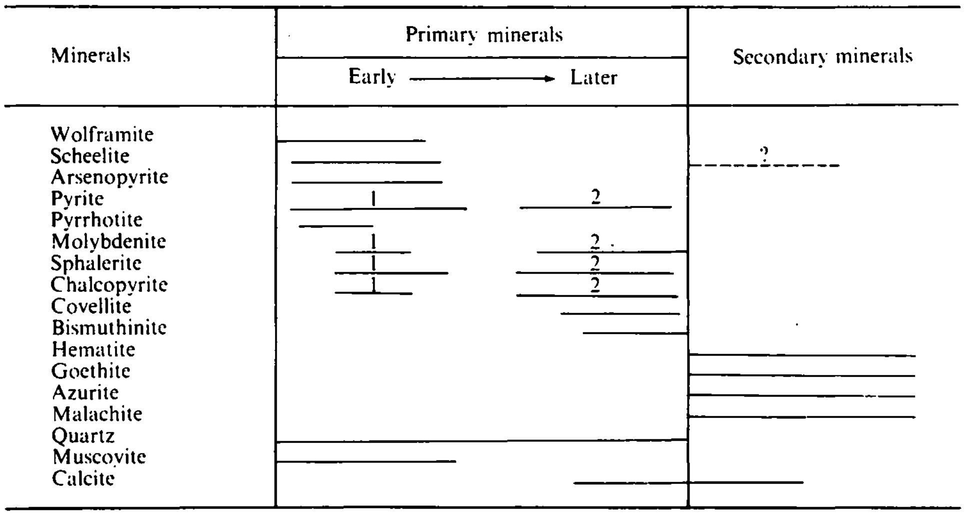


TABLE II

PARAGENESIS OF ORE MINERALS IN HYDROTHERMAL QUARTZ VEINS AT MAE SARIANG, PHA LAE, PA MARK AND HUAI LUANG MINES. (AFTER PANUPAISAL, S., 1977.)

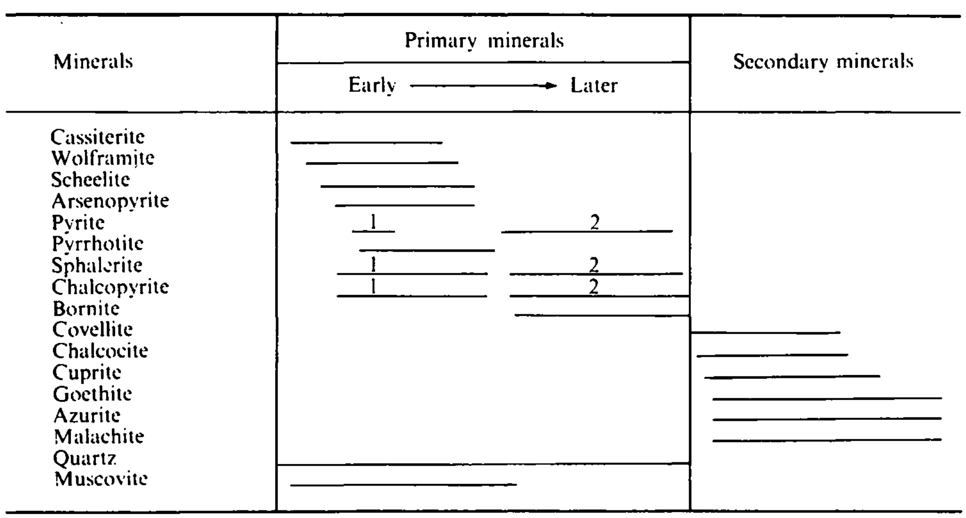


TABLE III

PARAGENESIS OF MINERALS IN PEGMATITE AT HUAI LUANG MINE.
(AFTER PANUPAISAL, 1977)

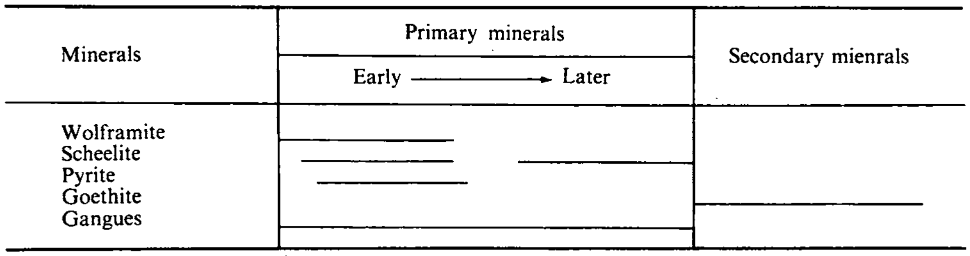
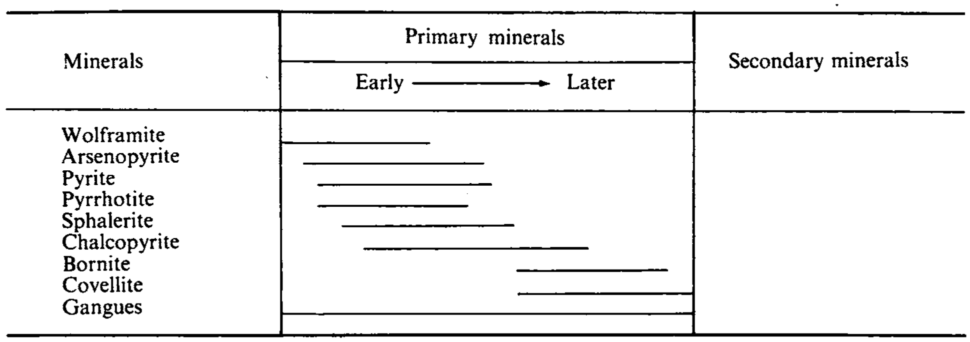


TABLE IV

PARAGENESIS OF ORE MINERALS IN APLITE VEINS AT PA MARK AND HUAI LUANG MINES. (AFTER PANUPAILSAL, 1977.)



Orthomagmatic mineralization

Cassiterite dissemination in granite was recently found in the deeper part of the Mae Lama mine (Chaodamrong, 1975). Wolframite-bearing porphyritic greisenized granite was found at Huai Luang mine. The rock (Plate 1A) is a medium grained greisenized granite, white and weathered. The major components are quartz, microcline, perthite, oligoclase and muscovite, with sericite, clay, and a number of brownish black disseminated grains of wolframite.

Microscopic features indicate that cassiterite is the earliest mineral followed by wolframite and scheelite. No sulfide minerals are associated with this greisenized granite.

Geochemistry

Aranyakanon and his colleagues (1969) mentioned that ".... Mae Lama granite contained 60 ppm. tin and 220 ppm. tungsten.."

Chemical data for the wolframite (Panupaisal, 1977) indicate that it is a typical wolframite with the MnO component a little higher than FeO (MnO:FeO = 1.05 – 1.68). WO_3 content ranges from 71.49% to 74.69% by weight (Table V). Neither ferberite nor huebnerite, end member minerals of wolframite, are found in this mining region. $(Nb/Ta)_2O_5$ exceeds 1% by weight, and SnO_2 in wolframite can be detected only on the specimens from the Huai Luang mine, where it is found in concentrations less than 1% by weight. TiO_2 content is highest at the Mae Lama mine.

GEOTHERMOMETRY

Several methods of geothermometry have been applied by Panupaisal (1977), and the results are given below.

Solid solubility of $MgCO_3$ in calcite

The mol % of $MgCO_3$ in calcite depends strongly on the temperature of formation in the MgO-CaO-CO_2 system (Goldsmith, Graft and Joensue, 1955). The angles of reflection peaks d_{104} by X-ray diffraction on samples of calcite from the Mac Lama mine were compared with the d_{104} of spec-pure standard calcite. The result indicates that skarn rocks formed at approximately 390° and sericitic rocks at 420 ± 15° C.

Determination of atomic % arsenic in arsenopyrite

Using the XRD method, 2θ on the d_{131} of arsenopyrite was compared with the 2θ angle on d_{311} of the fluorite standard (Kretschmar and Scott, 1976). The results show that the wolframite-quartz vein of the Mae Lama mine (associated with arsenopyrite and pyrite) crystallized at 428°–445° C and the sulfur fugacity was 6. Analyses of the calc-silicate skarn and aplite veins of the Pa Mark mine (arsenopyrite and pyrite) showed that the temperature of formation was from 468° to 474° C and the sulfur fugacity was 5. Aplite at the Huai Luang mine formed at from 432° to 477° C and the sulfur fugacity was 6.

Fluid inclusions

Using equipment invented by Dr. D. Breen and his research student, Mr. Prapon Viboonsuk (Department of Physics, Chiang Mai University), fluid inclusions in fluorite, calcite and quartz have been studied. Homogenization and rehomogenization temperatures were measured in μV and correlated with the calibrated curves. The resulting temperatures are indicated in Fig. 3.

Sphalerite-chalcopyrite exsolution

Edwards (1965) stated that "...at higher than 350–400° C sphalerite-chalcopyrite still occurs in solid solution". At the temperature range of 350–400° sphalerite and chalcopyrite are found as unmixed intergrowths of exsolution and contain approximately 10% chalcopyrite in the sphalerite host. The microscopic features of the polished ore samples from the Mae Lama and Pa Mark mines show clearly exsolved chalcopyrite within the sphalerite matrix. This suggests that these hydrothermal veins formed at from 350° to 400° C.

Tungsten mineralization in hydrothermal quartz veins at Mae Lama, as determined by several methods, took place at a wide range of temperatures ranging from 475° to 100° C. The primary fluid inclusions in fluorite are formed between 475° to 390° C. Temperature decreased from early vein basemetal sulfide and metasomatic stages to the late cavity filling and veinlet stages (Fig. 3).

TABLE V

CHEMICAL ANALYSES OF WOLFRAMITE FROM THE MAE LAMA MINING DISTRICT. (AFTER PANUPAISAL, 1977)

Components / Ore type	No. of sample	WO_3 (wt %)		FeO (wt %)		MnO (wt %)		$(Nb\ Ta)_2O_5$ (wt %)		SnO_2 (wt %)		TiO_2 p.p.m.	
		Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.	Mean	± S.D.
Mae Lama Mine													
Quartz vein	6	73.22	± 0.89	10.26	± 0.91	12.66	± 1.57	2.44	± 0.69	n.d.		205	± 73
Sericitic vein	5	72.15	± 0.47	10.89	± 1.20	13.54	± 0.92	2.67	± 0.97	n.d.		440	± 134
Mae Sariang Mine													
Quartz vein	1	73.32		11.65		12.19		1.80		n.d.		47	
Pha Lae Mine													
Quartz vein	1	74.44		8.06		13.56		1.32		n.d.		107	
Pa Mark Mine													
Quartz vein	2	73.71		9.64		14.58		2.2		n.d.		129	
Huai Luang Mine													
Quartz vein	4	73.18	± 1.85	11.67	± 2.29	12.41	± 0.03	2.07	± 0.42	n.d.	± 0.29	105	± 22
Pegmatite	1	73.26		9.89		12.92		1.61		0.63		48	
Greisenized granite	1	73.87		10.41		12.14		1.74		0.42	51		

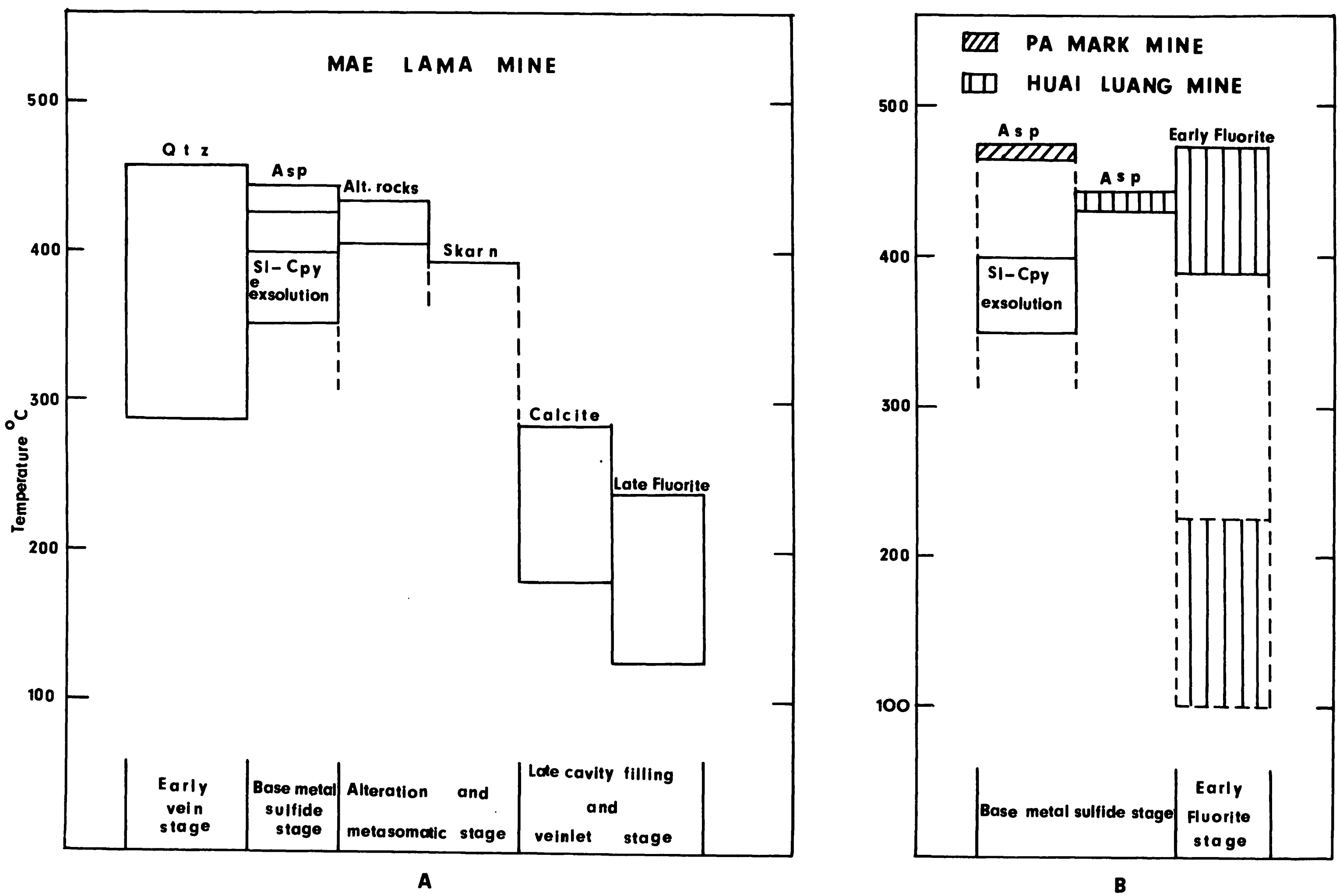


Fig. 3 Stages of mineralization and temperature of formation. (After Panupaisal, 1977).

Arsenopyrite geothermometry of aplite and calc-silicate rocks of the Pa Mark mine suggests that the base-metal sulfide stage formed at a slightly higher temperature than the Mae Lama hydrothermal quartz veins.

CONCLUSIONS

Tin and tungsten deposits in the Mae Lama Mining District are closely associated with the Mae Lama adamellite stock. Radiometric dating suggests that the intrusion and the mineralization should be not later than Late Cretaceous.

These wolframite–scheelite–cassiterite deposits are mainly hydrothermal veins and probably formed in a fracture system around a high level epizonal granitic cupola discordant to the Cambro-Ordovician metasediments. The fracture system developed at a late stage during the emplacement of the stock. Temperatures of formation of these veins range from 300° up to 475° C. Minerals formed include cassiterite, wolframite, arsenopyrite, pyrite and pyrrhotite.

Late hydrothermal and probably pneumatolitic alteration of the wall rock formed muscovite greisen and sericitic selvages on both sides of the quartz veins. Lower temperature hydrothermal minerals including molybdenite, chalcopyrite, bornite, bismuthinite, native bismuth, fluorite and calcite are associated with the quartz veins. Several secondary minerals are derived from the primary ores by supergene oxidation. Finally, cavity filling and veinlets of calcite and fluorite were formed. These deposits formed at a wide range of temperature from 475° C to 100° C.

Pegmatites, aplo-granite and orthomagmatic disseminates are also found mineralized. Temperatures of formation were probably higher than those of the hydrothermal veins. Edwards (1965) suggested that "Orthomagmatic deposits are formed at higher than 600° C and pegmatitic ones are formed between 570°–600° C."

Geochemistry of wolframite revealed that it is a typical true wolframite with MnO: FeO ratio exceeding one. Wolframite may originally have come from the same common source as the Mae Lama granite.

More detailed studies of the structural geology of the Mae Lama stock might determine whether the Mae Lama granite stock is a part of the Mae Sariang Granite Batholith or is a separate younger intrusion. If younger, it may be possible to relate this stock to the tectonic setting for emplacement of the tin-tungsten bearing granite belts in Southeast Asia.

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