

Tin mineralization patterns at Perlombongan Maju Hin Lee, Tanjong Rambutan, Perak, Malaysia

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Abstract: The mineralization in Perlombongan Maju Hin Lee, is essentially hydrothermal in origin. The primary mineralization is spatially related to the exposed granite and granite-metasediment contact in the form of quartz-cassiterite-tourmaline vein swarms, tungsteniferous pyrometasomatic deposit in granite, iron-ore deposits, quartz-magnetite-chlorite veins, cassiterite-polymetallic-sulphides lode and fluorite lode.

The main geological control of the emplacement of the ore bodies is a structural one, in which the pre-ore fracture system in the granite; have served as channelways for the migrating mineralizing agents. The prominent fracture system are joints (110–290° and 150–330°) and faults (080–260° and 020–200°).

Supergene enrichment consisting of erratic concentrates of cassiterite in gossanous ore bodies is characterised by its highly weathered iron-stain cappings on the slope of the granite mass. Some topographically low-lying areas contained tin-rich soil cover, which could have been developed by deposition of high alluvium bearing cassiterite and/or cassiterite-bearing colluvium.

INTRODUCTION

The general geology and the stratigraphy of the study area bears a close relationship to that of the Kinta Valley (Ingham & Bradford, 1960) (Fig 1). This mine, Perlombongan Maju Hin Lee (Fig 2); was formerly known as Tak Fatt Kongsu and is situated at latitude 4°38.5'N and longitude of 101°10.5'E.

The main rock type present is the medium to coarse-grained porphyritic biotite granite with minor occurrences of the non-porphyritic type, porphyritic biotite microgranophyre and aplite dyke. Metasediments such as pyroxene-epidote-schist and quartzite which is rich in sericite, are also found in the vicinity of the mine. The pyroxene-epidote-schist is found at the contact with the granite body, while the quartzite (sericite-rich) appears to occur as a roof pendant, at the southern tip of the flooded mine-pit where the pyritized zone is found.

TYPES OF PRIMARY MINERALIZATION

The primary mineralization is located in the schist and the granite, on both sides of the contact and well inside the contact. Field evidences have

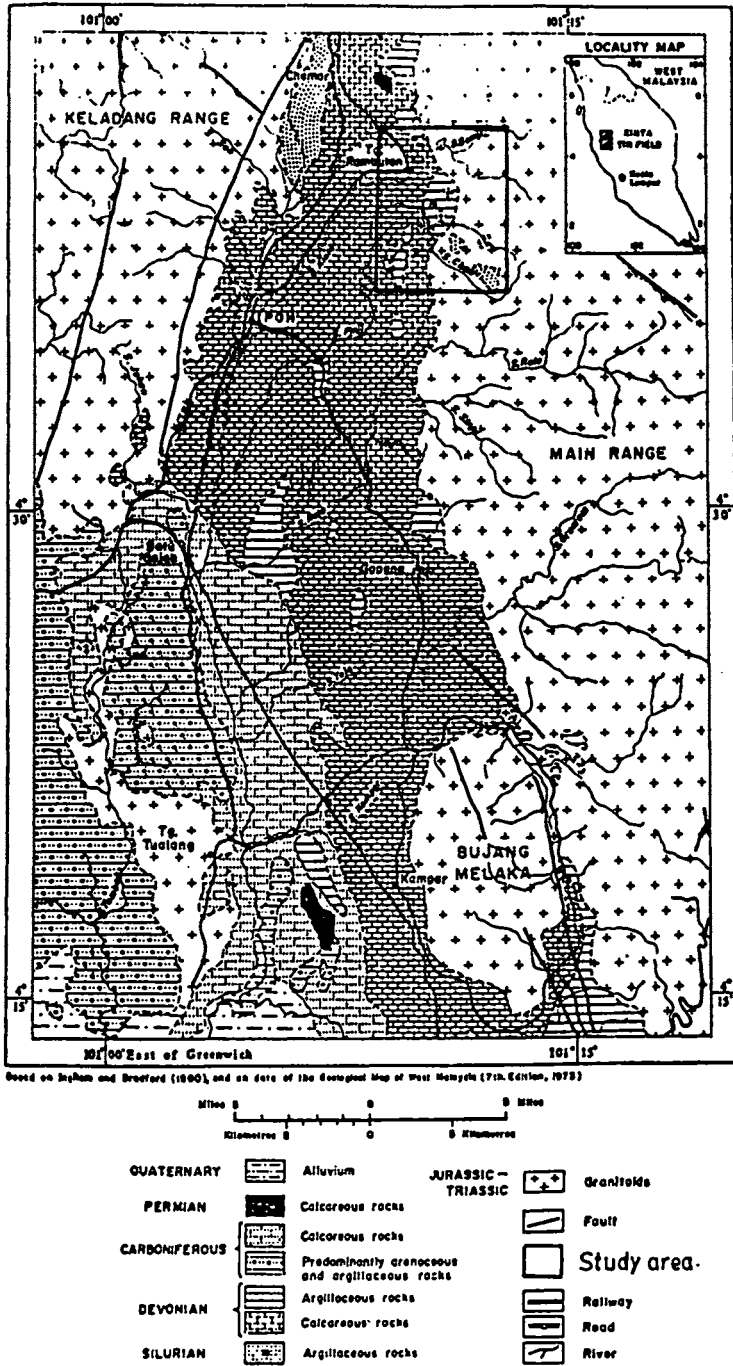


Fig 1. Geology of the Kinta Tinfield (extracted from S. S Rajah, 1979)

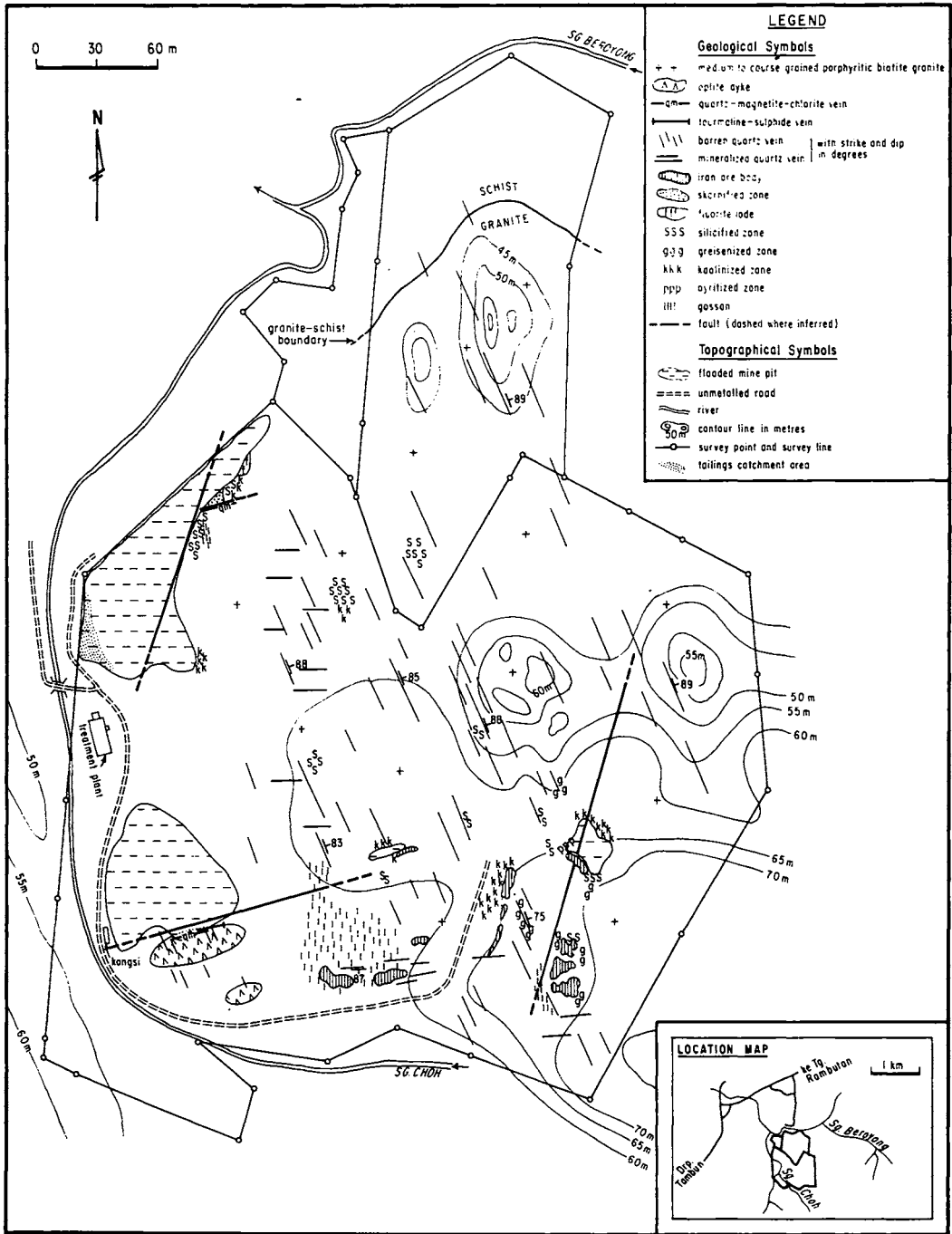


Fig 2. Geology of Maju Hin Lee Tin Mine, Tanjong Rambutan, Perak.

indicated that there are two phases of primary mineralization, namely:-

- (a) related to the early granite (Late-Triassic), which gave rise to a hydrothermal deposit,
- (b) related to the late granite (Late Cretaceous-Tertiary ?), which gave rise to a pyrometasomatic and a hydrothermal deposits.

Each type of mineralization with its distinct form, mineralogy and mode of formation have been recognized. They consist of the following:-

QUARTZ-CASSITERITE-TOURMALINE VEIN SWARMS

These mineralised veins are found cutting the high points of the granite mass and also in the schist bedrock.

Generally, the mineralised veins strike at 110–290° with almost vertical dips. There are also some which strike at 150–330° but usually developed in fracture systems and therefore show regularities in their orientation. They have widths ranging from 1 mm to 20 cm, while length usually varies with different branching systems. There are also huge veins which show pinch and swell structure. An approximate minimum depth of 20 metres for these veins is indicated from the mining operation.

The suite of ore minerals include cassiterite, pyrite, arsenopyrite and chalcopyrite. Gangue minerals are quartz, tourmaline, muscovite and sericite. Supergene minerals include scorodite and covellite.

Cassiterite occur as fine to coarse (5 mm–2 cm in diameter) euhedral crystals in quartz and usually associated with black tourmaline. They are probably the first ore mineral to be deposited because some fractured crystals are healed by pyrite. They exhibit high relief and extremely high birefringence. Twinning and zoning are commonly observed. Sericite is also found in the cassiterite crystals.

Pyrite is the most abundant sulphide mineral. The average size is about 2 mm and occurs as anhedral to subhedral crystals.

Arsenopyrite occurs as euhedral to subhedral crystals disseminated in quartz and occasionally as anhedral crystals in pyrite.

Chalcopyrite is the least in abundant. In polished section, it is brassy yellow and show weak anisotropism. It is seen to be veining pyrite. Hence, chalcopyrite is deposited later than pyrite.

Tourmaline occurs as early euhedral crystals with an average of size about 1 mm in the central portion of the quartz veins. Disseminated fine-grained tourmaline are also found in the sulphides.

Muscovite and sericite occur in minor constituents as interstitial grains among the earlier crystals.

The supergene minerals present are scorodite and covellite, which were the alteration products of arsenopyrite and chalcopyrite respectively.

CASSITERITE-POLYMETALLIC SULPHIDE LODE

This lode is found in a fluorite-tourmaline vein system. It has a very unique style of mineralization in which the cassiterite predominates over all other minerals. This lode is found within the fault zone which strikes 080–260°.

Mining for these lodes was stopped when the lodes graded into the hard-rock granite after they were excavated. The lodes were worked for its most payable parts where coarse-grained (about 1 cm in diameter) cassiterite occurred. The particular lode has a tabular body which plunges in the northeast-east direction and appears to be the richest lode ever mined.

Lateral migrations may have also occurred because some of these veins are found striking approximately between north and northeast. These veins usually form a group of parallel to sub-parallel veins extending into the granite body.

Examination of the polished sections reveal the presence of the following ore minerals: cassiterite, pyrite, stannite, sphalerite, arsenopyrite and chalcopyrite. Supergene minerals such as covellite and marcasite have also been observed. The suite of gangue minerals identified in thin section studies include tourmaline, fluorite, alkali feldspar, quartz and sericite.

Abundant euhedral cassiterite crystals averaging 1 mm in grain size, are light to dark brown in colour. Generally, they occur as coarse tetragonal crystals with zoning and twinning. In polished sections, they show typical properties of cassiterite especially its yellowish to reddish brown internal reflectance.

Pyrite is the most abundant sulphide mineral and occurs as subhedral to anhedral crystals ranging from 1 mm to 3 mm in grain size. Aggregates of fine cubic crystals also occur. Its yellowish-white colour and high reflectance are distinguishing features in polished sections. Some fractured grains are veined by stannite and sphalerite.

Stannite is usually found together with pyrite, sphalerite and chalcopyrite. In polished section, it usually occurs as brownish-grey veins in pyrite crystals.

Sphalerite shows low reflectance, isotropism and grey colour in polished sections. It also occurs as irregular fine-grained crystals associated with stannite.

Chalcopyrite is seen as irregular anhedral grains of minute ex-solution bodies in sphalerite and stannite.

Arsenopyrite occurs as anhedral grains in pyrite and stannite. It shows a very distinct anisotropism of greyish-blue. Covellite replaces chalcopyrite and stannite to exhibit a 'feathery texture', while marcasite occurs as fine-grained anhedral crystals along the boundaries of pyrite.

Gangue minerals like quartz, alkali feldspar and sericite occur as accessory minerals. 2V determination on the alkali feldspar shows that it is orthoclase in composition.

TUNGSTENIFEROUS SKARN

Skarnification in granite have given rise to this tungsteniferous skarn. Two bodies of skarn have been located and are found within a fault zone trending 020–200°. They are usually highly fractured and sheared.

Both of these skarn bodies are tabular in shape and appear dirty-green in colour. The skarn which is found beside the pyrite zone has a traceable length of approximately 25–30 metres and a minimum width of 3 metres. This particular body strikes at 078° with a dip of 40° towards southeast.

There are a series of greenish and rusty-red coloured veins traversing the adjacent granite rock. These veins are essentially of epidote and garnet respectively. The width of the veins ranges from 1 mm to 4 cm. It appears that these veins are replacing the coarse-grained porphyritic biotite granite.

The essential minerals are predominantly of pyroxene, garnet (andradite-rich), quartz, idocrase, epidote, actinolite and some ore minerals like cassiterite, scheelite, magnetite and specularite.

Magnetite is the most abundant oxide mineral found in the skarn. They occur as 'crustified bands' bordering the granitic veins.

Some trace amount of sporadic occurrences of cassiterite are found intimately linked with magnetite. They are normally fine-grained and without any obvious shape.

Besides numerous tiny quartz which cut the skarn and the granite body, there are also other veins which cut the skarn body. They are as follows:

(a) Quartz-feldspatic vein

These occur as parallel to sub-parallel pinkish-red veins with some branching out as horse-tail structure. They are about 1 cm in thickness. The alkali feldspar determined by comparing the 2V angles, suggests that they are mainly of orthoclase, with some minor amounts of microcline showing cross-hatched twinning.

The orthoclase have sutured contacts between each other and shows a preferred orientation, thus giving rise to 'crustification band. Trace amounts of plagioclase occurred as interstitial grains within the orthoclases. Occurring sporadically are minerals like actinolite and cassiterite. Other accessory minerals present are epidote, fluorite, chlorite and some sulphides.

(b) Greisenized quartz-muscovite vein

These are represented by a few veins that strike at 072°. Mineralogically, these greisenized veins consist of flaky muscovite, chlorite and occasionally with cassiterite.

(c) Granitic vein

This particular vein has been found cutting the skarn and the granite body. The essential minerals present are quartz, alkali feldspar, plagioclase and phlogopite. Accessories include garnet, tourmaline, fluorite, diopside and sulphide minerals. In the skarn, scheelite has been observed bordering the granitic vein. A 'web-like' texture is shown by the feldspars, suggesting a rather rapid cooling which has preserved the flow texture of the granitic vein.

DISCUSSION

The skarnification in granite is rather interesting because such occurrences are very rare. Generally, the effects of heat combined with accessions from the emanations of magma will give rise to skarnification, which normally needs a very high temperature environment (350–800°C). This is shown by the outstanding feature of the mineralogy which shows a distinctive assemblage of gangue-minerals characteristic of high temperature formation. This source of temperature is very unlikely to have been derived from the earlier granite. Thus, indicating that there could have been a later phase of granite intrusion. Other evidences to further support the existence of this later granite are the occurrences of granitic veins and also the quartz-feldspatic veins in the earlier granite and the skarn.

IRON ORE DEPOSITS

Most of the iron ore deposits are structurally controlled within a fault zone, which trends at 020–200°.

The individual ore bodies are usually massive and irregular in shape. Some have elongated bodies up to 40 metres in length and about 8 metres width. There are also some which show swelling at certain portions of the ore

bodies. Specular ore is the most commonly seen as a thin skin on cliff faces which obviously represent joint planes and also as narrow stringers which appear to be fracture fillings. This usually imparts a shining metallic lustre to the mineralised joint planes. In some of the magnetite ore, relicts of thin specularite veins are left in a cellular boxwork texture.

The iron ore deposits are predominantly of magnetite, hematite and quartz. Some pyrite, limonite and goethite have also been observed.

In polished section, magnetite occurs as aggregates of massive anhedral grains which are closely locked together. Massive hematite also occurs in intimate association with the magnetite, probably replacing them. The hematite exhibits different crystal habits ranging from fine, dense granular aggregates to fine, fibrous interlocking rosettes. It shows strong anisotropism of greenish-grey.

FLUORITE LODGE

A fluorite lode is found in a small lode near the northwest margin of the granite body. It is concentrated in the fault zone which is trending 020-200° and occurs as a network of multiple complex vein swarms of purple fluorite, in a granitic host rock.

The size of the lode ranges from 5-8 metres in length and have greenish spots all over it. These multiple vein swarms usually have width ranging from 1 mm to 2 cm and variable lengths. They formed complex branching vein swarms which criss-crossed among them. But all these veins appear to have a general trend of 120-300° and most likely, occurred as infilling in joints. Some pyrite crystals are also found with them. Generally, these veins are purple in colour with some pale-greenish crystals.

The mineralogy of this lode is essentially similar to the granite host except that this particular rock is highly enriched with fluorite vein swarms and some sulphide minerals.

QUARTZ-MAGNETITE CHLORITE VEINS

Those veins are rare and only found along the fault zone which trends 080-260°. One is seen resting on an aplite dyke while the other is seen lying next to the skarn body.

Both these veins are curved and display a dark greenish-grey colour. They have an average width of 20 cm and untraceable length due to their discontinuities and irregular outline.

The essential minerals present are magnetite, chlorite, quartz and fluorite. Accessories include cassiterite, apatite and muscovite. A mylonitic

texture is preserved: indicated by the brecciated fragments of magnetite grains.

Magnetite makes up about 50% of the vein and occurs as rows of broken fragments, which have irregular outlines.

Chlorite is abundant as bluish-green fibrous radiating crystals. Present together with chlorite is the acicular cassiterite.

SUPERGENE ENRICHMENT – OXIDATION AND ALTERATION

The so-called 'patchy' mineralization by the miner actually consists of erratic concentrates of cassiterite in gossanous bodies of limonitic iron ores. During the course of the writer's fieldwork, these ferruginous bodies are being sought for its tin value by the management. Usually, below the zone of oxidation, the gossan masses grade into massive iron-ore bodies.

The western slope of the granite mass is covered by a highly weathered iron-stain cappings with cellular masses of limonitic iron ores. They change at higher levels of the pit, from admixtures of yellowish brown and reddish oxides and their hydrates to dark-grey supergene enrichment lodges and finally the fresh greyish black iron ore are found down below. The limonite is probably formed during oxidation of iron-bearing sulphides and normally persists into the oxidation zone, thus imparting to gossan and capping its diagnostic rusty colour. These oxidized compounds of iron-sulphides consisting of hematite, limonite, goethite and residual base metal sulphides give a yellowish-brown cropping colours.

Field observations disclose that the gossans are closely associated with kaolinization suggesting that the solution formed during oxidation of sulphides could have effected a pronounced kaolinization of the hydrothermally altered granitic rocks. Weathering processes, however, have altered much of the ore to a porous network of filamentous, layered to concentrically developed iron oxides; forming a boxwork texture. Such gossans, sometimes sub-outcropping above the granite bedrock, are good indicators of underlying primary ore bodies.

WALL ROCK ALTERATION

Hypogene agents coming up along fractures in the granite during the post-magmatic stage of consolidation, have resulted in the reaction between the hot mineralizing fluids and the host rock in which the agents passed. Thus, wall rock alteration is commonly in evidence and has destroyed almost all the texture and mineralogy of the granitic wall rocks.

Generally, the commonly observed wall rock alterations adjacent to the

primary lodes are chloritization, kaolinization, silicification, greisenization, tourmalinization, fluoritization, skarnification and pyritization.

Chloritization usually imparts a dark green colouration to the rock. It is normally intense bordering the quartz-magnetite chlorite vein.

Kaolinitization is the most intense wall rock alteration and normally kaolinized granitic host rock contains soft and white clay, which was derived from alteration of feldspars, especially plagioclases. Generally, these strongly kaolinized zones grade gradually into decomposed granite with its intensity rapidly dying away from the immediate vicinity of the lodes. Some of the kaolin clay contains numerous relicts of quartz and is stained in shades of brown and reds, especially near the iron ore deposits.

Silicification is usually manifested as quartz vein swarms and silicified granite. It is rather intense in the high points of the granitic intrusion. The more resistant silicified rocks stand out better than others. The thoroughly silicified rock is composed of medium to coarse-grained anhedral quartz with interstitial muscovite flakes. An interesting silicified zone is found bordering the skarnified and pyritized zone. This particular rock is reddish in colour with disseminated pyrite cubes in it. The colour is probably due to the percolating supergene iron-bearing solutions.

Greisenization is usually found bordering the silicified zones. Intense greisenization is normally associated with thinner veins and can be easily distinguished by the reflectivity shown by the muscovite flakes. Occasionally, the alteration has gone to an extreme stage and the resultant rock composed entirely of muscovite.

Tourmalinization is quite widespread and pronounced as acicular aggregates of black tourmaline (elbaite type ?) in the mineralised quartz-cassiterite vein, while the blue tourmaline (schorlite type ?) in the cassiterite-polymetallic sulphide lodes. Some are also manifested as tiny veins ranging from 1 mm to 2 cm in thickness and as tourmaline clots/nests in the silicified granite. Sometimes, it is found superimposed on the silicified and greisenized rocks. When these superimpositions take place, the resultant rock is normally composed of medium-grained quartz, peppered with disseminations of tourmaline clots and veins, and muscovite.

Fluoritization is mainly found incorporated in the kaolinized zone. They occur as disseminated purple-coloured grains. Extreme fluoritization has also manifested in the deposition of fluorite lode. It is quite commonly found together with greisenization, suggesting that the emanations of the magmatic fluids must have been rich in fluorine content. This is also true for most of the primary lodes found.

Pyritization is found beside the skarn body. It contains dodecahedron

crystals up to 10 cm in diameter. This is probably due to the introduction of sulphur ions which may have reacted with the iron ions released by the iron-ore body lying beside it.

Skarnification have resulted in the formation of tungsteniferous skarn. There is a gradual change of skarnification to pyritization and silicification, away from the skarn body.

The above account of various types of wall rock alteration suggests the nature and intensity of the alteration depends upon the chemical character and temperature of the ore forming agents.

CLASSIFICATION OF PRIMARY MINERALIZATION

The classification of the primary ore bodies found is modified from:

- (a) Hosking's (1965) classification of primary tin deposits in West Malaysia, and
- (b) Yeap's (1979) classification of primary tin deposits of the Kuala Lumpur Tinfield.

Two types of primary mineralization have been identified, based on the host rock in which they occurred, their morphology and their mineralogy. They are as shown in Table 1.

Further classification based on their mineral assemblages, wall rock alterations, unmixing temperature of sphalerite and chalcopyrite, and

Table 1. Classification of the Primary Tin Deposits of Maju Hin Lee Mine.

Types of deposit	Sub-Group
PYROMETASOMATIC	A. In the Granite (a) Contact skarn type (with skarn species) – scheelite, cassiterite, magnetite. (b) Massive iron ore deposits
HYDROTHERMAL	A. In the Granite (a) Quartz-Cassiterite-Tourmaline vein swarms (b) Greisen bordered quartz veins (c) Cassiterite-Polymetallic-Sulphide lodes B. In the Schist (a) Quartz-Cassiterite-Tourmaline veins

geothermometry studies suggest a hypothermal deposit (Lindgren, 1933).

STRUCTURAL CONTROL OF MINERALIZATION

The main geological control for the emplacement of the ore bodies is structural one, in which the pre-lode fracture system in the granite, have served as open channelways for the mineralising agents.

These sets of fractures are well developed into two prominent directions: namely 110–290° and 150–330°, which corresponds with the regional direction of the joints in the study area (Gobbett, 1971). These have resulted in the formation of quartz-cassiterite-tourmaline veins, which are commonly found trending 110–290°.

The major ore bodies such as cassiterite-polymetallic sulphide lode, tungsteniferous skarn, fluorite lode and the quartz-magnetite-chlorite veins are located within two sets of fault zones: 080–260° and 020–200°. This is evidenced by the following observations:

- (a) fracturing of the early formed minerals like pyrite and cassiterite, and the absence of such features in the later minerals found in the cassiterite-polymetallic sulphide lode,
- (b) deformed and faulted lamellae of plagioclases in the sheared granite, and
- (c) the mylonitic texture shown in the quartz-magnetite- chlorite vein.

ORIGIN OF THE DEPOSITS

The ore deposits in Maju Hin Lee mine are spatially related to the early granite, which is part of the Main Range Granite and a later phase of granite intrusion, which is not exposed.

During the consolidation of the early granite, initial development of openings in the joints must have provided pathways for the mineralising fluids to exsolved and deposited the quartz-cassiterite-tourmaline vein swarms. Further import of the volatiles such as OH, F, Li, Sn, B and the removal of alkalis (especially Na, less pronounced K) in the mineralising fluid have resulted in the greisenized quartz veins and greisenized granite

Subsequently, wrench faultings occurred. These have brought about the manifestation of emanations from the later granite, which have resulted in the formation of the high temperature environment for the occurrence of the tungsteniferous skarn in the granite. Migrating upwards and outwards along the faulted planes, is the mineralising fluids which is enriched in iron content and were precipitated as oxides to form massive magnetite ore bodies.

Next, comes the phase for the deposition of the cassiterite-polymetallic sulphide lodes, which are very rich in fluorine. Oversaturation of the mineralising fluid in fluorine have resulted in the formation of the fluorite lode.

A simple paragenetic sequence of various stages of mineralization and a hypothetical cross-section view of the ore bodies would be as shown in Table 2 and Fig. 3 respectively.

CONCLUSIONS

Hosking (1974) postulated two distinct episodes of tin mineralization in the Western Tin Belt, to account for the occurrence of the xenothermal deposits in the Kuala Lumpur Tinfield. Teh (1976), also postulated the same view for the xenothermal deposits in Tekka Hill, Perak.

Therefore, the writer has arrived at the inescapable conclusion that the tin mineralization in the study area is also related to two episodes of granite intrusion. The early granite is of Late Triassic (Bignell & Snelling, 1977), while the late granite is probably of Late Cretaceous - Tertiary in age. It appears that the late granite is more mineralised compared to the early granite.

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Table 2. A paragenetic sequence of various stages of mineralization.

Time	Various stages of ore deposition	Source
EARLY	Early vein swarms (Quartz-Cassiterite-Tourmaline)	Early Granite
↓	Tungsteniferous Skarn	Late Granite
	Iron Ore Deposits	Late Granite
	Quartz-Magnetite-Chlorite veins	Late Granite
	Cassiterite-Polymetallic	
	Sulphide lodes	Late Granite
	LATE	Fluorite lode

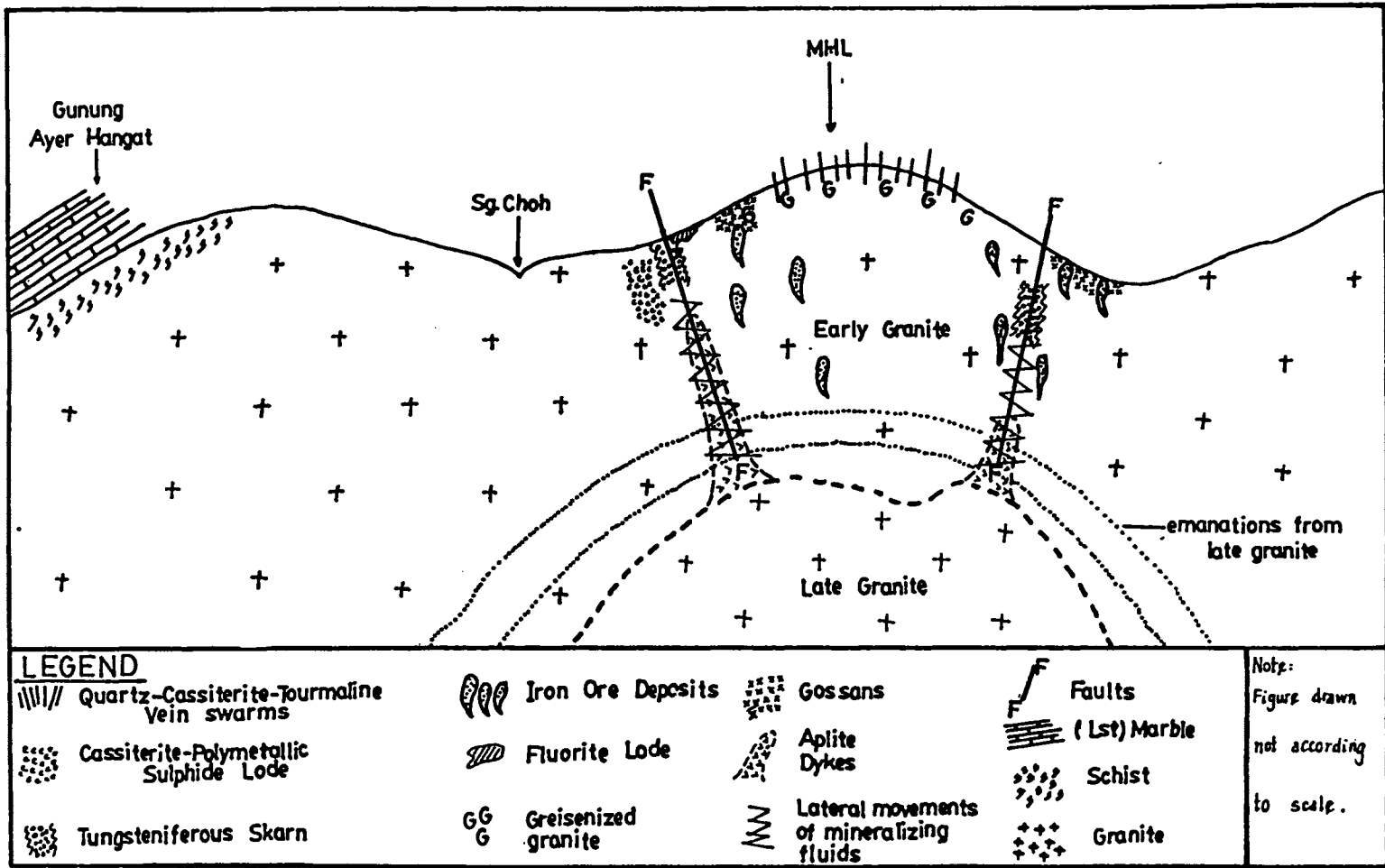


Fig. 3 A hypothetical Cross-Section of Maju Hin Lee Mine (MHL)

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