

## The Tekka tin deposit, Perak, Peninsular Malaysia

G.H. TEH

Department of Geology, University of Malaya, Kuala Lumpur.

**Abstract:** This paper is concerned, primarily, with the nature and genesis of the multi-mineralic veins at Tekka, Perak, Peninsular Malaysia.

The rock types in the area include marble, schist and granite. The granite emplacement and resulting tensional fractures, that trend approximately E-W and dip northwards, provided passageways for ascending mineralising agents, and the veins and adjacent country rocks became the sites of deposition of an impressive number of mineral species.

The genesis of these mineralised bodies was complex and involved at least three phases of mineralisation that were separated by periods of renewed fracturing. From a mineralogical and temporal point of view the veins can be classified into three main types:-

- (a) An early quartz-tourmaline type with or without cassiterite, wolframite, arsenopyrite and minor amounts of other sulphide-bearing species.
- (b) A second (later) type consisting of quartz with or without cassiterite, wolframite, arsenopyrite and minor amounts of other sulphide-bearing minerals.
- (c) A third, and still later, type consisting of quartz, stannite, other sulphides and sulpho-salts, with or without cassiterite and arsenopyrite.

The common non-metallic gangue minerals present are quartz, tourmaline, topaz, sericite, muscovite and fluorite, and, in addition, a number of supergene secondary products which includes varlamoffite. Wall-rock alteration adjacent to the veins includes silicification, tourmalinisation, greisenisation and kaolinisation.

The deposit is best classified as xenothermal because of the telescoping of high-temperature mineral species such as cassiterite, columbite/tantalite and wolframite which are closely associated with ones believed to be low-temperature minerals, such as galena and stibnite.

### INTRODUCTION

The Tekka deposit is one of the very few exposed and still-standing, hard-rock tin deposits in the Kinta Valley area. A detailed study of this deposit may serve to throw light on some characteristics of the many Kinta deposits, which have been the source of the outstandingly rich tin placers of the Kinta Valley, Perak, Peninsular Malaysia.

The area is bounded by latitudes 4°30'N and 4°31'N, and longitudes 101°9'E and 101°10'E (see Fig. 1). It lies 14 km south of Ipoh and 4 km north of Gopeng.

### GEOLOGICAL SETTING

The area is composed essentially of granite, quartz veins, crystalline limestone\* and schist (Fig. 2). Tekka Hill, an offshoot of the Main Range granite has associated

\*In the geological literature of Malaysia it has been customary to refer to the marble of the Kinta Valley, and elsewhere in Malaysia, as limestone, and the writer has followed this practice in this paper.

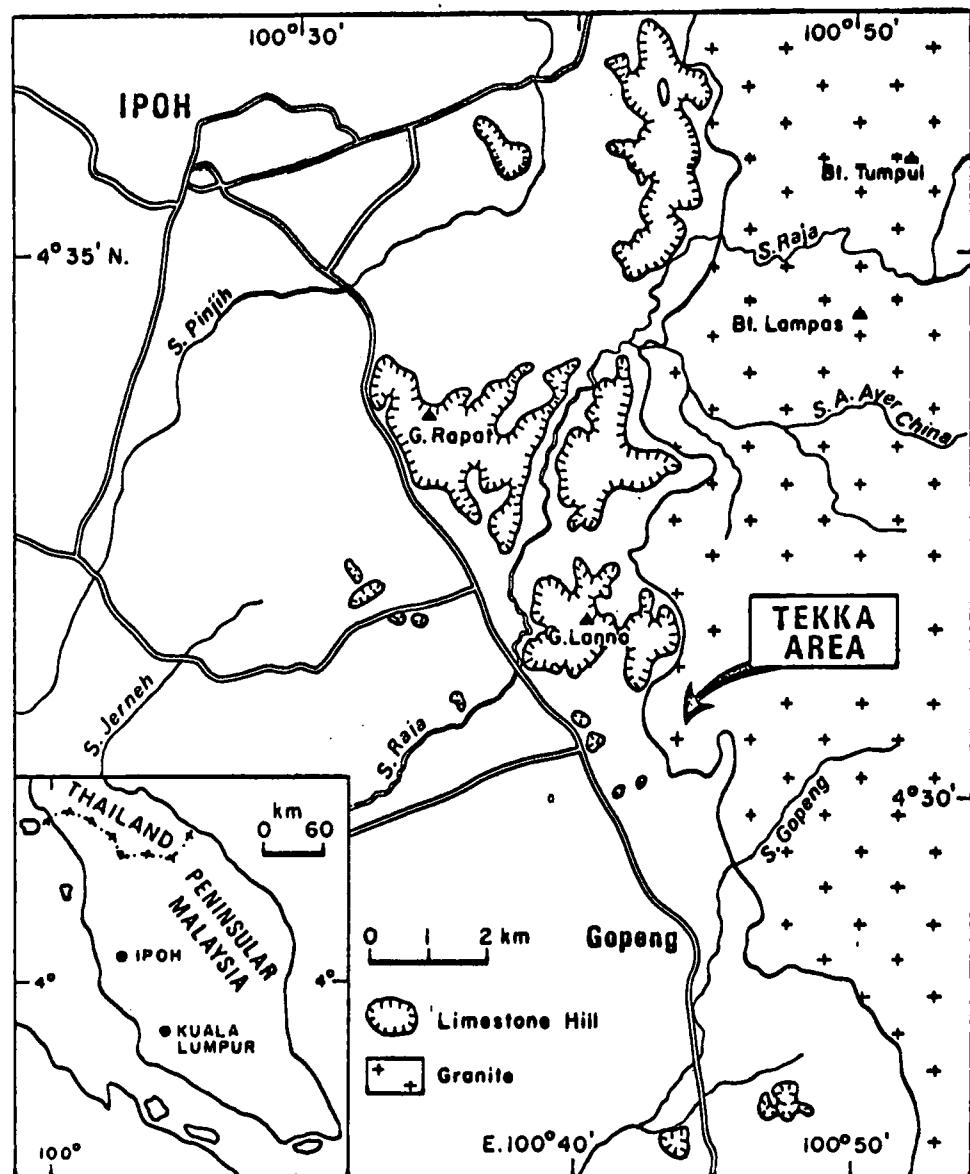


Fig. 1 Location of the Tekka area showing the adjacent limestone hills and granite areas.

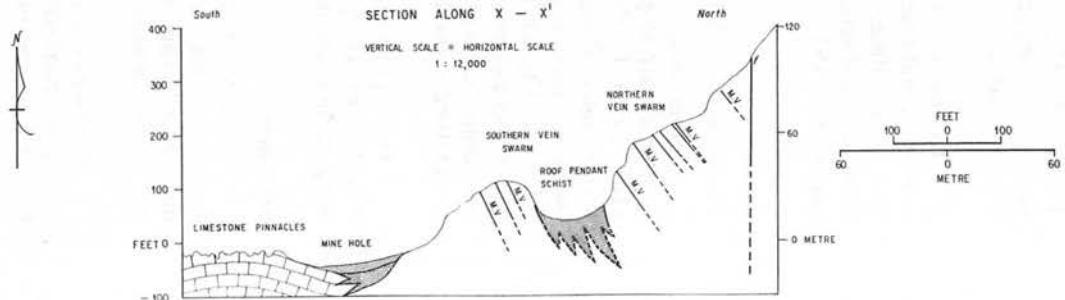
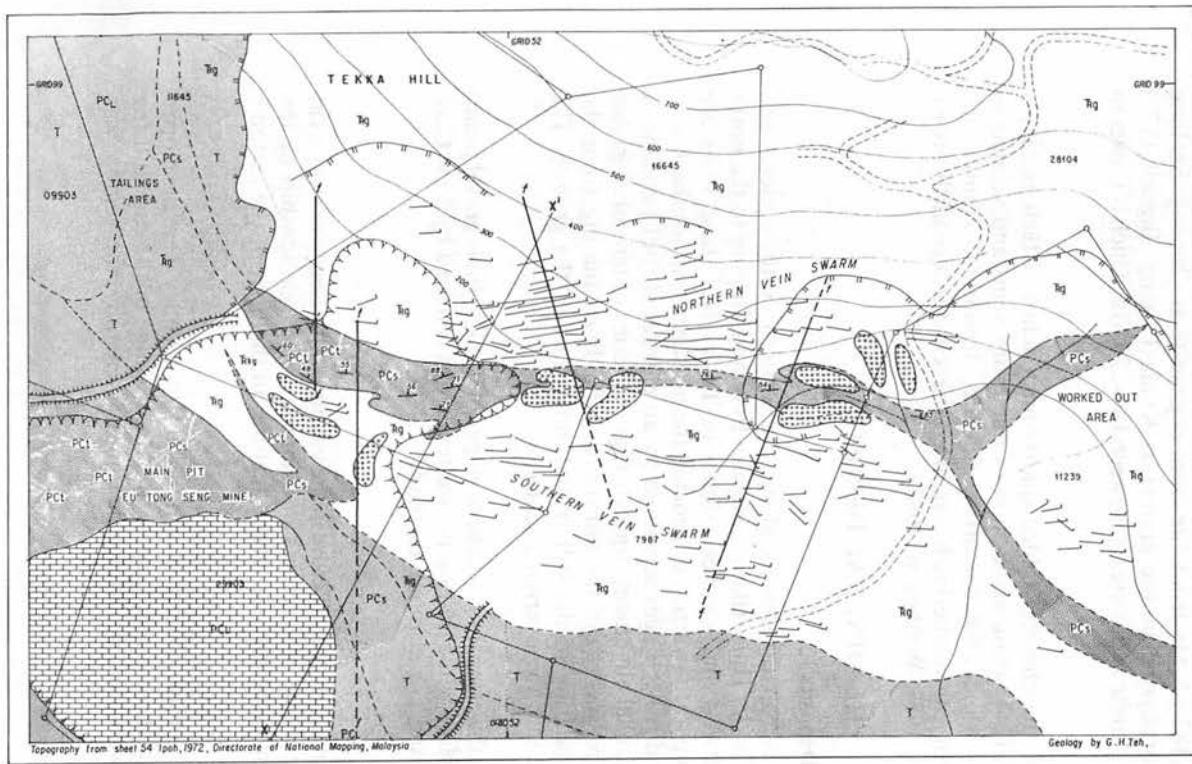


Fig. 2. Geology of Tekka Area, Tekka, Perak, Peninsular Malaysia.

### LEGEND



LOWER TRIASSIC TO UPPER JURASSIC  
**Tig**



Coarse porphyritic biotite granite. Marked with  
rock alteration in vicinity of vein swarms.



Koilimised granite.



SCHIST (PCs) :  
Schist with numerous micro-fluorite-tourmaline  
veins. Highly contorted and brecciated.



PCL - Tekko Clay, weathered schist



LIMESTONE (PCL) :  
White, light-brown or grey

### ROCK PILE



### MINE HOLE



### MINERALISED VEIN



### BUND



### STRIKE AND DIP OF FOLIATION



### RIVER



### CONTACT



defined



inferred

### MINING LOT BOUNDARIES AND PEGS



### FAULT



definite



inferred



### SCARP SLOPE



### MINING LOT NUMBER

29903

### CONTOUR LINE



100 Feet Interval



200

with it, irregular, elongated roof pendants of schist. In the northwest corner of Tekka Hill, the steep cliff faces of the limestone hill, Gunung Lanno, rise vertically from its contact with the granitic hill. Apart from limestone hills, the crystalline limestone forms the bedrock beneath the thick cover of alluvium and it is commonly interbedded with schist.

The granitic rock is generally a coarse-grained, porphyritic, biotite granite, with large phenocrysts of microcline and plagioclase. The granite adjacent to the mineralised veins has suffered extensive dislocation and wall-rock alteration.

Although no actual ages for the Tekka granite are available, those from two localities near to Tekka ( $183 \pm 8$  Ma lepidolite from pegmatite at Gopeng, Snelling 1965; and  $232 \pm 7$  Ma porphyritic biotite granite at Kuala Dipang, Bignell 1972) suggest that the age of the granite in this area is between 180–230 Ma, which is Lower to Upper Triassic.

The main feature of the chevron folded quartz-mica schist, which is highly contorted and brecciated, is the close association of numerous veins and veinlets of blue tourmaline, green, white and colourless fluorite, lepidolite, zinnwaldite, muscovite and sericite. Tropical weathering has reduced the schist to a reddish-brown clay (Jones, 1917; Rastall, 1927; Willbourn, 1963).

## THE MINERAL DEPOSITS

### Location of the Mineral Deposits

Mineralised veins outcrop in swarms along the western, southwestern and southern scarp slopes of Tekka Hill striking generally E-W and dipping to the north (Teh, 1976). In the southwest and southern slopes of Tekka Hill these veins are concentrated along two separate swarms, designated the northern and southern vein swarms, which form two distinct ridges separated by an elongated roof pendant of schist (see Fig. 2). This parallel alignment suggests that the series of tensional gashes (see structure) provided passage-ways for mineralising fluids emanating from the residuum that was accumulating in the still crystallising heart of the granite. The mineralised veins also cut into the overlying schist.

The deposit in the southwestern and southern slopes of Tekka Hill is gravel pump mined by Eu Tong Seng Mine while that on the western slope is mined by New Chin Seng Mine using the dry and gravel pump method.

### Structure

A detailed study was made of the structure in the vicinity of the two vein swarms at Tekka to work out the pattern of fractures and interpret the relationship of the mineralised veins and their associated structural features in the light of the tectonic history of the area.

Regionally, most of the rock structures seen in the Kinta Valley were developed during the emplacement of the granitic ranges, the Main Range in the east and the Kledang Range in the west, in late Mesozoic times. Generally the region was

dominated by the tectonic axes of these granitic ranges that strike approximately NNW and NNE (Ingham and Bradford, 1960). The Kinta Valley has then subjected to compressional forces operating mainly from WNW and to a lesser degree, from ENE.

At Tekka, however, the emplacement of the granitic cupola, as represented by Tekka Hill, has definitely given rise to local structural trends that have been superimposed upon and obscured the regional one. This is supported by an analysis of the fracture patterns (Fig. 3).

#### a) *Jointing*

Jointing is well developed within the area. Measurements of dips and strikes of joint planes made at different localities and the poles plotted and contoured on equal-area projections (Fig. 3) show that major joint directions can be divided into the following 5 sets:-

352°–028°, dipping 55–75°E  
 314°–344°, dipping 57–73°E  
 046°–072°, dipping 58–84°N  
 258°–277°, dipping 59–60°N  
 352°, dipping 52°E

All the five sets are believed to be formed by the same stresses and these were related to the local emplacement of the granite cupola. The general maximum stress is approximately parallel to the NNW–SSE direction. The 352°–028° and 314°–344° directions are first-order shear joints, while those in the 352° direction are cross (or extension) joints, and the 046°–072° and 258°–277° directions are 2nd order shear joints.

#### b) *The mineralised veins*

Equal-area projections of mineralised veins show that they are related to the joint stress system in the area (Fig. 3). The veins strike generally in a ENE–WSW to E–W direction and dip 54°–61° north. They are, in fact, tension joints or fractures infilled by minerals and are probably either the result of a slight relief of compressive stress, due to uplift which led to N–S relief of pressure, or to the effects of the regional compressive E–W stress.

As the vein quartz was emplaced under pressure from a lower level it opened up the fractures as it was invading them. Further, the orientation, or attitude, of these veins in depth, is greatly influenced and controlled by the shape of the roof of the intrusion.

#### c) *Faulting*

Further compression in the area initiated fault movements on the best developed pre-existing planes of weakness which were most suitably oriented (i.e., the first order shear joints and extension joints) to accomodate the stress application. This compressive orogenic stress caused strikeslip movements of up to 1 metre in the numerous faults encountered in the vicinity of the vein swarms. The faults generally strike in the 345°–020° direction (which is approximately N–S).

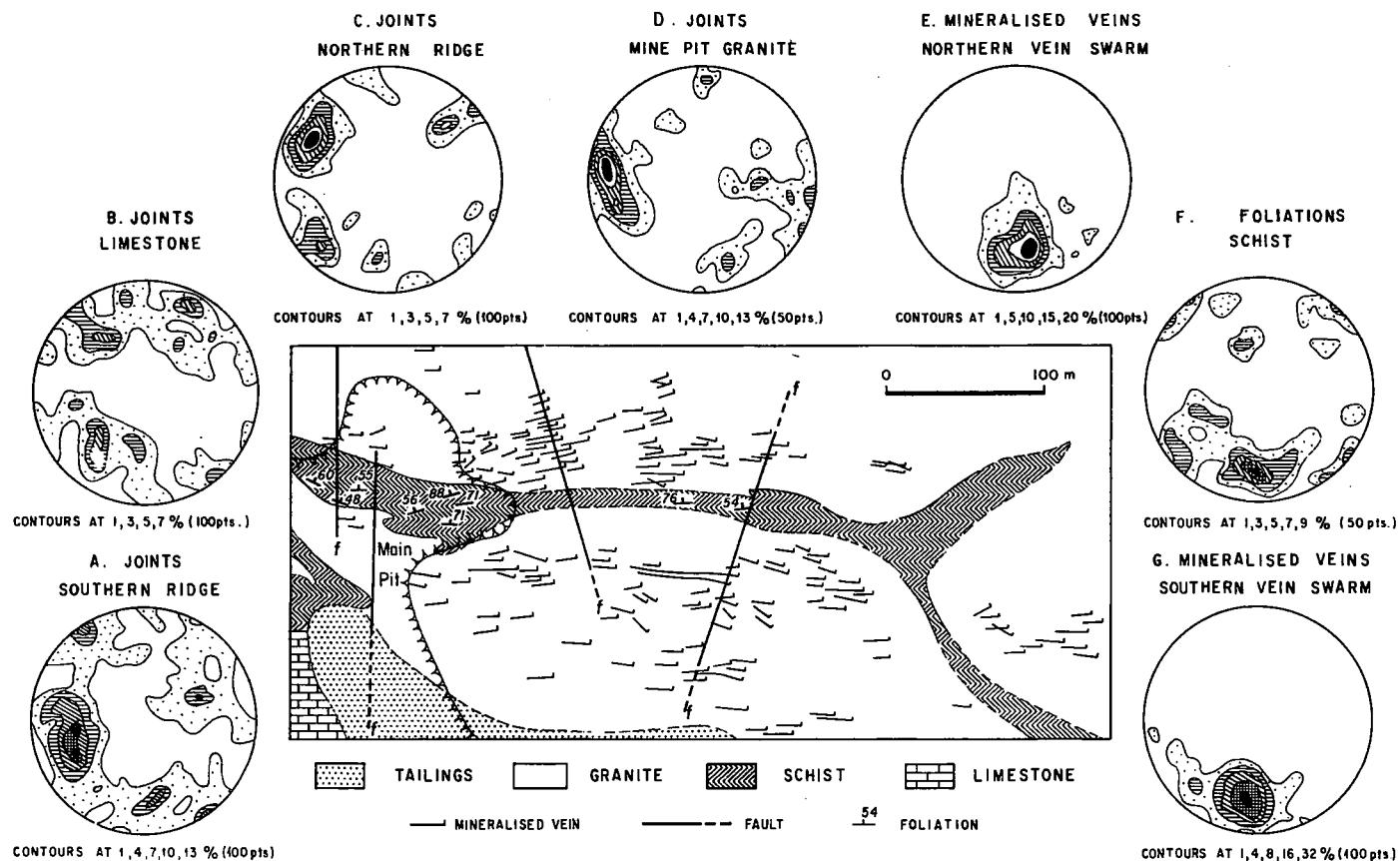


Fig. 3. Structural map of the Tekka area with corresponding contour diagrams (Lower Hemisphere Projections) of poles of joints, mineralised veins and foliations.

In most cases, the dip-slip movements are clearly shown by the dislocated veins with the eastern block the downthrown side along near-vertical fault planes. These planes appear to post-date the phase of mineralisation as they lack concentrations of the ore minerals and are probably a result of the last major movements in the area.

### Characteristics of the Mineralised Zones

Widths of the veins vary from 5 mm to 1 m. Many have strike lengths which are traceable up to 30 m. A single quartz-wolframite vein in the northern vein swarm has a strike length of about 50 m. At the northern end of the main pit a vein, about 30 cm in width, cuts the weathered overlying schist. The majority of the veins pinch and swell, split and joint are discontinuous along both strike and dip (Figs. 4 and 5).

The veins are both complex and composite. Successive pulses of quartz were introduced along with numerous non-metallic gangue minerals and ore minerals.

In the mine and in hand specimens there is great variation in the character of the veins with the minerals showing either a symmetrical crustification or randomly disseminated concentrations. Earlier crusts line the sides of the veins and normally late quartz completely fills the centres of the fissures. The many different vein assemblages encountered in the granite and schist include:-

#### *In Granite*

1. Quartz-tourmaline-topaz-cassiterite-wolframite-arsenopyrite  $\pm$  sulphides
2. Quartz-tourmaline-cassiterite-wolframite  $\pm$  topaz
3. Quartz-tourmaline-arsenopyrite  $\pm$  topaz
4. Quartz-tourmaline-cassiterite  $\pm$  topaz
5. Quartz-tourmaline  $\pm$  topaz
6. Quartz-cassiterite-wolframite-arsenopyrite  $\pm$  sulphides
7. Quartz-cassiterite-wolframite
8. Quartz-cassiterite-arsenopyrite
9. Quartz-cassiterite
10. Quartz-wolframite-arsenopyrite
11. Quartz-wolframite
12. Quartz-arsenopyrite
13. Quartz-stannite-sulphides-cassiterite-arsenopyrite  $\pm$  sulphosalts
14. Quartz-stannite-sulphides-cassiterite-arsenopyrite-sulphosalts  $\pm$  tourmaline
15. Quartz-stannite-sulphides-arsenopyrite  $\pm$  sulphosalts
16. Quartz-stannite-sulphides  $\pm$  sulphosalts

#### *In Schist*

17. Tourmaline-fluorite-sericite-lepidolite  $\pm$  cassiterite
18. Tourmaline-fluorite-lepidolite-zinnwaldite-sericite  $\pm$  cassiterite
19. Tourmaline-fluorite-sericite  $\pm$  cassiterite
20. Tourmaline-fluorite-muscovite-sericite  $\pm$  cassiterite
21. Tourmaline-muscovite  $\pm$  cassiterite
22. Quartz-sericite
23. Quartz-tourmaline-sericite

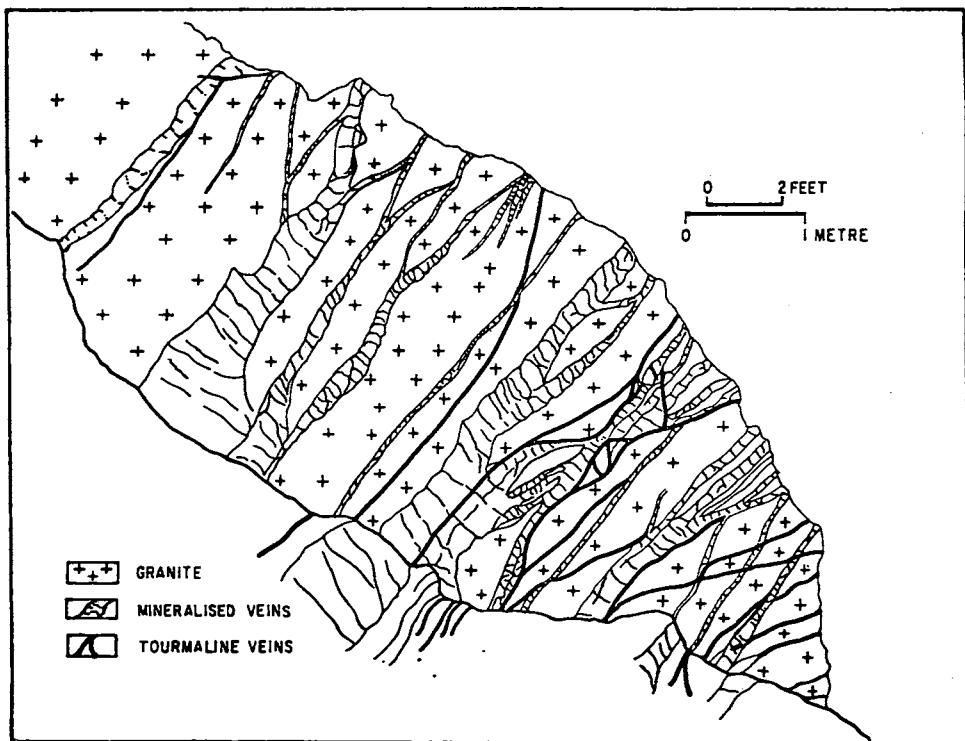


Fig. 4. Sketch of a section of northern vein swarm, looking eastwards, showing the mineralised veins dipping northwards.

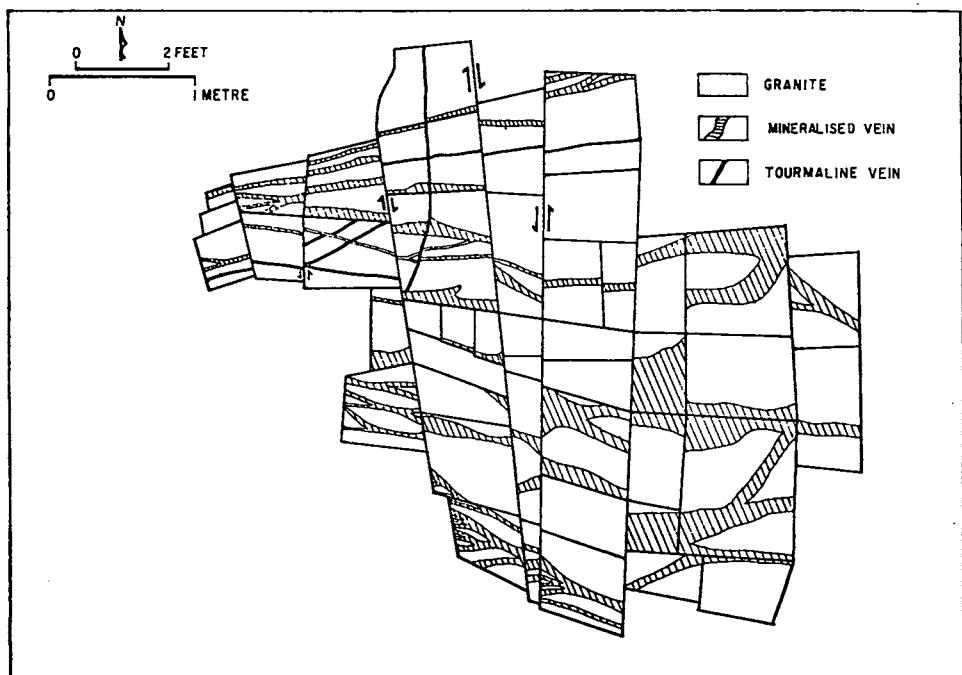


Fig. 5. Sketch of a section of the southern vein swarm (plan view) showing the numerous fractures.

From a mineralogical and temporal point of view the veins can be classified into the three following main types:-

- (a) An early quartz-tourmaline type with or without cassiterite, wolframite, arsenopyrite and minor amounts of other sulphide-bearing species.
- (b) A second (later) type consisting of quartz with or without cassiterite, wolframite, arsenopyrite and minor amounts of other sulphide-bearing minerals.
- (c) A third , and still later, type consisting of quartz, stannite, other sulphides and sulphosalts, with or without cassiterite and arsenopyrite.

This great variation indicates that during the phase of vein development new fractures were repeatedly formed and old ones, already mineralised, were, on occasions, repeatedly reopened. At the same time the nature of the ascending ore-forming agents was progressively changing.

Table 1 serves to demonstrate the homogenisation temperatures of 2-phase inclusions in quartz from three different vein assemblages at Tekka.

TABLE I

HOMOGENISATION TEMPERATURES OF 2-PHASE (LIQUID & VAPOUR) INCLUSIONS  
IN QUARTZ FROM THREE DIFFERENT VEIN ASSEMBLAGES AT TEKKA

Vein Type	Homogenisation temperature* of 2-phase (liquid and vapour) inclusions
Quartz-cassiterite vein	279/290–359 °C
Quartz-wolframite vein	260–306 °C
Quartz-arsenopyrite-cassiterite-sulphides vein	180–240 °C

\*No correction for pressure, so the figures indicate the minimum temperature of deposition. The higher temperature is probably the formation temperature and the lower is that of secondary quartz formed after fracturing.

Wall-rock alteration adjacent to the veins included silicification, tourmalinisation, greisenisation, kaolinisation and hematitisation.

#### Mineralogical Character of the Veins

In the complex Tekka deposit cassiterite is the only mineral of direct economic importance but it is associated with metallic species that might be of some limited economic value if the deposit is fully exploited. Some of these include wolframite, columbite/tantalite, scheelite and stannite. The common non-metallic gangue minerals present are quartz, blue and black tourmaline, topaz, sericite, muscovite, lepidolite, and fluorite.

In addition, in the mine, evidence shows that the more unstable species in the superficial environment have been locally oxidised and the products of oxidation have, in part, been fixed as secondary supergene species. These are mainly scorodite, varlamoffite, covellite and goethite. These light- to dark-green and yellow to yellowish-brown coatings of supergene products of copper, iron and tin appear on and near the primary ore minerals of the veins.

Table 2 lists the reflectance (R %) and microindentation hardness (VHN) measurements for the more abundant hypogene and supergene minerals of the Tekka deposit. A detailed account of each of the mineral species in the Tekka ore deposit can be found in Teh (1970 & 1976).

### Solid Solutions

Microscopic studies of polished sections of the Tekka ore show exsolution textures between the following minerals:-

#### *Solid solution in oxide minerals*

1. cassiterite—columbite/tantalite       $\text{SnO}_2-(\text{Fe},\text{Mn})(\text{Ta},\text{Nb})_2\text{O}_6$
2. cassiterite—tapiolite                        (cassiterite is host)

#### *Solid solution in sulphide and sulphosalts minerals*

1. sphalerite—chalcopyrite\*       $\text{ZnS}-\text{CuFeS}_2$
2. stannite—chalcopyrite               $\text{Cu}_2\text{FeSnS}_4-\text{CuFeS}_2$
3. stannite—sphalerite\*               $\text{Cu}_2\text{FeSnS}_4-\text{ZnS}$

(\*denotes either may act as host)

4. kobellite—tetrahedrite               $5\text{PbS}.4(\text{Bi},\text{Sb})_2\text{S}_3-\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$

Curiously randomly orientated ex-solution bodies of light-brownish grey columbite/tantalite and/or tapiolite are present in the cassiterite of the early quartz-tourmaline-cassiterite-wolframite-arsenopyrite veins and of the sulphide-rich veins. Rectangular-shaped inclusions of what is surely columbite/tantalite are also present in the cassiterite.

At Tekka there is evidence of extensive mutual solid solution between sphalerite ( $\text{ZnS}$ ), chalcopyrite ( $\text{CuFeS}_2$ ) and stannite ( $\text{Cu}_2\text{FeSnS}_4$ ). More than one mineral species may occur as ex-solution bodies in a given Tekka sulphide. However, the most common ex-solution texture found in these three sulphides is the apparently random arrangement of spherical blebs of one sulphide in another giving rise to an 'emulsion' texture, but locally 'compound' ex-solution bodies, that is, bodies consisting of more than one species, may also occur. Lenses, laths or rods, whose long axes and distribution are in parallel arrangement, are common features of sphalerite and chalcopyrite ex-solution bodies in stannite. A rim texture consisting of segregation veins of sphalerite, at times together with chalcopyrite, occurs along the perimeters of stannite. Locally sphalerite also forms curious assymetrical Chinese character-shaped bodies in the stannite (Hosking, 1970). In addition, 'cross-hatched' chalcopyrite in

TABLE 2

REFLECTIVITY AND MICRO-HARDNESS VALUES OF THE HYPOGENE  
AND SUPERGENE MINERALS OF THE TEKKA DEPOSIT

Mineral	Chemical Formula	Reflectance (R %) $\lambda = 546 \text{ nm}$		Micro-indentation hardness (VHN) (Load used in brackets)	
		Writer's value	Reference <sup>1</sup> values	Writer's values	Reference <sup>3</sup> values
Cassiterite	$\text{SnO}_2$	10.6–13.6	10.9–12.6	1288 (200)	811–1532
Columbite/tantalite	$(\text{Fe}, \text{Mn})(\text{Nb}, \text{Ta})_2\text{O}_6$	17.1–20.3	15.3–17.7	660–985 (200)	240–1021
Wolframite	$(\text{Fe}, \text{Mn})\text{WO}_4$	14.8–19.0	16.0–18.7	370–398 (100)	258–657
Scheelite	$\text{CaWO}_4$	9.8–11.5	10.0–10.3	332–368 (100)	285–464
Loellingite	$\text{FeAs}_2$	53.0	c.55	720–850 (200)	368–1048
Arsenopyrite	$\text{FeAsS}$	50.3–60.0	51.0–51.5	883–1006 (200)	715–1354
Stannite	$\text{Cu}_2\text{FeSnS}_4$	25.5–28.8	27.4–29.3 <sup>2</sup>	213–228 (100)	140–326
Pyrite	$\text{FeS}_2$	44.8–57.3	53.6	1032–1550 (200)	913–2056
Sphalerite	$\text{ZnS}$	15.8–19.1	17.28–19.66 <sup>2</sup>	197–232 (100)	128–276
Chalcopyrite	$\text{CuFeS}$	40.0–46.4	43.8–48.8	189–203 (100)	174–219
Kobellite	$5\text{PbS}.4(\text{Bi}, \text{Sb})_2\text{S}_3$	37.1–49.5	36.6–45.4	130–173 (50)	69–173
Tetrahedrite	$\text{Cu}_3\text{SbS}_3$	28.8–32.7	31.4–33.1 <sup>2</sup>	302–357 (100)	251–425
Enargite	$\text{Cu}_3(\text{As}, \text{Sb})\text{S}_4$	22.6–26.7	25.15–28.72	213 (100)	133–383
Galena	$\text{PbS}$	43.4–47.5	43.8	88.9–102 (50)	56–116
Stibnite	$\text{Sb}_2\text{S}_3$	41.6	31.4–46.8	120 (50)	42–129
Scorodite	$\text{FeAsO}_4.2\text{H}_2\text{O}$	6.1	—	—	—
Varlamoffite	$\text{SnO}_2.\text{H}_2\text{O}$	7.5	—	297 (100)	—
Covellite	$\text{CuS}$	9.2–15.6	72–74.3	68–71 (50)	59–129
Goethite	$\text{FeO}(\text{OH})$	17.5	c. 15–20	715–734 (200)	525–1010

<sup>1</sup>These values are those given for the specimen in question by Uyttenbogaardt & Burke (1971).<sup>2</sup>These reflectance values were determined at a wavelength of 540nm.<sup>3</sup>These micro-indentation hardness values are given by Uyttenbogaardt & Burke (1971) are those determined when using a standard load of 100g.

sphalerite and round blebs of sphalerite with chalcopyrite along the periphery locally occur in the stannite.

Kobellite and tetrahedrite in the Tekka ores form eutectic intergrowths. Elsewhere kobellite is known to form myrmekitic intergrowths with tetrahedrite (Uytenbogaardt and Burke, 1971). At Tekka kobellite is the host, whilst tetrahedrite develops spindle-shaped bodies within it which tend to have a parallel alignment (Fig. 6). This suggests unmixing along the cleavage or twin planes of the kobellite. Tetrahedrite is also present as emulsion blebs in kobellite. Locally, these tetrahedrite blebs tend to segregate to the edges of the kobellite.

### Paragenesis

A study of the Tekka deposit *in situ*, hand specimens, and their thin and polished sections, has enabled its paragenesis to be established (see Table 3) and has permitted considerable information to be acquired concerning the development of the mineralogical character of the ore deposit. Deposition, solution, replacement and change in solubility of the minerals appear to be the dominant processes during the formation of the ore deposit.

Quartz appears to be the earliest mineral species to be deposited and was repeatedly deposited throughout the mineralisation. Loellingite is also early, followed by arsenopyrite. Early black tourmaline was deposited soon after loellingite/arsenopyrite as it fills fractures in these species (Fig. 7). Slightly later, but together with tourmaline, there was the deposition of the micas, namely muscovite, sericite and lepidolite, together with topaz. Next, cassiterite and wolframite were deposited. Topaz is not as abundant as it must have been initially, as it has been partly replaced by cassiterite (Fig. 8). Intimate intergrowths of cassiterite and wolframite suggest that these two minerals were also deposited contemporaneously. Cassiterite, however, is slightly earlier as fractures in the cassiterite are cemented by wolframite and later cassiterite, and these filled fractures are also offset by wolframite veinlets. A later generation of lighter, less pleochroic cassiterite, heals fractures in the earlier cassiterite and wolframite. Locally this cassiterite also replaces wolframite. Tourmaline-arsenopyrite-cassiterite-wolframite veins also indicate that cassiterite is earlier than wolframite. These veins have an outer zone of early, more-fractured loellingite/arsenopyrite filled by quartz, tourmaline and cassiterite in that order. The centres of the veins were then filled by narrow bands of stumpy cassiterite and slightly later prismatic wolframite. Vein interstices were then filled with quartz.

Ex-solution bodies of tapiolite and columbite/tantalite are associated with the early cassiterite. Columbite/tantalite, however, also replaces the cassiterite (Fig. 9). A later generation of tourmaline heals fractures in the early cassiterite and wolframite (Fig. 10).

Next scheelite was deposited followed by a generation of blue tourmaline together with a second generation of muscovite. These were followed almost immediately by second generations of sericite and lepidolite, and zinnwaldite and fluorite. The fact that fluorite of a number of colour occurs in the deposit suggests that a number of generations of the species in question may be present. During this phase of the mineralisation, fractures in the earlier species (notably loellingite/arsenopyrite,

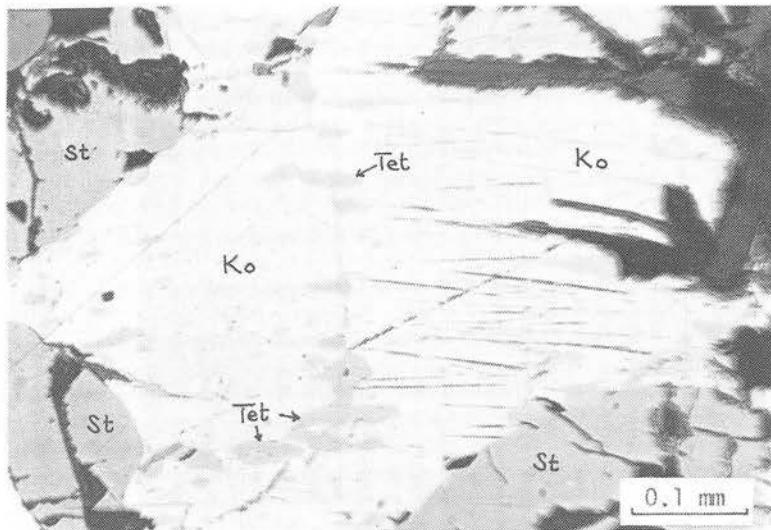


Fig. 6. Polished showing kobellite (Ko) with spindle-shaped ex-solution bodies of tetrahedrite (Tet) in stannite (St). Mineralised vein from Northern Vein Swarm, Tekka. (Plane-polarised light.)

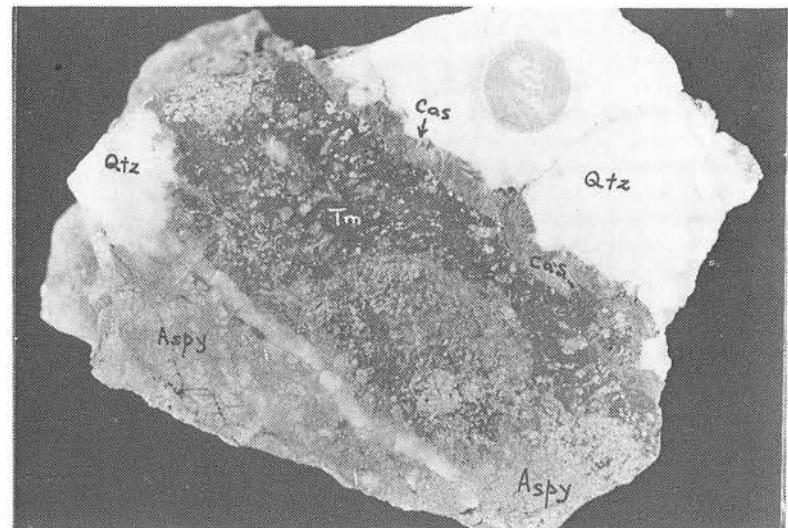


Fig. 7. Quartz-cassiterite-tourmaline-arsenopyrite vein from the Southern Vein Swarm, Tekka. Early arsenopyrite (Aspy) is highly fractured, followed by tourmaline (Tm), while late cassiterite (Cas) line the inside of the vein.

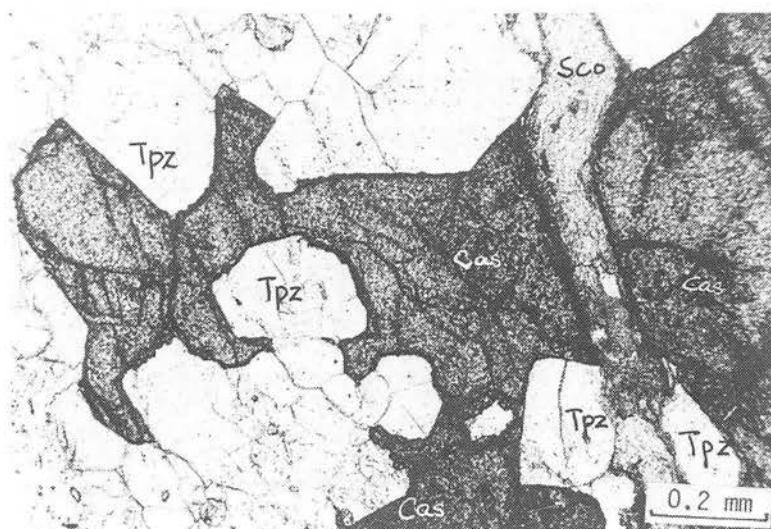


Fig. 8. Thin section showing early topaz (Tpz) replaced by cassiterite (Cas). Scorodite (Sco) fills a fracture in the cassiterite and the topaz. Mineralised granite, Northern Vein Swarm, Tekka. (Plane-polarised light.)

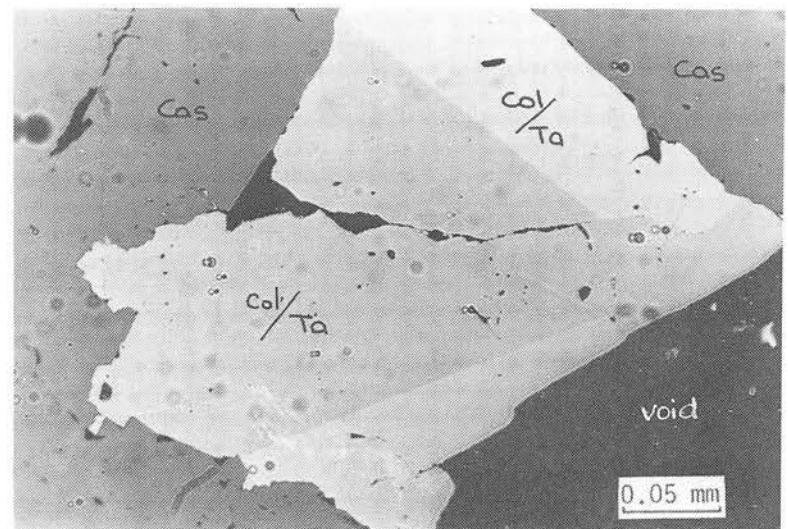


Fig. 9. Polished section showing columbite tantalite (Col Ta), with distinct bireflectance, replacing cassiterite (Cas). Mineralised vein, Northern Vein Swarm, Tekka. (Plane-polarised light.)

TABLE 3  
PARAGENESIS OF THE TEKKA DEPOSIT

MINERAL SPECIES		TIME
		Early ————— Late
HYPOGENE	Quartz	—
	Loellingite	—
	Arsenopyrite	—
	Tourmaline	black black blue
	Muscovite	—
	Sericite	—
	Lepidolite	—
	Topaz	—
	Cassiterite	—
	Wolframite	—
	Tapiolite	—
	Columbite/tantalite	—
	Scheelite	—
	Zinnwaldite	—
	Fluorite	—
	Pyrite	—
	Sphalerite	—
	Stannite	—
	Chalcopyrite	—
	Kobellite	—
	Tetrahedrite	—
	Enargite	—
	Galena	—
	Stibnite	—
HYPOGENE and/or SUPERGENE	Neodigenite	? — ?
	Chalcocite	? — ?
	Covellite	? — ?
	Hematite	? — ?
SUPERGENE	Scorodite	? — ?
	Varlamoffite	? — ?
	Goethite	? — ?
	Psilomelane	? — ?
	Malachite	? — ?
	Azurite	? — ?
	Chrysocolla	? — ?

The relative order of deposition of these *certain* supergene species cannot be established with any degree of certainty.

cassiterite and wolframite) were filled largely by a suite of later sulphides and sulphosalts. Euhedral pyrite was the first 'later' sulphide mineral deposited and it was replaced by stannite. Stannite, sphalerite, and chalcopyrite were, during one stage, simultaneously deposited as evidenced by ex-solution bodies within one another and by the nature of their mutual boundaries. Local replacement of sphalerite by stannite, and stannite by chalcopyrite indicates that sphalerite is the earliest, while chalcopyrite is the latest of these three sulphide minerals to be deposited.

Fractures in stannite are associated with later cassiterite, chalcopyrite and enargite. Myriads of small cassiterite crystals are also present in stannite at the stannite-arsenopyrite crystals boundaries (Fig. 11).

Chalcopyrite generally totally surrounds the earlier kobellite and replaces it as well. Locally kobellite replaces pyrite but late pyrite intersects kobellite. Tetrahedrite is generally contemporaneous with kobellite as it occurs as ex-solution bodies within the latter species but locally tetrahedrite replaces kobellite (Fig. 12). Enargite replaces stannite and chalcopyrite. Additions of arsenic, from the replacement of loellingite/arsenopyrite by cassiterite and wolframite, and of tin and copper, from the breakdown of stannite, to the ore-forming fluid may account for the formation of enargite (Leow, Hosking and Teh, 1969).

Galena and stibnite are the latest minerals in the paragenetic sequence. Galena replaces the late-phase pyrite. Stibnite locally engulfs the enargite.

Of the hypogene and/or supergene mineral species, neodigenite and chalcocite are early contemporaneous, forming solid-solutions. Covellite, which replaces the neodigenite and chalcocite may possibly be contemporaneous with some of the hematite. Varlamoffite is commonly associated with stannite (Fig. 13), while scorodite encrusts arsenopyrite.

The relative order of deposition of the definitely supergene species (namely scorodite, psilomelane, goethite, varlamoffite, malachite, azurite and chrysocolla) cannot, however, be established with any degree of certainty.

### Classification of the Tekka deposit

Earlier studies of these deposits by Riley (1967) and Hosking (1973) led these workers to classify the Tekka deposit as xenothermal in character. The work carried out by the parent writer has served to confirm this classification. The impressive assemblage of supposedly 'high' temperature minerals (e.g., cassiterite and wolframite) and supposedly low temperature ones (such as galena and stibnite) that are found in the veins, over very limited strike and dip lengths, means that these ore bodies developed at comparatively modest depths below the surface in an environment that was characterised by a fairly rapid waning of what was initially a fairly high temperature (that is, 'high' in the sense that the word is used by ore geneticists who are concerned with hypogene vein and replacement deposits).

### SUMMARY AND CONCLUSIONS

It is thought that this paper contains some of the results of the most detailed study yet conducted of the nature of one of the numerous xenothermal deposits that are now

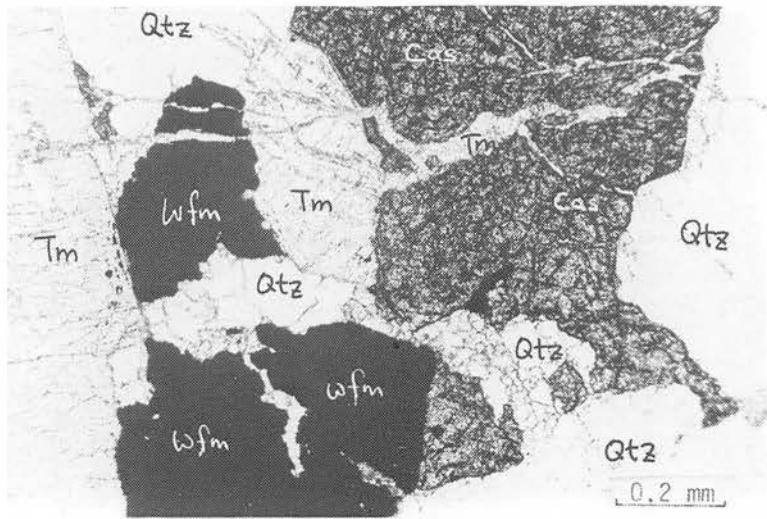


Fig. 10. Thin section showing second generation of tourmaline (Tm) and quartz (Qtz) infilling fractures in early tourmaline (Tm), cassiterite (Cas) and wolframite (Wfm). Mineralised vein from Northern Vein Swarm, Tekka. (Plane-polarised light.)

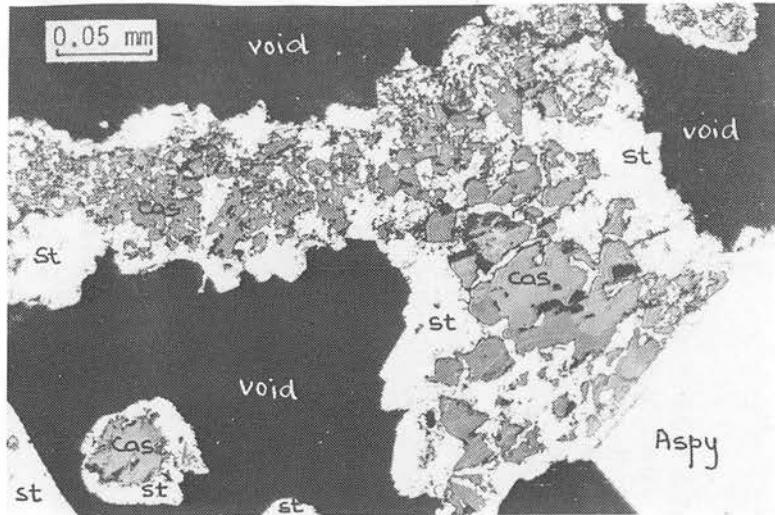


Fig. 11. Polished section showing relicts of cassiterite (Cas) following partial replacement of the oxide by stannite (St.). Mineralised vein from main pit, Eu Tong Seng Mine, Tekka. (Plane-polarised light.)

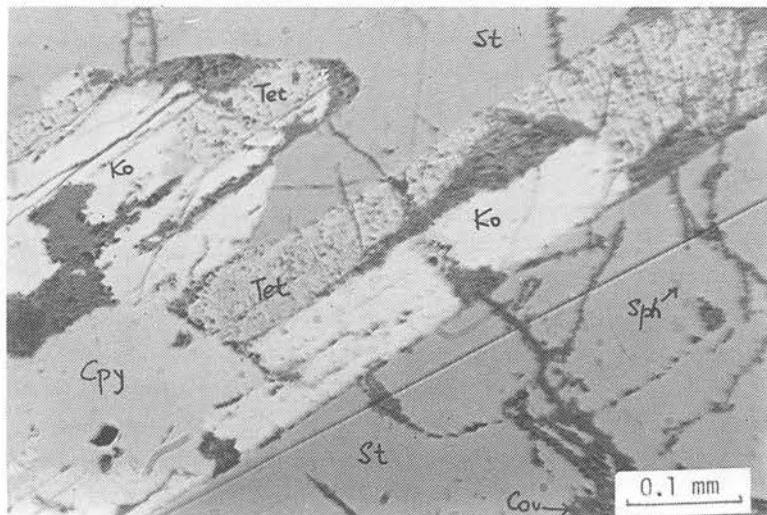


Fig. 12. Polished section showing kobellite (Ko) replaced by tetrahedrite (Tet). Covellite (Cov) development is centred around fractures in stannite and tetrahedrite. Locally, also, chalcopyrite (Cpy) replaces kobellite (Ko). Ex-solution blebs of sphalerite occur in the stannite. Northern Vein Swarm, Tekka. (Plane-polarised light.)

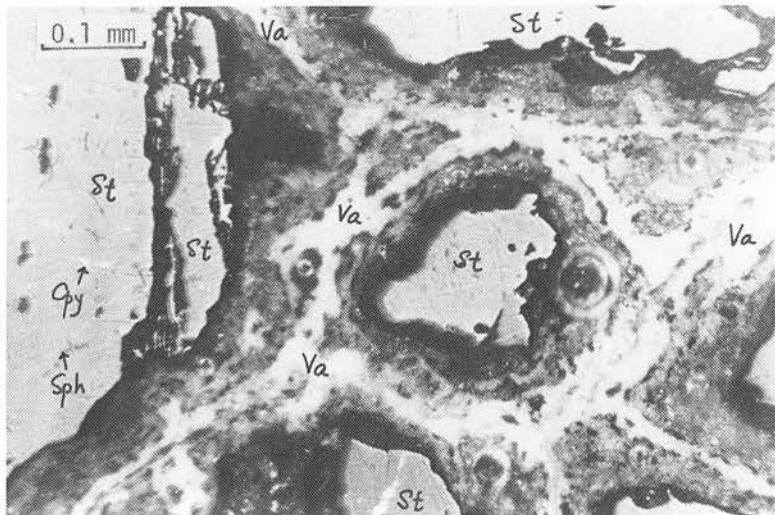


Fig. 13. Polished section (under oil) showing varlamoffite (Va) with colloform banding replacing stannite (St) with a "garland type" texture. Locally the stannite has ex-solution bodies of chalcopyrite (Cpy) and sphalerite (Sph). Main pit, Eu Tong Seng Mine, Tekka. (Crossed-polars.)

known to occur in the Western Half of Peninsular Malaysia. Nevertheless, the work has also established that there are still many further facets of the Tekka mineralisation that would well repay investigation. Of the more important of these one may site the following:-

- (i) Studies of the trace-element patterns of the vein components. The results of such work would provide further intimate details of the paragenesis.
- (ii) Geothermometric investigations. These would help to paint a more detailed picture of the development of the veins.
- (iii) Radiometric dating of components of the altered wall-rock adjacent to the veins and also of those of the granitic host. The results of this work may serve to unravel that enigmatic temporal relationship between the granite and its spatially-related veins.

From a distinctly practical point of view this study of the mineralogical character of the Tekka veins has served to emphasise their complexity, and, indirectly, to demonstrate to the mineral-dresser that he would experience problems of some magnitude were he to attempt to make a clean high-grade cassiterite concentrate from them. This is of some real importance to Malaysia as it is felt by many that with the rapid depletion of her stanniferous placers the time is not far off when her 'hard-rock' tin deposits will have to be exploited to the maximum if she is to hold her place for a further appreciable length of time, amongst the major tin producers of the world. So, it can be reasonably concluded that this study emphasises the need for *all* the known potentially economic hard-rock stanniferous deposits of Malaysia to be subject, without delay, to studies similar to those made of the Tekka potential ore. Also, it would seem realistic to subject the Tekka, and all those other known 'hard-rock' tin deposits, to mineral beneficiation investigations, *now*, at least on a laboratory scale.

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#### REFERENCES

- BIGNELL, J.D., 1972. *The geochronology of the Malayan Granites*. Univ. Oxford. Unpub. Ph.D. Thesis. Aug. 1972.
- HOSKING, K.F.G., 1970. Curious inclusions, essentially of sphalerite, in stannite from Tekka, Perak. *Geol. Soc. Malaysia Newsletter*, No. 26, 1-4.
- HOSKING, K.F.G., 1973. The Primary Tin Mineralisation Patterns of West Malaysia. *Geol. Soc. Malaysia Bull.* 6, 297-308.
- INGHAM, F.T. and BRADFORD, E.F., 1960. The geology and mineral resources of the Kinta Valley, Perak. *Mem. Geol. Surv. Dep. Fed. Malaya*, 9, 347p.
- JONES, W.R., 1917. The Origin of the Secondary Stanniferous Deposits of the Kinta District, Perak. *Quart. Journ. Geol. Soc. Lond.*, 72, 165-97.

- LEOW, J.H., HOSKING, K.F.G. & TEH, G.H., 1969. Aspects of the Mineralogy of the NE-SW trending veins at Tekka, Perak. *Geol. Soc. Malaysia Newsletter*, 21, 2-8.
- RASTALL, R.H., 1927. The Geology of the Kinta Valley. *Min. Mag. London*, 36, 329-338.
- RILEY, G. 1967. The Cassiterite-Stannite Occurrence at Tekka Mines, Kinta. *Geol. Soc. of Malaysia Newsletter*, No. 7, 10-12.
- SNELLING, N.J., 1965. Age Determination Unit. Summary of results from Malaysia. *Ann. Rept. Overseas Geol. Surveys* (for 1964), 142-147.
- TEH, G.H., 1969. *Geology of the Tekka Lodes including an account of a geochemical soil survey on Tekka Hill, Tekka, Perak, West Malaysia*. Unpub. B.Sc. (Hons) thesis, University of Malaya, 95p.
- TEH, G.H., 1975. The analysis of fluoride in tropical soils by selective ion electrode methods and its possible application to the search for sub-outcropping tin deposits in Peninsular Malaysia. *Warta Geologi* 1, 59-67.
- TEH, G.H., 1976. *Geochemical studies with supporting geological and mineralogical ones, of the Tekka area, Perak, Peninsular Malaysia*. Unpublished M.Sc. Thesis, University of Malaya, 265p.
- TEH, G.H., 1979. Geochemical studies around the Tekka Area, Perak, Peninsular Malaysia. *Bull. Geol. Soc. Malaysia* 11, 353-373.
- UYTENBOGAARDT, W. & BURKE, E.A.J., 1971. *Tables for Microscopic Identification of Ore Minerals*. 2nd Edition. Elsevier Publ. Co. Amsterdam, 430p.
- WILLBOURN, E.S., 1936. A short account of the geology of those tin-deposits of Kinta that are mined by alluvial methods. *Journ. Engng. Assoc. Malaysia*, 4, no. 255-264.

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