EPMA characterization of the Fe-Cu-Sn mineralisation at Waterfall Mine, Pelepah Kanan, Johor

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Abstract: The electronprobe microanalyser (EPMA) is used, for the first time locally, to characterise the Fe-Cu-Sn mineralisation at the Waterfall Mines, Pelepah Kanan, Johor.

Evidences from the field, reflected light microscopy and EPMA studies show that the mineralisation at Pelepah Kanan is essentially a replacement body within a calc-silicate sequence or skarn of early magnetite-cassiterite-fluorite-quartz (Fe-Sn) mineralisation that is intruded by a later phase of copper mineralisation and that both these were later cut by an even later hydrothermal cassiterite-K-feldspar-quartz vein swarm along fissures, joints and faults.

The EPMA was also instrumental in identifying a number of new minerals that have yet to be reported from Pelepah Kanan and they include native bismuth, tennantite (Cu3AsS3), wittichenite (Cu3BiS3), cuprite (Cu2O), native Cu and gold.

The variable pinkish nature of the feldspars in the cassiterite-K-feldspar-quartz veins was confirmed to be due to the alteration of Fe-Mn-O material isfilling cleavages in the feldspars. In addition EPMA mapping of the dark bands in highly pleochroic cassiterites show that they contain higher amounts of Fe.

Finally EPMA mapping of tailings samples show that they are worth reassessing as a large portion of them still have high iron oxide contents (80-90%).

INTRODUCTION

The purpose of this paper is the harnessing of the EPMA (electronprobe microanalyzer) to characterise the Fe-Cu-Sn mineralisation at the Waterfall Mine, Pelepah Kanan, Johor.

Since the discovery in 1901 by the English geologist Captain Snow (Abdullah Hasbi Hassan et al., 1981) and because of its unique mineralisation, the area has attracted various local and international workers (Willbourn, 1936; Roe, 1941; Burton, 1959; Grubb and Hamaford, 1966a, 1966b; Kee Thuan Moore, 1966; Bean, 1969; Ganesan, 1969, 1976; Khoo Han Peng, 1969; Cheng Eng Choon, 1975; Yeap Ee Beng, 1982; Nor Saawaludin Mohd. Nor, 1983; Zubaidi Abbas, 1983; Chu Ling Heng et al., 1984; Wan Fuad Wan Hassan et al., 2000; and Adong Laming, 2001; Lee, 2002).

The mine area is bounded by longitudes 103°50'5"E and 103°50'20"E and latitudes 1°49'50"N and 1°50'20"N covering an area approximately 30 km² (Fig. 1).

The main rock type in the area is a calc-silicate hornfels which has been intruded by the Lower Triassic porphyritic biotite granite and associated microgranite and aplite (Yeap, 1982) which are structurally controlled (Wan Fuad Wan Hassan et al., 2000) (Fig. 2).

METHOD AND MATERIALS

Field mapping was carried out taking into careful consideration the relationships between the iron, copper and tin mineralisations. In the laboratory, thin and polished sections of the rock types, ore minerals, iron ore and tailings, were prepared for both reflected microscopy (using a Leitz Laborlux microscope) and EPMA study.
The EPMA at the Geology Department, University of Malaya, is a Cameca SX100 fully automated with four wavelength dispersive spectrometers (WDS), 12 analysing crystals, and a PGT energy dispersive spectrometer (EDS). The EPMA was operated at 20 kV and 20 nA beam current. The backscattered electron (BSE) image was widely used to differentiate the ore minerals and X-ray mapping was performed to show the distribution of the various elements (Teh, 2002).

RESULTS AND DISCUSSIONS


After careful field investigations followed by laboratory studies, the authors support Hosking's (1973) opinion that the Fe-Sn and Cu mineralisations developed as a replacement body within a calc-silicate sequence or skarn which is associated with an even later swarm of stanniferous veins. However, the initial Fe-Sn mineralisation is essentially magmatic, intrusive (and possibly extrusive too) with rhythmic bands (wrigglites) of vesicular magnetite with fine cassiterite, fluorite (CaF₂) and calc-silicates (Fig. 3). This is followed by the primary copper mineralisation of copper sulphides, cuprite and native Cu which is essentially intrusive and in places flowing over the semi-consolidated earlier Fe-Sn mineralisation as evidenced by field observations of load structures of the copper-rich magma over the Fe-Sn mineralisation (Fig. 4). The copper mineralisation is easily recognised by the formation of the colourful secondary covellite, malachite and azurite, in particular in the area of incipient copper mineralisation of garnetiferous hornfels while the Fe-Sn mineralisation, on
the other hand, has been extensively altered to goethite and martite.

The earlier Fe-Sn and copper mineralisations are then cut by the much later hydrothermal cassiterite-K-feldspar-quartz veins or veinlets that have infilled fissures, joints or faults (Fig. 5).

EPMA studies have led to the discovery of a number of minerals that have not yet been mentioned at Pelepah Kanan, namely native Bi (Fig. 6), tennantite (Cu₃AsS₅) (Fig. 7), wittichenite (Cu₃BiS₅) (Fig. 8), associated cuprite (Cu₂O), native Cu (Fig. 9) and gold (Fig. 10).

Figure 4. Hand specimen showing load structure of copper mineralisation over earlier iron mineralisation cut by late cassiterite-bearing quartz veins.

Figure 5. Cassiterite-K-feldspar-quartz veins infilling fissures and joints in calc-silicate hornfels.

Figure 6. BSE image showing native Bi inclusions (white) in arsenopyrite.
**Figure 8.** EPMA X-ray map showing wittichenite (Cu, Bi, As) rimming covellite (Cu, S) with core of chalcopryite (Cu, Fe, S).

**Figure 9.** EPMA X-ray map showing native Cu, associated with cuprite (Cu, O) in fracture in cale-silicate hornfels (Si, Al, O).
With careful field observations coupled with mineral relationship determinations from microscopic and EPMA studies, detailed paragenetic tables were drawn up for the individual Fe, Cu and Sn mineralisations, culminating in an overall paragenetic table for all the mineralisations at Pelepah Kanan (Fig. 11).

Detailed EPMA study of the nature of the K-feldspars in the cassiterite-K-feldspar quartz veins revealed that their pinkish colour is due to the alteration to iron oxide of the Fe-Mn-O material infilling the cleavages of the K-feldspar (Fig. 12).

In addition EPMA mapping of the highly pleochroic cassiterite bands revealed that the darker coloured zones are due to the presence of higher Fe content.

A study was carried out on the tailings site at the entrance to the mine with the view of determining the economic value of the mine’s tailings and determining the nature of the main and other minerals present so that the milling process can be better tuned to recover the iron. Samples were also collected at different horizons. EPMA X-ray mapping show that the tailings should be reassessed for possible treatment due to their seemingly high iron content (80-90%) (Samples CN1-L1 and CN1-L3, Table 1), however, care should be taken in localities with high tin contents as well (sample CN1-L1) (Fig. 13) as this will jeopardise the grade of the iron ore.

**CONCLUSIONS**

The present study show that the mineralisation at the Waterfall Mine, Pelepah Kanan is essentially a replacement body within a calc-silicate sequence with an early Fe-Sn mineralisation being intruded by a later copper mineralisation and an even later cassiterite-K-feldspar-quartz vein swarm cutting the earlier two mineralisations along fissures, joints and faults.
Figure 12. EPMA X-ray map showing that the pinkish tint of K-feldspars is due to the alteration of Fe-Mn-O material infilling the cleavages.

Figure 13. EPMA X-ray mapping of tailings sample (CN1-L1) showing significant amounts of magnetite (Fe, O) (81.48%) and cassiterite (Sn, O) (17.04%).
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REFERENCES


ZUBAIDI ABBAS, 1983. Perubahan batuan dinding pada telerang berkasiterit, Kota Tinggi, Johor. Tesis Sarjana Muda Sains, Universiti Kebangsaan Malaysia.

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