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EPMA study of heavy minerals in the Tekka area, Perak

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Abstract: EPMA characterisation of heavy minerals in the tailings, *amang*, river concentrates and mineralised veins in the Tekka area in terms of their composition, abundances, distribution, inclusions and intergrowths have confirmed the presence of cassiterite, ilmenite, iron oxide, arsenopyrite, stannite, chalcopyrite, pyrite, sphalerite, galena, scorodite, and covellite. Further, the EPMA was able to differentiate rutile, topaz, xenotime, monazite, tantalite, columbite, wolframite and strüverite through X-ray mapping.

The EPMA was able to justify the occurrence of fine gold in fractures in cassiterite, wolframite and black tourmaline and identify lesser known minerals like stolzite ($PbWO_4$),enargite (Cu_3AsS_4) and yttrotungstite [(Ce, Nd, Y)$W_2O_6(OH)_3$] and report for the first time in the Tekka area the occurrence of native bismuth, bismuthinite (Bi_2S_3), matildite ($AgBiS_2$) and mimetite [Pb(AsO_4, PO_4)Cl].

The EPMA was able to identify inclusions of ilmenorutile, tapiolite, arsenopyrite and ilmenite in cassiterite besides confirming that the different colours of tourmaline found at Tekka is a reflection of their different Fe and Mg contents.

All the new information on the new mineral species and their related mineral associations have aided in the preparation of a more complete paragenetic sequence of the Tekka xenothermal deposit.

Abstrak: Pencirian EPMA mineral-mineral berat di dalam tailings, *amang*, konsentrat sungai dan telerang pemineralan di kawasan Tekka terhadap komposisi, kelimpahan, taburan, inklusi dan salingtumbuhan mereka telah membuktikan kehadiran mineral-mineral seperti kasiterit, ilmenit, oksida besi, arsenopirit, stannit, kalkopirit, sfalerit, galena, scorodit, dan kovelit. Kajian lanjutan EPMA telah bezakan rutil, topaz, xenotim, monazit, tantalit, columbit, wolframit dan strüverit melalui pemetaan sinar-X.

Peralatan EPMA telah sahkan juga kehadiran emas halus didalam retakan didalam kasiterit, wolframit dan tourmalin hitam dan kenalpastikan mineral kurang biasa seperti stolzit ($PbWO_4$), enargit (Cu_3AsS_4) dan yttrotungstit [(Ce, Nd, Y)$W_2O_6(OH)_3$] dan laporkan kali pertama di kawasan Tekka kehadiran bismut asli, bismutinit (Bi_2S_3), matildit ($AgBiS_2$) dan mimetit [Pb(AsO_4, PO_4)Cl].

EPMA juga camkan inklusi-inklusi ilmenorutil, tapiolit, arsenopirit, dan ilmenit didalam kasiterit selain daripada tunjukkan warna berbeza tourmalin yang dijumpai di Tekka cerminkan perbezaan kandungan Fe dan Mg mereka.

Semua maklumat ini tentang spesies mineral baru dan hubungan diantara mineral-mineral lain telah membantu menyediakan jujukan paragenesis yang lebih menyeluruh untuk mendapan xenoterma Tekka.

INTRODUCTION

The purpose of this paper is to characterise the cassiterite and various heavy minerals present in the tailings, *amang*, mineralised veins and river samples, inclusive of zoning, intergrowths and inclusions, using the EPMA and reflected light microscope with the view of refining the paragenesis of the mineralisation at Tekka. In addition the EPMA was called upon to determine the different coloured tourmalines at Tekka and EPMA X-ray mapping was utilised to quantify the different amounts of heavy minerals in the different samples in the Tekka area.

The study area is located 14 km south of Ipoh (Fig. 1). The area has been studied extensively for tin mineralisation and associated heavy minerals (Teh, 1969, 1976, 1979, 1981; Ismail, 1994; Sanusi, 1998; Irdawati, 2001; Teh and Irdawati, 2002). The area consists mainly of granite, schist and limestone (Ingham and Bradford, 1960) with Tekka Hill forming the main part of the coarse grained porphyritic biotite granite intrusion with roof pendants of schist and they are both cut by numerous mineralised quartz veins (Teh, 1969, 1981). Much of the hydrothermally altered granite in the area has been extensively weathered, making mining much easier, and a large proportion of the heavy minerals have also been released and washed into the adjacent streams and rivers.

METHOD AND MATERIALS

Samples of tailings, *amang* and hard rocks were collected from different localities in the Tekka area (Hooi, 2002). Samples were collected from the main pit, sand mine area, rivers and Merapoh Mine (Fig. 2). Samples from the river include B2, B3, B4, B5, B6, B7, B8 and D1. Samples from the main pit include X1, X2A, X2B, X3A, X3B, X4A and X4B. Samples X2A, X2B, X3A, X3B, X4A and X4B were collected from 2 different horizons in the tailings in the main pit area to compare their heavy minerals contents. Three samples were sampled in the sand mine namely Z5, Z6 and Z7. Three hard rock samples

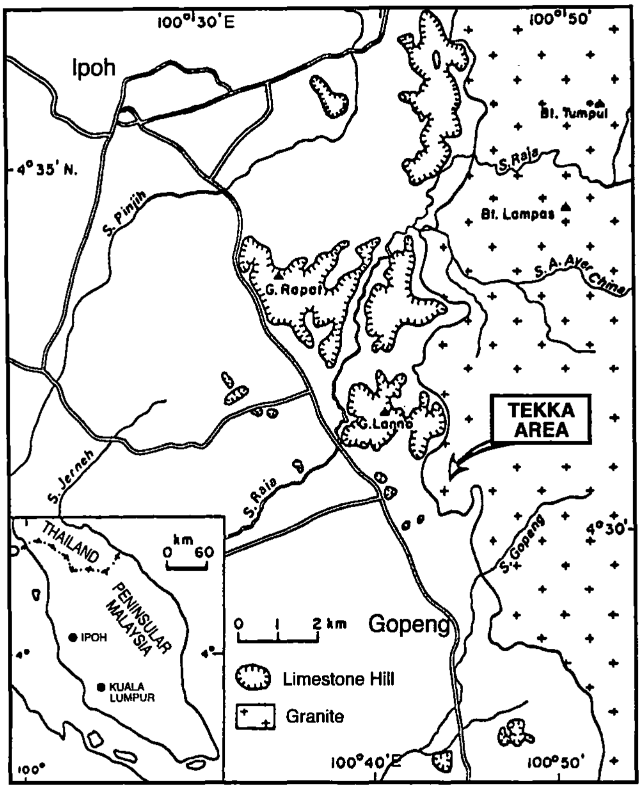

Figure 1. Location of the Tekka area.

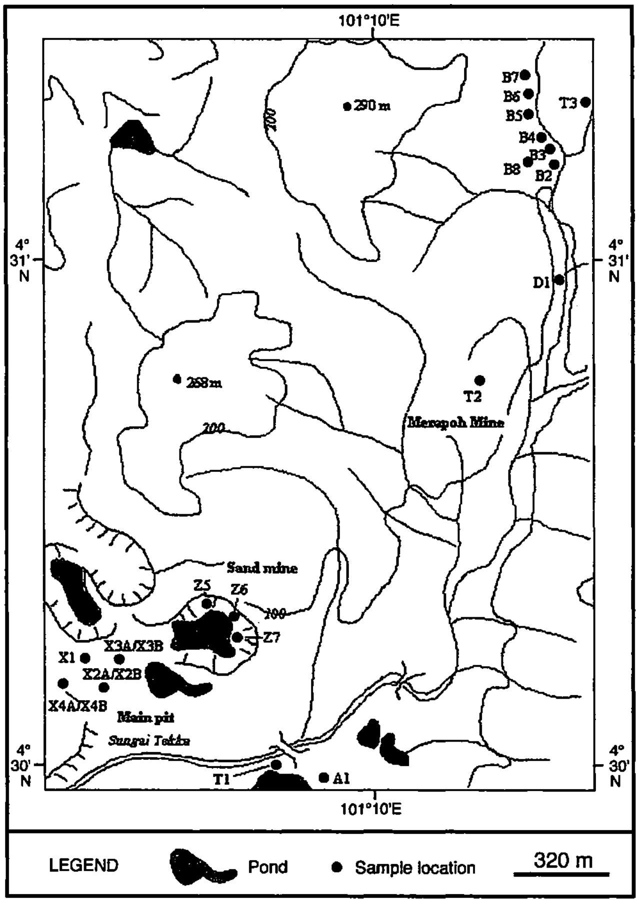

Figure 2. Map showing location of samples.

T1, T2 and T3 were collected from the main pit, Merapoh Mine and the eastern side of the Tekka Hill respectively. All the samples other than the hard rock samples were panned to concentrate the heavy minerals for EPMA and microscope study.

In the laboratory, polished sections of the samples were made to study the heavy minerals and their textures under the reflected light microscope. The EPMA (electronprobe microanalyzer) was later used to identify more precisely the heavy minerals, their intergrowths, textures, inclusions, chemical compositions and their abundances. The EPMA at the Geology Department, University of Malaya, is a Cameca SX100 with an energy dispersive spectrometer (EDS) and 4 wavelength dispersive spectrometers (WDS) with 12 analyzing crystals. The EPMA was operated at 20 kV and 20 nA beam current. X-ray mapping on the EPMA was ideal for differentiating the heavy minerals and their intergrowths. The BSE (backscattered electron) image is popularly used to initially differentiate the heavy minerals because it is dependent on atomic number, while the SE (secondary electron) image is best used for studying their morphology (Teh, 2002).

RESULTS AND DISCUSSIONS

The ore microscopy and EPMA study show that the heavy minerals encountered at Tekka include cassiterite, ilmenite, zircon, rutile, xenotime, monazite, wolframite, tantalite, columbite, strüverite, arsenopyrite, enargite, ilmenorutile, tapiolite, galena, native bismuth, bismuthinite, topaz, iron oxide, matildite, mimetite, yttrotungstite, stolzite and gold.

Of these minerals, native bismuth, bismuthinite (Bi_2S_3), matildite ($AgBiS_2$), mimetite [$Pb(AsO_4, PO_4)Cl$], yttrotungstite (Ce, Nd, $Y)W_2O_6(OH)_3$, and stolzite ($PbWO_4$), have not been reported before at Tekka. Gold occurrences have been reported by Ingham and Bradford (1960) but samples have never been displayed or described.

The new minerals, bismuth, bismuthinite, enargite, matildite and mimetite were revealed by the EPMA as inclusions and late infilled minerals. With the EPMA, native bismuth was found as ex-solution bodies in arsenopyrite (Fig. 3, Sample T13). Bismuthinite was picked up by the EPMA in the same mineralised vein (Sample T13) associated with inclusions of stannite, sphalerite, chalcopyrite and native bismuth in arsenopyrite (Fig. 3). Enargite was found associated with earlier cassiterite infilling a fracture in arsenopyrite in the same sample. Matildite was found in the same mineralised vein sample associated with arsenopyrite, stannite, chalcopyrite and sphalerite (Fig. 4). According to Ramdohr (1969), matildite can be found at both high and low temperatures. Mimetite was found associated with dark blue tourmaline by the EPMA (Fig. 5). Mimetite has been reported by Ingham and Bradford (1960) from Naga Bisi, near Ipoh.

Stolzite (Fig. 6) and yttrotungstite (Fig. 7) were found in the river concentrates and tailings from the main pit

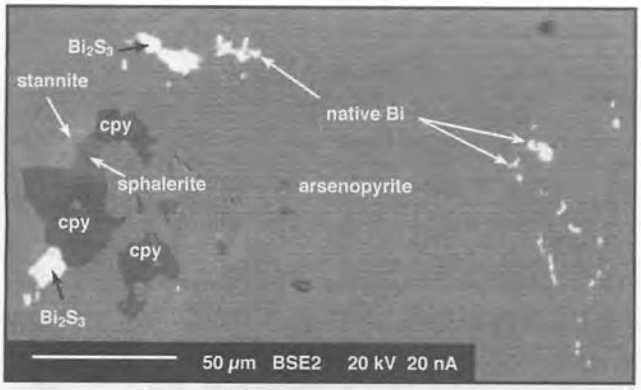

Figure 3. BSE image showing ex-solutions of native Bi and inclusions of bismuthinite (Bi_2S_3) associated with stannite, sphalerite and chalcopyrite (cpy) in arsenopyrite.

respectively. Stolzite, according to Ingham and Bradford (1960), was found associated with cassiterite and yttrotungstite at Pulai. Yttrotungstite, basically a yttrium-cerium tungstate, was first discovered in Pulai in 1921 (Ingham and Bradford, 1960).

In an *amang* sample (M4), gold was found in fractures in cassiterite (Fig. 8) and BSE image from the EPMA showed the gold to be very fine, ranging from 2-5 microns. Gold was also found in fractures in wolframite (Fig. 9) in a river concentrate sample (B8), with sizes ranging from 2-25 microns. The EPMA also picked up gold (about 10 microns in size) in a fracture in a black tourmaline sample (T12) (Fig. 10). The occurrences of gold in cracks and

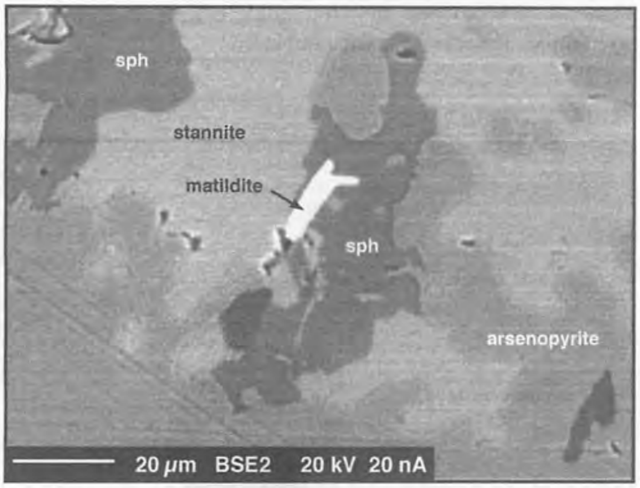

Figure 4. BSE image of matildite associated with sphalerite (sph), stannite and arsenopyrite.

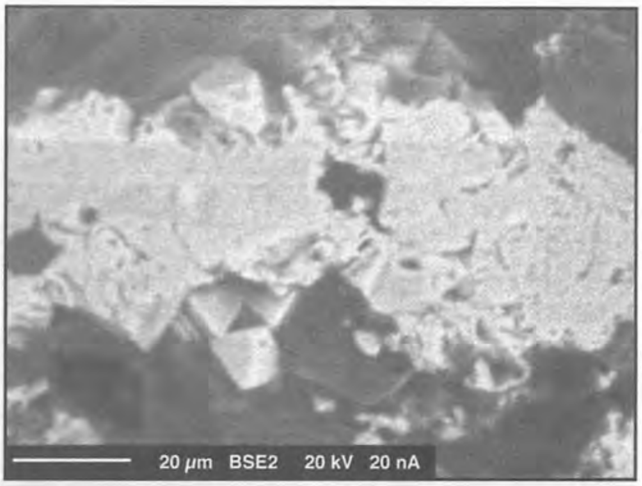

Figure 5. BSE image of monoclinic crystals of mimetite (white) associated with dark blue tourmaline.

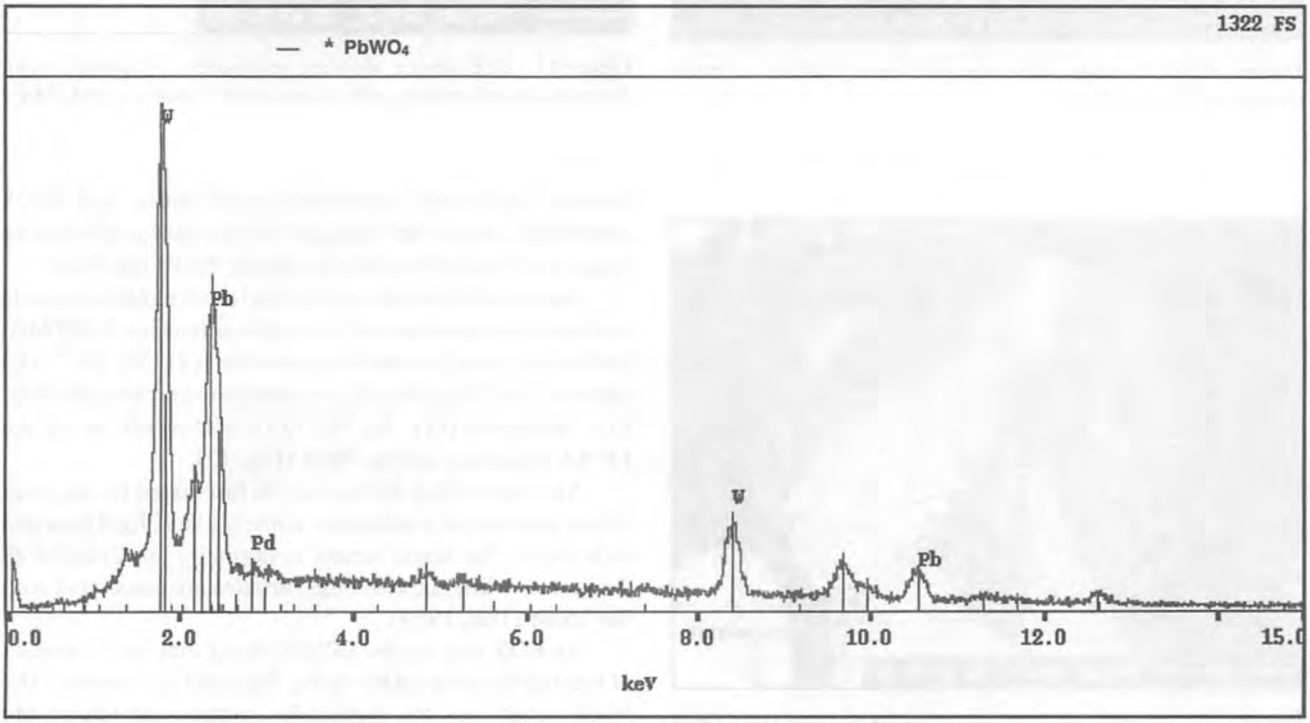

Figure 6. EDS scan of stolzite ($PbWO_4$) found in river concentrate at Tekka.

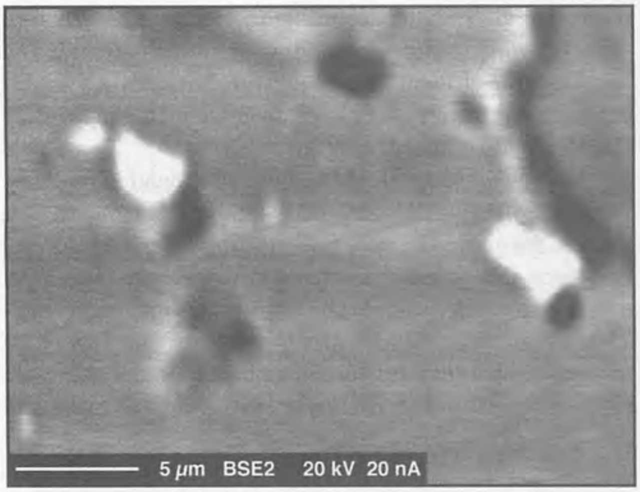

Figure 8. BSE image showing fine gold (white) in fracture in cassiterite. *Amang* sample M4.

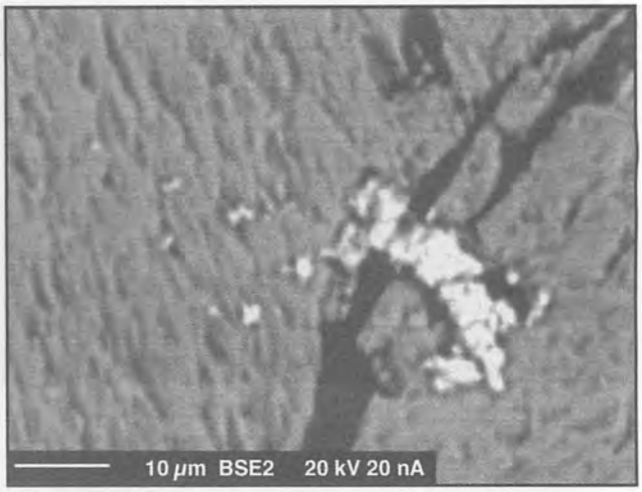

Figure 9. BSE image showing gold (white) in fracture in wolframite. River concentrate sample B8.

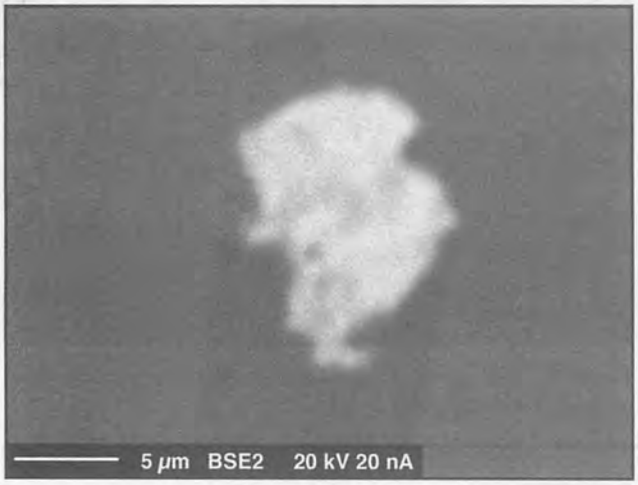

Figure 10. BSE image showing gold in a fracture in black tourmaline (sample T12).

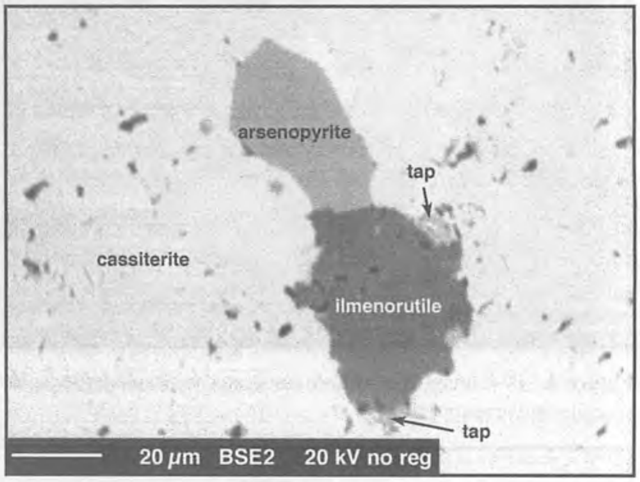

Figure 11. BSE image showing inclusion of tapiolite (tap), ilmenorutile and arsenopyrite in cassiterite. *Amang* sample M4.

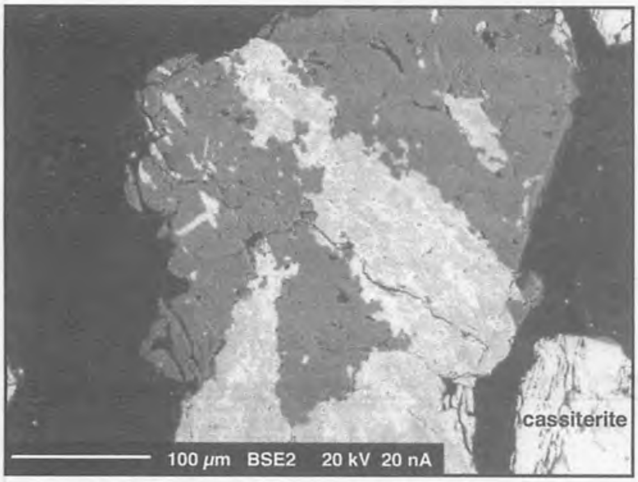

Figure 12. Strüverite showing intergrowths of rutile (grey) with columbite-tantalite (light grey and white). *Amang* sample M15.

fractures in early cassiterite, wolframite and black tourmaline, show the passage of the later gold-bearing fluids into the cooler portions of the Tekka ore body.

Study of inclusions in cassiterite was made possible with precise determination of compositions by the EPMA. Inclusions found include ilmenorutile [(Ti, Nb, $Fe^{+3})_3O_6$] tapiolite [Fe^{+2}(Ta, $Nb)_2O_6$], arsenopyrite and ilmenite (Fig. 11). Strüverite [(Ti, Ta, $Fe^{+3})_3O_6$] was picked up by the EPMA in *amang* sample M15 (Fig. 12).

Anyone visiting Tekka will be fascinated by the three colour varieties of tourmaline, namely black, light blue and dark blue. The black variety is normally associated with the granite while the two blue varieties are associated with the schist (Teh, 1969).

An EDS scan on the EPMA shows that the 3 varieties of tourmaline have different Fe, Mg and Ca contents. The black variety has the highest Fe content and lowest Mg content while the light blue variety has the highest Mg

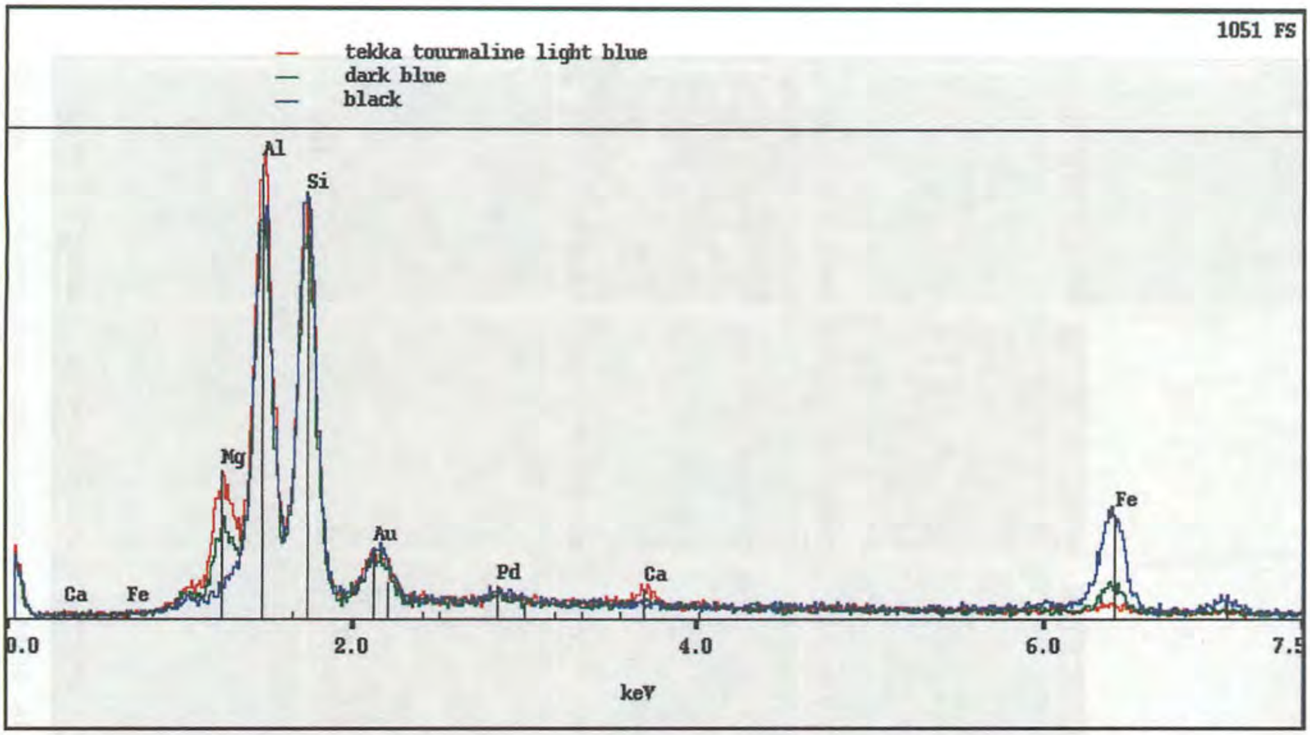

Figure 13. EDS scan showing black, dark blue and light blue tourmaline crystals with different contents of Fe, Mg and Ca. Black tourmaline has highest Fe and lowest Mg while light blue tourmaline has highest Mg and lowest Fe.

content and lowest Fe content (Fig. 13). The dark blue variety, on the other hand, has intermediate Fe and Mg compositions. The black tourmaline is schorl, the dark blue is feruvite and the light blue variety is uvite (www.mineral.galleries.com).

EPMA study revealed that minerals like monazite, xenotime, zircon and gold are associated with black tourmaline, and all are later, infilling cracks in the tourmaline. Dark blue tourmaline, on the other hand, was found associated with the mineral mimetite.

The EPMA is responsible for the identification of the many new minerals and their associated minerals at Tekka and with this information the paragenesis of the Tekka deposit, a xenothermal deposit (Teh, 1976, 1981), can be duly up-dated (Fig. 14).

X-ray mapping on the EPMA was carried out on the tailings from the main pit and sand mine areas, and *amang* from Merapoh Mine to determine the abundances, compositions as well as the distribution of the various heavy minerals. X-ray mapping shows that tailings collected from the main pit (Sample X3A) and sand mine (Sample Z7) areas still contain significant amounts of heavy minerals like ilmenite, cassiterite, and topaz (Figs. 15 and 16). Sample X3A has 10.3% cassiterite compared to 3.66% for sample Z7, 7.22% ilmenite compared to 19.5%, 5.15% wolframite compared to 0%, and 33% topaz compared to 9.76% respectively.

The coarser *amang* sample (M13) from Merapoh Mine at Tekka probably show the original ilmenite (29.3%), cassiterite (14.6%), topaz (6.1%) and wolframite (29.3%)

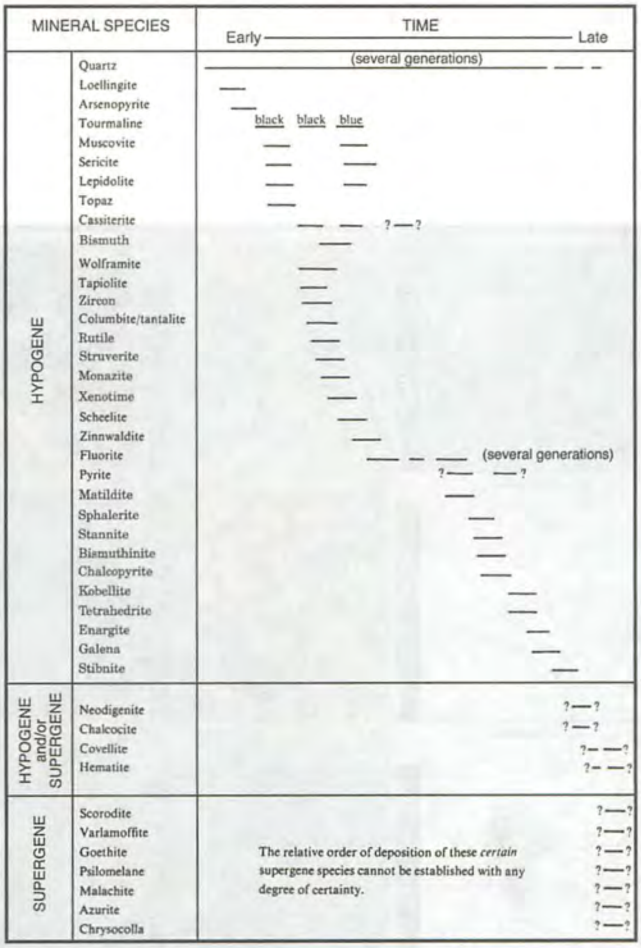

Figure 14. Up-dated paragenetic table of the Tekka xenothermal deposit (modified from Teh, 1981).

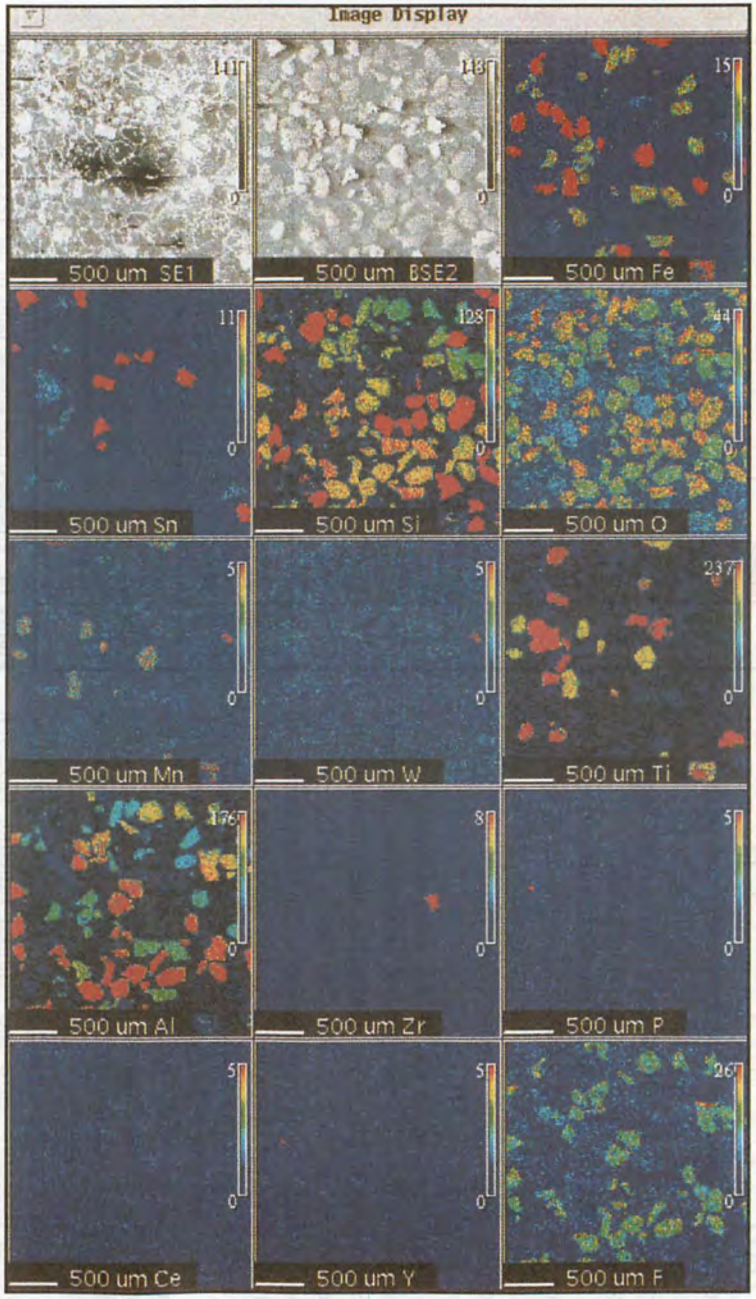

Figure 15. EPMA X-ray map of tailings sample from the main pit (X3A) showing significant amounts of ilmenite (Fe, Ti, O), cassiterite (Sn, O) and topaz (Si, Al, F).

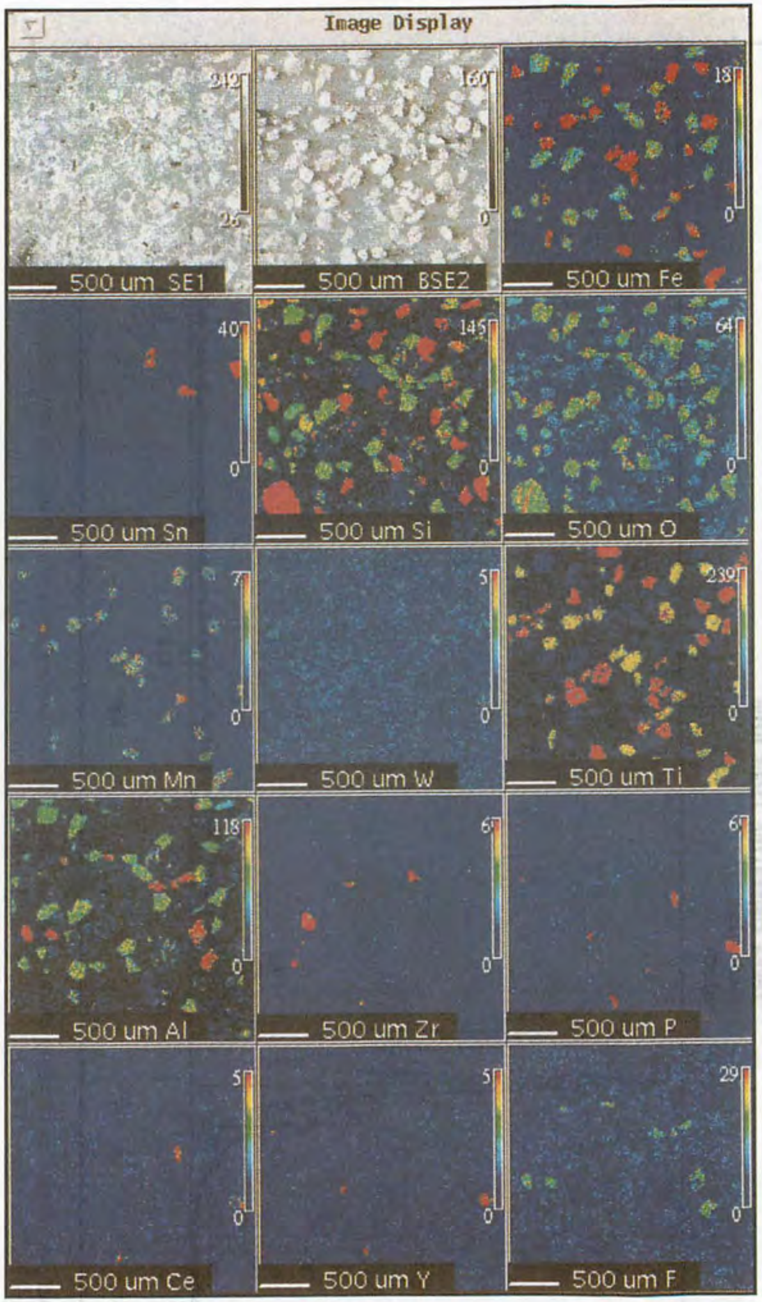

Figure 16. EPMA X-ray map of tailings sample from the sand mine (Z7) showing significant amounts of ilmenite (Fe, Ti, O), monazite (Ce, P, O), xenotime (Y, P, O) and zircon (Zr, Si, O).

constituents in *amang*. With EPMA X-ray mapping it was possible to differentiate the rutile from ilmenite, columbite and tantalite in strüverite and the presence of the phosphates, xenotime and monazite, and zircon.

CONCLUSIONS

The study involving reflected light microscopy and the EPMA was able to characterise cassiterite and associated heavy minerals in *amang*, tailings, mineralized veins and river concentrates in the Tekka area in terms of composition, abundance, inclusions and intergrowths.

Besides confirming the presence of common minerals, namely, cassiterite, ilmenite, iron-oxide, arsenopyrite, stannite, chalcopyrite, pyrite, sphalerite, galena, scorodite, and covellite, the EPMA was able to differentiate enargite, rutile, topaz, xenotime, monazite, tantalite, and columbite, justify the occurrence of gold in cassiterite, wolframite and black tourmaline and identify a number of lesser known minerals like stolzite, strüverite and yttrotungstite and revealed the presence of yet to be reported minerals like native bismuth, bismuthinite, matildite and mimetite in the Tekka area.

EPMA analysis show that the colour of tourmaline found at Tekka is a reflection of different contents of Fe and Mg. Black tourmaline is highest in Fe followed by dark blue and light blue tourmaline while the Mg content is the reverse, being highest in light blue tourmaline and lowest in black tourmaline.

The EPMA also aided the identification of inclusions in cassiterite like ilmenorutile, tapiolite, arsenopyrite and ilmenite.

All this additional information on the numerous mineral species present and their relationships have greatly helped in getting a better picture of the overall paragenesis of the xenothermal Tekka ore deposit which definitely has two generations of cassiterite, an earlier one associated with arsenopyrite, pyrite and wolframite and a later one associated with the sulphides like chalcopyrite, sphalerite and stannite.

The Tekka deposit will continue to be a haven for economic geologists because of its long list of both common and rare mineral occurrences and the relative abundance of topaz and tourmalines (black and blue) not found elsewhere in the country.

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