Reinterpretation of the Fe-Sn mineralization at the Waterfall Mine, Pelepah Kanan, Johore: Yeap Ee Beng, Dept. of Geology, Unversity of Malaya, Kuala Lumpur

The Fe-Sn mineralization at the Waterfall Mine, Pelepah Kanan, Johore takes the form of a lensoid massive marmitized coarsely crystalline martite body which occupied the trough of a gently plunging syncline formed by a band of highly weathered metasediments ovelying a thicker sequence of variegated light to dark green calc-silicate hornfels. The thinner southward plunging portion of the massive martite appeared to be connected vertically downward by a feeder zone consisting of a patch of magnetite + quartz + cassiterite on the west and a larger cresent-shaped magnetite + fluorite.+ cassiterite (± loellingite + quartz ± scheelite ± sulphides) on the east separated by a band of highly weathered metasediments cut by lenses of iron ore. Numerous feldspar + quartz + cassiterite + fluorite (± scheelite ± loellingite ± chlorite ± sulphides) veins cutting the calc-silicate hornfels parallel to the synclinal bedding traces radiated out from both flanks of the feeder zone while those within the zone strike roughly parallel to the fold axis and dip steeply to vertically.

Lower Triassic biotite granite is encountered below the hornfels while a smaller aplite body is exposed immediately NE of the ore body.

Early views on the genesis of the ore body include igneous intrusion, secondary enrichment (iron ore) of the amphibole-magnetitie rock and injection of a 'mobile mixture of Sn-F-B-Si compounds' which had segregated out from a highly siliceous magma. Later views agreed that the iron deposited was pyrometasomatic.(skarn) in origin while the spatially associated cassiterite bearing veins were hydrothermal.

The magnetite + fluorite + cassiterite body of the feeder zone exposed recently by opencut mining operation is observed to consist largely of contorted rhythmic and finely banded magnetite-fluorite (+ cassiterite) which had replaced the calc-silicate rocks or hornfels. Mineralogically and texturally, this portion of the ore body is similar to a special group of banded Sn-bearing magnetite-fluorite skarn from several parts of the world.

Mineralization of the Waterfall Mine Fe-Sn skarn took place in three distinct stages. Stage 1 resulted directly from the emplacement of the biotite granite and aplite which caused the conversion of the folded calcareous pelitic rocks into calc-silicate hornfels (hornblende + quartz + feldspar + sphene + diopside) and calc-silicate rocks (garnet + actinolite + grunerite + calcite + biotite). It is envisaged that Stage 2 mineralization started after the granite had formed a carapace and when fluid over-pressure derived from crystallizing magma further down, fractured the carapace and overlying hornfels and calc-silicate rocks at the feeder zone. Fe-rich high salinity fluid and volatile rich vapour phase migrated upwards via the feeder zone and caused the *replacement of calc-silicate rocks at the trough of the syncline by coarsely crystalline magnetite to form the massive capping ore body (stage 2a). Replacement was probably controlled by the chemistry of the rock (calcite and calc-silicate minerals) and also by cooling of the fluid (increasing distance from magmatic source). When the temperature of the mineralizing fluid fell and its composition changed (+ Si + F + Sn), the spaces between the coarsely crystalline magnetite were filled with finer cassiterite, quartz and cassiterite and replacement became active at the lower part of the lensoid body and at the feeder zone resulting in the formation of the rhythmic magnetite-fluorite (± cassiterite) ore and then the magnetite-quartz-cassiterite ore. Stage 3 mineralization involved the deposition of quartz + cassiterite + fluorite + chlorite (± epidote ± sulphides) superimposed on the rhythmic banded magnetite fluorite and as vein fillings.*

Preliminary fluid inclusion investigation revealed that Stage 2b fluid is quite strongly saline (30 to 50 equiv. wt. % NaCl by visual estimate) locally rich in CO_2 and showed intermittent boiling. Homogenization (largely in fluid) temperatures determined for early cassiterite, fluorite and quartz gave a range of 475°C to 495°. Stage 3 fluid is much less saline (< 26 equiv. wt. % NaCl) and did not show boiling phenomenon. Homogenization temperatures for quartz and fluorite gave a very narrow range of temperature of 185°C to 206°C.

The veins together with the feeder zone provided the plumbing system of the mineralization. Most of the veins flanking and within the feeder zone were developed at the start of Stage 2. The attitudes of the vein are consistent with fracturing as the result of localized pressure (fluid over-pressure) directed from below at the trough of the syncline. Prior to the Stage 3 mineralization reopening of the earlier vein-filled fractures occurred and new fractures were developed. While the veins within the feeder zone provided channel ways for the mineralizing fluids during replacement of the massive iron ore capping and the feeder zone ore bodies, the flanking veins are interpreted as leakaway veins largely for the Stage 2b mineralization and were also filled by Stage 3 minerals.

Three rhythmic banded magnetite-fluorite Sn-bearing deposits are found in Australia and these have been named as wrigglite skarn. Evidence of replacement of the wrigglite skarn by an assemblage of pyrrhotite + fluorite + F-biotite + cassiterite of the Moina Deposit, Western Tasmania to which the Waterfall Mine rhythmic banded magnetite + fluorite + cassiterite body resembles (in terms of texture, mineralogy, fluid inclusions and overall mineralization) has been regarded as a transition to the Sn-sulphide replacement deposits such as at Renison Bell, Tasmania, one of the world's largest primary tin deposits. Recognition of the presence of such wrigglite skarn mineralizing system in the Eastern Tin Belt of Peninsular Malaysia is significant in this respect.

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