An unusual cassiterite paragenesis and its genetic implications.

By L. J. LAWRENCE, Ph.D., B.Sc.
New South Wales University of Technology, Sydney, N.S.W.

[Communicated by Professor S. J. Shand; taken as read 24 January 1957.]

Summary. In the Torrington district of New South Wales the cassiterite occurs almost entirely in hydrothermal veins, with galena, blende, quartz, and chlorite; sometimes it replaces crinoid stems and gastropods. In the Madman vein, however, the cassiterite is associated with adularia, both minerals encrusting quartz. These observations suggest that the tin came in as alkali stannate solutions.

THE specimens described in this paper were obtained from the Torrington tin-mining field 350 miles north of Sydney, in the New England district of New South Wales. For many years this region was the largest producer of tin and tungsten ores in Australia.

Mineralization within the region is related to the closing stages of a differentiated suite of plutonic rocks of epi-Permian age intrusive into Permian sediments and volcanics.

Early stages of mineralization. Two main stages of mineralization may be identified—a high-temperature stage and a relatively low-temperature stage. The high-temperature stage follows what might be termed the normal pattern. Following closely upon the consolidation of the last of the differentiated plutonites—a biotite-granite—pegmatites of both simple and complex mineralogy were developed. The complex pegmatites consist of oligoclase, perthite, biotite, quartz, and beryl, together with a wide range of ore minerals including monazite, arsenopyrite, chalcopyrite, smaltite, safflorite, bismuth, bismuthinite, and large amounts of ferberite for which the Torrington pegmatites are renowned. The gangue minerals, which include fluorite, topaz, and tourmaline, indicate mineralization within a strongly acidic environment.

The pegmatites are closely associated both in space and time with areas of quartz-topaz greisen containing large tonnages of ferberite, together with smaller amounts of tourmaline and fluorite. Here again acidic conditions are manifest.

In a region renowned for its cassiterite production it is remarkable that this mineral has never been observed in the quartz-topaz greisen and occurred merely as an accessory in only two or three of some twenty ore-producing pegmatites.

Hydrothermal tin veins. A post-magmatic stage of ore deposition within the Torrington region was structurally controlled by a series of shear fractures developed some time after the pegmatite–greisen stage. The shear fractures are uniform in strike throughout the entire region and are of undoubted tectonic (orogenic) origin; they traverse both granite and sediments. When contained in the granite the walls adjacent to the shear are strongly chloritized; the chlorite appears to be hypogene as unaltered biotite is sometimes seen in the chlorite-metasomatized granite walls.

It is within these chloritized zones that the shear planes are situated. Galena, resin-coloured blende, and large amounts of cassiterite occur in a gangue of quartz and colloidal chlorite. A colloform texture has been noted on occasions. Precipitation from hydrothermal solutions of a slightly alkaline character may be postulated.

A significant feature was observed in the Hartz section of the New England lode system. This was the presence of a cross-course, acutely angled with respect to the main lode, containing smoky quartz crystals with copious inclusions of slender tourmaline crystals. Tourmaline crystals also occurred investing the quartz. This cross-course, formed apparently earlier than the main lode which transects it, was well prospected for cassiterite but failed to yield even a trace of that mineral which, in a gangue of quartz and chlorite, was abundant in the main lode.

Cassiterite–adularia vein. Among the many cassiterite veins and lodes of the region is one (the Madman vein) that appears to be unique.

This vein, having the same strike as the other hydrothermal veins and lodes, cuts through kaolinized granite near its contact with the adjacent sediments. It was barren of ore over most of its length; the small amount of cassiterite extracted from the vein occurred in vughs lined with well-formed quartz crystals tinted green by inclusions of colloidal chlorite and reminiscent of the Alpine type. Fig. 1 shows a typical specimen: the quartz is invested by small black cassiterite crystals intimately associated with adularia felspar; both the cassiterite and the adularia are loosely adhering and can be broken from the quartz with comparative ease leaving a clean smooth face of quartz; there has been no corrosion of the quartz and neither the cassiterite nor the adularia has penetrated it during their growth.

Three separate samples of adularia were crushed and examined under high magnification. They were perfectly free from inclusions or other forms of contamination. Spectrographic analyses were made of each sample giving consistent results as follows: Sn and Pb, trace; Fe and Mg, faint trace; Ca, absent. Each of the nine diagnostic spectral lines of Sn was present in the spectrogram.

FIG. 1. Quartz crystals loosely invested by black cassiterite crystals and crystals of adularia (white). The Madman tin vein, Torrington, New South Wales. $\times \frac{2}{3}$. This specimen has been presented to the British Museum (B.M. 1957,1).

Fragments of adularia from the figured specimen were examined optically by Mr. P. M. Game, and a partial microchemical analysis was made by Mr. D. I. Bothwell: $\gamma(=[010])$ 1·523, α:[100] 5 to 7°, $2V_\alpha$ $57\frac{1}{2}°$; cleavage (001) perfect, (010) very difficult; K_2O 16·9 %, Na_2O 0·7 %.

Discussion. It has already been suggested (p. 403) that in passing from the pegmatite-greisen stage of mineralization to the shear fissure stage the ore-bearing fluids changed in pH from distinctly acid to somewhat alkaline. The great bulk of cassiterite from the Torrington district thus appears to have been precipitated from somewhat alkaline hydrothermal solutions at moderate temperatures. The conditions of formation of these veins and lodes may be similar to the tin-chlorite veins of

Sungei Lembing, Malaya, which F. H. Fitch[1] suggests were formed at 'relatively low temperatures'.

The intimate association of cassiterite with adularia in one of the veins recalls experiments by F. Gordon Smith of Toronto. He showed[2] that tin could be transported as a sodium or potassium stannate and that cassiterite could be precipitated from such a solution, the best results being obtained at low temperatures.

The adularia of the Madman vein affords further evidence of the alkalinity of the solutions which deposited the associated cassiterite. Detection of Sn in the adularia may indicate a common lineage for the cassiterite and the adularia as follows:

$$K_2Sn(OH)_6 \rightarrow 2KOH + SnO_2 + 2H_2O.$$

The potash so liberated could combine with kaolin and silica to form adularia:

$$2KOH + 2H_2O . Al_2O_3 . 2SiO_2 + 4SiO_2 \rightarrow 2KAlSi_3O_8 + 3H_2O.$$

Kaolin, it will be noted, is prominent in the granite adjacent to the vein.

Such low-temperature reactions would be compatible with two other mineralogical phenomena recorded from this district. The first of these was the occurrence of cassiterite with zeolites in one of the veins (The Stilbite lode). T. W. E. David[3] records the occurrence thus: 'veinstuff quartz, felspar, and a variety of red stilbite, resembling heulandite. A shoot of tin-stone in heulandite from one to three feet wide and four feet deep was followed down from the surface to a depth of twenty feet for a horizontal distance of nine yards, producing three tons of ore.'

The second is that of the complete replacement of crinoid stems and gastropods by cassiterite with the perfect preservation of both internal and external detail; see fig. 2, and compare L. J. Lawrence.[4]

The cassiterite deposits of the Torrington district appear to have been formed over a wide range of temperature and other environmental conditions. In the case of the fossil replacements it is not unreasonable to postulate the intermingling of hypogene alkali stannate solutions with circulating groundwater. Such a composite solution, moving through fractures and joints in the sediments, would find a ready repository for

[1] Trans. Inst. Min. Met., 1948, vol. 57, p. 195.

[2] Econ. Geol., 1947, vol. 42, p. 251.

[3] The Vegetable Creek tinfield, New South Wales Department of Mines, 1887, p. 116.

[4] Proc. Roy. Soc. N.S.W., 1952, vol. 86, p. 119.

its stannate content in the easily replaceable calcium carbonate of the crinoid stems and gastropods.

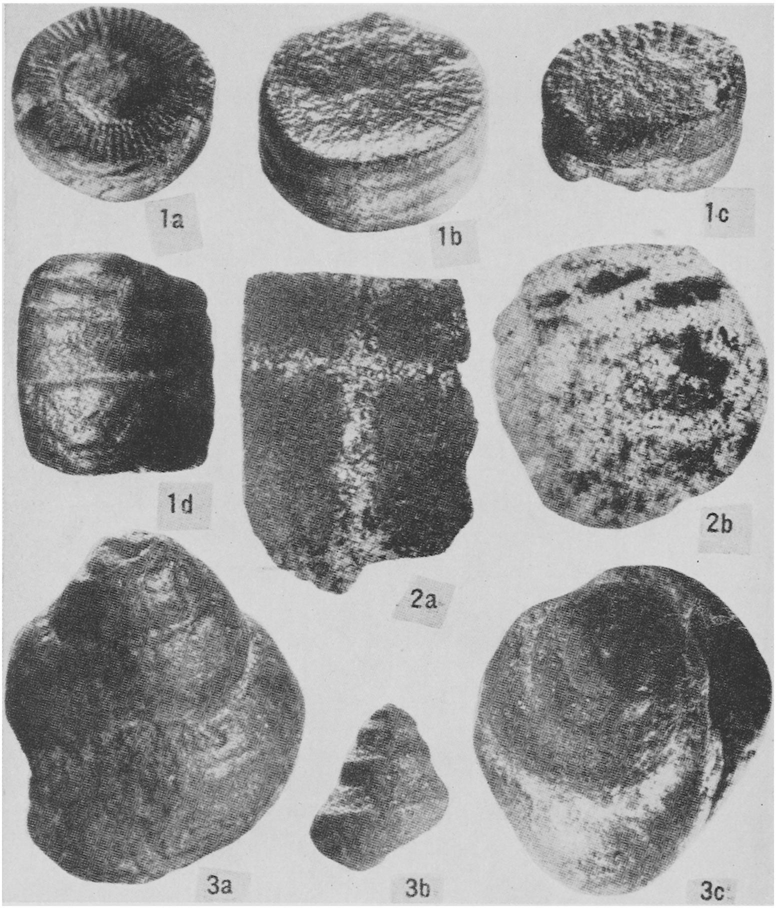

FIG. 2. Crinoid stems and gastropods completely replaced by cassiterite, Emmaville–Torrington district, New South Wales: *1a, 1b, 1c, 1d* crinoid stems showing preservation of external structure. ×2. *2a, 2b* longitudinal and transverse thin sections showing preservation of internal structure (ordinary light, ×10). *3a, 3b, 3c* *Ptycomphalina morrisiana* showing preservation of external detail. ×2.

Acknowledgements. The author wishes to record his thanks to Prof. S. J. Shand and to Prof. F. Gordon Smith for their comments on some of the views herein expressed.