

Difficulties with Refractory Ores: History of the Tolwong Mines, Shoalhaven Gorge NSW

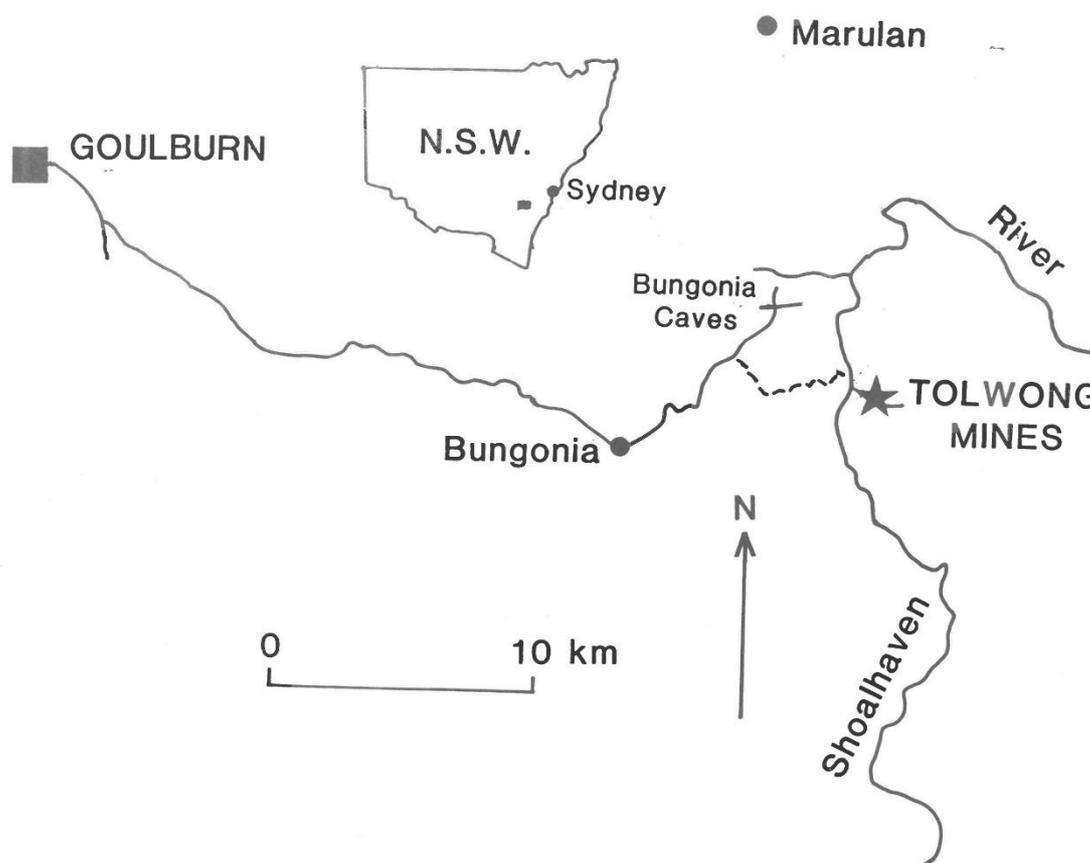
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This is a story about a small, failed mining project of the early 1900's. It is interesting and instructive because it highlights the complex interplay between nature, technology and management practices in determining the success or otherwise of a mining venture. This interplay is as relevant in today's large-scale mining as it was in the early history of Australian mining.

The Tolwong deposits

The Tolwong copper-tin-arsenic deposits were discovered in about 1904 by John Sivewright as exposed outcrops in an eastern tributary of the Shoalhaven Gorge, 10 km east of Bungonia.¹

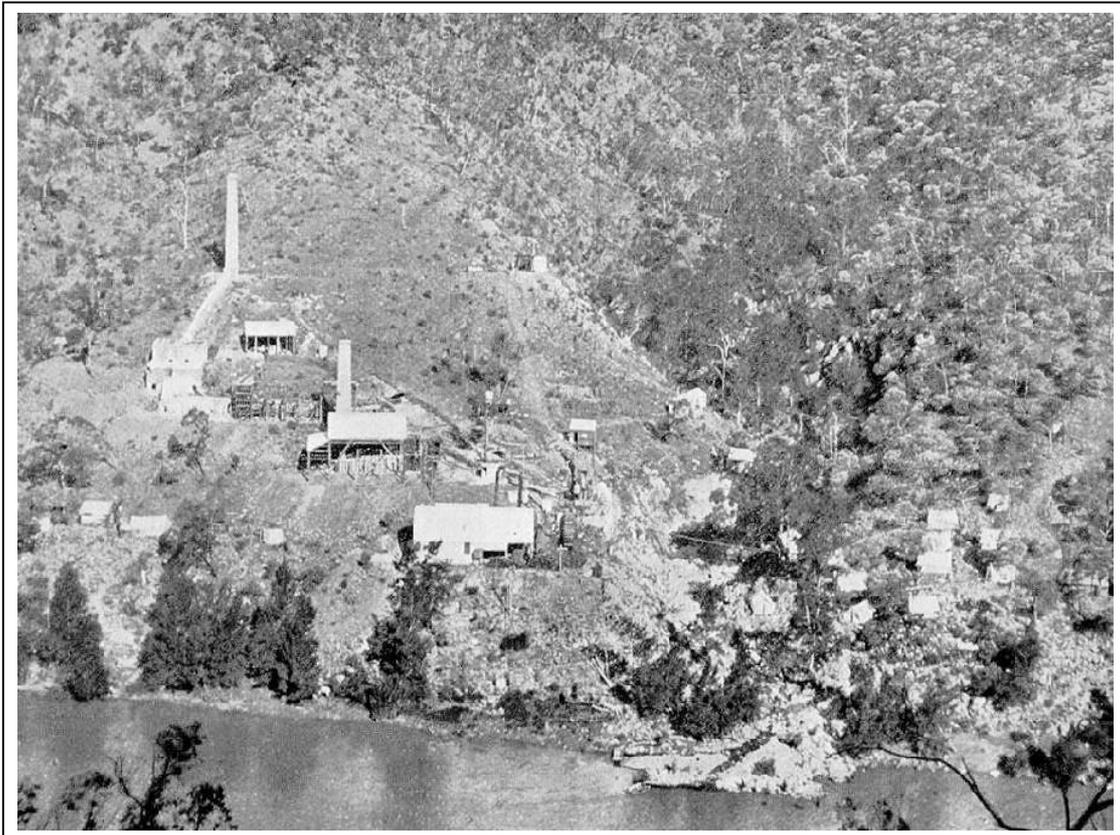
Map 1: *Location Tolwong Mines*



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Being narrow, rich lodes these deposits represented the style of mineralisation favourable for the low capital, labour intensive type of copper-tin mining of the early part of the twentieth century. The lodes or veins are of epigenetic hydrothermal origin. They occur in tightly folded Ordovician slates and sandstones in a region intruded by Carboniferous granites and minor dolerite dykes. The presence of abundant graptolite fossils in carbonaceous slates allowed the Ordovician rocks to be dated by T.S. Hall,² however at the time of discovery the age of the granite was more problematic. The lodes occupy dilational fracture systems which crosscut the Ordovician strata (Photo 1).

Photo 1: *General views, looking east, of the Tolwong treatment and smelting site on the Shoalhaven River, circa 1910.*



The top chimney is above the roasting kiln and arsenic collecting chambers, the lower chimney marks the reverberatory furnace and the lowermost building is the engine house and generator. The mine workings are up the steep gully to the right (photograph by W. Bennett in J.E. Carne, *The Tin Mining Industry and the Distribution of Tin Ores in New South Wales. Mineral Resources Geological Survey of NSW, 14*, Government Printer, Sydney, 1911)

The main Tolwong lode dips 30° SW over a length of at least 750m and varied in thickness from 5cm up to 3m, with the greatest thickness in sections where the host

fractures cut thick quartzite beds.³ This pinching and swelling in both vertical and horizontal directions has resulted in the main ore bodies occurring as a number of lenses. Lode outcrops occur on both sides of a precipitous gully, which has dissected the lode roughly in the direction of dip (Figure 1). The main minerals in the ore include abundant arsenopyrite with lesser amounts of stannite, chalcopyrite and galena, and minor sphalerite, pyrite, tetrahedrite and bournonite. Contained elements include copper, tin, zinc, lead, silver, trace gold, arsenic and sulfur. Quartz and fluorite are common gangue minerals. The mineralisation shows only minor surface weathering, with fresh sulfides at the surface and limited development of malachite and oxidation of arsenopyrite. Limited oxidation and supergene enrichment reflect rapid mechanical erosion and the deeply incised nature of the bedrock in the steep terrain. A survey by the author and students in 1995 revealed a well defined stream sediment geochemical anomaly in As, Zn and Cu extending down the gully from the mining area and for more than 1km along the Shoalhaven River.

History of Mining

In 1907 the Tolwong Mineral Company was formed to exploit the deposits for arsenic, copper and tin. The company was established with 60,000 shares at a nominal 2 shillings per share, with 45,000 shares issued privately to the original company and 15,000 shares held in reserve. Up until 1910, 5,100 additional shares were issued at various premiums up to 16s 6d raising £2,600 to apply to development and plant.⁴ A head office was established in the Lombard Chambers, 107 Pitt Street, Sydney and Mr William Tarleton was the Company's manager, accountant and auditor. The resident managing director was Mr Frederick Bennett and other members of the board were at various times Messrs Fitzwilliam Wentworth, W. Bennett, J.P. O'Neill and possibly J. Bennett, A.E. Nash and E.Y. Mills. Mr R. Gregory was engaged as consulting engineer in 1910.⁵

Between 1907 and 1909, the main Tolwong lode was explored and opened up by numerous small workings, underlay shafts and several interconnected tunnels. Typical ore assayed 6-10 per cent copper, 2-5 per cent tin, 1-15 per cent As, 30-60 g/t silver and a trace of gold.⁶ A quantity of ore was shipped by a German firm on an agreed assay of 11.22 per cent copper and 8.98 per cent tin, for which an advance of £10 per ton was obtained.⁷ In a report to the directors of the company in 1909, J.V. Vale painted a highly optimistic picture of the deposit and its future. He concluded:

the property as it now stands is a highly payable one, from which heavy dividends can be expected, but the possibilities are so great that I would hardly care to venture an opinion as to the future developments. I can only say that I have never inspected or seen a property that shows such great promise.⁸

Difficulties with the steep terrain were overcome by using two aerial tramways, one from the top of Shoalhaven Gorge to a treatment plant 520m below on the opposite side of the river and a second designed to transport ore from the mines, high up the tributary Tolwong Gorge, to the plant (Photo 1 and Figure 1). The main aerial tramway from an access road on the west side of the gorge to the plant site was partially operational by early 1910 and used to lower equipment and materials under gravity in loads of up to eight tonnes. The second tramway from the mine workings to the plant was completed soon after. Eventually both tramways were electrically powered by separate motors, one of 25 and the other of 15 brake horsepower. Electricity generation was by a 115 horsepower cross compound steam engine and an 80 kw, 500 volt generator. Electrically driven crushing equipment, including May's rockbreakers and rolls, was also installed by the end of 1910.⁹ Local timber was used as fuel. Limestone for smelting flux appears to have been brought in from South Marulan.

The presence of stannite as the major copper-tin mineral was unusual and led the company to model their smelting plant on the Oonah Proprietary at Zeehan in Tasmania where similar stannite-bearing ores had been encountered and were being experimentally treated. A wood-fired reverberatory furnace and Leggo roasting plant, complete with arsenic collection chambers, were constructed at the site between 1909 and 1910. The roasting process was an important adjunct to smelting to remove the deleterious arsenic from the ore. It also allowed the arsenic to be recovered for sale. The reverberatory furnace was capable of treating 90 to 100 tonnes of ore per week. Initially it was proposed to produce two mattes (impure metal sulfide alloys) from the smelting, for shipment and further refining.¹⁰ These were presumably a copper-rich and a tin-rich matte.

Ore production commenced in 1910 and at this stage the average number of men employed at the site was sixty.¹¹ The miners were working three shifts a day and a small tent settlement was established around the works.¹² By early 1911, 725 tonnes of ore had been stockpiled over a six month period of mining. The first attempts at smelting were in 1911 when approximately 350 tonnes of ore were smelted for production of 10 tonnes of 55 per cent copper matte worth £237, including £20 for silver content.¹³ Smelting at the site appears to have been abandoned at this stage with attention focused

on arsenic oxide production from roasting of the ore and sale of the roasted product for smelting elsewhere.¹⁴ Parcels of ore, roasted concentrate and other products were transported by aerial tramway to an ore discharge station at the top of the gorge and then by road to the railway line at Marulan. The company maintained an office in Marulan, with a telephone connection to the mine site.

Three subsidiary companies, Tolwong Minerals North Company, Tolwong South Extended Company and the Tolwong Block-Up Mineral Company were set up in 1910 to explore areas around the main Tolwong lode and to attract additional capital from investors. In 1910, J.P. O'Neil, the mine manager of the Tolwong Block-Up Mineral Company, reported a vein 9-18 cm wide containing black tin oxide (cassiterite) ore.¹⁵ A small amount of copper-lead-zinc-silver ore was produced by the Tolwong Block-Up Company in 1911 and shipped to Cockle Creek for treatment, returning £374.¹⁶ There is no recorded production from the other subsidiaries.

Failure of the Operation

Production from the Tolwong mines continued sporadically until June 1912 when the Tolwong Mineral Company went into liquidation after expenditure of £23,000 on plant and development of the mines.¹⁷ In early August 1912 the company applied to the Goulburn Mining Warden's Court for a suspension of labour conditions due to the liquidation. In the application the company noted that 100 tonnes of ore had been shipped to England for further testing and when the results were known the property would be put on the market.¹⁸ In 1913 it was reported that a new process for treating the ore might be tried but this would require a new plant and the property would need to be thoroughly tested first.¹⁹ No further work was reported from the main site, although minor work continued on some adjacent sites until 1916. Total ore production from all the deposits was probably less than 1,500 tonnes. The limited tonnage and refractory nature of the ore at Tolwong, and in particular the presence of stannite as the main copper-tin mineral, were major factors in the failure of the venture. Insufficient proving up of the lodes before erection of the treatment plant and other expensive surface installations contributed to the loss. After a visit to the site in October 1910, Assistant Government Geologist J.E. Carne, noted that proper prospecting and testing of the lodes, recommended by him in July 1908, had not preceded, or at least, kept pace, with surface expenditure. He also pointed out that:

in view of the complex and hitherto unsolved problem of stannite metallurgy, it was perhaps unwise to model a smelting plant on the slender evidence afforded by the experimental efforts of the Oonah Proprietary.²⁰

Most tin ores contain cassiterite (tin oxide) which can generally be easily concentrated by gravity separation before reduction to metallic tin by smelting. The combination of copper and tin in stannite (a sulfide mineral, also known colloquially as tin pyrites or bell-metal ore) makes it impossible to physically separate the copper and the tin before smelting. Until the discovery of stannite-rich ores in Australia, the very minor amounts of stannite encountered in other tin ores, for example in Cornwall, were discarded as tin ore and sold as copper ore. Experimental smelting of stannite-rich ore appears to have been first attempted at the Conrad Mines, Howell, New South Wales and later at Zeehan, Tasmania.²¹ Methods developed generally resulted in significant loss of tin to the slag and formation of a metallic matte of copper-tin-silver, saleable and treatable only as tin-silver or copper-silver. This meant that the full value of the ore could not be realised.

Since the early 1900's several companies, including Placer Prospecting Pty Ltd in 1965-66 and the Broken Hill Proprietary Company in 1971, have assessed the prospectivity of the Tolwong lodes and surrounding area.²² The size and style of the known mineralisation have been considered unsuitable for large-scale modern mining. Placer Prospecting concluded that prospects of a large tonnage of ore are small and development costs would be high. No further interest is recommended in the area.²³

The Ore Complexity

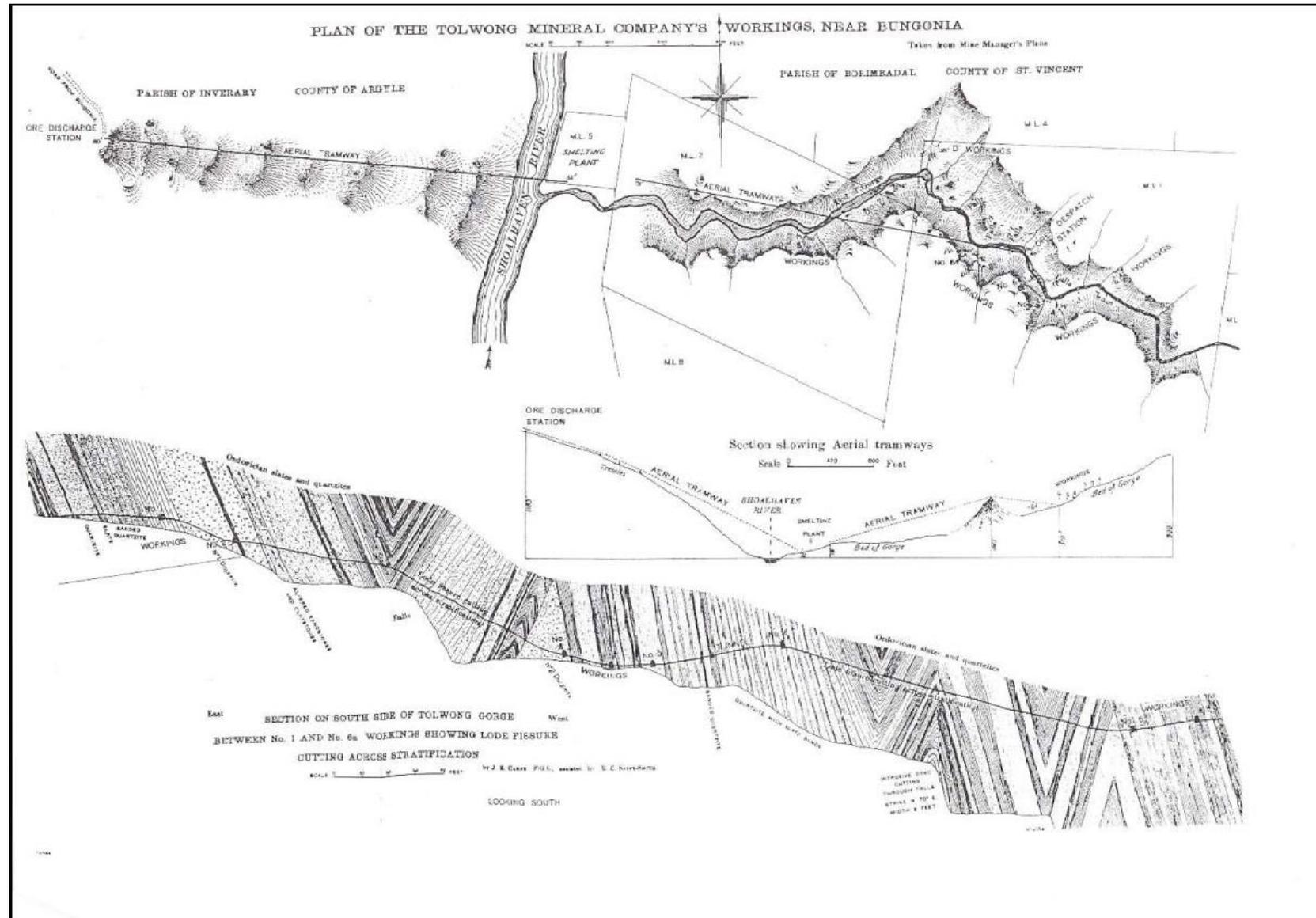
Early observations of the Tolwong ores and assaying of selected samples collected by JE Carne first revealed the presence of tin in stannite, in addition to the copper ore recognised by the miners.²⁴ Carne also predicted that the metallurgy would be complex and difficult.²⁵ Detailed microscopic studies of three specimens of Tolwong ores were carried out by F.L. Stillwell of CSIR (now CSIRO) in 1929. He confirmed the presence of stannite, arsenopyrite, chalcopyrite, as well as minor tetrahedrite, sphalerite, galena and hematite and described some of the complexity of the ore textures, particularly the fine-scale exsolution intergrowth of chalcopyrite in stannite.²⁶

Detailed mineragraphic studies by the present author of samples from some of the lodes, the dumps and the ore stockpile have confirmed the complex nature of the Tolwong ore assemblage and its likely refractory nature. The dominant ore minerals in

most of these samples are arsenopyrite and stannite. The bulk composition of the ores is also consistent with the observed dominance of arsenopyrite and stannite, with a contribution of copper from chalcopyrite (Figure 2). At the microscale there is intimate intergrowth of chalcopyrite and galena with abundant arsenopyrite and replacement and intergrowth of sphalerite by stannite. Chalcopyrite also occurs as numerous small inclusions in sphalerite (chalcopyrite disease) and in stannite (Figure 3). Electron microprobe analysis of some of the ore mineral has established their compositional characteristics (Table 1). Small amounts of silver are hosted by minor tetrahedrite (up to 4 wt percent) and possibly also in more abundant galena. The stannite has no detectable silver. The fine-scale and complex intergrowth of these minerals would have further complicated the metallurgy and also rendered gravity or magnetic separation of the different minerals, if it had been attempted, almost impossible.

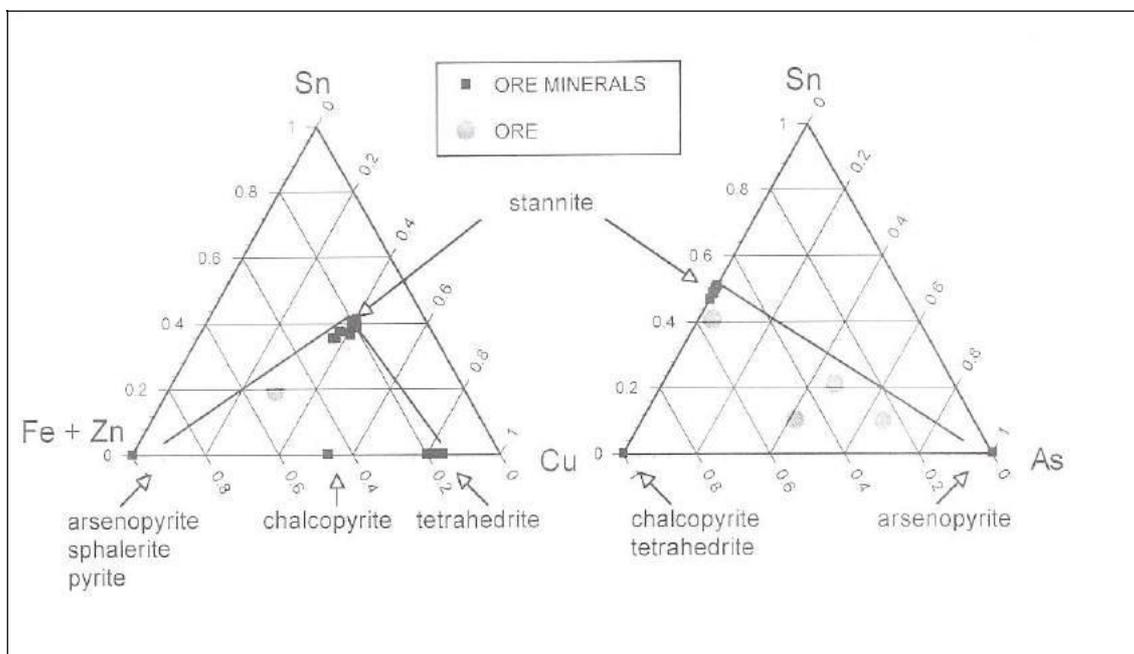
Observations on the slag produced by smelting at the site revealed the presence of abundant magnetite, probably reflecting the low sulfur content of the roasted smelter feed and also the very low pyrite content of the initial ore. The high magnetite content of the slag would have increased its viscosity and made it more difficult for the metal-bearing matte to separate.²⁷ Also in the slag there are numerous small inclusions of copper sulfides (chalcocite and covellite) and several different white and grey metallic phases, indicating that a significant metal component (possibly including tin) did not separate from the slag during smelting. This suggests smelting problems that may have contributed to the decision to abandon smelting at the site.

Figure 1: Plan and section of the Tolwong mines



Source: 'Mine Manager's Plans', J.E. Carne, The Tin Mining Industry and the Distribution of Tin Ores in New South Wales, Mineral Resources Geological Survey of NSW, 14, Government printer, Sydney, 1911.

Figure 2: Plots showing 'average' bulk ore compositions and ore mineral compositions from electron microprobe analyses (wt%). These plots show the dominance of arsenopyrite and stannite as the main ore constituents with a minor and variable contribution of copper from chalcopyrite.



Source: from original mine assay data reproduced in, J.E. Carne, *The Tin Mining Industry and the Distribution of Tin Ores in New South Wales. Mineral Resources Geological Survey of NSW, 14*, Government Printer, Sydney, 1911

Table 1: Representative analyses of stannite and tetrahedrite from the Tolwong deposits compared to 'ideal' compositions for these minerals.

Wt%	1.	2.	3.	4.	5.	6.	7.	8.
Cu	27.94	28.16	28.02	29.58	34.84	33.57	31.56	45.77
Fe	6.11	7.20	8.02	12.99	3.15	3.90	4.65	
Zn	6.74	7.58	5.62		4.40	3.49	3.29	
Ag	0.04	0.04	0.04		0.72	3.19	3.93	
Sn	28.48	28.25	29.06	27.61	0.16	0.37	0.12	
As	0.03	0.03	0.03		3.50	5.15	5.27	
Sb	0.03	<0.03	<0.03		27.74	25.07	25.54	29.22
S	30.25	30.37	30.16	29.82	25.26	25.08	24.65	25.01
Total	99.52	101.56	100.88	100.00	99.77	99.82	99.01	100.00

Source: J.W. Anthony, R.A. Bideaux, K.W. Bladh and M.C. Nichols, *Handbook of Mineralogy: Volume 1, Elements, Sulfides, Sulfosalts*, Mineral Data Publishing, Tuscon, 1990, pp. 490, 526.

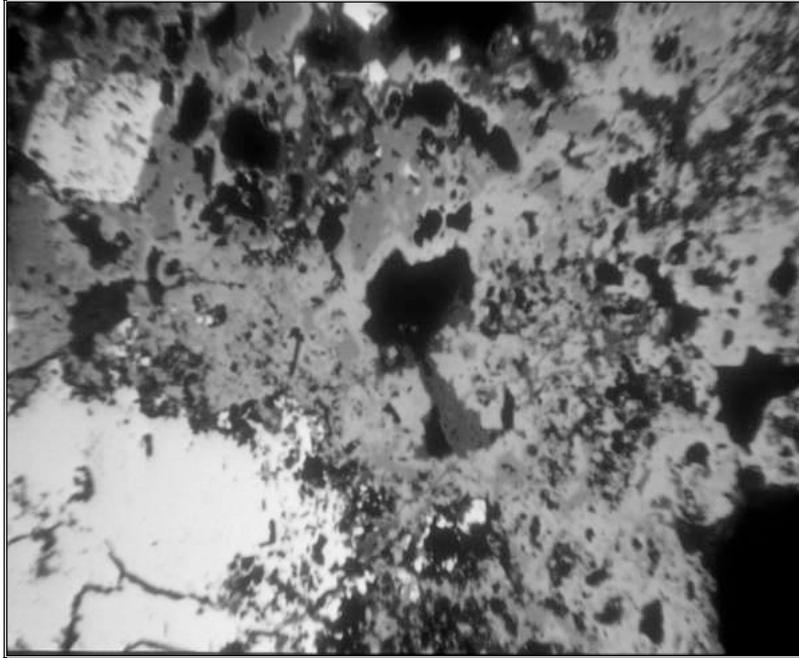
Notes: 1-3. Electron microprobe analyses of stannite from dump samples, Tolwong mines.

4. Composition of pure stannite (Cu_2FeSnS_4).³⁵ 5-7. Electron microprobe analyses of tetrahedrite from dump samples, Tolwong mines. 8. Composition of pure tetrahedrite ($Cu_{12}Sb_4S_{13}$).³⁶

Figures 3A & 3B:

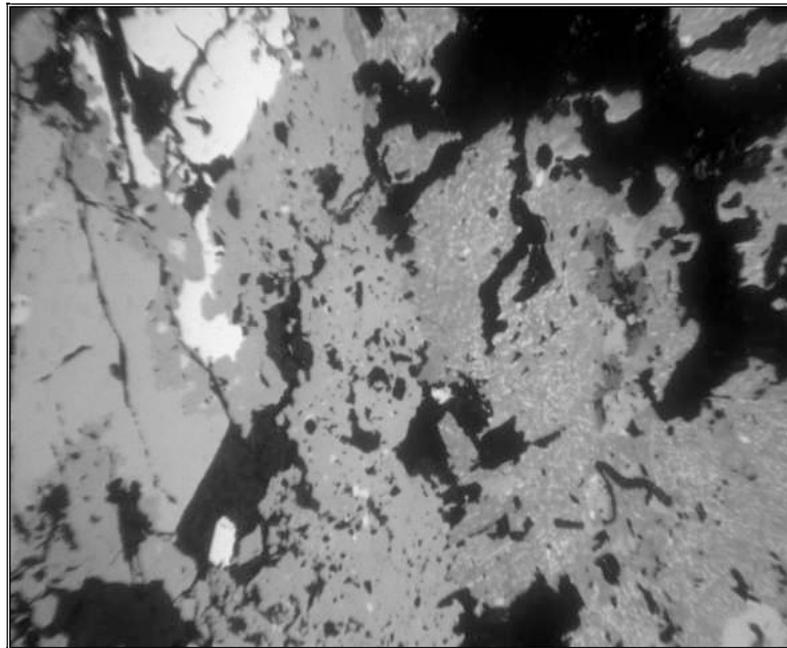
Photomicrographs of ore textures in samples from the Tolwong mineralisation, showing the complex intergrowth of refractory minerals. Width of field is 2.5mm.

Photomicrograph A



A. Arsenopyrite (white, lower left and top) with sphalerite and rimmingstannite (darker greys centre and left). Sample TW953.

Photomicrograph B



B. Tetrahedrite (left), arsenopyrite (white, top left) with minor galena and stannite (centre) and sphalerite with small inclusions of stannite and stannite (centre) and sphalerite with small inclusions of stannite and chalcopyrite (at right). Sample TW 951.

Acknowledgments

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Endnotes

- ¹ J.E. Carne, *The Copper Mining Industry and the Distribution of Copper Ores in New South Wales. Mineral Resources Geological Survey of NSW*, no. 6, 2nd ed., Government Printer, Sydney, 1908, p. 367.
- ² J.E. Carne, *The Tin Mining Industry and the Distribution of Tin Ores in New South Wales. Mineral Resources Geological Survey of NSW*, 14, Government Printer, Sydney, 1911, p. 346.
- ³ *Ibid.*, p. 344.
- ⁴ *The Australian Mining Standard*, 9 February; *Ibid.*, 9 March 1910.
- ⁵ *Ibid.*; Liquidation Records 1911, Location 3/5810, no. 3714, New South Wales State Archives.
- ⁶ Carne, *Distribution of Copper Ores*, pp. 413-14.
- ⁷ *The Australian Mining Standard*, 18 August 1909.
- ⁸ *Ibid.*
- ⁹ *Ibid.*, 9 February and 9 March 1910; Carne, *Distribution of Tin Ores*, p. 413.
- ¹⁰ *The Australian Mining Standard*, 9 February 1910.
- ¹¹ Annual report New South Wales Department of Mines, 1910, p.48.
- ¹² *The Australian Mining Standard*, 9 February 1910.
- ¹³ *Sydney Morning Herald*, 1st June 1911.
- ¹⁴ Annual Report New South Wales Department of Mines, 1911, p.53.
- ¹⁵ *The Australian Mining Standard*, 26 October 1910.
- ¹⁶ Annual Report New South Wales Department of Mines, 1910, p. 48; *Ibid.*, 1991, p.47.
- ¹⁷ *The Australian Mining Standard*, 15 August 1912.
- ¹⁸ *Ibid.*
- ¹⁹ Annual Report New South Wales Department of Mines, 1913, p. 53, NSW Dept. of Mines.
- ²⁰ Carne, *Distribution of Tin Ores*, p. 413.
- ²¹ *Ibid.*
- ²² Watts, Griffis and McQuat (Aust.) Pty Ltd., *Geological mapping, geological survey and literature survey, Areas 2a,3b. 3c EL 157 Ulladulla*, Open file report GS 1971/232, Geological Survey of NSW; Placer Prospecting Pty Ltd, *Geological Report on the Tolwong Mines*, Open file report GS 1966/166, Geological Survey of NSW.
- ²³ *Ibid.*
- ²⁴ Carne, *Distribution of Tin Ores*, p. 344.
- ²⁵ *Ibid.*, p.345.
- ²⁶ F.L. Stillwell, *Report on a collection of ore specimens from Cobar district, Tolwong and Howell*, Mineragraphic Report no. 10, CSIR Melbourne, 1929; A.B. Edwards, 'Some occurrences of stannite in Australia', *Proceedings of the Australasian Institute of Mining and Metallurgy*, no 160-161, 1951, pp. 5-59.
- ²⁷ J.D. Gilchrist, *Extractive Metallurgy*, Pergamon Press, Oxford, 3rd edn., 1989, p. 211.