Section 1 — Ore Dressing Investigations

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Note: Numbers immediately before titles refer to localities on the Locality Map, fig. 1.

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24. PLACER PROSPECTING PTY LTD: CONCENTRATION TESTS OONAH MINE ORE, ZEEHAN

Introduction

Placer Prospecting Pty Ltd submitted two samples of sulphide ore from the Oonah mine, near Zeehan, for chemical analysis and metallurgical tests to assess the probable recoveries of the economic minerals. The samples bear Mines Department registered numbers 642402 and 642403.

The samples contained tin, occurring as stannite and cassiterite, and copper, occurring as stannite and chalcopyrite. A considerable quantity of silver was also present. These three elements represent the major values in the ore, but also present were small but probably significant quantities of lead, antimony and bismuth.

The sample for metallurgical testing was obtained by combining roughly equal weights of the two samples submitted.

Mineralogy

Specimens of the samples and a selected stannite specimen were submitted to Mr G. Everard, Mines Department Mineralogist and Petrologist for mineragraphic examination. He reported:—

"The specimen consists of mixed sulphides, stannite, pyrite and chalcopyrite being visible in hand specimen, together with veinlets of quartz and carbonate.

Cassiterite is visible in crushed fragments under the microscope.

In polished section the cassiterite appears as euhedral crystals averaging 0.1 mm long. Pyrite is fine grained and massive with irregular borders suggesting replacement, but arsenopyrite is euhedral in lozenge shaped crystals up to 0.3 mm long. Chalcopyrite and bismuthinite appear as irregular small strings, blebs and patches, 0.05-0.5 mm long, in the stannite.

Pyrite and arsenopyrite appear to have been the first formed sulphides, to be partly replaced by stannite from which chalcopyrite and bismuthinite separated."

Sample for Research

The composite sample was roll crushed to minus ¼ inch, and a head sample cut out. Analysis of the head sample is as follows:—

	%		%
Copper	3.18	Zinc	0.25
Total Tin	4.50	Iron	19.4
Tin (as SnO_2)	2.25	Sulphur	23.4
Lead	0.76	Acid Insoluble	40.0
Arsenic	1.80	Silver	44 oz/ton
Antimony	0.48		
Bismuth	0.50		

This analysis approximates a mineral composition of the sample as follows:—

	%		%
Stannite	8.0	Bismuthinite	0.6
Chalcopyrite	2.0	Pyrite	35.3
Galena	1.0	Cassiterite	2.9
Arsenopyrite	4.4	Acid Insoluble	40.0
Stibnite	0.8		

An examination of the grain size of the cassiterite and a vanning assay were also performed on the sample with the object of anticipating recoveries obtainable by gravity concentration of this mineral. In general, cassiterite, plus 20 microns in diameter, can be recovered by gravity concentration. This applies approximately to the vanning assay also.

CASSITERITE GRAIN SIZE ANALYSIS

Fraction	*Cassiterite Particle Diameter—Microns*	*Cassiterite Distribution* %	*% Cum.*
+100 mesh B.S.S.	+152	4.8	4.8
+200 mesh B.S.S.	−152+ 76	9.9	14.7
+300 mesh B.S.S.	− 76+ 53	7.6	22.3
E.F. 2	− 53+ 28	20.9	43.2
3	− 28+ 20	10.9	54.1
4	20+ 13	17.5	71.6
5	− 13+ 10	18.6	90.2
6	− 10	9.8	100.0

E.F.=Elutriation Fraction

VANNING ASSAY

	%
Tin present as Cassiterite	2.18
Tin recovered by Vanning	0.93
Van Tin recovery	42.70

The Van Tin concentrate assayed 53.0 per cent Tin.

Investigation

PRELIMINARY COPPER FLOTATION TESTS

A series of preliminary flotation tests were carried out in an endeavour to establish a reagent combination to selectively float the copper-bearing sulphides from pyrite and gangue.

These tests were performed in a Denver D-1 laboratory flotation machine, using 500 gram charges. The charges were batch ground in a 12 inch diameter steel ball mill in a pulp of 70 per cent solids. Grinding time was generally about 10 minutes.

Reagents investigated were: Aerofloat 238 and sodium ethyl xanthate as promoters in pulps made alkaline with lime and with sodium cyanide present as a depressant for pyrite. The effect of pre-aeration to oxidize pyrite surfaces before copper flotation was also examined. Frother used throughout was M.I.B.C., at a rate sufficient to maintain froth

The results of these tests indicated that stannite behaves similarly to chalcopyrite in flotation and that good recoveries of the copper-bearing sulphides could be obtained by the use of sodium ethyl xanthate in the presence of lime and sodium cyanide. Pre-aeration enhances selectivity by depressing pyrite. pH of the pulp should be kept about 11. The lime and cyanide were added to the ball mill before grinding, promoter and frothers to the cell.

Aerofloat 238, pH 10-11, with lime and cyanide present showed good selectivity for the copper sulphides but recovery was not as high as that obtained with the xanthate.

The following results are typical of the best obtained during the series of tests.

Abbreviations Used in Tables of Results

In results for Tests N-10, N-11, and N-17, the following abbreviations have been used:—

F Flotation
C Concentrate
T Tailing

Digits immediately after a symbol signify the stage of the operation or product which the symbol describes.

For example:—In Test N-17 the product described in the table as "F4C1 0-2 mins" means "Flotation Stage 4, Concentrate Fraction 1 which was taken during the first two minutes of flotation".

TEST N-10

Flotation Conditions

Cycle	*Reagent*	*Added to*	*Rate of Addition*	*pH*
Grinding	CaO	Ball Mill	16 lb/ton	
	NaCN	Ball Mill	1 lb/ton	11.0
Roughing	NaEtX	Fl Cell	0.5 lb/ton	
	MIBC	Fl Cell	3 drops	
Cleaning	NaEtX	Fl Cell	0.25 lb/ton	11.0
	NaCN	Fl Cell	0.25 lb/ton	

Flotation Times: Roughing, 10 minutes; Cleaning, 7 minutes

Metallurgical Results

Product	Per Cent Weight	Per Cent Copper	Per Cent Copper Distribution
Cleaner FC	22.8	13.6	89.5
Cleaner FT	26.8	0.74	5.7
Rougher FT	50.4	0.33	4.8
Comp. Head	100.0	3.47	100.0

TEST N-11

Flotation Conditions

Cycle	Reagent	Added to	Rate of Addition	pH
Grinding	CaO	Ball Mill	16 lb/ton	
	NaCN	Ball Mill	1 lb/ton	10.8
Roughing	Aerofloat 238	Fl Cell	*0.2 lb/ton	
	MIBC	Fl Cell	1 drop	
Cleaning	Aerofloat 238	Fl Cell	0.05 lb	9.8

* 0.1 lb/ton added initially with a further addition of 0.1 lb/ton after 5 minutes.

Flotation Times: Roughing, 10 minutes; Cleaning, 5 minutes

Metallurgical Results

Product	Per Cent Weight	Per Cent Copper	Per Cent Copper Distribution
Cleaner FC	18.1	14.1	74.9
Cleaner FT	13.3	2.40	9.4
Rougher FT	68.6	0.78	15.7
Comp. Head	100.0	3.41	100.0

BULK FLOTATION OF SULPHIDES FOLLOWED BY SELECTIVE FLOTATION OF COPPER SULPHIDES

Effective gravity concentration of the tin present as cassiterite requires that the gravity feed be reasonably free from heavy sulphide minerals.

Accordingly, a number of tests were performed involving cleaner bulk flotation of sulphides to achieve this purpose.

The bulk sulphides were reground with lime and cyanide and refloated to produce a copper concentrate and a pyrite tailing.

The equipment used was the same as that used in the first series of tests.

From the results of these tests, the following observations were made—

(*a*) Activation of pyrite with copper sulphate in the bulk flotation stage reduced selectivity in subsequent copper flotation.

(*b*) A reasonably sulphide free gravity feed could be obtained without copper sulphate activation of pyrite.

(*c*) A confirmation that pre-aeration before copper flotation aids in depression of pyrite.

(*d*) Most of the copper is recovered in a good grade concentrate in the first two minutes of the final copper float. A further two minutes flotation increases recovery but may seriously depreciate grade.

(*e*) Maximum grade of copper concentrate produced was 19.2 per cent Cu. This concentrate contained 10.0 per cent tin as sulphide. A cyclosizer analysis of a copper concentrate and copper assays of the fractions showed no enrichment in any fraction, which indicated that this grade of concentrate is probably near the maximum obtainable, with reasonable recoveries of the copper-bearing sulphides.

The following is the result of the best of the tests described above.

TEST N-17

Flotation Conditions

Cycle	*Reagent*	*Added to*	*Rate of Addition*	*pH*	*Time*
Ro Bulk Flot. (F1)	NaEtX MIBC	Fl Cell Fl Cell	0.5 lb/ton 3 drops	6.0	7 min
Cl Bulk Flot. (F2)	NaEtX MIBC	Fl Cell Fl Cell	0.25 lb/ton 2 drops	6.0	5 min
Regrinding (F2C)	CaO NaCN	Ball Mill Ball Mill	4 lb/ton 1 lb/ton		10 min
Cu Ro Flot. (F3)	NaEtX MIBC	Fl Cell Fl Cell	*0.5 lb/ton 2 drops	10.8	5 min
Cu Cl Flot. (F4)	MIBC	Fl Cell	3 drops	10.4	4 min
	No further reagents addition—Successive cuts of FC at 2 min, 3 min, and 4 min				

* 0.25 lb/ton added initially with a further addition of 0.25 lb/ton after 2 minutes.

Metallurgical Results

Product	Per Cent *Weight*	Per Cent *Copper*	Per Cent *Copper Distribution*	*Remarks*
F4C1 0-2 min	12.9	19.2	77.1	Copper concentrate fractions
F4C2 2-3 min	2.8	8.64	7.2	
F4C3 3-4 min	1.4	4.96	2.1	
F4T	3.8	2.24	2.5	
F3T	30.1	0.76	6.8	Pyrite concentrate
F2T	6.6	0.88	1.8	
F3T	42.4	0.20	2.5	
Comp. Head	100.0	3.35	100.0	

GRAVITY CONCENTRATION OF THE TIN PRESENT AS CASSITERITE

Having established conditions for bulk desulphidizing of the ore and production of a copper-tin sulphide concentrate, a larger scale test was undertaken to investigate the gravity concentration of the cassiterite tin in the flotation tailing.

Closed circuit grinding is essential to avoid overgrinding of cassiterite. The grinding was done continuously in the pilot plant 12 inch x 12 inch ball mill in closed circuit with a 60 mesh Hummer screen. The screen undersize was pumped to a 10 kg Agitair flotation machine. Bulk sulphides were reground for copper flotation as described previously.

Flotation tailings were fed to a three spigot Geco hydrosizer and the products from this unit tabled separately.

The attached flowsheet—Test N-21 (fig. 42)—describes the test procedure in these operations.

During the test it was noted that the minus 60 mesh sulphides contained a high proportion of composite sulphide-insoluble silicate particles. It was therefore necessary to introduce a secondary grinding stage (Ball Mill 2 in fig. 42) followed by bulk flotation (Flotation 2A), to separate these components. Flotation tailings from these operations were concentrated separately (Test N-21). It is noteworthy that nearly half of the total tin recovery was obtained from this fraction. Sizing of Ball Mill 2 discharge was 90 per cent minus 200 mesh.

Several sizings were made of products from this test, namely the 60 mesh screen under size, the reground sulphides (No. 3 Flotation feed) and the first Copper Concentrate (F4C1). This last sizing has been mentioned previously.

The results of this test indicate that:—

(*a*) Recovery of tin present as cassiterite is unlikely to exceed 40 per cent under any circumstances involving gravity concentration processes. The cassiterite metallurgy of Test N-21 is confirmed in part by the grain size analysis and vanning assay mentioned previously.

(*b*) While grinding to minus 60 mesh may be desirable to effect release of coarse cassiterite without over-grinding, further grinding to the order of 200 mesh is necessary to effect total or near total release of the finer grained fraction of this mineral.

(*c*) In commercial treatment of the ore, tilting decks and/or vanners would be preferred to tables for maximum cassiterite tin recovery by gravity means.

It will be noted in the tabulated results of Test N-21 that copper recovery is not as good as in the smaller scale tests quoted previously. This can be accounted for by the fact that different equipment has been used and flotation conditions could therefore require some slight modification.

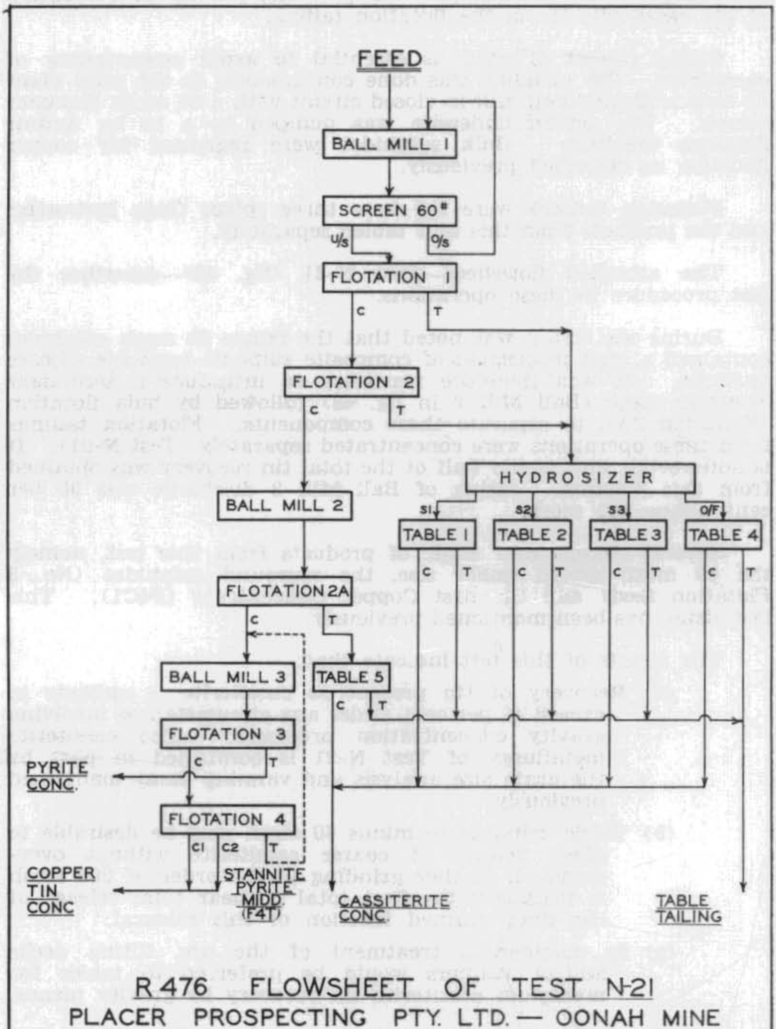

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FIGURE 42

TEST N-21

Metallurgical Results

Product	*Per Cent* *Weight*	*Per Cent* *Copper*	*Per Cent* *Sol. Tin*	*Per Cent* *Insol. Tin*	*Per Cent Distribution* *Copper*	*Per Cent Distribution* *Sol. Tin*	*Per Cent Distribution* *Insol. Tin*
Copper Conc. F4C1 ..	10.26	19.5	10.4	0.86	58.0	47.5	4.4
Copper Conc. F4C2 ..	3.45	16.0	10.0	0.86	16.0	15.4	1.5
Copper Conc. F4T	11.10	4.5	2.3	0.89	14.5	11.4	18.4
Pyrite Conc. F3T	30.83	0.93	0.76		8.3	10.4	
Gravity Tailing T1T	2.33	0.12	0.60	1.35	1.2	9.4	1.5
Gravity Tailing T2T	6.88			0.98			3.3
Gravity Tailing T3T	8.97			0.83			3.7
Gravity Tailing T4T	16.77			2.10			17.4
Gravity Tailing T5T	7.44	0.48	1.40	4.82	1.0	4.8	13.2
Gravity Conc. T1C ..	0.33	1.20	1.20	42.6	0.4	0.5	7.0
Gravity Conc. T2C ..	0.21			36.8			3.8
Gravity Conc. T3C ..	0.25			34.2			4.3
Gravity Conc. T4C ..	0.33			33.8			5.5
Gravity Conc. T5C ..	0.85	2.60	1.70	38.2	0.6	0.6	16.0
Composite Head	100.00	3.45	2.25	2.02	100.0	100.0	100.0

NOTE: Sol. Tin = Tin present as stannite. Insol. Tin = Tin present as cassiterite.

Summary of Concentrates Produced

Copper Conc.	*Oz/ton Silver*	*Per Cent*			*Per Cent Recovery of Metals*			
		Copper	*Sol. Tin*	*Insol. Tin*	*Silver*	*Copper*	*Sol. Tin*	*Insol. Tin*
F4C1 + F4C2	196	18.6	10.3	0.86	61.0	74.0	62.9	5.9

Cassiterite Conc.:	*Per Cent*			
	Insol. Tin	*Sol. Tin*	*Copper*	*Insol. Tin Recovery*
Table Concs. 1-5	37.6	0.56	0.51	36.7

The above results should be studied in conjunction with the attached flowsheet (fig. 42).

Sizing Analysis of Products from Test N-21

Fraction (B.S.S.)	*Per Cent*						
	60 Mesh Screen U/S		*F3 Feed*		*F4C1*		
	Weight	*Cum. Weight*	*Weight*	*Cum. Weight*	*Weight*	*Cum. Weight*	*Cu*
+ 85 Mesh	2.7	2.7					
100	4.4	7.1					
150	14.9	22.0					
200	12.5	34.5	1.8	1.8	1.2	1.2	8.5
C.S. 1	19.0	53.5	19.2	21.0	10.4	11.6	19.2
C.S. 2	9.8	63.3	12.9	33.9	12.4	24.0	18.4
C.S. 3	9.5	72.8	16.5	50.4	19.6	43.6	17.6
C.S. 4	6.8	79.6	13.5	63.9	18.0	61.6	18.4
C.S. 5	3.3	82.9	7.2	71.1	9.6	71.2	18.4
C.S. 6	17.1	100.0	28.9	100.0	28.8	100.0	

ANALYSIS OF THE COPPER CONCENTRATE

Element	*F4C1* %	*F4C2* %
Copper	19.5	16.0
Sol. Tin	10.4	10.0
Insol. Tin	0.86	0.86
Antimony	2.70	3.00
Arsenic	1.33	1.74
Lead	3.10	1.80
Bismuth	0.90	0.70
Zinc	1.10	1.0
Iron	24.0	27.2
Sulphur	31.6	32.61
Acid Insol.	4.0	4.1
Silver	192 oz/ton	207 oz/ton

Note: The ore is known to contain tetrahedrite and the antimony in the concentrate is probably present as this mineral. Tetrahedrite usually contains arsenic and the same conclusions apply to this metal also.

Summary

In summarizing the results of this investigation, the preliminary nature of the test work must be stressed. Not much attention has been given to establishing optimum reagent combinations or additions for the various flotation stages and furthermore the use of Aerofloat 238 and other selective copper flotation reagents has not been studied to any extent.

In addition, the degree of grinding required for release of cassiterite from gangue and sulphides and release of copper-bearing sulphides from pyrite has not been firmly established, although it appears that grinding to minus 200 mesh would achieve both these functions.

However, the results have shown that it is feasible to produce from this type of ore a sulphide concentrate containing 19 per cent copper, 10 per cent tin and 200 oz/ton of silver plus significant amounts of other economically valuable metals. It is anticipated that a market could be found for such a concentrate.

In view of the fineness of the cassiterite grain size it would be unwise to anticipate recoveries much in excess of 40 per cent of the tin present as this mineral in concentrates of the grades shown.