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RECOVERY OF BISMUTH FROM TAILING

(A.M.D.L. Report No. 294)

by

E.E. Moskovits

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* of the Australian Mineral Development Laboratories, Adelaide.

Introduction

This project was sponsored to ascertain whether bismuth was present in gold and copper tailings in the Tennant Creek area in quantities sufficient to be economically interesting, and to explore the possibilities of concentrating the bismuth minerals as a prerequisite for leaching. Dump samples were also checked for the occurrence of elements of possible economic value.

The report has been included in the Bureau's Record series so that it may have a wide distribution through the Bureau's Open File system. It has not been altered in any way.

2/1/3

AMDL Report 294
November, 1963

RECOVERY OF BISMUTH FROM TAILING

by

E. E. Moskovits

to

BUREAU OF MINERAL RESOURCES

Investigated by: Metallurgy Section
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THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES
Adelaide South Australia

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1. INTRODUCTION

In the Tennant Creek area are a number of tailing dumps which have resulted from gold and copper mining operations and which contain bismuth in various amounts. Dumps containing significant tonnages of tailing exist at Peko and Noble's Nob mines and at the No. 1 and 2 and Central Government Batteries, Tennant Creek.

Work by Woodcock and Dunkin[1] showed that bismuth could be recovered by leaching and this treatment would appear to be economic, provided that the leach feed had a bismuth content in the order of 2 per cent.

The current work, therefore, was aimed at upgrading or concentrating the bismuth minerals as a prerequisite for leaching. The work was limited and designed to establish the feasibility of concentrating bismuth from the various dumps. In addition, the dump samples were checked for other elements of possible economic value.

All work was carried out on samples of approximately 5 lb weight and testing was limited to small scale.

2. SUMMARY

Samples representing residue dumps at Peko and Noble's Nob mines and Central and No. 1 and 2 Government Batteries were examined for recovery of bismuth minerals.

No satisfactory concentration of bismuth was achieved by screening, magnetic separation, gravity concentration or flotation on any of the samples tested.

On all samples bismuth tends to concentrate in:

a. finer particle-size ranges
b. non-magnetic fractions
c. heavy fractions
d. flotation concentrates.

These trends are not sufficiently significant for satisfactory separation.

It was not possible to identify bismuth minerals by standard mineralogical techniques because of the very low bismuth content of the samples.

Spectrographic analyses did not indicate any unexpected elements of significance except rubidium which, however, was not confirmed by chemical analysis.

Some further work on flotation of battery tailings may be warranted depending upon the value of the dumps and on the economics of leaching the material.

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1. Commonwealth Scientific and Industrial Research Organisation and the Mining Department, University of Melbourne, Ore-Dressing Investigations, Report No. 615, 1961.

3. MATERIAL EXAMINED

3.1 Peko Mines NL Sample

A 5 lb sample of material from Peko No. 1 tailings dump was received from Peko Mines NL in March, 1962. The material was thoroughly mixed and samples riffled out for test work.

A spectrographic analysis of the sample is shown in Table 1.

TABLE 1: SPECTROGRAPHIC ANALYSIS

%				Element
Major	10	to 100		Si, Fe
Minor	1	to 10		Mg, Al
Heavy trace	0.1	to 1		Cu, Co, As
Trace	0.01	to 0.1		Pb, Zn, Ni, Bi, Mo, Mn, Ca
Faint trace	10	to 100	ppm	Cr
Very faint trace	1	to 10	ppm	Ag, V, Be, Ge, In, B, Ti, Zr, Ba, Sr, Y

Other elements were not detected at the limits quoted in Appendix A except alkalis and P which were not sought.

A chemical analysis of the sample is shown in Table 2.

TABLE 2: CHEMICAL ANALYSIS

Element		%
Copper	Cu	0.86
Cobalt	Co	0.38
Nickel	Ni	0.008
Bismuth	Bi	0.12
Molybdenum	Mo	0.010

A screen analysis of the sample is shown in Table 7.

3.2 Australian Development NL, Sample

A 5-lb sample of material from Noble's Nob residue dam No. 2 was received from Australian Development NL in May, 1962. The material was thoroughly mixed and samples riffled out for test work.

A spectrographic analysis of the sample is shown in Table 3.

TABLE 3: SPECTROGRAPHIC ANALYSIS

	%			Element
Major	10	to	100	Si
Minor	1	to	10	Bi, Fe, Mg, Al
Heavy trace	0.1	to	1	- - - - -
Trace	0.01	to	0.1	Cu, Zn, B
Faint trace	10	to	100 ppm	Pb, Ni, Ca, Ti, Ba, Mn
Very faint trace	1	to	10 ppm	Co, Ag, Cr, V, Zr, Sr

Other elements were not detected at limits quoted in Appendix A except alkalis and P which were not sought.

A chemical analysis of the sample gave the following results:

		%
Bismuth	Bi	0.34
Copper	Cu	0.03

The screen analysis of the sample is shown in Table 12.

3.3 No. 1 Battery Tailings Dump

A 5-lb sample of material labelled "Sample No. 1 B.M.R. O/N MR21734" from No. 1 Battery tailings dump, situated about 25 miles NW of Tennant Creek was received in July, 1962. The sample was obtained from a total of 471 samples taken over an area representing approximately 9000 tons.

The material was thoroughly mixed and samples riffled out for test work.

A spectrographic analysis of the sample is shown in Table 4.

TABLE 4: SPECTROGRAPHIC ANALYSIS

	%			Element
Major	10	to	100	Si, Fe
Minor	1	to	10	Bi, Al
Heavy trace	0.1	to	1	Mg, Na
Trace	0.01	to	0.1	Cu, Zn, Mo, As, Mn, Ti, K
Faint trace	10	to	100 ppm	Pb, Ni, Co, V, Cr, Ca, Zr, Ba, Y, Li
Very faint trace	1	to	10 ppm	Ag, Ge, B, Sr

Other elements were not detected at limits quoted in Appendix A except P which was not sought.

A chemical analysis of the sample gave the following results:

		%
Bismuth	Bi	0.44
Molybdenum	Mo	0.016

Mineragraphic examination did not detect bismuth minerals by standard mineralogical techniques. (See Appendix B).

The screen analysis of the sample is shown in Table 15.

3.4 No. 2 Battery Tailings Dump

A 5-lb sample of material labelled "Sample No. 2 B.R.M. O/N MR21734" representing No. 2 Battery tailings dump situated about 8 miles east of Tennant Creek was received in July, 1962. The dump, which contains approximately 4000 tons, was bored to a 10 ft grid and a sample of approximately 2 lb taken for every 5 feet of depth. The dump is spread over a large area and only exceeded 5 feet in depth in 18 bores. In all 618 samples were taken and from these the 5 lb sample was obtained.

The material was thoroughly mixed and samples riffled out for test work.

A spectrographic analysis of the sample is shown in Table 5.

TABLE 5: SPECTROGRAPHIC ANALYSIS

	%			Element
Major	10	to	100	Fe, Si
Minor	1	to	10	Al, K
Heavy trace	0.1	to	1	Bi, Mg, Na
Trace	0.01	to	0.1	Zn, Mo, Rb
Faint trace	10	to	100 ppm	Pb, Co, Ni, V, Cr, Mn, Ca, Ti, Ba, Y, Li
Very faint trace	1	to	10 ppm	Cu, Ag, Sn, Ge, B, Zr, Sr,

Other elements were not detected at limits quoted in Appendix A except P which was not sought.

A chemical analysis of the sample gave the following results:

		%	
Bismuth	Bi	0.27	
Rubidium	Rb	< 0.005	
Molybdenum	Mo	< 0.005	< = Less than.

The screen analysis of the sample is shown in Table 21.

3.5 No. 3 Tailings Dump – Central Battery

A 5-lb sample of material labelled "Sample No. 3 B.M.R. O/N MR21734" representing No. 3 Battery Tailings dump at Central Battery, Tennant Creek was received in July, 1962.

The dump which contains approximately 25,000 tons was bored to a 10 ft grid and a sample of approximately 2 lb taken for every 5 feet of bore depth. In all 1,072 samples were taken and from these the 5 lb sample was obtained.

The material was thoroughly mixed and samples riffled out for test work.

A spectrographic analysis of the sample is shown in Table 6.

TABLE 6: SPECTROGRAPHIC ANALYSIS

	%			Element
Major	10	to	100	Si
Minor	1	to	10	Fe, Al, K
Heavy trace	0.1	to	1	Bi, Mg, Na
Trace	0.01	to	0.1	Cu, Zn, Rb
Faint trace	10	to	100 ppm	Pb, Sn, Mo, V, Mn, Ca, Ti, Ba, Li
Very faint trace	1	to	10 ppm	Co, Ni, Cr, Ge, B, Zr, Sr, Y

Other elements were not detected at limits quoted in Appendix A except P which was not sought.

The chemical analysis of the sample gave the following results:

		%
Bismuth	Bi	0.37
Rubidium	Rb	< 0.005

< = Less than.

The screen analysis of the sample is shown in Table 25.

4. EQUIPMENT

The major items of equipment used were:

a. Rotap[(a)] screening machine and British Standard (BSS) laboratory screens.

b. Laboratory stainless steel rod mill, $7\frac{1}{2}$ inches diameter, 10 inches long, with 10 1-inch diameter rods.

c. Davis tube magnetic separator.

d. Haultain Superpanner.

e. Denver laboratory flotation cell.

f. Infrasizer.

5. PEKO MINES NL SAMPLE

5.1 General

A description of the Peko Mines NL sample is given in Section 3.1. The head assay of this sample was:

		%
Bismuth	Bi	0.12
Copper	Cu	0.86
Cobalt	Co	0.38
Nickel	Ni	0.008
Molybdenum	Mo	0.010

5.2 Experimental Procedure and Results

5.2.1 Screening

A screen analysis of the sample is given in Table 7.

(a) Reference to specific equipment in this report is made to facilitate understanding and does not imply endorsement of such equipment by The Australian Mineral Development Laboratories.

TABLE 7: SCREEN ANALYSIS

Mesh BSS			Weight %		Assay, % Bi	Assay, % Co	Assay, % Cu	Distribution, % Bi	Distribution, % Co	Distribution, % Cu
	+	36	2.2							
- 36	+	52	5.1	21.2	0.075	0.285	0.845	19.7	26.5	25.5
- 52	+	72	7.0							
- 72	+	100	6.9							
- 100	+	150	11.5							
- 150	+	200	7.8	32.6	0.070	0.270	0.870	28.9	16.1	39.9
- 200	+	300	13.3							
- 300			46.2	46.2	0.085	0.295	0.530	51.4	57.4	34.6
	Feed (calc.)		100.0	100.0	0.076	0.230	0.705	100.0	100.0	100.0

5.2.2 Magnetic Separation

A sample was separated into magnetic and non-magnetic fractions in a Davis tube separator.

The conditions of the test were as follows:

Weight of sample	44.8 g
Coil current	2.7 amp
Stroke frequency	65 cycles per minute
Water feed rate	200 cc per minute

The results are shown in Table 8.

TABLE 8: DAVIS TUBE TEST

Product	Weight %	Assay, %		Distribution, %	
		Bi	Co	Bi	Co
Magnetic	69.5	0.08	0.19	47.5	42.2
Non-magnetic	30.5	0.21	0.60	52.5	57.8
Feed	100.0	0.11	0.31	100.0	100.0

5.2.3 Gravity Concentration

An enriched feed consisting of a combined sample of 11.8 g original sample and 8.5 g non-magnetic fraction from the Davis tube test assaying 0.133 per cent Bi and 0.358 per cent Co was used as feed for gravity separation by the Haultain Superpanner. The results are given in Table 9.

TABLE 9: HAULTAIN SUPERPANNER TEST

Product	Weight %	Assay, %		Distribution, %	
		Bi	Co	Bi	Co
Concentrate[a]	16.0	0.23	0.64	27.2	28.5
Tailing	84.0	0.13[b]	0.32[b]	72.8	71.5
Feed	100.0	0.133	0.358	100.0	100.0

(a) The concentrate assayed 1.3 per cent Cu.
(b) Calculated values.

5.2.4 Flotation

One anionic and one cationic flotation experiment were conducted on the sample. Demineralised water was used for the flotation tests and the temperature was maintained at 22°C.

In the anionic flotation test potassium amyl xanthate was used as collector and in the cationic flotation test Armac SD, a long chain amine acetate derived from soyabean, was used as collector. In both types of flotation Aerofroth 65 was used as frother.

Because of the small quantity of sample available, flotation tests were conducted at low pulp density with approximately 8 per cent solids in the pulp. Under such conditions it was preferred to express initial reagent concentration in "grams per litre" instead of reagent amount.

Conditions of the tests were:

a. Anionic Flotation

The pulp was conditioned with sodium sulphide in the cell for 5 minutes, then potassium amyl xanthate was added and conditioning continued for an additional minute.
Reagent concentrations were 0.23 grams per litre Na_2S, and 0.15 grams per litre potassium amyl xanthate. The pH (natural) at commencement of the test was 3.4 changing to 4.2 at the end of the test. The rougher concentrate was cleaned twice.

b. Cationic Flotation

The pulp was conditioned with Armac SD in the cell for one minute before each flotation stage which lasted 4 minutes. Reagent concentration was 2 grams per litre Armac SD. The first concentrate was taken off at pH 4 (natural), but in the other stages the pH was adjusted with NaOH to 7.4.

Results are shown in Tables 10 and 11.

TABLE 10: ANIONIC FLOTATION

Fraction	Weight %	Assay, %			Distribution, %		
		Bi	Co	Cu	Bi	Co	Cu
2nd Cleaner concentrate	22.3	0.05	0.18	0.70	11.1	11.3	12.3
2nd Cleaner tailing	7.1	0.11	0.41	1.37	88.9	88.7	87.7
1st Cleaner tailing	15.7						
Rougher tailing	54.9						
Feed	100.0	0.09	0.36	1.22	100.0	100.0	100.0

TABLE 11: CATIONIC FLOTATION

Fraction	Weight		Assay, %			Distribution, %		
			Bi	Co	Cu	Bi	Co	Cu
Concentrate 1	8.4	25.5	0.155	0.355	1.110	46.5	32.3	35.2
Concentrate 2	17.1							
Concentrate 3	20.4	31.0	0.070	0.325	0.845	25.6	36.4	32.9
Concentrate 4	10.6							
Concentrate 5	14.2	43.5	0.055	0.195	0.570	27.9	31.3	31.9
Tailing	29.3							
Feed	100.0	100.0	0.086	0.278	0.790	100.0	100.0	100.0

5.2.5 Discussion

The screen analysis shows some enrichment of the bismuth in the minus 300-mesh fraction, but this has no practical significance.

The magnetic separation shows a slight concentration of bismuth and cobalt in the non-magnetic product.

The Haultain Superpanner test shows a slight concentration of bismuth and cobalt in the heavy fraction.

Flotation gives no indication of being a practical method of concentration.

None of the beneficiation techniques applied showed any encouraging trends. The best ratio of concentration was achieved using magnetic separation but further investigation of this method is not warranted.

6. AUSTRALIAN DEVELOPMENT NL, SAMPLE

6.1 General

The Australian Development NL sample is described in Section 3.2. The head assay of this sample was:

		%
Bismuth	Bi	0.34
Copper	Cu	0.03

6.2 Experimental Procedure and Results

6.2.1 Screening

A screen analysis of the sample is given in Table 12.

TABLE 12: SCREEN ANALYSIS

Mesh BSS			Weight %		Bi %	Distribution %
	+	52	0.4			
- 52	+	72	1.6	6.7	0.13	3.2
- 72	+	100	4.7			
- 100	+	150	10.7			
- 150	+	200	7.0	28.7	0.155	16.3
- 200	+	300	11.0			
- 300			64.6	64.6	0.34	80.5
Feed (calc.)			100.0	100.0	0.27	100.0

6.2.2 Magnetic Separation

A sample was separated into the magnetic and non-magnetic fractions using a Davis tube separator.

The conditions of the test were as follows:

Weight of sample	49.5 g
Coil current	2.7 amp
Stroke frequency	80 cycles per minute
Water feed rate	200 cc per minute

The results are shown in Table 13.

TABLE 13: DAVIS TUBE TEST

Product	Weight %	Bi %	Distribution %
Magnetic	20.8	0.09	5.6
Non-magnetic	79.2	0.38	94.4
Feed	100.0	0.32	100.0

6.2.3 Flotation

Two flotation tests were conducted.

In the first test (Test 1) 0.38 gram per litre phosphorus pentasulphide was used as sulphidizing agent and 0.15 gram per litre potassium amyl xanthate was used as collector.

Aerofroth 65 was used as frother in both tests. Demineralised water was used and the temperature was maintained at 22^{0}C.

The pulp was conditioned with reagents in the cell for 3 minutes with the sulphidizing agents and for an additional minute with the collectors.

Results are shown in Table 14.

TABLE 14: FLOTATION

Test No.	Fraction	Weight %	Bi %	Distribution %
1	Concentrate	18.8	0.46	29.1
	Tailing	81.2	0.26	70.9
	Feed	100.0	0.30	100.0
2	Cleaner concentrate	7.5	1.03	22.3
	Cleaner tailing	17.6	0.28(a)	77.7
	Rougher tailing	74.9		
	Feed	100.0	0.34(b)	100.0

(a) Calculated.
(b) Head assay.

6.2.4 Discussion

The screen analysis shows that there is a definite tendency for bismuth to report to the minus 300-mesh fraction.

The magnetic separation shows some slight concentration of bismuth in the non-magnetic fraction.

Flotation results are not satisfactory though some concentration of the bismuth was obtained in the concentrate. With cleaning the grade of concentrate was improved, with further decrease of recovery.

None of the beneficiation techniques applied are considered to have given results sufficiently encouraging to warrant further investigation.

7. NO. 1 BATTERY TAILING DUMP

7.1 General

The sample "B.M.R. O/N MR21734 No. 1" is described in Section 3.3. The head assay of this sample was:

		%
Bismuth	Bi	0.44
Molybdenum	Mo	0.016

7.2 Experimental Procedure and Results

7.2.1 Screening and Infrasizing

The screen analysis of of the sample is given in Table 15.

TABLE 15: SCREEN ANALYSIS

Mesh BSS			Weight %		Bi %	Distribution %
	+	52	6.2			
- 52	+	72	6.6	20.1	0.34	11.5
- 72	+	100	7.3			
- 100	+	150	9.6			
- 150	+	200	4.9	23.0	0.40	15.5
- 200	+	300	8.5			
- 300			56.9	56.9	0.76	73.0
Feed (calc)			100.0	100.0	0.59	100.0

Infrasizing of the sample was done and the results are shown in Table 16.

TABLE 16: INFRASIZING

Cone No.	Average Particle Diameter[a], μ			Weight %		Bi %	Distribution %
1		+	52.6	26.3			
2	- 52.6	+	38.6	2.5			
3	- 38.6	+	26.3	4.0			
4	- 26.3	+	18.8	6.8	57.0	0.29 (calc)	28.8
5	- 18.8	+	13.2	8.8			
6	- 13.2	+	9.4	8.6			
7	- 9.4			43.0	43.0	0.97	71.2
Feed (calc.)				100.0	100.0	0.59	100.0

(a) Nominal.

7.2.2 Magnetic Separation

A sample was separated into magnetic and non-magnetic fractions in a Davis tube separator.

The conditions of the test were as follows:

Weight of sample	49.8	g
Coil current	2.7	amp
Stroke frequency	80	cycles per minute
Water feed rate	200	cc per minute

The results are shown in Table 17.

TABLE 17: DAVIS TUBE TEST

Product	Weight %	Bi %	Distribution %
Magnetic	18.5	0.23	7.1
Non-magnetic	81.5	0.68	92.9
Feed	100.0	0.59	100.0

7.2.3 Gravity Concentration

Gravity separations using a Haultain Superpanner were made on 20 g non-magnetic, 28 g minus 300-mesh and 30 g plus 300-mesh fractions of the original sample.

The results are shown in Table 18.

TABLE 18: HAULTAIN SUPERPANNER TESTS

Fraction	Product	Weight %	Assay Bi %	Distribution Bi %
Non-magnetic	Concentrate	9.0	0.99	13.2
	Tailing	91.0	0.65(a)	86.8
	Feed	100.0	0.68	100.0
- 300 mesh	Concentrate	13.2	0.85	14.8
	Tailing	86.8	0.73(a)	85.2
	Feed	100.0	0.755	100.0
+ 300 mesh	Concentrate	10.0	0.71	19.2
	Tailing	90.0	0.33(a)	80.8
	Feed	100.0	0.370	100.0

(a) Calculated by difference.

7.2.4 Flotation

Six anionic flotation tests and one cationic test were conducted. For the anionic flotation the following collectors were used:

a. Potassium amyl xanthate

b. Six component emulsion, composed of —

	Wt %
Sulphonated sperm whale oil	10
Fuel oil	61
Naphthenic acid	9
Sorbitan mono oleate	2
Octylphenoloxyethylene condensate	4
Linseed fatty acids(a)	14

(a) 40% oleic acid, 20% linoleic acid and 10% linolenic acid.

For the cationic flotation Armac SD, a long chain amine acetate derived from soyabean, was used as collector.

Aerofroth 65 was used as frother in both types of flotation. For all flotation tests demineralised water was used and the temperature was maintained at 22°C in each test.

Where reagents were added to the flotation cell, the pulp was conditioned for 1 minute before air was introduced. Concentrates were removed for periods of 10 minutes in the rougher stages and for 4 minutes in the cleaner stages. Conditioning in the attritor was done at 50 per cent

solids and for a period of 20 minutes. In Test 6 desliming was done by decantation, using three successive settling periods of 25 minutes. Sodium silicate and calgon equivalent to 8 lb per ton and 2.5 lb per ton respectively were added initially to prevent flocculation.

Other test conditions are set out in Table 19.

The concentration of Na_2S was 0.23 grams per litre.

Results are shown in Table 20.

TABLE 19: FLOTATION TEST CONDITIONS — TESTS 3 TO 8

Test No.	Collector	g/l	Pulp Density	Conditioning	Cleaner Stages	Sulphidizing Agent
3	Potassium amyl xanthate	0.15	8	Flotation cell	Nil	Na_2S
4	Potassium amyl xanthate	0.15	8	Flotation cell	1	Na_2S
5	Emulsion	1.2	8	Flotation cell	Nil	Nil
6(a)	Potassium amyl xanthate	0.15	8	Flotation cell	1	Na_2S
7	Potassium amyl xanthate	0.15	27	Flotation cell	5	Na_2S
8	Emulsion	2.3	27	Attritor	5	Nil

(a) Deslimed feed.

TABLE 20: ANIONIC FLOTATION

Test No.	Fraction	Weight %	Assay Bi %	Distribution Bi %
3	Concentrate	21.2	1.45	52.0
	Tailing	78.8	0.355	48.0
	Feed	100.0	0.59	100.0
4	Cleaner concentrate	9.6	2.49	40.5
	Cleaner tailing	12.1	0.38(a)	59.5
	Rougher tailing	78.3		
	Feed	100.0	0.59	100.0
5	Concentrate	33.0	0.89	49.6
	Tailing	67.0	0.45(calc)	50.4
	Feed	100.0	0.59	100.0
6	Slime	20.1	0.91	30.4
	Cleaner concentrate	7.9	2.09	27.9
	Cleaner tailing	4.4	0.34(a)	41.7
	Rougher tailing	67.6		
	Feed	100.0	0.59	100.0
7	3rd Cleaner concentrate	2.4	1.18	4.2
	3rd Cleaner tailing 2nd Cleaner tailing Cleaner tailing Rougher tailing	97.6	0.58(a)	95.8
	Feed	100.0	0.59	100.0
8	3rd Cleaner concentrate	25.0	0.81	34.2
	3rd Cleaner tailing 2nd Cleaner tailing Cleaner tailing Rougher tailing	75.0	0.52(a)	65.8
	Feed	100.0	0.59	100.0

(a) Calculated by difference.

Cationic Flotation. The pulp was conditioned with Armeen SD in the flotation cell for 1 minute before each rougher stage which lasted 4 minutes.

Results are shown in Table 21.

TABLE 21: CATIONIC FLOTATION

Fraction	Weight %		Assay Bi %	Distribution Bi %
Concentrate 1	5.5			
Concentrate 2	4.0			
Concentrate 3	9.0	31.0	0.805	43.2
Concentrate 4	7.0			
Concentrate 5	5.5			
Tailing	69.0	69.0	0.475	56.8
Feed	100.0	100.0	0.578	100.0

7.2.5 Discussion

The screen analysis shows a definite trend towards concentration of bismuth in the minus 300-mesh fraction. The infrasizing results show that bismuth is concentrated in the minus 9.4 microns fraction.

The magnetic separation shows little concentration of bismuth in the non-magnetic fraction.

Results of the Haultain Superpanner test show a very slight increase in bismuth in the heavy fraction.

Flotation with anionic reagents gave a cleaner concentrate assaying 2.49 per cent bismuth with a recovery of 40.5 per cent and a concentrate assaying 1.45 per cent with 52.0 per cent recovery.

Flotation with Armac SD gave a concentrate assaying 0.805 per cent bismuth with a recovery of 43.2 per cent bismuth. Further work involving flotation of slime material would probably improve the grade of concentrate and recovery, but the small quantity of material involved (9000 tons) probably does not justify the investigation.

8. NO. 2 BATTERY TAILING DUMP

8.1 General

The sample "B.M.R. O/N MR21734 No. 2" is described in Section 3.4. The head assay of this sample is:

		%
Bismuth	Bi	0.27
Rubidium	Rb	<0.005
Molybdenum	Mo	<0.005

< = Less than.

8.2 Experimental Procedure and Results

8.2.1 Screening

A screen analysis of the sample is given in Table 22.

TABLE 22: SCREEN ANALYSIS

Mesh BSS			Weight %		Assay Bi %	Distribution Bi %
	+	52	8.1			
- 52	+	72	7.6	23.8	0.135	12.1
- 72	+	100	8.1			
- 100	+	150	11.7			
- 150	+	200	5.2	25.6	0.150	14.8
- 200	+	300	8.7			
- 300			50.6	50.6	0.375	73.1
Feed (calc)			100.0	100.0	0.256	100.0

8.2.2 Magnetic Separation

A magnetic separation was made on the sample using a Davis tube.

The conditions of the test were as follows:

Weight of sample	48.3	g
Coil current	2.2	amp
Stroke frequency	80	cycles per minute
Water feed rate	200	cc per minute

The results are shown in Table 23.

TABLE 23: DAVIS TUBE TEST

Product	Weight %	Assay Bi %	Distribution Bi %
Magnetic	17.2	0.13	8.4
Non-magnetic	82.8	0.29	91.6
Feed	100.0	0.262	100.0

8.2.3 Gravity Concentration

A gravity separation was made using the Haultain Superpanner on 20 g of the non-magnetic fraction of the sample from the Davis Tube test. The results are shown in Table 24.

TABLE 24: HAULTAIN SUPERPANNER TEST

Product	Weight %	Assay Bi %	Distribution Bi %
Concentrate	10.0	0.44	15.2
Tailing	90.0	0.22 (calc)	84.8
Feed	100.0	0.29	100.0

8.2.4 Flotation

Three flotation tests were conducted using as collector sodium ethyl xanthate in Test 9 and potassium amyl xanthate in Test 10 and 11. Aerofroth 65 was used as frother. Phosphorus pentasulphide was used in Test 9 and sodium sulphide in Test 10 and 11 as sulphidizing agents. The conditioning time was 3 minutes. In Test 9 and Test 10 tailing in the as-received condition was used as feed. In Test 11 the tailing was ground for 5 minutes in the rod mill before flotation.

The reagents were added to the flotation cell and a rougher flotation concentrate removed over a period of 10 minutes. The rougher concentrates from Test 10 and Test 11 were cleaned for 4 minutes. Initial pulp density was 8 per cent solids.

Where applicable, reagent concentrations were:

	g/l
Sodium ethyl xanthate	0.15
Potassium amyl xanthate	0.15
Phosphorus pentasulphide	0.38
Sodium sulphide	0.23

In the tests demineralised water was used and the temperature was maintained at 22°C.

Results are shown in Table 25.

TABLE 25: FLOTATION

Test No.	Fraction	Weight %		Assay Bi %	Distribution Bi %
9	Concentrate	21.3		0.395	32.6
	Tailing	78.7		0.22	67.4
	Feed	100.0		0.257	100.0
10	Cleaner concentrate	12.1		1.08	50.0
	Cleaner tailing	15.3	87.9	0.15	50.0
	Rougher tailing	72.6			
	Feed	100.0		0.26	100.0
11	Cleaner concentrate	22.7		0.36	31.9
	Cleaner tailing	26.5	77.3	0.22	68.1
	Rougher tailing	50.8			
	Feed	100.0		0.256	100.0

8.2.5 Discussion

The screen analysis shows a slight concentration of bismuth in the minus 300-mesh fraction.

Magnetic separation gives some concentration of bismuth in the non-magnetic fraction.

The Haultain Superpanner test shows an increase of bismuth in the heavy fraction.

None of these techniques gives any indication of being practical.

Flotation shows some promise for recovery of bismuth and further work could probably improve results. However the small quantity of material (4000 tons) is unlikely to justify the investigation.

9. NO. 3 TAILING DUMP — CENTRAL BATTERY

9.1 General

The sample BMR — O/N MR21734 No. 3 is described in Section 3.5. The head assay of the sample was:

		%
Bismuth	Bi	0.37
Rubidium	Rb	<0.005

9.2 Experimental Procedure and Results

9.2.1 Screening

A screen analysis of the sample is given in Table 26.

TABLE 26: SCREEN ANALYSIS

Mesh BSS			Weight %		Assay Bi %	Distribution Bi %
	+	52	9.0			
- 52	+	72	10.8	30.2	0.14	12.4
- 72	+	100	10.4			
- 100	+	150	11.1			
- 150	+	200	6.3	26.2	0.23	17.7
- 200	+	300	8.8			
-300			43.6	43.6	0.54	69.9
Feed (calc)			100.0	100.0	0.34	100.0

9.2.2 Magnetic Separation

A magnetic separation was made on the sample using a Davis tube. The conditions of the test were as follows:

Weight of sample	50.0	g
Coil current	2.7	amp
Stroke frequency	80	cycles per minute
Water feed rate	200	cc per minute

The results are shown in Table 27.

TABLE 27: DAVIS TUBE TEST

Product	Weight %	Assay Bi %	Distribution Bi %
Magnetic	32.0	0.15	13.3
Non-magnetic	68.0	0.46	86.7
Feed	100.0	0.36	100.0

9.2.3 Gravity Concentration

Gravity separation by the Haultain Superpanner was made on a 20 g sample from the non-magnetic fraction of the Davis Tube test.

The results are shown in Table 28.

TABLE 28: HAULTAIN SUPERPANNER TEST

Product	Weight %	Assay Bi %	Distribution Bi %
Concentrate	14.0	0.68	20.6
Tailing	86.0	0.31 (calc)	79.4
Feed	100.0	0.46	100.0

9.2.4 Flotation

In this series five flotation tests were conducted. Two tests were carried out on the sample in the as-received condition, and three tests on material ground for 5 minutes (nominally 97.3 per cent passing 300-mesh).

Demineralised water was used in all tests and the temperature was maintained at 22°C in every test.

Initial pulp density was 8 per cent solids.

Flotation test conditions are set out in Table 29.

Aerofroth 65 was used as frother in all tests. In order to adjust the pH, H_2SO_4 and NaOH were used as necessary.

Results are shown in Table 30.

TABLE 29: FLOTATION TEST CONDITIONS — TESTS 12 TO 16

Test No.	-300 Mesh %	Collector	Collector Concentration g/l	Sulphidizer	Sulphidizer Concentration g/l	pH
12	43.6	Sodium ethyl xanthate	0.15	Phosphorus pentasulphide	0.38	9
13	43.6	Potassium amyl xanthate	0.15	Sodium sulphide	0.23	10
14	97.3	Potassium amyl xanthate	0.15	Sodium sulphide	0.23	10
15	97.3	Potassium amyl xanthate	0.15	Sodium sulphide	0.23	11
16	97.3	Potassium amyl xanthate	0.15	Sodium sulphide	0.23	4

TABLE 30: FLOTATION

Test No.	Fraction	Weight %	Assay Bi %	Distribution Bi %
12	Concentrate	12.6	0.68	24.6
	Tailing	87.4	0.30	75.4
	Feed	100.0	0.34	100.0
13	Cleaner concentrate	6.9	1.77	35.8
	Cleaner tailing	13.6	0.23	64.2
	Rougher tailing	79.5		
	Feed	100.0	0.34	100.0
14	Cleaner concentrate	12.6	1.50	56.2
	Cleaner tailing	27.0	0.17(a)	43.8
	Rougher tailing	60.4		
	Feed	100.0	0.34	100.0
15	Cleaner concentrate	11.1	1.28	42.2
	Cleaner tailing	23.0	0.22(a)	57.8
	Rougher tailing	65.9		
	Feed	100.0	0.34	100.0
16	Cleaner concentrate	10.2	1.81	54.5
	Cleaner tailing	21.2	0.17	45.5
	Rougher tailing	68.6		
	Feed	100.0	0.34	100.0

(a) Calculated by difference.

9.2.5 Discussion

The screen analysis shows some concentration of bismuth in the minus 300-mesh fraction.

The magnetic separation shows a minor tendency for bismuth to concentrate in the non-magnetic product.

The gravity concentration also showed a tendency for some bismuth to concentrate in the heavy fraction.

None of the above techniques appear to have an application to this sample. However, flotation could possibly be developed with further investigation, and further work may be warranted because of the size of the dump.

Similar material submitted for leaching tests gave an extraction of 73 per cent of bismuth (Madigan, AMDL Report 256, 1963) and this seems the most obvious approach to enable the bismuth to be recovered from the samples.

10. CONCLUSION

No satisfactory response was obtained by standard mineral dressing methods on any of the samples.

Further work on flotation could possibly enable an enriched bismuth concentrate to be produced from the various battery tailings. However, in the case of tailings from No. 1 and from No. 2 Government Batteries, the small size of the dumps probably does not justify further work. In the case of tailing from No. 3 Tailing Dump — Central Battery, leaching work has shown that a recovery of 73 per cent of the bismuth is possible. If the economics of leaching are such that enriched feed is essential, further investigations into flotation may be warranted.

APPENDIX A

SPECTROGRAPHIC ANALYSES
Detection-Limit Concentrations of Elements
D. C. Arc Excitation

ELEMENT	Per cent	ppm	ELEMENT	Per cent	ppm
Ag	0.00005	0.5	Na	0.00005	0.5
Al	0.0002	2	Nb	0.003	30
As	0.01	100	Nd	0.001	10
Au	0.001	10	Ni	0.0002	2
B	0.001	10	Os	0.005	50
Ba	0.0002	2	P	0.02	200
Be	0.0005	5	Pb	0.0002	2
Bi	0.0005	5	Pd	0.001	10
Ca	0.0002	2	Pr	0.001	10
Cd	0.001	10	Pt	0.005	50
Ce	0.04	400	Rb	0.0001	1
Co	0.0002	2	Re	0.01	100
Cr	0.0001	1	Rh	0.001	10
Cs	0.0002	2	Ru	0.001	10
Cu	0.00005	0.5	Sb	0.002	20
Dy	0.001	10	Sc	0.0002	2
Er	0.001	10	Si	0.002	20
Eu	0.001	10	Sm	0.05	500
Fe	0.0005	5	Sn	0.001	10
Ga	0.0003	3	Sr	0.0001	1
Gd	0.02	200	Ta	0.01	100
Ge	0.0002	2	Tb	0.001	10
Hf	0.01	100	Te	0.02	200
Hg	0.01	100	Th	0.01	100
Ho	0.001	10	Ti	0.001	10
In	0.0001	1	Tl	0.0001	1
Ir	0.005	50	Tm	0.001	10
K	0.0002	2	U	0.02	200
La	0.001	10	V	0.0005	5
Li	0.0001	1	W	0.005	50
Lu	0.001	10	Y	0.001	10
Mg	0.0002	2	Yb	0.001	10
Mn	0.001	10	Zn	0.0025	25
Mo	0.0005	5	Zr	0.001	10