Dr. Cunningham

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OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 73-67

A METHOD FOR IMPROVING BISMUTH RECOVERY AT TERRA MINING AND EXPLORATION LTD., HAY RIVER, N.W.T.

by

D. RAICEVIC AND R. W. BRUCE

MINERAL PROCESSING DIVISION

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SUMMARY OF RESULTS

The major constituents in the ore sample, received for this investigation, were silver and copper with bismuth, lead, zinc, nickel, cobalt and uranium as minor constituents.

Currently the Terra concentrator recovers in saleable products about 95 per cent of the silver, 90 per cent of the copper and about 30 per cent of the bismuth by applying jigging and flotation methods.

A laboratory procedure, consisting of jigging, slime-deck tabling of the fines from the jig tailing, and flotation,was developed by which similar silver and copper recoveries to those of Terra's concentrator were produced with about 55% bismuth recovery.

The investigation showed that it was not economically feasible to recover the other minor consitutents in the ore.

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*Research Scientist and **Head, Non-Ferrous Minerals Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

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INTRODUCTION

Location of Property

The mine is a silver, copper and bismuth producer located in the Great Slave Lake region in Camsell River area south of Port Radium in the Northwest Territories.

Current Mill Operation

Terra's concentrator, treating about 170 tons of ore per day, recovers silver and copper, and a small amount of bismuth.

In brief the mill flowsheet consists of the following main steps:

(a) jigging of minus 28-mesh ground ore to produce a jig concentrate and jig tailing,

(b) separating the jig tailing by cyclone into cyclone underflow and cyclone overflow,

(c) the cyclone underflow is returned to a ball mill for further grinding and cyclone overflow is treated by flotation to produce a flotation concentrate; the flotation tailing is discarded.

The operating results of September and October 1971 are recorded in Table 1.

TABLE 1

Operating Results for September and October, 1971*

Metal	Heads	Jig concentrate		Flotation conc	
	Assay	Assay	Recovery	Assay	Recovery
	September,1971				
Ag	26.3 oz/ton	1999.0 oz/t	56.8%	253.6 oz/t	37.5%
Cu	1.05%	(3.36)%	(2.4)	24.1%	91.1%
Bi	0.19%	2.73%	21.6	(1.14)%	(47.0)%
	October,1971				
Ag	66.7 oz/ton	3863.0 oz/t	69.2%	897.6 oz/t	26.6%
Cu	0.39%	(1.3)%	(4.0)%	16.8%	82.9%
Bi	0.12%	3.58%	37.8%	(1.8)%	(27.3)%

*Company's more recent results were not available.

The figures in brackets are metals recovered, but not paid for based on the present smelter schedule. The company, therefore, does not receive financial benefits for the copper contained in the jig concentrate or for bismuth contained in the flotation concentrate.

Ore Shipments

(a) Two ore samples were received for this investigation. One sample, consisting of ore specimens, was designated for mineralogical examination; the other sample weighing about 300 lb, representing 30 days of ball mill feed, was used for this investigation.

The chemical analysis of a head sample cut from the sample of ball mill feed is shown in Table 2.

TABLE 2

Chemical Analysis of Head Sample

Silver	(Ag)	-	55.98	oz/ton
Copper	(Cu)	-	0.86	%
Bismuth	(Bi)	-	0.12	%
Lead	(Pb)	-	0.16	%
Zinc	(Zn)	-	0.13	%
Nickel	(Ni)	-	0.07	%
Cobalt	(Co)	-	0.09	%
Arsenic	(As)	-	0.44	%
Antimony	(Sb)	-	0.12	%
Uranium	(U)	-	0.016	%

These assays show that this ore has a good silver-copper grade; of the minor constituents only bismuth appears to be of economic interest.

(b) About 100-lb sample of jig tailing from Terra concentrator was received in June 1973 and used for test work related to the improvement of the bismuth recovery.

The chemical analysis of the sample of jig tailing is recorded in Table 3.

TABLE 3

Chemical Analysis of Jig Tailing

Silver (Ag)	-	9.00	oz/ton
Copper (Cu)	-	0.12	%
Bismuth (Bi)	-	0.031	%

Nature of Investigation

In a letter of December 2, 1971, Mr. C. A. McLeisch, Mine Manager, said that the chief problem was to recover as much of the minor minerals as possible in saleable products without major changes in their milling operation. Later, in a letter dated October 9, 1972, Mr. M. G. Stoner, General Manager, stated that the major concern was an improvement in bismuth recovery while maintaining the present high silver and copper recoveries.

MINERALOGICAL EXAMINATION

Separate mineralogical examinations on each ore sample, as well as on some laboratory jig concentrates, were done by Dr. D. C. Harris, of the Mineral Science Division (Mines Branch Investigation Reports IR 72-37 and IR 73-27). Only pertinent mineralogical results, related to the concentration of the minerals, will be recorded from these reports.

"Two distinct mineral assemblages (zones) are evident in the Cu-Ag ore, namely a sulphide and an arsenide assemblage. The sulphide zone consists of pyrite, chalcopyrite, sphalerite and galena, whereas the arsenide zone, which is more complex, consists mainly of niccolite, safflorite, skutterudite, rammelsbergite, arsenopyrite, native silver, native bismuth, mathildite, and bismuthinite".

The minerals identified in these ores and jig concentrates are given in Table 4.

TABLE 4

Minerals Identified

Chalcopyrite*	$CuFeS_2$
Pyrite*	FeS_2
Marcasite*	FeS_2
Sphalerite*	ZnS
Galena*	PbS
Tetrahedrite*	$(Cu,Ag,Fe\ Zn)_{12}(Sb,As)_4S_{13}$
Bismuthinite	Bi_2S_3
Native Ag	Ag
Native Bi	Bi
Pearceite	$(Ag,Cu)_{16}(As,Sb)_2S_{11}$
Acanthite	Ag_2S
Niccolite	NiAs with minor Sb
Gersdorffite	NiAsS with minor Sb
Rammelsbergite	$NiAs_2$
Safflorite	$(Co,Fe)As_2$
Skutterudite	$(Co,Ni,Fe)As_3$
Arsenopyrite	FeAsS
Cobaltite	CoAsS
Matildite	$AgBiS_2$
Pavonite	$AgBi_3S_5$
Unknown AgPbBi sulphosalt	$Ag_2Pb_2Bi_5S_{22}$
Magnetite	Fe_3O_4
Siderite	$FeCO_3$

*Minerals which occur in the sulphide zone.

Chalcopyrite

Chalcopyrite is the principal copper mineral in the ore. It occurs as large (several mm) irregular masses to finely disseminated fragments in gangue and as 1 to 5 micron blebs and irregular inclusions in sphalerite pyrite and marcasite (Figures 1 and 2).

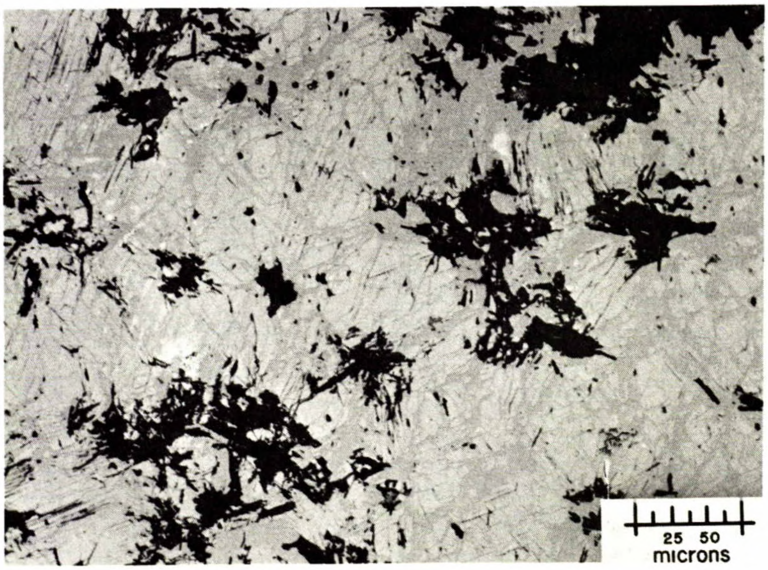

Figure 1. Photomicrograph of brecciated pyrite (light grey) replaced by chalcopyrite (medium grey). The dark areas are gangue.

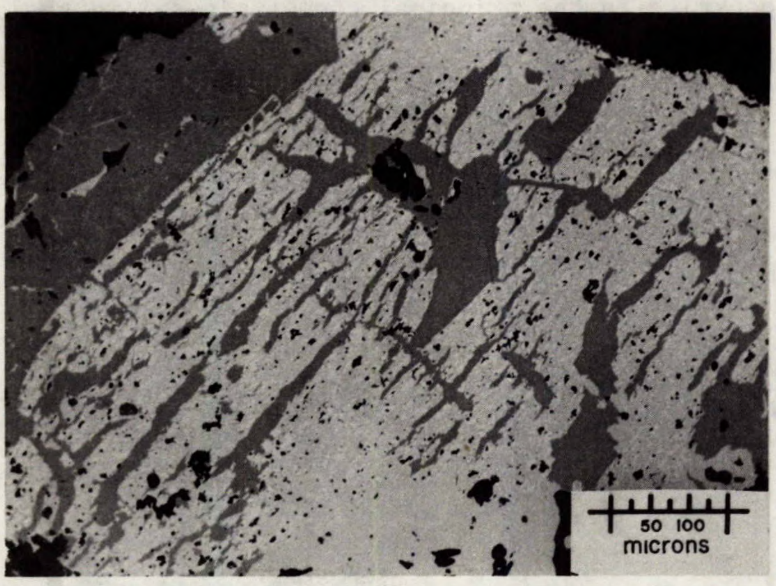

Figure 2. Photomicrograph showing remnants of brecciated pyrite (light grey) replaced by chalcopyrite (medium grey) with subsequent replacement by sphalerite (dark grey).

Silver-Bearing Minerals

Native silver, matildite, and acanthite are the principal Ag-bearing minerals with minor amounts of pearceite, tetrahedrite, and an unknown Ag-Pb-Bi sulpho-salt.

Native silver is the most important silver mineral in the ore. It occurs mainly as inclusions in the arsenides (Figure, 3, 4, 5, 13) and nicolite (Figure 6) although it was noted in gangue and as fracture fillings in pyrite. In grain size, native silver ranges from one-micron inclusions in arsenides to liberated fragments several hundred microns long.

Matildite appears to be the next important silver-bearing mineral. It occurs as inclusions, up to 200μ in diameter, in arsenides (Figure 7 and 8)

Acanthite appears to be rare in the ore. The mineral was observed only in the jig concentrate as liberated fragments, several hundred microns long.

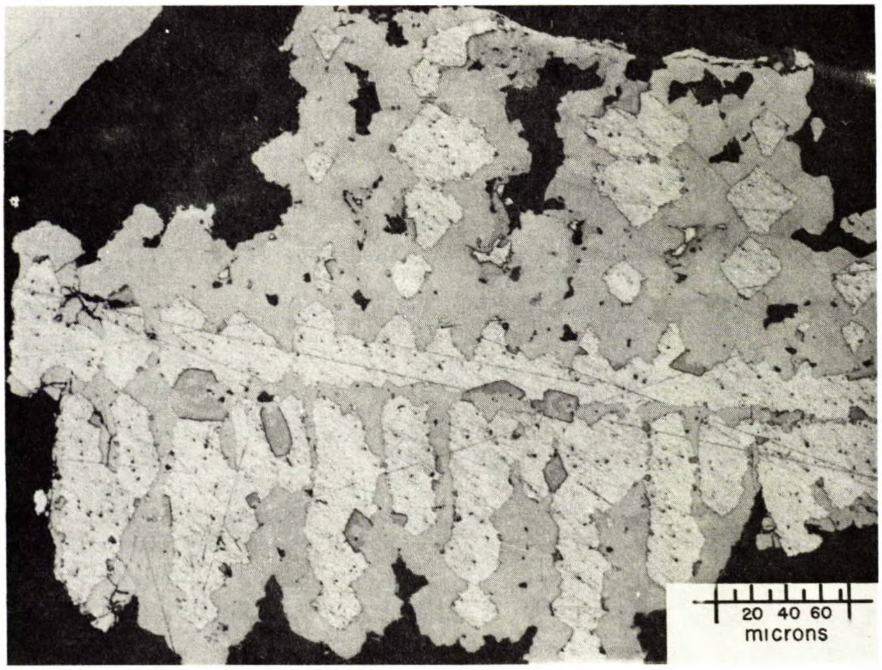

Figure 3. Photomicrograph of dendritic native silver (white) inclusions in arsenides (grey).

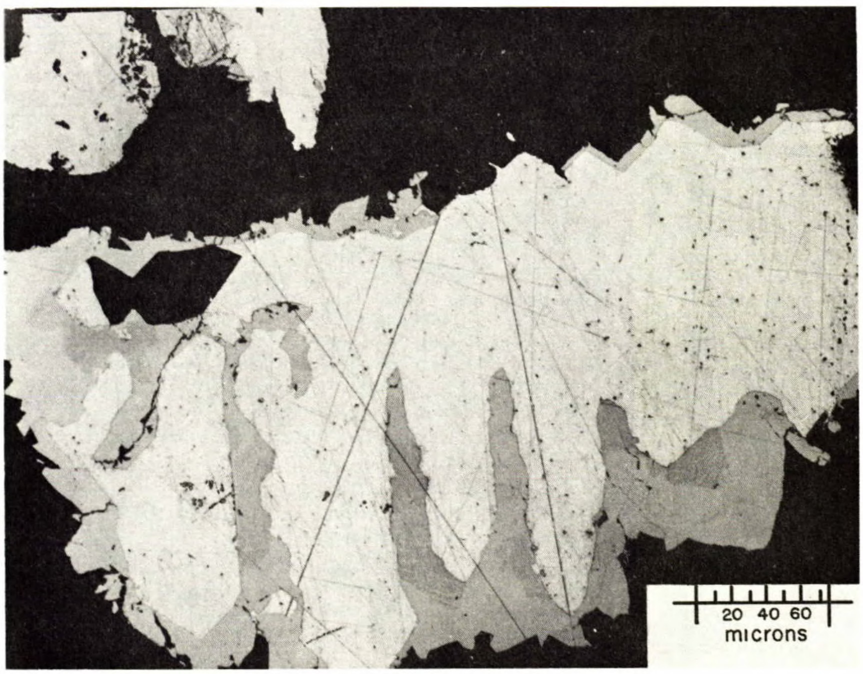

Figure 4. Photomicrograph of native silver (white) surrounded with arsenides (grey).

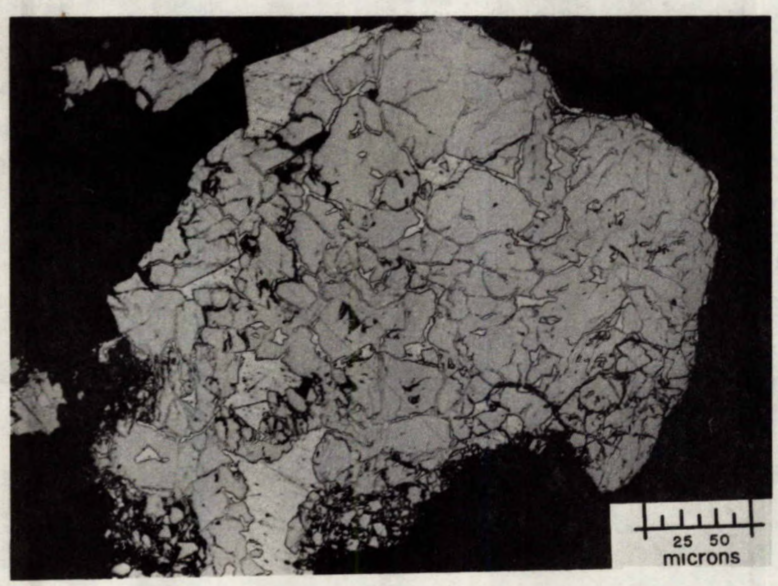

Figure 5. Photomicrograph showing native silver (white) occurring as fracture fillings in arsenides (grey).

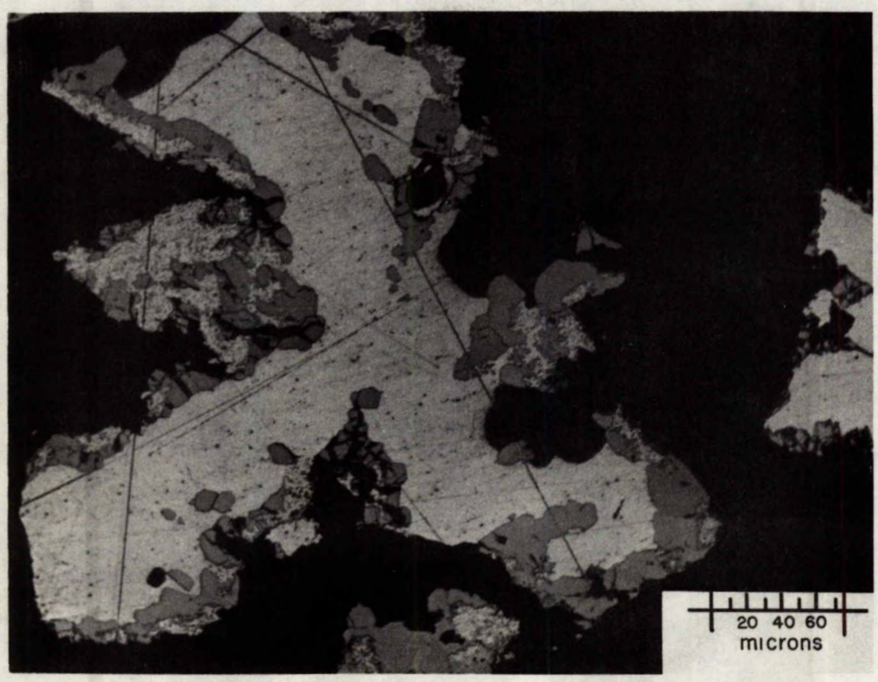

Figure 6. Photomicrograph of a native silver fragment containing inclusions of niccolite (grey).

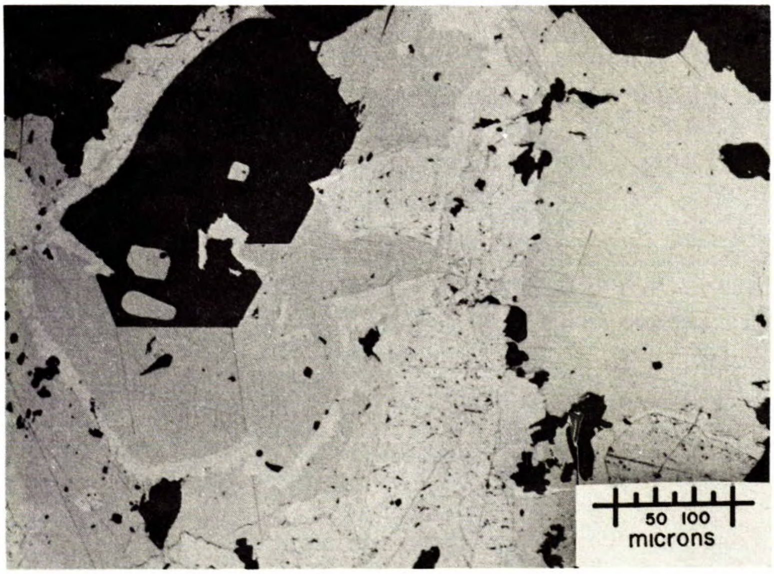

Figure 7. Photomicrograph of matildite (large smooth light grey areas) rimmed with arsenides (white) with native bismuth (white, pitted) occurring within the arsenide rims.

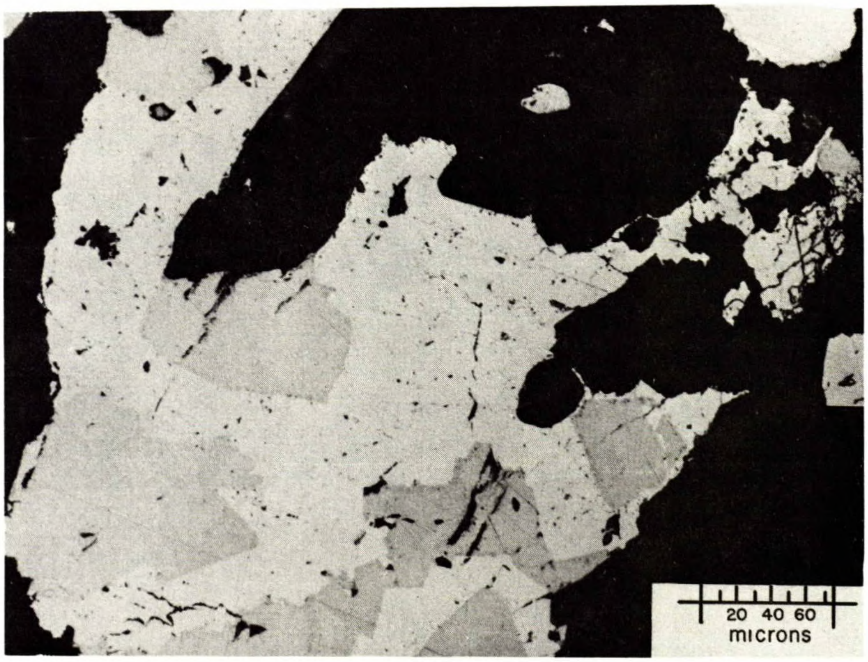

Figure 8. Photomicrograph of matildite (dark grey) enclosed in arsenides (grey).

Bismuth-Bearing Minerals

Native bismuth, bismuthinite and matildite are the principal Bi-bearing minerals with minor amounts of the unknown Ag-Pb-Bi sulpho-salt.

Native bismuth accounts for the major portion of the bismuth content in the ore. In the jig concentrate, it was frequently observed as liberated fragments (Figures 9 and 10) and as finely disseminated inclusions in arsenides (Figures 11, 12 and 13).

The occurrence of matildite has been discussed under "Silver-Bearing Minerals" whereas bismuthinite is rare in the ore and occurs as inclusions up to 200 microns in diameter, in arsenides.

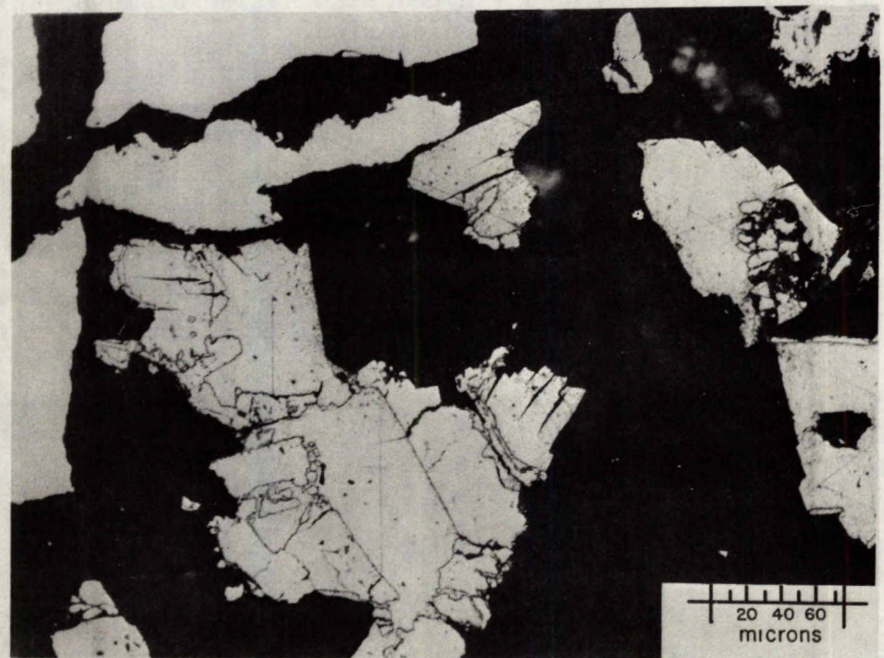

Figure 9. Photomicrograph of liberated native bismuth fragment (grey pitted surface). The white irregular grains in top left portion of photo are native silver.

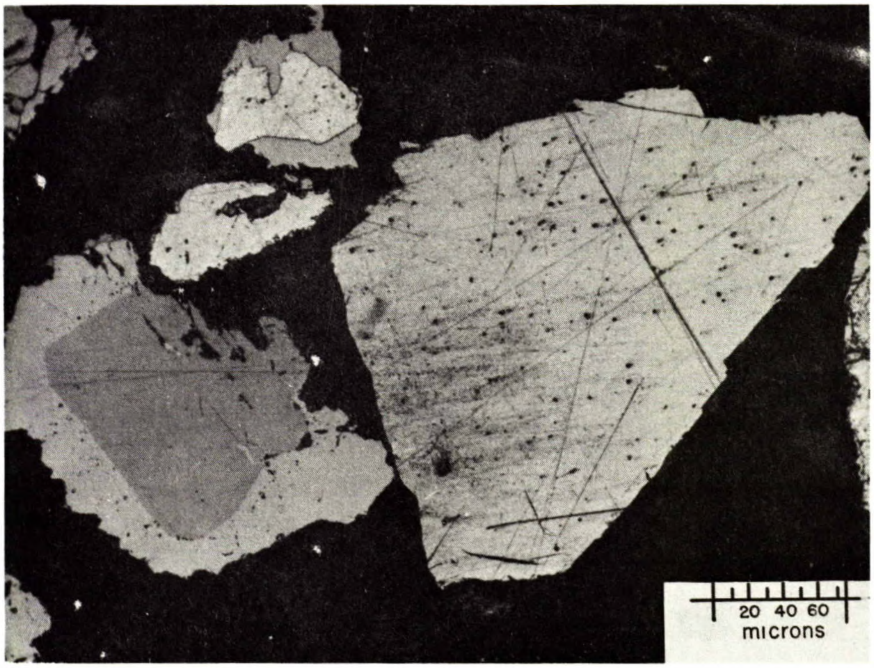

Figure 10. Photomicrograph showing a large liberated fragment of native bismuth, two liberated silver fragments (white), one enclosed in arsenides (top of photo), and a fragment of matildite (dark grey) enclosed in arsenide.

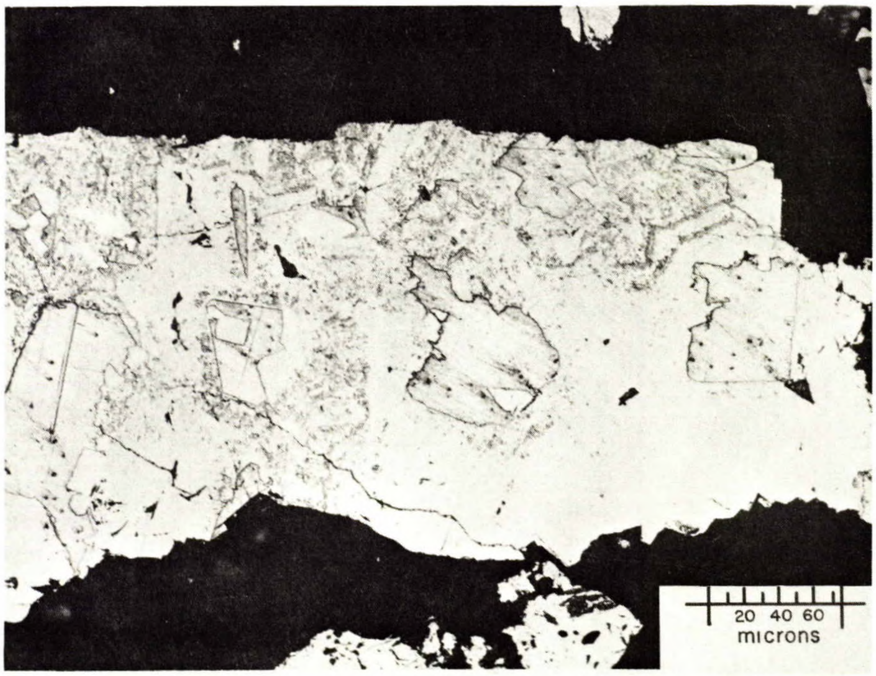

Figure 11. Photomicrograph of coarse to finely disseminated native bismuth inclusions in arsenides.

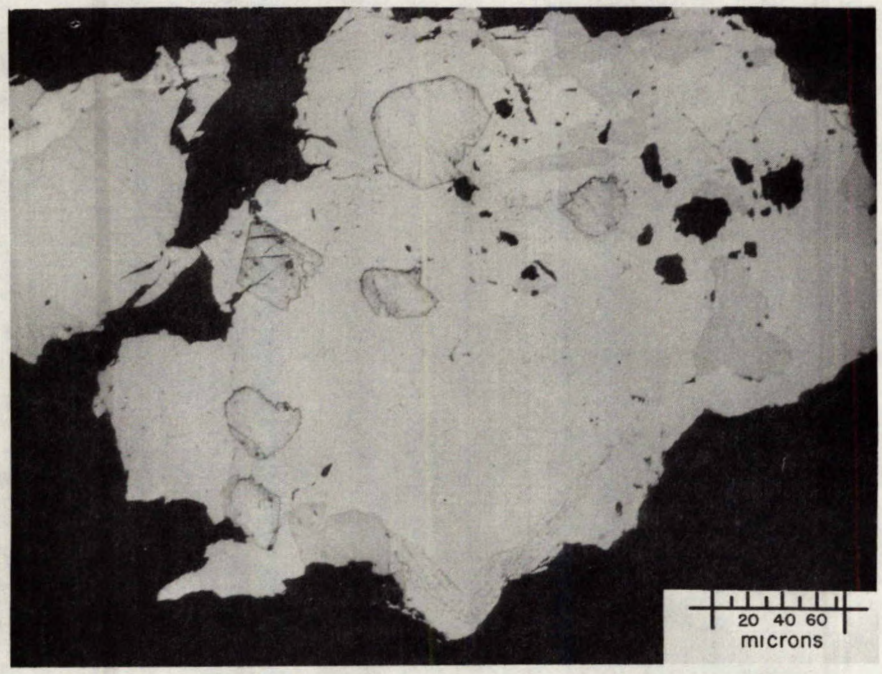

Figure 12. Photomicrograph showing inclusions of native bismuth (grey pitted surface) and matildite (medium grey) in an arsenide fragment.

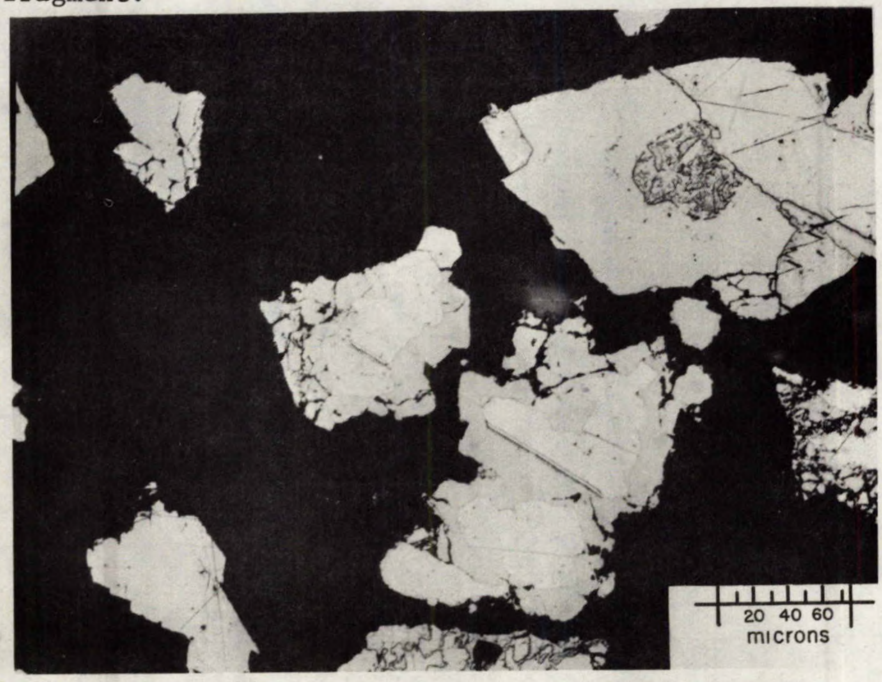

Figure 13. Photomicrograph of two native silver grains (white) enclosed in arsenides (centre of photo), native bismuth associated with an arsenide (top right), and a liberated native bmismuth fragment (lower left).

Galena

Galena is not too abundant in the ore and, like sphalerite, it is associated with chalcopyrite.

Tetrahedrite

Tetrahedrite is rare in the ore and occurs as minute inclusions in chalcopyrite.

Sphalerite

Sphalerite is the principal zinc mineral associated with chalcopyrite either as inclusions or irregular grains in gangue. The mineral varies in grain size between 1000 and a few microns but is generally minus 300 microns. The sphalerite contains numerous inclusions of chalcopyrite. (Figure 4).

Pyrite and Marcasite

Pyrite and marcasite are the major constituents of the sulphide zone. The pyrite is more abundant than marcasite and occurs as masses of several millimeters in size to finely brecciated fragments of micron size. The marcasite generally occurs as small stringers or clusters of grains in chalcopyrite or within large masses of pyrite. Some of the pyrite has been highly brecciated and subsequently replaced with chalcopyrite along the fracture planes, at times completely enclosing the pyrite (Figures 1 and 2).

OUTLINE OF INVESTIGATION

The first part of the investigation consisted of developing a laboratory procedure which would give results similar to those of Terra's concentrator.

Despite the low uranium content in the ore (0.016% U) the concentration of the uranium minerals was investigated.

Due to low lead, zinc, nickel, cobalt, arsenic and antimony contents in the ore (Table 2) no testwork was done on the recovery of these metals but the products from one test were assayed for lead and zinc.

Because Terra concentrator recovers about 30% of the bismuth in the ore (Table 1), a specific request was made by the Company to investigate the possibility of improving the bismuth recovery. As a result, an extensive investigation was done towards this objective.

DETAILS OF INVESTIGATION

Laboratory Procedure

After a few preliminary tests, a laboratory procedure, consisting of jigging and flotation, was developed. This procedure gave similar results to those of Terra concentrator.

The main steps and conditions of this procedure were as follows:

(1) A sample of the ore, crushed to minus 10 mesh was ground to minus 28 mesh in a laboratory rod mill. The size analysis of this primary grind is given in Table 5:

TABLE 5

Size Analysis of Jig Feed (Primary Grind)

Screen Size	% Weight
+ 35 mesh	19.2
+ 48 "	15.7
+ 65 "	12.3
+ 100 "	10.2
+ 150 "	6.8
+ 200 "	6.3
+ 325 "	5.9
- 325 "	23.6
Total	100.0

(2) The ground ore was fed to a 1M Denver laboratory jig and a jig concentrate and jig tailing were produced. The jigging conditions are recorded in Table 6.

TABLE 6

Jigging Conditions for 28-mesh un-sized ore

Jig:	1M Denver laboratory jig	
Supporting screen	20 mesh	
Speed	250 rpm	
Stroke	1/8 inch	
Ragging:		
Type	Steel balls	Ilmenite
Size	1/8 inch	-10 +14 mesh
Weight	100 grams	67 grams
Water:		
Top	350 cc/min	
Bottom	600 cc/min	
Feed Rate	22 grams/min	

(3) The jig tailing and the jig bed were ground to minus 65-mesh and used as flotation rougher feed. The screen analysis of this secondary grind is given in Table 7:

TABLE 7

Size Analysis of Flotation Feed (Secondary Grind)

Screen Size	% Weight
+ 65 mesh	Nil
+ 100 "	13.3
+ 150 "	15.4
+ 200 "	14.5
+ 325 "	13.5
- 325 "	43.3
Total	100.0

(4) A rougher and two scavenger concentrates were floated at a pH of 11.4 and 11.3 respectively using lime as an alkalinity regulator. Methyl isobutyl-carbinol (MIBC) frother was used in all circuits. Isopropyl xanthate (0.32 lb/ton of ore) was added to the rougher conditioner and potassium amyl xanthate (0.36 lb/ton of ore) was added to the two scavenger conditioners. Conditioning time was about 8 minutes and the flotation time was 4 minutes for the rougher float and 3 minutes for each scavenger float.

(5) The rougher concentrate and the two scavenger concentrates were combined and cleaned with small amounts of lime, MIBC frother and collector. The pH of the cleaner float was 11.9 and flotation time was about 3 minutes.

(6) The cleaner concentrate was re-cleaned at about the same alkalinity as in (5) with the addition of 0.008 lb of NaCN per ton of ore to produce a final concentrate. The flotation time was about 3 minutes. No other reagent was required in this final cleaning stage.

The results of this procedure are recorded in Table 8.

TABLE 8

Laboratory Results from Jigging and Flotation

Product	% Wt	Assays						Distribution					
		Ag oz/ton	Cu %	Bi %	Pb %	Zn %	U* %	Ag %	Cu %	Bi %	Pb %	Zn %	U %
Jigging:													
Jig conc	1.5	2656.0	3.90	3.30	1.5	0.22	0.24	66.1	8.1	52.0	21.3	3.3	32.2
Jig tail	98.5	20.0	0.70	0.05	0.09	0.15	0.008	33.9	91.9	48.0	78.7	96.7	67.8
Flotation:													
Re-cl conc	2.1	553.6	20.27	0.72	1.76	1.46	0.046	22.1	58.2	15.0	34.5	21.9	8.7
Re-cl tail	1.8	183.22	7.38	0.32	0.62	0.96	0.034	5.7	18.0	6.0	9.7	11.3	5.2
Cl tail	1.7	84.35	3.70	0.48	0.67	0.69	0.034	2.4	8.2	8.0	9.7	8.0	5.2
Scavn tail	92.9	2.35	0.06	0.02	0.03	0.09	0.006	3.7	7.5	19.0	24.8	55.5	48.7
Feed(calcd)	100.00	58.22	0.75	0.10	0.11	0.15	0.012	100.0	100.0	100.0	100.0	100.0	100.0

*To obtain U_3O_8 assay, multiply U assay by 1.179.

(i) Silver and Copper Concentration

If it is assumed that by recycling the cleaner and re-cleaner tailings about half of the values from these tailings would be recovered, the silver and copper results from Table 8 would be similar to those of the plant operation (Table 1).

(ii) Uranium Concentration

The results from Table 8 showed that this ore sample contained about 1/4 pound uranium per ton of ore. The jig concentrate obtained has an acceptable uranium grade - 4.80 lb U or 5.65 lb U_3O_8 per ton of the concentrate - but the uranium recovery was only 32.2%, or about 1/8 of a pound per ton of ore. At the present price of about $8.00 per pound of uranium, it is doubtful that leaching of the jig concentrate for uranium recovery would be profitable.

The other products from the test were too low in uranium to be of economic interest.

(iii) Lead and Zinc Concentration

The products from the test were assayed for lead and zinc. As can be seen from the results in Table 8, no significant concentration of these metals was obtained.

(iv) Bismuth Concentration

The results from Table 8 showed that the laboratory jigging of the un-sized ore, ground to minus 28-mesh and fed at a normal feed rate under closely controlled laboratory conditions, recovered 52% of the bismuth, while the Terra jigging operation recovers between 21.6% and 37.8% of the bismuth in the ore, i.e.,an average bismuth recovery of about 30 per cent. (Table 1).

Because the bismuth minerals are brittle and are easily ground to fine sizes, and as jigging is not very efficient in recovering the fines from the un-sized feed, it can be expected that some of the bismuth-bearing, silver-bearing and other fines, would remain in the jig tailing. This is particularly true if the jig is operated at a maximum capacity which is usually the case in most operating plants.

To observe bismuth distribution in the laboratory jig tailings obtained from the jig feed ground to minus 28-mesh and to minus 48-mesh, the jig tailings of these two grinds were sized, each size fraction assayed separately and bismuth distribution calculated. The results are recorded in Table 9.

TABLE 9

Size and Bismuth Distribution in Jig Tailings from Various Grinds

Grind	Product, Mesh Sizes	% Weight	% Bismuth Assay	% Bismuth Distn
	Jig tail, Test T-7			
	+ 48 mesh	33.1	0.03	18.0
	+ 65	13.5	0.03	8.0
	+ 100	11.9	0.04	8.0
	+ 150	8.6	0.04	6.0
	+ 200	4.8	0.05	4.0
	+ 325	6.5	0.07	10.0
	- 325	21.6	0.11	46.0
-28 mesh	Total Jig tail (calcd)	100.0	0.05	100.0
	Jig tail, Test T-8			
	+ 65 mesh	13.9	0.03	8.0
	+ 100	21.7	0.03	12.4
	+ 150	15.6	0.03	9.3
	+ 200	8.2	0.04	6.3
	+ 325	9.6	0.06	11.0
	- 325	31.0	0.09	53.0
-48 mesh	Total Jig tail (calcd)	100.0	0.05	100.0

As expected, most of the bismuth in the jig tailings was in the minus 325-mesh fraction. This was particularly so with a finer (minus 48-mesh) grind, confirming that jigging was not efficient in recovering fines from the un-sized feed.

During flotation of the jig tailing, most of the bismuth fines are concentrated in the flotation concentrate. As the company presently does not get paid for the bismuth contained in the flotation concentrate, this bismuth is therefore lost. As a result it was decided to try to recover the bismuth-bearing fines from the jig tailings prior to flotation.

As the bismuth-bearing and silver-bearing material has a high specific gravity (6 to 8), concentration of fines from jig tailing was done by a gravity method applying slime-deck tabling. As chalcopyrite has a specific gravity of 4.1 to 4.3, the fine chalcopyrite present in the jig tailing would respond less to the gravity concentration and thus only a small amount of copper will be lost in the table concentrate.

To observe the effect of various fineness of grind on the bismuth recovery from the ore, three ore samples were ground to minus 28 mesh, minus 48 mesh and minus 65 mesh. Each ground sample was jigged under closely controlled laboratory conditions at a normal feed rate. The jig tailings were screened on a 325 mesh-screen. The minus 325 mesh fractions were tabled on a Deister slime deck. This procedure produced jig concentrates and table concentrates as well as plus 325-mesh fraction of the jig tailing and a minus 325-mesh table tailings. The latter two were combined to form the flotation feed.

Details of the laboratory procedure developed are presented in Figure 14, and jigging and tabling results in Table 10.

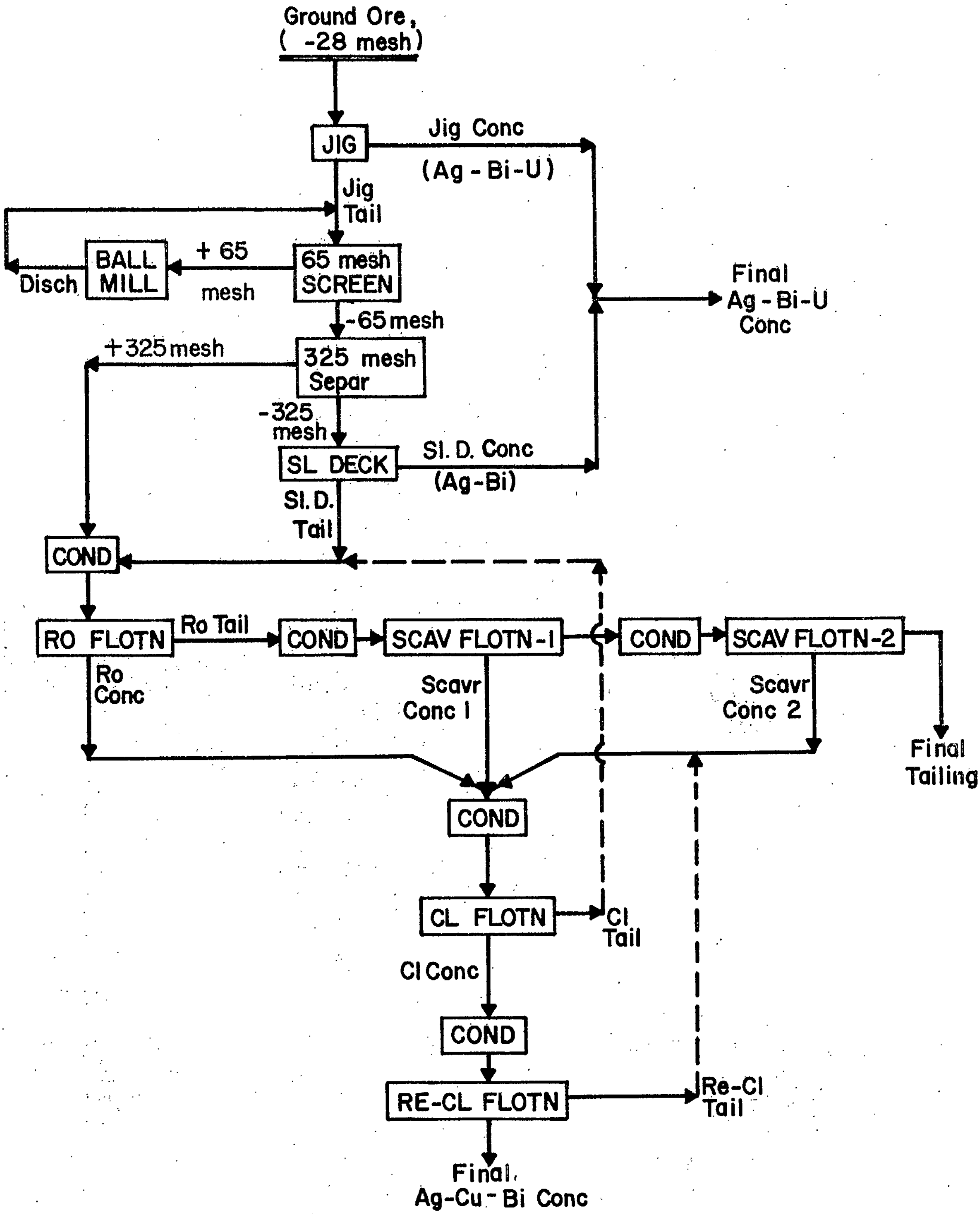

Figure 14 - LABORATORY PROCEDURE

TABLE 10

Results of Jigging the Ground Ore and Tabling Fines from Jig Tailings

Grind Mesh	Product	% Weight	Assay oz/t Ag	Assay % Cu	Assay % Bi	Distribution % Ag	Distribution % Cu	Distribution % Bi
	Test T-2							
	Jig conc, -28 mesh	1.5	2656.0	3.90	3.30	66.1	8.1	52.0
	Table conc, -325 mesh	0.1	1516.0	4.43	5.49	2.1	0.4	3.0
	Comb Ag-Bi conc	1.6	2468.0	3.93	3.45	68.2	8.5	55.0
	Table tail, -325 mesh and Jig tail, +325 mesh (comb)	98.4	18.83	0.69	0.05	31.8	91.5	45.0
-28	Feed (calcd)	100.0	58.22	0.75	0.10	100.0	100.0	100.0
	Test T-8							
	Jig conc, -48 mesh	1.1	2917.0	3.15	4.82	62.8	3.9	50.4
	Table conc,-325 mesh	0.2	423.0	8.73	2.20	1.7	1.9	4.2
	Comb Ag-Bi conc	1.3	2530.0	4.00	4.41	64.5	5.8	54.6
	Table tail, -325 mesh	26.9	15.3	1.03	0.07	8.1	31.1	17.9
	Jig tail, +325 mesh	71.8	19.5	0.78	0.04	27.4	63.1	27.5
-48	Feed (calcd)	100.0	50.97	0.89	0.105	100.0	100.0	100.0
	Test T-6							
	Jig conc, -65 mesh	2.3	1644.3	5.56	2.00	66.7	14.7	44.9
	Table conc, -325 mesh	0.1	1149.3	2.50	5.82	2.0	0.3	5.6
	Comb Ag-Bi conc	2.4	1625.0	5.36	2.16	68.7	15.0	50.5
	Table tail, -325 mesh	35.4	20.50	1.05	0.09	12.8	43.5	31.2
	Jig tail, +325 mesh	62.2	16.71	0.57	0.03	18.5	41.5	18.3
-65	Feed (calcd)	100.0	56.71	0.86	0.103	100.0	100.0	100.0

These results showed that an additional silver-bismuth concentrate, similar to the jig concentrate, was obtained from the jig tailing by tabling the fines (minus 325-mesh fraction) of this tailing.

The table concentrate produced can be combined with the jig concentrate to form a final silver-bismuth concentrate and thus increase the overall bismuth recovery from the ore with little or no increase in the copper loss.

The results in Table 10 also showed that jigging the minus 28-mesh and minus 48-mesh ore was slightly better than jigging the minus 65-mesh ore, the latter giving a bismuth recovery slightly lower but the copper loss considerably higher than in the other two coarser grinds.

As mentioned earlier, the jigging results in Table 10 were obtained under closely controlled laboratory conditions and at a normal feed rate. To observe the effect of an increased jig feed rate a jigging test was conducted in which ore was ground to minus 28-mesh and the jig feed rate increased by one third of that in Test T-2, Table 10. The results of this jig test are given in Table 11.

TABLE 11

Jigging Results From High Feed Rate

Grind, Mesh	Product	% Weight	Assays			Distribution		
			oz/t Ag	% Cu	% Bi	% Ag	% Cu	% Bi
	Test T-9							
	Jig conc	0.8	3342.0	4.00	4.57	55.6	3.1	35.5
	Jig tail	99.2	31.0	0.82	0.07	44.4	96.9	64.5
-28	Feed (calcd)	100.0	58.13	1.04	0.103	100.0	100.0	100.0

Comparison of these results (high feed rate) with the results of Test T-2, Table 10 (normal feed rate) shows that, as expected, the high jig feed rate resulted in lower silver and bismuth recoveries in the jig concentrate but also a lower copper loss. The silver and bismuth recoveries in the jig concentrate, as well as the copper loss of Test T-9 (Table 11) are similar to those of the Terra's concentrator.

(b) Jigging of Sized Ore

As an alternative method to jigging the un-sized ore followed by tabling of the fines from the jig tailing, a method consisting of separating the 28-mesh ore into plus and minus 100-mesh fractions and jigging each fraction separately, was investigated. The objective of this procedure was to find out if jigging of the fines from ground ore would recover the fine bismuth-bearing material produced during the grinding operation and thus eliminate the slime-deck tailing of the fines from jig tailing.

The jigging conditions are recorded in Table 12 and the results in Table 13.

TABLE 12

Jigging Conditions for Sized Ore

Operation	Conditions	
	Plus 100-mesh fraction	Minus 100-mesh fraction
Feed rate:	25 g/min.	10 g/min.
Jig:		
Type	1D Denver lab jig	1D Denver lab jig
Supporting screen	20 mesh	48 mesh
Speed	250 rpm	250 rpm
Stroke	1/8 inch	1/8 inch
Ragging:		
Type	Nickel balls	Ilmenite
Size	-10 mesh	-20 +28 mesh
Weight	150 grams	77 grams
Water:		
Top	300 cc/min.	250 cc/min.
Bottom	500 cc/min.	400 cc/min.

TABLE 13

Results from Jigging Sized Ore

Grind, Mesh	Product	% Weight	Assay			Distribution		
			oz/t	%	%	%	%	%
			Ag	Cu	Bi	Ag	Cu	Bi
	Test T-10							
	Jig conc, + 100 mesh	1.1	1,780	3.68	3.28	43.8	5.4	35.5
	Jig conc, - 100 mesh	0.2	1,814	2.63	8.00	6.3	0.6	12.5
	Comb jig conc	1.3	1,786	3.54	3.84	50.1	6.0	48.0
	Jig tail, + 100 mesh	70.0	23.3	0.58	0.04	35.3	53.3	27.0
	Jig tail, - 100 mesh	28.7	23.0	1.10	0.09	14.6	40.7	25.0
	Comb jig tail	98.7	23.4	0.73	0.055	49.9	94.0	52.0
-28 mesh	Feed (calcd)	100.0	46.22	0.78	0.104	100.0	100.0	100.0

Comparison of these results with those of jigging the 28 mesh un-sized ore (Table 10) shows that jigging of sized ore did not improve bismuth recovery.

(c) Bismuth Recovery from Terra's Jig Tailing

To verify the laboratory results and to find out what portion of the jig tailing from Terra's concentrator should be tabled, if this procedure is applied in Terra's operation, about 100-lb sample of jig tailing from Terra's concentrator was received, sized and each size fraction assayed separately. The size and metal distribution are recorded in Table 14.

TABLE 14

Size and Metal Distribution of Terra Jig Tailing

Terra jig tailing, mesh	% Weight	Assays			Distribution		
		oz/t Ag	% Cu	% Bi	% Ag	% Cu	% Bi
+ 48	1.0	6.75	0.07	0.006	0.4	0.5	1.9
+ 65	3.8	6.75	0.04	0.007	1.4	1.2	8.7
+ 100	11.9	7.50	0.05	0.013	4.9	4.8	4.8
+ 150	15.1	9.50	0.10	0.008	7.8	12.1	3.8
+ 200	11.1	17.50	0.08	0.020	10.7	7.2	7.0
+ 270	6.1	23.20	0.10	0.020	7.8	4.9	3.9
+ 325	5.5	35.50	0.16	0.015	11.0	7.3	2.9
+ 325 (cum)	54.5	14.68	0.086	0.019	44.0	38.0	33.0
- 325	45.5	24.20	0.17	0.046	56.0	62.0	67.0
Jig tailing	100.0	18.12	0.12	0.031	100.0	100.0	100.0

These results showed that:

(i) copper and bismuth contents in the Terra jig tailing (0.12% Cu and 0.031% Bi) were considerably lower than those in our laboratory jig tailing (0.8% Cu and 0.1% Bi);

(ii) per cent weight of the minus 325-mesh fraction in the sample of the Terra jig tailing was 45.5% as compared to 14.2% given in Mr. Ed Schmidt's letter of February 23, 1973;

(iii) 67% of the bismuth in the Terra jig tailing was in the minus 325-mesh fraction (fines) assaying 0.046% Bi; which is less than one-half of the bismuth in the minus 325-mesh fraction of our laboratory jig tailing.

The results obtained from tabling the minus 325-mesh fraction of the Terra jig tailing are given in Table 15.

TABLE 15

Results from Tabling Fines of Terra Jig Tailing

Product	% Weight	Assay			Distribution		
		oz/t Ag	% Cu	% Bi	% Ag	% Cu	% Bi
Table conc, -325 mesh	0.1	2,691	1.47	4.56	13.1	1.2	17.2
Table tail, -325 mesh	44.5	17.08	0.18	0.032	36.9	66.4	53.0
Terra jig tail, -325 mesh	44.6	23.10	0.19	0.042	50.0	67.6	70.2
Terra jig tail, +325 mesh	55.4	18.46	0.07	0.014	50.0	32.4	29.8
Total Terra jig tail	100.0	20.49	0.12	0.027	100.0	100.0	100.0

These results show that, despite the low bismuth content in the minus 325-mesh portion of the Terra jig tailing, the slime-deck tabling of these fines produced a silver-bismuth concentrate of suitable bismuth grade (4.56% Bi), containing 17.2% of bismuth in the jig tailing as well as a suitable silver grade (2,691 oz/ton). This table concentrate, therefore, can be combined with the jig concentrate and thus improve the over-all bismuth recovery from the ore.

As the metallurgical results from Terra concentrator for the day when the sample of the jig tailing was taken are not known, the over-all improvement in the bismuth recovery which might be expected by the above procedure cannot be calculated. If it is assumed, however, that an average bismuth recovery in Terra concentrator is 30% (Table 1), a 17.2% bismuth recovery from the Terra's jig tailing represents an additional bismuth recovery of about 12%. The bismuth recovery from tabling the jig tailing will vary depending on the bismuth content in the tailing.

CONCLUSIONS

The laboratory procedure developed in this investigation and illustration by Figure 14, recovered about 55% of the bismuth in the ore while maintaining normal silver and copper recoveries.

Although uranium content in the ore was low (0.016% U) a jig concentrate with marketable uranium grade (4.8 lb U per ton of conc) was produced but the uranium recovery was low (32.2%). At the present uranium prices the uranium recovery from this ore would not be economically feasible.

The lead, zinc, nickel and cobalt contents in the ore were too low for economic consideration. The improvement in bismuth recovery was confirmed by applying the laboratory procedure on a sample of jig tailing from Terra concentrator. This resulted in about 17% of the bismuth from this tailing being recovered in a marketable bismuth-silver concentrate.

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