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IMAGE ANALYSIS STUDY OF THE MINERALS IN THE SECONDARY ZINC CIRCUIT OF THE BMS CONCENTRATOR

WILLIAM PETRUK AND MICHAEL R. HUGHSON

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IMAGE ANALYSIS STUDY OF THE MINERALS IN THE SECONDARY ZINC CIRCUIT OF THE BMS CONCENTRATOR

by

William Petruk* and Michael R. Hughson**

ABSTRACT

Samples collected in September, 1979, from the secondary zinc circuit of the BMS concentrator were studied to determine the behaviour of the sphalerite, galena and chalcopyrite. The liberations and size distributions of the minerals were determined and the data were processed by the MATBAL 2 program to adjust the analysed values so that there would be a balance between amounts fed to and discharged from the flotation cells. A comparison of the results with similar data for samples collected in 1977 shows that sphalerite recovery was better from some cells and poorer from other cells. This suggests that monitoring the zinc content of the tailings from the cells would indicate when corrective steps need to be taken to maintain a constant recovery. It was also observed that large, free chalcopyrite grains were lost to the mill tailings as in 1977.

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ÉTUDE PAR ANALYSE D'IMAGES DES MINÉRAUX DU CIRCUIT SECONDAIRE DE RÉCUPÉRATION DU ZINC DU CONCENTRATION BMS

par

William Petruk* et Michael R. Hughson**

RÉSUMÉ

On a étudié des échantillons recueillis en septembre 1979 dans le circuit secondaire de récupération du zinc du concentrateur BMS, pour déterminer le comportement de la sphalérite, de la galène et de la chalcopyrite. On a déterminé la libération et la granulométrie des minéraux, et traité les données à l'aide du programme MATBAL 2 pour ajuster les valeurs analysées, de façon à maintenir un équilibre entre les quantités apportées aux chambres de flottation et les quantités provenant d'elles. En comparant ces résultats à des données similaires obtenues avec des échantillons recueillis en 1977, on a constaté que dans certaines cellules de flottation, on obtenait de plus grandes quantités de sphalérite que dans d'autres. Il est donc possible qu'en surveillant le taux de zinc dans les résidus provenant des cellules de flottation, on puisse déterminer quand effectuer un rajustement pour obtenir un taux constant de récupération de la sphalérite. En 1977, on a aussi constaté que de gros grains libres de chalcopyrite étaient perdus avec les résidus de traitement.

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INTRODUCTION

The behaviour of minerals in the concentrator of Brunswick Mining and Smelting Corporation Limited (BMS) was studied by Petruk and Schnarr (1981) by analyzing samples that were collected in September 1977. Subsequently the secondary zinc circuit of the concentrator was slightly modified and resampled in September 1979 by R. Grant, Project Development Metallurgist, BMS. The 1979 samples were studied in the same way as the 1977 samples but the analyses were extended. In the initial study, material balances were calculated from the chemical analysis data, using MATBAL 2 (Laguitton 1980), and the liberations and size distributions of the sphalerite in the feed, concentrate and tailings for each bank of flotation cells were determined with the Quantimet 720 image analyser. In the current study the procedure was repeated, but liberations and size distributions were also determined for the galena and chalcopyrite and the materials balance procedure was applied to the image analysis data as well as to the chemical analyses.

FLOWSHEET, ASSAYS AND MATERIALS BALANCE

The flowsheet of the secondary zinc circuit is shown in Fig. 1. The weight per cent (wt %) of material and assays and distributions of zinc, lead and copper in the zinc concentrate and tailings products are given in Table 1. Details for assays and distributions in the cells are given in Table 2. A materials balance analysis was performed with the MATBAL 2 program using the assay values (raw data) to determine the weight per cent of material going through each point in the circuit (Table 2). To obtain a materials balance, the MATBAL 2 program adjusts the chemical analyses to best fit by applying a weighting to each analysed value because there is always some analytical and sampling error. The balanced values meet the condition that the amount of material, element or mineral, discharged from a bank of flotation cells as concentrate plus tailings is equal to the amount fed to the cells. The balancing program is recycled by the computer until the change in values between successive cycles is less than 0.01. The adjusted chemical analyses, balanced weight per cent of material, and recovery of each element at each sample point are listed in Table 2. Comparable values for the 1977 study are included in the table.

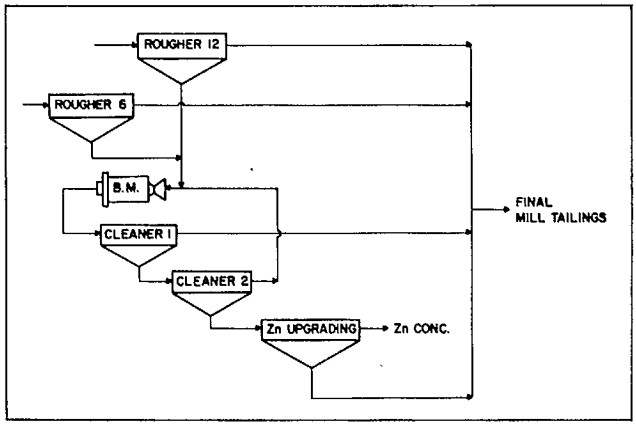

Fig. 1 — *Flowsheet of secondary zinc circuit.*

All the zinc, lead and copper in each sample were assumed to be in sphalerite, galena and chalcopyrite respectively. This is because no other zinc and lead-bearing minerals were found and only a trace amount of copper-bearing tetrahedrite was present. The quantity of tetrahedrite was so small that it could not account for more than 1% of the copper and was below the limit of analysis.

MINERAL LIBERATION AND RECOVERIES

The proportions of sphalerite, galena and chalcopyrite that were present as free and unliberated grains were determined with a Quantimet 720 image analyser by measuring the surface areas of mineral grains observed in about 50 fields of the polished section using a 16X objective at a magnification of 1.6. At this magnification, the minimum size of grain detected was 1.5 μm in diameter and it had a surface area of about 2.25 μm^2. Each field analysed was 370 μm by 290 μm and had a surface area of about 107,300 μm^2. Therefore, the total surface in 50 fields was 5,365,000 μm^2 or about 5 mm^2. About 35% of the surface area analysed consisted of mineral grains and the remainder was mounting medium. Each field analysed

Table 1 - Assays and distributions of elements in zinc concentrate and tailings

Product	wt %	Zinc		Lead		Copper	
		Assay	Distribution	Assay	Distribution	Assay	Distribution
1979							
Rougher 12 tailing	59.22	1.53	34.09	0.67	46.15	0.06	36.66
Rougher 6 tailing	31.42	1.44	17.00	0.79	28.81	0.09	27.52
Cleaner 1 tailing	5.35	3.62	7.28	1.60	9.92	0.17	9.28
Upgrading tailing	3.15	20.55	24.27	2.92	10.65	0.76	23.94
Zinc concentrate	0.86	53.53	17.36	4.46	4.47	0.30	2.60
Feed	100.00	2.68	100.00	0.86	100.00	0.10	100.00
1977							
Rougher 12 tailing	58.73	0.85	27.43	0.98	47.51	0.13	49.04
Rougher 6 tailing	31.69	0.92	15.94	1.10	28.96	0.16	32.87
Cleaner 1 tailing	6.36	4.54	15.92	2.83	14.93	0.21	8.64
Upgrading tailing	1.99	12.28	13.31	2.25	3.62	0.69	3.98
Zinc concentrate	1.23	40.49	27.40	5.00	4.98	0.31	5.47
Feed	100.00	1.82	100.00	1.21	100.00	0.16	100.00

contained about 1000 to 1500 grains, 1.5 to 100 μm in diameter. This is equivalent to analysing about 6 to 10 grains of chalcopyrite per field in a sample containing 0.35 wt % Cu, 6 to 10 grains of sphalerite per field in a sample containing 0.6 wt % Zn, and 4 to 6 grains of galena per field in a sample containing 0.9 wt % Pb. Proportionally more or fewer grains were analysed when the assays were respectively higher or lower. Since the zinc assays varied from about 1.5 to 53 wt %, about 1000 to 35 000 sphalerite grains were analysed in the respective samples. Similarly 0 to 1900 galena grains and about 40 to 500 chalcopyrite grains in the respective samples were analysed.

The analysed values were corrected to account for the slicing effect that causes unliberated grains to appear free in polished sections (Petruk, 1978). The correction was: the corrected per cent of unliberated grains equals the analysed per cent of unliberated grains times 1.15. The corrected per cent of free grains is, therefore, 100% minus corrected per cent unliberated. The corrected percentages of free sphalerite, galena and chalcopyrite (as observed) are listed in Table 3. The corrected percentages of free mineral grains were adjusted to a materials balance by using the MATBAL 2 so that the amount of free mineral grains entering each cell was equal to the amount discharged. This was done by converting the corrected percentage of free sphalerite, galena and chalcopyrite to a weight per cent of zinc, lead and copper respectively due to free minerals in each sample and performing a materials balance analysis using the MATBAL 2 program. In this balancing step the weight per cent of material at each sample point was fixed to the values in the top line of Table 2, thus the weight per cent of each element due to free mineral grains was forced to adjust. Most of the adjustments were less than 15% of the amount analysed, although one was 36%. This suggests that the error of analysis for mineral liberations is ±15% of the amount analysed. The weight per cent of free sphalerite observed in the samples for the 1977 study is included for comparison. The correlation is poor for most samples, although the values are in the same order of magnitude for the

Table 2 - Analysed and balanced assays and recoveries of zinc, lead and copper

	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading		
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails (Zn conc)
t % material 1979	64.61	5.39	59.23	35.39	3.97	31.42	10.98	10.98	10.98	5.63	5.35	5.63	4.01	1.62	4.01	3.15	0.86
t % material 1977	64.54	5.81	58.73	35.46	3.77	31.69	12.32	12.32	12.32	5.96	6.36	5.96	3.22	2.74	3.22	1.99	1.23
n assay raw data 1979	1.68	6.98	1.86	3.66	23.82	1.48	13.00	19.26	19.26	23.38	3.64	23.38	28.94	10.40	28.94	20.04	52.67
n assay balanced 1979	1.96	6.70	1.53	3.94	23.71	1.44	13.41	13.41	13.41	22.71	3.63	22.71	27.66	10.48	27.66	20.55	53.53
n assay balanced 1977	1.60	9.17	0.85	2.22	13.16	0.92	9.58	9.58	9.58	14.98	4.54	14.98	23.04	5.54	23.04	12.28	40.49
n recovery, 1979	47.63	13.55	34.09	52.36	35.36	17.00	55.30	55.30	55.30	48.02	7.28	48.02	41.63	6.39	41.63	24.27	17.36
n recovery, 1977	56.63	29.20	27.43	43.37	27.43	15.94	64.59	64.59	64.59	48.67	15.92	48.67	40.71	7.96	40.71	13.31	27.40
b assay, raw data 1979	0.92	2.06	0.82	1.06	2.36	0.76	2.38	2.44	2.44	3.04	1.64	3.04	3.02	3.08	3.02	3.34	4.68
b assay, balanced 1979	0.80	2.18	0.67	0.98	2.47	0.79	2.40	2.40	2.40	3.17	1.60	3.17	3.25	2.97	3.25	2.92	4.46
b assay, balanced 1977	1.10	2.36	0.98	1.41	3.95	1.10	3.10	3.10	3.10	3.40	2.83	3.40	3.30	3.51	3.30	2.25	5.00
b recovery, 1979	59.79	13.64	46.15	40.21	11.40	28.81	30.63	30.63	30.63	20.71	9.92	20.71	15.12	5.59	15.12	10.65	4.47
b recovery, 1977	58.82	11.31	47.51	41.18	12.22	28.96	31.67	31.67	31.67	16.74	14.93	16.74	8.60	8.14	8.60	3.62	4.98
u assay, raw data 1979	0.08	0.30	0.06	0.19	0.92	0.08	0.30	0.38	0.30	0.58	0.16	0.58	0.52	0.20	0.52	0.76	0.30
u assay, balanced 1979	0.08	0.24	0.06	0.14	0.58	0.09	0.35	0.35	0.35	0.53	0.17	0.53	0.66	0.20	0.66	0.76	0.30
u assay, balanced 1977	0.13	0.20	0.13	0.19	0.44	0.16	0.30	0.30	0.30	0.40	0.21	0.40	0.45	0.34	0.45	0.69	0.31
u recovery, 1979	49.38	12.72	36.66	50.62	23.10	27.52	39.06	39.06	39.06	29.78	9.28	29.78	26.54	3.24	26.54	23.94	2.60
u recovery, 1977	56.42	7.38	49.04	43.58	10.71	32.87	24.16	24.16	24.16	15.52	8.64	15.52	9.45	6.07	9.45	3.98	5.47

concentrates from the rougher 6, cleaner 1, and cleaner 2 and for the upgrading tails which is the zinc concentrate (Table 3).

The recoveries of the free and unliberated sphalerite, galena and chalcopyrite at each sample point were calculated from the weight per cent material and the balanced assay values due to free and unliberated mineral grains (Table 4) and the results were plotted in Figs. 2 and 3. Figure 2 shows that, for the 1979 suite, there was good recovery of free sphalerite from the cleaners but poor recovery from the roughers, especially rougher 12. By contrast, for the 1977 suite, there was good recovery of free sphalerite from the roughers, but a significant loss from the first cleaner. Figure 3 shows that only very small proportions of the free and unliberated galena and chalcopyrite were recovered in the zinc concentrate. Most were lost to the circuit tails.

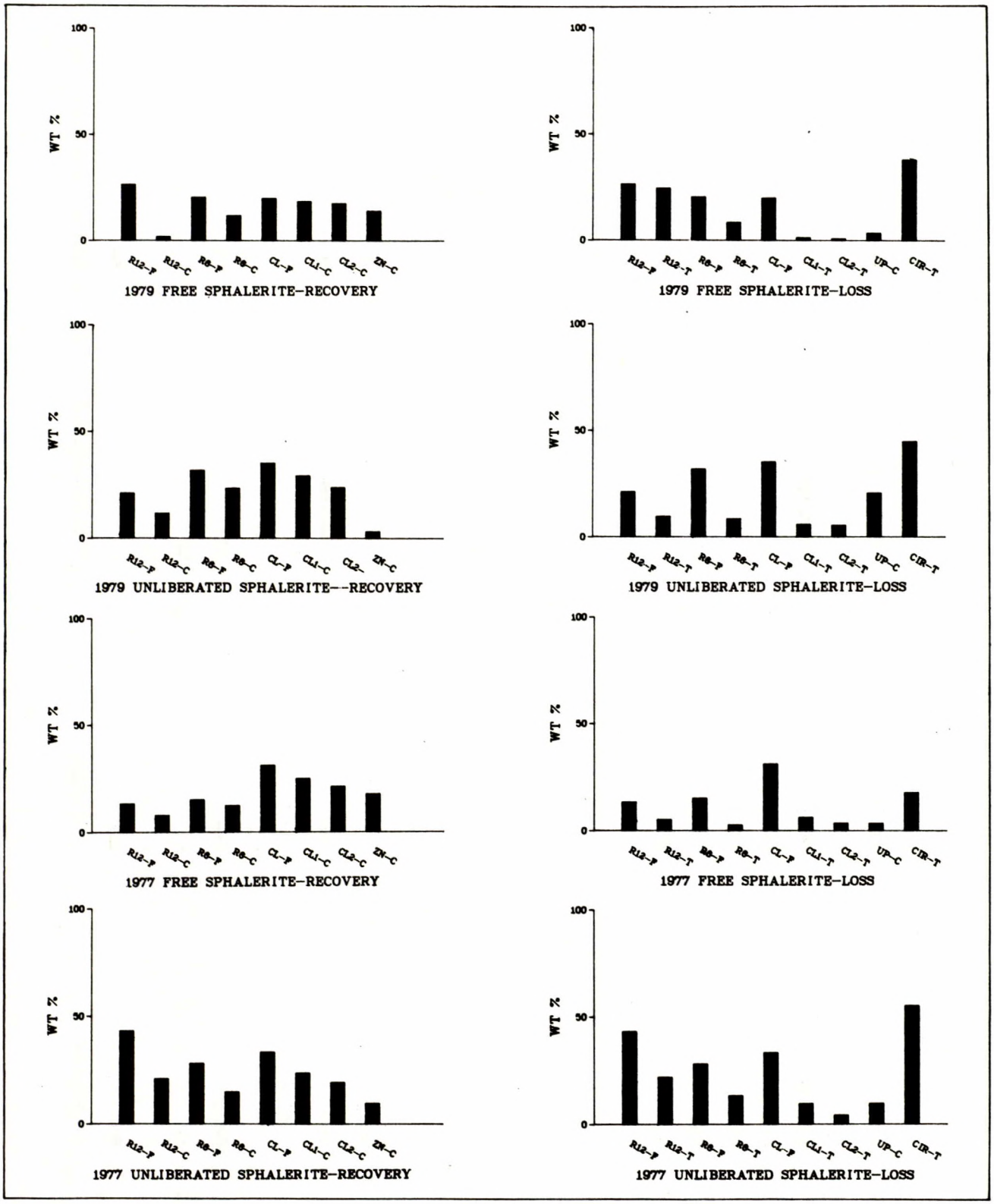

Fig. 2 — *Histograms showing the recoveries and losses of free and unliberated* **sphalerite** *for the 1979 and 1977 suites.* The last bar (ZN-C) of the recovery graphs shows the recovery in the zinc concentrate and the last bar (CIR-T) of the loss graphs shows the total loss from the circuit. R12-F and R6-F are the amounts in the rougher 12 and 6 feeds and R12-C and R6-C are the recoveriesfrom the respective roughers; R12-T and R6-T are losses from the rougher to the tails. CL-F is the amount in the cleaner circuit feed and CL1, CL2 and up are either recoveries or losses from the 1st and 2nd cleaners and upgrading cells respectively. The total amount of free plus unliberated sphalerite in the circuit is 100%.

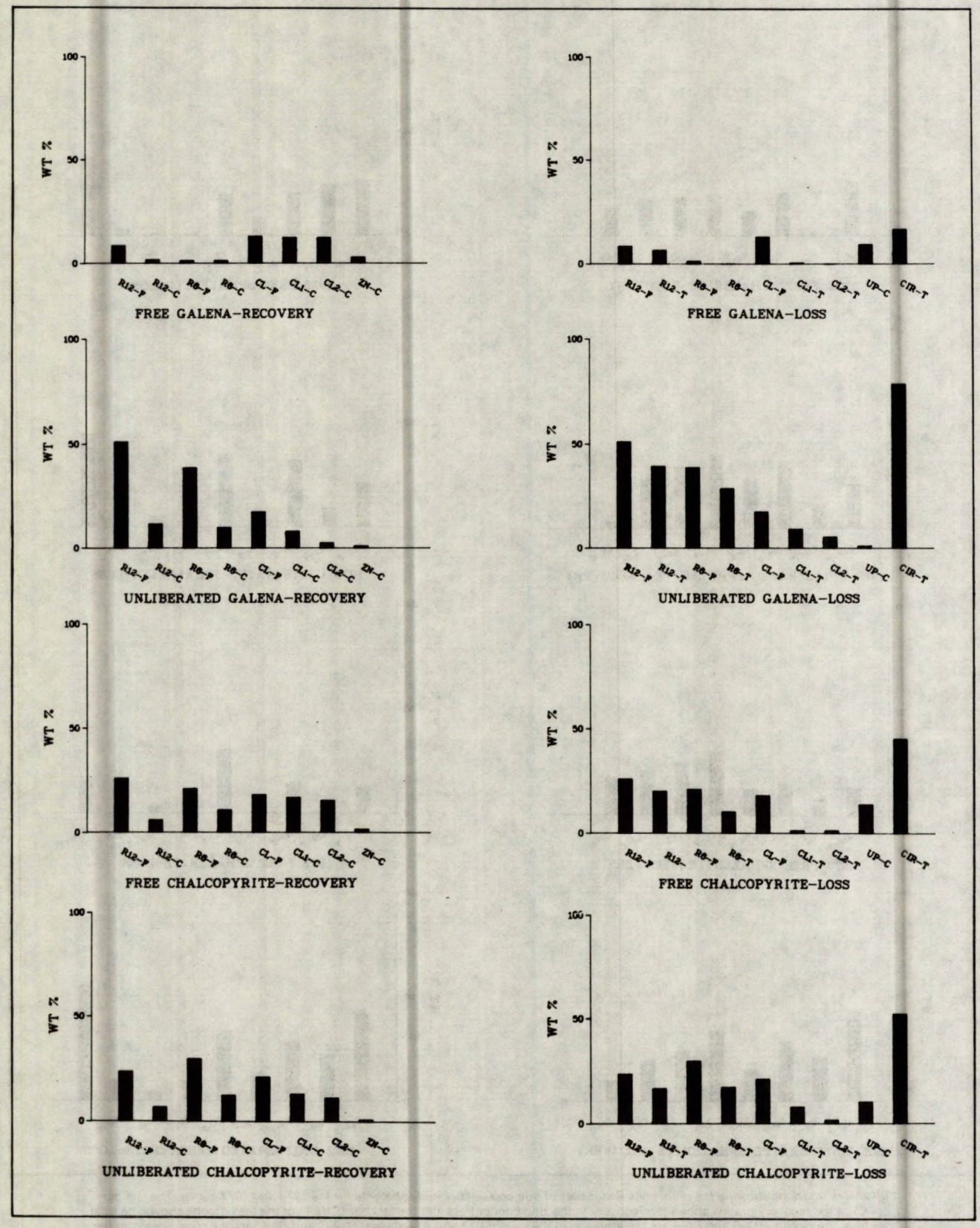

Fig. 3 — *Histograms showing the recoveries and losses of free and unliberated* **galena and chalcopyrite** *for the 1979 suite.* The last bar (ZN-C) of the recovery graphs shows the recovery in the zinc concentrate; the last bar (CIR-T) of the loss graphs shows the total loss from the circuit. Total amount of free plus unliberated mineral in circuit is 100%.

Table 3 - Mineral liberations*

	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading		
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails
Sphalerite (obs.) 1979	62	14	53	45	36	48	24	41	41	42	19	42	46	14	46	14	68
Sphalerite (bal.) 1979	55	14	72	39	34	50	26	36	36	39	19	39	43	14	43	15	81
Sphalerite (obs.) 1977	22	27	18	34	45	15	-	47	47	51	37	51	52	44	52	30	63
Galena (obs.) 1979	0	0	0	0	0	0	24	0	0	15	17	15	91	0	91	48	41
Galena (bal.) 1979	15	13	15	3	12	0	10	42	42	60	6	60	82	0	82	88	68
Galena (obs.) 1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
Chalcopyrite (obs.) 1979	58	0	51	4	54	75	42	0	0	67	15	67	65	45	65	62	60
Chalcopyrite (bal.) 1979	53	46	55	41	46	37	31	46	46	56	14	56	58	44	58	57	60
Chalcopyrite (obs.) 1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32

* weight per cent of mineral as free grains

Table 4 - Grades and recoveries as free and unliberated minerals

	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading			In
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	circuit
wt % Zn as free sp* 1979	1.08	0.92	1.10	1.54	7.96	0.72	3.60	4.85	4.85	8.80	0.68	8.80	11.76	1.49	11.76	3.02	43.56	
wt % Zn as free sp 1977	0.35	2.43	0.15	0.75	5.79	0.14	3.55	4.54	4.54	7.57	1.70	7.57	11.98	2.44	11.98	3.71	25.43	
wt % Zn as unlib sp 1979	0.88	5.78	0.67	2.40	15.75	0.72	9.90	8.57	8.57	13.91	2.94	13.91	19.90	8.99	19.90	17.53	9.97	
wt % Zn as unlib sp 1977	1.25	6.74	0.70	1.47	8.61	0.78	6.02	5.03	5.03	7.40	2.84	7.40	11.06	3.10	11.06	8.50	15.06	
Rec. as free sp 1979	26.4	1.9	24.5	20.5	11.9	8.6	14.7	20.0	20.0	18.6	1.4	18.6	17.7	0.9	17.7	3.6	14.1	52.2
Rec. as free sp 1977	13.3	8.0	5.3	15.1	12.4	2.7	24.0	31.0	31.0	24.8	6.2	24.8	21.2	3.6	21.2	3.5	17.7	35.4
Rec. as unlib sp 1979	21.2	11.7	9.6	31.9	23.5	8.5	40.6	35.3	35.3	29.4	5.9	29.4	23.9	5.5	23.9	20.6	3.2	47.8
Rec. as unlib sp 1977	43.3	21.2	22.1	28.3	15.0	13.5	40.6	33.6	33.6	23.9	9.7	23.9	19.5	4.4	19.5	9.8	9.7	64.6
wt % Pb as free ga**	0.12	0.29	0.10	0.03	0.30	0.00	0.25	1.02	1.02	1.90	0.09	1.90	2.67	0.00	2.67	2.51	3.03	
wt % Pb as unlib ga	0.68	1.89	0.57	0.95	2.17	0.79	2.15	1.38	1.38	1.27	1.51	1.27	0.58	2.97	0.58	0.41	1.43	
Rec. Pb as free ga	8.6	1.8	6.7	1.4	1.4	0.0	3.2	13.0	13.0	12.4	0.6	12.4	12.4	0.0	12.4	9.4	3.0	19.8
Rec. Pb as unlib ga	51.2	11.8	39.4	38.8	10.1	28.8	27.4	17.6	17.6	8.3	9.3	8.3	2.7	5.6	2.7	1.2	1.5	80.2
wt % Cu as free cp***	0.04	0.11	0.03	0.06	0.27	0.03	0.16	0.16	0.16	0.30	0.02	0.30	0.38	0.09	0.38	0.44	0.18	
wt % Cu as unlib cp	0.04	0.13	0.03	0.08	0.31	0.06	0.19	0.19	0.19	0.23	0.15	0.23	0.28	0.11	0.28	0.32	0.12	
Rec. Cu as free cp	25.9	5.9	20.0	20.9	10.7	10.2	18.0	18.0	18.0	16.7	1.3	16.7	15.3	1.4	15.3	13.7	1.6	46.8
Rec. Cu as unlib sp	23.5	6.8	16.7	29.7	12.4	17.3	21.1	21.1	21.1	13.1	8.0	13.1	11.3	1.8	11.3	10.3	1.0	53.2

* sp=sphalerite

** ga=galena

*** cp=chalcopyrite

SIZE DISTRIBUTIONS

The size distributions of the free and unliberated grains were determined with the image analyser, and the values were adjusted to a materials balance using the same procedure as for the mineral liberations. The results are given in Tables 5 to 10 and in Figs. 4 to 9. Size distributions from the 1977 study for the zinc concentrate (upgrading tails) and for the combined mill or circuit tails (12 rougher tails + 6 rougher tails + 1st cleaner tails + upgrading concentrate) are included. It is noted that all the free and unliberated grains in the 1977 samples were finer-grained than in the 1979 samples. The relationship between the size of unliberated grains in the zinc concentrate and in the combined mill tailings (Figs. 5-7), however, was the same in both the 1979 and 1977 samples. Unliberated sphalerite, unliberated galena, and unliberated chalcopyrite grains in the zinc concentrate are coarser-grained than in the combined mill tailings; the free chalcopyrite in the combined mill tailings in both the 1977 and 1979 samples is coarse-grained; and the free galena grains in the zinc concentrates are coarser-grained than in the tailings.

The recoveries and losses of the different sized free and unliberated grains in the various cells, the zinc concentrate and the circuit tails were calculated using the size distributions of Tables 5 to 10 and recoveries of Table 3. The results are given in Tables 11-13 and are plotted as histograms in Figs. 10-15.

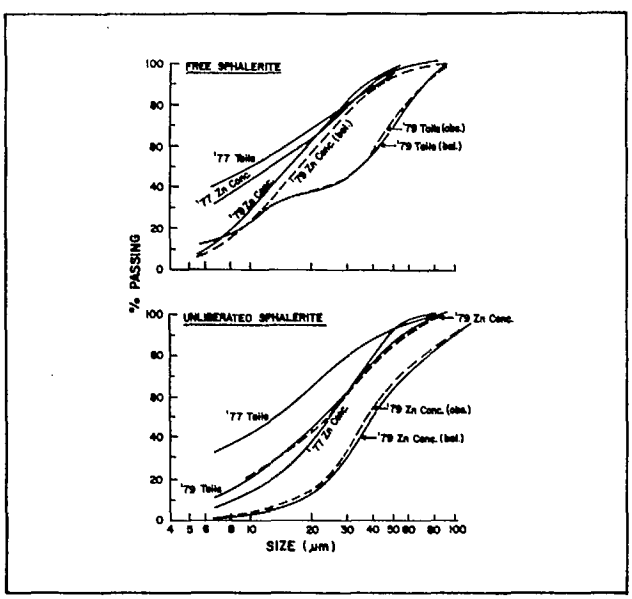

Fig. 4 — *Size distributions of free and unliberated* **sphalerite** *in tails and zinc concentrates.* Plotted as cumulative per cent passing.

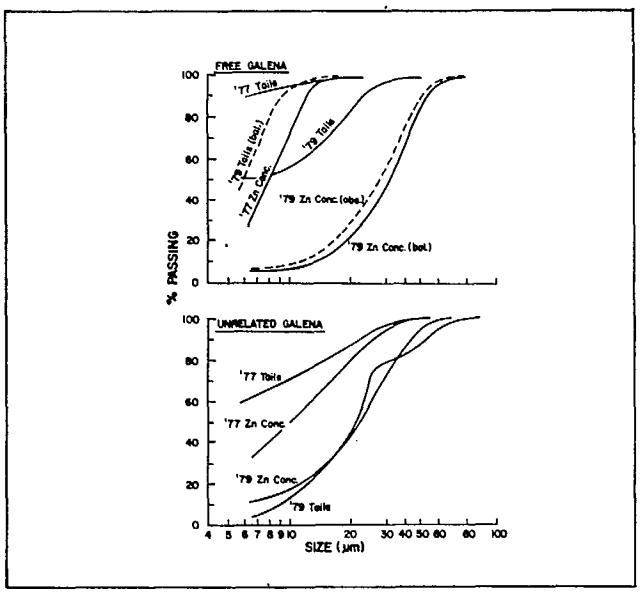

Fig. 5 — *Size distributions of free and unliberated* **galena** *in tails and zinc concentrates.* Plotted as cumulative per cent passing.

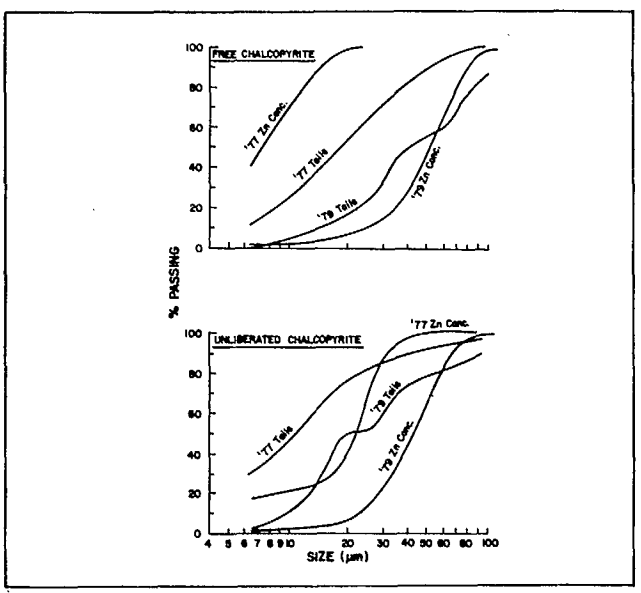

Fig. 6 — *Size distributions of free and unliberated* **chalcopyrite** *in tails and zinc concentrates.* Plotted as cumulative per cent passing.

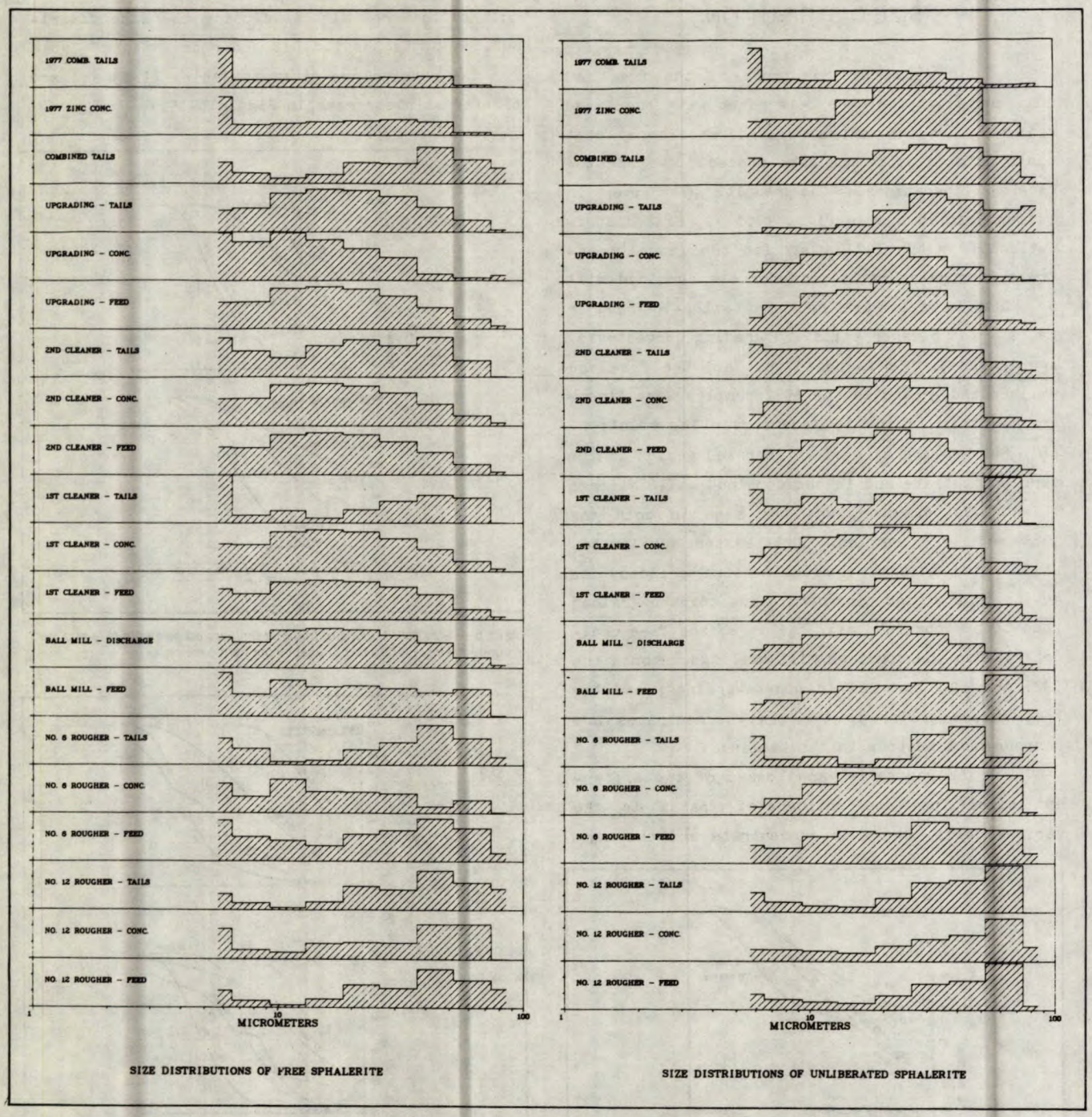

Fig. 7 — *Size distributions of free and unliberated* **sphalerite** *in products.*

Plotted as relative quantities of mineral in each size range of the Tyler series, i.e., $\sqrt{2}$.

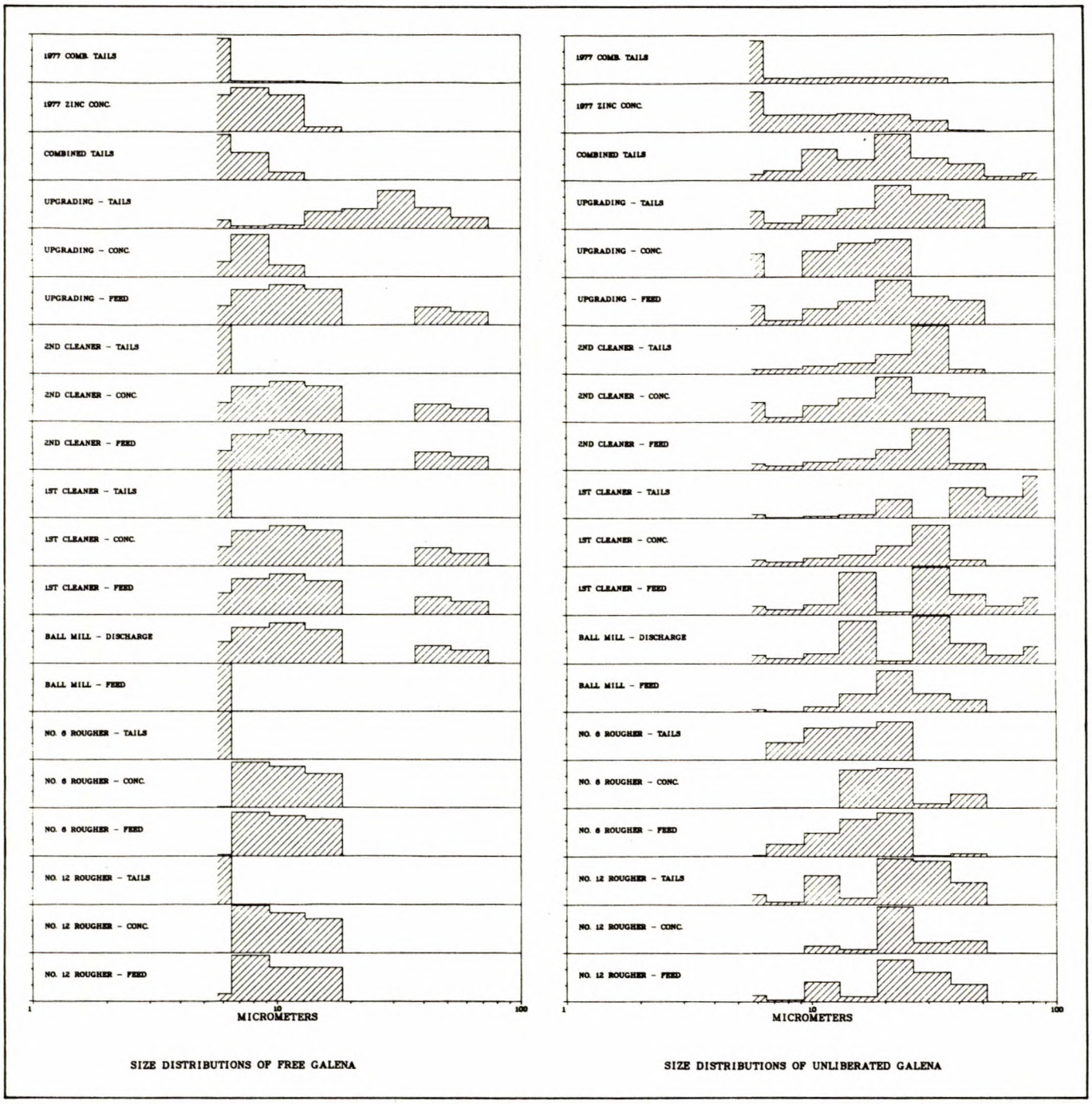

Fig. 8 — *Size distributions of free and unliberated* **galena** *in products.*

Plotted as relative quantities of mineral in each size range of the Tyler mesh series, i.e., $\sqrt{2}$.

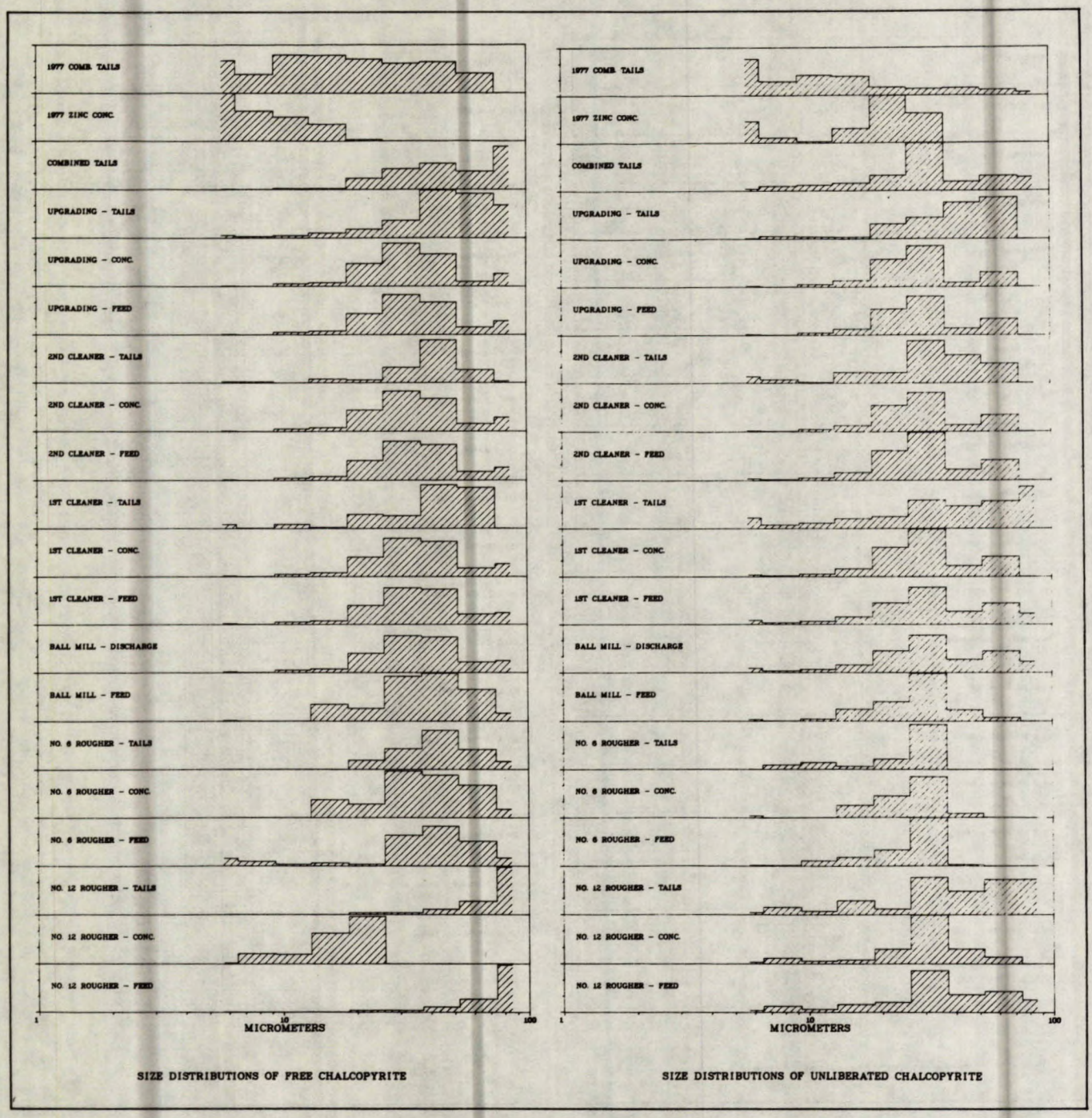

Fig. 9 — *Size distributions of free and unliberated* **chalcopyrite** *in products.*

Plotted as relative quantities of mineral in each size range of the Tyler mesh series, i.e., $\sqrt{2}$.

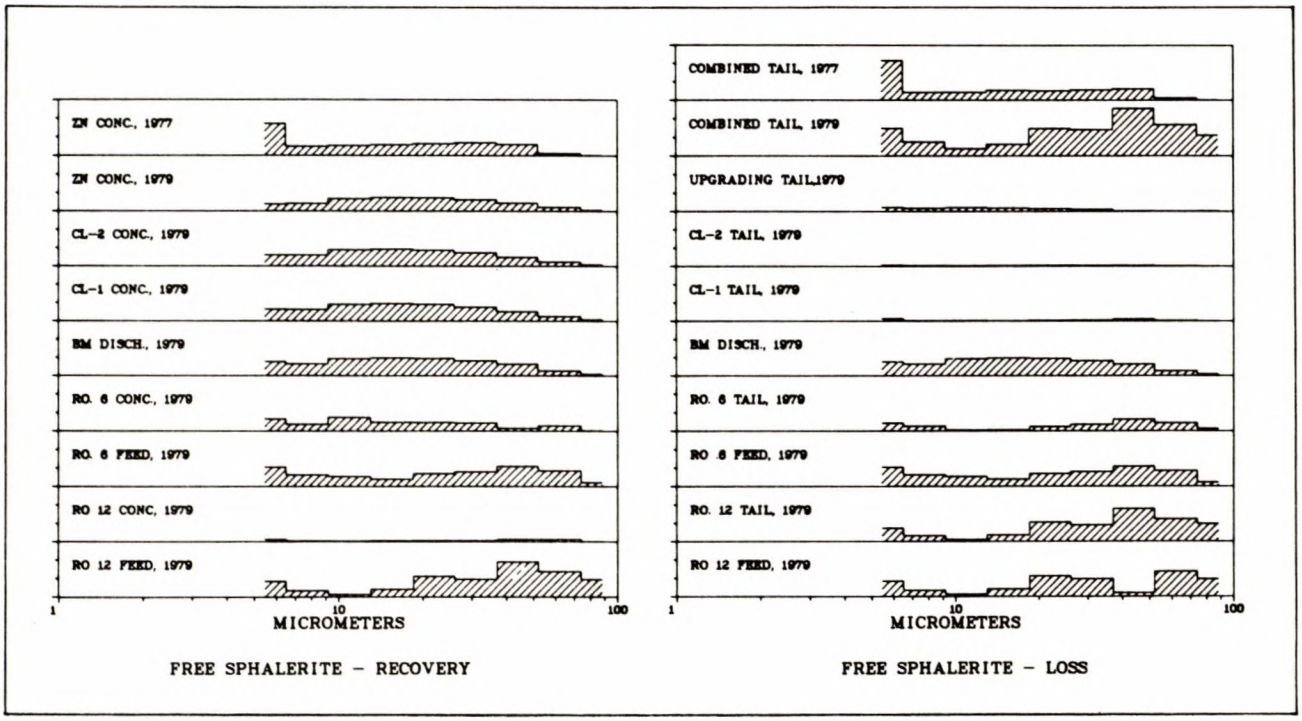

Fig. 10 — *Quantities of sized* **free** *sphalerite grains recovered and lost* from rougher 12, rougher 6 and cleaner cells (BM'Disch = cleaner circuit feed), and recovered and lost in zinc concentrate and circuit tails (combined tail) respectively. Data for 1977 are included for comparison. Vertical scale = 0 to 10%.

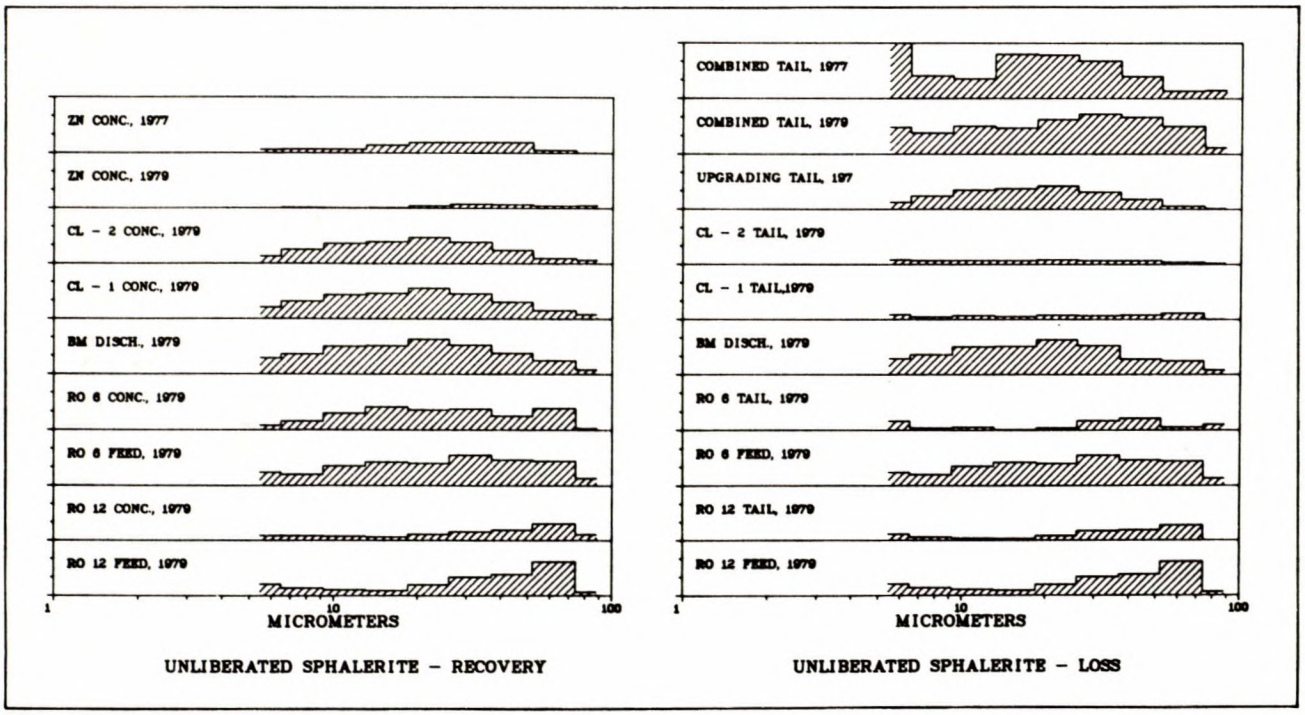

Fig. 11 — *Quantities of sized* **unliberated** *sphalerite grains* (size of sphalerite in middling particle) recovered and lost, as in caption to Fig. 10. Vertical scale = 0 to 10%.

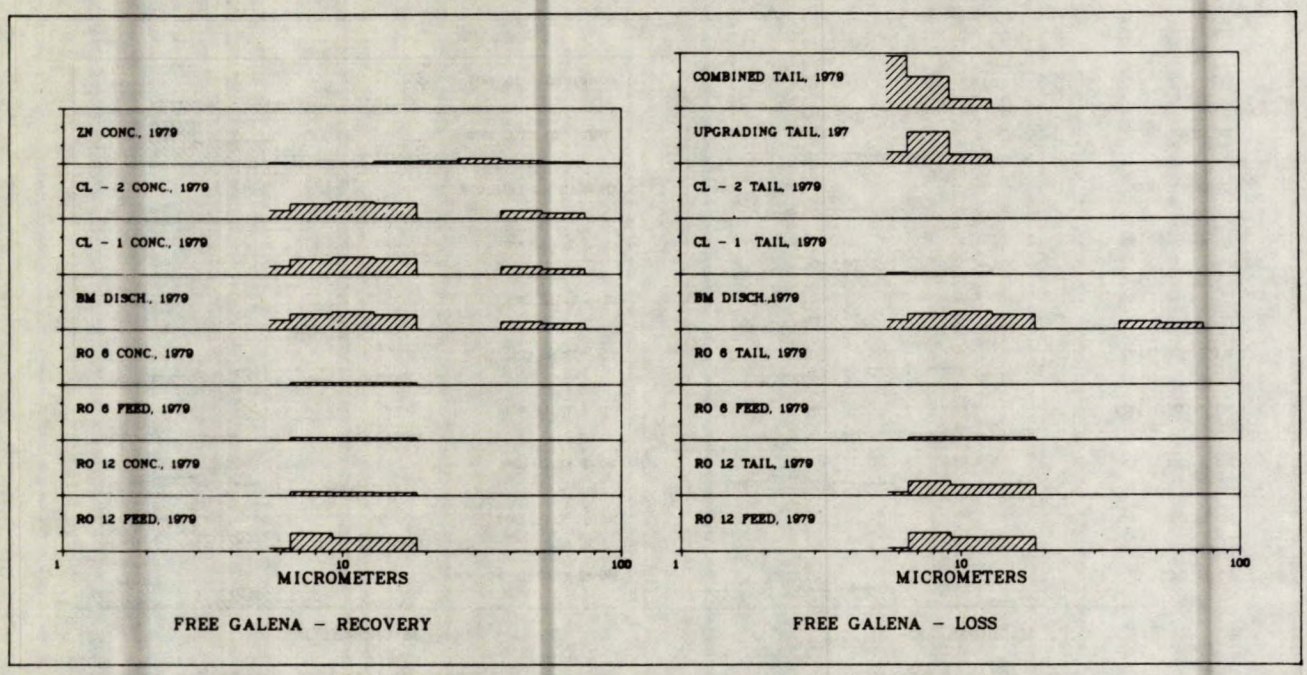

Fig. 12 — *Quantities of sized* **free** *galena grains recovered and lost*, as in caption to Fig. 10. Vertical scale = 0 to 10%.

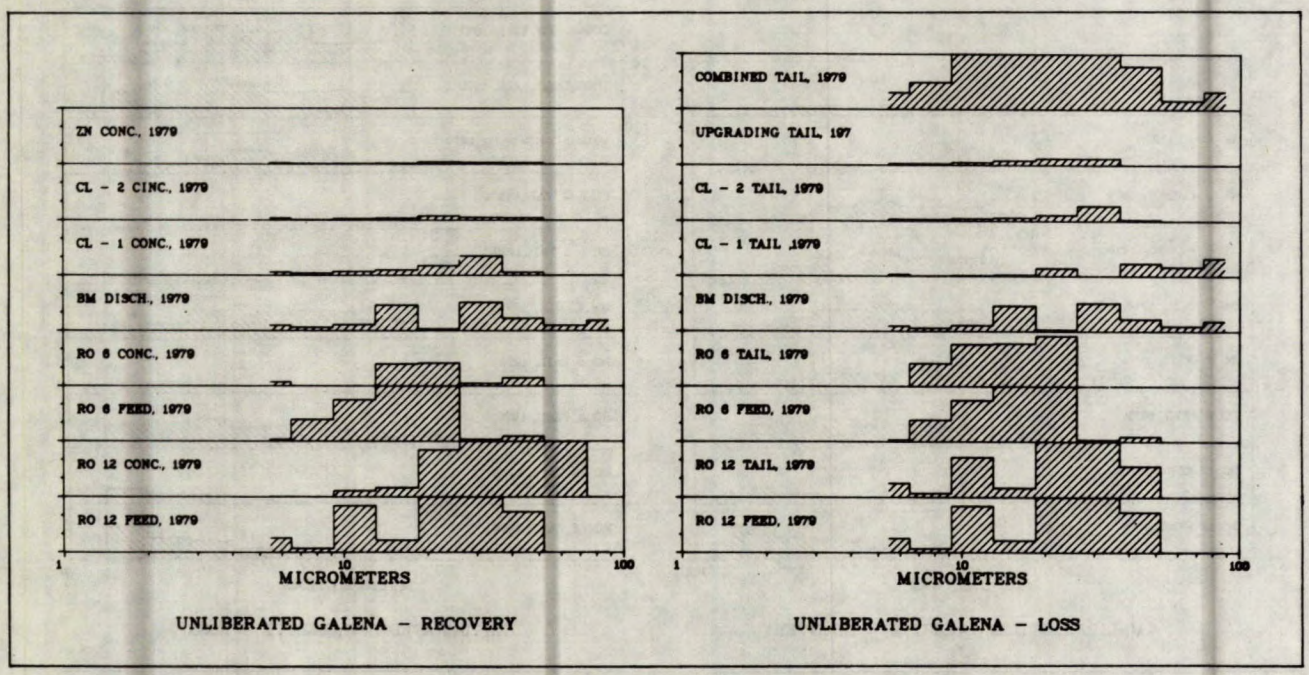

Fig. 13 — *Quantities of sized* **unliberated** *galena grains* (size of galena in middling particles) recovered and lost, as in caption to Fig. 10. Vertical scale = 0 to 10%.

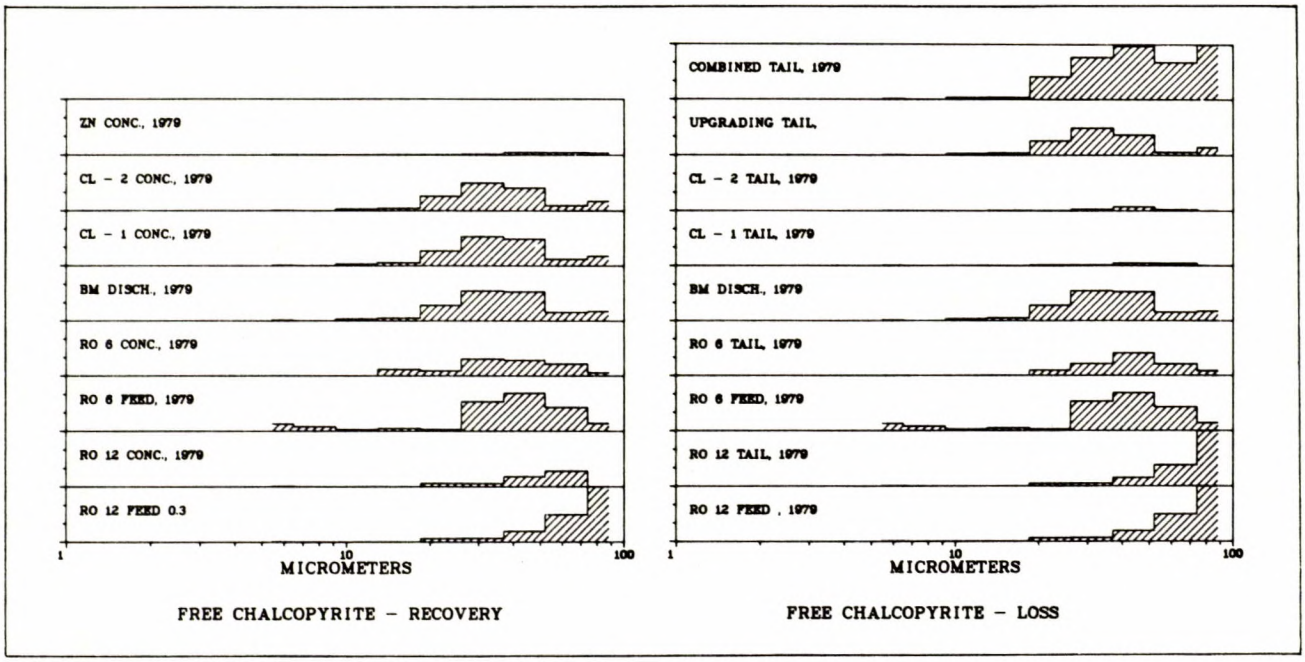

Fig. 14 — *Quantities of sized* **free** *chalcopyrite grains recovered and lost*, as in caption to Fig. 10. Vertical scale = 0 to 10%.

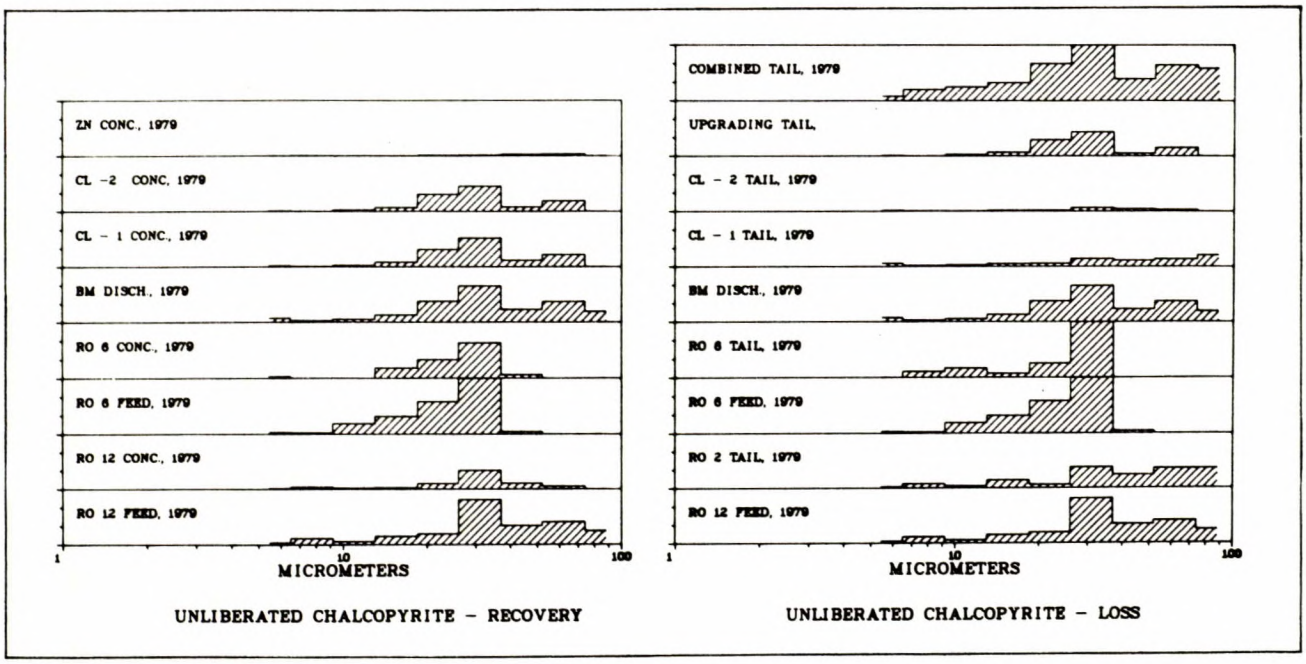

Fig. 15 — *Quantities of sized* **unliberated** *chalcopyrite grains* (size of chalcopyrite in middling particles) *recovered and lost*, as in caption to Fig. 10. Vertical scale = 0 to 10%.

Table 5 - Size distributions* of free sphalerite

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced 6.5	10.4	18.3	9.7	16.8	18.1	16.2	17.9	12.6	12.6	11.3	30.0	11.3	11.0	16.2	11.0	19.6	8.9	12.9		
9.3	14.6	23.8	13.8	26.8	28.2	26.1	27.0	23.2	23.2	22.3	34.7	22.3	22.1	26.9	22.1	35.4	18.7	19.4		
13.0	16.1	27.8	15.0	35.2	49.1	27.9	42.0	38.8	38.8	38.6	42.3	38.6	38.8	34.8	38.8	55.1	34.7	22.7		
18.5	21.4	37.3	19.9	41.5	62.4	30.7	54.3	55.1	55.1	55.8	45.2	55.8	56.2	47.9	56.2	71.8	52.3	28.2		
26	35.5	47.5	34.3	52.7	75.4	40.1	67.0	70.8	70.8	72.1	53.5	72.1	72.5	63.5	72.5	84.8	69.4	41.1		
37	47.4	57.4	46.5	65.5	87.5	54.1	78.6	84.3	84.3	85.6	67.1	85.6	86.0	76.6	86.0	94.2	84.0	53.4		
52	71.3	78.6	70.6	83.1	91.5	78.8	88.4	94.7	94.7	94.7	94.4	94.7	94.8	93.1	94.8	96.8	94.2	75.8		
74	88.3	99.9	87.2	96.7	99.6	95.2	99.7	98.9	98.9	98.9	100.0	98.9	98.8	99.9	98.8	97.8	99.1	90.4		
+74	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Observed 6.5	9	18	10	20	17	16	20	23	23	8	28	8	16	17	16	21	11	13	32	40.5
9.3	12	24	12	26	36	26	26	35	35	15	34	15	30	28	30	39	25	18	41	48.3
13.0	21	28	14	36	45	28	37	46	46	29	42	29	47	35	47	58	40	22	51	56.4
18.5	27	37	19	41	57	32	46	61	61	45	45	45	61	49	61	74	58	28	62	66.4
26	40	48	33	47	70	42	57	72	72	64	54	64	74	64	74	87	76	41	74	75.9
37	56	58	44	69	80	55	68	84	84	79	67	79	87	77	87	96	90	52	87	86.3
52	80	79	68	86	85	79	78	93	93	92	94	92	94	93	94	98	99	74	98	97.9
74	87	100	88	93	100	96	81	98	98	100	100	100	99	100	99	98	99	91	100	99.9
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 6 - Size distributions* of unliberated sphalerite

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced 6.5	9.6	7.1	11.6	7.4	3.3	18.8	5.8	8.1	8.1	6.9	14.5	6.9	5.3	14.3	5.3	6.0	0.1	10.8		
9.3	16.0	14.1	17.5	13.6	10.1	23.3	13.4	18.4	18.4	17.7	22.1	17.7	15.8	26.6	15.8	17.6	3.6	19.3		
13.0	20.9	20.4	21.3	24.7	22.9	29.6	24.5	32.8	32.8	32.6	33.9	32.6	31.1	39.2	31.1	34.6	6.5	30.7		
18.5	25.0	25.5	24.5	38.0	40.5	31.1	37.9	47.4	47.4	48.4	42.2	48.4	47.7	51.7	47.7	52.8	11.7	41.2		
26.0	34.0	35.1	33.1	50.5	55.7	36.1	51.5	65.3	65.3	67.3	55.0	67.3	67.5	66.4	67.5	73.4	25.7	55.2		
37	50.2	48.7	51.4	67.7	71.7	56.5	66.3	80.1	80.1	82.7	66.5	82.7	83.6	78.4	83.6	88.4	49.8	71.4		
52	68.3	64.9	71.1	82.1	82.2	81.7	78.5	90.8	90.8	92.9	80.1	92.9	93.5	90.1	93.5	96.9	69.9	86.2		
74	97.4	91.1	100.0	95.9	98.8	87.8	96.5	97.7	97.7	97.3	99.6	97.3	97.4	96.8	97.4	99.5	83.7	97.4		
+74	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Observed 6.5	9	8	15	14	3	16	5	11	11	15	14	15	4	13	4	7	0	11	6.0	33.3
9.3	15	15	21	21	9	21	13	19	19	29	22	29	14	24	14	16	3	19	13.0	40.6
13	19	23	25	28	21	29	23	33	33	47	34	47	28	37	28	30	6	29	20.0	46.9
18.5	22	32	34	40	38	31	38	44	44	63	42	63	44	50	44	49	11	41	35.0	61.4
26	29	44	46	48	56	36	52	63	63	79	55	79	64	65	64	68	24	56	55.0	75.6
37	45	55	65	63	74	58	67	78	78	88	66	88	78	77	78	85	47	73	75.0	87.8
52	63	70	81	75	88	84	79	88	88	94	80	94	88	90	88	96	66	88	95.0	94.9
74	100	91	100	100	96	87	93	92	92	98	100	98	96	98	96	100	79	98	100	97.3
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 7 - Size distributions* of free galena

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced 6.6	6	0	8	1	0.4	100	100	13.3	13.3	11.9	50	11.9	11.9	100	11.9	21.9	6.9	56.3		
9.3	44	39	46	37	38	100	100	35.4	35.4	33.9	75	33.9	33.9	100	33.9	83.1	8.9	90.4		
13	72	72	73	70	72	100	100	60.4	60.4	58.9	100	58.9	58.9	100	58.9	100	11.9	100		
18.5	100	100	100	100	100	100	100	81.1	81.1	81.1	100	81.1	81.1	100	81.1	100	26.3	100		
26	100	100	100	100	100	100	100	81.1	81.1	81.1	100	81.1	81.1	100	81.1	100	42.7	100		
37	100	100	100	100	100	100	100	81.1	81.1	81.1	100	81.1	81.1	100	81.1	100	74.0	100		
52	100	100	100	100	100	100	100	92.0	92.0	92.4	100	92.0	92.0	100	92.0	100	91.0	100		
74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Observed 6.6	100	100	100	100	100	100	100	60	60	15	1	15	3	100	3	13	6	51	30	91.8
9.3	100	100	100	100	100	100	100	100	100	21	1	21	9	100	9	20	7	55	66	95.0
13	100	100	100	100	100	100	100	100	100	26	1	26	21	100	21	35	9	63.4	96	98.0
18.5	100	100	100	100	100	100	100	100	100	61	1	61	34	100	34	62	20	78.6	100	99.8
26	100	100	100	100	100	100	100	100	100	100	13	100	45	100	45	90	34	94.4	100	100
37	100	100	100	100	100	100	100	100	100	100	46	100	68	100	68	100	65	100	100	100
52	100	100	100	100	100	100	100	100	100	100	65	100	74	100	74	100	100	100	100	100
74	100	100	100	100	100	100	100	100	100	100	100	100	74	100	74	100	100	100	100	100
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 8 - Size distributions* of unliberated galena

		No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Size μm	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced	6.6	5.0	0	6.3	0.7	0	0	2.1	5.3	5.3	6.5	3.0	6.5	12.3	4.8	12.3	19.5	10.9	3.8		
	9.3	6.3	0	8.0	10.8	0	14.5	2.3	8.5	8.5	10.8	3.5	10.8	15.2	9.6	15.2	19.5	14.4	10		
	13	22.7	9.2	26.2	30.1	0	41.1	7.6	14.8	14.8	19.1	5.0	19.1	25.4	17.5	25.4	41.1	22.7	29.4		
	18.5	26.9	13.9	30.3	60.8	39.6	68.2	26.2	41.1	41.1	30.6	7.8	30.6	40.1	28.2	40.1	69.1	35.1	42.1		
	26	61.6	71.5	59.0	96.8	81.0	100	69.0	42.8	42.8	51.6	23.2	51.6	67.7	47.5	67.7	100	61.7	70.5		
	37	85.8	84.6	86.2	97.6	85.4	100	87.7	72.0	72.0	94.0	23.2	94.0	85.1	96.2	85.1	100	82.5	84.0		
	52	100	99.9	100	100	100	100	100	84.4	84.4	100	48.1	100	100	100	100	100	100	93.9		
	74	100	100	100	100	100	100	100	89.6	89.6	100	65.5	100	100	100	100	100	100	95.9		
	+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Observed	6.5	6	32	6	10	13	0	2	10	10	5	3	5	8	7	8	15	11	3.6	33	62
	9.3	20	76	7	12	54	14	2	15	15	6	4	6	10	14	10	20	15	9.4	47	69
	13	26	100	24	26	100	59	6	15	15	14	5	14	15	20	15	40	23	22.1	61	77
	18.5	26	100	32	100	100	59	18	45	45	45	8	45	52	31	52	67	36	39.4	76	85
	26	54	100	68	100	100	100	51	76	76	86	24	86	72	51	72	100	62	75.0	90	93
	37	100	100	80	100	100	100	65	100	100	100	24	100	100	100	100	100	84	81.0	99	100
	52	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	94.1	100	100
	74	100	100	100	100	100	100	100	100	100	100	67	100	100	100	100	100	100	96.1	100	100
	+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 9 - Size distributions* of free chalcopyrite

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced 6.5	0.1	0.8	0.1	6.1	0	0	0.3	0.6	0.6	0.4	3.2	0.4	0.3	1.2	0.3	0.2	1.5	0.2		
9.3	0.1	11.2	0.1	9.8	0	0	0.3	0.7	0.7	0.5	3.5	0.5	0.3	2.4	0.3	0.2	2.3	0.2		
13	0.1	20.8	0.1	11.0	0	0	0.3	2.7	2.7	2.4	7.0	2.4	2.4	2.4	2.4	2.3	3.7	1.0		
18.5	0.1	52.0	0.1	13.4	11.1	0	10.7	5.7	5.7	5.6	7.8	5.6	5.5	7.0	5.5	5.3	6.8	1.9		
26	2.6	100	2.5	14.7	19.4	9.5	18.5	21.6	21.6	21.8	19.5	21.8	22.9	10.3	22.9	24.1	12.2	11.1		
37	5.2	100	5.0	40.2	48.4	31.0	46.2	52.2	52.2	53.6	30.0	53.6	55.9	29.3	55.9	59.6	23.0	28.1		
52	12.7	100	12.6	73.1	74.8	71.4	75.8	81.6	81.6	82.6	66.2	82.6	82.6	82.5	82.6	86.0	52.5	49.6		
74	31.8	100	31.7	93.5	94.9	91.9	95.3	90.2	90.2	89.5	100	89.5	88.7	98.4	88.7	89.7	79.8	64.5		
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Observed 6.5	1	1	0	4	7	0	0.5	1	1	0.5	3	0.5	1	1	1	2	2	0.7	40	13.4
9.3	1	11	0	7	25	12	0.5	1	1	0.5	4	0.5	1	3	1	3	3	3.7	65	21.2
13	2	21	0	8	71	31	0.5	3	3	2	7	2	3	4	3	7	4	9.3	85	37.0
18.5	4	51	0	10	100	45	12	4	4	7	8	7	8	7	8	19	7	16.2	99	52.6
26	4	100	2	10	100	45	35	24	24	19	19	19	21	10	21	41	12	24.0	100	66.6
37	4	100	8	27	100	100	57	64	64	46	30	46	52	29	52	67	23	47.3	100	78.9
52	15	100	12	53	100	100	82	100	100	64	66	64	100	83	100	91	53	57.4	100	91.8
74	59	100	30	80	100	100	100	100	100	72	100	72	100	100	100	100	81	69.0	100	100
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 10 - Size distributions* of unliberated chalcopyrite

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner			2nd cleaner			Upgrading				1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Conc.	Tails	Comb tails	Zn conc.	Comb tails
Balanced 6.5	1.3	1.5	1.1	0.9	2.2	0	1.4	3.3	3.3	1.3	6.5	1.3	0.7	5.3	0.7	0.7	0.4	1.5		
9.3	6.3	7.2	5.7	1.6	2.2	6.3	1.4	4.5	4.5	1.9	8.6	1.9	0.9	8.0	0.9	0.7	2.6	5.4		
13	8.6	9.8	7.7	8.1	2.2	16.0	3.4	7.0	7.0	4.0	11.9	4.0	3.2	8.6	3.2	3.2	4.1	10.2		
18.5	15.1	13.6	16.3	18.9	17.2	20.0	15.5	13.3	13.3	10.5	18.0	10.5	9.4	17.4	9.4	9.8	5.4	16.5		
26	23.4	28.5	19.7	38.6	44.1	34.9	35.6	31.3	31.3	34.9	25.4	34.9	36.4	25.9	36.4	38.3	17.8	29.3		
37	57.8	78.3	42.5	98.6	95.1	100	84.9	62.4	62.4	74.4	43.0	74.4	76.5	61.0	76.5	80.7	35.5	69.1		
52	72.3	93.3	56.7	100	100	100	96.4	73.2	73.2	83.3	56.9	83.3	83.2	84.0	83.2	85.0	65.7	76.6		
74	89.7	100	78.3	100	100	100	100	91.0	91.0	100	74.0	100	100	100	100	100	100	88.9		
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Observed 6.5	2	7	1	2	15	0	1	5	5	2	6	2	1	5	1	3	1	1.8	18	30.3
9.3	5	16	7	2	35	15	1	6	6	4	8	4	1	7	1	5	3	9.4	22	41.9
13	9	27	7	7	38	46	3	8	8	6	11	6	2	8	2	7	4	20.5	23	58.8
18.5	13	54	23	17	100	100	14	16	16	9	17	9	8	18	8	22	5	47.4	35	74.8
26	20	82	23	31	100	100	32	44	44	30	24	30	33	26	33	44	18	52.6	75	81.6
37	53	100	45	100	100	100	78	76	76	73	41	73	67	61	67	88	36	71.0	100	87.1
52	68	100	59	100	100	100	100	100	100	87	54	87	67	82	67	100	66	79.9	100	93.2
74	100	100	72	100	100	100	100	100	100	100	72	100	100	100	100	100	100	86.8	100	97.6
+74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* weight per cent passing

Table 11 - Quantities* of sphalerite in different size ranges

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner		2nd cleaner		Upgrading			1977	
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Conc.	Tails	Conc.	Tails	Conc.	Tails**	Comb tails	Zn conc.	Comb tails
A. Free sphalerite																	
<6.5	2.75	0.35	2.38	3.44	2.15	1.39	2.63	2.52	2.10	0.42	1.95	0.15	0.71	1.25	4.91	5.66	7.17
6.5-9.3	1.10	0.10	1.00	2.05	1.21	0.85	1.34	2.12	2.05	0.07	1.96	0.09	0.56	1.39	2.48	1.60	1.38
9.3-13	0.40	0.08	0.30	1.73	2.48	0.16	2.20	3.12	3.03	0.10	2.96	0.07	0.71	2.25	1.26	1.77	1.42
13-18.5	1.40	0.18	1.20	1.29	1.59	0.24	1.81	3.26	3.20	0.04	3.08	0.12	0.60	2.48	2.09	1.94	1.78
18.5-26	3.72	0.19	3.52	2.29	1.54	0.81	1.87	3.14	3.03	0.12	2.88	0.14	0.47	2.42	4.92	2.13	1.68
26-37	3.13	0.19	2.94	2.63	1.44	1.20	1.70	2.70	2.51	0.19	2.39	0.12	0.34	2.05	4.69	2.30	1.86
37-52	6.30	0.40	5.96	3.61	0.48	2.13	1.44	2.08	1.69	0.38	1.56	0.15	0.09	1.44	8.53	1.95	2.05
52-74	4.51	0.41	4.04	2.78	0.96	1.41	1.67	0.84	0.79	0.08	0.71	0.06	0.04	0.69	5.56	0.35	0.36
>74	3.09	0.00	3.16	0.68	0.05	0.41	0.04	0.22	0.20	0.00	0.21	0.00	0.08	0.13	3.66	0.00	0.01
Total	26.40	1.90	24.50	20.50	11.90	8.60	14.70	20.00	18.60	1.40	17.70	0.90	3.60	14.10	38.10	17.70	17.70
B. Unliberated*** sphalerite																	
<6.5	2.04	0.83	1.11	2.36	0.78	1.60	2.35	2.86	2.03	0.86	1.27	0.79	1.24	0.00	4.82	0.58	18.35
6.5-9.3	1.35	0.82	0.57	1.98	1.59	0.38	3.09	3.64	3.17	0.44	2.51	0.67	2.40	0.12	3.79	0.68	4.02
9.3-13	1.04	0.74	0.36	3.54	3.01	0.54	4.51	5.08	4.38	0.70	3.65	0.70	3.49	0.09	5.08	0.68	3.47
13-18.5	0.87	0.59	0.31	4.24	4.14	0.12	5.44	5.15	4.65	0.49	3.97	0.68	3.75	0.16	4.69	1.46	7.99
18.5-26	1.98	1.13	0.83	3.99	3.57	0.43	5.52	6.32	5.56	0.76	4.73	0.81	4.24	0.45	6.24	1.94	7.83
26-37	3.36	1.59	1.75	5.49	3.76	1.73	6.01	5.23	4.52	0.67	3.85	0.66	3.09	0.77	7.22	1.94	6.72
37-52	3.84	1.89	1.90	4.59	2.47	2.14	4.95	3.77	3.00	0.81	2.37	0.65	1.75	0.65	6.61	1.94	3.91
52-74	6.12	3.07	2.77	4.40	3.90	0.52	7.31	2.44	1.30	1.15	0.93	0.36	0.54	0.44	4.99	0.48	1.32
>74	0.60	1.04	0.00	1.31	0.28	1.04	1.42	0.81	0.79	0.02	0.62	0.18	0.10	0.52	1.16	0.00	1.49
Total	21.20	11.70	9.60	31.90	23.50	8.50	40.6	35.30	29.40	5.90	23.90	5.50	20.60	3.20	44.60	9.70	55.10

* Total free plus total unliberated sphalerite in rougher 12 plus rougher 6 = 100%

** Upgrading tail = zinc concentrate

*** Size of unliberated sphalerite is size of sphalerite inclusions in larger middling particles

Table 12 - Quantities* of galena in different size ranges

Size µm	No. 12 rougher Feed	No. 12 rougher Conc.	No. 12 rougher Tails	No. 6 rougher Feed	No. 6 rougher Conc.	No. 6 rougher Tails	Ball mill Feed	Ball mill Discharge	1st cleaner Conc.	1st cleaner Tails	2nd cleaner Conc.	2nd cleaner Tails	Upgrading Conc.	Upgrading Tails**	Comb tails
A. Free galena															
<6.5	0.52	0.00	0.52	0.01	0.01	0.00	3.2	1.73	1.48	0.25	1.48	0.00	2.06	0.21	9.46
6.5-9.3	3.26	0.70	2.56	0.51	0.51	0.00	0.00	2.87	2.72	0.15	2.72	0.00	5.74	0.06	5.73
9.3-13	2.41	0.60	1.81	0.46	0.46	0.00	0.00	3.25	3.10	0.15	3.10	0.00	1.60	0.09	1.61
13-18.5	2.40	0.50	1.81	0.42	0.42	0.00	0.00	2.69	2.76	0.00	2.76	0.00	0.00	0.43	0.00
18.5-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00
26-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00
37-52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42	1.40	0.00	1.42	0.00	0.00	0.51	0.00
52-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.04	0.94	0.00	1.04	0.00	0.00	0.27	0.00
>74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	8.60	1.80	6.70	1.40	1.40	0.00	3.2	13.00	12.40	0.55	12.40	0.00	9.40	3.00	16.80
B. Unliberated*** galena															
<6.5	2.56	0.00	2.48	0.27	0.00	0.00	0.58	0.93	0.54	0.28	0.33	0.27	0.23	0.16	2.99
6.5-9.3	0.67	0.00	0.67	3.92	0.00	4.18	0.05	0.57	0.36	0.05	0.08	0.27	0.00	0.06	4.88
9.3-13	8.39	1.09	7.17	7.49	0.00	7.66	1.45	1.10	0.69	0.14	0.28	0.44	0.26	0.12	15.27
13-18.5	2.15	0.55	1.62	11.91	4.00	7.80	5.10	4.63	0.95	0.26	0.39	0.60	0.34	0.19	9.99
18.5-26	17.77	6.80	11.31	13.97	4.18	9.16	11.73	0.30	1.74	1.43	0.75	1.08	0.37	0.40	22.35
26-37	12.39	1.54	10.71	0.31	0.45	0.00	5.12	5.14	3.52	0.00	0.47	2.73	0.00	0.31	10.63
37-52	7.27	1.82	5.54	0.93	1.47	0.00	3.39	2.18	0.50	2.31	0.40	0.21	0.00	0.26	7.79
52-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	1.62	0.00	0.00	0.00	0.00	1.57
>74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	3.21	0.00	0.00	0.00	0.00	3.23
Total	51.20	11.80	39.40	38.80	10.10	28.80	27.40	17.60	8.30	9.30	2.70	5.60	1.20	1.50	78.70

* Total free plus total unliberated galena in rougher 12 plus rougher 6 = 100%

** Upgrading tail = zinc concentrate

*** Size of unliberated galena is size of galena inclusions in larger middling particles

Table 13 - Quantities* of chalcopyrite in different size ranges

Size µm	No. 12 rougher			No. 6 rougher			Ball mill		1st cleaner		2nd cleaner		Upgrading		Comb
	Feed	Conc.	Tails	Feed	Conc.	Tails	Feed	Discharge	Conc.	Tails	Conc.	Tails	Conc.	Tails**	tails
A. Free chalcopyrite															
<6.5	0.03	0.05	0.02	1.27	0.00	0.00	0.05	0.11	0.07	0.04	0.05	0.02	0.03	0.02	0.09
6.5-9.3	0.00	0.61	0.00	0.78	0.00	0.00	0.00	0.02	0.01	0.01	0.32	0.01	0.00	0.02	0.00
9.3-13	0.00	0.57	0.00	0.25	0.00	0.00	0.00	0.36	0.32	0.04	0.47	0.00	0.29	0.02	0.36
13-18.5	0.00	1.84	0.00	0.50	1.19	0.00	1.88	0.54	0.54	0.01	2.66	0.07	0.41	0.05	0.41
18.5-26	0.64	2.83	0.48	0.27	0.89	0.97	1.40	2.86	2.70	0.15	5.05	0.04	2.57	0.08	4.16
26-37	0.68	0.00	0.50	5.33	3.10	2.19	4.99	5.51	5.31	0.14	4.09	0.27	4.87	0.18	7.68
37-52	1.94	0.00	1.52	6.88	2.82	4.12	5.32	5.29	4.84	0.47	0.93	0.75	3.61	0.47	9.72
52-74	4.95	0.00	3.82	4.26	2.15	2.09	3.51	1.55	1.16	0.44	1.73	0.22	0.51	0.44	6.73
>74	17.66	0.00	13.66	1.36	0.55	0.83	0.88	1.76	1.75	0.00	0.00	0.02	1.41	0.32	16.05
Total	25.90	5.90	20.00	20.90	10.70	10.20	18.00	18.00	16.70	1.30	15.30	1.40	13.70	1.60	45.20
B. Unliberated*** chalcopyrite															
<6.5	0.31	0.10	0.18	0.27	0.27	0.00	0.30	0.70	0.17	0.52	0.08	0.10	0.07	0.00	0.79
6.5-9.3	1.17	0.39	0.77	0.21	0.00	1.09	0.00	0.25	0.08	0.15	0.02	0.04	0.00	0.03	2.03
9.3-13	0.54	0.18	0.34	1.93	0.00	1.68	0.42	0.53	0.27	0.28	0.26	0.02	0.26	0.01	2.52
13-18.5	1.53	0.26	1.43	3.20	1.86	0.69	2.55	1.33	0.86	0.49	0.70	0.15	0.68	0.01	3.29
18.5-26	1.95	1.01	0.57	5.85	3.34	2.58	4.24	3.79	3.15	0.59	3.05	0.15	2.94	0.13	6.69
26-37	8.08	3.40	3.81	17.82	6.32	11.26	10.40	6.57	5.22	1.41	4.54	0.64	4.36	0.18	20.82
37-52	3.41	1.00	2.37	0.42	0.61	0.00	2.43	2.28	1.16	1.11	0.75	0.41	0.45	0.30	3.92
52-74	4.09	0.46	3.61	0.00	0.00	0.00	0.76	3.75	2.19	1.37	1.90	0.29	1.54	0.34	6.44
>74	2.42	0.00	3.62	0.00	0.00	0.00	0.00	1.90	0.00	2.08	0.00	0.00	0.00	0.00	5.80
Total	23.50	6.80	16.70	29.70	12.40	17.30	21.10	21.10	13.10	8.00	11.30	1.80	10.30	1.00	52.30

* Total free plus unliberated chalcopyrite in rougher 12 plus rougher 6 = 100%

** Upgrading of tail = zinc concentrate

*** Size of unliberated chalcopyrite is size of chalcopyrite inclusions in larger middling particles

DISCUSSION

A comparison between the 1979 and 1977 samples shows several differences in the behaviour of sphalerite in the secondary zinc circuit. The main problem observed in the 1977 operation was a loss of free sphalerite to the first cleaner tailings (Table 4). This loss was reduced in the 1979 operation to 1.4 wt % of the zinc from 6.2 wt %. On the other hand, in the 1979 operation there was a higher loss of free sphalerite to the rougher tailings than in 1977 (24.5% vs 5.3% for No. 12 rougher cell and 8.6 vs 2.7% for the No. 6 rougher cell). The grain size analysis (Figs. 10 and 11) shows that the free sphalerite grains in the rougher cells are large enough to be recovered. This suggests that, periodically, parts of the concentrator do not operate efficiently. It is proposed that fluctuations in the operation of the rougher cells in the secondary zinc circuit could be reduced to a minimum by monitoring the zinc content of the rougher tailings and keeping the value around 0.9 wt % Zn which is the value obtained in the 1977 operation.

The grade of the zinc concentrate from the 1979 operation was much higher than from the 1977 operation (53.5 vs 40.5 wt % Zn), but the recovery was lower (17.3 vs 27.4% of the zinc in the secondary zinc circuit). The higher grade zinc concentrate was achieved by discarding more of the unliberated sphalerite (7% of the total unliberated sphalerite in the circuit was recovered in zinc concentrate versus 15% in 1977), but there was also a high loss of free sphalerite (35% of the total free sphalerite in the circuit was recovered in zinc concentrate versus 50% in 1977).

Most of the galena in the circuit (80 wt %) is in middling grains and nearly all of it (79 wt %) is lost to the tailings. The free galena is very fine-grained and most of it (17 wt % of galena) is also lost to the tailings (Fig. 13). A small amount of free galena (3.0 wt % of galena in the circuit), and of galena attached to sphalerite (1.5 wt % of galena in the circuit) is recovered in the zinc concentrate.

A significant amount of the chalcopyrite (47 wt %) in the circuit is free and most of it (45 wt %) is discharged to the tailings. Much of this free chalcopyrite is in grains larger than 37 μm in size. In the 1977 samples a significant proportion of the chalcopyrite in the tailings was also in large free grains. The unliberated chalcopyrite grains are also discharged to the mill tailings. Some of the unliberated grains are large enough to be liberated by regrinding.

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