A METHOD OF STUDYING SILVER LOSSES IN CONCENTRATOR TAILINGS

by

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Major Professor Date

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CHAPTER I

INTRODUCTION

In the milling of ores the tailing of a concentrator is undoubtedly the most important product to control, for the amount of the values lost in this product often spells the difference between a profitable and a non-profitable operation.

In the operation of a concentrator it is important that the study of losses in tailings be a matter of routine work if maximum efficiency in the saving of the values is to be achieved. This routine work deals chiefly with determinations involving the character of the losses such as (1) losses due to faulty operation, (2) to grinding degrees, or (3) to association of the valuable minerals with refractory minerals.

Present routine methods for making determinations to establish character of losses are (a) sizing-assay tests, and (b) microscopic examination made on polished surfaces for the purpose of studying minerals association and to some extent determining the efficiency of grinding operations in liberating valuable minerals. The first mentioned method is of value mainly in the location of the losses in the various sizes of the tailing and is of

assistance when the losses are due either to lack of grinding or over grinding, but otherwise the method gives no indication as to what the causes of the losses maybe. The usefulness of the second method is limited due mainly to the tremendous amount of labor involved in isolating such small and infrequent particles as those that make up the losses, more especially in the tailing of gold and silver concentrators. If some method could be devised to concentrate the occasional particles, then this disadvantage would be removed and the method would become a distinct advantage in examining such products.

The method of studying tailing losses described in this thesis offer (1)suggestions for concentrating or isolating the minerals responsible for the losses, (2) suggestions for studying the concentrated or isolated fractions mainly by ratios established by chemical analyses, and (3) indications of the possibilities in studying refractory assocations in the concentrated fractions by aid of the microscope.

In planning the experimental work described in this paper the writer was of the opinion that if two fractions could be produced by two methods of concentration each method based upon different principles of concentration a study of the ratios of any two metals in each concentrate would indicate, to a more or less degree, the association of any of the two metals. It was, therefore, decided to

use magnetic separation and specific gravity concentration by means of heavy solutions for producing the two fractions.

The use of magnetic concentration limits the method, of course, to those ores in which the values are associated, or partially so, in minerals that have a magnetic susceptibility great enough and different from the associated gangue minerals to effect a separation. The results obtainable in establishing ratios of two metals on fractions produced by gravity methods alone, although lacking confirmation, would give some indication, no doubt, of mineral associations. However, the low grade manganese-silver ores of the Southwest are best adapted to the suggested method and these ores have been the source of the material used in this thesis.

One of the motivating ideas suggesting this experimental work was the desire to produce a method of direct attack in studying the treatment of Southwestern refractory ores. The usual procedure has been an indirect attack by treating the ores by various process and reagent combinations without much information as to the reason for low recoveries. With the cause for the losses known, a more scientific and concentrated approach to the solution of the problem is possible.

As an example of this hit and miss attack in studying the treatment of ores, the La Colorada tailing in

northern Mexico was subjected to all of the various methods of ore testing for a period of some ten to twenty years and at a very great expense. All the results were of no avail in pointing the way to a solution of the problem and the actual cause of low recoveries was not established until the association between the silver and manganese was established by T. G. Chapman[1] thus confining further testing to the finding of a method for saving the manganese associated with the silver or liberating the silver from its manganese association.

It was from this work of Doctor Chapman that the idea of this thesis originated. A search of the literature has revealed no information regarding this method.

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1 Chapman, T. G., Professional Report on Treatment of La Colorada Tailing, Aug. 1928.

CHAPTER II

APPARATUS, MATERIALS, AND ANALYTICAL METHODS USED

Apparatus

The Wetherill Magnetic Separator was used in the separation of the magnetic minerals. A sketch of this machine is shown in Fig. 1.

Separations by specific gravity methods were effected in a separatory funnel shown in Fig. 2. The ore was added to the funnel which contained a solution of acetylene tetrabromide having a specific gravity of 2.9. The pulp was agitated by means of a stirring rod and the heavy minerals allowed to settle. The solution was then drawn off and filtered to remove any suspended heavy minerals. The filtrate was returned to the funnel and the light fraction again agitated. This procedure was repeated as often as necessary to make the desired separation.

Materials

The tailings employed for this experimental work were produced from the treatment of typical Southwestern ores which contained refractory so-called "manganese-silver" associations. Two tailings were used, one from the flotation treatment of Pankey Mine ore, Socorro County, New Mexico, and the other from the tailing dump at La Colorada, Sonora, Mexico.

The results of one of the flotation tests used for the treatment of original Pankey ore to produce tailing for the experimental work are given in Table 1. The results given in this table compare favorably with the mill results obtained in the commercial treatment of this ore.

Table 1 - Results of flotation treatment of original Pankey ore.

	Weight, grams	Tons in 50	Assays, ounces per ton Gold	Silver	Tons x assays Gold	Silver	Per cent of total Gold	Silver
Heads	2000.0	50.00	0.22	5.86	11.20	293.2	100.0	100.0
Concentrate	15.0	0.375	19.17	352.58	7.19	132.2	64.2	45.1
Middling	17.1	0.427	2.48	51.03	1.06	21.8	9.5	7.4
Tailing	1967.9	49.198	0.06	2.83	2.95	139.2	26.3	47.5

Referring to Table 1, the flotation treatment of Pankey ore, when ground to 1 per cent plus 65-mesh, indicated that 64.2 per cent of the gold and 45.1 per cent of the silver were recovered as a finished concentrate assaying 19.17 and 352.58 ounces per ton gold and silver, respectively. The losses in the tailing, not including the middling, amounted to 26.3 per cent of the gold and 47.5 per cent of the silver. A cyanidation test indicated that 95 per cent of the gold and 50.7 per cent of the silver were soluble. This indicated that the gold is substantially free and therefore its recovery is a matter of degree of grinding employed. Thus eliminating the necessity of further consideration

of the gold in the tailing. The silver, however, seemed to be in part associated with some refractory mineral or minerals for in both flotation and cyanidation, about 50 per cent did not respond to treatment.

In the La Colorada tailing similar conditions have been revealed. Previous work on this material by T. G. Chapman and preliminary experimental work by the writer indicated that the gold is essentially free and can be dissolved by cyanide solutions if the ore is ground finely enough. Approximately 50 per cent of the silver occurs as finely disseminated argentite or proustite and can be recovered by either flotation or cyanidation, while the remaining 50 per cent is associated with a refractory mineral or minerals.

Methods of Analyses

Silver was determined by the usual fire methods. Manganese determinations were made by the bismuthate method and iron analyses by the method of Zimmermann-Rheinhardt. Due to the small quantities of some of the products available it was necessary to run both the iron and manganese determinations on the same sample. This was accomplished by fusing the sample with sodium carbonate and dissolving in hydrochloric acid, then making up to a known volume and taking aliquot parts for each determination.

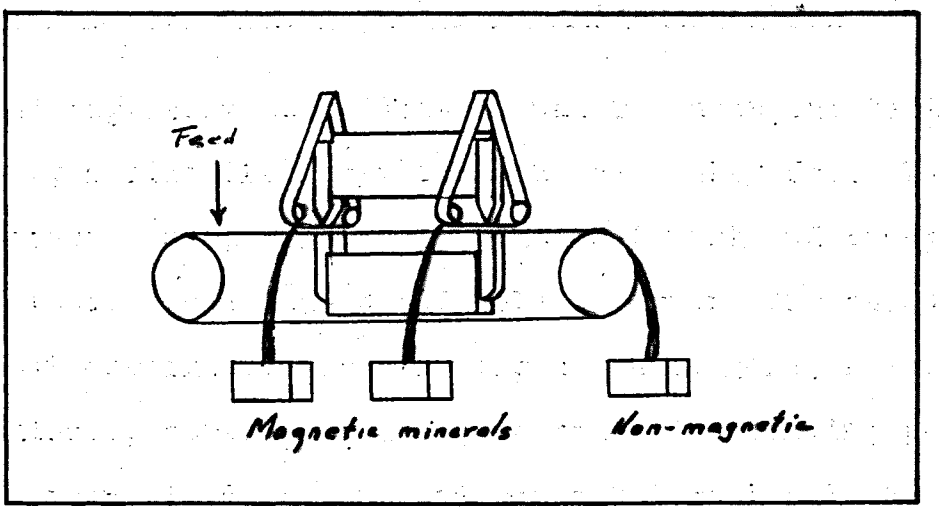

Fig. 1

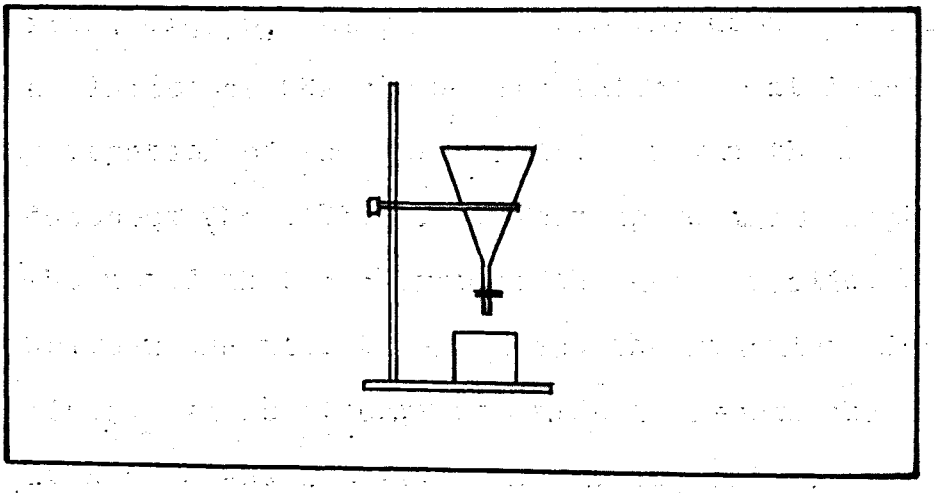

Fig. 2

CHAPTER III

EXPERIMENTAL WORK

Sizing-assay test on Pankey flotation tailing.

A sizing-assay test (Test 1) was run upon the tailing produced by a flotation operation on the Pankey Ore. The ore was ground to approximately minus 200-mesh and treated by flotation in a Fahrenwald cell employing the standard reagent combination for the flotation of gold, namely, lime, xanthate, aerofloat, and pine oil. The tailing produced was then sized on plus and minus 325-mesh and the granular minus 325-mesh material was separated from the slimes by washing with water. Each product was assayed for iron, manganese, and silver; the results are given in Table 2.

A graph, Fig. 3, was plotted from the data given in Table 2 and indicates the close association or at least similar segregation of the three metals in the three sized products of the tailing. Referring to this graph it should be noted that the iron is the most erratic, especially between the plus 325-mesh and the granular minus 325-mesh sizes. As no attempt was made to remove the metallic iron or magnetite from the tailing and as the fact that both of these materials are tough and do not tend to slime to the same degree as other iron minerals is believed to be the cause of the iron segregating in the

Table 2. Sizing-assay test of Pankey flotation tailing.

	Weight, grams	Ton in 50	Assays: Silver, ozs per ton	Assays: Manganese per cent	Assays: Iron per cent	Tons x assays: Silver ounces	Tons x assays: Manganese lbs	Tons x assays: Iron lbs	Per cent of total: Silver	Per cent of total: Manganese	Per cent of total: Iron
Heads	300.0	50	2.29	0.61	1.11	114.57	601.23	1113.57	100.00	100.00	100.00
+325 mesh	44.3	7.38	2.27	0.36	1.34	16.75	53.14	197.78	14.67	8.82	17.76
Granular -325 mesh	20.0	3.33	3.30	0.91	0.89	10.99	60.90	59.27	9.59	10.13	5.32
Slimes -325 mesh	235.7	39.29	2.21	0.62	1.09	86.83	487.19	856.57	75.79	81.04	76.91

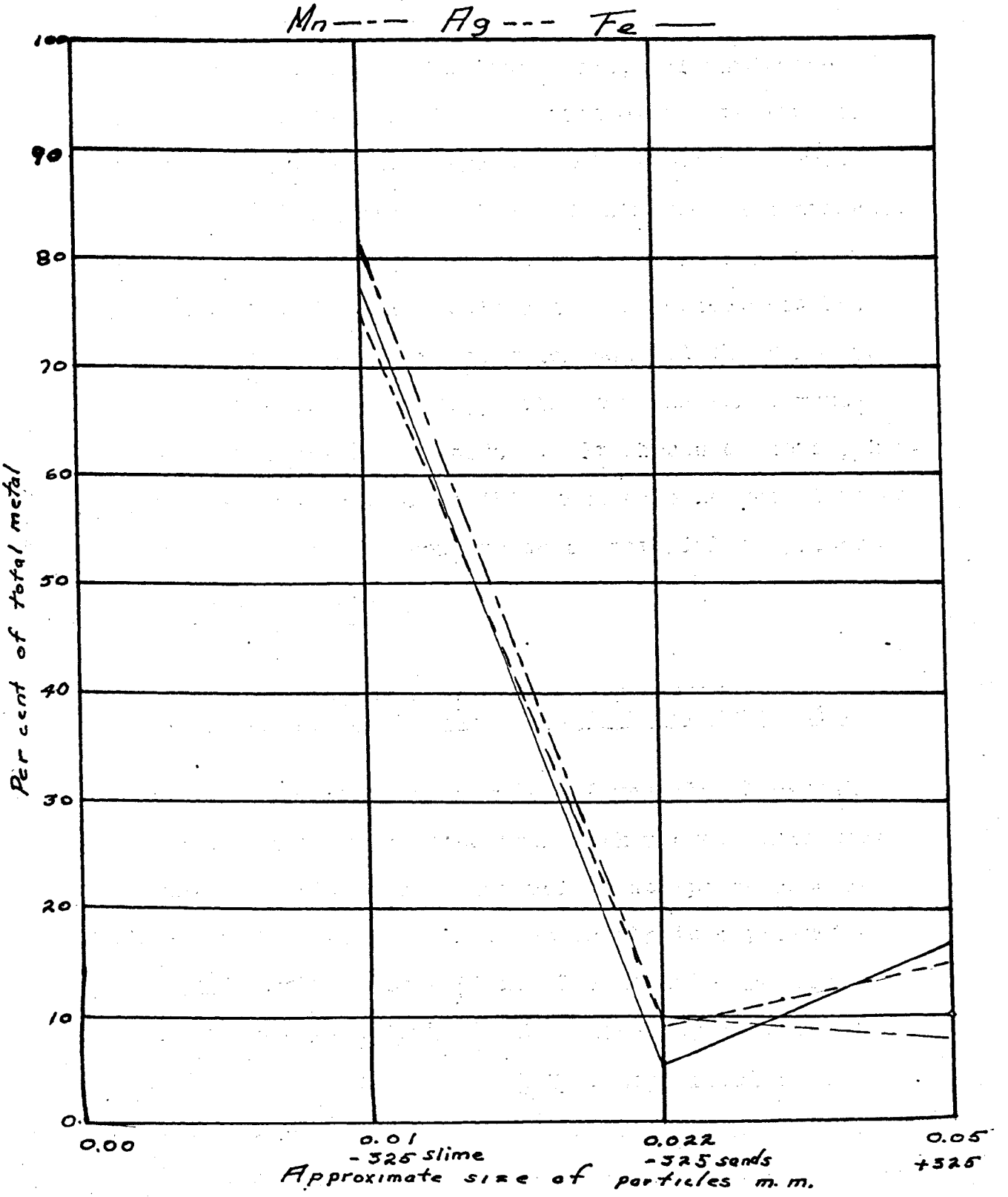
Mn--- Ag--- Fe ——
100
90
80
70
60
50
40
30
20
10
0.
Per cent of total metal
0.00
0.01
-325 slime
0.022
-325 sands
0.05
+325
Approximate size of particles m. m.

Fig. 3

plus 325-mesh sizes.

The fact that the silver, iron, and manganese segregated in the colloidal portion of the tailing to about the same degree suggests that either the three metals are associated together, within the same mineral, or that the various properties of the different minerals, assuming that the three metals are not associated but occur as separate minerals, which control the formation of colloidal slimes are approximately the same, would appear a remarkable coincident. It should be noted, however, that the results of this test give no more than an indication as the preponderance of material is present in the finest size.

Segregation of refractory manganese and iron minerals by magnetic concentration

The material used for Test 2 was plus 100-mesh flotation tailing produced from Pankey ore. This test was made to determine if any relationships or associations existed between the three metals in a product produced by magnetic separation. The detailed results of this test are presented in Table 3. Referring to Table 3, the results indicate that the metals concentrated in the magnetic material in the following percentages of the total amounts originally present in the feed to the magnetic machine; silver 13.38 per cent, manganese 17.36

Table 3. The results of segregating refractory minerals of Pankey tailing by magnetic concentration.

	Weight, grams	Assays: Ton in 50	Assays: Silver ozs. per ton	Assays: Manganese per cent	Assays: Iron per cent	Tons x Assays: Silver ounces	Tons x Assays: Manganese pounds	Tons x Assays: Iron pounds	Per cent of total: Silver	Per cent of total: Manganese	Per cent of total: Iron
Heads	200.0	50.	3.01	0.48	0.69	150.79	487.22	692.92	100.00	100.00	100.00
Magnetic Concentrates	3.6	0.9	22.43	4.70	3.58	20.19	84.60	64.44	13.38	17.36	9.30
Non-magnetic tailings	196.4	49.1	2.66	0.41	0.64	130.60	402.62	628.48	86.61	82.63	90.70

per cent, and iron 9.30 per cent.

Assuming first that all the manganese was associated with the silver a calculation made by the following proportion (13.38 : 17.36 :: x : 82.63) indicated that 63.6 per cent of the silver was associated with the manganese in the tailing of the magnetic concentrator. Since 13.38 per cent of the silver was obtained in manganese minerals of the magnetic product, based on the assumption given, 63.6 per cent was found in the non-magnetic material associated with manganese, the total silver associated with manganese amounted to 77 per cent thus leaving 23 per cent unaccounted for or in other words present in some form not associated with manganese. Following the same line of reasoning for iron in place of the manganese it is found that 130.05 per cent of the silver occurred in the non-magnetic product associated with the iron. Since this condition is obviously impossible, the results suggest the presence of at least two separate iron minerals, one obtained in the magnetic material and present also as included grains in the non-magnetic material, the other a non-silver bearing, non-magnetic mineral present in the tailing of the magnetic machine. The assumption made is open to error due to the fact that all the iron minerals contained in the magnetic product were assumed to be argentiferous. It is believed that some non-argentifer-

ous magnetite was present in the magnetic product.

Assuming a second condition, namely, that the association existed between all three metals the data indicated that 13.33 per cent of the total manganese plus iron concentrated in the magnetic product, which compares very favorably with 13.38 per cent of the silver concentrating in the same product.

Segregation of refractory manganese and iron minerals by both magnetic separation and heavy solution concentration

Following the indications obtained from the results of Tests 1 and 2, three tests numbered 3, 4, and 5 were made employing both magnetic and heavy solutions concentration to obtain segregations of refractory minerals to establish silver, manganese, and iron ratios.

The procedure which follows was used for each of the tests mentioned. A sample of tailing was sized and, in some cases deslimed before sizing, as neither magnetic or specific gravity concentrations are applicable to the separation of slimed minerals. After sizing, certain products were selected for treatment by the Wetherill magnetic machine which treatment produced a magnetic product and a non-magnetic product. Metallic iron and magnetite were separated from the magnetic product by means of a hand magnet. The non-magnetic product was

treated in a separatory funnel (Fig. 2) with acetylene tetrabromide as described in Chapter II. This treatment produced a "sink" product and a "float" product. All products were analyzed for iron, manganese, and silver.

The results of test 3, involving segregation from plus 150-mesh Pankey flotation tailing are given in Table 4; data of segregation obtained by treating plus 200-mesh Pankey flotation tailing are presented in Table 5; and the results of segregation obtained with deslimed minus 90-mesh La Colorada cyanide tailing are given in Table 6.

Employing the assumption previously mentioned, namely, that an association existed between all three metals, it was found that this association was not as apparent as indicated in the results of Test 2. In the plus 150-mesh magnetic product of Test 3 the silver concentrated amounted to 33.08 per cent of the total while only 14.35 per cent of the combined iron and manganese was found in the same product. Also in the sink product of the non-magnetic material there was 12.65 per cent of the total silver compared to 7.31 per cent of the combined iron and manganese. These results do not seem to bear out the assumption to the degree shown in Test 2, but indicate only a part of the iron and manganese associated with the silver. This condition was confirmed

Table 4. Data for Test 3 segregations - Pankey plus 150-mesh tailing .

	Weight, grams	Tons in 50	Assays			Tons x Assays			Per cent of total		
			Silver ozs per ton	Manganese per cent	Iron per cent	Silver ounces	Manganese pounds	Iron pounds	Silver	Manganese	Iron
Heads	150.00	50.00	2.96	0.94	0.64	148.00	938.45	638.85	100.00	100.00	100.00
Strongly Magnetic Minerals	0.75	0.25	3.89	-	-	0.97	-	-	0.65	-	-
Weakly Magnetic Minerals	1.50	0.50	53.72	6.28	4.80	26.86	62.80	48.00	18.08	6.69	7.51
Non-magnetic tailing	147.85	49.25	2.44	0.89	0.61	120.17	875.65	590.85	81.19	93.30	92.48
Heavy solution heads	147.85	49.25	2.23	0.89	0.60	120.27	876.96	559.24	100.00	100.00	100.00
Sink product	0.33	0.11	61.45	31.85	8.50	6.76	70.07	18.70	5.62	7.98	3.34
Float product	147.52	49.14	2.31	0.82	0.55	113.51	805.29	540.54	94.38	92.01	96.65

Table 5. Data for Test 4 segregations - Pankey plus 200-mesh tailing.

	Weight, grams	Tons in 50	Assays			Tons x Assays			Per cent of total		
			Silver ozs per ton	Manganese per cent	Iron per cent	Silver ounces	Manganese pounds	Iron pounds	Silver	Manganese	Iron
Heads	150.00	50.00	3.39	1.06	1.35	169.50	1065.21	1357.60	100.00	100.00	100.00
Strongly magnetic minerals	2.00	0.67	2.52	-	-	1.69	-	-	0.99	-	-
Weakly magnetic minerals	3.50	1.17	47.93	8.88	5.33	56.08	207.79	124.70	33.08	19.52	9.18
Non-magnetic tailing	144.5	48.16	2.32	0.89	1.28	111.73	857.42	1232.90	65.92	80.47	90.81
Heavy solution heads	144.5	48.16	2.34	0.89	1.25	112.64	846.79	1201.69	100.00	100.00	100.00
Sink product	2.27	0.75	31.21	5.25	4.27	23.41	78.75	64.05	20.77	9.27	5.33
Float product	142.2	47.41	1.88	0.81	1.20	89.23	768.04	1137.84	79.22	90.71	94.67

Table 6. Data for Test 5 segregations - La Colorada tailing.

	Weight, grams	Tons in 50	Assays			Tons x Assays			Per cent of total		
			Silver ozs per ton	Manganese per cent	Iron per cent	Silver ounces	Manganese pounds	Iron pounds	Silver	Manganese	Iron
Heads	150.00	50.00	2.88	1.83	1.11	144.28	1833.55	1172.33	100.00	100.00	100.00
Weakly magnetic minerals	5.80	1.93	17.50	9.42	9.18	33.77	362.61	355.15	23.40:	19.77	30.29
Non-magnetic tailing	144.20	48.07	2.30	1.53	0.85	110.51	1470.94	817.19	76.60:	80.22	69.70
Heavy solution heads	144.20	48.07	2.31	1.53	0.85	111.29	1470.94	817.19	100.00:	100.00	100.00
Sink product	6.92	2.37	11.67	2.48	2.48	27.66	117.55	120.34	24.90:	7.99	19.72
Float product	137.31	45.70	1.83	1.46	0.76	83.63	1353.39	896.85	75.10:	92.01	85.27

by the magnetic product of the 200-mesh material produced in Test 4, where 18.08 per cent of the silver concentrated in the magnetic product to 7.31 per cent of the iron plus manganese. However, the sink product of Test 4 contained 4.56 per cent silver and 5.26 per cent of the combined iron plus manganese which confirms the results of Test 2. Although dealing with a different tailing, namely the La Colorada tailing, the results on the magnetic product confirm the results of Test 2, for in this product there was 23.40 per cent of the silver compared with 25.03 per cent of the iron plus manganese. In the heavy solution sink 19.07 per cent of the silver concentrated to 11.31 per cent of the combined iron plus manganese which tends to confirm Test 3 results.

CHAPTER IV

CONCLUSIONS

The data presented in Test 1 give what may be considered as qualitative evidence that the silver, manganese, and iron segregated in the Pankey colloidal slime to approximately the same degree. This condition indicated, as previously mentioned that either the three metals occur within the same mineral, or in three separate minerals each having approximately the same properties affecting sliming.

The results of Test 2 are considered quantitative and show that the three metals, namely, silver, manganese, and iron were present in the magnetic product. Since no known silver mineral has sufficient magnetic susceptibility to explain its presence in the magnetic product then it follows that the silver must necessarily be combined with the iron, manganese or both. If the iron and manganese occur as two separate minerals it is not probable that each would segregate to approximately the same extent in the magnetic product since this condition would imply equal liberation by grinding, and furthermore each mineral must have sufficient magnetic susceptibility to enter the magnetic product. The evidence presented from the results of Test 2 indicate, therefore, an association between the silver, iron, and manganese at an approximate ratio one silver to one combined iron and manganese when expressed as per cents of the total metals recovered in the magnetic

product.

The data of Tests 3 to 5, inclusive, present confirmatory quantitative data in that two segregations were effected one by magnetic separation and the other by specific gravity concentration. Tests 3 and 4 involved Pankey tailing and the results on both magnetic and gravity fractions confirmed the fact that both manganese and iron were present in those fractions. The ratios of silver to combined manganese and iron, however, varied as the size of feed varied to the magnetic machine. In Test 2 the ratio of silver to combined manganese and iron was approximately 1 to 1 when expressed as per cents of total metals recovered as magnetic product but in Tests 3 and 4 the ratios were 2.3 to 1 in each case. In the "sink" products of Tests 3 and 4, however, the ratios of silver to combined iron and manganese were 1.7 to 1, and 1.2 to 1 respectively, showing that the relative amount of manganese plus iron increased as the size of the feed to the specific gravity concentrator decreased.

The evidence that the silver, manganese, and iron were associated within the same mineral would have been fairly conclusive if these variations had not been found in the ratios of silver to manganese, to iron, or to the combined iron and manganese. However, the data indicate rather definitely some association between the three metals although it is quite probable that more than one

iron mineral exists in both tailing treated and possibly more than one manganese mineral. The association of manganese and iron indicated by the experimental work described in this paper raises a question as to the status of the well known so-called "refractory silver-manganese" association. The data presented indicates that this association, at least in two Southwestern ores, is a "refractory silver, manganese-iron association. The data presented also gives at least a hint as to the reason for repeated failures in floating Southwestern manganese minerals. The reason may be due to iron occurring with the manganese in a mineral or minerals not definitely established.