Process Mineralogical Consulting Ltd.

Gravity Concentration and Flotation Preliminary Mineralogy / Mineral Processing Study of Sample 2 (massive carbonatite ore) from the Good Hope Nb Project

Prepared for

PLATO GOLD

AUG2019-05
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1.0 SUMMARY

One sample, identified as ‘Sample 2’ (39.8 kg), was submitted to PMC Ltd. for mineralogical analysis and an initial mineral processing preliminary evaluation for the concentration of Niobium minerals. The sample was provided for initial characterization by a size-by-size mineralogical study, and the results were used to design a gravity concentration and flotation testing program aiming at evaluating an initial pyrochlore concentration flowsheet. The submitted sample was a composite of crushed ¼ HQ drill core representing an approximately 22 m long intersection within a “massive” carbonatite unit. The original sample was finely crushed to nominally -2 mm, homogenized and split into several charges for further studies. The charge studied in the Size-by-Size study was milled to a P_{80} of 300 microns.

To understand the gravity and flotation test results, the conclusions previously obtained in the Size-by-Size study (AUG2019-05, December 17, 2019) are summarized:

1. Sample 2 is predominantly composed of calcite (76.3 wt.%), dolomite (6.5 wt.%), and apatite (7.5 wt.%). Accessory phases (<1wt.%) are **strontianite ((Sr, Ca)CO3), columbite and pyrochlore-group minerals, rare earth-bearing minerals, zircon**, and sulphates.

2. The niobium grade in this sample, as determined by fractional assays (fusion XRF; Table 2), is 0.17% Nb (or 0.24% Nb_2O_5), and it is contained predominantly in pyrochlore, which constitutes up 0.46 wt.% of the sample and trace amounts of ferrocolumbite.

3. The pyrochlore has a significant coarse-grained (P_{80} of ~200 µm) component and is predominantly liberated (76.7 wt.% of pyrochlore liberated by surface area exposure).

4. Approximately 21.5 wt.% of the pyrochlore occurs as free grains, while 7.4 % form binary grains and 14.4% form ternary grains (predominantly with carbonates and minor apatite) and 56.7% form complex particles composed of 4 or more phases.

5. The mass-balanced metal distribution for this sample indicates a bimodal Nb distribution with approximately 41% of the Nb reporting to the >150 µm fractions and 35.8% reporting to the <75 µm fractions. This supports the initial work done by Roger Mitchell, which was summarised in the PMC Mineralogical Note dated September 05, 2019.

6. Pyrochlore and calcite showed a similar PSD, indicating that these have parallel breakage characteristics. However, there was a distinction in the distribution of particles between 10 and 50 µm, where calcite has more fine particles by weight percent than pyrochlore.

Gravity concentration with Mozley table (G-1)

A representative portion of ~2000g was riffled for the gravity concentration study and was milled to a P_{80} of 106 µm. From the milled material, a representative split (100g) was riffled for whole-rock analysis, including Nb by fusion XRF. MSA laboratories completed all assays. The remaining sample was wet screened at 75 µm. From each size fraction, a representative portion was taken for assay, and the remainder was concentrated using the Mozley Table. For the >75 µm material, the V-profile deck was employed, while for the <75 µm, the flat deck was used.

Concentrate, Middling and Tailings products were collected from each table concentration test. These products were dried and weighed, with an assay cut taken for whole rock analysis and Nb_2O_5 by fusion XRF.

Gravity and flotation exploratory test 1 (F-1)

The amenability for the flotation of Sample 2 was evaluated using a rougher-cleaner flotation test configuration. With the information obtained from the gravity concentration test, it was decided to preconcentrate the sample using a Wilfley-Holman shaking table. For this study, an initial mass of 6 kg was employed.

Results of the mineralogical Size-by-Size study (PMC Ltd. report “A Size-by-Size Mineralogical Characterization of Sample 2 [massive carbonatite ore] from the Good Hope Nb project”, December 17, 2019), indicated that the theoretical size of total liberation of the pyrochlore was around 80 µm. Based on this information, the target P_{80} of 120 µm was chosen to avoid overgrinding and for better table concentration performance.

A laboratory rod-mill was used for the grinding of the feed at 65% solids. The ground material was further fed onto the shaking table. Operating variables (tilt, angle, and wash water feed) were adjusted visually until an even concentrate pattern on the table’s surface was achieved. Rougher table Concentrate and Middling were saved for flotation. The Tailings were collected and submitted to a Scavenger table concentration to assess further recoveries. A Scavenger Concentrate, Middling and Tailings were produced.

The flotation testwork comprised a magnetic separation, sulphide rougher flotation, pyrochlore rougher flotation and a 1st cleaner pyrochlore flotation. The equipment employed was a Denver D12 flotation cell. The remaining cleaner stage was carried out using the Mozley Gravity Table due to froth stability issues experienced in the 2nd Cleaner stage during flotation. The flowsheet of the testwork can be consulted in Appendix A.

Gravity and flotation exploratory test 2 (F-2)

After evaluating the results of F-1, the testwork processing flowsheet was modified to attempt to optimise the recovery of the shaking table. A similar configuration of preconcentration was employed, but a size classification of the sample was carried out before the gravity concentration by wet screening the Table Feed material at a screen size of 106 µm. The first target P_{80} remained the same.

A “coarse” and a “fines” table concentration was subsequently completed for each size fraction (>106 µm and <106 µm), with a Rougher and Scavenging for each; a total of four shaking table concentration tests were achieved. At the end of the test, the slimes were separated from the settled particles. Combined Concentrates and Middling from each table were collected for the flotation test. Tailings were filtered, dried, and had a representative sample taken for WRA +Nb assay.

The coarse (>106 µm) preconcentrate was milled in the laboratory rod-mill until a P_{100} of 106 µm was attained. The preconcentrated fines (<106 µm) were ground for one minute to obtain a fresh surface. All table Concentrate and Middling were combined for the flotation test.

Flotation followed the same stages as in F-1: magnetic separation, sulphides rougher flotation, pyrochlore rougher flotation and two cleaner stages.

Major findings

The following summary is based on tables and figures presented throughout this report.

Results of the Mozley Table concentration (G-1):

1. Most of the pyrochlore reports to the particle size <75 µm (63.5% wt.), while the rest was in the coarse fraction (36.5% wt.). The grade of the >75 µm size fraction increased compared to the feed grade, while the opposite occurred for the fines (Table 1). The increased grade would suggest that it is easier to reject gangue by classification methods at coarse particle sizes and that gangue minerals are more friable and tend to break preferentially.

2. The sized gravity concentrates (tips) obtained for Nb_2O_5, had an enrichment ratio of 19.3 for the >75 µm size fraction and 13.7 for the <75 µm fraction with respect to the sample head. Titanium-bearing minerals (approximated by TiO_2) had a similar enrichment ratio (21.4 for the >75 µm and 13.6 for <75 µm), suggesting that these minerals have similar size and distributions.

3. While the concentrate (tips) grades of pyrochlore were high in both sized fractions, pyrochlore mainly reported to the Middling products in both fractions (Table 2). Having more pyrochlore mass reporting to the Middling may be due to a combination of the relative size of the particles and the presence of complex particles of 4 or more (lighter) constituents (see also Roger Mitchell's pyrochlore images). Apatite and other phases tend to have a close association with pyrochlore, thus reducing the overall particle density and, therefore, their settling rate in a gravity concentration process.

Results of the gravity and flotation exploratory test F-1:

1. Gravity concentration using a shaking table was found to be a viable course to pre-concentrate the ore mineral in this sample. Gravity concentration recovery was up to 70.7% with a rougher and scavenging table, at three times the head grade when concentrates and middlings are taken into account (Table 4). However, a significant amount of Nb_2O_5 was lost to the fines or slimes (29.3% wt.) using this method.

2. Mineral flotation method was able to recover up to 66% of Nb_2O_5 in a first cleaner stage, with a grade of 2.7% Nb_2O_5 and 12.6% P_2O_5 (Table 5, Figure 1).

3. For an initial exploratory test, the results demonstrate that the Nb is recoverable by a combination of gravity and flotation concentration.

4. The liberation analysis of three tailings products, the Wilfley Table, Nb_2O_5 Rougher, and Nb_2O_5 Cleaner, revealed the following:

    4.1. In the Wilfley Table tailings, 70% wt. of the Nb-bearing minerals are well liberated (≥ 80% of the mineral is exposed); however, the particles' size is less than 53 µm (Table 12), at which most gravity concentration methods struggle to obtain acceptable recoveries. Nearly 14% of the pyrochlore in this product is locked in gangue with particle size >53 µm, and the remaining are middling and sub-middling particles (Figure 6).

    4.2. At the rougher flotation stage, pyrochlore losses are attributed to fine, liberated, and middling particles (46.6 and 31.1wt.% of the total pyrochlore, respectively). The most substantial part of it constitutes liberated pyrochlore grains less than 20 µm in size observed in the tailings. Particles in size range of 20-150 µm occur as released grains and middlings, with an overall account of 9.6% of locked pyrochlore (Table 13).

    4.3. Pyrochlore found in the cleaner tails (Table 14) were primarily classified as middlings (48.1% wt. of the pyrochlore), with lesser amounts as liberated (26.8 % wt. of the pyrochlore), and sub-middlings (17.0% wt. of the pyrochlore) particles.

5. The F-1 MT Concentrate contains additionally a significant amount of apatite, which also concentrated with the pyrochlore. Its presence dilutes the overall grade of the bulk concentrate but also adds considerable value as a secondary product stream. The mineral abundance of the MT Concentrate estimated 24% of apatite (Table 10).

6. The F-1 MT Concentrate also contains a proportion of zirconium bearing minerals (i.e. zircon and potentially baddeleyite), which were concentrated during the gravity work.

Results of the gravity and flotation exploratory test F-2:

1. There was more rejection of gangue in the gravity concentration of the coarse fraction (>106 µm), compared to the fines table, with a grade of 0.64% Nb_2O_5 and a recovery of 88.2% in the coarse table feed (Table 8), which accounts for 52.1% of the overall recovery by gravity (Table 7). The grade of the losses in the >106 µm fraction was 0.05% Nb_2O_5.

2. The fine fraction concentration indicated more losses (61.6 wt.% of the Nb_2O_5 of the <106 µm, 21.5% of the gravity circuit feed) due to the small grain size of the pyrochlore (Table 9). The grade of the final losses in the <106 µm fraction grade was 0.12% Nb_2O_5.

3. Overall, the Concentrate and Middling collected from both shaking tables contained 71.5% of the pyrochlore (Table 6)—a slight improvement from test F-1, which accounted for 70.7% in the gravity circuit.

4. The recovery performance in the flotation circuit of F-2 was lower in comparison to the F-1 test. There was a quick rejection of pyrochlore in the rougher stage in the pyrochlore circuit due to an increased addition of acid. The total recovery of Nb_2O_5 in the F-2 test (gravity and flotation) to the final concentrate was calculated as 7.0%, while for P_2O_5, it was 0.6% (Table 6).

5. The grade of the obtained flotation concentrate was reported as 10.7% Nb_2O_5 and 11.9% P_2O_5 (an approximation for apatite) by WRA – XRF assay. Despite the low recovery, the flotation test F-2 performed better than F-1 at demonstrating that it is possible to get a higher-grade concentrate through flotation.

Conclusions

The initial preliminary study yields encouraging results that provide a broad understanding of the ore; however, the limited number of tests conducted does not allow for a conclusion regarding the quality of concentrate that is possible to achieve. Despite this, valuable general information was obtained, at the definition level that is expected of an initial preliminary study:

- Pyrochlore is the only Nb-bearing mineral identified in this sample.

- The pyrochlore is not considerably ultrafine, as ~4% of the pyrochlore grains are <20 µm (as per the results of the Size by Size study from December of 2019). However, due to the brittle nature of pyrochlore, the size reduction of particles does preferentially produce fines with additional regrinds.

- There does not appear to be any severe metallurgical concerns that would impede the recovery of the pyrochlore to a flotation concentrate. Nonetheless, not enough reagent schemes were tested in these two tests; only a cationic flotation was explored.

- A typical flowsheet and current technology, although complex as is common for Nb recovery, might be enough for the recovery of pyrochlore in this sample.

- Apatite and zirconium-bearing minerals were also concentrated on both tests. The concentration of these pay minerals may offset a significant portion of operating costs if further resources are found and developed.

There is a variety of flowsheet parameters that need to be studied and evaluated:

- The gravity feed in two size fractions for preconcentration in the Wilfley Table improved recovery in the coarse fraction; however, there continued to be Nb losses to the tailings in the fines fraction. If further gravity preconcentration is desired to be pursued, the challenges are in the recovery of very fine particles (less than 53 um).

- The reagent scheme used for this test was the most commonly used for this type of pyrochlore ore. There are two types of chemistry used for pyrochlore flotation: anionic and cationic; the latter was used in this preliminary test program. Suitability of the second type of flotation should be investigated.

- A full scoping study typically will focus on various reagent combinations and the identification of tests that provide a better metallurgical performance in a rougher flotation test. Since only one reagent chemistry was applied, it is necessary to carry out further test work to narrow the reagent suite to something suitable for this ore. This is particularly important for the flotation of non-sulphide minerals for which their selective flotation is usually much more complicated than the flotation of sulphide ores.

- The flotation testwork of this preliminary study included one cleaner stage. In contrast, a typical flotation circuit includes up to 5 or more cleaner stages, which further increase the grade in the concentrate. The obtention of high-grade concentrates is usually investigated in the late stages of a flotation test program and after several rougher flotation tests to obtain enough sample for performing cleaner flotation tests. To move towards this step, a much larger sample is required.

Recommendations

1. Perform a complete flotation scoping study on a much larger sample (~100kg) with the selection of a reagent scheme. This type of investigation is done in a comparative rougher scoping test before any other parameters are optimized. The results obtained will establish an order-of-magnitude level of pyrochlore recovery and provide an indication of the quality of the concentrate.

2. The gravity and flotation tailings could be investigated in size by size manner to evaluate where the losses occurred.

3. Losses of fine pyrochlore could potentially be recovered with an optimization of the operating parameters of the Wilfley Table for slimes, which would be part of a more robust sampling and testing program. The small improvement in the gravity circuit in F-2 indicates that an increased recovery can be gained through attention detail to size constraints, which provides a platform to carry on further testing once additional resources and samples are available.

4. Additional gravity concentration method that allows recovery of fines could also be investigated in conjunction with further test work. These may include jigs, spirals, and centrifugal concentrators (Knelson and Falcon).

5. Pyrochlore is primarily associated with apatite with only minor amounts associated with the magnetic minerals (magnetite, hematite), as discussed in the Size-by-Size report (December 17, 2019). The exploration of sorting techniques to reject magnetics, which accounts for 2% of the sample mass and is coarsely grained, may assist in increasing concentrate grades in gravity concentration.

6. Size by size investigation of the flotation tails would clarify the cause of the losses and poor recoveries. Integrating a regrind could increase recoveries in the flotation circuit if the losses are due to liberation factors.

7. Conducting a direct flotation testwork without gravity preconcentration can provide a direct comparison of the recovery of fine pyrochlore (≥ 20 < 53 µm) against gravity methods.

8. Further characterisation of the concentrate along with additional test work to optimise a strategy to produce an apatite concentrate will imply an additional benefit to the development of this deposit.

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Yolanda Aguilar-Hinojosa, M.Eng., E.I.T.
Project Metallurgist
Process Mineralogical Consulting Ltd.

Geoffrey R. Lane, B.Sc., P.Geo
Chief Mineralogist
Process Mineralogical Consulting Ltd.

Lab work carried out by:
Yolanda Aguilar-Hinojosa, Project Metallurgist;
Thomas Chudy, Senior Mineralogist;
Jason Redpath, Principal Technologist
James Soriano, Principal Mineral Technician.
Nazanin Joorabcian, Minerals Technician

Consulting Metallurgist Dan Lang, Grade Recovery Strategies

2.0 MATERIAL BALANCES

Mozley Table gravity concentration (G-1)

Table 1. Material balance of the sized "Sample 2" material in test G-1.

Product	Mass Distribution (%)	Grade (%)				Distribution (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
+75	27.46	0.27	1.86	4.08	0.29	36.47	17.76	34.99	43.48
-75	72.54	0.18	3.26	2.87	0.14	63.53	82.24	65.01	56.52
Head (Calc)		***0.20***	***2.88***	***3.20***	***0.18***	100.0	100.0	100.0	100.0
Head (Assay)	**100**	**0.21**	**2.83**	**3.21**	**0.20**				

Table 2. Material balance of the Mozley table concentration products of "Sample 2" in test G-1.

Product	Mass Distribution (%)	Grade (%)				Distribution (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
+75 Mz Tail	25.13	0.11	1.34	2.59	0.14	13.6	**11.7**	**20.3**	**19.2**
+75 Mz Midd	2.01	1.67	7.84	16.16	1.55	**16.5**	5.5	10.1	17.0
+75 Mz Tip	0.32	**4.06**	**5.35**	**46.06**	**4.27**	6.3	0.6	4.5	7.3
-75 MZ Tail	41.68	0.07	1.31	2.07	0.05	14.4	19.0	26.9	11.4
-75 Mz Midd	29.44	0.20	5.44	3.08	0.15	**29.0**	**55.6**	**28.3**	**24.1**
-75 Mz Tip	1.42	**2.88**	**15.52**	**22.11**	**2.73**	20.1	7.7	9.8	21.1
Head (calc)	100	*0.20*	*2.88*			100.0	100.0	100.0	100.0
Head (assay)		0.21	2.83						

Gravity and flotation exploratory test 1 (F-1)

Table 3. Material balance of the gravity-flotation concentration products in test F-1.

Product Name	Weight (%)	Grade (%)			Recovery (%)		
		Nb_2O_5	P_2O_5	TiO_2	Nb_2O_5	P_2O_5	TiO_2
Mozley Con	0.3	20.6[c]	9.9 [c]	6.50[c]	26.5	1.0	9.9
Mozley Midd	0.2	1.48[b]	26.6 [b]	1.49[b]	1.6	2.3	1.9
Mozley Tails	2.5	0.70	11.6	0.52	7.8	10.2	6.8
Pyrochlore Cl Tails	8.3	0.34	6.9	0.68	12.6	20.2	29.6
Pyrochlore Ro Tails	2.3	0.53	6.4	0.54	5.5	5.3	6.6
Mag Con	0.4	NA[a]	NA[a]	NA [a]	NA	NA	NA
Py Ro Con	0.8	0.08	0.7	0.26	0.3	0.2	1.0
Scavenger Con	2.5	1.06	9.7	1.00	11.7	8.5	13.0
Scavenger Midds	10.0	0.11[b]	0.5[b]	-	4.7	1.7	-
Scavenger Tails	72.8	0.09	2.0	0.08	29.3	50.7	30.7
Calculated Head	100	0.22	2.83	0.19	100	100	99.5
Direct Head	100	0.21	2.83	0.19			

[a] No assays; losses assumed as negligible.
[b] Calculated grade.
[c] Calculation based on measured mineral abundance by TIMA.

Table 4. Material balance of the Wilfley Table gravity circuit in test F-1.

Product Name	Weight (%)	Grade (%)			Recovery (%)		
		Nb_2O_5	P_2O_5	TiO_2	Nb_2O_5	P_2O_5	TiO_2
Table Feed	100	0.22	2.83	0.19	100	100	100
Rougher Con + Midd	14.8	0.82 [a]	7.5	0.7	54.3	39.1	55.9
Scavenger Con	2.5	1.06	9.72	1.00	11.7	8.5	13.0
Scavenger Midds	10.0	0.11 [a]	0.49 [a]	-	4.7	1.7	-
Scavenger Tails	72.8	0.09	1.97	0.08	29.3	50.7	30.7
Combined WT Con + Midds	27.2	0.58	5.13	0.48	70.7	49.3	68.9

[a] Calculated grade

Table 5. Material balance of the flotation circuit in test F-1.

Product Name	Weight (%)	Grade (%)			Recovery (%)		
		Nb_2O_5	P_2O_5	TiO_2	Nb_2O_5	P_2O_5	TiO_2
Flotation Feed	100	0.82 [b]	7.5	0.74	100	100	100
Mag Con	2.6	NA [a]	NA [a]	NA [a]	NA	NA	NA
Py Ro Con	5.1	0.08	0.7	0.3	0.5	0.46	1.80
Pyrochlore Ro Tails	15.8	0.53	6.4	0.5	10.2	13.6	11.6
Pyrochlore Cl Tails	56.0	0.34	6.9	0.7	23.1	51.7	51.5
Pyrochlore Cl Con	20.4	2.66	12.6	1.2	66.2	34.3	32.3
Pyrochlore Circuit Tails	71.8	0.38	6.8	0.6	33.4	65.2	63.0

[a] No assays; losses assumed as negligible
[b] Calculated grade

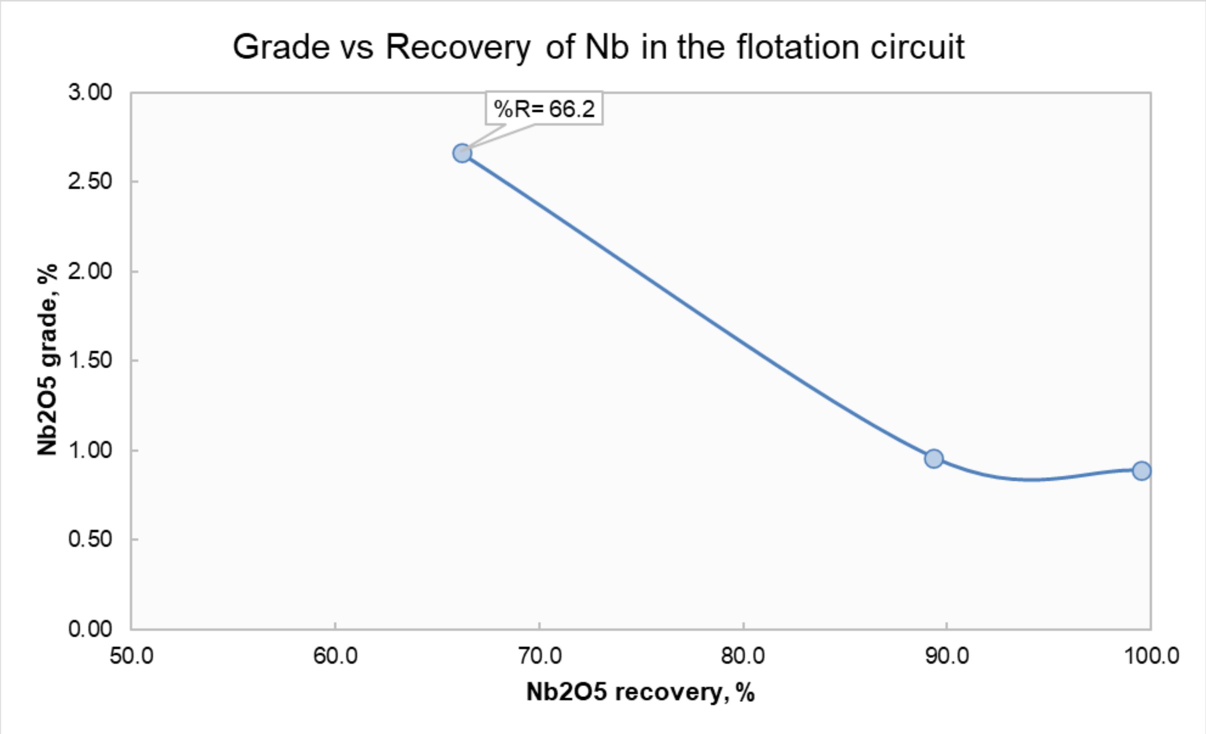

Figure 1. The Nb_2O_5 grade-recovery curve of the flotation circuit in test F-1.

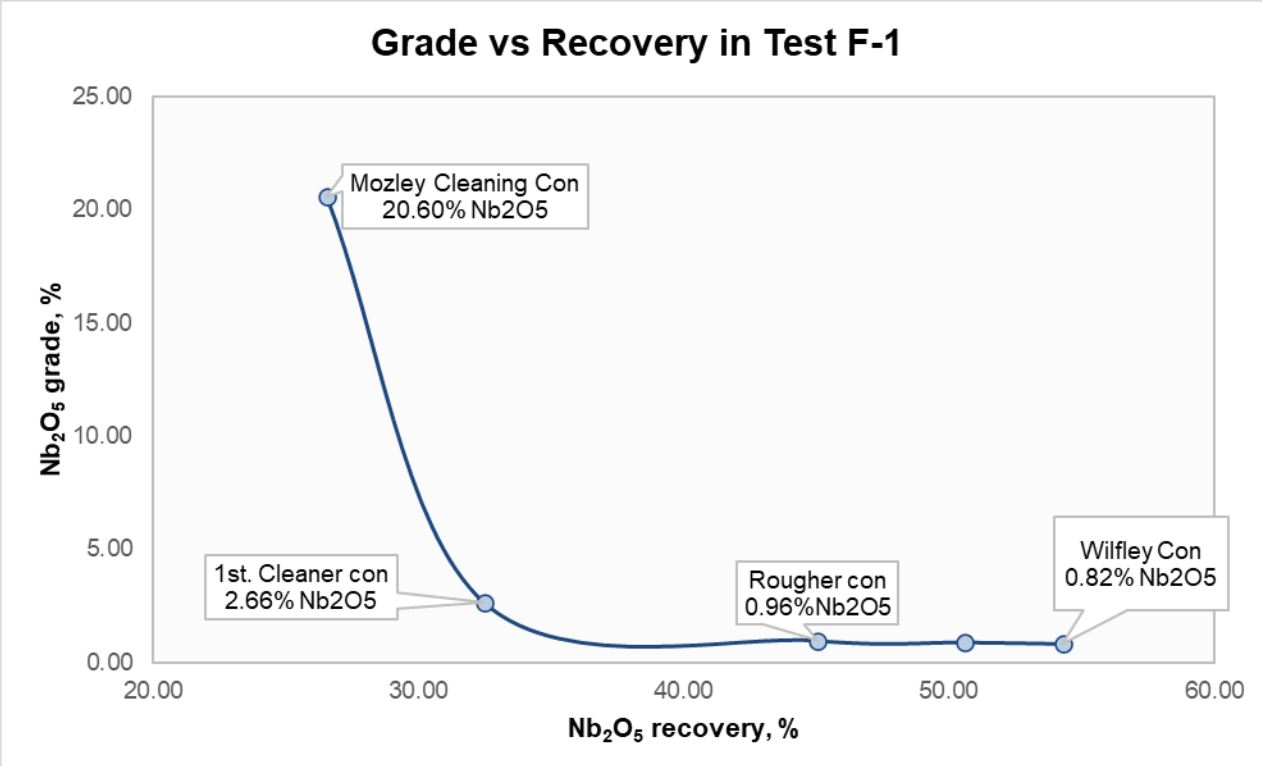

Figure 2. The Nb_2O_5 overall grade-recovery curve of the gravity and flotation circuit in test F-1.

Gravity and flotation exploratory test 2 (F-2)

Table 6. Material balance of the gravity-flotation concentration products in test F-2

Product Name	Weight (%)	Grade (%)				Recovery (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
Cleaner Con	0.15	*10.7*	*11.9*	*5.9*	*6.57*	7.0	0.6	0.2	4.4
Pyrochlore Total Cleaner Tails	7.78	0.91[a]	10.8[a]	3.85[a]	0.91[a]	30.8	27.2	8.3	31.4
Flotation Slimes	2.1	0.60	4.4	4.3	0.5	5.5	3.0	2.5	5.1
Pyrochlore Ro Tails	14.8	0.42	5.4	2.9	0.4	27.0	25.9	12.1	26.2
Pyrite Con	1.1	0.14	1.1	52.5	0.15	0.7	0.4	16.2	0.7
Magnetics Con	0.6	0.21	1.2	78.7	1.91	0.6	0.2	13.9	5.4
+106 Scavenger Tailings	32.2	0.05	1.0	1.9	0.06	7.0	10.4	17.4	8.6
-106 Scavenger Tailings	41.2	0.12	2.4	2.6	0.10	21.5	32.3	29.4	18.3
Calculated Head	100.0	0.23	3.09	3.60	0.23	100.0	100.0	100.0	100.0
Direct Head	100.0	0.20	2.82	3.15	0.19				

[a] Calculated grade

Table 7. Material balance of the gravity circuit in test F-2.

Product Name	Weight (%)	Grade (%)				Recovery (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
Calculated Head	100.0	0.23[a]	3.09[a]	3.60[a]	0.23[a]	100.0	100.0	100.0	100.0
+106 Rougher Con + Midds	9.0	1.10	8.39	11.40	1.15	42.9	24.4	28.5	45.8
+106 Scavenger Con + Midds	9.6	0.22	4.19	3.08	0.26	9.21	13.1	8.3	11.1
-106 Rougher Con + Midds	3.8	0.56	8.02	5.70	0.53	9.20	9.83	6.00	8.90
-106 Scavenger Con + Midds	4.2	0.23	5.71	3.10	0.22	4.17	7.72	3.60	4.07
+106 Scavenger Tailings	32.2	0.05	1.00	1.94	0.06	6.99	10.4	17.4	8.6
-106 Scavenger Tailings	41.2	0.12	2.42	2.56	0.10	21.5	32.3	29.4	18.3
Combined Tailing	73.4	0.09[a]	1.80[a]	2.29[a]	0.08[a]	28.5	42.7	46.7	26.8

[a] Calculated grade
Note: The calculated head used represents the balance in the entire F-2 test. Recoveries in the gravity circuit do not sum 100% due to discrepancies in the assay grades between the gravity and flotation stages.

Table 8. Material balance of the "coarse" table concentration in test F-2.

Product Name	Weight (%)	Grade (%)				Recovery (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
+106 Rougher Con + Midds	17.7	1.10	8.39	11.40	1.15	72.6	50.9	52.6	69.9
+106 Scavenger Con + Midds	19.0	0.22	4.19	3.08	0.26	15.6	27.3	15.3	17.0
+106 Scavenger Tailings	63.3	0.05	1.00	1.94	0.06	11.8	21.8	32.1	13.1
Combined Concentrates + Middling	36.7	0.64[a]	6.21[a]	7.09[a]	0.69[a]	88.2	78.2	67.9	86.9
+106 Head (Calc)	100.0	0.27[a]	2.91[a]	3.83[a]	0.29[a]	100.0	100.0	100.0	100.0

[a] Calculated grade

Table 9. Material balance of the "fines" table concentration in test F-2.

Product Name	Weight (%)	Grade (%)				Recovery (%)			
		Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2	Nb_2O_5	P_2O_5	Fe_2O_3	TiO_2
-106 Rougher Con + Midds	7.7	0.56	8.02	5.70	0.53	26.4	19.7	15.4	28.5
-106 Scavenger Con + Midds	8.5	0.23	5.71	3.10	0.22	12.0	15.5	9.2	13.0
-106 Scavenger Tailings	83.8	0.12	2.42	2.56	0.10	61.6	64.8	75.4	58.5
Combined Concentrates + Middling	16.2	0.39[a]	6.81[a]	4.34[a]	0.37[a]	38.4	35.2	24.6	41.5
-106 Head (Calc)	100.0	0.16[a]	3.13[a]	2.85[a]	0.14[a]	100.0	100.0	100.0	100.0

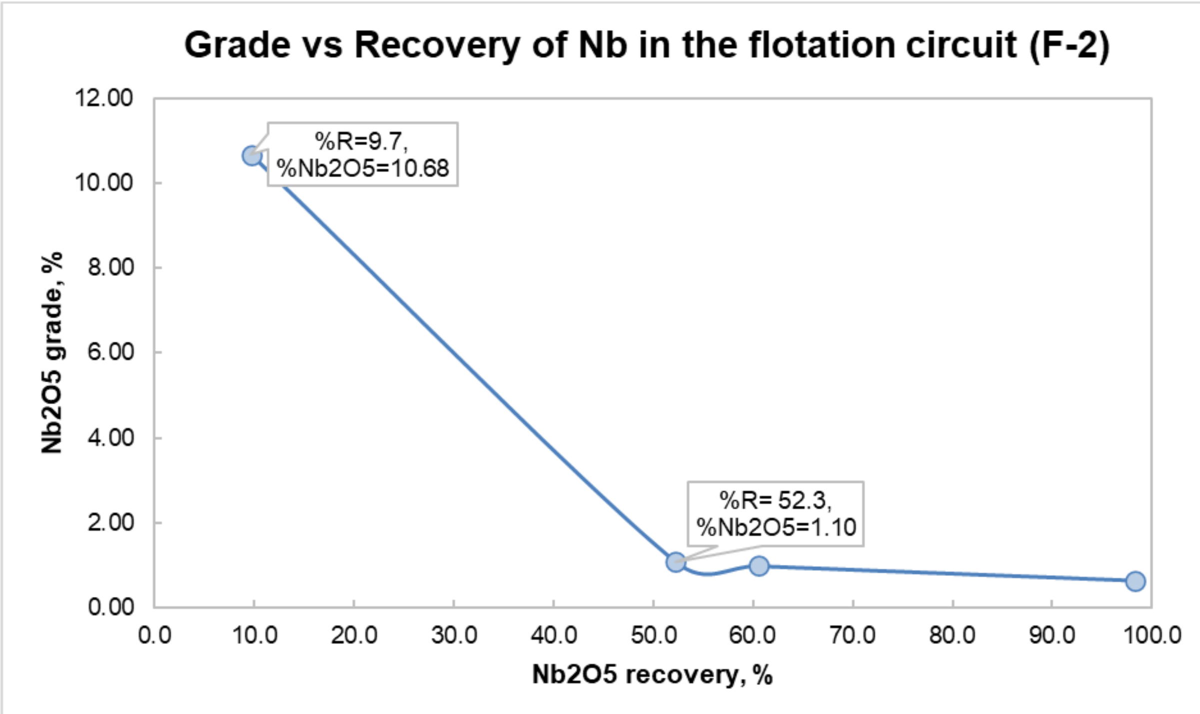

Figure 3. The Nb_2O_5 grade-recovery curve of the flotation circuit in test F-2.

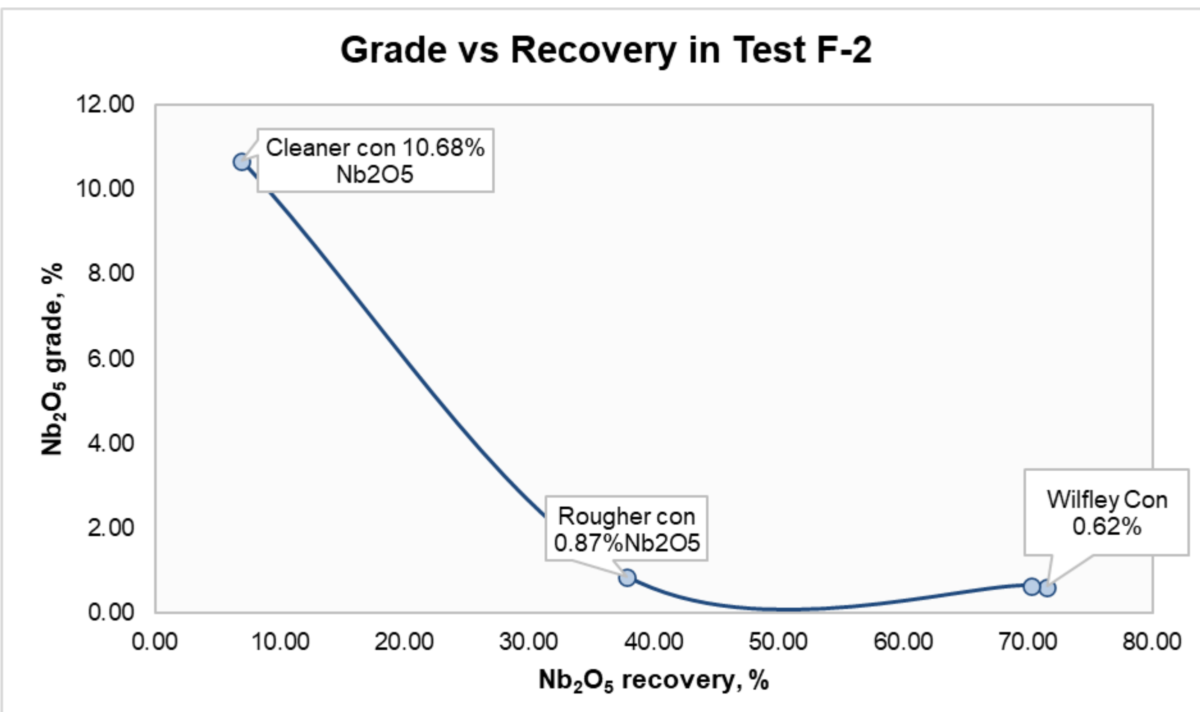

Figure 4. The Nb_2O_5 overall grade-recovery curve of the gravity and flotation circuit in test F-2.

3.0 TIMA RESULTS

Table 10. Mineral abundance in mass percent in three Tailings products of the F-1 test. The results are normalized for each product.

Mineral	Mass (%) in product			
	Wilfley Table Tailings	Pyrochlore Rougher Tailings	1st Cleaner Tailings	MT Concentrate
Pyrochlore	0.08	1.00	0.50	32.38
Columbite	0.0	0.06	0.0	
Apatite	4.4	17.1	18.4	24.2
Rare Earths	0.07	0.25	0.18	0.26
Siderite	0.10	0.05	0.04	0.13
Calcite	82.6	65.3	66.2	11.1
Dolomite/Ankerite	6.4	9.5	7.9	5.9
Strontianite	0.84	0.90	0.95	0.47
Quartz	0.81	0.73	0.67	0.64
Feldspar	0.68	0.36	0.48	0.72
Pyriboles	2.4	2.1	2.2	3.3
Chlorite	0.05	0.02	0.01	0.02
Muscovite/Sericite	0.01	0.01	0.00	0.03
Biotite/Phlogopite	0.86	0.91	0.89	0.64
Pyrrhotite/Pyrite	0.26	0.16	0.02	3.96
Fe&Ti Oxides	0.17	1.26	1.09	14.0
Sulphates	0.07	0.15	0.19	0.69
Zircon	0.03	0.19	0.24	1.59
Other minerals	0.14	0.03	0.03	0.09
Total	**100**	**100**	**100**	**100**

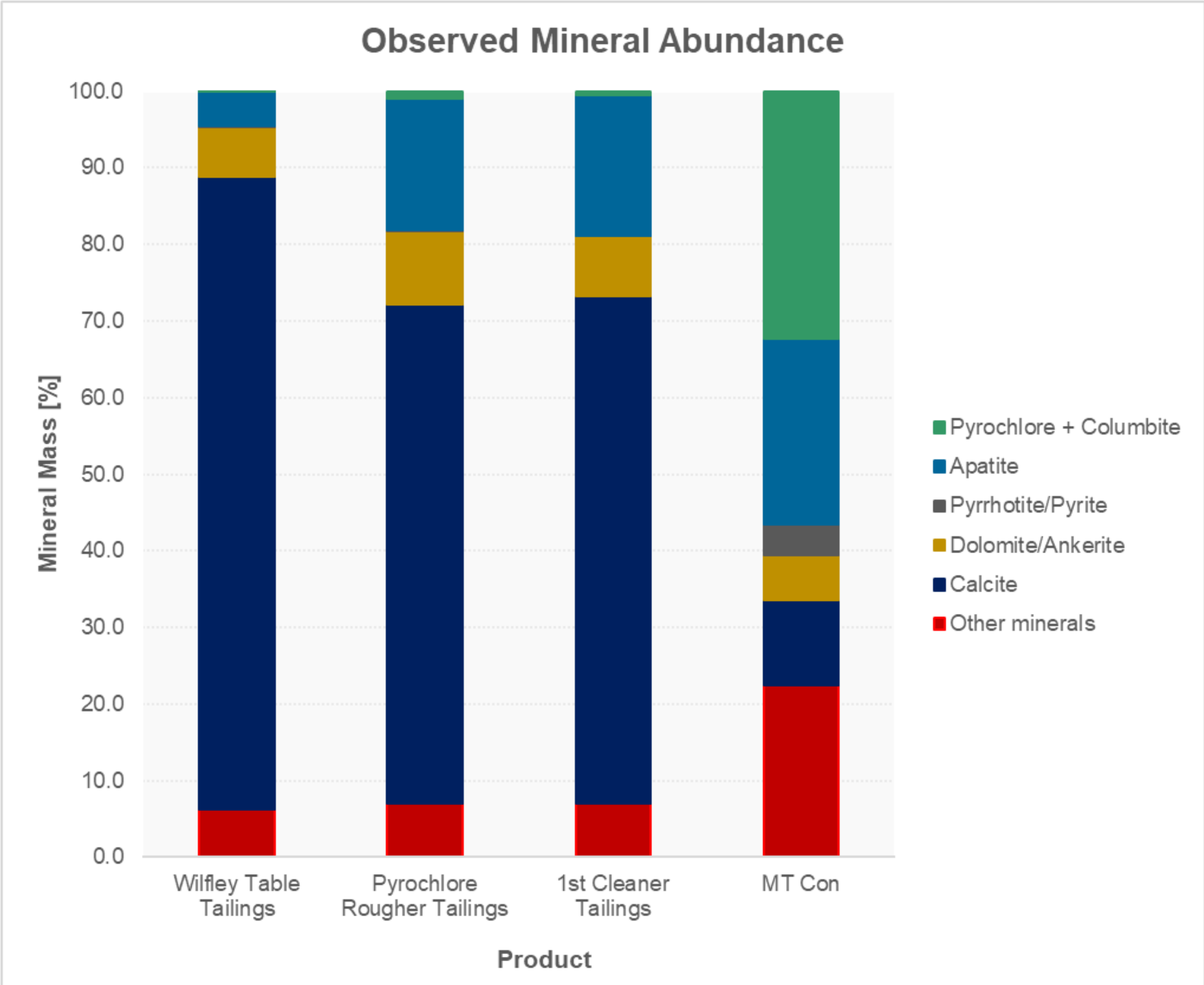

Figure 5. Observed abundance of minor and major minerals in mass percent in selected products of the F-1 minerals processing test.

Table 11. Mass distribution of pyrochlore and all particles in selected Tailings products of the F-1 test.

Size (µm)	Pyrochlore Weight Distribution (%)			Particle Mass Distribution (%)		
	WT Tails	1st Clnr Tails	Pyro Ro Tail	WT Tails	1st Clnr Tails	Pyro Ro Tail
≥150	2.6	37.6	10.5	6.7	5.3	15.7
≥75 <150	4.3	50.9	46.7	27.2	33.2	33.1
≥53 <75	3.8	3.8	16.3	10.8	20.6	16.6
≥20 <53	20.3	6.7	23.2	25.1	33.9	27.5
<20	69.1	1.1	3.3	30.2	7.1	7.1
	100.0	100.0	100.0	100.0	100.0	100.0

Table 12. Degree of liberation of pyrochlore by particle size classification in the Wilfley Table Tailings from test F-1.

Free surface % of Pyrochlore	Size classification (µm)					All particles
	≥150	≥75 <150	≥53 <75	≥20 <53	<20	
<30.00	100	100	100	11.9	1.3	14.0
≥30.00<50.00	0	0	0	8.0	3.3	3.9
≥50.00<80.00	0	0	0	17.9	11.9	11.8
≥80.00	0	0	0	62.2	83.6	70.3
Total	100	100	100	100	100	100

Table 13. Degree of liberation of pyrochlore by particle size classification in the Pyrochlore Rougher Tailings from test F-1.

Free surface % of Pyrochlore	Size classification (µm)					All particles
	≥150	≥75 <150	≥53 <75	≥20 <53	<20	
<30.00	15.0	12.8	7.9	3.1	0.7	9.6
≥30.00<50.00	53.2	6.4	15.4	7.1	0.3	12.7
≥50.00<80.00	31.8	37.1	33.7	20.9	2.1	31.1
≥80.00	0.0	43.7	43.0	68.9	96.8	46.6
All particles	100	100	100	100	100	100

Table 14. Degree of liberation of pyrochlore by particle size classification in the Pyrochlore Cleaner Tailings from test F-1.

Free surface % of Pyrochlore	Size classification (µm)					All particles
	≥150	≥75 <150	≥53 <75	≥20 <53	<20	
<30.00	3.2	8.2	39.8	17.8	3.8	8.1
≥30.00<50.00	22.0	13.7	27.8	9.5	5.3	17.0
≥50.00<80.00	74.8	35.8	15.4	18.2	0.8	48.1
≥80.00	0.0	42.3	17.1	54.5	90.2	26.8
Total	100	100	100	100	100	100

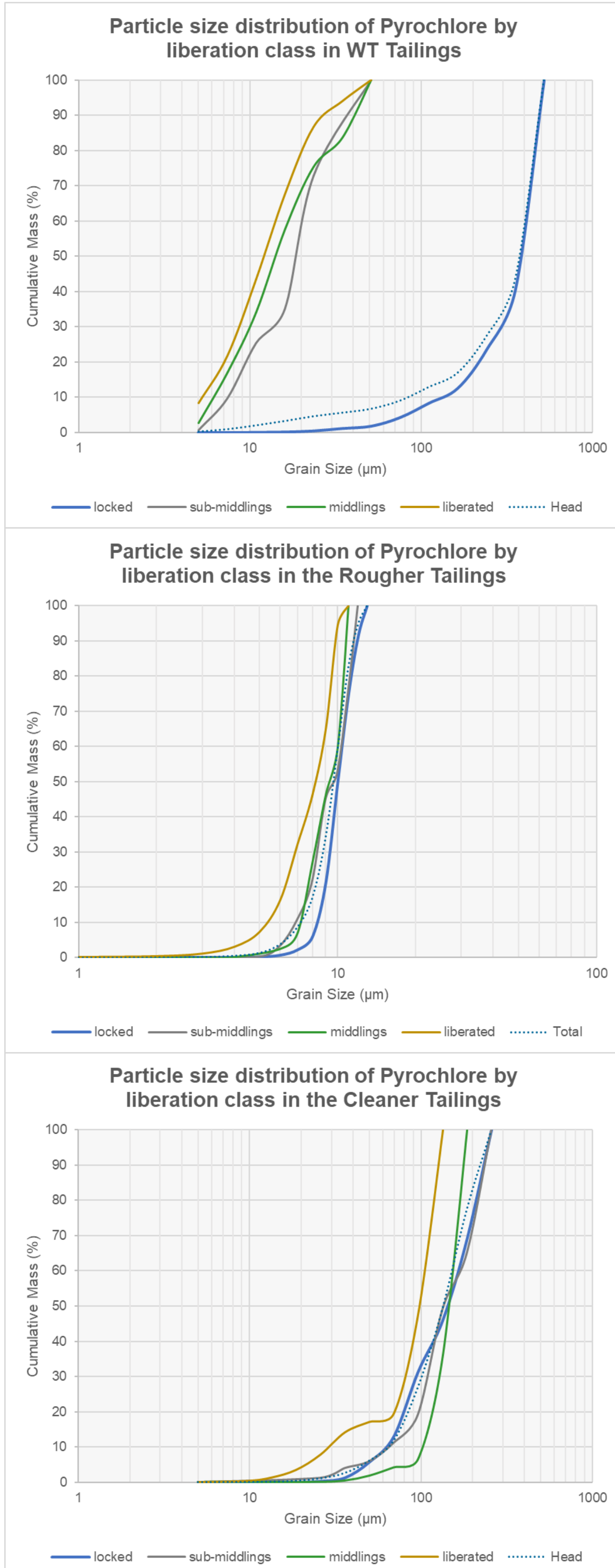

Figure 6. The particle size distribution of pyrochlore in three tailings products of the F-1 test.

Appendix A

Testwork flowsheets: Gravity and Flotation

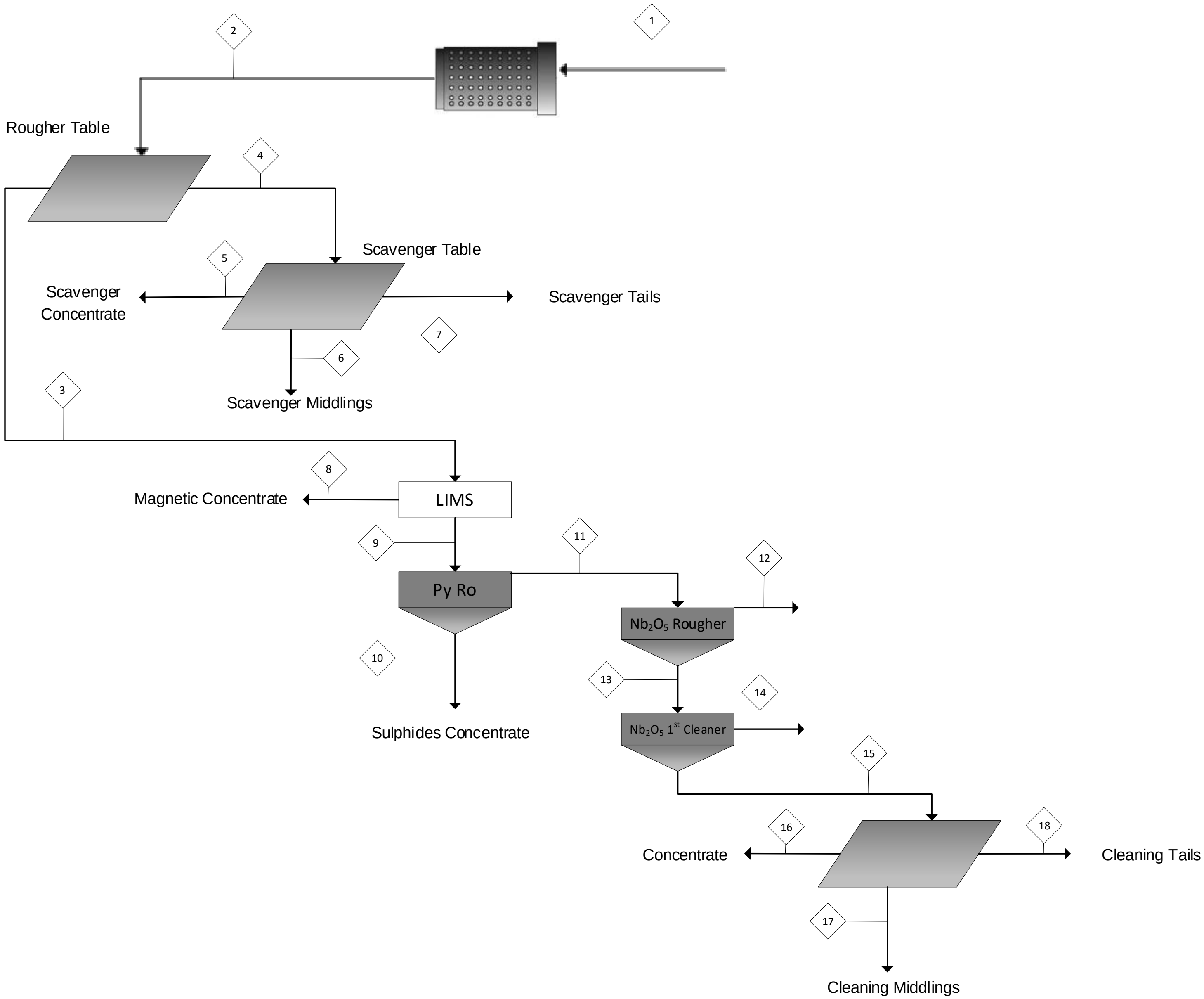

Figure A-1. Mineral processing flowsheet for exploratory test F-1.

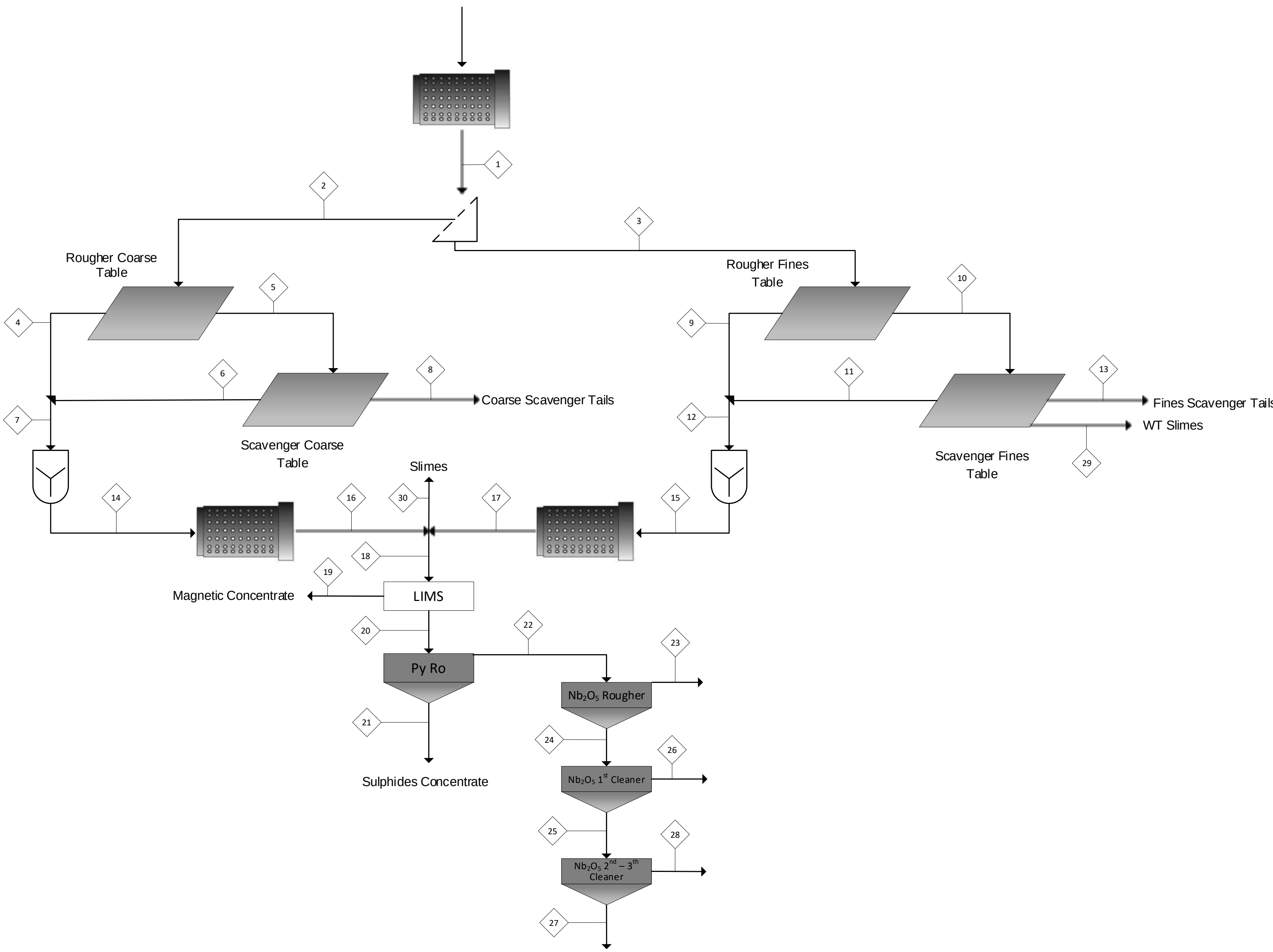

Figure A-2. Mineral processing flowsheet for exploratory test F-2.