Mineralogical Analysis and Metallurgical Testwork on Gold Ores from the Frotet Project

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Abstract

Frotet Project is an advanced exploration-stage gold project in Quebec, Canada, where high-grade gold mineralization is dominantly hosted in shear hosted quartz veins mainly localized within the Regnault Diorite. Broader low-grade gold mineralization is also present in the alteration halos surrounding these veins. This study evaluated the relationship between gold mineralogy and preliminary metallurgical response using TIMA-based mineralogical analysis, cyanidation tests, and gravity separation tests on 21 composite samples. Based on the results of the mineralogy analysis, all samples were classified as “vein-dominated,” with the exception of one sample that was classified as “host rock-dominated” due to its extremely low quartz-feldspar content. Gold occurred mainly as native gold, electrum, and Au-Te minerals. Cyanidation tests showed consistent Au extractions of 83.5–89.9% for the vein-dominated samples, whereas the host rock-dominated sample showed lower extraction of 79.1%. Gravity separation recovered 20.6–30.2% Au from the vein-dominated samples but only 6.8% from host rock-dominated sample. Gold minerals in the gravity concentrate from host rock-dominated sample were finer, with a P_{80} of 15 µm, than those from the vein-dominated samples, which showed P_{80} values of 37–40 µm. This finer grain size may reflect a greater proportion of gold enclosed within host-rock minerals and is consistent with the lower gravity recovery. In gravity concentrates from the vein-dominated samples, native gold and electrum were relatively coarse, whereas Au-Te minerals were fine-grained, with P_{80} values of 7–11 µm. Although low-Au/Te samples showed slower initial Au extraction, they reached an extraction plateau within 24 h, indicating that the fine-grained Au-Te minerals did not cause substantial residual Au under the tested conditions. Because vein and host-rock materials will occur as mixtures during operation, future work should evaluate continuous mineralogical indicators related to host-rock dilution and their relationships with Au recovery and flowsheet performance.

Keywords

Mineralogical analysis, Cyanidation, Gravity separation, Gold, TIMA

1 Introduction

The Frotet Project is an advanced exploration-stage gold project located about 100 km north of Chibougamau, Quebec, Canada, and is wholly owned by Sumitomo Metal Mining Canada Ltd. The principal host rock is diorite. Gold mineralization occurs in a structural setting favorable for orogenic gold systems and is mainly associated with quartz veins mainly localized within the Regnault Diorite.

Understanding the relationship between mineralogical characteristics and metallurgical response is important for evaluating future processing options. In particular, gold recovery by cyanidation and gravity separation can be affected by gold mineral species, grain size, and association with gangue minerals.

This study characterized gold deportment in selected ore samples and evaluated preliminary metallurgical response through TIMA (TESCAN Integrated Mineral Analyzer)-based mineralogical analysis, cyanidation leach tests, and gravity separation tests, with the aim of identifying implications for future flowsheet development.

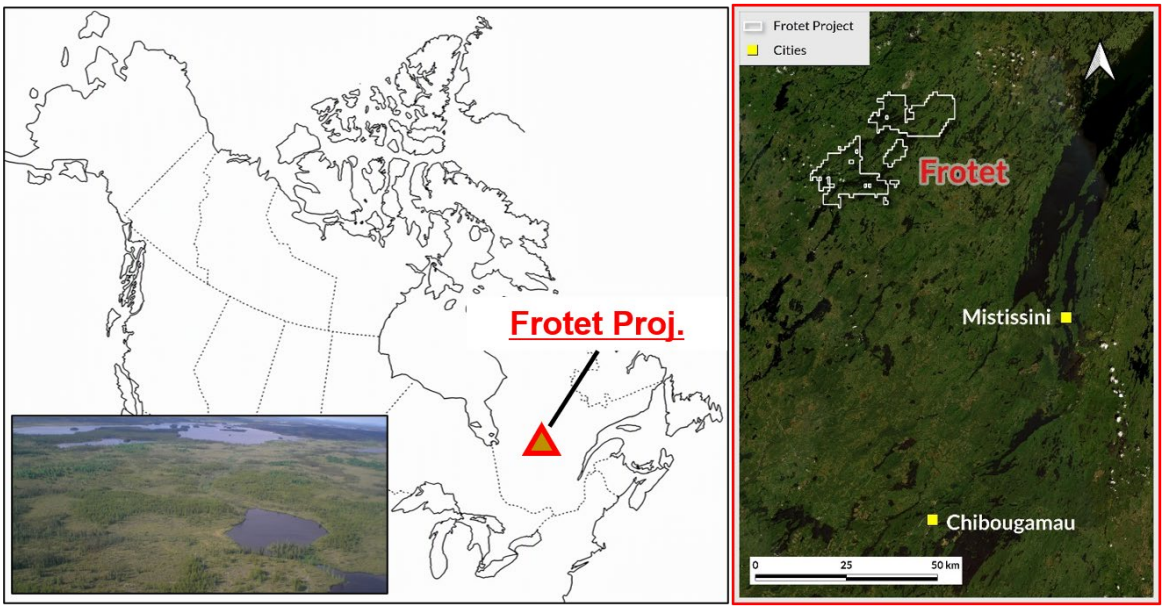

Fig. 1 Location and property boundary of the Frotet Project, Quebec, Canada.

2 Materials and Methods

2.1 Sample selection

Exploration drilling has identified several mineralized trends, in the Regnault area in the southern Frotet Project. Assay reject samples from drill core were selected from multiple trends to represent key mineralized domains and a range of geological and geochemical characteristics.

Individual composite samples were prepared based on gold grade and Au/Te ratio, used as an indicator of potential variation in Au-Te minerals. In total, 21 composites were prepared to represent variations in mineralized area, gold grade, and Au/Te ratio. After initial fire assay and chemical analyses, selected composites were used for cyanidation and/or gravity separation tests, depending on remaining sample mass. The analytical results and testwork are summarized in Table 1.

Table 1 Fire assay and chemical analysis results, and testwork conducted for each sample.

Composite	Au grade	Te grade	Au/Te	TIMA	Cyanidation	Gravity separation
ID	g/t	ppm				
A	77.7	110	0.72	●		
B	16.6	10	1.51	●		
C	4.0	<10	1.00	●	●	●
D	30	40	0.79	●		
E	203.0	230	0.88	●	●	
F	35.2	50	0.75	●		
G	14.8	20	0.74	●		
H	14.3	20	0.75	●	●	
I	135.0	150	0.88	●		
J	9.8	20	0.41	●		
K	5.8	20	0.34	●		
L	6.6	10	0.60	●		
M	2.7	<10	0.90	●		
N	7.2	<10	1.80	●	●	
O	8.5	20	0.53	●	●	
P	16.6	20	0.79	●		●
Q	5.3	<10	0.88	●	●	
R	76.2	100	0.78	●		●
S	5.1	<10	0.57	●	●	●
T	82.6	110	0.79	●		
U	15.8	30	0.53	●	●	●

※Au/Te was calculated based on the reference analytical value for Te grade.

2.2 Mineralogical analysis

Mineralogical analysis was conducted using polished resin-mounted sections prepared from each composite sample. Samples were dispersed in ethanol by ultrasonic treatment, vacuum-filtered, dried, gently disaggregated, mixed with phenolic resin powder, and mounted under heat and pressure. The mounted blocks were polished to a mirror finish and carbon coated. The sections were analyzed using TIMA in two modes. Liberation mode was used to determine bulk

mineralogy and textures. Bright Phase Search (BPS) mode targeted particles containing grains with BSE brightness ≥50% to detect gold-bearing minerals efficiently. For each size fraction (+75, +20, -20 µm), two sections were measured in Liberation mode and six in BPS mode.

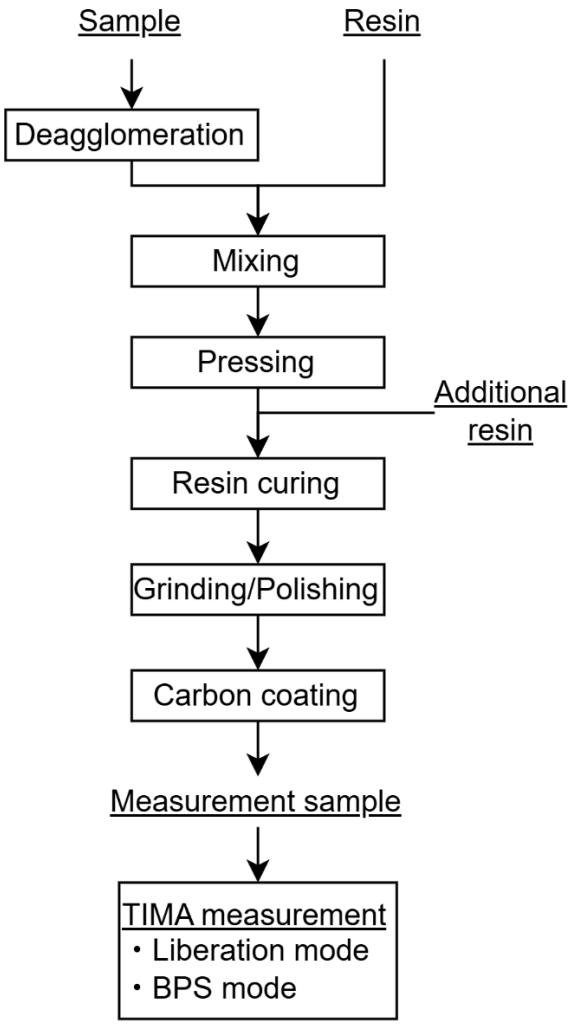

Fig. 2 Flowsheet of TIMA analysis

2.3 Cyanidation leach tests

Cyanidation leach tests were conducted to evaluate Au and Ag extraction from selected samples. Samples were selected based on gold mineralogy and head grade, ground to P_{80} = 100 µm, and adjusted to 40 wt.% solids in plastic leach bottles. Prior to cyanide addition, the slurries were pre-conditioned on a pot mill at 60 rpm for 24 hours with oxygen sparging at 1 L/min. The pH was adjusted to 10.5 ± 0.5, and NaCN was added to 0.5 g/L. Leaching was conducted for 48 hours with air sparging. Solution samples were collected at 2, 6, 24, and 48 hours for Au, Ag, and free cyanide analyses, and final residues were assayed for Au and Ag.

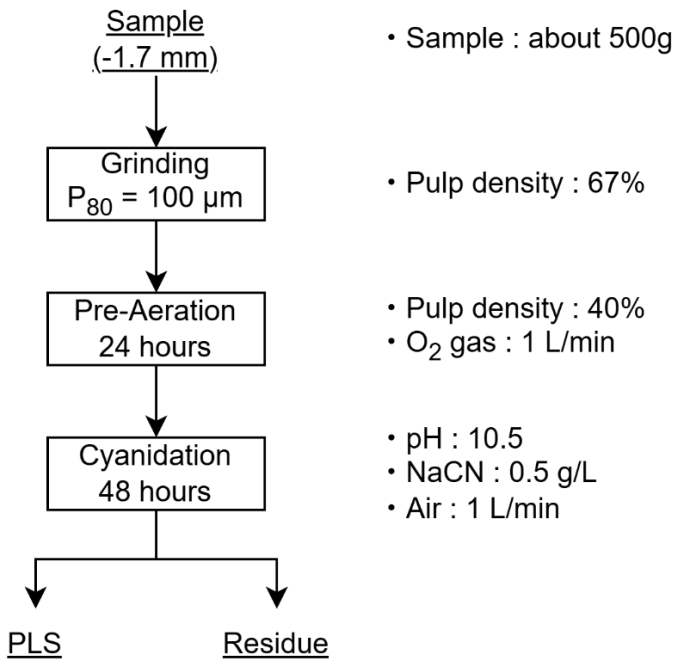

Fig. 3 Flowsheet of Cyanidation

2.4 Gravity separation tests

Gravity separation tests were conducted to assess the recoverability of coarse gold particles from selected ore samples. Crushed material with a top size of approximately -10 mesh (-1.7 mm) was used, and 500 g of sample was ground in a stainless-steel laboratory mill to P_{80} = 100 μm for each test. The ground slurry was treated using a Knelson concentrator MD-3 at a feed rate of 1 kg/min, a pulp density of 60%, a rotation speed of 1,500 rpm, and a fluidization water flow rate of 3.5 L/min. The gravity concentrate and gravity Tailinging were collected separately and submitted for Au and Ag assays.

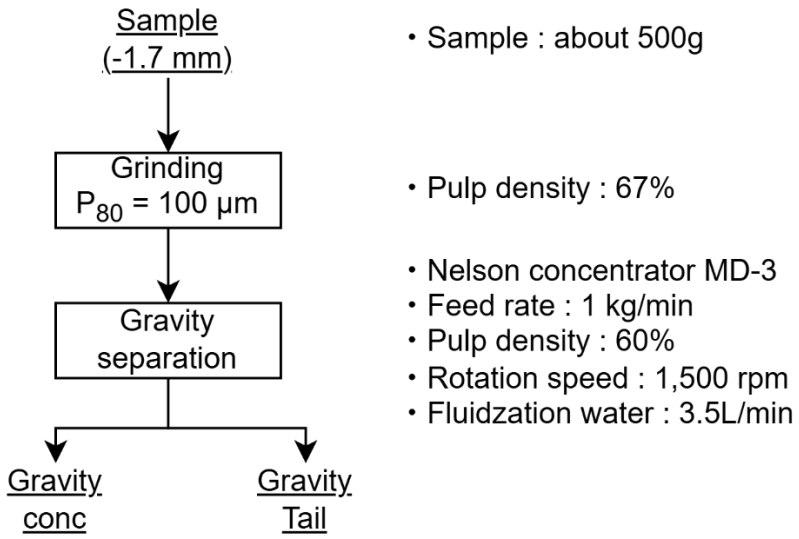

Fig. 4 Flowsheet of gravity separation

3 Results and discussion

3-1 Mineralogical analysis result

Fig. 5 shows the bulk mineralogical composition of each composite sample measured by TIMA. The samples were dominated by quartz and feldspar, predominately plagioclase, with minor alteration and sulfide minerals. Because diorite is a plagioclase-rich, quartz-poor rock, with less than 5% quartz when the quartz, alkali feldspar, and plagioclase components are normalized to 100%. Because alkali feldspar was negligible, the quartz proportion was calculated as quartz/(quartz + plagioclase) as shown in Fig. 6 and used as a relative indicator of vein-material contribution. Sample C showed the lowest quartz proportion, at 8.1%, whereas all other samples showed values of approximately 18% or higher. Accordingly, Sample C was classified as the only host rock-dominant composite, while the remaining 20 composites were classified as vein-dominant. This operational classification was based on the relative quartz proportions of the composite samples.

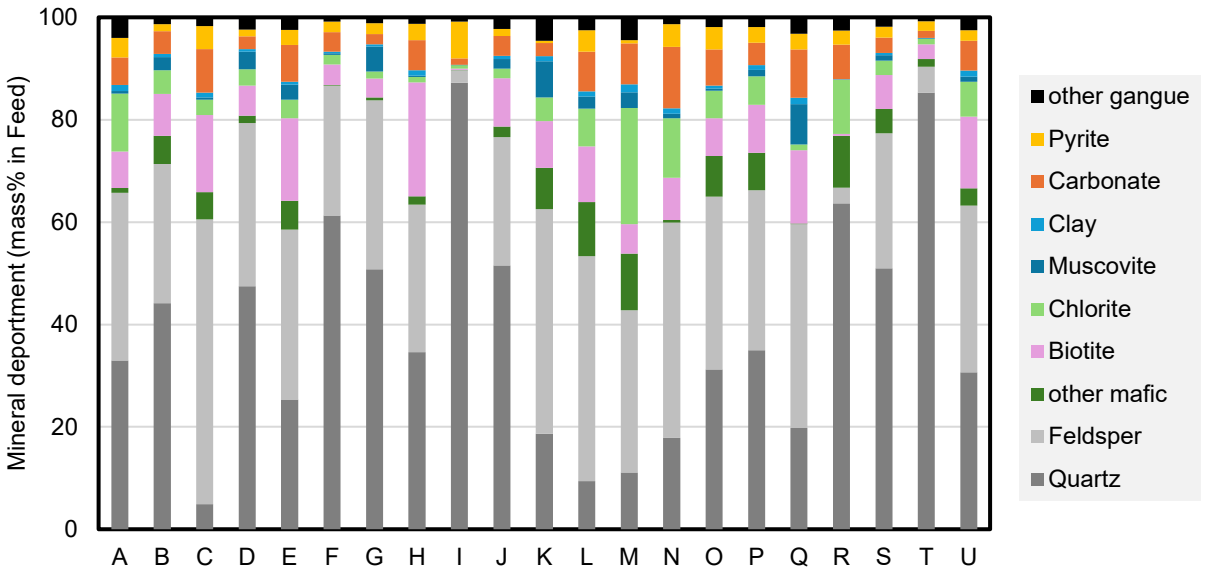

Fig. 5 Mineral component of each composite sample determined by TIMA.

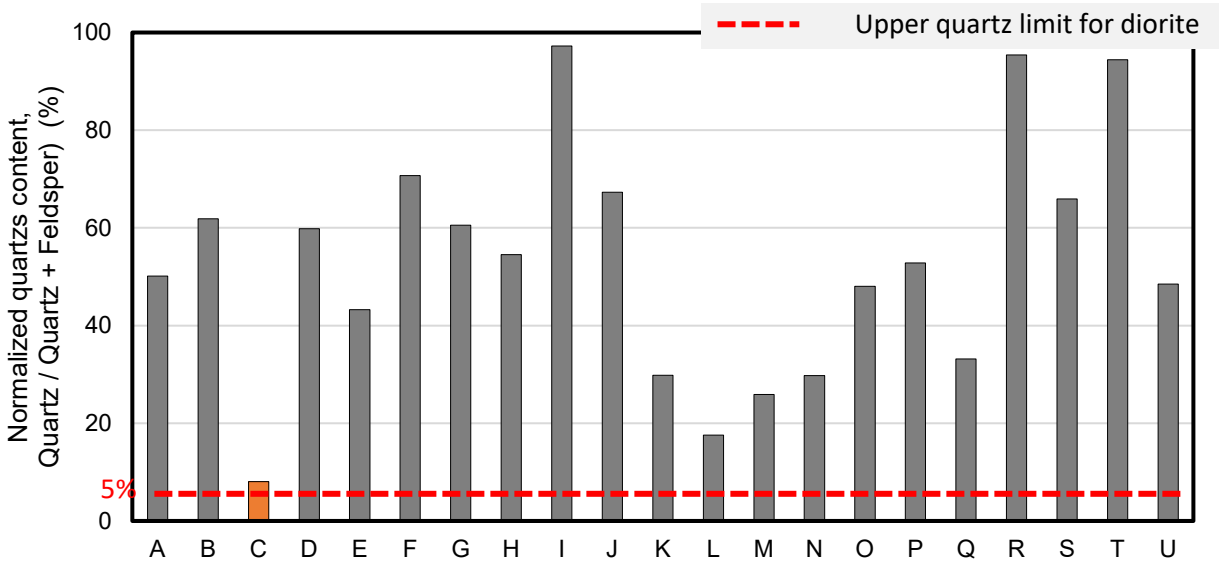

Fig. 6 Normalized quartz proportions of composite samples relative to the diorite reference

Fig. 7 summarizes the gold mineral deportment of each composite sample. The vertical axis represents TIMA-detected Au metal expressed as a percentage of the total feed Au metal calculated from the head assay. Gold-bearing minerals detected by TIMA were broadly classified into native gold, electrum, and Au-Te minerals, mainly petzite and calaverite. Because Au-Te minerals may dissolve more slowly during cyanidation than Native gold / Electrums [1], their relative abundance was considered when selecting samples for leach tests.

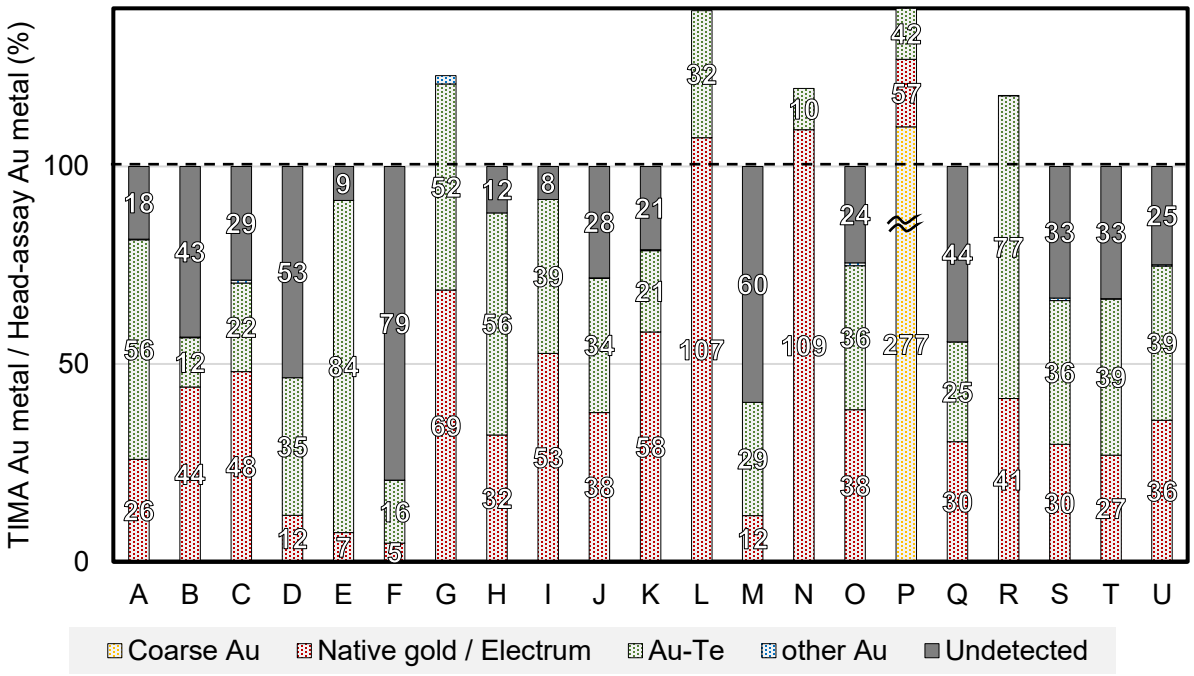

Fig. 7 Gold mineral deportment by composite sample based on TIMA-detected Au metal normalized to total feed Au metal from head assay.

The TIMA back-calculated Au grades were lower than the fire assay head grades in 16 of the 21 composites, probably due to the difficulty of detecting sparsely distributed coarse gold grains in polished sections. Coarse gold grains larger than 50 µm were detected only in Sample E, a very high-gold grade sample, and Sample P, in which an approximately 80 µm native gold grain was identified (Fig. 8).

Based on ore type, Au head grade, and Au/Te ratio, selected composites were used for cyanidation tests: low-grade vein-dominated Samples N, O, Q, and S; medium-grade vein-dominated Samples H and U; very high-grade Sample E; and host rock-dominated Sample C. Samples O and S, with relatively low Au/Te ratios, were selected for detailed kinetic evaluation of potential undissolved Au-Te minerals.

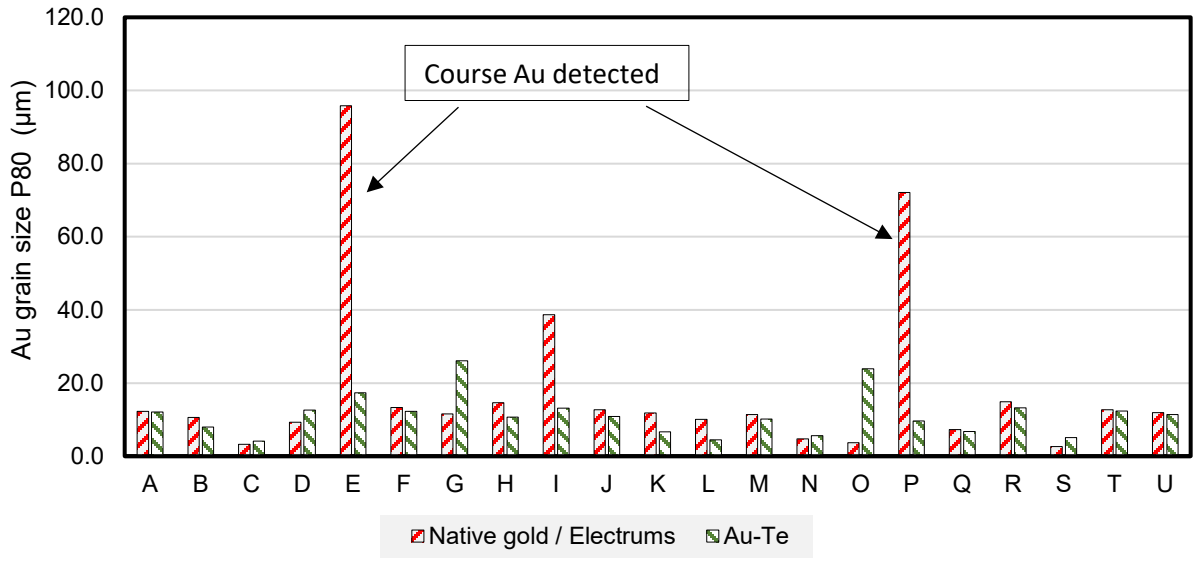

Fig. 8 P_{80} grain size of gold minerals detected by TIMA for each composite sample.

3-2 Cyanide leaching test results

The cyanidation leach test results are summarized in Table 2 as 48-hour Au extractions. Vein-dominated ores showed favorable and consistent Au extraction, ranging from 83.5% to 89.9% and averaging 86.8% across the tested head-grade range. In contrast, the host rock-dominated Sample C showed lower Au extraction of 79.1%, approximately 7.7 percentage points below the vein-dominated average.

Table 2 Summary of 48-hour Au and Ag extraction by cyanidation leach tests.

Type			**vein-dominated**							**host rock-dominated**
Composite name			E	H	N	O	Q	S	U	C
Feed grade (g/t)	Au	g/t	203.0	14.3	7.2	8.5	5.3	5.1	15.8	4.0
Back calc. feed grade(g/t)	Au	g/t	214.1	15.9	10.0	8.4	5.4	5.9	14.6	4.3
Grade in leach residue	Au	g/t	24.5	1.6	1.3	1.2	0.90	0.80	2.1	0.90
Extraction rate (48 h)	Au	%	88.6	89.9	87.0	85.7	83.5	86.4	86.3	79.1

Among samples with comparable Au head grades, Samples O and S, which had relatively low Au/Te ratios, and Sample N, which had a relatively high Au/Te ratio, were selected to evaluate the effect of Te-bearing gold minerals on final Au extraction. As shown in Fig. 9, Sample N showed faster initial Au extraction than Samples O and S. Although Samples O and S exhibited slower initial extraction, both reached an Au extraction plateau within 24 h. These results indicate that Au-Te minerals were associated with slower initial leaching kinetics, but their incomplete dissolution was unlikely to cause a significant reduction in final Au extraction under the tested conditions.

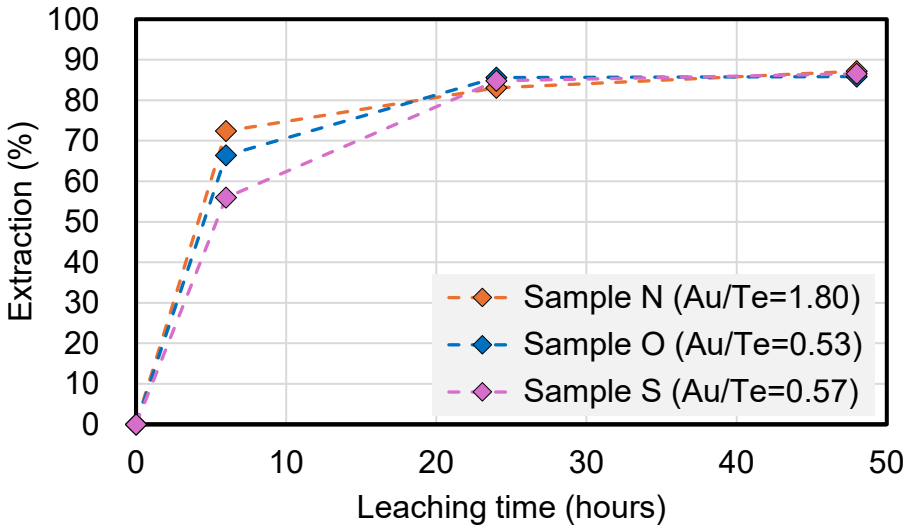

Fig. 9 Kinetic gold extraction relatively low-grade composite samples

3-3 Gravity separation test results

Gravity separation results are summarized in Table 3. Au recoveries to the gravity concentrate were 20.6–30.2% for the vein-dominated samples, whereas the host rock-dominated Sample C showed only 6.8%. The P_{80} of all gold minerals detected in the gravity concentrates was 37–40 µm for the vein-dominated samples, compared with 15 µm for Sample C. Gold in Sample C was finer and may have been more commonly enclosed within host-rock minerals, which likely caused its lower gravity recoverability. This interpretation is consistent with gold mineralization in the host rock-dominated ore occurring mainly in small, mineralized veinlets within the dioritic host rock.

Furthermore, in the gravity concentrates from the vein-dominated samples, Native gold / Electrums were relatively coarse, with P_{80} values of 38–50 µm, whereas Au-Te minerals were fine-grained, with P_{80} values of 7–11 µm. As shown in Fig. 9, the low Au/Te samples showed slower initial leaching, but their fine grain size likely facilitated dissolution and resulted in limited residual Au. This interpretation is consistent with the low-Au/Te samples reaching an Au extraction plateau within 24 h.

Table 3 Gravity separation results and TIMA-detected Au grain size in gravity concentrates.

Sample ID	P	R	S	U	C
Dominated type	vein	vein	vein	vein	host rock
Feed grade (g/t)	16.6	76.2	5.1	15.9	4.0
Au recovery of gravity separation	27.6	25.4	20.6	30.2	6.8
All Au grain size in gravity conc, P_{80} (μm)	37	37	40	N/A	15
Native gold / Electrum grain size in gravity conc, P_{80} (μm)	50	38	40	N/A	3
Au-Te grain size in gravity conc, P_{80} (μm)	10	11	7	N/A	19

4 Conclusions

Among the 21 composite samples from the Frotet Project, 20 were classified as vein-dominated and one sample, Sample C, was classified as host rock-dominated based on bulk mineralogical composition. TIMA analysis showed that gold occurred mainly as native gold, electrum, and Au-Te minerals, mainly petzite and calaverite.

Cyanidation tests showed favorable Au extraction for the vein-dominated samples, ranging from 83.5% to 89.9% and averaging 86.8%, whereas the host rock-dominated sample showed lower extraction of 79.1%, indicating a risk of increased Au losses to the leach residue and lower overall Au recovery. Although the low-Au/Te samples showed slower initial Au extraction, they reached an Au extraction plateau within 24 h, suggesting that undissolved Au associated with Au-Te minerals was limited under the tested conditions. Gravity separation preferentially recovered relatively coarse gold, particularly Native gold / Electrums, from the vein-dominated samples.

In actual operation, vein and host-rock materials will be processed as a mixture. Therefore, future work should move beyond a binary classification of vein-dominated and host rock-dominated ores and evaluate continuous mineralogical indicators related to the degree of host-rock dilution. The relationship between these indicators, Au recovery, and flowsheet performance should also be established.

References

[1] Marsden, John, and Iain House. *The chemistry of gold extraction*. SME, 2006.