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Cu–Ni processing improvements at First Quantum's Kevitsa mine

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ABSTRACT

First Quantum's Kevitsa Mine is located in northern Finland and mines a large, low grade, polymetallic ore body. The processing rate is currently 6.7 million tonnes per annum (mtpa) up from the design rate of 5.5 mtpa. Payable metals include nickel, copper, gold and PGM group metals. Profitability, at high volume, low grade operations like Kevitsa, is highly geared to metal prices and process improvements. Unusually, for a high tonnage low grade operation, metal losses at Kevitsa are primarily in the finer fractions.

Since the operation commenced there has been a focus on maximising the separation process so as to improve the Cu–Ni process profitability. This has included:

1. Optimising the flowsheet
2. Installing column cells
3. Improving fines recovery

This paper will outline these process improvements, their introduction and efficacy.

1. Introduction

Kevitsa Mining Oy is a Ni–Cu–PGE project in Finland and is owned by First Quantum Minerals. The deposit was acquired from Scandinavian Minerals Limited in 2008 and a decision to develop was made in November 2009. Construction of the mine facilities including the processing plant began in 2010 and was completed in May 2012. Commissioning of the processing plant began in earnest in June of the same year leading to production of the first concentrate. Commercial production status was achieved well ahead of schedule and by August the project had moved from commissioning to commercial production status. Currently the operation is processing 6.7 mtpa up from the design throughput of 5.5 mtpa and a permit to operate at 10 mtpa has since been awarded giving room for further expansion.

1.1. Mineralogy

The Kevitsa Ni–Cu–PGE deposit is disseminated in style while having some minor sulphide veins. Pyrrhotite is the main sulphide mineral followed by chalcopyrite and pentlandite. The sulphide grain size is fine to medium. In near surface parts of the mineralisation, pyrrhotite is partly replaced by pyrite and pentlandite by millerite and heazlewoodite (Kojonen et al., 2008). Major and minor sulphide minerals in the ore are listed with some of their characteristics in Tables 1 and 2.

Being a low grade deposit, gangue minerals dominate the ore treated, with the pyroxene group (including altered forms) being the major non sulphide gangue (NSG). Sulphides contribute less than 5% of the total mineralogy with chalcopyrite and cubanite being the main Cu minerals and pentlandite and to a lesser extent millerite the main Ni sulphide minerals. Sulphide gangue minerals in the ore are pyrrhotite (which exists in both hexagonal and monoclinic forms, with varying proportions). As much as 20% of the nickel in the plant feed is contained in non-sulphide minerals. Similarly, up to 10% of the copper in feed can be in non-sulphide copper minerals.

Variability in feed grades, gangue and sulphide minerals presents challenges to the concentrator operations. Low metal feed grades result in a commercially unforgiving ore, with little room to maneuver to manage the substantial variability and still maintain profitability. This is unlike more commercially forgiving copper–nickel ores from other sites where the nickel and copper content in the ore can be 5–10 times the grades at Kevitsa (Lawson et al., 2014).

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Table 1
Major sulphide minerals for the Kevitsa ore.

Mineral name	Emipirical formula	Chemical formula	Crystal system	Hardness
Pentlandite	$Fe^{2+}_{4.5}Ni_{4.5}S_8$	$(Fe, Ni)_9S_8$	Isometric	3.5–4
Pyrrhotite	$Fe^{2+}_{0.95}S$	$Fe_{1-x}S$	Hexagonal	3.5–4
Chalcopyrite	$CuFe^{2+}S_2$	$CuFeS_2$	Tetragonal	3.5
Troilite	$Fe^{2+}S$	FeS	Hexagonal	3.5–4
Talnakhite	$Cu_9Fe^{2+}_6Ni_2S_{16}$	$Cu_9(Fe, Ni)_8S_{16}$	Isometric	4–4.5

A recently published review of different nickel processing operations worldwide highlighted ore variability characteristics (Lawson et al., 2014). They categorise nickel – chalcopyrite ores into 4 main types:

1. Nickel and copper in a pyrrhotite bearing sulphide deposit.
2. Nickel and copper in a pyrrhotite bearing sulphide deposit with moderate to high pyrrhotite to pentlandite ratios.
3. Low grade nickel and copper in a high grade pyrrhotite deposit that are uneconomic.
4. Low grade nickel and copper in a low grade sulphide that can be economically processed.

The Kevitsa ore would be categorised as type '4' with average sulphur in feed of about 1–1.5%, and pyrrhotite in plant feed of around 2%.

1.2. Kevitsa processing

1.2.1. Crushing and grinding

The comminution circuit includes a crushing and autogenous grinding (AG) circuit as shown in Fig. 1.

Crushing consists of 2 stages; primary crushing using a Sandvik CG820 gyratory crusher. The secondary and tertiary crushing is done in two MP800 Metso cone crushers fitted with different bowl and mantle liners in line with their duties. Primary crusher product is screened on a double deck vibrating screen having a 100 mm top deck and a 25 mm bottom deck. Feed to the secondary and tertiary crushers is the −100 mm + 25 mm fraction which is presplit into −60 mm and +60 mm fraction by a single deck scalping screen. The −60 mm fraction feeds the tertiary crusher whilst the +60 mm fraction is feed to the secondary crusher. Some of this fraction (+60 mm) is drawn to provide the secondary mill with grinding media as pebbles. The +100 mm, −25 mm and products from both the secondary and tertiary crushers are deposited on a stockpile from which four feeders draw to feed the 2 AG mills in parallel.

Primary milling is 100% autogenous and is carried out in 2 primary 7 MW AG mills of 8.5 m × 8.5 m dimensions. Discharge from the 2 AG mills is screened on a vibrating screen fitted with 10 mm × 40 mm aperture panels with oversize rejects being conveyed back to the secondary and tertiary crushers for crushing. The screen under size is split into 2, one stream feeding a cyclone cluster in closed circuit with the mill and the other stream feeding the secondary mill. The secondary mill is 14 MW and is of similar dimensions to the primary mills with a grate discharge. Pebbles are fed to it as grinding media and the mill is in closed circuit with a cyclone cluster. The overflows from the 3 mill cyclones are combined in a surge tank that feeds flotation.

Table 2
Minor sulphide minerals for the Kevitsa.

Mineral name	Emipirical formula	Chemical formula	Crystal system	Hardness
Heazlewoodite	Ni_3S_2	Ni_3S_2	Trigonal	4
Millerite	NiS	NiS	Trigonal	3–3.5
Nickeline	NiAs	NiAs	Hexagonal	5.5
Maucherite	$Ni_{11}As_8$	$Ni_{11}As_8$	Tetragonal	5
Gersdorffite	NiAsS	NiAsS	Isometric	5.5
Cubanite	$CuFe^{2+}_2S_3$	$CuFe_2S_3$	Orthorhombic	3.5
Bornite	$Cu_5Fe^{2+}S_4$	Cu_5FeS_4	Orthorhombic	3
Mackinawite	$Fe^{2+}_{0.75}Ni_{0.25}S_{0.9}$	$(Fe, Ni)S_{0.9}$	Tetragonal	2.5

1.2.2. Flotation

The Kevitsa concentrator employs a copper–nickel sequential flotation circuit see Fig. 2.

Cu is floated first with a Cu selective collector and a high pH (>12) is employed to reduce Ni flotation to copper concentrate. The circuit has a roughing and scavenging stage with the concentrates from these banks reporting to the cleaning circuit. There are 4 stages of cleaning in total with the column cell as the final cleaning stage. The depressant, carboxy methyl cellulose (CMC) is added to both the roughing and cleaning circuits to reduce flotation of NSG. The cleaner tails are open to final copper tails and combine with copper rougher scavenger tails to feed the Ni circuit. Plant copper recovery to copper concentrate and copper concentrate grade are as expected for an ore with low feed grades, but copper recovery is constrained by the necessity to maximise copper–nickel selectivity in the copper circuit. Selectivity against nickel is good with on average less than 4% of nickel sulphide reporting to the copper concentrate.

The feed to Ni flotation is at a high pH (10.8) and requires adjustment to pH 10 by sulphuric acid to improve Ni flotation kinetics. A selective xanthate is used as collector to minimise pyrrhotite recovery, with CMC as the NSG depressant. The circuit has 4 cleaning stages treating mainly rougher scavenger concentrates and Ni column tail. The Ni column is fed with rougher concentrate producing a final concentrate grade in one cleaning stage. Like the copper circuit, the Ni cleaner circuit tail is open to the final tail. In the nickel circuit the main mineral separation challenge is the pentlandite–pyrrhotite separation, and to a lesser extent the pentlandite–gangue separation. The average sulphide nickel in feed is around 0.22% at Kevitsa, which is less than the tail grade at most nickel flotation operations.

Because of the complexity of the cleaner circuits for both copper and nickel, but especially for nickel, there are large recirculating loads and long residence times in the cleaner circuit. Moreover, there is active depression of gangue and pyrrhotite with flotation at high pH and multiple dosing of chemical depressants.

Ni tails are subjected to an unselective bulk float for sulphides to generate a high sulphur tail which is impounded in a lined pond for environmental reasons. The final tails, low in sulphur are deposited in the bigger, unlined pond from where process water is reclaimed for reuse in the process. The circuit employs a stronger xanthate and frother.

The PGMs are strongly associated with the Ni minerals with gold reporting predominantly to the Cu concentrate The PGMs and Au are payable in both the copper and nickel concentrate.

1.3. Kevitsa performance

The performance of the Kevitsa plant has steadily improved since commissioning with the plant results summarised in Table 3.

1.4. Optimising the flowsheet

The Kevitsa concentrator flotation flowsheet as designed is illustrated in Fig. 3 and has gone through several changes to arrive at the current flowsheet shown in Fig. 2.

The original flotation flowsheet is a typical, conventional flowsheet but was designed without detailed information about