RAJALA, J. and DESCHENES G. Extraction of gold and silver at the Kupol Mill using CELP. *World Gold Conference 2009,* The Southern African Institute of Mining and Metallurgy, 2009.

Extraction of gold and silver at the Kupol Mill using CELP

J. RAJALA* and G. DESCHENES†

**Kinross Gold Corporation, Canada*
†CANMET, Mining and Mineral Sciences Laboratories, Canada

The Kupol mill facility processed a high grade free milling gold/silver ore containing 28.2 g/t Au, 324.8 g/t Ag and approximately 0.5% pyrite during 2008 operation. Gold predominantly occurs as electrum in the ore and silver is predominantly present in the forms of acanthite, stephanite, pyrargyrite and proustite. Mill start-up was in mid-May 2008 and the mill reached the design throughput of 3 000 tpd in October. The ore was ground to approximately 70%–53 microns. A Knelson Concentrator recovered 9.8% gold and 0.5% silver. The gravity tails reported to a cyanidation circuit that has 14 hours pretreatment and 116 hours leaching. The slurry from cyanidation was then processed by countercurrent decantation (CCD) thickening to wash and separate the leach residue from the pregnant leach solution. Precious metals are recovered from the pregnant solution using the Merrill-Crowe process. The washed CCD leach residue slurry is treated with calcium hypochlorite to destroy cyanide and then sent to the tailings impoundment.

Leaching is performed with a new technology called 'CELP' (CANMET Enhanced Leach Process). The Kupol mill overall gold and silver recoveries for 2008 were 95.4% and 85.6% respectively, which were 2.8% and 7.5% higher than targets. Gold and silver extractions in the leach circuit were 94.2% and 84.5% respectively. Leach profiles indicated that gold extraction reached a plateau in the 4th tank while minor silver dissolution occurred in the 5th tank. With the CCD circuit included, total gold and silver extractions increased to 95.4% and 86.6%, respectively. Optimization of the leaching strategy made it possible to reduce sodium cyanide concentration to as low as 410 ppm without compromising precious metals extractions. Silver was effectively leached from the refractory silver minerals because CELP produced more oxidized mineral surface relative to the conventional cyanidation leached mineral surfaces. The average cyanide consumption for 2008 was 1.3 kg/t. The new leaching technology proved to be very robust and performed efficiently even with changes in feed grade and ore mineralogy. Laboratory experiments produced results that were indicative of plant performance. The robustness of the technology and the laboratory test work contributed to the success of the Kupol mill start-up.

Introduction

Kinross Gold Corporation acquired 75% interest in the Kupol project, located in far East Russia, on February 28, 2007 through its acquisition of Bema Gold. The remaining 25% interest is held by the government of the Chukotka Region where the project is located. The Kupol mine consists of a high-grade gold and silver vein which remains open along strike. Development and construction of the project, which uses both open pit and underground mining methods, began in 2005. In mid-May 2008, the Kupol mill began processing ore. Figure 1 presents a drawing of the mill complex. The mill process facility is located in the upper center section of the drawing.

Gold and silver extraction is performed using a proprietary technology called CELP (CANMET Enhanced Leaching Process). This technology, which also uses cyanide, was the option selected over the conventional cyanidation with the AVR (acidification-volatilization-recycling) to reduce cyanide consumption[1]. Work on refractory silver minerals demonstrated the technical advantages of the CELP[2,3]. This paper presents some of the experimental results used to develop the leach circuit conditions as well as plant performance and production data.

Developing Mill Leach conditions

Laboratory tests were performed to determine the mill leach conditions and control strategies. The sections below present the non-proprietary details of the work.

Experimental approach

Materials

The sample used in the leach experiments was called CELP 8–06. CELP 8-06 was to represent the mill feed in 2008 which would be primarily from a large stockpile of ore from the open pit and underground mine operations. The sample had previously been ground to a target P_{80} of 53 μm and subjected to gravity separation using a Knelson concentrator and a Mozley table. The CELP 8–06 gravity tails were received as bulk samples, pulped in distilled water and split with a rotary separator into 1 kg lots in glass jars with Teflon lids and stored in a refrigerator at ~4°C. The CELP 8-06 sample overall head grade was 22.7 g/t Au, 210 g/t Ag, 1.75% Fe, 0.99%S(tot) and 0.22% As (Table I). Three 8-06 gravity tail samples averaging 16.6 g/t Au and 192 g/t Ag were tested. Gold was predominantly in the form of electrum and some occurrence of native gold.

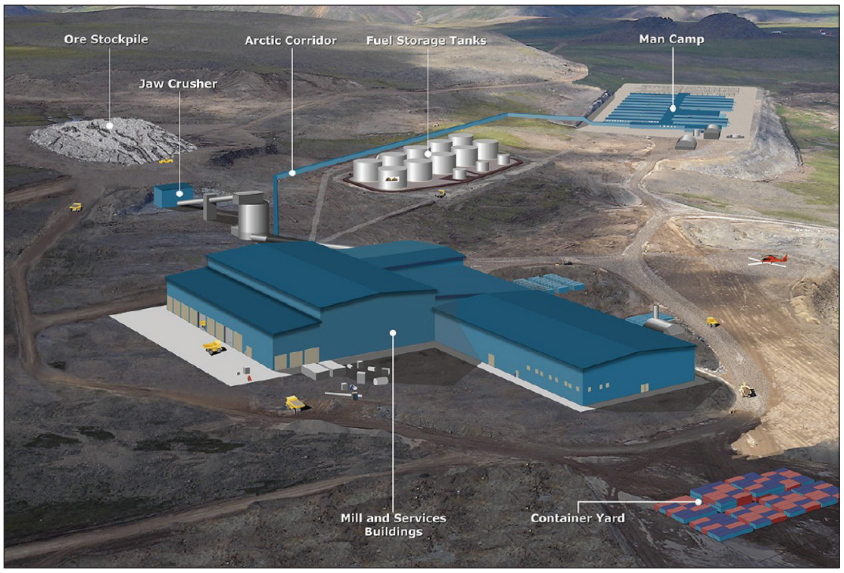

Figure 1. Kupol mill complex drawing

Table I
Analysis of elements for CELP8-06

Au g/t	Ag g/t	Fe %	As %	Sb %	S %	S= %	SO_4 %	S° %
22.7	210	1.75	0.22	0.017	0.99	0.35	0.9	<0.5

Table II
Semi-quantitative analysis of CELP8-06

Bi g/t	Ca g/t	Cu g/t	K g/t	Mg g/t	Mn g/t	Ni g/t	Pb g/t	Zn g/t
<20	170	103	19000	1300	90	<20	87	67

Silver was in the form of acanthite, stephanite, pyrargyrite, proustite, native silver and electrum. A semi-quantitative analysis of other elements is presented in Table II.

Reagents, equipment and experimental procedures

The quick lime ($Ca(OH)_2$ sodium cyanide, lead nitrate and oxygen used in the test work were all certified reagent grade chemicals. Deionized water was used.

Cyanidation tests

The leaching of the gravity tails samples was performed in jacketed cells made of glass, with a capacity of 1 L or 2 L. The cell cover has four openings that allow the insertion of electrodes, an agitator and a tube for adding air. The oxygen concentration was controlled by sparging a mixture of air and oxygen into the slurry and monitored by an Oxi 340 oxygen meter. The temperature was controlled by circulating a mixture of water and ethylene glycol from a heat exchanger through the cell jacket. For the majority of tests, the temperature was maintained at 20°C. Agitation was accomplished with 25 mm Teflon paddles powered by a variable-speed electric motor.

For the pretreatment, the sample was introduced into the reactor and adjusted to the designated pulp density (50% solids). Quick lime was added at the start of the pretreatment that lasted for 16 hours. In this preliminary assessment, no lead nitrate was added in the pretreatment. No filtering was done after this stage and the same pulp was used in the cyanidation. The cyanidation tests were 120 hours in duration. The lime and cyanide concentrations were adjusted after 1, 2, 4, 6, 24, 30, 48, 72 and 96 hours of leach. A different sampling pattern was used when samples had a lower weight. A 2 mL sample of the pregnant solution was taken by pipette after 1 and 30 hours leach for cyanide and lime titration and a 15 mL sample of the pregnant solution was taken after 2, 4, 6, 24, 30, 48, 72, 96 hours and at the end of the leach again for the titration of cyanide as well as for assay of gold and silver contents. Due to the small amount of feed available and to prevent removing too much liquid from the leaching system, which would significantly increase the pulp density, the number of liquid samples for gold and silver analysis was reduced for some tests. The solids taken during sampling were returned to the reactor after the pregnant solutions were filtered.

At the end of the tests, the pulps were filtered and the filter cakes were washed with 1000 mL of water. The filter cakes were dried, homogenized, sampled and analysed for gold and silver by fire assay. The final pregnant solutions were also analysed for CN_{total}, CN_{wad}, CNO-, CNS-, Fe, and Cu. The liquid samples were submitted for determination of the gold by fire assay and silver by direct reading using coupled plasma atomic emission spectrometry, respectively. CN_{total} and CN_{wad} (±5%) were determined by flow injection analysis using CNSolution™ 3000.

The Fe and Cu contents were analysed by ICP-AES (inductively coupled plasma atomic emission spectrometry). The CNO- and CNS- were determined by gradient elution HPLC (high performance liquid chromatography). For metal accounting purposes, assays on the solids were performed in triplicate for gold and silver. The gold and silver assays for the time series liquid samples were performed using fire assay. The gold and silver extractions were based on the metal content of the leach

residue and the gravity tails head assay. The gold and silver concentration in the solution was used to plot the extraction kinetic curves.

Free cyanide was determined by titration with silver nitrate using rhodanine as an indicator. For the free cyanide concentration, the controlled value was a time weighted average obtained by the summation of the average content values (C_i) within the sampling interval multiplied by the length of sampling interval (t_i) divided by the total time (t), i.e. the free cyanide concentration = $(\Sigma(C_i \times t_i)/t)$. In this investigation, the variation of the realized average free cyanide concentration relative to the target free cyanide concentration was within ±10%. Free cyanide was also determined for the final leach and wash solutions.

Results and discussion

Investigation of CELP 8-06 sample

Gravity separation test results

The results of the gravity separation for 3 separate tests on the CELP 8–06 composite are presented in Table III. The two additional gravity separation tests were conducted after the initial test in order to produce gravity tails product for follow-up testing.

The gravity gold recovery varied from 19.1 to 29.0%, whereas silver recovery ranged from 2.5 to 3.9%. The finer grind sizes feeding gravity separation produced higher gold recovery and much higher concentrate grades despite the lower percentages on concentrate weights because of improved liberation.

Laboratory leaching tests

Figures 2 and 3 illustrate the bench-scale leaching of gold and silver using CELP conditions and conventional conditions on the CELP 8–06 composite. The conventional conditions produced a leach residue with a lower gold extraction i.e. 90.8% vs 91.7% as well as a lower silver extraction 68.3% vs. 76.9%. The silver leaching plots indicates a severe passivation using the conventional leaching mode. The overall gold and silver recoveries (gravity + leach) were 94.1% and 77.5%, respectively using CELP.

These recoveries were 0.6% higher for gold and 8.4% higher for silver compared to conventional cyanidation conditions, which is consistent with past comparisons of the two leaching regimes.

The dissolution of gold and silver in a cyanide solution are a electrochemical reactions. Elsner's equation illustrates the dissolution of gold according to:

$$4Au + 8NaCN + O_2 + 2H_2O \Leftrightarrow 4NaAu(CN)_2 + 4NaOH \quad [1]$$

Li and Wadsworth[4] identified the following mechanisms: anodic dissolution of silver, cathodic reduction of oxygen and leaching of silver in cyanide solution. The overall anodic dissolution is:

$$Ag + 2\,CN^- \rightarrow Ag(CN)_2^- + e \quad [2]$$

which may be separated in two steps:

$$Ag + CN^- \rightarrow Ag(CN) + e \quad [3]$$

$$AgCN + CN^- \rightarrow Ag(CN)_2^- \quad [4]$$

Luna and Lapidus (5) suggested the following reaction for the dissolution of acanthite:

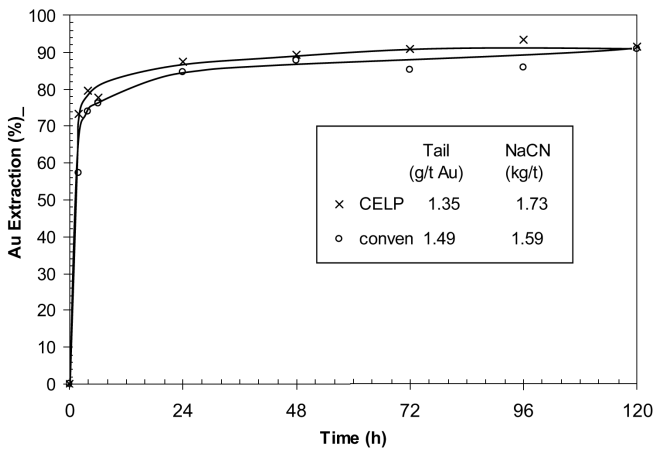

Figure 2. Comparison between the conventional cyanidation and CELP for gold leaching kinetics for CELP 8-06 from Kupol Mine. 1 000 ppm NaCN, 20°C

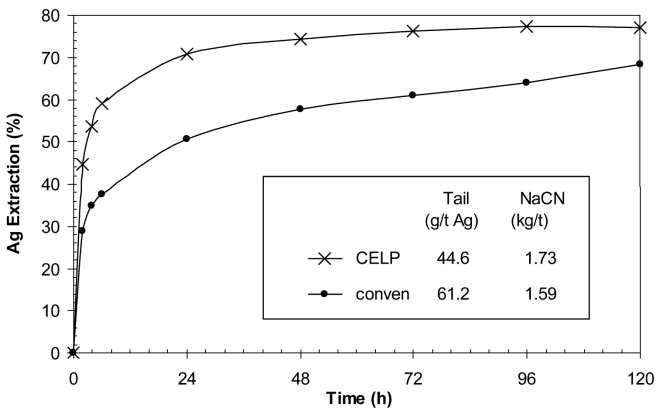

Figure 3. Comparison between the conventional cyanidation and CELP for silver leaching kinetics for CELP 8-06 from Kupol Mine. 1 000 ppm NaCN, 20°C

Table III
Gravity separation results for the CELP 8-06 composite

CELP P8-06 Sample split	80% Passing grind size (microns)	Gravity concentrate					Gravity tails (leach feed)	
		Weight	Assay (g/t)		Recovery (%)		Assya (g/t)	
		(%)	Au	Ag	Au	Ag	Au	Ag
First (16 kg)	50	0.027	24 198	18 080	29.0	2.5	16.2	193
Second (3 kg)	59	0.080	5 058	9.279	19.2	3.9	17.2	184
Third (4 kg)	47	0.025	21 094	24 502	24.2	3.0	16.5	198

$$Ag_2S + 4\ CN^- + O_2 + 0.5\ H_2O \rightarrow 2\ Ag(CN)_2^- + 0.5\ S_2O_3^{2-} + OH^- \quad [5]$$

No hydrogen peroxide was formed and that the kinetics of dissolution were a second order reaction controlled by dissolved oxygen and mineral concentration. Senanayake[6] also suggested the following reaction:

$$2Ag_2S + 10CN^- + 2H_2O + O_2 \rightarrow 4Ag(CN)_2^- + 2SCN^- + 4OH- \quad [6]$$

XPS analysis of high purity individual silver mineral particles leached by conventional cyanidation and CELP was instrumental in understanding the differences in the mechanisms of dissolution and to explain the improvement of silver dissolution[3]. The CELP leached acanthite surface has Ag(I) bonded with oxide. The metal oxide component in the O1s data is associated with the Ag. The surface also has Pb. The S2p spectrum has contributions from monosulphide and polysulphide. The monosulphide peak has a line position that is comparable with that of PbS and is interpreted to be from PbS. The surface also has appreciable $Pb(OH)_2$.

Leached stephanite surface, using the conventional cyanidation, has Ag and Sb bonded with sulphide and the leached surface is a modified stephanite lattice with detectable amounts of Pb. The major species is a Pb^{2+} oxide or sulphide. The surface also has appreciable $Pb(OH)_2$. The stephanite surface has been considerably altered during the CELP leaching. The surface has considerable Ag^+ and Sb^{5+} oxide species. Ag sulphide was not detected. The sulphide content is greatly diminished relative to pristine surfaces and the sulphide species appears to be an Sb^{3+} sulphide. The Pb binding energy is low and is strongly suggestive of PbS. However, there remains some ambiguity and the possibility for PbO remains. There is an increase in lead hydroxide on this leached surface relative to the previous surface.

The pyrargyrite leached, using the conventional cyanidation, has a surface chemistry that is very similar to the fresh reference material. The only detectable differences that are seen in the leached surface spectra are slightly broadening in the Sb and S photoelectron lines. This peak broadening may indicate that the leached pyrargyrite surface is only slightly modified relative to the bulk matrix. The surface also has detectable Pb. The major species is a Pb^{2+} oxide or sulphide. The absence of Pb sulphide contribution in the S2p data and the presence of a metal oxide component in the O1s data may indicate that the species is a Pb^{2+} oxide. The surface also has a small amount of $Pb(OH)_2$.

The leach extraction profiles for both gold and silver as a function of cyanide concentration are relatively flat from 1 000 ppm NaCN down to 500 ppm for a period of 120 hours (Figure 4). Leaching high grade refractory silver minerals at a cyanide concentration as low as 500 ppm is a significant improvement compared to the actual industrial practice. Reducing the cyanide concentration further from 500 to 300 ppm NaCN, however, produced a marked decrease in gold extraction of 1.8% and an even sharper decrease in silver leach extraction of 7.5%. The results of the cyanide concentration test series indicate that there may be a potential to reduce the cyanide concentration based on leach economics. Cyanide consumption decreases by 0.52 kg/t when the cyanide concentration is reduced from 1 000 to 500 ppm NaCN. There would also be some reduction in calcium hypochlorite consumption in cyanide destruction at the lower leach cyanide concentration. However, thiocyanate (SCN) concentration only decreased from 281 to 254 ppm when the cyanide concentration was reduced from 1 000 ppm to 500 ppm NaCN by improving the leaching strategy.

Mill flowsheet

Figure 5 presents a simplified flowsheet of the Kupol mill facility. Run-of-mine ore is initially crushed with a jaw crusher, stored in a bin and then ground in a SAG mill and a ball mill. Coarser, free gold (primarily as electrum) is recovered with a Knelson concentrator followed by a shaking table. Recoveries at this stage are 9.8% Au and 0.5% Ag. Gravity tails proceed to a deep cone thickener and the thickener underflow advances to the leach circuit. Leaching has one pre-aeration (pretreatment) tank (~ 14.5 hours residence time) and 5 mechanically agitated leaching tanks (~116 hours duration). The CCD circuit has 5 thickeners and adds approximately 48 hours of process residence time. The pregnant leach solution is treated in a Merrill-Crowe circuit for the recovery of precious metals from solution using zinc precipitation. The zinc precipitate and gravity concentrate are smelted separately in induction furnaces to produce dore bars. The No. 5 CCD thickener underflow is treated with calcium hypochlorite ($Ca(OCl)_2$) in cyanide destruction (CND process) prior to tailings disposal in an impoundment. Calcium hypochlorite is used because the operation is regulated on total cyanide and thiocyanate concentrations.

In the Kupol leach circuit, cyanide addition can be made to the initial 3 tanks; however, cyanide is usually only added to the leach tanks no. 1 and no. 2. Figure 6 shows a leach profile for silver and gold. Gold extraction reached a plateau in the 4th tank while minor silver dissolution occurred in the 5th tank. Cyanide concentration is controlled to a setpoint value in leach tanks no. 1 and no. 2 using an OCM5000 Cyanide Analyzer manufactured by Cyantific Instruments. The CANMET Enhanced Leach Process (CELP) uses standard agitated leach tanks.

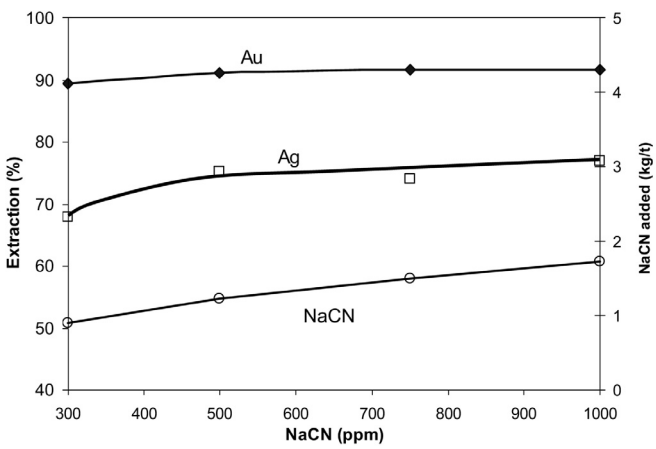

Figure 4. Gold and silver extractions with CELP as a function of cyanide concentration; 120 h, 10 ppm DO, 20°C

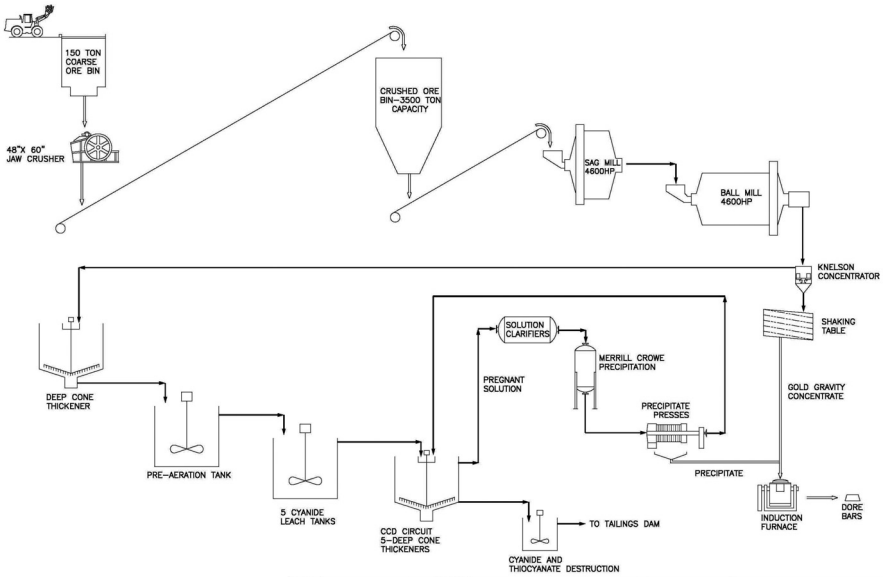

Figure 5. Simplified Kupol mill flowsheet

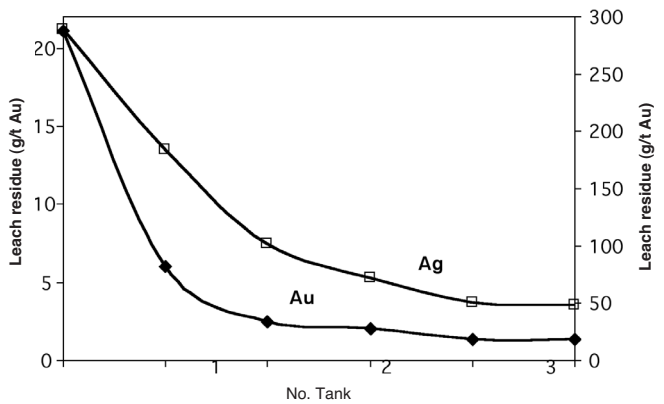

Figure 6. Leach profile for gold and silver

Mill and leach circuit start-up and performance

The mill initially started on waste material to bed the process tanks and thickeners and then the feed was switched to low grade ore (~6 g/t Au and 60 g/t Ag) after 5 days. When the switch to low grade ore was made, cyanide addition to the leach circuit was initiated. Low grade ore was processed in the mill for 7 days and then the feed was switched to high grade ore (>20 g/t Au and > 200 g/t Ag) for the remainder of 2008.

The leach circuit average cyanide concentration was maintained at approximately 150 ppm NaCN while initially processing low grade ore and was then increased to an average concentration of about 800 ppm NaCN when high grade ore began feeding the mill. However, after approximately one week of operation, it was recognized that the concentration could be reduced because leaching was essentially complete by the 4th tank as indicated in the daily leach profiles. Efforts were invested to optimize the leaching strategy and the cyanide level was decreased to an average circuit concentration ranging from 410 up to 580 ppm NaCN for the remainder of 2008.

In the daily operation, cyanide concentration was maintained at a level to try and achieve high precious metals extraction through the leach circuit, while also attempting to minimize cyanide consumption to reduce reagent costs in leaching and cyanide destruction. The additional residence time of approximately 48 hours in the CCD thickener circuit also resulted in some incremental extraction of gold and silver which provided an opportunity to decrease cyanide concentration in the leach circuit.

Table IV presents a summary of 2008 monthly and year-to-date metallurgical performance of Kupol leach and CCD thickener circuits with the CANMET Enhanced Leach Process. Key points of the summary include the following:

Table IV
Summary of 2008 leach and CCD circuit metallurgical performance with CELP

	Mill feed rate	Leach feed grade		Process tails solids		Leach extr'n		CCD extr'n		Ov'll extr'n		NaCN conc.	NaCN cons
Month	(tonnes/hour)	Au (g/t)	Ag (g/t)	Au (g/t)	Ag (g/t)	Au (%)	Ag (%)	Au (%)	Ag (%)	Au (%)	Ag (%)	(ppm)	(Kg/t)
May	98.6	18.9	250.9	0.75	23.0	94.0	89.3	2.0	1.5	96.0	90.8	544	1.97
June	111.7	32.9	425.2	1.28	46.9	94.2	86.0	1.9	3.0	96.1	89.0	580	1.60
July	120.5	24.6	307.8	1.11	41.3	93.2	83.6	2.3	3.0	95.5	86.6	578	1.30
August	128.7	26.5	311.3	1.10	40.0	94.7	85.4	1.2	1.8	95.8	87.2	475	1.25
September	135.5	22.0	293.8	1.19	41.4	93.9	84.7	0.7	1.2	94.6	85.9	468	1.19
October	134.7	29.4	331.9	1.36	50.8	94.6	82.8	0.8	1.9	95.4	84.7	545	1.35
November	135.6	25.3	369.5	1.21	47.5	94.4	85.9	0.8	1.3	95.2	87.1	480	1.18
December	140.0	20.3	261.2	1.05	41.6	94.0	81.4	0.8	2.7	94.8	84.1	410	1.07
2008 YTD	127.6	25.4	323.1	1.16	43.2	94.2	84.5	1.2	2.1	95.4	86.6	510	1.30

- Gold and silver leach, CCD and overall extractions were high in the start-up month on May and remained high throughout the year (94.8% to 96.1% for gold and 81.4% to 90.8% for silver).
- Gold and silver extractions were relatively consistent on a monthly basis despite variable gold/silver leach feed grades. The gold content of the feed varied from 18.9 g/t to 32.9 g/t and the silver content from 251 g/t to 425 g/t.
- Over 2008 the CCD circuit extracted an additional 1.2% gold and 2.1% silver, which contributed significantly to overall precious metals extraction.
- The leach circuit cyanide consumption decreased dramatically from 1.97 kg/t to 1.30 kg/t after the first two months of operation and continued to trend downward throughout the year.
- Leach circuit cyanide concentration varied from a high 580 ppm to a low of 410 ppm NaCN. Using such a low concentration of free cyanide to leach refractory silver minerals so efficiently is an outstanding performance.
- The mill feed rate on an hourly basis exceeded the design level of 133 tph in September, whereas the mill daily design tonnage of 3 000 was first achieved in October.

Table V presents a summary of 2008 monthly and year-to-date Kupol mill performance with the CANMET Enhanced Leach Process in terms of monthly production data. The overall recoveries for the mill were consistently high throughout the year despite quite large swings in the gold and silver feed grades (by up to 57% for gold and 69% for silver). The consistent recoveries were a result of removal of gravity recoverable gold at the front-end of the mill process, and also due to the robust performance of CELP. CELP allowed the mill to ramp-up to the mill design tonnage of 3 000 tpd on schedule with the 2008 mill production budget. Year-end gold and silver recoveries were 2.8% and 7.5% higher than the targets, while precious metals production was 138 000 ounces of gold and 2 000 000 ounces of silver higher than plan.

Comparison of plant and laboratory results

Table VI presents a comparison of the plant and laboratory metallurgical results for the CANMET Enhanced Leach Process. The month of December 2008 plant results were used to compare with the lab results on the CELP 8–06 sample because the leach feed grade in December was nearest the lab sample leach feed grade.

Key points from the comparison of the plant and lab results in Table VI were the following:

- Plant gold and silver leach extractions exceeded laboratory extractions by 2.3% and 4.5%, respectively by doing incremental improvement of the leaching strategy. The higher plant extractions were also attributed to the higher leach feed grade and the classification that contributed to produce finer gold and silver grains.
- Plant and laboratory tails solids assays for gold and silver were in relative agreement, which may be a better comparison on precious metals extraction performance. The plant leach residues is collected after the CCD thickener circuit, so the plant assays would be naturally be slightly lower than the laboratory because of the incremental CCD circuit extraction mentioned previously.
- Overall, the laboratory results provided conservative predictions of plant performance.

Conclusions

The Kupol mill start-up with the CANMET Enhanced Leach Process proceeded smoothly. The design throughput of 3 000 tpd was achieved in 6 months. The mill overall gold and silver recoveries for 2008 were 95.4% and 85.6% respectively, which were 2.8% and 7.5% higher than targets. Gold and silver extractions in the leach circuit were 94.2% and 84.5% respectively. With the CCD circuit included, total gold and silver extractions increased to 95.4% and 86.6%, respectively. Sodium cyanide concentration as low as 410 ppm was used in leaching, without compromising precious metals extractions. Using such a

Table V
Summary of 2008 mill monthly and year-to-date performance with CELP

	Mill tonnage	Mill feed grade		Overall recovery (Grav + leach/CCD)		Precious metals production	
Month	(tonnes/hour)	Au (g/t)	Ag (g/t)	Au (%)	Ag (%)	Au (oz)	Ag (oz)
May	30 430	21.0	252.0	96.2	91.5	1 452	819
June	73 890	36.6	427.4	95.8	87.8	57 823	564 778
July	84 524	26.1	308.7	95.3	85.7	85 953	948 285
August	92 732	28.2	312.5	95.4	86.0	82 981	865 585
September	81 012	25.3	295.6	94.9	85.0	63 940	638 598
October	94 533	33.4	334.4	95.6	83.8	90 123	917 694
November	96 225	27.9	371.0	95.3	86.1	90 864	951 162
December	94 986	23.1	263.0	95.2	82.8	68 825	680 733
2008 YTD	648 332	28.2	324.8	95.4	85.6	541 962	5 567 654

Table VI
Comparison of plant and laboratory metallurgical results with CELP

Plant/lab	Leach feed grade		Tails solids assays		Leach extr'n		Overall recovery		NaCN conc.	NaCN cons.
Month sample	Au (g/t)	Ag (g/t)	Au (g/t)	Ag (g/t)	Au (%)	Ag (%)	Au (%)	Ag (%)	(ppm)	(kg/t)
December-08	20.3	261	1.05	41.6	94.0	81.4	95.2	82.8	410	1.07
CELP 8-06 Sample	16.2	193	1.35	44.6	91.7	76.9	94.1	77.5	1 000	1.68

low concentration of cyanide was possible because of the unique feature of CELP that produced oxidized silver mineral surfaces. The average cyanide consumption for 2008 was 1.3 kg/t.

Laboratory results were very useful to predict and improve the actual plant performance.

The new CANMET leaching technology proved to be very robust and performed efficiently even with changes in feed grade and ore mineralogy. The robustness of the CELP technology and the laboratory test work contributed to the success of the Kupol mill start-up.

Acknowledgements

We would like to acknowledge Kinross Gold and CANMET/MMSL for the authorization to publish this paper, Rob Henderson for his technical review, Mike Fulton and Hai Guo for their participation in the experimental work, Regina Karwowska and her staff for the chemical analyses and SGS Lakefield for arranging the assay of laboratory samples.

References

1. DESCHENES, G., RAJALA, J., and FULTON, M. Leaching of gold and silver from Kupol composite sample: part II—assessment of the CELP. *2009 SME Annual Meeting*, Feb. 2009, Denver, Col., preprint, Society for Mining, Metallurgy and Exploration.
2. DESCHENES, G., FULTON, M., GUO, H., PRICE, J., and XIA, C. A new technology for the treatment of gold ores containing a high concentration of silver. *Proceedings of International Workshop on Process Hydrometallurgy*, Domic, E.M. and Casas de Prada, J.M. (eds). Iquique, Chile, Gecamin Ltd, 2006, pp. 113–122.
3. DESCHENES, G., FULTON, M., XIA, C., and PRATT, A. Progress on the assessment of CANMET Enhanced Leaching Process technology for the gold and silver leaching of high grade ores. *Proceedings of International Workshop on Process Hydrometallurgy*, Menacho, J and Casas de Prada, J.M. (eds). Santiago, Chile, Gecamin Ltd, 2008, pp. 47–59.
4. LI, J. and WADSWORTH, M.E. Rate processes of silver cyanidation. *Proceedings of the EPD Congress 1992*. Hager, J.P. (ed.), The Minerals, Metals and Materials Society, 1991, pp. 257–271.
5. LUNA, R.M. and LAPIDUS, G.T. Cyanidation of silver sulfide. *Hydrometallurgy*, vol. 56, 2000, pp. 171–188.
6. SENANAYAKE, G. A review of effects of silver, lead, sulfide and carbonaceous matter on gold cyanidation and mechanistic interpretation, *Hydrometallurgy*, vol. 90, 2008, pp. 46–73.

Guy Deschênes

Senior Research Scientist, Natural Resources Canada, CANMET/MMSL

BSc in metallurgical engineering from Laval University with a B.Sc. in 1981. M.Sc in ectrometallurgy in 1987 and a PhD hydrometallurgy of gold in 1990, both at Laval University. He holds the position of gold project leader at CANMET/ MMSL. He developed new leaching strategies for mild refractory gold ores. He has authored 83 publications and 102 contract reports, one book and wrote the chapter on cyanidation of gold in the book entitled 'Latest Advances in Cyanidation of Gold'. Since 2002, he has led a series of Gold extraction professional development seminars. In 2004, he was awarded the Federal Partner in Technology Transfer Award. He is the founder of the World Gold Conference series. He was the Chairman of the International symposium on gold extraction in 2005. He serves on the Editorial Advisory Board of Minerals Engineering Journal and SME publications. He is a member of CIM and Quebec Engineering group.

J. Rajala

Process Manager, Kinross Gold Corporation, Toronto, Ontario, Canada

Currently with Kinross Gold Corporation as process manager for the Fruta del Norte Project in Ecuador. Previously mill manager for Kinross at the Kupol Gold Mine. Have been with Kinross Gold for the past 13 years.