XPS BULLETIN

ISSUE 19: CMP 50TH ANNIVERSARY EDITION

IN THIS ISSUE

➤ XPS will once again be exhibiting at PDAC 2018 in March at Booth #615 in the Trade Show.

XPS EXPERT PROCESS SOLUTIONS
A GLENCORE COMPANY

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Congratulations CMP for 50 Years of Service to our Industry

THIS YEAR MARKS THE 50TH ANNIVERSARY OF CANADIAN MINERAL PROCESSORS (CMP), A SOCIETY OF THE CANADIAN INSTITUTE OF MINING AND METALLURGY (CIM).

Canadian Mineral Processors
A technical society of CIM

The CMP had its beginning as an operator-oriented group called the Canadian Gold Metallurgists, the formation of which was predicated on the principle of "Cost plus tails", i.e. obtaining the lowest possible cost per ton of ore milled with the highest recovery possible.

This focus on operators and their interests is maintained as a priority to this day at the annual National Operators Conference, held in mid-January in Ottawa, Canada, and at the regional meetings held across the country throughout the year. The annual conference would not be possible without the significant and exemplary volunteer effort provided by CANMET and its dedicated staff.

XPS is proud to continue to support the CMP and this support has taken several forms, including submission of technical papers, plenaries, panel discussions, contributions to special volumes, presentations for the annual and regional technical programs, (See 50th CMP Technical Program for details), and of course sponsorships.

Historically, the sponsorships of the CMP student program provides funding for up to 30 students from more than 15 educational institutions to travel to Ottawa and CMP each January. This program is a model for support of students within the CIM Societies and is a significant contribution to the development of the next generation of mineral processing engineers and technologists.

In addition to the student program sponsorship, XPS has sponsored and participated (*...despite the questionable +/- or contribution of points!*) in the annual Ray MacDonald Memorial Hockey Game organized by the Toronto Chapter of the CMP.

Local branches are extremely important to CIM and CMP and XPS has sponsored local branches including Central Ontario (Sudbury), N.E. Ontario (Timmins) and Ottawa-Montreal-Quebec.

XPS has nominated and supported nominations to the CMP awards program to recognize the work and commitment of our peers, and over the last several years has also volunteered at various levels within the CMP executive up to and including National Chairman.

We value our voluntary contributions because XPS truly believes the National CMP and its local branches are necessary as a forum for innovation, technical exchange, problem solving, networking, new technology development and adaptation and for building and maintaining the relationships that are so critical to our industry's success.

We at XPS wish to acknowledge and congratulate CMP on this 50th Anniversary and thank the 2018 CMP Executive for all the extra efforts in preparing for this milestone and celebration.

This special CMP Edition of the XPS Bulletin will focus on mineral processing with articles describing our unique experience in quantitative mineralogy with the XPS Advantage, why depressants are sometimes a good thing in mineral processing, our significant expertise in Cu/Ni separation and thickener control strategies.

We hope you enjoy and find value in the articles and wish you the very best for a safe and profitable 2018.

Dominic Fragomeni, P.Eng., FCIM
Vice President, XPS
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XPS develops Copper-Nickel Separation for Nickel Creek Platinum Corp.

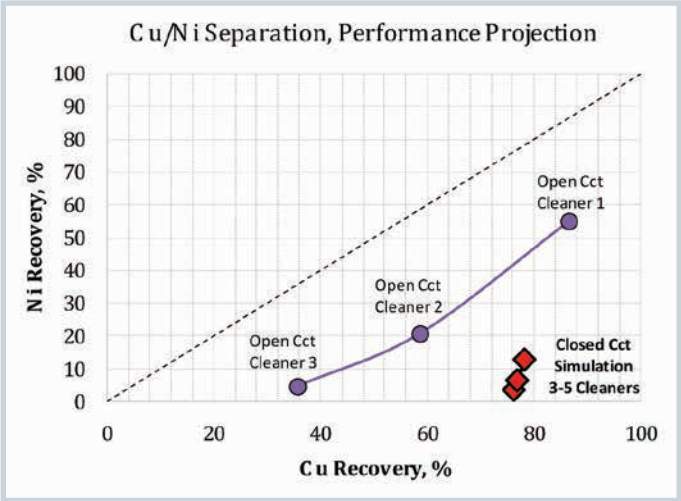
(formerly known as Wellgreen Platinum Ltd.)

NICKEL CREEK PLATINUM CORP. IS A CANADIAN MINING EXPLORATION AND DEVELOPMENT COMPANY FOCUSED ON THE ACTIVE ADVANCEMENT OF ITS 100%-OWNED NICKEL, COPPER AND PLATINUM GROUP METAL (PGM) PROJECT, LOCATED IN THE YUKON TERRITORY, CANADA.

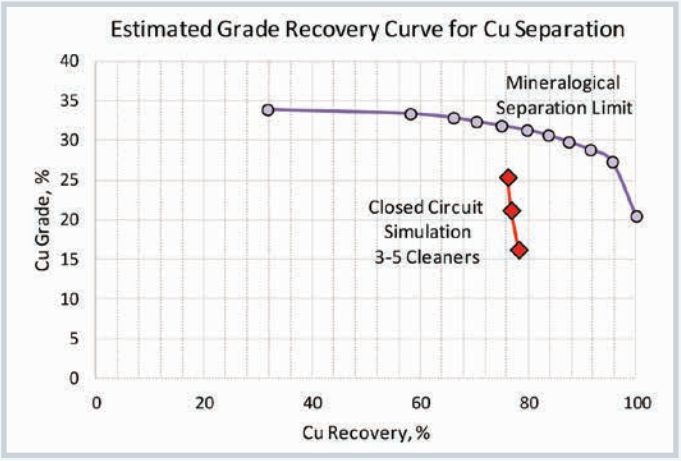
In the current NI 43-101 technical report for the project (which can be obtained under the company's profile at www.sedar.com), the proposed operation contemplates a bulk nickel-copper concentrate. The ability to separate copper concentrate from the bulk Ni-Cu concentrate has the potential to generate significant incremental project value.

XPS has extensive experience in copper-nickel separation and has worked collaboratively with Nickel Creek Platinum Corp. to explore the feasibility of such a separation. The ultimate grades and recovery of concentrates produced by Cu-Ni separation can only be determined from tests on bulk concentrate produced through steady state evaluation. Due to the developmental stage of the project and the relatively low mass pulls to concentrate, there was insufficient ore mass available to do large scale concentrate generation for steady state evaluation. In such cases it is normal to do open scale batch testing followed by closed circuit simulation based upon the open circuit metal split factors. This metal split factor approach, combined with a confirmation of mineralogy, allows for the advanced evaluation of the conditions required to achieve a Cu-Ni separation and to determine targets for future work.

The metal split factors were generated from a series of flotation tests on the ore and bulk concentrate which were conducted to determine the separability of copper minerals from the bulk concentrate. The program included assessment of chemical depressants, oxidative conditioning and lime-based pH adjustment. The total mass of feed required to complete the assessment was only about 20kg. Designing an effective process assessment around limited sample availability was a key deliverable of the program.



	Particle Type	Grade	Pn	Cpy	Po	Gangue
Liberation	Locked	<30%	11.2	12.4	9.9	7.0
	Low Grade Mid	>30%	16.5	21.1	34.0	16.4
	High Grade Mid	>80%	17.7	16.6	30.6	17.6
	Liberated	>95%	24.2	18.1	17.5	27.9
	Free	100%	30.4	31.7	8.0	31.2



Open circuit testing showed good flotation selectivity between copper and nickel, but with relatively low open circuit stage recoveries, as is normal for sequential batch cleaners in this float. The three stage open circuit cleaner results were used to simulate 3-5 stages of closed circuit cleaning (with five stages typically considered to be equivalent to industrial column cleaning). The simulation estimated a recovery of about 76% of the copper with about 3% of the nickel into the copper concentrate.

The feed to the open circuit separation was simultaneously assessed by QEMSCAN mineralogical assessment so that a theoretical grade/recovery relationship can be cal-

culated and compared to the closed circuit performance projections. Assessment of the liberation of the CuNi bulk concentrate allowed the construction of a theoretical grade/recovery relationship for CuNi separation, based upon perfect separation. At 76% copper recovery (based upon CuNi separation feed) the liberation data suggests that a Cu concentrate grade of approximately 32% Cu would be the maximum theoretically achievable.

The two independent assessments provide a reality check for the metallurgical predictions, and yield a best estimate of copper/nickel separability until such a time as the projections can be replaced with an empirical, larger-scale, stable-state demonstration of the process. The results, therefore, suggest that pending the generation of larger-scale continuous circuit data, the metallurgical projections (26% Cu concentrate at 76% Cu recovery from bulk concentrate) can be treated as realistic process targets that are not in conflict with independently generated mineralogical separability data.

The Nickel Creek Platinum Corp. Cu-Ni separation program has produced high quality process estimates for the exploration project using very modest quantities of sample material, and has supported the case for basic viability of Cu-Ni separation for this project. The results and conclusions are generally consistent with Cu-Ni separation at Sudbury Strathcona nickel operations which has also been similarly modelled. Thus, the results of the Nickel Creek Platinum Corp. assessment are considered to be both internally consistent between the two applied methodologies (metallurgical and mineralogical) as well as being consistent with external industry practice.

The methodologies described here, while useful for process estimation, do not replace a continuous pilot plant demonstration of copper nickel separation. However, the results do indicate substantial physical separability of copper from nickel that point towards separation efficiencies consistent with the project requirements. Quantitative and definitive demonstration of copper-nickel separability is planned in the upcoming year employing the same conditions developed and applied in the small scale open circuit testing.

For more details on XPS experience in Cu/Ni separation, please contact Gregg Hill, XPS Mineral Processing Lead at gregg.hill@xps.ca

COLLABORATION

XPS Collaboration with Cambrian College

Although XPS has a long-term relationship with Cambrian College - a local educator that has trained most of the technicians in our workforce – the relationship is going to get even closer as XPS is supporting Cambrian through the College Strategic Sector/Cluster/Technology Platform Program (CSSCTP).

Through this endeavor, XPS will work in partnership with the College to develop innovative strategies to enhance general productivity and performance in mining operations.

Our goal is to address sector-wide R&D challenges - in combination with Cambrian's strategy to build capacity under their Innovations in Predictive and Preventative Maintenance (IPPM) program – and we expect that this will help to create a more efficient and sustainable marketplace that supports high-value jobs.

Through this collaborative partnership, XPS expects to establish and enhance processing solutions that are 'best practices' for the industry, while at the same time supporting experiential learning opportunities for students at Cambrian.

Glencore – Centre for Innovation at Cambrian College

We are confident that this collaboration will foster new and innovative strategies in the mining cluster, ultimately leading to long-term community economic growth.

If you are interested in pursuing innovation projects through this XPS-Cambrian collaboration, please contact Mika Muinonen, XPS General Manager, Process Metallurgy at mika.muinonen@xps.ca

In Mineral Processing... Depression Can Be a Good Thing

THE SUCCESS OF BASE METAL FLOTATION PROJECTS IS OFTEN LIMITED BY THE GRADE OF CONCENTRATE THAT CAN BE PRODUCED.

Reagent testing at XPS Labs

Although the concept of grade/recovery trade-off is well understood, at times the required grade is practically unachievable at any recovery.

This is particularly the case when a gangue sulphide with partial flotability is present in large quantities or when selectivity is impaired; therefore, in such cases, mineral depression is often the key to restoring selectivity in flotation.

The causes of many selectivity issues can be hard to diagnose, since flotability is a complex surface phenomenon. Gangue mineral hydrophobicity often involves unwanted interaction between gangue and the collectors that are added to impart hydrophobicity to the desirable mineral species.

This type of interaction can be induced or facilitated by the presence of transient mobile metal ions, oxidative processes, and electrochemical or galvanic effects. In other words, selectivity can be affected by any feature of ore chemistry, ore history, water chemistry, or the grinding environment.

The dependence of flotability on local conditions and environment means that selectivity often departs from theoretical models constructed from observing the behaviour of pristine ore. The practical application of depressant technologies is governed, not only by theory, but also by a combination of experience and empirical observation.

As a general principle, the predictability of flotation is improved by the removal of transient metal ions that can migrate from surface to surface in the pulp. For this reason, the depressant toolbox involves a number of metal sequestrants that reduce the activity of metal ions by complexation. These include cyanide, ammonium, chelating organic acids, or organic amines.

The specific agent and dosage used depends upon the particular ore and its chemistry. In some cases, depressants are used to actually mask the surfaces of gangue particles by creating hydrophilic layers around them. Compounds capable of achieving this objective include calcium ions; complex high-molecular weight organics, such as carboxymethylcellulose, lignin sulfonates, dextrines and saccharides; as well as some polyacrylic acid derivatives.

Many depressant situations revolve around the depression of iron sulphides, although there are also applications in the rejection of arsenic, suppression of gangue silicates or carbonates, suppression of graphite in carbonaceous ores, or suppression of specific minerals such as galena and/or sphalerite in the flotation of copper minerals.

The selection of depressant systems for the enhancement of concentrate grade is often commodity specific, with certain classes of depressants used repeatedly among deposits of a similar type.

The ability to design and implement a successful system comes from understanding a unique combination and balance of selectivity, the specific circumstances associated with a given ore situation, and practical experience with depressant systems.

At XPS, our team of senior mineral processors has the ability to select and optimise depressant systems for enhancing selectivity and grade over a wide spectrum of commodities. Our successes include pyrrhotite rejection from nickel and zinc ores, magnesium rejection from nickel and copper ores, zinc suppression in copper flotation, lead suppression in sequential copper/lead flotation, and many more.

We invite you to discuss your specific issues with us, and to see the role that depressants and selectivity modifiers can play in optimising your flotation process.

For more information on XPS expertise in use of depressants in flowsheet development and optimisation, contact Gregg Hill, XPS Mineral Processing Lead at gregg.hill@xps.ca

The Advantages of Using XPS for Process Mineralogy

XPS OPERATES A WORLD-CLASS PROCESS MINERALOGY LABORATORY WITH THE EXPERIENCED PERSONNEL AND STATE-OF-THE-ART EQUIPMENT THAT CAN ADD SUBSTANTIAL VALUE TO ANY OF YOUR PROJECTS.

With more than 65 combined years of experience, our team of mineral processing and metallurgical engineers brings a set of unique skills and substantial industrial experience to the interpretation of the process implications from mineralogical data.

Although the group focuses primarily on analyzing process samples, we routinely examine exploration, mine, and environment samples for our various clients.

High quality sample preparation is the foundation upon which minerology data is based. XPS has the capability to size down to 3μm (CS7).

This fine-particle resolution - which is normally not offered by other commercial labs - is particularly valuable when interpreting flotation performance. It is the finest fraction where both entrainment in concentrates and losses to tailing can occur. Producing a size fraction distribution that separates out these particles from the coarser part of the distribution is important.

This method of fine-particle sizing performed by XPS personnel has been critical for diagnosing performance issues at many of our clients operations.

In the figure below, the non-sulphide gangue (NSG) present in the Ni concentrate has been recovered through entrainment of ultra-fine liberated particles, while a significant proportion of the Ni losses to the tails occur as liberated pentlandite with grain sizes less than 3μm.

NB: To reduce costs, combining of size fractions prior to QEMSCAN measurement is quite common. We encourage clients to consider the loss of resolution and misinterpretation of data when combining size fractions that may contain both fine entrained and floatable particles such as typically found discretely in CS3-5, CS6 and CS7.

The XPS Advantage is Available to You

XPS operates a variety of specialized equipment, such as QEMSCANs (Quantitative Evaluation of Materials by Scanning Electron Microscope) and EPMA (Electron Probe Micro Analysis), both of which are utilized in process mineralogy projects.

There is significant value in having the two instruments within the same lab because samples can be easily transferred from one instrument to another improving mineral identification, QA/QC, and ultimately a more accurate result in element deportment calculations.

This combination of technology is important in determining accurate metal deportments for Cu, such as in mixed oxide and sulphide deposits; Ni, as in pyrrhotite and gangue; and REE as well as better understanding trace or penalty elements (F, As, Bi, Co).

XPS also operates an XRD (X-ray Diffraction) unit, which offers a fast and inexpensive way to identify non-trace

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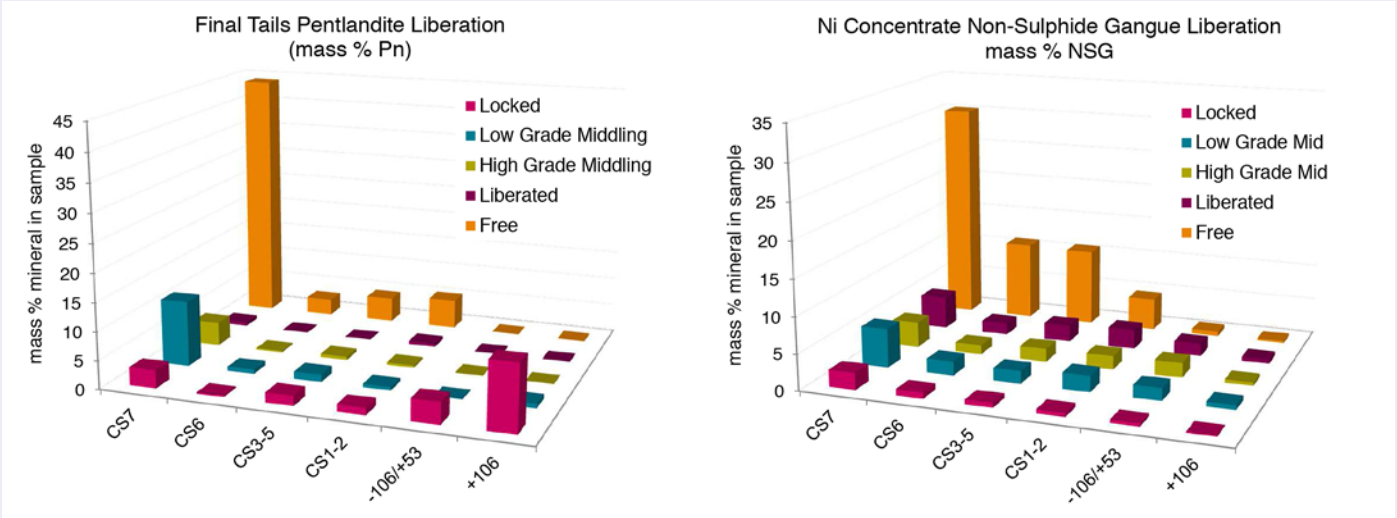


Liberation profile examples of free gangue slimes (CS7 or -3μm) entrained to concentrate (left) and ultrafine (CS7 or -3μm) free and liberated pentlandite losses to final tails

Improving Thickener U/F Density Control and Measurement

MOST MINERAL SEPARATION PROCESSING INVOLVES THE USE OF A CONSIDERABLE AMOUNT OF WATER; THEREFORE, TO MAKE IT ECONOMICALLY VIABLE FOR SHIPMENT, THE FINAL CONCENTRATE USUALLY REQUIRES DE-WATERING TO PRODUCE A THICKENED UNDERFLOW OF THE REQUIRED CONCENTRATION.

The nickel concentrate thickener at the Glencore Strathcona Mill is a conventional thickener with positive displacement underflow pumps. Nickel concentrate from the mill is then shipped by slurry tank truck to the smelter for further processing. Because the concentrate is shipped in slurry form, it is important from a cost-efficiency perspective that there is reduced variability and that the final concentrate density is close to the process limit.

The density of the underflow slurry is measured by nuclear density gauges. One of the pre-conditions for good control performance is measurement accuracy and all instruments need to be calibrated in order to provide a representative value of the measurement. Although nuclear density gauges are considered to be high-accuracy instruments, often it is difficult to achieve the required accuracy due to difficulties with their calibration.

In response to this need, an initiative was taken at the Strathcona Mill to improve slurry measurement accuracy and density control performance.

In the past, the underflow pump speed was determined by the greater of the two PID outputs from the density controller and the inventory controller. As a result, the pump speed was always varying, which resulted in a highly-variable concentrate density.

With the new control strategy it is now possible to control density with a standard deviation of <1% of the setpoint, hence, a product with consistent density can be produced.

Density gauges are now calibrated following a two-point calibration method, where one point is obtained with process water and a second obtained by controlling the density at a stable reading. The density is initially checked by Marcy Scale with operators taking repeated manual sample cuts within a short interval.

The same sample is then taken to a lab for an accuracy check and then an adjustment is made to the density gauge calibration based on the lab verification. Following this method it was possible to calibrate the density gauges with high accuracy and repeatability.

The nickel concentrate density improved over time as a result of the better density reading, plus a new control strategy and changes in operating practices. The accuracy of density reading is monitored by periodic lab test and it has been identified that this calibration method reduced the frequency of regular maintenance work. A higher density is helping the mill to reduce the cost in slurry shipment.

Figure 1: Old Strategy.

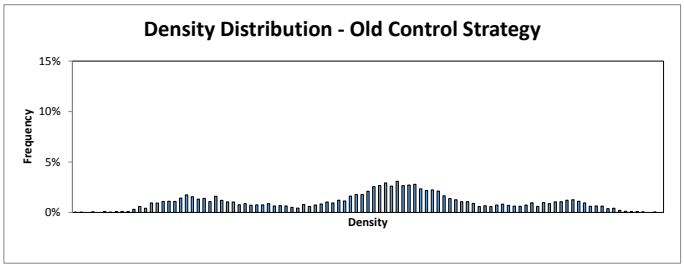
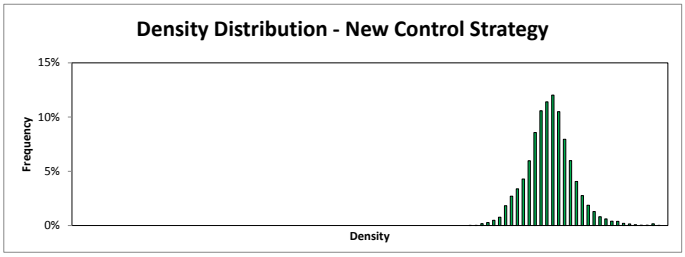


Figure 2: New Strategy.



Distribution of density measurement comparing old and new control strategies; the standard deviation of density measurement is reduced with a process consistently operating at the higher end of the design limit.

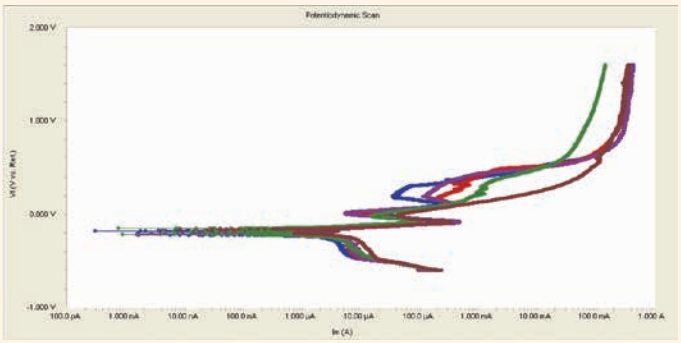
For more information on XPS expertise in thickener controls, please contact Naseeb Adnan, Process Control Engineer at naseeb.adnan@xps.ca

XPS Offers Expanded Electroplating Services

TO MEET THE SPECIFIC RESEARCH NEEDS OF ONE OF OUR CLIENTS, XPS RECENTLY UPGRADED THE ELECTROPLATING LABORATORY TO INVESTIGATE ANODIC DISSOLUTION OF PLATING MATERIALS UNDER VARIOUS CONDITIONS.

The upgrades included a new power supply to meet the energy requirements of four cells in series and calibrated temperature controls to ensure the resistance heating was kept at an ideal temperature as the electrolyte circulated through the cells.

The installation also includes continuous monitoring and logging of individual cell voltage and current, plus a walk-in fume hood that ensures the safe and continuous 24-7 operation of the cells.



Potentiodynamic Curves

Anodic Material after Potentiodynamic Scans

Electroplating Laboratory

In this experiment, titanium baskets contained the anodic metal and anode bags were used to collect anode residue for characterisation. Samples were plated for several weeks to achieve steady state operation and to understand the dissolution mechanisms.

Partially-corroded anodes were mounted and evaluated using optical and scanning electron microscopy. The cell voltage and current data was also analyzed and correlated with different conditions in the cell allowing for evaluation of anodic products and optimisation of conditions for dissolution.

Potentiodynamic analysis as well as evaluation of the anodes was also conducted to further confirm the mechanism of dissolution for various anodic products.

The end result allowed our client to optimise the properties of the anodes and to recommend procedures for ideal plating.

This electroplating laboratory is adaptable to a number of metal-aqueous systems, including Cu, Zn, Co, Cr, Ni and others to evaluate conditions required for metal plating or electro-refining.

For more information on XPS electroplating expertise, please contact Mika Muinonen, XPS General Manager, Process Metallurgy at mika.muinonen@xps.ca

Welcome to XPS

Abigail Sequeira – New Extractive Metallurgist

XPS welcomes Abigail Sequeira, P.Eng. to the extractive metallurgy team as a Program Engineer.

Abigail is a P.Eng. and earned her degree from the University of Toronto. She also holds a Professional Project Manager designation and has over 10 years of expertise in extractive metallurgy. She has worked in various areas including milling, roasting, smelting, and chemical refining.

Abigail brings strong technical skills and professional experience to expand and complement the XPS Extractive Metallurgy Group. Her ability to work with operations and technologists/ technology personnel was clearly demonstrated during her tenure at the Vale Copper Cliff operations.

Please join us in welcoming Abigail to XPS and our talented team.

Napoleon Reata – New Process Control Engineer

XPS is pleased to welcome Napoleon Reata, P.Eng. to the XPS Process Control Group as a Process Control Engineer.

Napoleon is a graduate of the National University of Singapore where he received a Master of Science Degree in Chemical Engineering. He has certifications in Emerson Delta V and extensive experience programming Yokogawa DCS, Rockwell Automation PLCs and Tuning PID loops.

Napoleon has over 12 years of work experience most recently with ConocoPhillips in Alberta where he was in charge of automation commissioning & start-up, system maintenance and optimisation. Prior to this Canadian experience, Napoleon worked for Yokogawa in automation and advanced control in Middle East and Philippines. Aside from his process control background, he also brings large petrochemical operations experience from his time as an operations engineer.

Please join me in welcoming Napoleon and his family to XPS and Sudbury.

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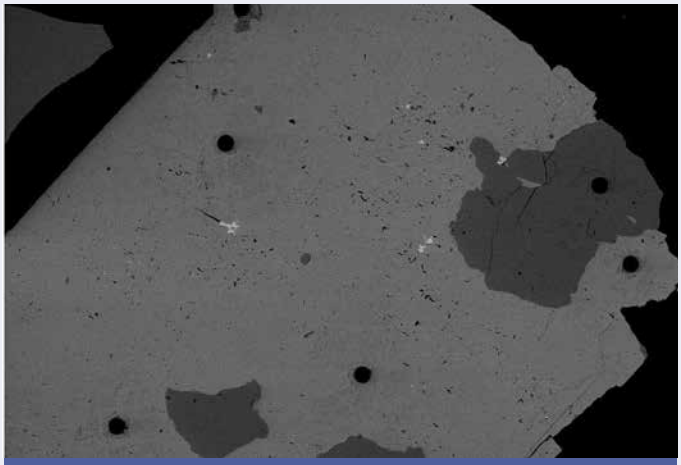
The Advantages of Using XPS for Process Mineralogy

phases within samples. In addition, this technique is often used to differentiate between polymorphic minerals (hexagonal vs. monoclinic pyrrhotite) and perform clay speciations.

LA-ICP-MS (Laser Ablation - Inductively Coupled Plasma - Mass Spectrometry) is the latest technology that XPS operates and this unit integrates a variety of process mineralogy programs. It can detect low concentrations of metals, including Au and PGEs that occur as solid solution within other phases (such as sulphides) down to detection limits of 0.05ppm.



Laser Ablation trace in Spodumene

The combination of these data with QEMSCAN and EPMA results, can provide a powerful tool on which processing interpretations are based. This technology has also proved invaluable for comprehensive process mineralogy on Lithium-bearing deposits where conventional x-ray techniques are unable to identify and quantify the Li as it is a light element.

When you come to XPS for mineralogical analysis, you are receiving the benefit of high- quality sample preparation capability and substantial experience in operation and data processing. Most importantly, the work is performed by a lab team that is fully integrated with mineral process engineers which strengthens the interpretation of the results.

It is not just an analytical result, the XPS advantage produces an integrated 'process mineralogy' solution.

For more information on the XPS advantage, please contact Lori Kormos, XPS Principal Geoscientist at lori.kormos@xps.ca

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