Short Course on Methods and Applications of Geometallurgy and Process Mineralogy

Inco Innovation Centre, Micro-Analysis Facility, St. John's, Newfoundland, Canada

Basic Course – May 12-14, 2008
Advanced Course – May 15-16, 2008

Scheduled Lecturers - Louis Cabri (Memorial University and Cabri Consulting Inc), Chris Hamilton (Barrick Gold Corp), Michelle Huminicki (Rockcliff Resources), Rolando Lastra (CANMET), Kurt Moeller (JKTech Pty Ltd), Paul Sylvester (Memorial University); with laboratory exercises led by Michael Shaffer (Memorial University) and Marc Beauchamp (Memorial University).

Intended audience – Metallurgists and geologists who use mineralogical information for the development of mineral deposit projects, resource assessment, and understanding ore processing issues.

Course content - The emphasis is on the interpretation and application of quantitative mineral data collected using the scanning electron microscope (SEM)-based mineral liberation analyser (MLA). The basic 3-day course introduces modern multidisciplinary approaches for applied and process mineralogy, integrated with quantitative image analysis by MLA. This material is intended for those new to SEM-based automated mineralogy and their applications in the minerals industry, or those wishing to update their knowledge of these methods. The 2-day follow-on advanced course deals with more detailed issues surrounding data collection by MLA, and their implications for solving problems in process mineralogy and geometallurgy. The advanced material will be of interest to more experienced users of quantitative mineralogical data and those already possessing a basic background in MLA data collection and interpretation.

Enrollment – Attendees may register in either the basic or advanced course, or both. The enrollment will be limited to a maximum number of 16 to ensure optimal instruction in the laboratory.

Syllabus of Basic Course

May 12 – Principles of Quantitative Mineralogy

8:30am Paul Sylvester
Welcome and course overview

8:45am Louis Cabri
The mineralogist's toolbox: A historical perspective and overview of modern microbeam instruments for quantitative mineralogy (SEM, XRD, EPMA, PIXE, SIMS, LA-ICPMS)

Short summary: Development of techniques available from the early 1960's through to current practice. Advantages and disadvantages will be reviewed together with relevant aspects such as volumes measured, levels of detection; standardization issues, etc.

9:25am Rolando Lastra
The Scanning Electron Microscope as a platform for image analysis: A brief history and discussion of the components and basic principles required of an SEM/EDX image analyser

Short summary: Very early in the development of systems for quantitative mineralogy, it was realized that minerals could be better identified automatically by using scanning electron microscopes or electron microprobes. A brief review will be presented of the past and present systems. In addition, the desired characteristics, advantages and limitations of the various components of the SEM/EDX will be reviewed.

10:05am Chris Hamilton
An overview and comparison of modern commercially available image analysers (MLA and QemSCAN)

Short summary: Although there are several systems in use around the world, commercial systems include MLA and QemSCAN which, although offering ostensibly the same service, differ in fundamental aspects. Key differences between the systems will be addressed in this lecture, including their strengths and weaknesses, principles by which they operate, and the theoretical and practical philosophy upon which they are based.

10:30am Coffee Break

10:50am Chris Hamilton
Available data outputs from image analysis (mineral modes, mineral associations, grade recovery curves, particle size distributions, etc)

Short summary: Outputs ranging from mineral modes to liberation data are the essential deliverables of our services. Examples and guidelines for data

presentation are covered in this presentation. The roles of mineralogy and metallurgy and the cross-disciplinary nature of this important crossover will be covered and the key questions of 'what the metallurgist really wants/needs' addressed. The difference between geological and metallurgical mineral groupings will be covered, which aims to strike a balance between appropriate mineral descriptors and metallurgically meaningful data.

11:15am Chris Hamilton
Sampling: From the macro to the micro scale

Short summary: Fundamentals of Sampling Theory and practise are an essential component of quantitative mineralogy, as are the downstream sampling protocols within a mineralogical laboratory. Concepts of nomograms, cumulative error and sources of error will be covered in this module. Included in this lecture are quality control issues, discriminating measurement vs. sampling error and guidelines for statistical criteria. Many of these guidelines are borrowed from Ore Resource and Mineral Inventory Methods used in Exploration Geochemistry.

11:40am Louis Cabri
New methods for mineral separation: electric-pulse disaggregation (EPD) and hydroseparation (HS)

Short summary: EPD and HS are new technologies for the west, though the former was developed in the Soviet Union in the 1950's and HS was developed in Russia within the last decade. EPD is used to liberate minerals without breaking individual minerals or producing dust and fines, and HS is used to concentrate minerals. Examples will demonstrate their usefulness in the minerals industry.

12 noon Lunch Break

1:00pm Kurt Moeller
The MLA Method: The concepts of setup and analysis, to data processing

Short summary: Fundamental principles of MLA measurement and data processing are introduced, as well as some basic SEM operations for MLA analysis (selecting accelerating voltage; tuning electron source; selecting amp time and adjusting spot size; calibrating backscattered electron image contrast and brightness).

1:45pm Kurt Moeller
Overview of the different MLA modes

Short summary: The various measurement modes of the MLA are reviewed. These are backscattered electron (BSE) analysis; extended BSE (XBSE) analysis; grain X-ray mapping (GXMAP); sparse phase liberation (SPL); X-ray modal (XMOD) analysis; and rare phase search (RPS). The focus in this introduction will be on the XBSE and GXMAP modes.

2:30pm (Divide into 2 groups)

Michael Shaffer, Marc Beauchamp and Michelle Huminicki
GROUP 1 - Lab 1 (on SEM): Hands-on instrument training (sample change, zoom, contrast, EDX analysis); tour of Inco Centre and LA-ICPMS and SIMS labs.

Michael Shaffer, Marc Beauchamp and Michelle Huminicki
GROUP 2 - Lab 2 (classroom demo): Setting up for the online acquisition using the XBSE (extended BSE liberation analysis) MLA mode

3:30pm Coffee Break

3:45pm Group Exchange (GROUP 1 – Lab 2; GROUP 2 – Lab 1)

4:45pm Discussion and Questions

5:00pm Adjourn

May 13 – Applications in Exploration and Geometallurgy

8:30am Chris Hamilton
Introduction to Geometallurgy

Short summary: Geometallurgy is a fairly recent development in the Minerals Industry, yet it builds on two long-held key premises. These are predictive metallurgy and the question of ore variability and it's affect on mine performance on both a day-to-day and life-of-mine basis. Knowing the variability of mine block value, relationships between texture and mineralogy and performance, as well as grinding costs, the NPV and mining plan can be constrained ahead of mining, thereby reducing significant risk. Aspects of variability on both a within-block basis and between block basis will be covered, as well as some working hypotheses and strategies on identifying and determining correlations between metallurgy and mineralogy.

9:20am Paul Sylvester
Use of MLA data for green-fields mineral exploration

Short summary: Quantitative mineralogical data may be used in the early stages of exploration to assess the significance of metal anomalies in samples from outcrops, drill cores or stream and till sediments. In particular, MLA data can help constrain models of ore genesis that often form the basis of exploration strategies. Preliminary assessments of metal recoveries may also be made. Examples will be provided for iron ores, uranium ores and diamonds.

10:10am Coffee Break

10:30am Michelle Huminicki
Geometallurgical approach to mine development and advanced exploration

Short summary: Systematic and quantitative determinations of mineral identifications and abundances throughout an ore body can be used in a predictive manner to aid in advanced exploration (vectoring toward additional resources), mining (ore blending for the mill), metallurgy (improving mineral liberation and metal recoveries), and ore genesis studies (defining the source and differentiation processes of ore-forming magmas). Systematic textural classifications (grain size, phase alignment, exsolution relationships, etc) can also be applied during the "logging" process and/or through MLA analysis of samples to predict mineral processing issues and determine ore genesis. This integrative approach will be demonstrated by applications to base metal sulfide deposits (i.e., magmatic Ni-Cu-Co massive sulfide deposits or Pb-Zn-Cu volcanogentic massive sulfide deposits).

11:20am Chris Hamilton
Integration of MLA results with other datasets

Short summary: Data integration considerations range from simple inputs (e.g. probe analyses and/or trace mineral data for precious metals in sulphides) through to extrapolation of unmeasured fractions and the addition of external parameters. Some guidelines and cautions regarding integrating data will be covered, as well as their implications for interpretation. Focus and context will be emphasized, with the intention of creating a coherent and logical mineral inventory, with auditable and reproducible results with satisfactory confidence levels.

12 noon Lunch Break

1:00pm Michael Shaffer, Marc Beauchamp and Michelle Huminicki
Lab 3 (classroom demo): Processing of MLA data (XBSE)

3:10pm Coffee Break

3:30pm (Divide into 2 groups)

Michael Shaffer, Marc Beauchamp and Michelle Huminicki
GROUP 1 - Lab 4 (classroom demo): Setting up for online acquisition using the GXMAP (grain-based X-ray mapping) MLA mode (e.g., for pentlandite versus chalcopyrite discrimination in sulfide ores)

Louis Cabri
GROUP 2 - Lab 5: Hydroseparator (HS) demonstration

Short summary: Using the current HS-11 model, a demonstration will illustrate the basics of HS separation of sized minerals. This will show the ease and control over results that can be achieved using this toxic-free method of mineral concentration.

4:15pm   Group Exchange (GROUP 2 – Lab 4; GROUP 1 – Lab 5)

5:00pm   Adjourn

May 14 – Applications in Process Mineralogy

8:30am   Rolando Lastra
Quantitative mineralogy and mineral processing

Short summary: A series of examples on the application of quantitative mineralogy to mineral processing will be presented, illustrating the major impact and benefits that can be obtained.

9:20am   Louis Cabri
Mineral processing and metallurgy of precious metal minerals (including mineralogical balances)

Short Summary: The process mineralogy of the precious metal minerals may be divided into three groups: gold, silver, and the platinum-group elements (PGE). In general, all three occur as rare discrete minerals of one or more metals, as well as occurring in trace quantities in more common minerals. Each of the precious metals presents specific possibilities for deportment that need to be investigated for determination of a mineralogical balance.

10:10am   Coffee Break

10:30am   Michael Shaffer, Marc Beauchamp and Michelle Huminicki
Lab 6 (classroom demo): Processing of MLA data (GXMAP)

12:30pm   Lunch Break

1:30pm   Kurt Moeller, Michael Shaffer, Marc Beauchamp, and Michelle Huminicki
Lab 7 (classroom demo): Extraction of final data base and presentation of MLA data (use of Dataview software for MLA)

4:30pm   Adjourn

Syllabus of Advanced Course

May 15 Advanced Methods for Quantitative Mineralogy by MLA

8:30am   Paul Sylvester
Welcome and course overview

8:45am   Kurt Moeller, Michelle Huminicki and Michael Shaffer
Advanced Process Mineralogy Exercise

Short summary: Utilising Dataview software of the MLA to view and manipulate quantitative mineralogical data, and solve a practical hypothetical scenario in Process Mineralogy.

12 noon   Lunch Break

1:00pm   Kurt Moeller
Description and applications of non-routine but useful MLA modes (SPL, XMOD, RPS)

Short summary: Use of the sparse phase liberation (SPL), X-ray modal (XMOD) analysis, and the rare phase search (RPS) modes of the MLA to solve problems in metallurgy will be illustrated.

2:00pm   Michael Shaffer, Marc Beauchamp and Michelle Huminicki
Lab 1 - Setting up for online acquisition using sparse phase liberation (SPL/SXBSE) mode of the MLA

4:00pm   Adjourn

May 16 Advanced Methods for Quantitative Mineralogy by MLA (continued)

8:30am   Michael Shaffer, Marc Beauchamp and Michelle Huminicki

Lab 2: Processing of non-routine MLA mode run (SPL)

Lab 3: Hands-on clarifications for special interest cases of MLA experienced users

Lab 4: Detailed review of extraction parameters, de-agglomeration parameters, segmentation parameters, deletion, touch-up, grouping

12 noon   Lunch Break

Sample Preparation and Sampling Methods

1:00pm   Sample preparation methods (Michael Shaffer and Marc Beauchamp)

Short summary: Preparation of mill samples for mineral liberation analysis involves splitting, sieving and riffling, mounting the resulting sized particles in epoxy resin and finely polishing the surface of the mount with diamond abrasives. These procedures will be described in detail, highlighting practices which have been shown to yield the most reliable MLA results.

2:00pm   Representativeness (Louis Cabri and Paul Sylvester)

Short summary: Non-representative sampling can produce inaccurate data about the mineralogical characteristics of an ore, and lead to misleading assessments of geometallurgical and processing problems. Sampling biases can be produced during sample splitting, sieving and mounting of grain mounts, and in the selection of massive (unprocessed) samples for polished thin sections. Sample bias can also occur during analysis if an insufficient number of particles are measured by the MLA. This lecture gives examples of various types of non-representative samples and analyses, and provides procedures that may be used for recognizing them.

2:30pm   Coffee Break

2:50pm   Stereology (Chris Hamilton)

Short summary: Stereological bias is a much maligned and misunderstood phenomenon. While a basic introduction into the subject cannot do it justice, and runs the risk of down-playing this effect, several points will be introduced and explained. After this session, participants will be able to understand the difference between stereological and other errors and their interdependence. The practical and empirical basis and the limitations will be emphasized.

3:30pm   Bias and corrections of liberation measurements (Rolando Lastra)

Short summary: In general polished sections are used for the determination of mineral liberation. These two-dimensional measurements introduce a bias due to stereology. The nature of the bias, their magnitude, methods of corrections and their effect will be presented.

4:10pm   Quality Control/Quality Assurance (Chris Hamilton)

Short summary: Following on from the preceding presentations on sampling and measurement error, the statistical and associated metrics concerning quality control will be covered in this session. Key issues such as fundamental error, assay reconciliation, particle statistics and aspects of representivity and minimizing errors and error-propagation will be addressed.

4:50pm   Adjourn

REGISTRATION FORM

Short Course on Methods and Applications of Geometallurgy and Process Mineralogy - May 12th-16th,2008

Registration Fees: (check one) *(13% HST will be applied to all prices if applicable)*

☐ Basic Course - $1000 CAD   ☐ Advanced Course - $500 CAD   ☐ Basic & Advanced - $1200 CAD

Fees include all course materials, lunch, and coffee and snacks twice a day.
*Prepayment and pre-registration must be received by **April 15th, 2008.***

Payments may be made by either cheque payable to "Memorial University" or electronic transfer following inovice of your employer by Memorial University. (Please quote invoice number when making payment)

To Register:
Send your completed registration form (below) and cheque (payable to Memorial University) or invoice information to:
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Memorial University
230 Elizabeth Avenue, P.O. Box 4200
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Attention: Ms. Melissa Wilson
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Name: [   ]   **Position:** [   ]

Employer: [   ]

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Address 2: [   ]

Telephone: [   ]   **Fax:** [   ]   **Email:** [   ]

Check one: ☐ **Cheque enclosed**   ☐   **Invoice the individual below:**

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Address 2: [   ]

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For additional information contact Paul Sylvester at pauls@esd.mun.ca or Michelle Huminicki at mhuminicki@hotmail.com.

We thank our sponsors for their generous support of this short course.

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