

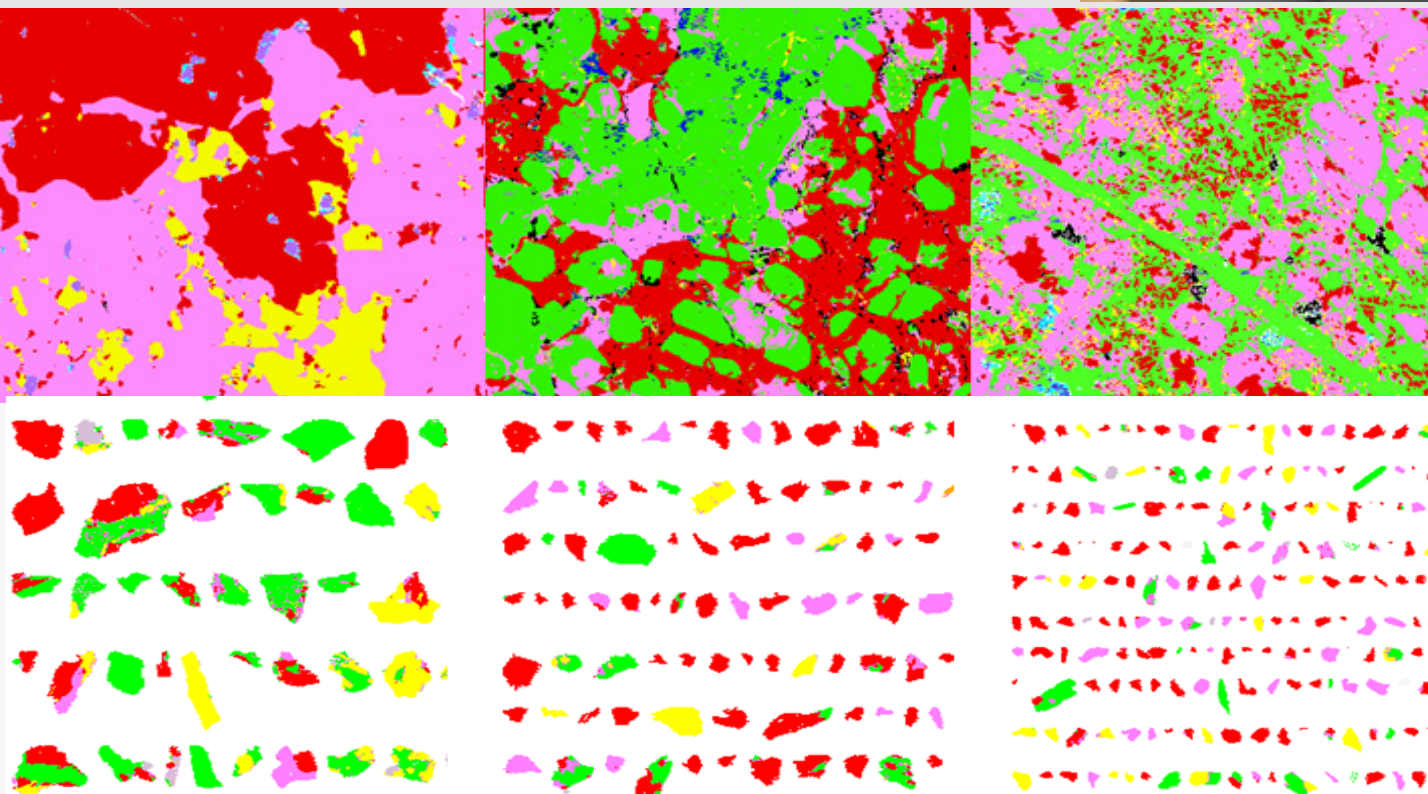
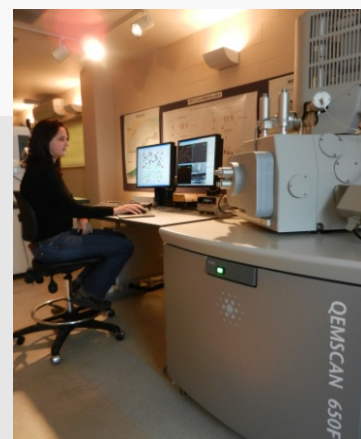
QEMSCAN

KEY CAPABILITIES

Modal Mineralogy • Size-by-Size Liberation • Element Department by Mineral • Grain Sizes • Mineral Associations • Mineral Recoveries • False Coloured Images

APPLICATIONS

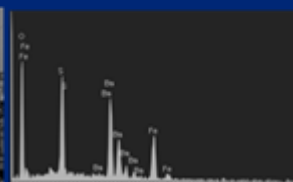
Ni Sulphide Deposits/Concentrators • Ni Laterites • VMS/Sedex Deposits/Concentrators • MVT deposits • Heavy Mineral Sands • REE • PGM/Au/Ag Deposits/Concentrators • Alloys/Materials • Potash • Smelter Products • Environmental Mineralogy • Filter Analysis (e.g. High Volume Air Filters)



QEMSCAN images of Ni ore (top image) and sized concentrator products (bottom image); yellow=Cpy, pink=Po, red=Pn, green=silicate gangue

QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) is an automated technique used for measurement and characterization of minerals and materials. XPS' Process Mineralogy group offers a wide range of QEMSCAN mineralogical testwork including metallurgical support for plant audits, lab flotation programs which identify opportunities for improved plant performance and flowsheet design, and ore characterization of composite material.

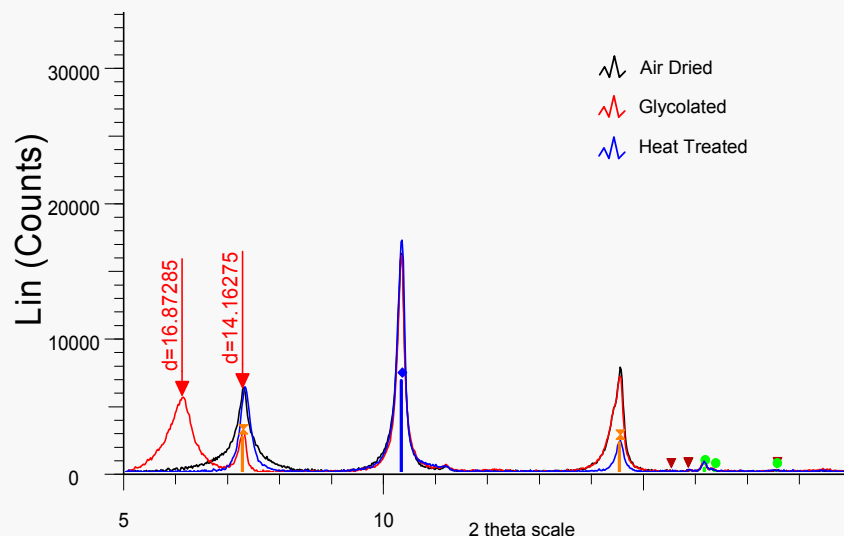
The XPS facilities includes on-site sample preparation (sample sizing and polished section preparation). Complimentary tools such as XRD and Electron Microprobe support the QEMSCAN programs and provide clients with an all-inclusive option at our testwork facility.



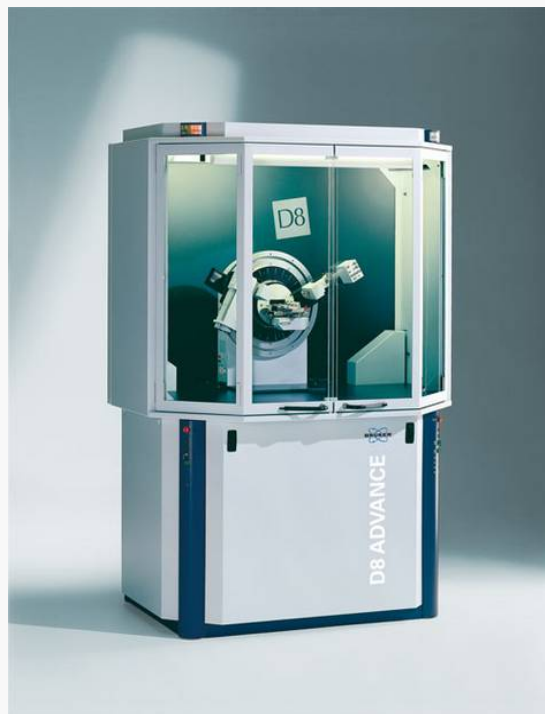
X-Ray Powder Diffraction

APPLICATIONS

- Precipitates and scale in plant lines and pipework
- Dust
- Soils (Ni laterite)
- Asbestos (clinocrysotile)
- Finely ground products
- Element speciation as oxide, sulphide and carbonate
- Clay speciation
- Phase transformation in pyrometallurgical program
- Monoclinic/hexagonal pyrrhotite analyses



Partial XRD spectra from a clay speciation analysis

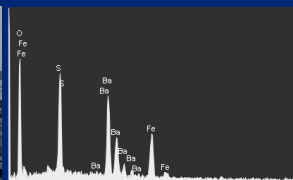


ADVANTAGES

- Rapid identification of minerals (qualitative and semi-quantitative)
- Ease of sample preparation
- Small mass required
- Low cost
- Identifies polymorphs
- Automated analysis

XPS Consulting & Testwork Services employs a world class Mineral Science laboratory that includes a Bruker D8 Advance X-ray Powder Diffractometer (XRD). XRD data is often used in conjunction with other mineral analytical techniques based on electron beam instruments such as QEMSCAN and Electron Microprobe Analysis (EPMA).

An International Centre for Diffraction Data database of 160,000 diffraction patterns is used for a search/match routine to identify candidate phases that match the diffraction pattern. Background history and assay data for the unknown are crucial to reliable interpretation. Data can be reported as qualitative (major, minor and trace minerals) or as semi-quantitative using Rietveld Refinement.



Electron Probe Micro-Analysis

CAPABILITIES

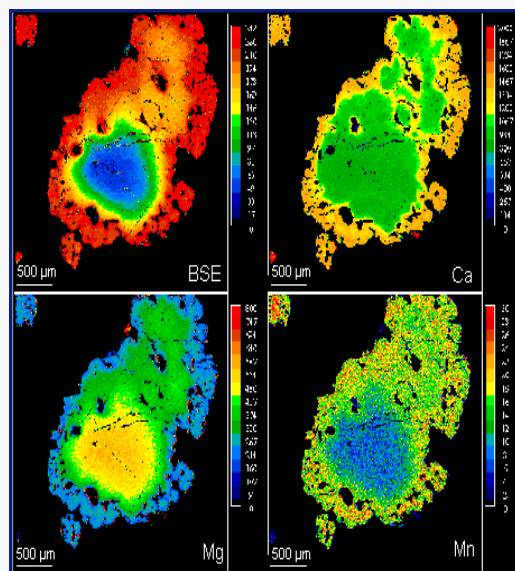
- Powerful combination with QEMSCAN platform:
 - ✓ Provides detailed compositional data to combine with modal analysis producing accurate elemental department.
 - ✓ Quality control measure in the development and refinement of SIPS (Species Identification Program) for quantitative mineralogy.
- Quantification of pay metal values in solid solution which may be lost to non-recovered phases in processing plants.
 - ✓ Cr losses to slag
 - ✓ Base-metals in non-recoverable minerals
 - ✓ Leach residue compositions
- Quantification of deleterious elements recovered to concentrates due to solid solution levels in recovered phases.
 - ✓ Cd in sphalerite
 - ✓ As in chalcocite
 - ✓ Bi in bornite
- Detailed compositional characterization of slag, mattes, alloys, mineral concentrates and tailings.

APPLICATIONS

- Analytical detection limits between ~100-200ppm.
- Non-destructive (can be performed on polished mounts or standard polished thin sections).
- Secondary Electron (SE), Backscattered Electron (BSE) and reflected light imaging.
- Analysis across a wide range of element from B to U
- Detailed multi-element compositional mapping.
- Equipped with 5 Wavelength Dispersive Spectrometers (WDS) and one Energy Dispersive Spectrometer (EDS) for fast and efficient analysis.
- Point analysis on grains as small as 5 μm .
- Unattended automated mineral analysis



XPS' Cameca SX-100 Microprobe



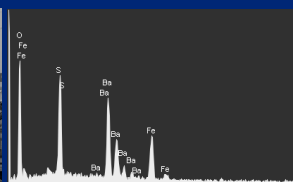
EPMA compositional maps of mineral grains

XPS Process Mineralogy Group utilises Electron Probe Microanalysis (EPMA), a fully quantitative method of non-destructive elemental analysis of solid materials, with detection limits in the order of 100 ppm.

The mineralogy lab is equipped with a Cameca SX-100 Microprobe – a diverse platform which delivers a range of quantitative mineralogical analyses in addition to reflected light microscopy, scanning electron imaging and elemental concentration mapping.

Microprobe analysis combines Scanning Electron Microscopy (SEM) tools such as Secondary Electron (SE) and Backscatter Electron (BSE) imaging for identification and classification of mineralogical features with the added benefit of robust compositional analysis utilizing Wavelength Dispersive Spectrometry (WDS). When combined with QEMSCAN modal analysis, detailed elemental departments can be calculated.

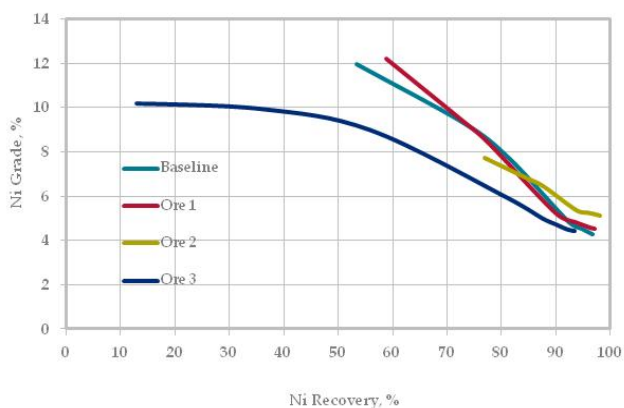
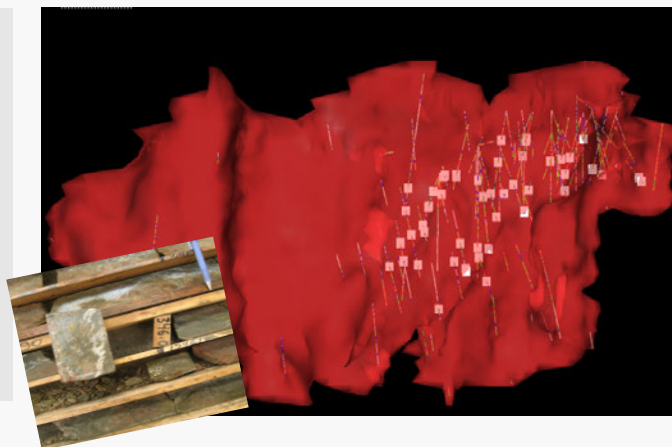
Elemental concentration mapping enhances the impact of compositional analysis by enabling a visual representation of the chemical variation within the specimen.



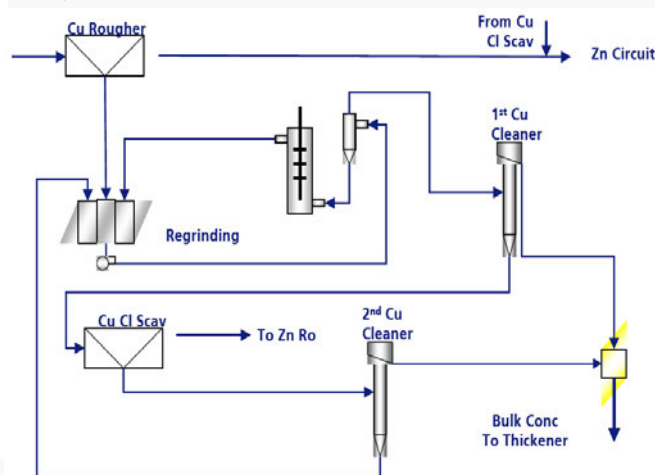
Geometallurgical Unit Flotation Testwork

APPLICATIONS

- Selection of spatially and chemically representative samples by Geometallurgical Unit
- Crushing and blending to ensure representativity
- High confidence flotation testwork leading to recommendations for flowsheet design
- Scoping studies, metallurgical testing and flowsheet development



Grade recovery curves highlighting variability in recovery between different ore types



XPS Consulting & Testwork Services Process Mineralogy team can perform metallurgical testwork as a follow-up to an Ore Characterization Study.

Typically, the resource is categorized into Geometallurgical Units which are grouping of ores that possess similar compositional and textural characteristics and are expected to exhibit similar metallurgical performance. Evaluation of ores at a geometallurgical level will better quantify variation and lead to a stronger understanding of the metallurgical performance.

Our mineralogy team has designed a quality control protocol to perform drill core sampling on a GU basis. Statistically representative samples are produced while considering the spatial distribution, pay metal grades and grade distributions along with lithology and alteration distribution. Crushing and blending procedures produce representative sample material for metallurgical testing (flotation and hardness), and design purposes.

We recommend that this approach is considered at a typical scoping level leading into further lab scale piloting and testing for optimisation purposes. Process Mineralogy metallurgical testwork forms a crucial building block in the process of flowsheet design, predictive metallurgy and optimisation.

Drill Core Mineralogy

CAPABILITIES

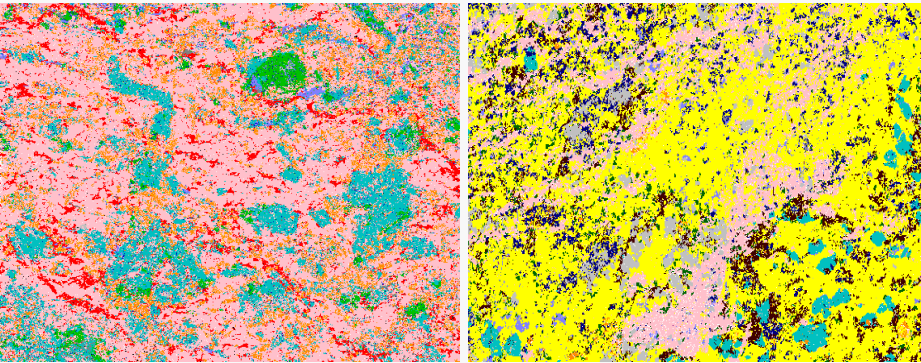
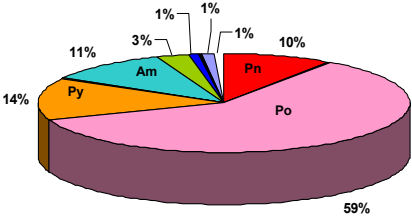
The following are key deliverables provided by QEMSCAN for CORESCAN analyses:

- Modal mineralogy
- Estimated assays and elemental deportment by mineral based on chemical formulas
- Colour images of core textures
- Rapid turnaround

APPLICATIONS

Rapid drill core characterization can be used in the following applications:

- Greenfields Exploration
- Lithotyping and indicator minerals
- Mapping alteration assemblages
- Metallurgical performance indicators
- Calibration of drill core logging for grade estimations



QEMSCAN coloured image of core showing examples of textures. Each colour represents and a different mineral phase.

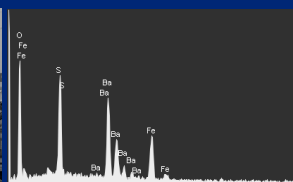
Sample	Name	Core 1
	Po:Pn	6.2
	Ni Tenor	3.62
Elemental Mass	Cu (QEMSCAN)	0.1
	Fe (QEMSCAN)	48.8
	Ni (QEMSCAN)	3.1
	S (QEMSCAN)	33.0
Mineral Mass	Pentlandite	9.6
	Chalcopyrite	0.3
	Pyrrhotite	59.6
	Pyrite	13.6
	Quartz	0.1
	Amphibole	10.8
	Epidote	2.9
	Pyroxene	0.8
	Magnetite	0.4
	Calcite	0.9
	Other	0.9

Quantitative data determined from QEMSCAN analysis of minerals from a core slab

Drill core mineralogy is a rapid mineralogical characterization tool which provides valuable data directly from the surface of smooth cut drill core samples. With the use of QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscope) your drill core is measured as presented with minimal sample preparation. Minimal preparation ensures fast turnaround of results, cost effective analyses and because the method is non-destructive, the drill core can be returned at the end of analysis.

Drill core mineralogy can help support strategic decisions early in a program to ensure focused exploration based on key mineralogical factors including modal abundances, metal ratios, grade and textures.

As an independent consulting service, XPS has two QEMSCAN's which offer CORESCAN measurements to the industry.



QEMSCAN Filter Analysis

APPLICATIONS

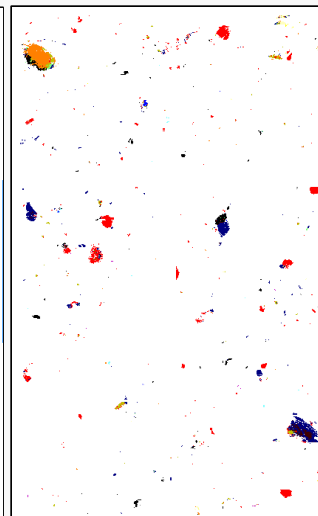
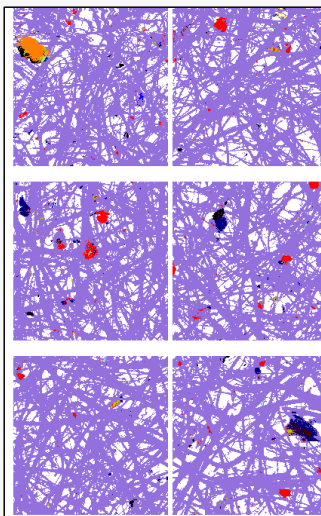
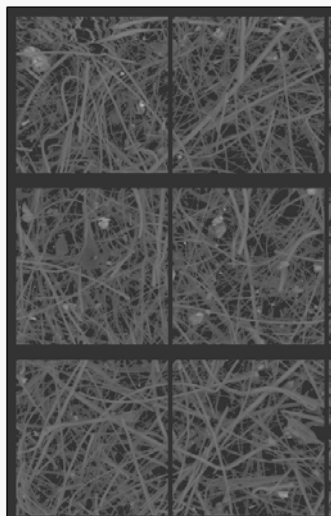
- Hi-vol Air Filters
- Filter Cloths (e.g. concentrate filters)

CAPABILITIES & APPLICATIONS

- Provides quantitative analysis of particulate matter on filter surfaces including modal **abundance, estimated particle size and particle loading**
- Entire surface of filter is measured for a more robust analysis
- Powerful method of determining source material of particulates
- Estimated elemental deportments can be calculated based on filter assays and compositions of possible source material



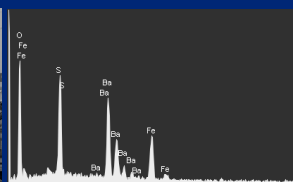
Hi-vol samplers mounted on glass slides



Back Scattered Electron (BSE) image, QEMSCAN image with filter included and QEMSCAN image with filter removed

Hi-vol air samplers are positioned near many operations and allow for continuous sampling of air quality. After a specified period of time, the filters are retrieved and sent for assay. In cases where there is a metal exceedence based on government regulated limits, the filters can be sent for mineralogical examination in order to characterize the particulate matter on the filter.

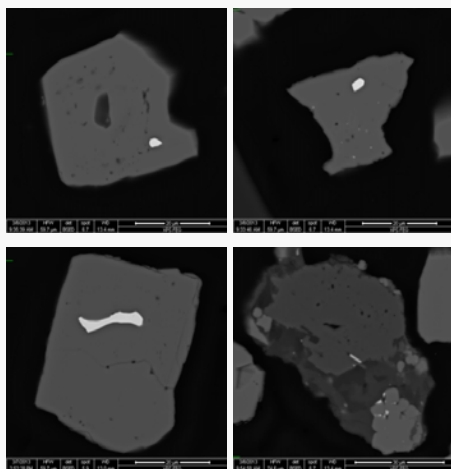
XPS has used QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscope) to evaluate the particulate matter. The samples are unusual in that they are not mounted in a flat polished section. Rather, the raw filter is carbon coated and placed directly in the SEM for measurement. A Quanta 650 FEG instrument has provided the resolution required for detailed characterization. Both particulate matter and the filter are measured and once complete, the filter is digitally removed during the data processing phase of work. This method provides a more robust data set compared to standard Hi-vol scans which only measure particles with a higher BSE threshold than the filter. The figures above show the transition from backscattered electron images to the QEMSCAN false coloured images and the processed particulates where the filter has been digitally removed. Each colour in the QEMSCAN image represents a different phase identified by its unique X-ray spectrum.



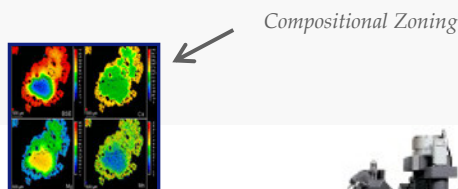
Diagnostic Gold Mineralogy

QEMSCAN APPLICATIONS

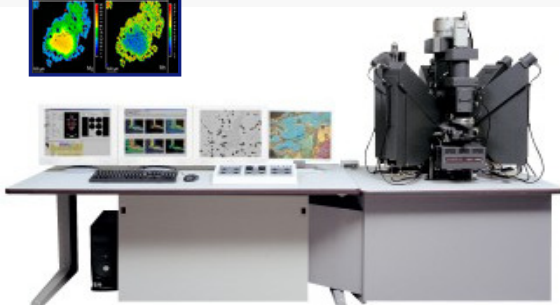
- Used in conjunction with diagnostic leach analysis
- State of the art QEMSCAN FEG capable of high resolution imaging ($>5\mu\text{m}$)
- Find gold grains and gold minerals using Trace Mineral Search
- Pre-concentration and measurement of gravity separates
- Gold deposit mineral characterisation for:
 - Ore and gangue mineralogy, preg robbing minerals
 - Grain sizes
 - Grain shapes, textures and associations
 - Liberation in concentrator or metallurgical test products
 - Quantify diluting minerals in concentrates
 - Quantify form of gold losses in tailings



Above: BSE images of Au minerals (bright phases) in pyrite and other silicate minerals taken with the high resolution QEMSCAN FEG.



Compositional Zoning



CAMECA SX-100 Microprobe

ELECTRON PROBE MICRO-ANALYSIS (EPMA) APPLICATIONS TO GOLD

- The SX-100 EPMA provides low detection limits for most elements
- Check refractory gold in pyrite or arsenopyrite before using SIMS, PIXE or LA-ICPMS
- Determine Au content in electrum
- Check for deleterious elements (e.g. As, Bi, Se and Te) in host gangue and ore minerals such as calaverite and sylvanite
- Analyze for compositional zoning
- Use mineral compositions with QEMSCAN data for calculated assays and metal department