Advancements in Minerals Identification and Characterization in Geo-Metallurgy: Comparing E-Beam and Micro-X-ray-Fluorescence Technologies

Samuel Scheller[1], Roald Tagle[1], Gerda Gloy[2], Monserrat Barraza[3] and Andrew Menzies[4]

[1.] Bruker Nano GmbH, Product Management and Applications, Berlin, Germany
[2.] Bruker Pty. Ltd., Applications, Brisbane, Australia
[3.] Universidad Católica del Norte, CISEM, Antofagasta, Chile
[4.] Universidad Católica del Norte, Departmento de Ciencias Geológicas, Antofagasta, Chile

Since the introduction and use of automated mineralogy in the mining industry in the 1970s, a variety of companies have developed competing and complementary technologies with a range of capabilities. A historical summary of automated mineralogical systems is shown in Sandmann (2015) [1]. However, all of them were based on electron beam (e-beam) systems (such as scanning electron microscopes (SEM) with energy dispersive X-ray spectrometers (EDS)). Recent advancements in X-ray optics have made it possible to focus an X-ray beam by polycapillary optic to spot sizes less than 20 micrometers, allowing micro-XRF (X-ray fluorescence) to be operated using similar parameters as an e-beam system. The results yield comparable results with traditional automated mineralogical analysis. The advantages and limitations of each technique are discussed, including aspects such as sample preparation, analytical conditions, as well as sample information and processing.

One of the main advantages of micro-XRF are sample handling, including simpler sample preparation and the ability to analyze large samples, with an analytical area of up to 20 cm x 16 cm. Furthermore, the X-ray excitation yields significantly lower limits of detection. The e-beam on the other hand offers smaller beam size and interaction volume, providing the advantage of much higher magnification and interactive imaging. Even though both methods are considered as surficial analytical techniques, it should be noted that micro-XRF has a greater depth penetration and hence excitation volume than e-beam analysis, which can lead to differences in results of the special analysis. This can be both advantage and disadvantage depending on the analysis objective. Other differences, especially in spectra, can also be traced back to the different excitation voltages and excitation probabilities. With the X-ray excitation, the acceleration voltage is generally between 35 and 50 kV, whereas with e-beam between 15 and 25 kV. Ionization of X-ray excitation occurs generally with inner electron shells while in contrast electron excitation exhibits ionization of the outer shells. This leads to better sensitivity of lighter elements, below Ca for e-beam excitation, but weaker for heavier elements and higher energy lines.

Practically, both systems are equipped with silicon drift detectors (SDD) for EDS analysis, where the e-beam scans by deflection and the micro-XRF moves the stage with the sample. The e-beam acquires an image (field of view) at a given magnification, and can then perform point or area analysis. The micro-XRF has an inbuilt dual magnification co-axial (visible) light microscope to focus on the analytical working distance and obtain mosaic images to define measurement points or areas. For automated mineralogy, there are fundamental parameters that impact on the mineralogical classification and analytical time; these includes (but is not limited too) X-ray beam excitation (kV and µA), detector active area(s) (mm²), pixel spacing (µm), and dwell time (ms).

A variety of case studies are used as the basis for comparison, including samples from exotic-Cu deposits in Chile, epithermal Au-Ag deposits in New Zealand, diamond deposits in South Africa, and REE deposits in Chile. Each of the case studies has been the subject of detailed investigations and thus a wealth of information exists to support the evaluation of the automated mineralogy results. The results are based on a Bruker M4 TORNADO^{AMICS} micro-XRF and a Zeiss based EVO QEMSCAN E430.

Figure 1 is an example of the analysis of exotic-Cu samples from northern Chile. Sample AHM-ET-007-C highlights the complex textures of Cu mineralisation in exotic-Cu deposits. The different Cu mineral species, which can be broadly grouped into black-Cu and green-Cu minerals, displaying fine-scaled inter-related textures (Figure 1c) as well as variable compositions within each mineral grouping which is apparent in the varying elemental concentrations within each mineral group as observed in (Figures 1 d, e, f).

References:

[1] Sanderman, D., Method development in Automated Mineralogy, doctoral thesis, Technische Universitat Bergakademie, Freiberg, Germany. (2015). p. 3.

Figure 1. Sample AHM-ET-007-C exotic-Cu sample from El Tesoro. Images by single analysis using the M4 TORNADO^{AMICS} micro-XRF: (a) optical image using 10x mag (of the entire rock section); (b) Cu intensity distribution map; (c) Mn intensity distribution map; (d) Fe intensity distribution map; (e) x-ray signal intensity map (similar to a back-scatter electron image); (f) mineral map; (g) modal mineralogy of sample AHM-ET-007-C from an exotic-Cu deposit.

Mineral	Colour	Mass %
Albite		1.8
Anhydrite		1.3
Chrysocolla (Green-Cu)		57.1
Cu-Mn Wad (Black-Cu)		30.5
Quartz		4.2
Other		5.05