# Innovative µXRF Mapping of Ore Samples: A Comparison of Novel Synchrotron- and Lab-Based Technology

Lisa L. Van Loon[1,2], Neil R. Banerjee[2*], Jessica M. Stromberg[3], Arthur Woll[4], Wenbing Yun[5], Benjamin Stripe[5], and Stewart McIntyre[6]

[1.] LISA CAN Analytical Solutions Inc., Saskatoon, SK
[2.] Department of Earth Sciences, Western University, London, ON
[3.] CSIRO, Perth, Australia
[4.] Cornell High Energy Synchrotron Source, Ithaca, NY, USA
[5.] Sigray, Concord, CA, USA
[6.] Department of Chemistry, Western University, London, ON
* Corresponding author: neil.banerjee@uwo.ca

Understanding the association between economic metals and trace elements in ore minerals is critical in mineral exploration and ore deposit research. In particular, the importance of *in situ* characterization of these spatial relationships to understand the geochemical relationships within a mineralogical and geological context is vital. Micro-X-ray fluorescence (µXRF) mapping is a powerful technique to create chemical images of a sample. The use of high intensity, synchrotron source µXRF (SR-µXRF) -is well-established in environmental sciences including remediation studies but has been limited in use for mineral exploration and production [1,2]. The combination of the 384-element Maia detector with synchrotron-source allows for very fast data collection with high count rates, making it possible to image large areas (i.e., a thin section, core, or rock slab) relatively quickly [2]. New developments in lab-based X-ray sources and optics are happening at a dizzying pace, improving the resolution, sensitivity, and speed of lab-based µXRF systems, in some cases approaching what is possible at a synchrotron facility in certain cases [3]. We have analysed a suite of gold ore samples at the CHESS synchrotron with the Maia detector and with the new Sigray AttoMap system to demonstrate their complementarity as powerful tools for studying geochemical associations in gold ore systems.

Four rock offcuts, Fig. 1 Top, were analysed for their major and trace element composition at the F3 hard bend magnet beamline at the CHESS synchrotron in Ithaca, NY and at Sigray in Concord, CA. SR-µXRF mapping was done by rastering across the sample with a 20 µm x 20 µm beam spot size and a 5 msec dwell time with an incident X-ray energy of 16.2 keV. The incident flux was 5.6 x $10^8$ photons/second. There was no attenuation of the beam. XRF signal was measured with a 384-element Maia detector. The data was collected as full spectrum MCA data and analysed using GeoPIXE [4]. Micro XRF mapping with the Attomap was done by across the sample with 10 µm x 10 µm beam spot size and 15 msec dwell time with a Mo target providing an X-ray excitation energy of 17.4 keV. The data was collected as full spectrum MCA data with a silicon drift (SDD) detector and analysed using the Sigray analysis software.

The capability of directly mapping flat rock surfaces that provide meaningful geochemical information for previously uncharacterized samples was investigated using synchrotron and lab-based µXRF mapping. Vein samples from two different gold deposits from the historic Timmins mining camp in northern Canada display distinct differences in their associations between gold and trace elements. Gold is identified in multiple contexts, associated with carbonate-rich vein material, concentrated in sulfide rich vein margins, as well in overprinting quartz veining. Sample specific maps reveal variability in the

geochemistry of vein material, which can be related to macro scale textural observations such as banding, cross cutting relationships, and the relationship with host rock lithologies.

Micro XRF mapping of ore samples with the AttoMap instrument provided excellent agreement with images collected using the Maia detector at the F3 beamline at the CHESS synchrotron. Acquisition time is somewhat longer using the AttoMap, however, considering the possibility that one of these instruments could be used 24 hrs a day 7 days a week in a laboratory environment makes the time savings practically negligible. Small variations in signal intensity are observed (e.g., As in Fig. 1 Middle and Bottom). Further post processing of full spectrum μXRF images with the Peakaboo software [5] convincingly demonstrates the complementarity of the techniques. For samples with relatively high local concentrations at moderate spatial resolution, the speed at which XRF mapping can be performed at synchrotron sources may be limited by the speed of the detector, rather than the source. This paper demonstrates that a laboratory μXRF instrument like the AttoMap can achieve comparable results with only a moderate increase in total scan time. This represents a paradigm shift in terms of access to rapid and innovative sample characterization that is a key requirement of the mining industry [6].

References:

[1] N Banerjee et al., Microsc. Microanal. **24 (Suppl2)** (2018), p. 510.
[2] J.M. Stromberg et al., Ore Geo. Rev. **104** (2019), p. 589.
[3] B. Stripe, "Compositional Analysis with the AttoMap Micro X-ray Fluorescence System",
https://www.sigray.com (accessed February 10, 2019).
[4] Maia GeoPIXE Software: Wizard Programming Interface, CSIRO Report EP155331.
[5] N Sherry et al., Science Studio Project Summary. (2012), http://sciencestudio.net/summary.php.
[6] This work is based upon research conducted at the Cornell High Energy Synchrotron Source
(CHESS) which is supported by the National Science Foundation under award DMR-1332208.
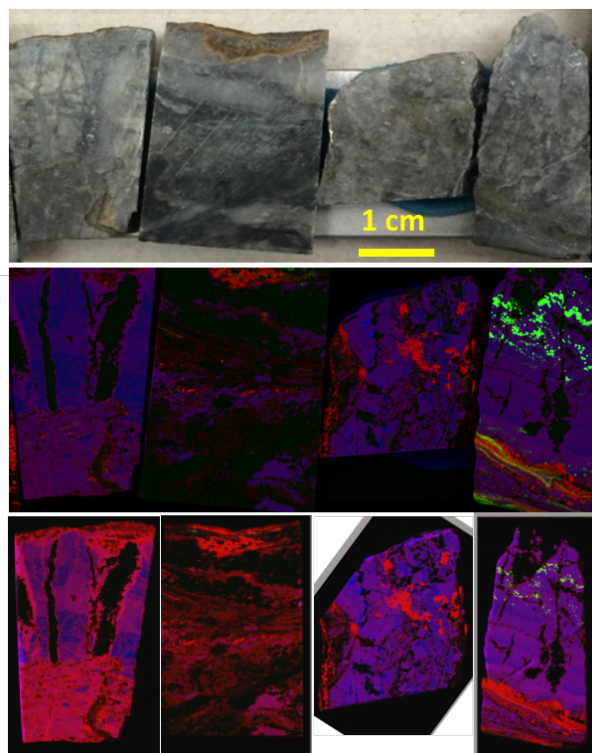
**Figure 1.** (Top) Photograph of the 4 thin section offcuts mapped; Three-element (Fe (red) As (green) Ca (blue)) μXRF maps of the four offcuts collected with (Middle) a 17 keV incident energy from a synchrotron source at 20 μm with a 5 msec dwell time and (Bottom) a 17.4 keV incident energy from a Mo tube source at 10 μm resolution and 15 msec dwell time.