Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.32352

What's the use? Adventures and problem-solving in metal(loid) geochemistry, from the molecular to field scale

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Our collective understanding of the geochemistry of trace metal(loid)s continues to expand, contributing fundamental scientific knowledge to the field and helping address applied environmental challenges. A scientific approach that integrates data across multiple scales—often engaging a combination of molecular, benchtop, computational, and field-based methodologies—can reveal insights into the behavior of metals that are both case-specific and transferable to other systems and locales.

Our research group has explored a wide variety of environmental geochemistry questions related to trace metal interactions, mobility, transformation, and bioaccessibility, all sharing the broad goal of informing practical solutions to environmental problems. Examples include:

- Examining the relationships between arsenic speciation, microspatial distribution of arsenic, and weathering conditions on arsenic bioaccessibility in gold mine wastes
- Characterizing different mechanisms of Fe-OOH nanoparticle aggregation (e.g. pH, ionic strength, heating, freezing, drying, and organic matter) and their effects on Cu(II) and Zn(II) ion adsorption and retention
- Simulating freshwater to saltwater transitions and corresponding impacts on metal ion retention to iron oxyhydroxides
- Quantifying lead and arsenic distribution in ash-impacted soils resulting from the 2025 Eaton wildfire in Southern California and assessing their bioaccessibility as a function of location, soil depth, and time
- Reproducing ambient diurnal fluctuations in temperature and humidity at accelerated frequency to study effects on metal bioaccessibility in mercury mine wastes over timespans simulating several years

We have employed a range of methods to address these questions, including X-ray synchrotron-based techniques, benchtop macroscopic adsorption/desorption experiments, particle size and surface area analysis, portable X-ray fluorescence field measurements, simulated gastric and lung fluid extractions, rainwater and sediment runoff sampling, and semi-automated computational analyses of metal microspatial maps. From this research, nearly all of which has been and is being conducted with undergraduate students, we aspire to expand our understanding of metal behavior in the environment in ways that form a useful framework for constraining, then addressing, and ideally solving, real environmental problems.