SMMR'S RESEARCH & INNOVATION FOCUS: ADVANCING THE SUSTAINABILITY OF MINING

THE UNIVERSITY OF ARIZONA

School of Mining & Mineral Resources

INTRODUCING THE SCHOOL OF MINING & MINERAL RESOURCES AT UARIZONA

The School of Mining and Mineral Resources (“SMMR”) in Tucson, Arizona, USA, is the latest extension of the University of Arizona’s rich history of successful interdisciplinary programs and top-tier mining education, which stretches back to 1884.

The University of Arizona ("UArizona") has been a global leader in mining education since it was founded, offering globally ranked programs in mining engineering and geosciences and a complete ecosystem of mining disciplines, with programs in economic geology, social & environmental sciences, hydrology, global mining law, and much more.

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TRANSFORMING MINERAL RESOURCES EDUCATION **FOR A FAST-CHANGING WORLD**

At a time when many universities are shutting down mining & mineral resources programs, UArizona is investing in growing and modernizing these career pathways through SMMR, to advance mining curriculum and fill the talent pipeline for these critical jobs.

Located in the heart of mining country with world-class ore deposits, operating mines and technology companies, our rich ecosystem provides unparalleled partnership opportunities for real-world learning and research. As a designated Hispanic Serving Institution located near Arizona's border with Mexico, UArizona is uniquely positioned to develop the mining and mineral science workforce of the future, and we're doing it right now.

ADVANCING RESEARCH THROUGH OUR INNOVATION ECOSYSTEM

UArizona has dozens of disciplines, centers, institutes, facilities and other resources to contribute to transdisciplinary, collaborative research. In addition to mining-specific disciplines, UArizona boasts experts in areas ranging from optical science and machine learning to Native American relations and water resource management. With centers for safety, environment, tailings and geotech, and even a student-run mine – you name it, UArizona has it!

By creating a global network of experts and cultivating partnerships across industry, academia, government, communities, and NGOs, SMMR has a developed a rich innovation ecosystem—providing a higher standard of education for students and ground-breaking solutions for stakeholders and partners.

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RESEARCH CENTERS

GEOTECHNICAL CENTER OF EXCELLENCE

The University of Arizona's Geotechnical Center of Excellence (GCE) is an industry-funded and stakeholder-led organization committed to bridging gaps that exist within and between academia, industry and other fields of study.

GCE uses a pragmatic, collaborative approach to connect industry with experts, innovate through research aimed at solving real-world problems, and fill knowledge gaps by educating and developing geotechnical engineering professionals.

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CENTER FOR ENVIRONMENTALLY SUSTAINABLE MINING

The Center for Environmentally Sustainable Mining (CESM) develops research and educational initiatives that enhance the environmental sustainability of mining. CESM is guided by a Technical Advisory Committee of industry and consulting professionals who identify issues of concern to the hard-rock mining and rock products industries.

The CESM model emphasizes collaboration with industry partners through research cooperatives, and cross-campus collaboration with academic partners from diverse colleges and schools.

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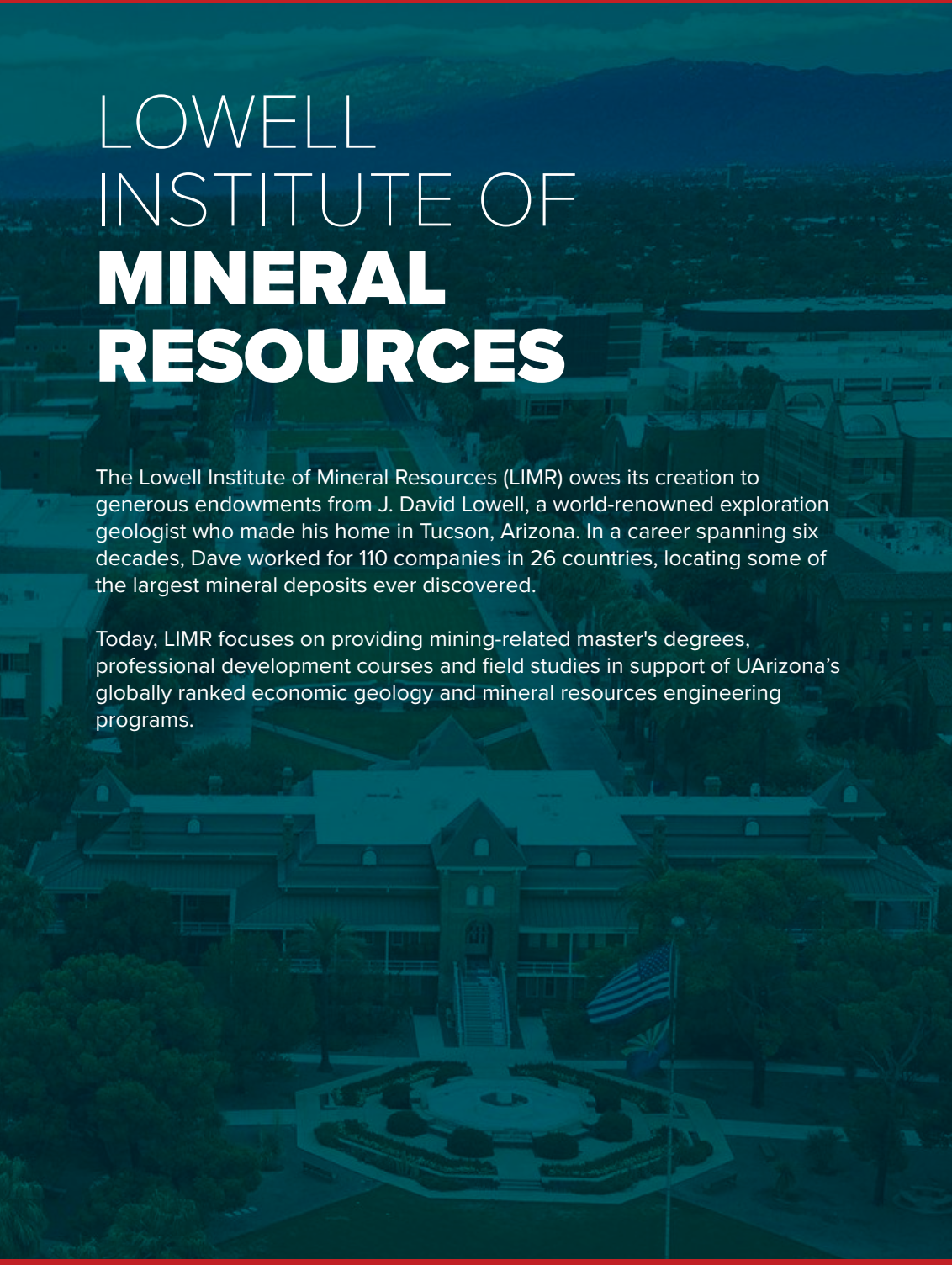
LOWELL INSTITUTE OF **MINERAL RESOURCES**



The Lowell Institute of Mineral Resources (LIMR) owes its creation to generous endowments from J. David Lowell, a world-renowned exploration geologist who made his home in Tucson, Arizona. In a career spanning six decades, Dave worked for 110 companies in 26 countries, locating some of the largest mineral deposits ever discovered.

Today, LIMR focuses on providing mining-related master's degrees, professional development courses and field studies in support of UArizona's globally ranked economic geology and mineral resources engineering programs.

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THE TAILINGS CENTER

Launched in 2020 in response to industry demand, the Tailings Center has a two-fold mission: providing mining industry members with professional development opportunities in Tailings Management; and conducting research aimed at enhancing safety and minimizing the environmental impact of mine tailings.

A collaborative effort between UArizona, Colorado School of Mines, and Colorado State University, the Tailings Center offers six certificate courses on the fundamentals of tailings management, covering the lifecycle of tailings from planning to closure.

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THE MINE HYPERSPECTRAL **RESEARCH CONSORTIUM**

This industry-focused consortium was founded to optimize hyperspectral technology and related types of sensing, specific to the needs and environment of mining. Launched in January 2023, current partners include Freeport-McMoRan, BHP, Maptek, and EchoLabs, with additional partners onboarding and new partners welcomed.

University of Arizona's MIINERS (Mine Imaging INfrared Emission and Raman Spectroscopy) Laboratory has a VNIR (0.4-1.0 microns), SWIR (1.0-2.5 microns) and MWIR (2.7-5.3 microns) imaging spectrometers and access to Raman imaging scanner, in addition to ASD LabSpec and FieldSpec3 with proposals in for additional equipment.

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Research is focused on a variety of mining related topics ranging from ore deposit characterization, geometallurgy, exploration, mine operations (leach pads, open pit bench mapping), and mine tailings, amongst others. Experiments on developing novel sensor types have been performed, with a planned multi-year effort to develop and pilot new sensors. The center currently holds regular technical advisory committee meetings, and an annual symposium and 10-day short course are in development.

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SUPERFUND RESEARCH CENTER

UArizona's Superfund Research Center has a laudable mission: to advance science and use their research findings to improve human health and the environment. Sponsored by the National Institute of Environmental Health Sciences, the Superfund Center uses an interdisciplinary approach to study hazardous waste issues in the U.S. Southwest, including the Arizona-Sonora border and Native Nations lands.

Focused on arsenic and mine tailings, the Superfund Center's biomedical and environmental scientists collaborate to investigate risks, develop remediation strategies, and translate research findings to government stakeholders and the affected communities.

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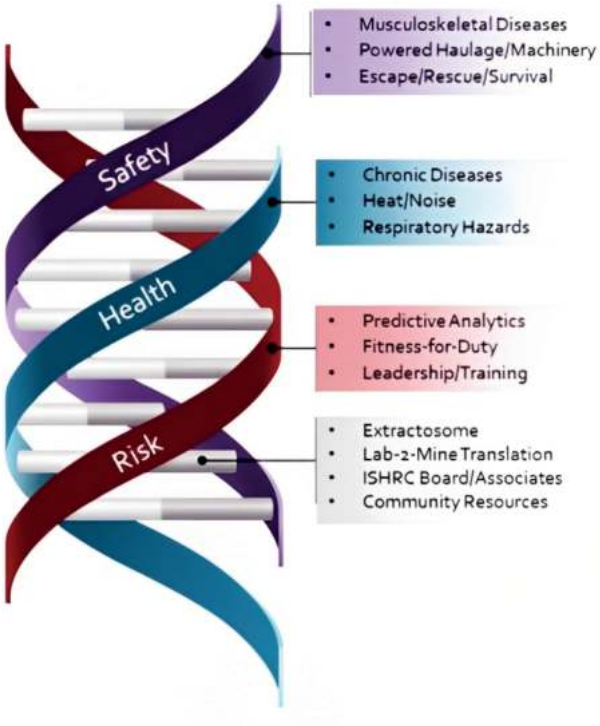
MINING SAFETY
CENTER OF EXCELLENCE

The Mining Safety Center of Excellence (SCE) at UArizona is a top-tier research, education, and workforce training community that innovates mining methods toward achieving zero injuries, illnesses, and fatalities.

The SCE uses predictive analytics to address the most pressing mining safety, health, and risk challenges facing the industry today, including safety concerns, leadership development, fitness-for-duty, and miner health.



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UARIZONA ACHIEVEMENTS RANKINGS & FACTS

- R1 Top Ranked Research Universities
- TOP 20 Public Research Institution
- No. 5 in NASA Funding
- $761M Total Research Expenditures
- 2,455 Invention Disclosures
- 128 Startups Launched

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BEST NATIONAL UNIVERSITY RANKINGS

#2 in Geology*

#2 in Water Resources*

#9 in Earth Sciences*

#3 in Mining Engineering**

*According to U.S. News & World Report
**According to QS World

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SMMR-SUPPORTED RESEARCH PROJECTS

MINING SAFETY PROJECTS

THE UNIVERSITY OF ARIZONA

HAZARD RECOGNITION APP FOR **UNDERGROUND MINES**

PI: **Angelina Anani, PhD, Mining and Geological Engineering (MGE).**

Co-PI(s): **Nathalie Risso, PhD, MGE; Edward Wellman, MGE.**

RESEARCH ASSISTANTS: **Pedro Lopez; Carolina Gamez Gonzales**

The goal of the Hazard Recognition in Underground Mines application or "HUMApp" is to improve safety by automatically detecting structural hazards in underground mines. Developing the app involved creating a labeled images dataset for underground mines hazards, an ML (Machine Learning) computer vision-based model to identify geotechnical hazards, and a prototype for a mobile app for real-time prediction.

Completed tasks include data collection, labeling, training, and app demonstrations. Next steps include increasing the dataset, recording a training video, and writing a literature review paper. The app has been demonstrated at the annual Society for Mining, Metallurgy, and Engineering (SME) conferences in the U.S. and at the 2023 Canadian Institute of Mining, Metallurgy, and Petroleum (CIM) convention.

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CAMERA-AIDED TECHNOLOGY FOR **UNDERGROUND MINE SAFETY**

PI: **Nathalie Risso, PhD, Mining and Geological Engineering (MGE).**

Co-PI(s): **Angelina Anani, PhD, MGE; Hee-jeong Kim, PhD, Department of Civil and Architectural Engineering and Mechanics.**

RESEARCH ASSISTANTS: **Carlos Olmos de Aguilera**

In this collaborative project, researchers at the Mine Automation & Autonomous Systems Laboratory sought to develop a system for automatic PPE detection for industrial and underground mining environments.

The project, “Camera Aided Technology for Underground Mine Safety” or CAT-UMS, utilized a regular camera and Machine Learning to detect if a person is wearing a hardhat. Progress to date includes an initial labeled dataset of 1,000 images, software for helmet detection, and successful mobile demos of the system with accompanying articles. Ongoing work includes installation of cameras and IR illumination for testing at our student-run San Xavier mine.

USING PREDICTIVE ANALYTICS TO MODEL OPERATORS' HEALTH AND SAFETY TRAJECTORY

PI: **Leonard D. Brown, Public Health.**

Co-PI: **Hong Cui, School of Information.**

RESEARCH ASSISTANT: **Yanyan Dong**

PARTNERS: **UArizona School of Information; South Dakota School of Mines; Anonymous Mine Operators**

In this cross-campus collaboration with support from industry, Professors Leonard D. Brown and Hong Cui led an investigative team to move the mining industry towards using leading indicators (pre-incident predictors) rather than lagging indicators (realized accidents, injuries, or other negative outcomes) to improve the health and safety trajectory of mine operators.

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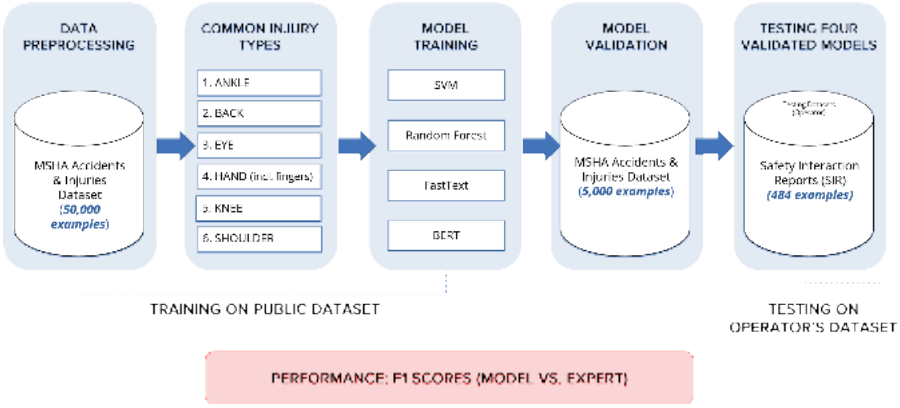
This project employed Machine Learning to better utilize safety reports to infer potential incidents and improve risk management at mine sites. Data was obtained from the Mine Safety & Health Administration's Accidents & Injuries public dataset and segmented into common classes of injury in mining and other industries. Models were validated and tested against hundreds of operator-reported Safety Interaction Reports (SIRs).

Ongoing development will increase the robustness of algorithms and datasets, enhance the web-based dashboard, and allow for scaling and deployment into a production environment. A data analytics course and workshop are planned as professional development offerings, helping to promote a pre-emptive versus reactive approach to mine worker safety.



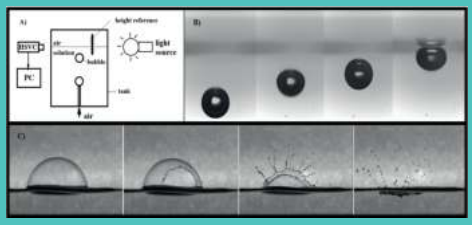
ACID MIST SUPPRESSANT FOR CU EW

PI: **Jinhong Zhang, Freeport McMoRan Copper & Gold Chair in Mineral Processing, Department of Mining and Geological Engineering (MGE).**

PARTNERS: **Freeport McMoRan Copper & Gold Inc.**

Acid mist is produced at mine sites when oxygen bubbles in copper electrowinning solution rise and burst at the surface, releasing acidified mist into the air which can lead to serious health and corrosion problems. Developed by the Dept of Mining & Geological Engineering with support from Freeport McMoRan, this research project's objective was to study the impact of working conditions on O2 bubbles produced in copper electrowinning solution, with the aim of mitigating acid mist production.

A high-speed video camera system was set up to capture and study the bubbles bursting at the air/liquid surface. The acid solution was characterized by the number of drops related to bubble size, viscosity, density, and surface tension. This study successfully clarified the mist formation process, enabling more successful methods of suppression and enhanced training methodology.



Sistema de cámara de video de alta velocidad (HSVC) para estudiar el estallido de burbujas en la superficie del aire/líquido

BIOINSPIRED GLYCOLIPIDS AS MINING DUST MITIGATION AGENTS

PI(s): **David Hogan, PhD, Environmental Science (ES); Minkyu Kim, PhD, Materials Science and Engineering; Raina Maier, PhD, ES.**

PARTNERS: **Chett Boxley, PhD, GlycoSurf, Inc.; Steve Trussel, Arizona Rock Products Association; Mark Eddy, ASARCO**

Ambient air pollution is a leading contributor to disease burden, increasing morbidity and mortality rates. With 12% of global health impacts related to particulate matter attributed to the mining industry, there is a high value on effective dust mitigation methods. In this partnership between academia and industry, researchers investigated ways to suppress dust contributing to air pollution at mine sites by identifying and developing glycolipid formulations that work as dust suppressants.

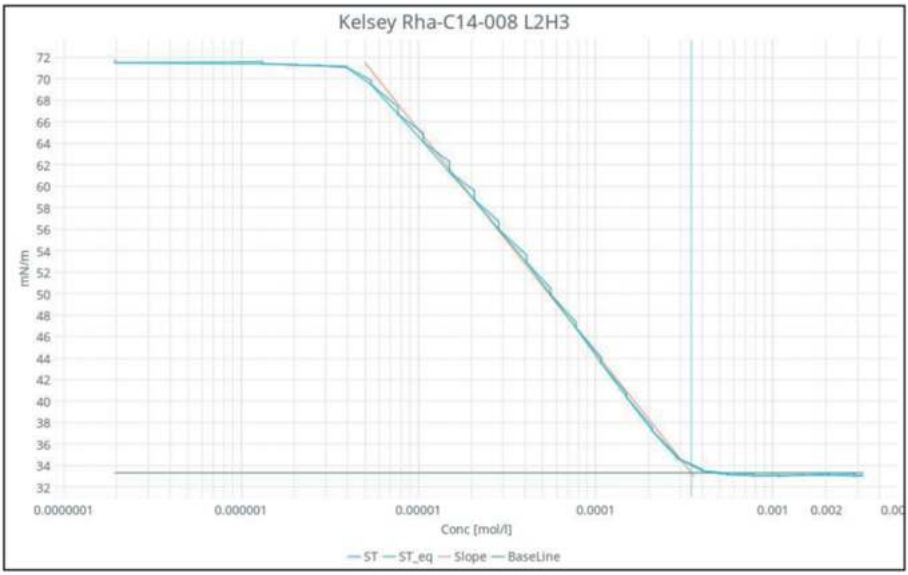
Table 1. Results of wind erosion test against tailings dust treated with glycolipids, and commercial product with water as control

AQI*	Glycolipids	Sugar	Tail	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)
1	Rhamnolipid C10	rhamnose	C10	182.0 ± 25.8	92.9 ± 26.8
2	Rhamnolipid C14	rhamnose	C14	81.8 ± 51.3	27.9 ± 17.5
3	Rhamnolipid C18	rhamnose	C18	45.1 ± 15.2	20.1 ± 7.8
4	Xylolipid C10	xylose	C10	97.1 ± 26.3	38.7 ± 7.6
5	Xylolipid C14	xylose	C14	61.6 ± 3.4	21.5 ± 0.8
6	Xylolipid C18	xylose	C18	19.0 ± 0.1	6.2 ± 0.4
7	Rhamnolipid C10C10	rhamnose	C10C10	16.9 ± 2.7	6.5 ± 0.8
8	Rhamnolipid C12C12	rhamnose	C12C12	16.5 ± 1.2	5.5 ± 0.1
9	Rhamnolipid C14C14	rhamnose	C14C14	17.2 ± 0.6	6.6 ± 0.6
10	Xylolipid C14C14	xylose	C14C14	195.5 ± 38.9	79.8 ± 23.3
11	Melibiose-1-oxy-C10	melibiose	C10	38.7 ± 13.4	15.8 ± 4.1
12	Cellobiose-2-oxy-C10	cellobiose	C10	71.6 ± 10.4	31.7 ± 2.83
13	Cellobiose-2-oxy-C12	cellobiose	C12	22.0 ± 5.3	8.6 ± 1.56
14	Bio-diRha	dirhamnose	C10C10	69.8 ± 6.6	28.1 ± 2.5
15	EnviroTech-II	-	-	478.7 ± 145.4	207.5 ± 74.6
16	Water	-	-	702.7 ± 229.5	273.9 ± 64.0

*Note: EPA AQI categories are based on the results of $PM_{2.5}$, more hazardous to human health than PM_{10}. The green, yellow, orange, red, purple, and dark red indicate AQI levels of "good", "moderate", "unhealthy for sensitive groups", "unhealthy", "very unhealthy" and "hazardous", respectively.

Glycolipids are biologically based surfactants that are non-toxic, renewable and biodegradable and have proven to be effective at suppressing fugitive dusts in mining operations. A total of 19 glycolipids were analyzed in this project. Structure/function trends and surfactant characteristics were identified, allowing for an efficacy rating to be developed for each glycolipid combination through wind erosion tests against tailings.

Next steps for this research include a 3-year field test and dust suppression trial in agricultural soils sponsored by a grant from the United States Department of Agriculture (USDA).



SEPARATION & RECOVERY OF ENERGY-CRITICAL **METALS FROM AQUEOUS SOURCES**

PI: Raina Maier, PhD, Environmental Science (ES), College of Agriculture and Life Sciences (CALS).

Co-PI(s): David Hogan, PhD, ES/CALS; Douglas Loy, Materials Science and Engineering, Engineering and Chemistry and Biochemistry, College of Science.

PARTNERS: Gary Amy, Clemson University; John Crittendon, Georgia Tech University; Chett Boxley, GlycoSurf Inc.; John Haynes, KGHM International; Casey McKeon, Rio Tinto; Marty Weems, Western Rare Earths

A cross-functional team of academic researchers in collaboration with multiple industry partners, joined forces to develop novel approaches for the separation and recovery of metals from aqueous sources. The focus was on energy-critical metals, rare earth elements, platinum group metals, and other metals including uranium and copper.

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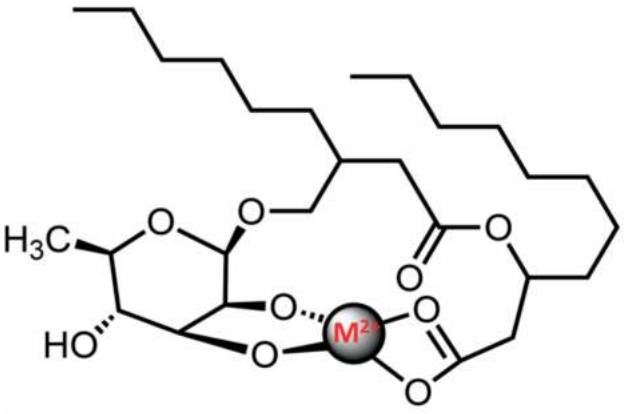
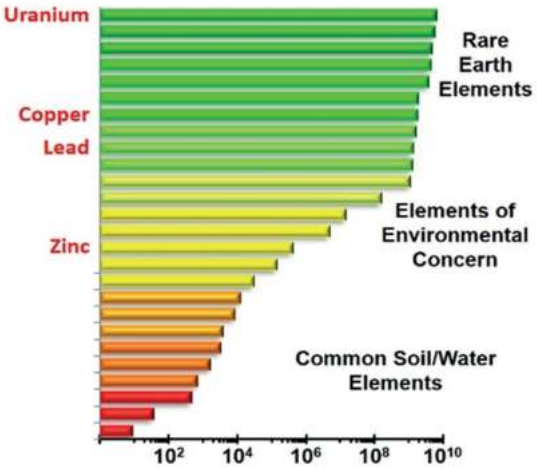
The outcomes of this research include a provisional patent, a published paper, and valuable training opportunities for graduate and undergraduate students. A challenge grant award from Rio Tinto Corporation is supporting ongoing development, with plans to bring this technology to commercialization in the next 8-10 years.



Rhamnolipid-Metal complex



STRENGTH OF BINDING

ENVIRONMENT & SUSTAINABILITY PROJECTS

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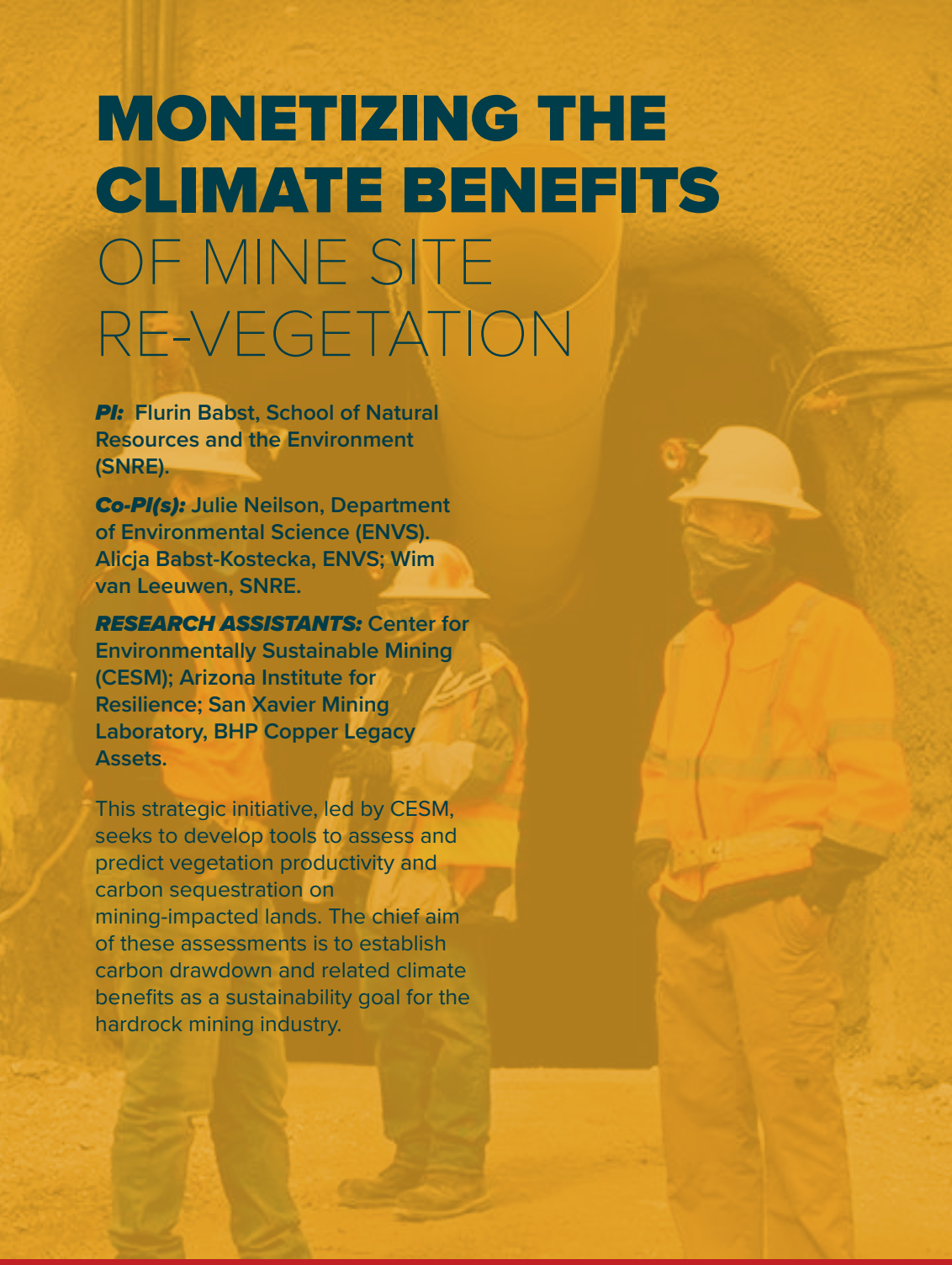
MONETIZING THE CLIMATE BENEFITS OF MINE SITE RE-VEGETATION



PI: **Flurin Babst, School of Natural Resources and the Environment (SNRE).**

Co-PI(s): **Julie Neilson, Department of Environmental Science (ENVS). Alicja Babst-Kostecka, ENVS; Wim van Leeuwen, SNRE.**

RESEARCH ASSISTANTS: **Center for Environmentally Sustainable Mining (CESM); Arizona Institute for Resilience; San Xavier Mining Laboratory, BHP Copper Legacy Assets.**

This strategic initiative, led by CESM, seeks to develop tools to assess and predict vegetation productivity and carbon sequestration on mining-impacted lands. The chief aim of these assessments is to establish carbon drawdown and related climate benefits as a sustainability goal for the hardrock mining industry.

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Ten sampling plots were established in Spring 2023 at UArizona's San Xavier Mining Laboratory. Phase 1 of the project is complete, which involved taking measurements and mapping shrubbery and vegetation using field observations, ground, and airborne remote sensing. Soil and wood density samples were obtained, and terrestrial LiDAR scans of the plots were performed.

Phase 2 (Fall 2023) involves independent validation from partners and identification of key parameters that drive carbon sequestration. Phase 3 (Spring 2024) is to implement statistical and/or process-based modeling to predict vegetation productivity and carbon sink.

ACCELERATED MINERAL CARBONATION FOR ACID MINE DRAINAGE TREATMENT, **MINE TAILINGS STABILIZATION & CARBON DIOXIDE SEQUESTRATION**

PI: **Lianyang Zhang, Professor of Civil and Architectural Engineering and Mechanics. Research Assistant: Hamid Vashaghian**

PARTNERS: **ASARCO and Freeport**

There are two key goals for this project: to better understand the use of accelerated mineral carbonation to treat acid mine drainage and stabilize mine tailings while sequestering carbon dioxide, and to generate preliminary data for preparing competitive proposals for ongoing research funding.

Progress to-date includes characterized mine tailings, prepared and characterized AMD (Acid Mine Drainage), the development of equipment for testing, and commencement of an experiment on MT carbonation. Future research includes monitoring progress of MT carbonation, collection and testing of samples, and ongoing analysis of data.

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MEASUREMENT AND MODELING OF SULFIDE TAILINGS DIAGENESIS IN CONTROLLED EXPERIMENTATION: IMPLICATIONS FOR MINE WASTE REMEDIATION

PI: Jon Chorover, Professor and Department Head, Environmental Science.

Co-PI(s): Bo Guo, Assistant Professor, Department of Hydrology and Atmospheric Sciences; Mark Brusseau, Professor; Rob Root, Associate Research Professor, Department of Environmental Science.

PARTNERS: Charlie Alpers, USGS (United States Geological Survey); Roger Hooberheide, USEPA (United States Environmental Protection Agency) Region 8; Jennifer Crawford, USEPA Region 10; Barbara Neilson, Freeport McMoRan; Bryce Romig, Freeport McMoRan; Bryan Moravec, BHP; Anne Christopher, EPA Region 10; Jeffrey Dhont, EPA Region 9; Yolanda Sanchez, EPA Region 9; Dante Rodriguez, EPA Region 9; Jeff Collins Nevada, DEP; Nick Peterson, BP; Brian Milton, EPA 9.

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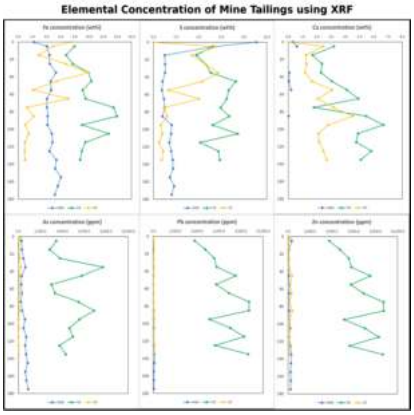
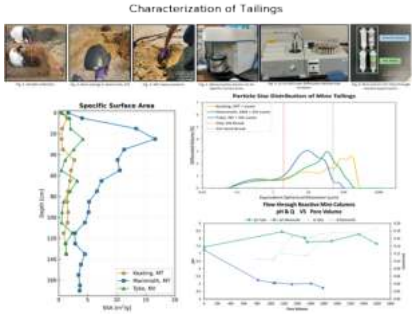
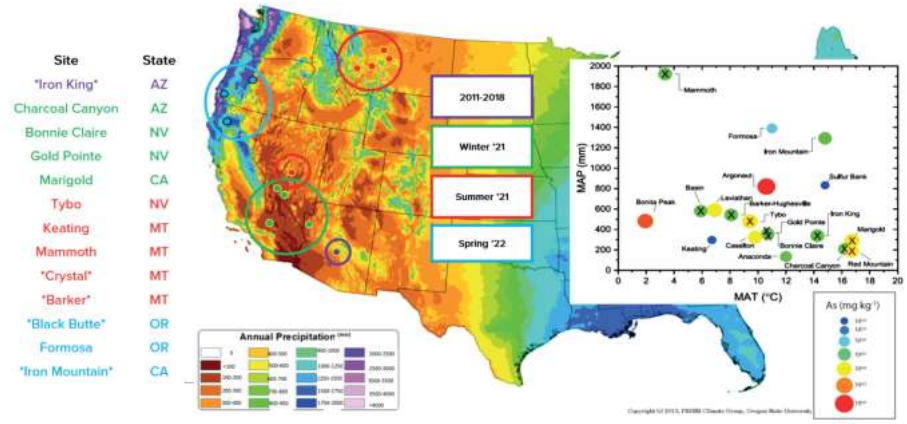
In this three-year research project, we are conducting column experiments on multiple sites to measure, in real time, the chemical reactions controlling weathering of mine tailings.

Anticipated outcomes are to produce a Reactive Transport Model of the weathering reactions happening in mine tailings that are affecting the metal(loid)s mobility, and how the environmental conditions of the site affect them after 50 to 100 years of exposure.







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CESM REPURPOSING MINE WASTE STRATEGIC INNOVATION: IDENTIFICATION OF METAL-HYPERACCUMULATING PLANTS AS POLYMETALLIC SYSTEMS FOR ECOCATALYSIS

PI: Alicja Babst-Kostecka, Department of Environmental Science (ENVS) & CESM.

Co-PI: Julie Neilson, ENVS & CESM

PARTNERS: BHP Copper Legacy Assets Team; Raina Maier, Superfund Research Center; Tomasz Wlodarczyk, ENVS doctoral student; Owyn Stokes, undergraduate student

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In this SMMR strategic initiative, an extension of the collaboration between CESM and BHP to survey plant diversity at their legacy mine tailings site in Arizona, the team is focused on the characterization of resilient, self-sustaining native plant species that have persisted on the reclaimed site for the past 70 years.

This information will be used to inform seed mixes for future reclamation efforts and will boost the scientific basis of revegetation to develop efficient and site-tailored solutions for metal-impacted lands across the Southwestern United States.

A MACHINE LEARNING-BASED APPROACH TO RECYCLING MINE WASTE FOR DEVELOPING SUSTAINABLE CONSTRUCTION MATERIALS

PI(S): Hee-Jeong Kim, Civil and Architectural Engineering and Mechanics.

Co-PI(s): Angelina Anani, Mining and Geological Engineering

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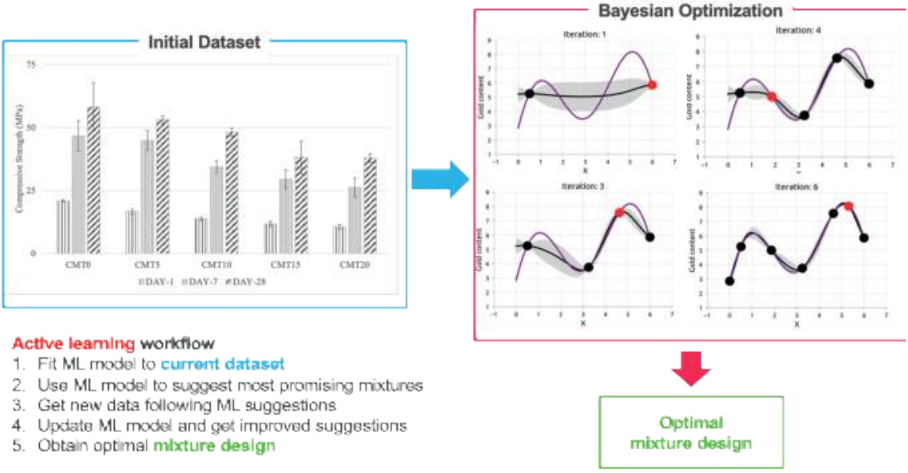
The goal of this research project is to maximize utilization of copper mine wastes as supplementary cementitious materials (SCM) or aggregate to achieve sustainability by using a machine learning-based approach to understanding the relationship between chemical and physical properties. Data from this trial will serve as preliminary results for additional grant proposals.

Research activities include collection of mine wastes and XRF, XRD data for mine tailings, fabricating concrete and measuring mechanical properties, and applying the machine learning-based approach. Principal outcomes from this effort will be the determination of the effect of copper tailings on compressive strength of concrete at different curing ages, and the determination of the effect of copper slag on compressive strength of concrete at different curing ages.

NEXT STEPS: ACTIVE LEARNING OF OPTIMAL MIXTURE AND CURING TIME

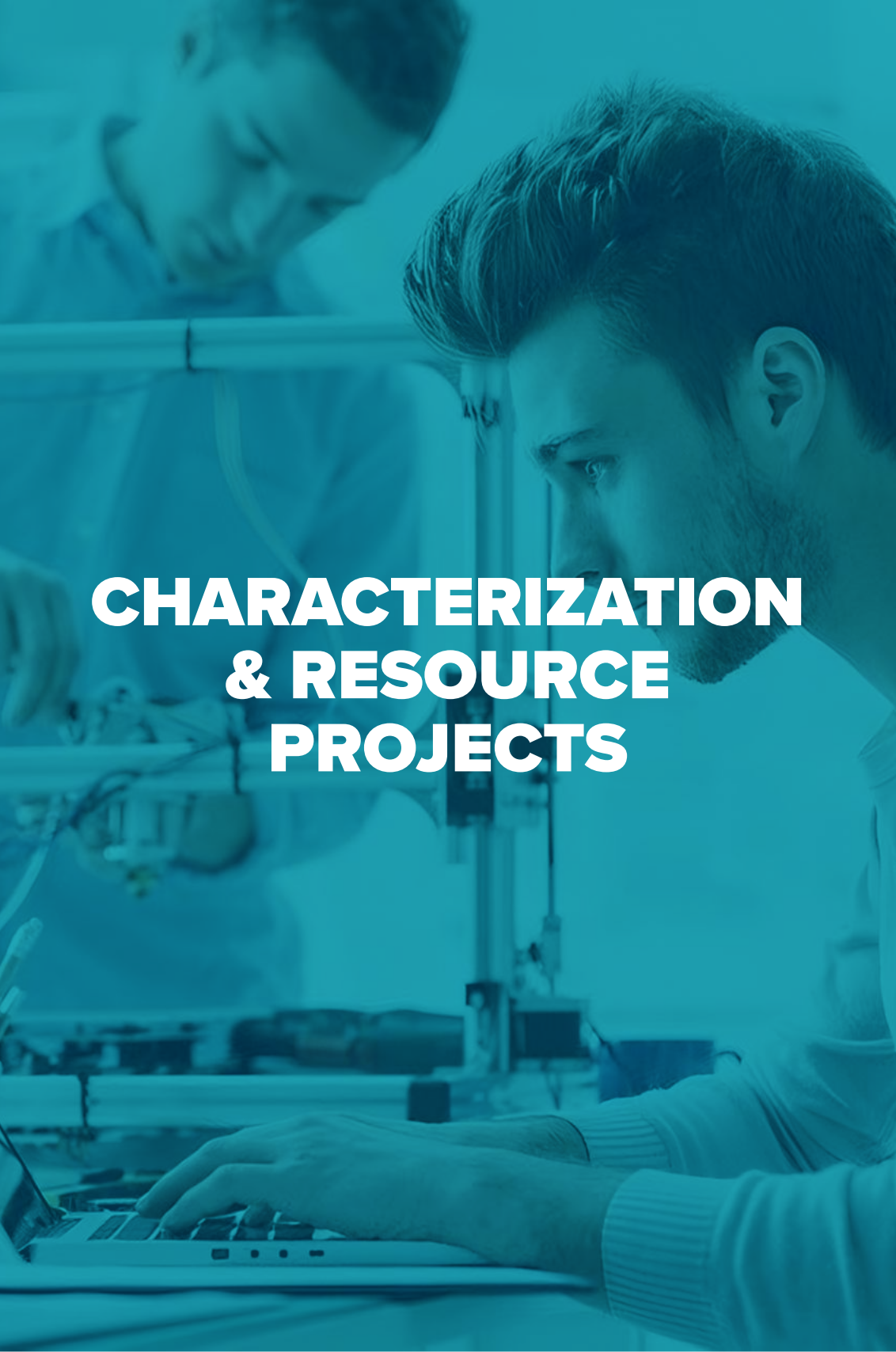


TRANSLATING SUSTAINABILITY METRICS INTO ENGINEERING DECISIONS: **EXPLORING STRATEGIES FOR SUSTAINABLE MATERIAL USE IN DESIGN AND MANUFACTURING**

PARTICIPANTS: **Dr. Hannah Budinoff, Assistant Professor of Systems and Industrial Engineering (SIE); Hongyue Jin, Assistant Professor (SIE); David Manford, PhD student**

Key goals of this SMMR-funded research effort are to explore how environmental impact affects engineers' decision-making during mine design, and to pilot an engineering decision-making study for additive manufacturing.

Progress to date includes start-up of a life cycle assessment database to calculate sustainability metrics for fused filament fabrication (FFF), development of predictive models to predict material usage and energy usage during FFF processing, and development of a Cura tool to integrate sustainability metrics into manufacturing preparation.



CHARACTERIZATION & RESOURCE PROJECTS

ADVANCING UA MINERAL RESOURCES AND GEM SCIENCE ANALYTICAL CAPABILITIES WITH NEW LAB

PI: Mark Barton, Lowell Institute of Mineral Resources (LIMR)

PARTNERS: Isabel Barton, Mining & Geological Engineering (MGE); Ananya Mallik, Dept of Geosciences (GEOS); Hervé Rezeau, GEOS; David Killick, School of Anthropology (ANTH); Jen McIntosh, Hydrology & Atmospheric Sciences (HAS); Tom Meixner, HAS; Jon Chorover, Dept of Environmental Science (ENVS); Joaquin Ruiz, GEOS; Frank Mazdab, GEOS

The purpose of this grant is the advancement of UArizona mineral and gem science analytical capabilities through development of an interdisciplinary lab and new analytical techniques made possible by new equipment. Development of the joint “Mineral Characterization Facility” includes a new femtosecond laser, the first of its kind for minerals applications in U.S.

Other acquisitions include a Nu Plasma ICP-MC-MS, a renovated Gould-Simpson 114 with two lasers, plus three ICP-MS with different capabilities, and new Micro Raman microscopes. The lab has been fully renovated and used for several SMMR projects and other sponsored research, and has formed the basis for $2M+ in new proposals to industry and National Science Foundation (NSF) grant requests.

Beyond the multiple ICP-MS, LA, Raman, and varied petrographic microscopes, the lab has SEM-EDS-CL, VNIR-SWIR, fluid inclusion stages, and related equipment. Next steps in this project include ongoing technique development and multiple projects in-pipeline.

MINERS LAB: ACTIVE SPECTRAL IMAGING

PI: **Dean Riley & Isabel Barton, Mining & Geological Engineering**

PARTNERS: **Dave Brady, Optical Sciences & Engineering**

Multispectral and hyperspectral sensors are expensive to deploy and restricted to use only under optimal solar conditions. This project proposed a low-cost active imaging solution tailored to the material characterization (TRL – 0). Initiated in September 2022, testing has been performed on initial active source selection and initial camera requirements.

Principal outcomes are ongoing, including development of a tunable multispectral camera.

Next steps are to finalize active source emission requirements and active camera sensitivity requirements, test against laboratory hyperspectral imagers, and the writing and filing of patent(s).

GEOCHRONOLOGY OF REE-BEARING PEGMATITES

PI: **Calvin Mako, (Mako, Arizona Geological Survey (AZGS)**

PARTNERS: **Carson Richardson (AZGS)**

Pegmatites are currently being explored in Arizona as potential sources of Rare Earth Elements (REE), Li, and other critical elements. The age and genesis of a large belt of pegmatites in Arizona is poorly understood. The goal of this project is to determine the age(s) of these pegmatites to aid in exploration and to better understand their origin.

Principal outcomes of this project are analyzing the age and tectonic setting of the Arizona pegmatite belt, and understanding if Arizona's pegmatites have a common genetic style or geochemical affinity. We further seek to understand how Arizona's pegmatites relate to known resources outside of Arizona. Answering these questions will broadly affect pegmatite exploration strategies.

Sample collection and mineral separation are completed, with imaging and identification in progress. Geochemical and data analysis are underway, with publication and further work being planned.

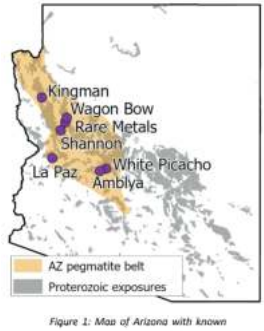


Figure 1: Map of Arizona with known

NOVEL SOURCES OF CRITICAL MINERALS FROM PORPHYRY COPPER DEPOSITS

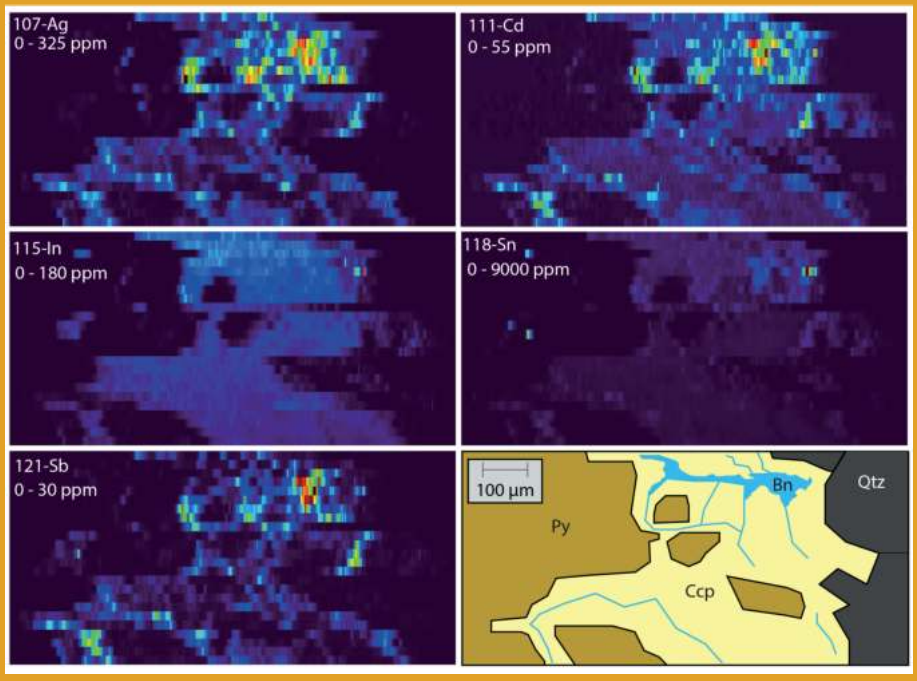
PI: Mark Barton Director, Lowell Institute for Mineral Resources. Professor, Geosciences

CO-PI(S): Isabel Barton, Mining and Geological Engineering, Frank Mazdab, Geosciences (GEOS), Jason Kirk (GEOS).

PARTNERS: Freeport-McMoRan, Asarco, South32, Hudbay, AZGS

Porphyry copper mining moves huge masses of many critical minerals that aren't recovered. This pilot study looks at that potential, primarily from a geological and geometallurgical perspective.

All key objectives are successfully completed: to develop and demonstrate the capacity to do critical element analyses in a variety porphyry copper-related minerals and materials environment; to expand collaborations to work on key examples in the Soutwestern United States and to develop a National Science Foundation (NSF) proposal, which we submitted on April 14, 2023, to the Geosciences Directorate "Critical Minerals" initiative.



LA-ICPMS maps (from the new Minerals Characterization Facility) of critical elements in sulfides from an Arizona PCD

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